IRON-BEARING DEPOSITS IN BOSSIER, CADDO, AND WEBSTER PARISHES, LOUISIANA.

By Ernest F. Burchard.

INTRODUCTION.

The bright-red soil and abundance of débris of limonite (hydrated iron oxide) in bowlders, slabs, and gravel on the summits and slopes of the hills in northwestern Louisiana have for many years given rise to the hope that at least some of the deposits of this useful mineral might eventually be found to be of value. In 1886–1888 Lawrence C. Johnson, of the United States Geological Survey, made a reconnaissance of northern Louisiana and eastern Texas, studying the stratigraphy and the outcrops of the iron-bearing beds. A brief report[1] on this work was issued in 1888, but it contained little discussion bearing on the commercial availability of the deposits, partly because at the time of Johnson's work only one railroad, the Vicksburg, Shreveport & Pacific, served the northern section of Louisiana, and had important iron-bearing deposits been noted they would for the most part have been too remote from transportation routes to be of economic value. The transportation situation is greatly changed now. Two lines running north and south, the Kansas City Southern and the Texas & Pacific, traverse Caddo Parish, passing through Shreveport; the St. Louis Southwestern Railway runs northward from Shreveport through Bossier Parish; and the Louisiana & Arkansas Railway runs northward from Minden through Webster Parish. (See fig. 11.) Several other lines connect Shreveport with the south, east, and west. In view of the increased facilities for transportation, which have brought most of the known deposits of limonite within 4 miles of a railroad, interest in their possibilities has been revived and requests have been made by the citizens of northwestern Louisiana that the iron-bearing deposits should be further examined by the United States Geological Survey. It should be stated here that since the work of Johnson several other geologists, including G. D. Harris, A. C. Veatch, and

[1] Johnson, L. C., The iron regions of northern Louisiana and east Texas: 50th Cong., 1st sess., House Ex. Doc. No. 195, 54 pp., 1888.

G. C. Matson, have made extensive studies in the region, for both the State and the Federal geological surveys, but these studies have had reference more particularly to the general and structural geology as affecting the distribution of petroleum and natural gas or underground water, and little special attention has been devoted to the iron-bearing deposits. An opportunity was presented for a reconnaissance of these deposits in connection with those of northeastern

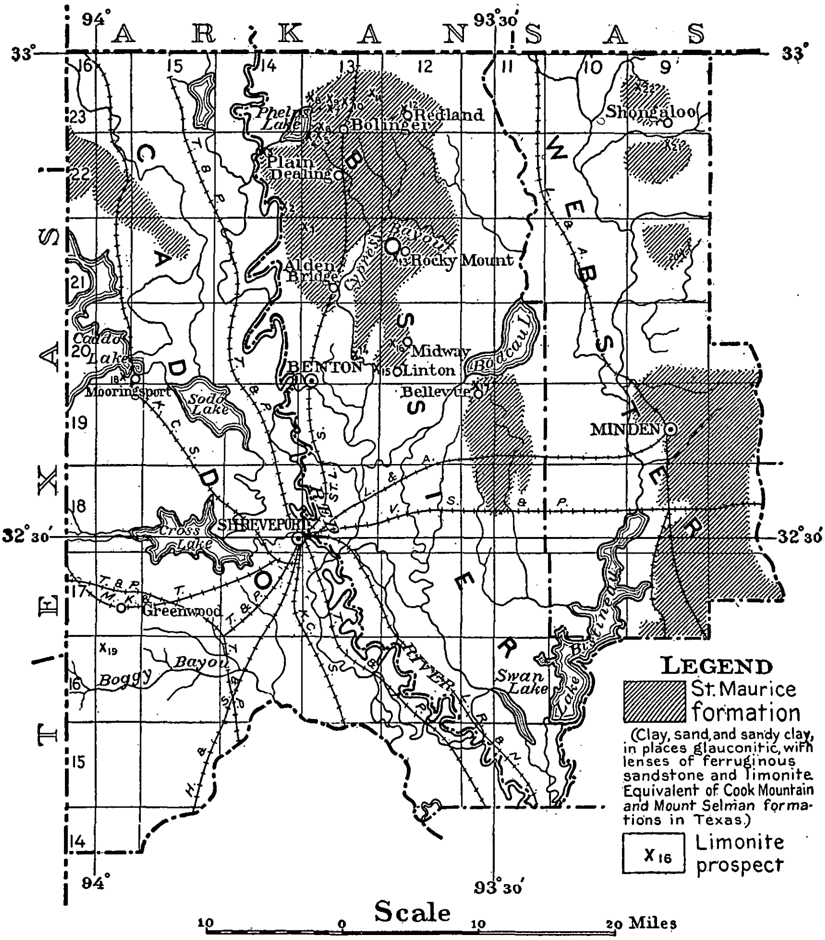

FIGURE 11.—Map of Bossier, Caddo, and Webster parishes, La., showing approximate location of limonite deposits examined.

Texas in the autumn of 1914, and accordingly the writer spent about two weeks in examining the most promising iron-bearing deposits in Bossier and Caddo parishes before proceeding to Texas. Although little encouragement could be offered as a result of these examinations, it was believed that more definite information would be yielded by prospecting in certain localities, and as the owners or trustees for these properties expressed a willingness to do the necessary prospecting the localities were designated by the writer with suggestions for carrying out the work. After four weeks spent in a reconnaissance of the northeastern Texas field the writer returned to Shreveport in order to examine the results of the prospecting. At this time a trip was also made to Minden and northern Webster Parish.

The limonite deposits of northern Louisiana are by no means confined to the three parishes mentioned above. Johnson mentions the occurrence of limonite also in Bienville, Claiborne, De Soto, Jackson, Lincoln, Ouachita, Union, and Winn parishes, and the writer noted certain of these deposits in De Soto and Winn parishes. It is believed, however, that the deposits described in the following pages are typical, if not the best representatives, of the iron-bearing deposits in northern Louisiana. Johnson, who had opportunity to study the field as a whole, regarded Bossier Parish as one of the most promising districts of the iron-bearing region, and it is to-day even more certain that if the limonite deposits in general were of sufficient magnitude to be mined for iron ore those of Bossier Parish would be first to be drawn upon, as Shreveport would become the logical iron-manufacturing center. Therefore, if the most favorably situated deposits fail to meet the requirements of the iron industry there would seem little need to extend the investigation further. A comparison between the characteristic limonite deposits of northwestern Louisiana and the productive deposits of northern Alabama is given on page 150, under "Conclusions," in order that the disparity between them may be readily appreciated.

On page 109 will be found a bibliography of publications relating to the geology and iron-bearing deposits of northern Louisiana and northeastern Texas.

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THE IRON-BEARING DEPOSITS.

CHARACTER.

The principal iron-bearing minerals in northwestern Louisiana are hydrated iron oxides, the most common of which is limonite, expressed by the formula $2Fe_2O_3.3H_2O$. Pure limonite contains approximately 59.8 per cent of metallic iron, 25.7 per cent of oxygen, and 14.5 per cent of water. Limonite is seldom found in an entirely pure condition, generally containing more or less silica and alumina, intimately mixed with it in the form of sand and clay, and small percentages of manganese, phosphorus, and sulphur in certain chemical combinations, chiefly with oxygen. The presence of impurities reduces the percentage of metallic iron in limonite, so that the bulk of the commercial chemical analyses show only 45 to 55 per cent of iron.

The hydrated iron oxides are generally found near the surface and above ground-water level. Below the permanent level of ground water, where oxidation does not so readily take place, there may be found iron minerals which are not very stable when exposed to the atmosphere. Siderite (iron carbonate, $FeCO_3$) and pyrite (iron disulphide, FeS_2) are the most common of these minerals found in the clays and sands of northwestern Louisiana below the level of ground water. Both of these minerals become altered to limonite. In the deposits to be noted below siderite plays a very unimportant part, being noted in only one locality, where it occurs in an impure form known as "clay ironstone." Pyrite is rarely found near the surface. Where deposits of limonite or other iron-bearing minerals pure enough to be used for the manufacture of iron occur in quantities sufficient to render them of actual or potential value they may be termed iron ores.

The forms in which limonite and other hydrated oxides of iron occur in this region are varied but may be grouped under a few general types. Limonite is widely distributed in small quantities as a cementing material in sandstone, conglomerate, and breccia. Thus it may be found in all stages from a thin, soft crust in the sand, in which the iron hydroxide is visible only as a faint stain, to a massive, hard bed, in which the iron mineral appears to compose the major portion of the rock. To this type of deposits Johnson,[1] in his classification of the iron-bearing deposits of this region, has applied the general term "impregnation" deposits, from the fact that the iron hydroxide has been carried into the beds in solution. Such deposits are being formed at the present time, and instances will be cited farther on in this paper. Another common type of limonite is the nodular form, including concretions, geodes, and other modifications, such as are produced when a number of these forms are grown together into a honeycombed or cellular mass. Iron carbonate is most frequently found in nodules. Still another type is a more or less compact layer or bed of limonite that may have been formed in a bog. The deposit of this type may vary greatly in purity. They have been termed "lacustrine" by Johnson, but this term is misleading, for not all well-defined beds of limonite have been deposited in

[1] Johnson, L. C., op. cit., pp. 24–25.

bogs. Another type consists of limonite gravel, formed of the débris of former deposits at the same or higher levels. Gravel deposits are likely to be found on or near the tops of hills. In their general order of value these types might be summarized as follows, although local conditions may greatly influence the value of any particular deposit: (1) Nodular; (2) bedded; (3) gravel; (4) impregnation.

TOPOGRAPHIC RELATIONS.

The most conspicuous limonite deposits of Bossier, Caddo, and Webster parishes are situated on the plateaus and ridges that rise to heights of 100 to 300 feet above the low-water level of Red River, or 260 to 460 feet above sea level. In the northern part of Bossier Parish there is a crescent-shaped area of high red-surfaced land extending from Phelps Lake to and beyond Rocky Mount, and in the northern part of Webster Parish there is a corresponding high area east of Bodcau Lake. The higher lands of Caddo Parish are in the southwestern part of the parish. There are two horizons at which limonite is commonly found—one at or near the tops of the plateaus and ridges, the other near the top of a terrace-like area intermediate between the Red River valley and the highest levels.

GEOLOGIC RELATIONS.

The rock formations in which the limonite deposits of northwestern Louisiana occur are mostly unconsolidated sandy clay and sand, with a few beds of clay nearly free from sand and local indurated lenses of ferruginous sandstone. In the reconnaissance of the limonite deposits made by the writer there was small opportunity for study of the local geology and of course none for mapping the formation boundaries. Probably, however, all the beds with which the limonite deposits are associated in the area under consideration except those near Mooringsport (fig. 11, No. 18) may be assigned to the St. Maurice formation[1] of the Claiborne group (Eocene). Deussen[2] regards the St. Maurice as the equivalent of the Mount Selman and Cook Mountain formations, in which the limonite deposits of northeastern Texas are found. The Mooringsport beds are in the Wilcox formation, which underlies the Claiborne group.

A small collection of fossils was obtained by the writer from the lenticular bed of concretionary limonite in the wagon-road cut in the SE. ¼ sec. 25, T. 20 N., R. 13 W., Bossier Parish. These fossils have

[1] Harris, G. D., Oil and gas in Louisiana: U. S. Geol. Survey Bull. 429, pp. 120–121, pl. 12, 1910.

[2] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, p. 51, 1914.

been examined by William H. Dall, who reports as follows concerning them:

While none of the casts are sufficiently complete to enable me to be absolutely certain of the species, the ensemble is such that I feel there can be no great doubt that the horizon is lower Claiborne. The recognizable forms are Venericardia cf. *V. parva* Lea; Protocardia, probably *P. nicoleti* Conrad; Modiolaria sp.; Avicula cf. *A. claibornensis* Lea; Arca sp.; Leda cf. *L. catasarca* Dall; Leda cf. *L. acala* Dall; Corbula cf. *C. oniscus* Conrad; Ampullina? sp.; Volutilithes cf. *V. defrancei* Lea; and Pleurotoma cf. *P. sayi* Lea. This combination is unmistakably Eocene.

The bed yielding these fossils lies at the lower of the two limonite horizons mentioned above. The layers or deposits of limonite that simulate beds appear to be of small extent and are lenticular rather than tabular in form. They generally lie nearly flat but show noticeable dips in a few places. As rock dips in this region are of considerable significance to the petroleum geologist a caution should be inserted here against placing too much reliance on apparent dips in limonite layers. These layers are likely to develop along any irregular plane or zone within a bed of sand or sandy clay that affords a passage for iron-bearing solutions. Some cross-bedded sands afford favorable places for the deposition of limonite, with the result of imparting to the limonite seam, which stands out most conspicuously on weathering, a very misleading appearance so far as its relation to the dip of the local sediments is concerned.

DEPOSITS EXAMINED.

BOSSIER PARISH.

WEST OF PLAIN DEALING.

At a few points west and southwest of the town of Plain Dealing there are outcrops of limonite which have long attracted attention, Johnson having mentioned them in his report.[1] One of these outcrops shows two or three thin layers of nodular and concretionary limonite in a wagon-road cut on the south slope of a hill in the western part of sec. 6, T. 21 N., R. 13 W. (fig. 11, No. 1), about 5½ miles in an air line southwest of Plain Dealing. This is the place mentioned by Johnson as situated 2 miles south of Collinsburg, a town no longer in existence. The limonite appears to be of good quality, but not one of the layers is as much as a foot thick, and where all three are present their aggregate thickness is less than 2 feet. Johnson's detailed section is as follows:

[1] Johnson, L. C., op. cit., pp. 35–36.

Section 2 miles south of Collinsburg, La.

	Feet.
Sands and loam of higher ground	1–20
Clayey sands and sandy clays	1
Nodules of limonite	½
Clayey sand	2
Limonite in fine nodules	½
Clayey sand	4
Nodules of limonite	⅝–1
Reddish clay to depth unknown.	

If this limonite were concentrated into a single bed, close enough to the top of the hill so that stripping would not exceed 5 or 6 feet, and the bed were persistent throughout 300 acres or more, it would probably be of some value, for it lies within 3½ miles of a railroad. None of these essential conditions are fulfilled, however. The layers appear to be lenticular and only local segregations of limonite in the inclosing clay and sand.

Other outcrops that attracted attention in early years are along the bluffs of Red River. On the slope above the low bluff south of the site of the old Gilmer landing, in the NE. ¼ sec. 35, T. 22 N., R. 14 W. (fig. 11, No. 2), are outcrops of two thin strata of concretionary and nodular limonite, each about 8 inches thick at the maximum, separated by about 10 feet of clay and sand. The débris from these strata produces a noticeable showing of limonite on the hill slope below the outcrops, giving the impression that thick beds are present, yet the débris itself is at most but a few inches thick, as is easily demonstrated by a pick. The quality of this limonite appears fair. The shells and septa are of clear dark-brown limonite, nearly free from sand, but ocher is present in the cavities of unbroken nodules. There are thin lenses of hard ferruginous sandstone in the formation in this locality. An analysis of the limonite is given on page 147 (No. 1).

About 4 miles north-northwest of the old Gilmer landing, near the mouth of the bayou which drains Phelps Lake, is a hill known as Millers Bluff in the western part of sec. 10, T. 22 N., R. 14 W. (fig. 11, No. 3). This bluff is now about a quarter of a mile from Red River, but the river, which changes its course considerably from time to time, is said to have flowed near the base of the bluff at the time of Johnson's visit, in 1886. A layer of concretionary limonite of good quality, 6 to 8 inches thick, crops out near the base of the hill a few feet above the flood plain. From 20 to 30 feet higher there is much débris of a very sandy limonite or ferruginous sandstone. Sandstone from this horizon is now being hauled from all available outcrops within a radius of 3 to 4 miles for use as riprap to prevent undermining of the banks of Red River at flood stage. Occasionally bowlders of limonite are found and included with the sandstone, and this is probably the best use to which they can be put, for the deposits are too thin and scattered and too remote from a railroad (4 to 6 miles) to possess potential value as iron ore.

NEAR BOLINGER.

Northwest of the deposits just mentioned, mainly in the high country between Phelps Lake and the St. Louis Southwestern Railway, limonite in some form can be found on nearly every section of land. Some of the deposits have been known for 40 years or more, and others have been brought to notice through the extensive logging operations of the Bolinger Lumber Co.

In the NE. ¼ sec. 6, T. 22 N., R. 13 W., sandy limonite crops out in two prominent ledges just below the brow of the hill in a steep road that descends northwestward toward Phelps Lake (fig. 11, No. 4). These ledges are each about 1 foot thick, and at the top of one is about an inch of good limonite. The material, on the whole, is too siliceous to be regarded of value. In the adjoining portions of sec. 5, T. 22 N., R. 13 W., and sec. 32, T. 23 N., R. 13 W., particularly on the land of G. E. Gilmer, there are some of the best showings of limonite in Bossier Parish. On the Gilmer place much limonite débris is scattered about the surface of the fields that lie a few feet lower than the highest parts of the ridge. Piles of this fragmentary limonite in slabs 3 to 6 inches thick and up to 1 foot long have been gathered during cultivation of the fields, and some small fragments appear in the sandy fields on the highest parts of the place. In a creek bottom southwest of the farmhouse a bed of soft ferruginous sandstone and conglomerate is exposed for 100 feet or more. It is of very recent formation, and during wet seasons is evidently receiving ferric hydroxide from waters that percolate down from higher levels.

The best exposures of limonite on the Gilmer place are in two or three steep ravines in the northwest slope of the bluff facing Phelps Lake. The following two sections indicate the thickness and character of the limonite layers and their relations to the inclosing beds:

Section in ravine cutting bluff facing Phelps Lake in NW. ¼ sec. 5, T. 22 N., R. 13 W. (fig. 11, No. 5).

	Ft.	in.
Red sandy loam, with slabs and bowlders of limonite on the slope from top of plateau	5–8	0
Limonite, dark brown, of good quality, with mammillary surface and concretionary structure, but fairly free from cavities		9
Limonite, sandy		3–4
Red sandy loam and reddish soft sandstone, with a few scales of sandy limonite	4	0

	Ft.	in.
Limonite, light brown, sandy in places; weathers shaly and shows ocherous layers. Forms an overhanging ledge	1	4
Gray and red, slightly sandy clay, exposed for 15 to 20 feet, then covered and exposed only at two or three places	40	0
Hard bed of ferruginous sandstone and breccia, exposed to bottom of small pool. The fragments are mainly angular pieces of ferruginous sandstone	3	9
Concealed by wash of sand and clay	96	0
Grayish soft laminated sand	15	0
Flood-plain deposits of fine sand, silt, and organic matter.		

The next section was observed in a ravine about a quarter of a mile northeast of the point where the preceding section was measured, but it gives only the limonite-bearing sediments.

Section in ravine cutting bluff facing Phelps Lake in SW. ¼ sec. 32, T. 23 N., R. 13 W. (fig. 11, No. 6).

	Ft.	in.
Sandy soil on slope	5	0
Limonite, dark brown, generally compact and lustrous		10–16
Slope concealed by soil, vegetation, and limonite débris	42	0
Limonite, dark brown, slightly concretionary, with mammillary top surface; contains much lustrous, rich limonite, but some sandy nodules and streaks, and a few inclusions of ocherous material	1	1
Sandy clay, in part concealed	18	0
Limonite in slabs 3 to 4 feet in length; top 7 inches of rich limonite with mammillary surface; lower half sandy. These slabs appear to be out of place and to have slumped down on their outer edges, owing to the undermining of the underlying soft beds. Possibly they may represent bed 4. (Compare analyses Nos. 3 and 4, p. 147)		10–14
Clay and sandy beds, mostly concealed	35	0
Conglomerate and breccia of ferruginous sandstone cemented by limonite. At the top is a layer, about 10 inches thick, of shaly limonite and ocher, apparently a replacement of sandy, shaly clay. Over the face of the bed where gullied out by wet-weather streams is a sheet of porous limonite in process of deposition from chalybeate seepage	4	0

Chemical analyses of beds 2, 4, and 6 are given on page 147 (Nos. 2, 3, 4). The coincidence between the analyses of beds 4 and 6 is also strong evidence that the slabs noted as bed 6 in the section have broken off from bed 4. The analyses indicate that the upper bed (No. 2) is of good quality, and if it were of sufficient thickness

(2 feet or more) and extended over an area of 200 acres or more, at a depth not exceeding 5 feet from the surface, it should possibly be able to compete with the limonite in Cass County, Tex. There are, however, nowhere any indications that this bed reaches a thickness much greater than that indicated in the exposures, nor is it likely that the areal extent, through which this excellence of quality is maintained will prove to be very great. In fact, at several other places where the corresponding bed is exposed it is much more siliceous. In a well in the E. ½ SE. ¼ sec. 31, T. 23 N., R. 13 W., near the points where the last two sections were made, hard rock was struck 10 feet below the surface and at intervals down to the bottom, at 32 feet. A fresh sample from a depth of 10 feet, which should correspond to the rich bed of limonite, is highly siliceous. Some prospecting for ore is reported to have been done on the Gilmer land. Although this work was not sufficiently thorough to yield definite results, further prospecting should be undertaken only with the understanding that the chances of success are slight.

In two abandoned lumber tramway cuts 1¼ miles west and 1¾ miles northwest of Bolinger there are showings of limonite. The only one worthy of mention is in the more distant cut, which is said to be in the SW. ¼ NW. ¼ sec. 28, T. 23 N., R. 13 W. (fig. 11, No. 7), on the Means place. A face of 9 or 10 feet shows about 7 feet of interstratified sand and limonite. The limonite occurs in streaks one-fourth to 1 inch thick and in concretionary layers 2 to 4 inches thick. Some of the sand is slightly glauconitic. If the material shown in the face of this cut were concentrated, the limonite, good and poor together, would probably not aggregate more than 20 per cent by volume. An analysis of a sample averaged from the limonite streaks and concretions and freed from sand and clay is given on page 147 (No. 6). The content of metallic iron, 43.21 per cent, is fair, although not quite as high as the general run of desirable brown ores, which average about 45 per cent. The silica, 19.15 per cent, considerably exceeds the average, and the alumina is a trifle high. The phosphorus and sulphur are both low. As the sample was taken with care to free it from sand and clay it is comparable to washed and screened ore, and it is not likely that a higher grade could be produced through commercial methods of concentration.

Another type of ferruginous deposit that has been noted with interest in the wooded country northwest of Bolinger crops out in the form of heavy ledges of dark-reddish rock on the hillsides or caps some knolls. This rock yields a bright-red powder, but examination with a field lens discloses the presence of a considerable percentage of sand grains, which are not readily visible to the unaided eye. These deposits would fall within Johnson's class of impregnation deposits and are found to grade within short distances into the ferruginous conglomerate already mentioned. One of the most prominent exposures of this ferruginous sandstone is on the crest of a hill about half a mile east of Phelps Lake, at the northeast corner of the NW. ¼ SE. ¼ sec. 19, T. 23 N., R. 13 W., on land of J. C. Bolinger (fig. 11, No. 8). The ledge is 3 feet 9 inches to 4 feet thick and breaks off in large blocks weighing 5 to 10 tons each. The material here is fine grained and hard and gives a very red powder. There are some cavities in the rock filled with ocherous material. This deposit seems to be a local development. It lies practically flat and thins toward the south, as indicated on two hills within a quarter of a mile in that direction. Toward the southeast the bed merges into a conglomerate and breccia, and it appears in this form on the Lee place, in the SW. ¼ sec. 21, T. 23 N., R. 13 W. (fig. 11, No. 9). Here it is 1 foot to 1 foot 3 inches thick and is composed of small angular fragments of limonite and ferruginous sandstone, cemented together by limonite. A sample of the material from the heavy ledge on the Bolinger land, which is the richest deposit of this type to be noted, gave on analysis only 26.63 per cent of metallic iron.

A fairly thick slab of brown and yellow laminated limonite, more or less porous, was examined on the Honeycut place, reported to be in the SW. ¼ sec. 22, T. 23 N., R. 13 W. (fig. 11, No. 10). This slab is 1½ to 2 feet thick and is probably not in its original place, as it appears to have slumped down the side of a steep gully, where it lies about 75 feet below the top of the hill. Analysis of a sample that was averaged as well as possible from the exterior of this mass (p. 147, No. 8) shows it to contain 40.99 per cent of iron and 20.81 per cent of silica. The quality is therefore not sufficiently good to warrant its use as an ore.

The localities near Bolinger, mentioned above, are all from three-quarters of a mile to 3 miles west of the St. Louis Southwestern Railway. Several old tramway grades run through the woods, so that arrangements might easily be made for getting out ore if it should be found in the requisite quantity and quality.

East of the railroad limonite crops out at four or five places, but it appears to be of poor quality. In the NW. ¼ sec. 24, T. 23 N., R. 13 W., on the hills north of the Wyche place (fig. 11, No. 11), a heavy ferruginous sandstone, in places 2½ feet thick, caps the hills and forms much débris down the slopes. The material contains conglomerate and breccia and some limonite in streaks fairly free from sand, but on the whole it is leaner in iron than the rock sampled in sec. 19. Near Redland, which takes its name from the color of the soil, there is much limonite débris in the soil and surficial deposits. In the NE. ¼ sec. 29, T. 23 N., R. 12 W., outcroppings of a layer of limonite, good in some places, poor in others, and less than 1 foot thick, were observed on the Keown place (fig. 11, No. 12). The well near the house, which passed through this limonite horizon, encountered only a thin layer of very sandy limonite.

ROCKY MOUNT.

Limonite occurs at several places between Redland and Rocky Mount, but nowhere in sufficient quantity to be of great importance. Johnson notes the occurrence of sandy ferruginous rock containing casts of Claiborne fossils in secs. 18 and 26, T. 22 N., R. 12 W., and of nodular limonite of good quality in sec. 29. Much ferruginous rock is exposed in the immediate vicinity of Rocky Mount, a relatively high point, which owes both its name and its altitude to the heavy beds of ferruginous sandstone which lie just below the surface of the highest ground and whose débris is scattered down the steep slopes. The chief occurrence of limonite at Rocky Mount mentioned by Johnson is in the clay sides of the cellar under Hughes's old storehouse. On investigation this material proved to be several thin plates of limonite, whose aggregate thickness does not exceed 4 or 5 inches, embedded in the clay. East of this old storehouse there is a good deal of residual débris on the surface. Along the road to Benton, just southwest of Rocky Mount, may be seen exposures of thin bands of ocherous limonite about 100 feet below the level of the high land. About 20 to 30 feet below the top of the hill a sandy layer of limonite less than 1 foot thick shows in the road, and the same layer crops out as a prominent ledge on the slopes of a wooded ravine east of the wagon road and about a quarter of a mile south of the store at Rocky Mount. Some parts of this bed are rich in limonite, other parts are coarse, pebbly cemented limonite, and in places the silica pebbles seem to have been replaced largely by limonite, so that altogether it is rather variable. In the graveyard, a quarter of a mile southeast of the store, much limonite has been thrown out of the excavations. Some is of good quality, but the greater part is sandy. There is a small knoll in Burke's field that stands about 15 feet above the rest of the plateau and is the highest ground at Rocky Mount. This knoll shows considerable débris of ocherous, more or less sandy limonite, representing the residue from a deposit that once lay still higher.

In the autumn of 1914 seven prospect pits, or wells, ranging from 6 to 17 feet in depth, and one trench, about 3 feet deep and 40 feet long, were dug on the rough land southwest of the cemetery, in the SW. ¼ sec. 17, T. 21 N., R. 12 W. (fig. 11, No. 13). The pits ranged from near the level of the plateau to a point low enough to give a fairly good section of about 40 feet of beds. The test pits and trench collectively show the following general section:

Section shown by prospect pits at Rocky Mount.

	Ft.	in.
1. Soil and limonite débris		1–2
2. Dark soil and roots		10–12
3. Reddish sandy clay with two to four seams of dark sandy limonite, one-fourth to one-half inch thick, coated with yellow sand that is sparingly glauconitic	6	0
4. Hard yellowish-red sand, slightly glauconitic	1±	
5. Dark hard sandy limonite (sand runs in pockets)		6–10
6. Yellowish-red sand, sparingly glauconitic, with two or three seams of sandy limonite about one-half inch thick	8	0
7. Sand, mostly silica, with some admixture of clay; color yellow, becoming lighter below	8	0
8. Sand similar to bed 7, becoming nearly white in lower part; carries a thin streak of sandy limonite	10–15	

The limonite found in the vicinity of Rocky Mount seems to be associated with sand that is sparingly glauconitic. The richness or leanness of the limonite in Bossier Parish seems to bear about the same relation to the abundance or scarcity of glauconite in the inclosing sands and clays as in northeastern Texas. A sample for analysis was averaged from layer No. 5 from the prospect trench, and the results are given on page 147 (No. 9). The small content of metallic iron, 36.86 per cent, together with 35.55 per cent of insoluble matter, shows that the material can not be regarded as an iron ore.

EAST OF BENTON.

The limonite deposits east of Benton lie mainly between Benton and Midway, at distances ranging from 3½ to 7 miles from the St. Louis Southwestern Railroad. Along the Benton-Midway wagon road about a quarter of a mile northeast of Big Cypress Bayou, in the SW. ¼ sec. 23, T. 20 N., R. 13 W. (fig. 11, No. 14), a layer of concretionary limonite is exposed in the ditches on both sides of the road. This layer shows a maximum thickness of about 1 foot 2 inches, but is interlaminated with shaly and ocherous material and in places grades downward into glauconitic sand. Two prospect holes were dug here. The upper one, which is about 8 feet deep, starts above the limonite horizon and probably does not go deep enough to penetrate it. This hole is in gray to yellowish-red shale with no streaks of limonite whatever. A second pit, about 4 feet deep, was dug in a "fill" of red clay, and although started at about the level of the limonite ledge it did not encounter any limonite. There are no indications of limonite in any of the roadside exposures for 15 feet above and 10 feet below the ledge, and further prospecting should be discouraged. When the prospects were examined the exposed portions of the limonite layer had become soaked by recent rains and appeared to be much more clayey and ocherous than when examined in dry weather.

In the SE. ¼ sec. 25, T. 20 N., R. 13 W., about 5 miles east-southeast of Benton and 1½ miles west of Linton, a layer of concretionary cavernous limonite crops out at intervals for 150 to 200 feet in the cut at the west side of the wagon road (fig. 11, No. 15). This layer is 12 to 19 inches thick and is overlain and underlain by clay. The limonite is light brown and shows little free silica, but contains much yellow ocher and reddish clay in the pockets and cavities. It is fossiliferous and yielded casts of a number of forms, mentioned on page 133, from which it has been concluded that the horizon is lower Claiborne. Three shallow test pits have been dug here, one of them on the opposite side of the road. The pits were started above the limonite and go below the horizon of the bed. The pit east of the road encountered fragments of low-grade ocherous limonite, perhaps the feather edge of the lens. One pit about 20 feet west of the road shows no ore, and one a few feet away from the exposure shows no increase in the thickness or improvement in the quality of the layer. This limonite when water-soaked shows the presence of clay and ocher more prominently than when dry. The clay for at least 30 feet above and below the limonite layer was carefully examined, and only one slightly ferruginous seam, about 25 feet below it, was found. The small quantity of limonite present here discourages further prospecting. A chemical analysis of a sample averaged from the layer at the point where the fossils were collected is given on page 147 (No. 10). This limonite is evidently of fairly good grade, for the percentage of metallic iron, 44.74, is close to the average of commercial limonites, and the impurities are not far above the normal. It is disappointing to find that the quantity is so small.

Thin layers of limonite were noted in several places along the Benton-Midway wagon road in the SE. ¼ sec. 18 and the SW. ¼ sec. 17, T. 20 N., R. 12 W., and in gullies on the old Belcher plantation north of this road (fig. 11, No. 16). This limonite is not more than 6 to 8 inches thick where exposed. It is concretionary, and apparently occurs at the same horizon as the layer in sec. 25, just described. At any rate the two layers are at the same altitude and are associated in a similar manner with clay, and above each on the highest ground a bed of light-gray fine sand overlies the clay. A chemical analysis of a sample of limonite from the Belcher place (see p. 147, No. 11) indicates a limonite of very good quality, which, if found in 2-foot to 3-foot beds, would be well worth prospecting to determine its areal extent. Little encouragement toward finding any great quantity can be given, however, as a result of study of the local conditions.

BELLEVUE.

On the east slope of Bodcau Lake limonite sandy layers 1 inch to 2 or 3 inches thick appear in the wagon-road cuts in several places. Some half-formed concretionary masses occur in the sandy strata, the cementing material being a small percentage of iron oxide. Northwest of the site of the former town of Bellevue, in the NW. ¼ sec. 5, T. 19 N., R. 11 W. (fig. 11, No. 17), about 40 feet below the upland level, is a layer 6 to 8 inches thick of nodules, mostly of limonite but probably originally siderite. These nodules display interesting structure when broken open. They generally show septarian markings on the exterior and have large hollows in the interior, with relatively thin shells. The hollows are generally lined with corrugations and partitions of limonite that extend part way to the center, some of them as thin and sharp as a knife blade. Some are arranged in parallel bands around the circumference and at right angles to the exterior walls, but in some nodules they cross one another and form angular cells. Shrinkage cracks are also shown in the interior. Usually some powdery ocher or dry clay is found in the sealed cavity when the nodule is broken open, but in one nodule water and mud were found inside. While of interest from the viewpoint of the student of natural history these nodules or geodes of limonite are not present in sufficient quantity to be of commercial value. That they had attracted attention nearly 30 years ago is shown by the fact that Johnson mentioned them in his report.[1]

CADDO PARISH.

Only two localities were examined for iron minerals in Caddo Parish—near Mooringsport and about 3½ miles southwest of Greenwood. According to Johnson, who spent considerable time in this region, there are no other localities of interest in this connection in this parish.

MOORINGSPORT.

On the beach along the south shore of Caddo Lake half to three-quarters of a mile west of the Mooringsport station, in the northern parts of secs. 35 and 36, T. 20 N., R. 16 W. (fig. 11, No. 18), several layers of "clay ironstone," or impure iron carbonate, are exposed. They dip noticeably toward the southeast and have a total thickness of perhaps 2 feet in about four layers. The layers are formed of concretionary masses 3 to 8 inches thick and 2 to 3 feet in diameter. These masses are hard and brittle and are divided into septa, and

[1] Johnson, L. C., op. cit., p. 38.

their surfaces scale off concentrically. Along the septarian planes oxidation to limonite has taken place to a depth varying from that of a thin scale to more than half an inch. On weathered surfaces the limonite partitions stand out in relief above the checked surfaces of the concretions. Small concretions are oxidized through to the center. The unoxidized iron carbonate is gray, is faintly laminated, and contains minute sand grains. These sand grains are also discernible in the portions that have been oxidized to limonite. Only a faint effervescence is produced by dilute hydrochloric acid on the unweathered material. The specific gravity of this concretionary material is noticeably greater than that of limestone, which it resembles in appearance. Four oil pipe lines extend along the beach, and in leveling for them some of the clay ironstone has been dug out. In the low bluff that stands 15 to 25 feet above the beach two layers of concretionary sandy limonite 2½ inches apart are exposed, associated with calcareous shale. These layers are 3 to 7 inches thick and form the "ferruginous ledge" shown in a photograph by Harris.[1] This locality is near the Croom Clubhouse oil well No. 1.

The beach where the lower layer of concretions was noted is subject to floods. Caddo Lake was rather low at the time of visit, the stage being, according to local report, 161 feet above sea level, as compared with 174 feet for high-water stage. It is probable, therefore, that this layer, being covered by water part of the year, has not yet had time to become thoroughly oxidized.

At Mooringsport, both east and west of the Kansas City Southern Railway bridge, the "ferruginous ledge" may be traced for some distance along the lake bluff, about 10 feet below the top. The material is concretionary impure iron carbonate, altered on the surface to limonite, and becomes soft and shaly on weathering. The thickness does not exceed 7 inches. At the base of this bluff the lower layer has been dug into in leveling for the pipe lines. It was reported that several wagon loads of the iron carbonate and limonite from Mooringsport had been shipped to an iron furnace for analysis and test, but this report was not confirmed by records. It is certain that even if the tests proved favorable the quantity of iron-bearing material here is not sufficient for exploitation.

NEAR GREENWOOD.

About 3½ miles southwest of Greenwood the altitude of the hills forming the stream divides reaches about 300 feet in places, and on the higher points there are patches of very red loam containing débris of high-grade limonite. In the SW. ¼ sec. 3, T. 17 N., R. 16 W., on

[1] Harris, G. D., op. cit., pl. 13.

land of J. E. Whitworth (fig. 11, No. 19), there is a conspicuous showing of residual limonite. This material consists largely of gravel composed of fragments of the shells of geodes, but it contains also some whole geodes of limonite. The residual limonite mantles the top of the hill and extends down the north slope about 25 feet vertically. The thickness of the limonite gravel is not known, but it can be determined at little expense by means of a few test pits. The wagon road, which has been cut down a few feet and graded, does not show limonite in the roadbed, but in the roadside ditches there is more or less limonite within a foot or two of the surface and apparently parallel to the contour of the hill. The whole geodes range from 1½ to 6 or 8 inches in diameter. Some have thin shells, while others are nearly solid. Within the cavities is usually found a colored powder. In several geodes this powder is purplish and grades into the hard lining. In others the powder is gray or yellow, and in some it is coarse enough to be termed sand. Clay of various colors has also been found inside the geodes. The limonite composing the shells is generally of high grade. The shell and powder of one of these geodes were analyzed separately with the results given on page 147 (Nos. 12 and 13). The powder was purple and yielded 0.45 per cent of manganese. The shell of this geode proved to be the richest sample of limonite of all that were analyzed from northwestern Louisiana. It contained 50.61 per cent of metallic iron and only 9.85 per cent of insoluble matter and the other impurities were low. This analysis, it is of interest to note, coincides very closely with one published by Johnson, given on page 147 (No. 14), but he did not specify the locality further than that it came from Greenwood. It is doubtful whether there is much limonite in the immediate vicinity of Greenwood, for the altitude there is not as great as that of the observed horizons of residual material south of the town. Between the Whitworth land and Greenwood, at an altitude 100 feet lower than the residual limonite, a few crusts of sandy limonite, half an inch to 3 inches thick, crop out from sandy beds at the roadside, but these crusts carry a much lower percentage of iron than the sample analyzed.

As stated above, a few test pits should indicate the thickness attained by the residual limonite. If it is 4 or 5 feet or more, and the limonite débris constitutes one quarter or more of the volume of the surface material it should be worth while to extend the prospecting so as to determine the exact areal extent of the deposit. There is little probability of deposits being found here that would justify the extension of a railroad spur such a distance, and if ore is ever marketed it must be hauled by wagon or motor trucks to the railroad at Greenwood, down grade a good part of the distance.

WEBSTER PARISH.

NORTH OF MINDEN.

A hasty trip was made northeastward from Minden over the Lewisville road to and beyond Shongaloo, in the northern part of the parish. On the plateau 12 miles northeast of Minden and about 200 feet higher than the town, in the western part of sec. 14, T. 21 N., R. 9 W. (fig. 11, No. 20), there is a considerable spread of limonite in bowlders and gravel. This residual mantle appears to be about 1 foot thick and would yield a considerable quantity of limonite of good quality, but it is spread out too thin and is too far from a railroad at present to be of value.

Johnson[1] mentions the occurrence of a bed of recent conglomerate about 4 miles north of Minden from which a block was sent to the New Orleans exhibition of 1884–85. This conglomerate was said to contain about 26 per cent of metallic iron in the limonite cement. It contained quartz pebbles and angular fragments of sandstone and probably is analogous to the ferruginous conglomerate noted by the writer in the northern part of the parish.

NEAR SHONGALOO.

About 1 mile south of Indian Creek, west of the Lewisville road and 2 miles south of Shongaloo, on the W. H. H. Slack place, in the SW. ¼ sec. 3 and the SE. ¼ sec. 4, T. 22 N., R. 9 W. (fig. 11, No. 21), considerable ferruginous conglomerate is present. This conglomerate is found on the banks of small creeks and is forming to-day in the beds of the creeks. In places it is fairly rich in iron and carries only a moderate quantity of silica, but in others it contains pebbles of white quartz and chert. It could not possibly be utilized as an ore of iron.

On the James Roseberry place, in the SE. ¼ sec. 18, T. 23 N., R. 9 W., about 4 miles northwest of Shongaloo (fig. 11, No. 22), a bed of ferruginous conglomerate appears in the bed of a spring branch about 50 feet below the level of the high plateau. Some parts are rich in iron, but others contain quartz pebbles. It is reported that this bed was found to be about 4 feet thick in a prospect pit made about 1899. About 15 feet higher on the right bank of the creek a 7-foot prospect pit cuts through a reported thickness of about 2 feet of limonite. Part of the limonite from this bed is sandy, but 4 to 6 inches of it is rich in iron. There is no limonite here that could be mined profitably. An analysis of a sample of limonite from Allen Creek, near Shongaloo, published by Johnson, is given on page 147 (No. 15).

[1] Johnson, L. C., op. cit., pp. 40–41.

ANALYSES.

In the following table are arranged fifteen analyses of limonite from northwestern Louisiana—eleven being from Bossier Parish, three from Caddo Parish, and one from Webster Parish. Eleven of the samples were collected by the writer in the autumn of 1914 and four of the analyses are republished from the paper by Johnson already cited. Only the metallic iron was determined on sample No. 7. Most of these analyses have been discussed in the notes on the several localities from which the samples were derived. For convenience in comparison an analysis averaged from several hundred commercial analyses of washed brown ores produced in the Birmingham district, Ala., is given as No. 16 in the table. It is of interest to note that seven of the fifteen Louisiana limonites carried more than the Birmingham average of metallic iron, that three others nearly approached this average, and that if No. 7 is omitted the average of the remaining fourteen samples is 45.3 per cent of metallic iron, or a trifle higher than the Birmingham average.

Analyses of limonite from Bossier, Caddo, and Webster parishes, La., and from Birmingham district, Ala.

No.	Metallic iron.	Insoluble (practically SiO_2).	Al_2O_3.	Mn	P	S	Loss on ignition.
1	38.35	21.40	.....	.....	0.18	0.34	.....
2	51.94	5.21	4.17	None.	1.15	.01	14.22
3	42.87	23.28	1.97	0.20	.93	.02	11.94
4	40.95	23.85	3.31	None.	.99	None.	11.34
5	49.97	12.15	.....	.....	.62	.08	.....
6	43.21	19.15	4.51	None.	.26	.09	14.38
7	26.63	(a)	(a)	(a)	(a)	(a)	(a)
8	40.99	29.81	1.53	None.	.07	.06	10.90
9	36.86	35.55	2.23	None.	.24	.07	10.16
10	44.74	17.30	3.51	None.	.19	Trace.	16.71
11	48.92	13.16	2.77	None.	.16	.01	13.64
12	50.61	9.85	5.16	None.	.17	Trace.	13.64
13	48.67	19.97	1.09	.45	.41	.20	8.33
14	50.32	6.37	.....	.079	Trace.	.100	10.26
15	45.72	18.72	.....	.007	.247	.170	11.25
16	44.99	SiO_2 14.59	3.99	.74	.47	.....	5.40

[a] Not determined.

1. From Millers Bluff, Bossier Parish. Cited by L. C. Johnson, op. cit., p. 36.
2. From SW. ¼ sec. 32, T. 23 N., R. 13 W., Bossier Parish, bed No. 2. Analyst, W. C. Wheeler, U. S. Geological Survey.
3. From SW. ¼ sec. 32, T. 23 N., R. 13 W., Bossier Parish, bed No. 4. Analyst, W. C. Wheeler, U. S. Geological Survey.
4. From SW. ¼ sec. 32, T. 23 N., R. 13 W., Bossier Parish, bed No. 6. Analyst, W. C. Wheeler, U. S. Geological Survey.
5. From SW. ¼ sec. 32, T. 23 N., R. 13 W., Bossier Parish (probably bed No. 2). Cited by L. C. Johnson, op. cit., p. 37.
6. From SW. ¼ NW. ¼ sec. 28, T. 23 N., R. 13 W., Bossier Parish (old tramway cut). Analyst, W. C. Wheeler, U. S. Geological Survey.
7. From NW. ¼ SE. ¼ sec. 19, T. 23 N., R. 13 W., Bossier Parish. Analyst, W. C. Wheeler, U. S. Geological Survey.
8. From SW. ¼ sec. 22, T. 23 N., R. 13 W., Bossier Parish. Analyst, W. C. Wheeler, U. S. Geological Survey.

9. From SW. ¼ sec. 17, T. 21 N., R. 12 W., Bossier Parish (Rocky Mount). Analyst, W. C. Wheeler, U. S. Geological Survey.
10. From SE. ¼ sec. 25, T. 20 N., R. 13 W., Bossier Parish. Analyst, W. C. Wheeler, U. S. Geological Survey.
11. From SE. ¼ sec. 18, T. 20 N., R. 12 W., Bossier Parish. Analyst, W. C. Wheeler, U. S. Geological Survey.
12. From SW. ¼ sec. 3, T. 17 N., R. 16 W., Caddo Parish, near Greenwood. Analyst, W. C. Wheeler, U. S. Geological Survey.
13. From SW. ¼ sec. 3, T. 17 N., R. 16 W. (powder from geode interior), Caddo Parish, near Greenwood. Analyst, W. C. Wheeler, U. S. Geological Survey.
14. From locality near Greenwood, Caddo Parish. Cited by L. C. Johnson, op. cit., p. 49.
15. From locality near Shongaloo, Webster Parish. Cited by L. C. Johnson, op. cit., p. 40.
16. From Woodstock and Champion areas, Birmingham district, Ala. Average of several hundred analyses of washed brown ore shipped to blast furnaces, 1906–1908.

LIMESTONE.

During the examination of limonite deposits in Bossier Parish the question arose whether supplies of limestone for flux would be available in case the limonite deposits should prove promising. Accordingly an examination was made of certain exposures of an impure grayish-blue limestone that occurs in the form of concretions embedded in the sandy clay near Red River west of Alden Bridge station. These concretions are exposed in ravines that lead down to the river and also in the river bluffs in the NW. ¼ sec. 35, T. 21 N., R. 14 W. They range in diameter generally from 6 to 18 inches, but in the bluffs of Red River they reach 5 or 6 feet. The concretions have septarian divisions along which they may be broken apart, and along these planes thin films of calcite are found. The larger the masses the more sandy they appear to be on weathered surfaces. No analyses are available showing the content of calcium carbonate, but when freshly broken the rock effervesces only slowly with dilute hydrochloric acid—an indication that the limestone is not pure, or else that it contains magnesia. As to quantity available, the concretions are not abundantly exposed, and not enough of this rock was seen in the brief reconnaissance to last a modern blast furnace one day; furthermore, under present conditions it would not be practicable to obtain limestone for flux from deposits where several hundred times as much dirt as stone would have to be removed. Limestone of similar character was noted by Johnson[1] at Carolina Bluff, on Red River 8 miles south of Collingsburg.

If limestone should be needed for flux in this locality, the most convenient places to obtain it would be where erosion has exposed the Cretaceous limestones in areas of structural domes. Such an area, where a limestone quarry has already been developed, is 5 miles west of Winnfield, La., where a much-fractured bluish-gray and white banded, irregularly crystalline limestone occurs. This rock contains

[1] Johnson, L. C., op. cit., p. 35.

considerable coarse crystalline calcite and has been locally termed marble. Minute crystals of barite ($BaSO_4$) have been deposited in open spaces on the calcite. Whether or not the presence of barite in minute quantities would effect the value of the limestone as a flux is a question. The following analysis of the stone by W. F. Hillebrand[1] shows its high degree of purity:

Analysis of limestone from Winnfield, La.

Insoluble	0.65	MgO	0.60
Al_2O_3	Trace.	CO_2	43.43
FeO	Trace.	SO_3	.27
MnO	.10	H_2O	.13
CaO	55.01		

Traces of barium, strontium, chlorine, and organic matter were also found.

CONCLUSIONS.

In the foregoing notes the endeavor has been to present for each deposit examined the facts that are essential to determine its commercial availability and to interpret these facts in the light of observations made on many deposits of brown iron ore in other districts of the South. In some of these districts considerable money has been spent in unprofitable prospecting for brown ore; in others much has been lost in attempting to mine deposits whose value had not been demonstrated by prospecting. In certain of these localities it was not possible to determine from a study of surface indications the true or probable conditions. In northwestern Louisiana, however, conditions are such that geologists should have no great difficulty in appraising the limonite deposits, and it is with regret that the writer is forced to the conclusion that these deposits offer no encouragement for development in the near future. If this conclusion prevents useless prospecting, the examination will not have been made in vain, although, of course, the result is disappointing to the community, which had hoped for the development of a local iron-ore industry.

The tabular summary on page 150 permits a rough quantitative comparison of the northwestern Louisiana limonite with the deposits that are being worked in northeastern Texas and at Russellville, Woodstock, and Champion, Ala.

[1] U. S. Geol. Survey Bull. 419, p. 194, 1910.

Summary of quantitative data of limonite deposits in northwestern Louisiana, northeastern Texas, and northern Alabama.

Locality.	Form of deposit.	Thickness.	Relative units of area.	Possible methods of working.
Northwestern Louisiana.	Residual limonite débris and soil.	Generally less than 1 foot.	Acres	By hand, if at all.
	Concretionary ledges	A few inches to 1½ feet.		
Northeastern Texas.	Residual limonite débris and soil.	A few inches to 5 feet.	Hundreds of acres.	By hand, and exceptionally by steam shovel.
	Concretionary ledges	A few inches to 6 feet.		
	Laminated beds	1 to 4 feet		
Russellville, Ala.	Residual limonite débris, sand, and gravel.	5 to 35 feet	Square miles	By steam shovel.
	Pockets of massive limonite.	10 to 25 feet		
Woodstock, Ala.	Residual limonite débris, sand, and gravel.	3 to 10 feet	do	Do.
	Pockets of massive limonite.	10 to 80 feet		
Champion, Ala.	Residual limonite débris, sand, and gravel. Pockets of massive limonite.	20 to 60 feet	Hundreds of acres.	Do.