IRON ORE IN CASS, MARION, MORRIS, AND CHEROKEE COUNTIES, TEXAS.

By Ernest F. Burchard.

INTRODUCTION.

In response to many requests received by the Geological Survey during the last three or four years for published data concerning the iron-ore deposits of northeastern Texas, it was directed that a reconnaissance of this area be made in the fiscal year 1914–15. Accordingly the writer spent four weeks in northeastern Texas in the autumn of 1914, a most opportune time, for the results of extensive prospecting were then open for inspection. The following notes on the ore field and its development are presented in the hope that, together with the literature listed at the end of the paper, they may furnish the essential facts concerning several of the most favorably situated of the promising deposits. The reports by Dumble, Kennedy, Penrose, and others of the early Texas Survey (1890–1892) contain a mass of data concerning outcroppings of ore in 20 or more counties, but as they are not illustrated by detailed county maps the value of much of the text is considerably lessened. Moreover, these early investigations were made before systematic prospecting of the concretionary ores had been carried on, and little was known as to their vertical extent and the unoxidized iron carbonate. The laminated ore bed of Cherokee County was better known, because it had been opened by mining in several places.

Two brief examinations of the iron ores in this field had already been made by the United States Geological Survey. The first was a reconnaissance of the stratigraphy and the iron-ore deposits by Lawrence C. Johnson[1] in 1886–1888, and the second was a rapid reconnaissance of the northeastern part of the ore district by E. C. Eckel[2] in 1914. Johnson's report does not consider the economic features of the iron-bearing deposits. Of his own work Eckel says:

[1] Johnson, L. C., The iron regions of northern Louisiana and eastern Texas: 50th Cong., 1st sess., House Ex. Doc. 195, 1888.

[2] Eckel, E. C., Iron ores of northeastern Texas: U. S. Geol. Survey Bull. 260, pp. 348–354, 1905.

"Two ends were in view—a brief report on the present condition and future prospects of the iron industry and an examination of the district with a view to selecting areas for more detailed work." The report was brief, it described conditions at comparatively few localities, and its conclusions with regard to future prospects of the iron industry might now be regarded as conservative in the light of the results of recent prospecting.

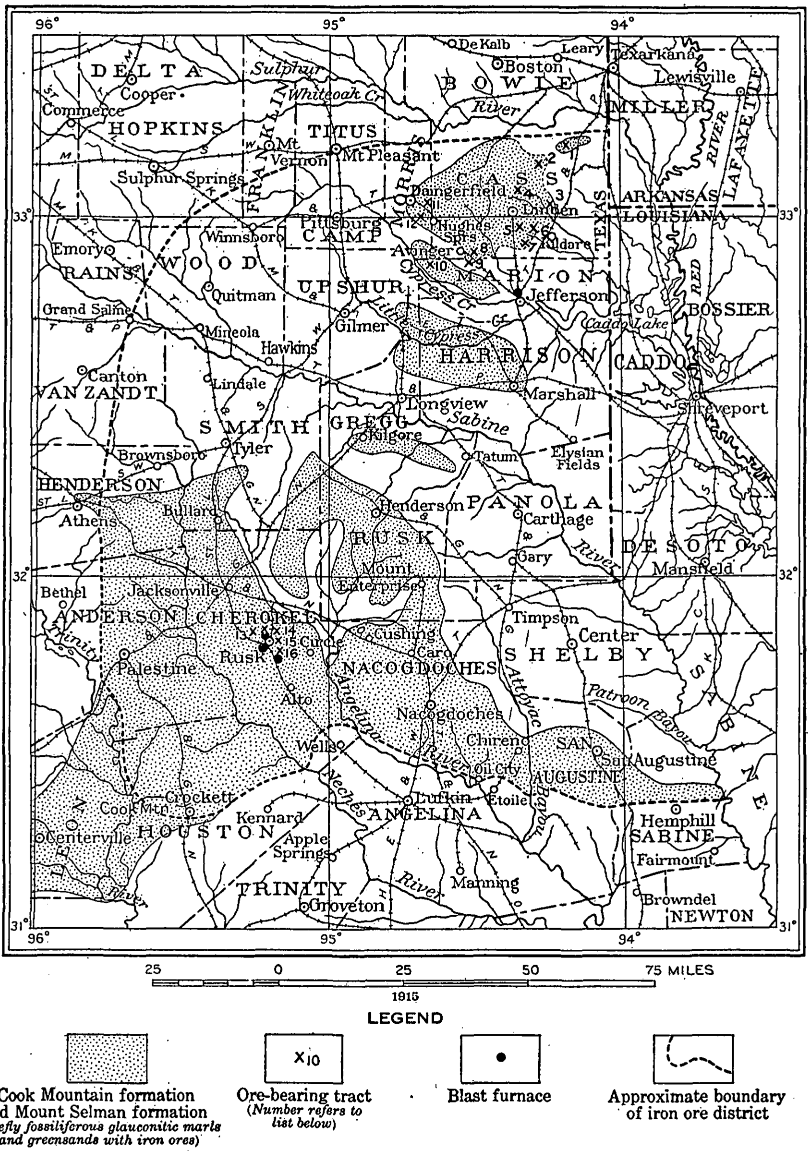
The present paper is essentially a preliminary report, but it is hoped that a more comprehensive study of the ore deposits may be taken up in the near future. The Survey will therefore appreciate the receipt from interested citizens of any additional data that may be obtained by prospecting in this field.

The work of the University of Texas Bureau of Economic Geology and Technology on the iron ores of northeastern Texas in 1910 to 1914, under the direction of William B. Phillips, has comprised the publication of a general map of the iron-ore fields, the summarizing of ore analyses and other data of the early Texas Survey, published mainly in papers devoted to the iron trade, the examination of certain of the important ore deposits, and studies of methods for the concentration of the ores.

The writer is under obligations to Dr. Phillips for valuable data placed at his disposal. Others to whom special acknowledgments are due are Prof. Alexander Deussen, of the University of Texas; Col. L. P. Featherstone, of Longview, Tex., president of the East Texas Brown Ore Development Co.; and H. A. O'Neal, vice president, E. E. Vaughan, general manager, and J. J. Skinner, chemist, of the Texas Iron Association, Atlanta, Tex.

LOCATION AND EXTENT OF ORE FIELD.

The iron-ore district of northeastern Texas lies between parallels 31° 30′ and 33° 30′ N. and meridians 94° and 96° W. and measures roughly about 135 miles from north to south and 110 miles from east to west. (See fig. 3.) Deposits characterized as brown iron ore have been noted by the Texas Geological Survey in the following 21 counties within this area: Anderson, Camp, Cass, Cherokee, Gregg, Harrison, Henderson, Hopkins, Houston, Marion, Morris, Nacogdoches, Panola, Rusk, Sabine, San Augustine, Shelby, Smith, Upshur, Van Zandt, and Wood. The distribution of these ores, with the exception of certain deposits in Camp, Hopkins, and Upshur counties, is shown in a general way on Plate IV of the Second Annual Report of the Texas Geological Survey, published in 1890. A later map, showing the same ore deposits with minor additions and including also the lignite outcrops and mines, blast furnaces, and producing oil fields, was published in 1912 by William B. Phillips, director of the University of Texas Bureau of Economic Geology and Technology. South and southwest of this area isolated deposits of brown ore have been noted in several counties, one of considerable extent in Gonzales County having been recently visited by Dr. Phillips.[1]



LIST OF ORE-BEARING TRACTS

1 Bowie Hill	5 Pruitt	9 Lasater	13 State mine
2 Waters	6 Harris	10 Gilbert	14 State mine
3 Bivins	7 Jernigan	11 Norwood	15 Star and Crescent
4 Surratt	8 Orr	12 Veal's	16 Tassie Belle

FIGURE 3.—Outline map of the northeastern Texas iron-ore district. Geology by Alexander Deussen, with additions by E. F. Burchard.

[1] Personal communication, December, 1914.

Topographic maps of the Daingerfield, Linden, and Atlanta 15-minute quadrangles, all in the northern part of the iron-ore field, have been issued by the United States Geological Survey. The New Boston and Texarkana 15-minute quadrangles, in the next tier north, have also been mapped, but they lie beyond the area of the ore field. These maps are printed on a scale of 1:62500, or about 1 mile to 1 inch, with 20-foot contour intervals. The price of each map is 10 cents.

THE IRON ORE.

TOPOGRAPHIC RELATIONS.

The surface of northeastern Texas is a plateau, 450 to 600 feet above sea level, that has been moderately dissected by erosion to depths of 200 to 400 feet. Much of the surface is gently rolling, with shallow stream valleys, but the highest portions of the former plateau are now flat-topped ridges with steep slopes incised by sharp ravines. These flat-topped ridges are generally narrow and crooked and have many spurs or branches. In places, however, they widen out into level areas a mile or more in width. These high level areas are particularly well developed in Cherokee County. They have persisted because of the greater resistance to erosion offered by certain beds of hard sandstone and limonite with which they are capped.

GEOLOGIC RELATIONS.

In the iron-ore district of northeastern Texas the surface rock formations consist chiefly of sand, clay, gravel, and silt, varying greatly in their degree of induration but predominantly soft or little consolidated. The most recent deposits—those that form the bars, flood plains, and terraces of streams—are of Quaternary age, but the great masses of sand and clay with which the iron-ore deposits are associated are of early Tertiary age (Eocene).

The two Eocene formations which contain the principal deposits of brown ore are termed the Mount Selman formation and the Cook Mountain formation. These formations constitute the lower two-thirds of the Claiborne group. They overlie the Wilcox formation, which is also widespread in the area, and to the south they underlie the Yegua formation, the topmost formation of the Claiborne group. The most recent outline of the stratigraphy of eastern Texas is that given by Deussen,[1] whose paper is illustrated by a geologic map that groups together the Mount Selman and Cook Mountain formations, but in more detailed mapping it may be possible to differentiate the two formations. It has been determined that of the

[1] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 26–83, 1914.

deposits discussed in this paper those of the northern counties, Cass, Morris, Marion, and Upshur, are comprised in the Mount Selman formation, and those near Rusk, Cherokee County, in the Cook Mountain formation. The occurrence of the northern deposits in the lower rocks is due to the fact that the strata have a slight dip in a south-southeasterly direction, so that the surface bevels the edges of the rocks, exposing the older formations progressively northward and northwestward.

A succinct description of the surface formations in this iron-ore district can best be given by adapting those portions of Deussen's outline of the Cenozoic deposits of the Texas Coastal Plain[1] which relate to the area.

Outline of geologic formations in northeastern Texas brown-ore district.

System.	Series.	Group and formation.		Thickness.	Lithology.
				Feet.	
Quaternary	Recent.			0-50	Fluviatile deposits, consisting of brown, red, or black sandy clay or silt of the low overflow terraces of the streams; also present flood-plain materials, including sand and gravel bars.
Erosion interval.					
Tertiary.	Eocene.	Claiborne group.	Cook Mountain formation.	400	Palustrine and marine deposits, consisting of lenticular masses of yellow sand and clay; in places, lenses of green calcareous, glauconitic, fossiliferous marl. Beds of limonite and lignite. Some of the clays carry fossiliferous calcareous concretions. Formation as a whole is decidedly ferruginous.
			Mount Selman formation.	350	Palustrine and marine deposits, consisting of red, ferruginous indurated and probably altered green sand, with casts of shells, lenses of lignite and clay, and beds and concretions of limonite. The formation as a whole is conspicuously ferruginous.
		Wilcox formation.			Palustrine, marine, and littoral deposits. Does not carry ferruginous deposits of importance.

The Wilcox formation, which is the oldest one exposed in the brown-ore district, occupies portions of Anderson, Henderson, Van Zandt, Smith, Gregg, Wood, Hopkins, Titus, Camp, Upshur, Cherokee, Rusk, Marion, Harrison, Panola, Shelby, Nacogdoches, San Augustine, and Saline counties. It does not carry ferruginous deposits of economic importance.

The Mount Selman formation is exposed in parts of Anderson, Henderson, Cherokee, Rusk, Gregg, Harrison, Marion, Morris, and Cass counties. The Cook Mountain formation is exposed in Houston, Anderson, Cherokee, Nacogdoches, San Augustin, and Sabine counties. As indicated in the outline above, the Mount Selman and

[1] Deussen, Alexander, op. cit., pp. 27-29.

Cook Mountain formations are lithologically similar, although the Cook Mountain may carry more clay. The deposits of brown ore referred provisionally to these two formations differ in certain important respects, as will be shown in this paper.

All the deposits of iron ore, including both limonite and iron carbonate, so far as observed by the writer, are associated with glauconitic sand. Where the sand is more sparingly glauconitic the deposits are leaner in iron, and in beds that are composed only of silica sand no ferruginous deposits that could be termed iron ore are found. Iron pyrite has been observed in the unoxidized zone, but in relatively minute quantities, and to it can not be ascribed so important a part in the genesis of the ore as is evidently played by glauconite. The proximate source of the iron is believed to be the ferruginous sands and clays that inclose the ores, but it is probable that the ores themselves assumed their present form after the Claiborne sediments were deposited and had become a land area. All the ore material may have passed through the carbonate stage before becoming oxidized, but there is evidence that some of the limonite deposits near the surface are migrating downward through solution and redeposition.

CHARACTER.

Mineralogy.—The ore consists chiefly of limonite, or hydrated sesquioxide of iron ($2Fe_2O_3.3H_2O$), but it includes other hydrated oxides of iron and is popularly termed brown ore. There are, however, many deposits of limonite which are found to grade into iron carbonate ($FeCO_3$) of varying degrees of purity below the oxidized or weathered zone. The brown ore and the carbonate ore both contain more or less silica and alumina and other impurities, as indicated in the chemical analyses. (See pp. 86, 88, 90, 94, 96, 97.)

Form of deposits.—Both the brown ore and the iron carbonate occur in nodular and geodal forms segregated in glauconitic sand and clay in thin lenses and irregular ledges, and also as more or less honeycombed thin sheets and layers, fine fragments, crusts, small isolated nodules, and irregular masses of almost endless variety. Unconsolidated material, residual from the breaking down of such masses, is found in many places at the surface. The brown ore occurs also, particularly in central Cherokee County, in a rather persistent laminated bed, 1½ to 4 feet thick, near the top of the highest table-land. Another common form of ferruginous deposit is the conglomerate that crops out on the sides of many stream valleys and is even in process of formation in certain stream beds to-day. This conglomerate occurs as local lenses composed of pebbles of sandstone, which is more or less ferruginous itself, pebbles of limonite, and locally a few white quartz pebbles and angular fragments of silicified wood, the whole being cemented together by limonite. Bowlders of this conglomerate reach thicknesses of more than 2 feet in places, but it can not be considered as an iron ore.

The principal forms of the iron-ore deposits may thus be summarized as (1) residual, unconsolidated deposits of limonite; (2) nodular, geodal, and concretionary masses of limonite and iron carbonate; (3) laminated beds of limonite.

DISTRIBUTION OF DEPOSITS.

Ferruginous deposits such as are described above are characteristic of the Mount Selman and Cook Mountain formations wherever they are exposed in the 21 counties of northeastern Texas heretofore enumerated, but in only 6 or 7 of these counties have the deposits appeared of sufficient promise to warrant prospecting or development. Foremost among the counties that contain promising deposits of brown ore are Cass, Morris, Marion, and Cherokee, which are discussed in this paper. Other counties that may be considered as having deposits of possible future value are Upshur, Harrison, Anderson, and Henderson. All these counties were visited by the writer during the recent reconnaissance, and particular inquiry was made regarding possible areas in other counties, such as are indicated by the Texas State maps, but in view of the information obtained and the short time available it was not considered important to extend the reconnaissance farther at that time. There are, doubtless, within certain remaining counties, not visited by the writer, many deposits of brown ore which might be worthy of development if they were situated adjacent to a railroad but which do not warrant the construction of a single mile of spur track and from which it will not pay at present to haul ore by wagons.

DEPOSITS IN CASS COUNTY.

BOWIE HILL.

Some of the most important deposits of brown ore in Texas are within Cass County, but here, as elsewhere, the deposits are widely separated. Certain of these deposits are within the Atlanta 15-minute quadrangle, mapped by the United States Geological Survey. One of the best known of these deposits is on Bowie Hill, about 7 miles due north of Atlanta and 2 miles west of the Texas & Pacific Railway (fig. 3, No. 1). Bowie Hill is a flat-topped wooded ridge, $1\frac{3}{4}$ miles long, the highest part of which is about 200 feet above the bayous in the surrounding country, or 460 feet above sea level. The hill has resisted erosion more successfully than neighboring areas, on account of a cap of ferruginous beds above the 400-foot level.

The brown ore on Bowie Hill is found in the top 15 to 35 feet of the highest land on the hill. A generalized section from many test pits and prospect trenches is as follows:

Generalized section of ore-bearing beds on Bowie Hill.

	Feet.
Residual fragments of limonite in top soil, in places practically solid ore gravel	1–3
Ledge of nodular limonite, more or less solid	½–1¼
Scales and thin bands of limonite, with a few thicker layers or ledges interlaminated with glauconitic sandy layers. The limonite in this condition ranges from pieces of the thickness of small chips up to masses 1½ feet thick and is scattered through yellowish to red sand and clay. It occurs in overlapping, roughly lenticular streaks, or broken and discontinuous seams. The limonite constitutes, in the sections observed, 20 to 30 per cent, by volume, of the dirt. Thickness of limonitic sand and clay	12–15
Iron carbonate in nodular masses from the diameter of an acorn up to 6 inches, or in thin irregular lenses, embedded or interstratified in glauconitic sand and greenish-black clay called "buckfat" clay. The iron carbonate is in general partly altered to limonite or to reddish hydrated oxides of iron, which form a scale or crust of varying thickness around the carbonate nucleus and along cracks which intersect the masses. Thickness of exposed portions of the unoxidized beds	1–5

A section of the upper portion of the ore-bearing ground measures in detail as follows:

Section of cut at east end of washer trestle, Bowie Hill.

	Ft.	in.
1. Soil, roots, and limonite débris	1–6	
2. Limonite in layers 1 inch to 4 inches thick		8–12
3. Reddish-yellow sand, in part glauconitic		9–15
4. Limonite ledge with wavy and crumpled layers		6–15
5. Yellowish-red glauconitic sand with ocherous nodules and flakes		½–11
6. Limonite ledge with wavy and crumpled layers interstratified with a little yellowish clay and glauconitic sand. (Nos. 4 and 6 come together, No. 5 forming a wedge between)		1–5
7. Reddish clay and yellow sand, mostly glauconitic, with ocherous nodules and lenses	1	1–3
8. Limonite in ½-inch to 2-inch bands, interstratified with glauconitic sand and running into ocher		2–3
9. Yellow glauconitic sand, with small ocherous lenses		10
10. Limonite streak running into ocher		¼–1
11. Yellow glauconitic sand		3
12. Ocherous clay		1
13. Yellow glauconitic sand		4

	Ft.	in.
14. Limonite ledge, with slightly wavy laminæ containing thin seams of ocher and glauconitic sand	1	9
15. Yellow sand, not glauconitic		1
16. Limonite ledge, base concealed		1

Other members besides No. 5 of this section are more or less wedge shaped as exposed, and the great variability in thickness and extent of all the brown-ore members is easily demonstrated by the use of a pick, and is shown in the following two sections, displayed 35 feet apart in the same trench:

Section at face of trench south of wagon road, Bowie Hill.

	Ft.	in.
Soil and brown-ore débris	2	4
Reddish sand		8
Limonite		6–11
Reddish sand		10–14
Limonite		2½–6
Reddish glauconitic sand with light clay streaks		20–24
Limonite		2–6
Reddish glauconitic sand with four thin crusts of limonite	1	1
Reddish glauconitic sand with light clay streaks	1	3
Limonite		4
White and yellow clay and glauconitic sand		3–4
Limonite		3–4
White clay and yellow glauconitic sand	1	0
Limonite		4–6
Reddish-yellow glauconitic sand	1	3
Reddish clay, becoming greenish black at base		6–7
Iron carbonate, concretionary layer		6
Base concealed by water.		

Section at side of trench south of wagon road, Bowie Hill.

	Ft.	In.
Soil and limonite débris	2	1
Limonite layer, broken and interstratified with glauconitic sand and clay		7
Reddish clay and glauconitic sand containing limonite fragments	1	6
Limonite streaks and crusts in glauconitic sand and clay (about 25 per cent limonite)	2	6
Yellow glauconitic sand with white clay streaks	1	4
Limonite, in wavy and honeycombed layer		6
White to reddish clay		7
Limonite, in irregular seam		1–2
White to reddish clay with limonite fragments		5–8
Limonite		11
Yellow glauconitic sand		7
Ocherous sand		1
Yellow glauconitic sand		3
Limonite and ocherous sand		2–3

	Ft.	in.
Yellow glauconitic sand and ocherous nodules	1	0
Limonite		¼–1½
White clay		1
Yellow glauconitic sand with white clay streaks and a little limonite		7
Base concealed by water.		

The old Sulphur Fork iron furnace was built near Bowie Hill, west of Springdale, in 1864, and operated until April, 1865.

There are other small knobs and narrow ridges within a radius of 2 miles of Bowie Hill on which small residues of ferruginous material are present, but probably not in large enough areas to be worked independently.

NORTHWEST OF ATLANTA.

Two deposits of brown ore were noted northwest of Atlanta, one about 2 miles and the second about 6 miles from the town and about 1 mile southeast of Anti School (fig. 3, No. 2). In the first-named area there are good surface showings of ore, but little prospecting has been done. In the other area, which is known as the Waters tract, the surface above the 400-foot contour appears to be covered by a concentrated deposit of loose residual brown ore, in places 1 foot to 2 feet thick, ranging from fine gravel to 6-inch lumps mixed with some dirt. Here a number of prospect pits 6 to 35 feet in depth have disclosed a promising though small area of ore. The distance to the Texas & Pacific Railway at Queen City is 5 miles in an air line.

NEAR BIVINS.

The next and last fairly large area of brown ore within the Atlanta quadrangle lies 5½ to 7½ miles southwest of Atlanta and 1 to 3 miles northwest of the Texas & Pacific Railway at Bivins (fig. 3, No. 3). The ore-bearing area occupies the upper part of a branching wooded ridge and lies generally above the 360-foot level. Some mining of concretionary limonite near the surface was carried on in former years to supply the blast furnace at Jefferson, Tex. Only lump ore was taken, and the dumps contain much ore that might pay to wash. This area has been prospected by numerous shallow test pits, most of which show good ore in a ledge 6 to 8 inches thick near the surface and some of which show two or three more ledges below, besides thinner seams and crusts. Most of the pits here are not more than 8 feet deep and are too shallow to demonstrate the presence of ore at levels comparable with certain other tracts of ore land in Cass County, but it is reported that this area is to be prospected deeper with the Keystone drill.

The limonite near Bivins is associated with oxidized glauconitic sand, but this sand appears to be leaner in glauconitic oolites and to include a larger proportion of silica sand than that of certain areas that have been demonstrated to contain rich ore. Two deep prospect pits showed at the bottom iron carbonate in concretionary and lenticular forms.

NORTH OF LINDEN.

In the Linden quadrangle, which adjoins the Atlanta quadrangle on the west, there are several areas of brown ore, one of the largest of which occupies the wooded table-land in the vicinity of Central Grove School, 4 to 5½ miles north of Linden (fig. 3, No. 4). This area, known locally as the Surratt tract, is cut by the headwaters of Bowman Creek, along the lateral slopes of which limonite crops out in heavy ledges, generally 1 foot or more thick, and there is also much débris scattered over the slopes. The general altitude of the

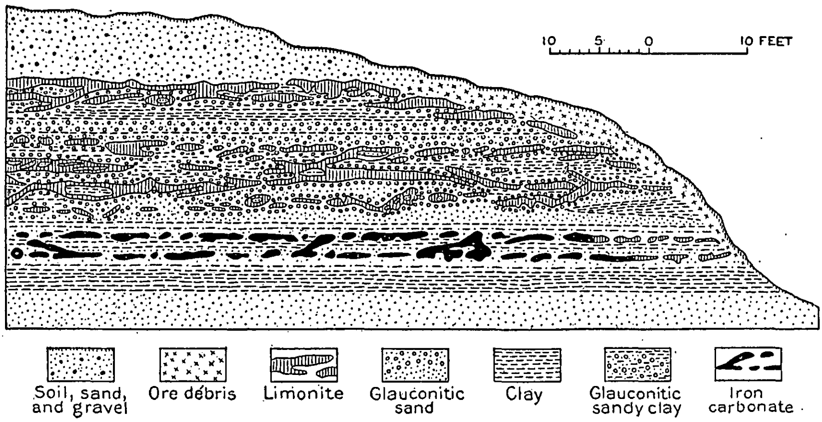


FIGURE 4.—Section showing associations of iron ore in trench from edge of hill on Surratt tract, north of Linden, Cass County, Tex.

top ledge is about 410 feet, and below this for 35 feet or more fragments and layers of limonite a quarter of an inch to 3 or 4 inches thick are found scattered throughout the sand and clay. Two prospect trenches on both the east and west sides of Bowman Creek show clearly the relations of the limonite, glauconitic sand, and clay and the fairly sharp line of demarcation between the oxidized zone, containing limonite and yellowish to reddish glauconitic sand, and the unoxidized zone, containing iron carbonate and green glauconitic sand and greenish clay, or "buckfat." This unweathered zone does not anywhere extend to the face of the hill but is roughly parallel to the surface, at 15 to 30 feet from it, except below ground-water level. The area has been prospected also by many test pits and some drill holes. On the pine-forested upland, which is surfaced by light-colored sand, there is little or no suggestion of limonite below, yet good showings are obtained in most of the prospects. (See fig. 4.)

The following section of the trench on the east side of Bowman Creek, near the experimental concentrating plant, is typical of the beds in this vicinity, except that the top ore ledge is not well represented.

Section of prospect trench on Bowman Creek 4½ miles north of Linden.

	Ft.	in.
Top soil and sand, with lumps of indurated glauconitic sand	2	3
Nodules of limonite		3
Sand and clay		2
Limonite		2-4
Reddish clay and glauconitic sand		10
Ore-bearing material, consisting of glauconitic sand with a little red clay. Contains 20 or more thin seams of limonite, ¼ to ½ inch thick. These seams lie practically flat. Some of them are sandy, and many are coated with layers of glauconitic sand, part of which may be separated by washing. Some of the glauconitic sand is indurated in thin seams	4	10
Glauconitic sand and white to yellow clay	1	0
Limonite		3
Glauconitic sand and white to yellow clay		8
Limonite		2
Glauconitic sand and white to yellow clay		3
Limonite		3-4
Glauconitic sand with fragments of limonite	2	6
Limonite		3
Glauconitic sand		3
Limonite		2½
Glauconitic sand	1	3
Limonite mixed with sand		7
Glauconitic sand with 18 to 20 streaks of ocherous limonite	8	4
Iron carbonate altered to limonite on top. The carbonate ore contains flakes of lignite		5
(A shaft has been dug below the level of the trench at this point and is reported to show yellow to greenish glauconitic sand and iron carbonate down for a depth of 36 feet.)		
Reddish-yellow glauconitic sand with a little red clay and much limonite in broken seams, fragments, and isolated nodules. This material has been estimated as capable of yielding 25 to 30 per cent by volume of limonite	10	6
(Here the section begins 50 feet nearer the slope of the hill, in oxidized material again.)		
Greenish-white clay with a few streaks of glauconitic sand and a little limonite. The lowest seam of limonite is 1 to 3 inches thick and appears to be the base of the ore-bearing material	4	4
White to yellowish fine sand containing a little clay	5	0

There are several areas of brown ore in the Linden quadrangle that may be noted in passing along the ridge roads between Linden and Central Grove School and between Linden and Atlanta, and there is some ore-bearing land in the immediate vicinity of Linden, but all these are relatively unimportant owing to their slight extent. In the southwest corner of the quadrangle, between Flat Creek and Concord School, a series of knobs extending northwest for a distance of about 2 miles reach an altitude of more than 400 feet and are reported to carry valuable deposits of brown ore.

SOUTHEAST OF LINDEN.

In the part of Cass County south of the Linden and Atlanta quadrangles, which has not yet been topographically mapped, there are several ore-bearing areas. One area that is being actively prospected by trenches, pits, and drill holes lies about 5 miles southeast of Linden and is known locally as the Pruitt tract (fig. 3, No. 5). In this tract the best showings of ore appear to be around the edges of the upland, where gullies have exposed it, although some of the pits have shown good ore-bearing material below the cotton fields that occupy the highest levels. Below these fields the ore is covered by 6 to 10 feet of light-gray sand mixed with a little clay. The following section is typical of the best showing of ore-bearing material in this vicinity:

Section in prospect trench 5½ miles southeast of Linden.

	Ft.	in.
Soil, sand, and limonite débris	2	6
Limonite, in thin plates		6–8
Reddish-yellow (oxidized) glauconitic sand	3	0
Limonite		10
Clay and reddish-yellow glauconitic sand		3
Limonite		1½
Grayish-white clay		3
Reddish-yellow glauconitic sand		9
Limonite		4–6
Reddish-yellow glauconitic sand		6
Limonite		½
Reddish-yellow glauconitic sand		2½
Limonite and oxidized glauconitic sand		7
Greenish-black (unoxidized) clay, or "buckfat"		11
Greenish (unoxidized) glauconitic sand		4
Iron carbonate, nodular ledge		4
"Buckfat" clay		4
Iron carbonate, nodules		3
"Buckfat" clay, base not exposed.		

This trench is cut about 120 feet into the north hillside facing a small creek. The altitude of the base of the trench is about 290 feet. On the opposite side of the creek a similar trench has been dug, showing possibly a slightly higher proportion of limonite and an equally sharp demarcation between the oxidized zone, containing limonite in reddish-yellow glauconitic sand and clay, and the unoxidized zone, containing iron carbonate associated with green glauconitic sand and greenish-black ("buckfat") clay.

The section given in detail above shows about 3 feet 6 inches of ore in a total of about 12 feet 6 inches of sediments. This corresponds to about 28 per cent of ore by volume, and perhaps 40 per cent by weight.

From 8 to 9 miles southeast of Linden and 1½ to 2 miles northwest of the Texas & Pacific Railway, an extensive limonite-bearing area has been prospected by two or more iron-ore companies that have holdings there. The ore is found on the high divides and tablelands. As shown by the trenches, some places are nearly barren, but in others there is a richer concentration of iron ore than has been seen by the writer elsewhere in northeastern Texas. This area contains the properties locally known as the Harris and Jernigan tracts (fig. 3, Nos. 6 and 7).

The following section, shown in a shallow trench about 125 feet long where brown ore was formerly mined for use in the blast furnace at Jefferson, illustrates one phase of the occurrence of ore in this vicinity:

Section in old mine trench 8½ miles southeast of Linden.

	Ft.	in.
Soil and residual limonite, mostly in kidney-shaped concretions	2	2
Reddish cross-bedded glauconitic sand		9
Limonite in crusts and concretions		3
Reddish glauconitic sand with streaks of white clay and a few concretions of limonite		8–10
Limonite		1–2
Reddish glauconitic sand and white clay		7
Limonite		2–3
Reddish glauconitic sand and white clay		5
Limonite		1½
Yellow ocherous silica sand, base concealed		4

The concretionary ore at the top is rich and is reported to have been in great demand when the blast furnace was in operation.

An unusually large prospect trench has been excavated in this tract a short distance southeast of the old mine trench. This large trench is 6 to 7 feet wide, about 14 feet deep, and 130 feet long and connects with a narrower trench at right angles, which extends for 50 to 60 feet, to the brow of the hill and affords drainage for the large trench. In addition to the material taken from the trench a block of the top ore-bearing ground about 50 feet square has been removed from one side of the trench, and the ore from the whole excavation has been stored in a large pile in a neighboring field. The following section indicates the character of the ore displayed in the large trench. The top 7 feet is especially rich in ore.

Section in large trench 9 miles southeast of Linden.

	Ft.	in.
Soil rich in ore débris	1	0
Ledge of limonite with a few seams of sand	4	10
Glauconitic sand and clay		7–10
Limonite, in part concretionary		3–8
Light-yellowish to reddish glauconitic sand		3
Limonite, in part concretionary		4–7
Reddish glauconitic sand and white clay, with a few small nodules of limonite; the sand is partly indurated by ferruginous streaks	1	9
Limonite		2–3
White and reddish glauconitic sand	1	11
Limonite lens, 3 feet long in sand layer		4
Limonite, with seams of indurated sand		10
Bluish-green clayey sand		3
Base concealed; iron carbonate reported below.		

The section outlined above thus shows about 8 feet of ore in 13 feet of sediments. A photograph of this prospect trench has been published.[1]

In contrast with the rich section just given is the following section, shown at the face of a cut about 200 yards east of the large trench:

Section in prospect trench 9 miles southeast of Linden.

	Ft.	in.
Sand, light colored, mostly silica	1	6
Limonite		14–18
Reddish glauconitic sand, with white clay streaks and five streaks of limonite, $\frac{1}{4}$ to $\frac{1}{2}$ inch thick	1	6
Limonite, with streaks of sand		4–5
Reddish glauconitic sand, cross-bedded, containing white streaks	1	11
Limonite		7
Yellowish sand		5
Limonite		2
Yellowish sand, cross-bedded		10
Limonite		4
Reddish glauconitic sand, cross-bedded, containing white clay streaks	3	7
Limonite		3
Reddish glauconitic sand, cross-bedded, containing white clay streaks	3	6

[1] Linton, Robert, Texas iron-ore deposits: Eng. and Min. Jour., Dec. 20, 1913, p. 1153.

According to this section there are about 3 feet 2 inches of limonite within 16 feet 3 inches of sediments.

In this area one prospect trench has been cut entirely through a small hill and affords a view of the iron-bearing sediments for a distance of about 350 feet and to a depth of 10 to 20 feet. The richest ore-bearing material in this trench appears to be just about the middle of the hill. The following two sections were measured in this trench:

Section in southeast portion of trench cut through hill 9 miles southeast of Linden.

	Ft.	in.
1. Soil and limonite débris		6
2. Limonite	1	7
3. Sand and limonite alternating in thin seams		7
4. Reddish-yellow glauconitic sand, cross-bedded, containing white clay streaks	1	11
5. Limonite		3
6. Sand, similar to No. 4		3
7. Limonite		4
8. Sand, similar to No. 4	1	5
9. Clay		2
10. Limonite		3
11. Sand, similar to No. 4		2½
12. Limonite		9
13. Sand, similar to No. 4		8
14. Limonite		1–2
15. Sand, similar to No. 4	1	6
16. Limonite		1
17. Sand, similar to No. 4		10
18. Sand, similar to No. 4, containing two seams of limonite, each about 2 inches thick	10	0

Section near middle of trench cut through hill 9 miles southeast of Linden.

	Ft.	in.
Soil and limonite débris		18–26
Limonite, in heavy ledge with lenses and "pots" of sand and clay	6	3
Yellow glauconitic sand, locally indurated, containing a few seams of limonite	3	4

The southwestern portion of this area, known locally in part as Jernigan Hill, has also been tested extensively by prospect pits from 9 to 44 feet deep. Some ore was found in nearly all the pits that were noted. Some of the top ore is too sandy to be of commercial value, but there is much good concretionary and nodular ore. There is generally a heavy ledge of limonite near the surface, irrespective of a difference in elevation of 25 to 30 feet, a fact which suggests a downward concentration, not only of the residual ore accompanying the degradation of the hill but also of iron hydroxide, thus continuing to build up ledges of ore a foot or two beneath the surface. Forest fires have partly dehydrated much of the surface ore, altering its color to a dark red. An ore seam 8 inches thick has been found at a depth of 45 feet below the highest part of the ridge.

The last portion of this area to be visited lies north of Jernigan Hill and is known as Nigger Hill. The test pits here range generally from 6 to 10 feet in depth, but a few are 18 feet deep. A well being dug for water encountered only fragments of ore but cut through some pyritiferous green sandstone and dark clay at a depth of 40 feet. The ore shown by the shallow pits consists largely of rather rich "kidney" concretions, but some portions are sandy. Ferruginous conglomerate containing quartz sand, rounded quartz pebbles, and angular fragments of silicified wood was noted on the surface.

NEAR LASATER.

In the southwestern part of Cass County, on the north side of the Missouri, Kansas & Texas Railway between Avinger and Lasater stations, is an area of brown ore that was formerly worked in several places to supply ore to the furnace at Jefferson. The railway cut at Avinger shows limonite in a thin ledge near the top, associated with reddish glauconitic sand; at the base is exposed bluish, unoxidized clay containing a few nodules of iron carbonate. Near Orr switch, at the south edge of the county, a ledge of limonite has been mined on the sides of the valley of a small creek, about a quarter of a mile northeast of the railway (fig. 3, No. 8). The ledge is generally 1 foot 4 inches to 2 feet thick, but attains in one place an exceptional thickness of 6 feet 6 inches in three reefs, separated by two lenses of glauconitic sand 4 inches to 1 foot 4 inches thick. At this place the ledge crops out at the surface, but where the ledge is thinner there are generally 2 to 3 feet of soil and loose ore débris above it. This ledge of limonite may be traced down the hill nearly to creek level. The ore is in rounded nodular masses, coalescing so as to form a ledge. Some of the ore is sandy and contains layers and coatings of glauconitic sand, but most of the ledge is limonite of good quality. It has been mined by pick and shovel along the outcrop in two or three places for a few hundred feet each. What is apparently the equivalent of this ledge has been mined at the top of the hill about a quarter of a mile southeast of the creek and about the same distance from the railway. Here a shallow trench extends around the crest of the hill and exposes ore generally from 1 foot to 1 foot 6 inches in thickness.

Two small iron furnaces were operated in early days in southwestern Cass County. The Nash furnace was erected within a few miles of Avinger several years prior to 1859, and is believed to have been the first furnace to utilize the brown iron ore of eastern Texas. The other furnace, known as the Hughes, was built about 1861 and was operated during the Civil War. It was 1½ miles southeast of Hughes Springs.

ANALYSES.

Many chemical analyses of the brown iron ores in Cass County have been published by the Geological Survey of Texas and by technical magazines. Analyses of the carbonate ore are not so readily available, probably because only recently has this type of ore been reached in prospecting. The analyses by the Texas Survey were evidently made on good average prospect samples rather than on picked samples of ore. Occasionally a sample was found in which the silica proved to be so high and the iron so low that the material could not be classed as an ore according to present standards. In making use of these data such analyses have not been included.

The following analyses indicate the composition of certain types of the deposits:

Analyses of Cass County iron ores.

	1	2	3	4	5
Silica (SiO_2)	10.96	20.25	37.86	2.50	1.10
Alumina (Al_2O_3)	3.51	12.91		2.10	1.02
Lime (CaO)					.16
Phosphorus (P)	.118	.149		.043	.05
Sulphur (S)	.124	.132		.096	.05
Loss on ignition (mostly combined water)	9.62	12.25			[a] .15 [b] 1.05
Carbon dioxide (CO_2)					36.54
Manganese (Mn)				.20	.10
Titanium dioxide (TiO_2)					.04
Metallic iron (Fe)	49.61	37.41	34.26	48.10	46.44

[a] Water driven off below 100° C. [b] Water driven off above 100° C.

1. Average of 22 analyses of nodular and concretionary limonite. Kennedy, William, Report on the iron-ore district of east Texas: Texas Geol. Survey Second Ann. Rept., pp. 79–87, 1891.
2. Average of 5 analyses of laminated limonite. Idem.
3. Average of 8 analyses of ferruginous conglomerate. Idem.
4. Analysis of nearly pure, cleaned carbonate ore. Linton, Robert, Texas iron-ore deposits: Eng. and Min. Jour., Dec. 20, 1913, p. 1156.
5. Analysis of average sample cleaned carbonate ore from vicinity of Linden. Analyst, R. C. Wells, United States Geological Survey, March 15, 1915.

DEPOSITS IN MARION COUNTY.

NEAR LASATER.

A few deposits of brown ore were examined in the northwestern portion of Marion County. Southwest of the Missouri, Kansas & Texas Railway ore has been mined at several places 1 to 2 miles west of Lasater (fig. 3, No. 9). Prospect trenches and old workings in this area show ore from 1 foot 2 inches up to nearly 5 feet thick, but the latter thickness is exceptional and is due to the formation of an unusually thick pocket of ore. Old stock piles of ore show a fair to good grade of limonite, some of which is ocherous and some of which is incrusted with glauconitic sand. In addition to the ore shipped to Jefferson, Tex., shipments of lump ore are reported to have been made to Birmingham, Ala., about 1908 or 1909. Little or nothing seems to be known as to whether there is ore in small fragments below the top ledge, as the deepest cuts are not more than 5 to 6 feet below the surface.

SOUTHWEST OF AVINGER.

The tract of ore land most recently developed in Marion County, known as the Gilbert tract, is situated in the extreme northwest corner of the county, about 6½ miles southwest of Avinger and 7 miles northeast of Ore City (fig. 3, No. 10). It is tapped by the Port Bolivar Iron Ore Railway, a line extending north from Longview, Tex., a distance of about 30 miles. This road was built to transport ore from this field to Longview and thence over the Texas & Gulf Railway (Atchison, Topeka & Santa Fe system) to Port Bolivar, on Galveston Bay. It is planned eventually to extend the Port Bolivar Iron Ore Railway northward to connect with the Texas & Pacific Railway, probably between Avinger and Hughes Springs. The ore is exposed along the brow of a high, flat-topped wooded ridge, known as 75-Acre Hill. The base of the main ore ledge lies about 80 feet above the railway spur and, according to company maps, is at an altitude of about 370 feet. In open cuts made in 1913 the ore is shown to be concretionary limonite, generally of high grade. In the cut which extends about 500 feet N. 30° W. from a point near the tipple the best ore forms a ledge 8 to 15 inches thick 2 to 4 feet below the surface, and is overlain by sandy ledges of ore and ore débris in the soil. The ledge is concretionary in structure, and some of the ore débris consists of concretions. About a quarter of a mile northwest of the first cut another cut has been made along the brow of the ridge and around the head of a hollow. This cut is about 800 feet long and 3 to 6 feet deep and discloses a ledge of ore that is in places very thick. In one place 5 feet of excellent ore was measured, composed of two concretionary ledges and extending down from the grass roots. At another place a concretionary mass of ore measures 4 feet in thickness. At other places the good ore is only about 1 foot thick, with sandy ore and clay above it.

Aside from the mine cuts, 75-Acre Hill seems to have been fairly well tested by pits and other marginal and surface cuts. A contour map on a scale of 200 feet to 1 inch, with 10-foot contour intervals, has been made, and by its use it has been determined that there is on this hill perhaps 30 acres of ore-bearing land, besides 25 acres carrying float ore. Most of the test pits are shallow and show a moderate quantity of ore, generally not more than 10 to 15 per cent by volume.

Many ferruginous bowlders are scattered about the surface, but these are mostly too sandy to be considered good ore. The contour and surface of the hill resembles that of Bowie Hill, Cass County, in many respects, particularly in the outstretching spurs and reentrant ravines on its borders. On the southeast margin of the hill a machine shop, tipple, and crusher platform have been erected, and an ore chute, or flume, extends down to the railway spur, 85 feet below. The chute evidently was not employed to carry ore, however, during the recent mining, as the product from the mine trenches was hauled down by wagons and dumped on a platform above the railway. Here the ore was shoveled into three chutes which discharge on grizzlies, where it was broken by sledges and fed through chutes into the cars.

Two steamer cargoes, each consisting of several thousand tons of high-grade brown ore, were shipped from this property to the furnaces of the Alan Wood Iron & Steel Co., near Philadelphia, Pa., in the summer of 1913.

An iron forge or furnace was operated many years ago at the base of 75-Acre Hill. The only evidences of its former activities are a few remnants of glassy slag.

ANALYSES.

The following series of analyses, which cover a wide range of samples, show the excellent grade of ores found in northwestern Marion County:

Analyses of Marion County iron ores.

	1	2	3	4	5
Silica (SiO_2)	9.05	4.460	6.135	9.40	9.74
Alumina (Al_2O_3)	3.92	2.377	2.728	1.40	4.78
Lime (CaO)				.07	
Magnesia (MgO)				Trace.	
Phosphorus (P)	.089	.100	.090	.099	.18
Sulphur (S)	.146	.103	.092	.067	
Manganese (Mn)		.170	.126	.16	1.22
Loss on ignition	10.37			11.70	
Metallic iron (Fe)	53.06	57.450	56.030	53.80	51.21

1. Average of 10 analyses of nodular and concretionary limonite. Kennedy, William, Report on the iron-ore district of east Texas: Texas Geol. Survey Second Ann. Rept., pp. 102–106, 1891.
2, 3. Analyses by A. S. McCreath & Son of two cargo samples of ore from Gilbert tract, discharged at Philadelphia, 1913. Dry basis.
4. Analyses by R. N. Dickman of sample averaged from 30 samples from Gilbert tract.
5. Average of six analyses by Charles Catlett of composite samples of ore from Gilbert tract. Dry basis.
Analyses in columns 2 to 5, inclusive, were placed at the disposal of the Survey by Col. L. P. Featherstone, president of the East Texas Brown Ore Development Co.

DEPOSITS IN MORRIS COUNTY.

NORTHWEST OF DAINGERFIELD.

The iron-ore map published by the University of Texas Bureau of Economic Geology and Technology shows a large iron-bearing area west and northwest of Daingerfield. So far as could be ascertained by a rapid reconnaissance and inquiries, the showings of ore in this area are limited to streaks of very red soil associated with a thin mantle of residual limonite gravel. This limonite gravel ranges from the size of shot up to the size of walnuts and is high in iron. Pieces of the limonite gravel that are comparatively fresh appear to be fragments of the crusts of geodes. On the crest of the ridge northwest of Daingerfield, which reaches an altitude of more than 600 feet, the rock is mostly ferruginous silica sandstone, containing here and there a streak fairly rich in iron, but on the whole too low in iron ever to be regarded as an ore. Bowlders of glauconitic sandstone, slightly ferruginous in streaks, are also found sparingly on the crest of the ridge.

SOUTHEAST OF DAINGERFIELD.

Near the Morris-Cass county line, within 1½ miles north and south of the Missouri, Kansas & Texas Railway, limonite ledges crop out at about the 500-foot level around the rim of the upland. On the Norwood and other neighboring places (fig. 3, No. 11) some surface mining was done 12 or 13 years ago to supply the blast furnace at Jefferson. Several shallow test pits dug in 1910 show limonite in ledges from 8 inches to 4 feet 4 inches thick, the maximum representing an unusually thick mass. In a water well on the place of John Wallace bowlders of iron carbonate containing glauconitic sand were struck in greenish clay at a depth of about 20 feet, and at a corresponding altitude (510 feet) a ledge of limonite crops out on the north slope of the hill a few hundred yards distant. There is much ore gravel over the surface in this vicinity, and many bowlders of concretionary ore of excellent quality. Some bowlders measure 1 foot 6 inches in diameter.

The Missouri, Kansas & Texas Railway cut at Veals switch, 2¼ miles northwest of Hughes Springs, shows the following section:[1]

Section in railroad cut at Veals switch.

	Ft.	in.
Soil		6–12
Yellow sand and sandstone	3–8	
Iron ore	1	0
Yellow sand		6
Iron ore		6
Sand		4
Iron ore		8
Sand	3–5	
Iron ore		1–2
Gray to chocolate-colored clays	8–10	

[1] Eckel, E. C., The iron ores of northeastern Texas: U. S. Geol. Survey Bull. 260, p. 352, 1905.

Nodules of iron carbonate occur at the ore horizons nearest to the dark-colored clay. In a well adjacent to Hervey's cotton gin at Veals switch masses of iron carbonate were found at a depth of about 40 feet. Limonite seams were also found at intermediate depths, and in places films and crusts of a green fibrous mineral occur in cavities in the limonite. This mineral has been determined by W. T. Schaller, of the United States Geological Survey, to be a hydrous iron phosphate, near dufrenite in composition.

South of the main Daingerfield-Hughes Springs wagon road, a mile or more from Veals switch (fig. 3, No. 12), there is much rich limonite scattered about the surface in bowldery concretions, and numerous shallow prospect trenches have disclosed the presence of a ledge of limonite a few inches to 6 feet thick underlying an area of many acres. Some pits, however, have been put down in barren ground.

ANALYSES.

Averages of series of six and four analyses of mixtures of nodular and concretionary brown ore from the principal deposits in Morris County are given below in columns 1 and 2, respectively:

Analyses of Morris County iron ores.[a]

	1	2
Silica (SiO_2)	8.18	4.86
Alumina (Al_2O_3)	3.46	5.29
Phosphorus (P)	.135	.114
Sulphur (S)	.016	Trace.
Loss on ignition (mostly combined water)	10.04	10.64
Metallic iron (Fe)	54.56	55.25

[a] Kennedy, William, op. cit., pp. 177-179.

DEPOSITS IN CHEROKEE COUNTY.

VICINITY OF RUSK.

The most valuable deposits of brown iron ore in Cherokee County are situated near the tops of the plateaus south of Jacksonville, those in the vicinity of Rusk probably being the most extensive and best known. According to Deussen[1] they are to be regarded as belonging to the Cook Mountain formation, the upper of the two iron-bearing divisions of the Claiborne group. The deposits in the vicinity of Rusk that were examined by the writer are of a type entirely distinct from those of Cass, Marion, and Morris counties, which are regarded as of Mount Selman age. Instead of consisting of irregular, ramifying, and fragmentary masses of more or less

[1] Deussen, Alexander, op. cit., pp. 62-63.

nodular ore distributed through 15 to 30 feet of beds, as in Cass County, the Rusk deposit consists essentially of one solid and fairly continuous bed of limonite with almost no residual concentration of ore above and but little ore in seams and nodules below. The limonite bed near Rusk forms a cap near the top of the flat-topped plateau, at an altitude of about 600 feet, and is overlain by unconsolidated gray sand ranging from 1 foot or 2 feet to 25 or 30 feet in thickness. Over areas comprising several square miles there are undulations in the altitude of the bed reaching a maximum of perhaps 30 feet, but in the absence of an adequate topographic map or of precise levels the altitude can not be accurately determined for any given place.

The ore bed ranges from 7 or 8 inches to 3 and even 4 feet in thickness, but the more common thicknesses are between 1 foot 3 inches and 2 feet 6 inches. At the top of the ore bed, however, is a "sand cap," or layer of more or less ferruginous hard sandstone, from half an inch to 4 inches thick. This sand cap may be split freely from the ore in mining. The ore bed is immediately underlain by a few inches of light-colored clay, below which are layers of sand and soft sandstone, some of which is glauconitic. The upper surface of the sand cap is not smooth but is crossed by shallow furrows extending N. 65°-70° W. The width of these furrows is 2½ to 3½ feet, and the height of the crests above the bottoms of the furrows is generally 2 to 3 inches. The sand cap is thickest on the crests of the furrows, but the furrowed surface is characteristic of the limonite also when stripped of its sand cap, although the furrowing is not so marked. At the base of the ore bed botryoidal and rootlike protuberances of limonite extend down into the underlying clay, so that the basal surface is very irregular and presents a strong contrast to the upper surface. (See fig. 5.)

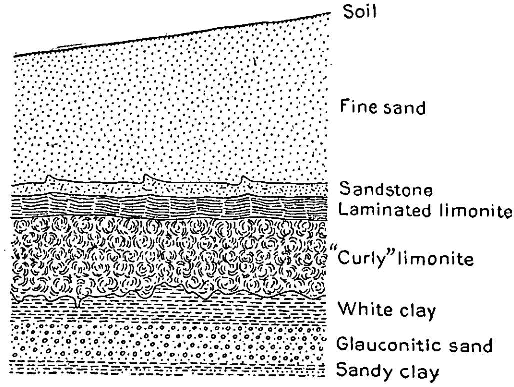


FIGURE 5.—Section of bedded limonite near Rusk, Cherokee County, Tex. Scale, 1 inch equals 5 feet.

The ore itself possesses certain characteristics of texture and color that make it easily distinguishable from the ores of the more northerly counties. The color, for instance, is light brown or buff, several shades lighter than that of the ore of Cass County, except where the latter is ocherous. The upper 2 to 4 inches of ore generally has fine open laminæ, parallel to the bed, lined with glossy black coatings, with here and there a spot colored bright red. The ore below the laminated layer presents a curly structure when freshly broken, in contrast to the more evenly concretionary type of ore in Cass and Marion counties. The ore with curly structure cracks and crumbles on weathering, and thus is known as "buff crumbly ore." Occasionally a cavity containing sand or sandy clay is found in the ore.

The Rusk ore is considered to carry a relatively high percentage of alumina, and there may be a relation between the presence of this ingredient and the light color of the ore. The ore from the top of the bed containing black-lined laminations is said by furnace men who have had experience in its use to contain a higher percentage of phosphorus than the rest of the ore in the bed.

The ore bed is exposed at a great many places around the rim of the table-land, which forms an irregular crescentic area extending about 3¾ miles northwest and 4¾ miles southeast of the town of Rusk. This area is bordered on the south and west by the Louisiana & Arkansas Railroad, the Texas & New Orleans Railroad extends northward across it from Rusk, and the Texas State Railroad touches its border just north of Rusk. Among the best exposures are those where the ore has been mined, as, for instance, at the several State mines, 3½ miles northwest, 1½ miles north, and 2½ miles northeast of Rusk; at the Star and Crescent mines, 1¾ miles east of Rusk; and at the mines 2¾ miles southeast of Rusk, worked in connection with the Tassie Belle furnace.

The latest and most extensive of the State mines are on the east-west spur of the plateau, beginning about 2½ miles northwest of Rusk (fig. 3, No. 13). These workings, which have been inactive since 1909, consist of open cuts and extend westward for more than 1 mile, interrupted by places where the cover of sand is too thick for stripping and by a ravine where the ore bed has been removed by erosion. An unusually good opportunity was afforded to the writer, in November, 1914, to examine the ore bed at one place where it had been stripped over an area of about 1½ acres. The regular furrowed surface of the ore bed is particularly well displayed in this stripped area, and when viewed from the top of a high bank of sand the surface resembles an abandoned plowed field in which the furrows are still faintly visible. The ore bed ranges in thickness from 15 to 36 inches and probably averages at least 2 feet. Adjoining the tract where the stripped ore bed is still in place piles of lump ore about 4 feet high have been stacked up over an area of about an acre.

In the cut on the Jacksonville wagon road a few thin streaks of brown ore are shown within 15 feet below the ore bed, but they are of no value and would not warrant mining any of the material below the ore bed.

A smaller abandoned open cut was noted on the rim of the plateau on the west side of the Texas & New Orleans Railroad, about 1 mile north of the State penitentiary, at Rusk. The thickness of the ore ranges from 7 to 16 inches where exposed, and the thickness of the stripping has reached 6 or 7 feet at the maximum. The cover, which is fine gray sand, thickens gradually to the northwest and probably reaches 30 feet at the highest level of the plateau. The ore bed shows a thickness of 2 feet in a railroad cut near by, and a few feet below it are a few thin streaks of limonite, possibly aggregating 5 or 6 inches within 10 feet of sand and soft sandstone, partly glauconitic. The ore was worked here by the State.

Another locality where mining was done by the State is 2 to 2½ miles northeast of Rusk, around the west rim of a northward-extending lobe of the plateau (fig. 3, No. 14). The open cut extends around the edge of the hill for a mile or more, and the stripping was carried to a maximum of 10 feet, but averages much less. The ore bed ranges in thickness from 12 to 30 inches. In places it contains a streak of sand, as is shown in the following section:

Section 2 miles northeast of Rusk.

	Ft.	in.
Sand, fine grained, gray, with soil and grass at top	7	0
Sandstone, hard, with streaks of limonite	1	5
Limonite, compact	1	0
Sand, yellow, soft		5
Limonite, compact	1	3
Clay, white; base not exposed.		

In this section the "sand cap" probably is merged into the ledge of limonitic sandstone above the ore. At other places the typical layer of sandstone, about 2 inches thick, is at the top of the ore. Near the north end of the workings the sand above the ore contains 3 to 4 feet of fairly hard concretionary sandstone, which rendered the work of stripping more difficult. Ore was carried from this place to the State blast furnace by a steam tramroad. The last operations are reported to have been carried on in 1906.

A good exposure of the ore bed was noted on the west margin of the plateau 1¾ miles east of Rusk, at the workings of the Star and Crescent furnace (fig. 3, No. 15), where the last operations are said to have been carried on in 1907. The ore measured 32 to 38 inches in thickness at this place. More ore is still available here, as the cover has not been stripped off to as great a thickness as at the State mines. Ore was trammed down to the blast furnace, a distance of about 1⅓ miles.

The old mines of the Tassie Belle furnace (fig. 3, No. 16) are 1 to 2 miles farther south along the west margin of the plateau, within a short haul of the furnace. These workings have lain idle for about 20 years. In one cut half a mile northeast of the furnace the ore bed is 27 to 29 inches thick and is covered by 3 to 4 feet of sand at the margin of the stripping. A pile of lump ore 1½ to 3 feet high, 50 feet wide, and about 300 feet long has been left here.

ANALYSES.

Averages of seven analyses of laminated brown ore from the bed worked to supply the State blast furnace, and of six analyses of laminated ores from other parts of Cherokee County are given below in columns 1 and 2 respectively.

Analyses of Cherokee County iron ores.[a]

	1	2
Silica (SiO_2)	[b] 19.0	14.08
Alumina (Al_2O_3)	....	10.38
Phosphorus (P)	.175	.062
Sulphur (S)	.020	.440
Water (H_2O)	12.25	8.85
Metallic iron (Fe)	45.68	39.49

[a] Walker, J. B., Reports on the iron-ore district of east Texas: Texas Geol. Survey Second Ann. Rept., p. 291, 1891.
[b] Insoluble.

COMPOSITION OF THE ORES.

In any discussion of the composition of the brown ores of northeastern Texas it must be borne in mind that the three types of ore, nodular, laminated, and conglomerate, show certain essential differences in their average composition, and therefore an attempt to calculate an average composition for all the ores of the area would give results of little or no value to the furnace man. The low percentage of metallic iron and the high percentage of silica in the conglomerate ore, without regard to quantity or accessibility, rule ore of this type out of consideration as a source of ore supply. If the nodular ore and the laminated ore chanced to occur in workable quantities in the same localities, or in localities so close together that both types of ore could be readily assembled and used in a mixed condition in the blast furnace, it might be of interest to average a number of analyses of these two types of ore together. However, as the workable deposits of ore in the counties north of Sabine River are practically all of the nodular or concretionary type and those south of the Sabine are of the laminated type, their geographic separation renders it improbable that they will ever be mixed to any great extent in the blast furnace, either locally or at eastern iron centers. It is reported that the Texas Iron Co., which leased but did not operate the State furnace at Rusk, planned to utilize a mixture consisting of three parts of Cass County nodular ore and one part of Cherokee County laminated ore. In such mixtures the influence that each type of ore may have on the mixture can be controlled.

A summary of analyses of Texas iron ores[1] has been published recently, from which are taken the following general data, with special data concerning the ores of Cass, Marion, Morris, and Cherokee counties:

In order to make satisfactory replies to the numerous inquiries with respect to the quality of the east Texas iron ores, we have undertaken to examine and classify 207 analyses. Many of them were taken from the report of William Kennedy on "The iron-ore district of east Texas" (Texas Geol. Survey Second Ann. Rept., 1889), which is our chief source of information with respect to these ores up to the time of its publication. This report has long been out of print and copies of it are scarce. In addition, we have had access to many more recent analyses, especially of ores from Cass and Marion counties, where extensive development work during the last two years, particularly that of the Texas Iron & Coal Co., has contributed so much to our knowledge of these ores and of the greatly enlarged area within which excellent material is to be found. * * *

In studying these analyses it was decided to divide them into four groups—for example, from 40 to 45, 45 to 50, 50 to 55, and 55 to 60 per cent of iron. All ores containing less than 40 per cent of iron are disregarded. The time may come when such low-grade material may be used, through processes of crushing, jigging, etc., but we need not concern ourselves with this now. We distinguish, then, four classes of these ores:

Medium, containing from 40 to 45 per cent of iron.
Good, containing from 45 to 50 per cent of iron.
Very good, containing from 50 to 55 per cent of iron.
Extra, containing from 55 to 60 per cent of iron.

It is probably the case that most of the so-called brown ores (and, with the exception of some carbonate ore, all of the east Texas iron ores are of this character) used in this country carry about 45 per cent of iron. It is an exception to the general rule when such ores carry as much as 50 per cent of iron, save when they are calcined, and this practice is not common. Such ores go direct from the washers to the stockhouse, a very small proportion being calcined or otherwise improved.

Cass County, 47 analyses.

	Per cent.
Medium	29.8
Good	23.4
Very good	23.4
Extra	23.4

[1] Phillips, W. B., Iron and steel making in Texas, II: Iron Age, Jan. 11, 1912, pp. 141–143.

Average composition.

	Medium.	Good.	Very good.	Extra.	Average, all analyses.
Metallic iron [Fe]	42.43	48.23	52.33	57.58	48.64
Silica [SiO_2]	18.26	11.85	5.19	3.94	10.64
Alumina [Al_2O_3]	11.33	7.85	5.21	5.21	7.65
Phosphorus [P]	.108	.147	.107	.052	.103
Sulphur [S]	.098	.133	.124	.065	.104

One sample, not included in this classification, contained iron, 60.44; silica, 3.50; phosphorus, 0.038; sulphur, 0.220.

Marion County, 65 analyses.

	Per cent.
Medium	4.6
Good	15.4
Very good	9.3
Extra	70.7

Average composition.

	Medium.	Good.	Very good.	Extra.	Average, all analyses.
Metallic iron [Fe]	43.18	46.69	53.80	57.43	54.91
Silica [SiO_2]	19.55	13.10	4.90	3.27	5.18
Alumina [Al_2O_3]	7.41	8.40	8.33	2.69	4.30
Phosphorus [P]	Trace.	.093	.070	.084	.073
Sulphur [S]	.030	.380	.156	.100	.067

In two of the good ores the silica was 26.43 per cent. In one the alumina was 19.96 per cent and maximum sulphur was 0.735. In one sample of the very good ore the alumina was 16.50 per cent; the maximum sulphur was 0.304. The maximum phosphorus in one sample of the extra ore was 0.22 and the maximum sulphur was 0.22. This county has not only the highest average of extra ore, but the highest general average in metallic iron—viz, 54.91 per cent.

Morris County, 10 analyses.

	Per cent.
Very good	50
Extra	50

Average composition.

	Very good.	Extra.	Average, all analyses.
Metallic iron [Fe]	52.82	56.85	54.83
Silica [SiO_2]	7.76	5.55	6.85
Alumina [Al_2O_3]	4.99	3.39	4.19
Phosphorus [P]	.132	.113	.125
Sulphur [S]	.007	.011	.009

In the very good ores the maximum silica was 13.10, maximum alumina 6.84, and the maximum phosphorus 0.209. Considering that no analyses with less than 51 per cent of iron are quoted from this county, it would appear that the best average of ore is from Morris County, although Marion County has the highest percentage of ore with more than 55 per cent of iron.

Cherokee County, 10 analyses.

	Per cent.
Medium	40
Good	60

Average composition.

	Medium.	Good.	Average, all analyses.
Metallic iron [Fe]	42.34	46.18	44.64
Silica [SiO_2]	22.62	17.19	19.01
Alumina [Al_2O_3]	11.47	10.35	10.94
Phosphorus [P]	.156	.140	.146
Sulphur [S]	.227	.029	.117

In the medium ores the maximum silica was 25.13, the maximum alumina 23.41, the maximum phosphorus 0.315, and the maximum sulphur 0.607. In the good ores alumina was determined in only one sample. The maximum silica was 20.36 and the maximum phosphorus 0.284. * * *

Of the ores represented by these analyses about one-fourth are of medium grade, about one-fourth are good, nearly one-fifth are very good, and nearly one-third are of extra quality and carry from 55 to 60 per cent of iron. It has been already stated that the total area involved in these 14 counties is 10,640 square miles. This must not be taken to mean that all of this territory is ore bearing. This is certainly not the case. Just how much of this area will be productive of workable ores of the medium good, very good, and extra grades is not now known. This is really the vital question, and not what will be the average composition of the ores. There is a vast difference, in so far as concerns shipments of these ores or even their use locally, between material carrying between 40 and 45 per cent of iron and material carrying between 50 and 55 per cent. This difference is acutely accentuated when we consider the ores of extra quality, carrying from 55 to 60 per cent of iron. If the statement that nearly one-third of these ores are of extra quality be true (and we believe it to be so, within a reasonable degree of accuracy), we have in them the very best brown ores in the country. When one considers the easy reducibility of these ores and the cheapness with which they can be mined and handled it may not be extravagant to say that they rank with the best ores of any kind, brown, hematite, or magnetite. What they lack in metallic iron would be more than counterbalanced by reduced cost in smelting.

It may, however, be urged that the extent of the deposits, of whatsoever grade, has not yet been definitely established. This same remark holds good for many other brown-ore deposits, some of which have yielded a very large amount of ore. But while this is true it does not affect the situation in Texas. That brown-ore deposits elsewhere, which have not been thoroughly prospected in advance of the shovel, have yielded and are still yielding large tonnages is no proof that these deposits will also yield large tonnages. In respect of brown ore it is particularly true that "the proof of the pudding is in the eating." Professor Pick-and-Shovel is the only competent instructor in this school.

DEVELOPMENT OF THE ORE DEPOSITS.

EARLY OPERATIONS.

The deposits of iron ore noted in the preceding pages, as well as many others in northeastern Texas, were known and worked from time to time on a relatively very small scale to supply ore for several small forges and furnaces before and during the Civil War. As a result of the rapid industrial development that followed the war these small furnaces soon became inadequate to compete with larger plants farther east, and they fell into disuse. The ore needed to supply them was obtained from the most favorably exposed ledges, and no thorough prospecting has been undertaken until recent years. Indeed, even the ore needed to supply the moderate-sized blast furnace at Jefferson was obtained only from shallow surface pits, very little mechanical equipment being used either for mining or concentrating the ore. A brief outline of present methods for the development of the deposits is of interest in this connection, for unless they can be worked on a much larger scale than heretofore they are not likely to prove commercially valuable.

PROSPECTING FOR ORE.

Systematic prospecting of a large tract of land bearing iron ore of the residual and nodular type, such as occurs in Cass and the adjoining counties, is by no means a simple and inexpensive operation. A preliminary study of the tract is first made, including examination of all the outcrops and natural sections of the iron-bearing sediments and tests by means of shallow pits and trenches in order to determine if possible whether the expense of further investigation is warranted. If the indications are favorable deeper prospecting may be done by means of test pits, open trenches, and drill holes.

The information to be derived from the prospecting, supplemented by concentration tests and chemical analyses, consists principally in determining the thickness of the cover, the total thickness of the ore-bearing ground, the section which will show approximately the volume ratio of ore to barren material, the weight ratio of ore to barren material, and the character of the ore itself.

The test pits are circular in cross section, about 3 feet in diameter, and as much as 35 feet in depth. They require two men—one for digging, the other for hoisting the excavated material to the surface by means of a windlass. Lump ore from a pit is usually piled at one side, and the sand and mixed fine ore and dirt are dumped on the other side. All the material from the pit is carefully preserved and forms a basis for the estimation of ratio of ore to dirt. The test pits are generally placed systematically a certain number of yards apart along lines which gridiron the tract except, of course, where surface features such as ravines, trees, or bowlders may interfere. Records of the sections exposed by the pits are carefully kept. A valuable supplement to the test pit is the drill hole. Holes are now being drilled in Cass County ore fields by means of a Keystone drilling outfit. The drill is operated and moved from place to place by means of a traction engine. In the soft or partly consolidated sediments in which the ores are found the machine drills about 90 feet a day, so that two or three holes can be sunk in a day if not too far apart. Such drilling is much more rapid and is less expensive than the sinking of test pits by hand. The drillings are saved on a screen, and the ratio of ore to dirt is determined later. The drill hole does not, of course, yield a visible section, and in that respect is of less value than the pit or trench. By drilling holes close to a few test pits whose sections are on record, the relative value of the information afforded by the two types of openings soon becomes apparent, and the engineer in charge of prospecting learns to what extent he may depend on each type. The application of drilling to prospecting of this sort is a comparatively new feature, and its possibilities have probably not yet been fully realized. Drilling would seem to be a good method of preliminary prospecting, and drilling in connection with sinking of test pits greatly reduces the number of necessary pits and materially lessens the expense.

Prospecting by means of trenches, particularly if the trenches are large and deep, is very expensive, for the work is practically all done by hand. If a trench is driven into a hill there is an advantage in that the excavated material may be wheeled out on a level floor, or perhaps down grade, instead of having to be hoisted out. A prospect trench affords a much better idea of the character of the ore-bearing ground and of the relations of the ore deposits to the inclosing sediments and is probably not exceeded in this respect even by the face of an open-cut mine, for the face of the trench is cut down vertical and clean. For the sake of economy, especially where the ore deposit is largely a residual deposit just below the surface, and where downward concentration of the limonite has resulted in the deposition of layers and masses of ore at a fairly even distance below and approximately parallel with the surface, a trench may be dug in steps and thus the extreme depth at the inner end, most of which might have to be dug in barren ground, may be avoided. If properties which contain important deposits of ore, of proved value, are to be displayed for sale or for financing, nothing is better than plenty of prospect trenches. Illustrations of certain trenches showing rich ore have been published by Linton.[1]

In connection with the prospecting work outlined above there should be carried on a thorough system of recording the results, preferably one which shall show them in as graphic a way as possible. This is effected by running careful levels over the property, making a large-scale topographic map with 5-foot contour intervals, and plotting each test pit or drill hole accurately on this map. Cross-section sheets are also made, on which all the test openings are shown to scale in their relative altitudes, together with the materials passed through, distinguished by means of appropriate patterns. Later, when concentration tests and ore analyses have been made, these data can be added to the cross-section sheets, which, together with the topographic map, will then contain all the essential data concerning each tested point on the property and enable a reasonably close estimate to be made as to the reserves and grade of available ore.

Such systematic prospecting and recording of results is, of course, very expensive and can not be undertaken unless the preliminary prospecting and natural indications are highly favorable, nor unless the property is large enough to warrant the expense, or several small properties may be prospected together. The engineering and mechanical corps necessary for such work must have a certain amount of special training and knowledge of the field, in order to produce the best results.

In prospecting laminated, bedded ore, such as occurs in Cherokee County, the problem is simpler than in prospecting the concretionary ores of the counties farther north. It is necessary to know the thickness of the cover above the ore, the thickness of the ore bed, its quality, and the altitude at which it lies. As the bed outcrops at a nearly uniform level around the plateau lands, generally on steep slopes, it is most conveniently prospected by pick and shovel on the outcrop. Drills might be used on the level upland, but in places where the cover exceeds 10 feet mining could hardly be carried on under present conditions; therefore systematic prospecting of such areas would be of little use.

RESULTS OF EXPLORATION.

The view taken by Phillips with regard to exploration of the ore fields up to the close of 1911 is shown in the following quotation,[2]

[1] Linton, Robert, Texas iron-ore deposits: Eng. and Min. Jour., Dec. 20, 1913, pp. 1153–1154.

[2] Phillips, W. B., Iron and steel making in Texas, II: Iron Age, Jan. 11, 1912, pp. 142–143.

and it may be added that prospecting during the last three years has been even more encouraging, indicating large reserves of iron ore. Trustworthy estimates of tonnage for the area can not be made, however, unless they are based on definite prospect data for every deposit, and unless every individual ore property is carefully prospected it had best not be included in any estimate.

The work that has been prosecuted during the last two years and which is still in progress has shown, among other important things, that the extent of the very good and extra ores is much larger than anyone had reason to anticipate. Ground which did not appear to be ore bearing at all in a commercial sense has been found to carry very considerable deposits of ore with more than 50 per cent of iron, and under such conditions that it can be mined and loaded for less than $1 a ton. The greater part of these ores are not held in tenacious clay. This is a point much in their favor, as it will diminish in a marked degree the cost of preparing them for shipment. The record of about 2,600 tons, not mined with any special care, neither washed nor screened, shows a content of metallic iron above 57 per cent, with phosphorus ranging from 0.10 to 0.20 per cent.

The clays with which these ores are so closely associated are sandy, friable, of loose texture, and easily removed over a screen or in an ordinary log washer. This means a minimum amount of water and a maximum amount of ore per cubic yard of raw dirt. The three general classes—viz, laminated, concretionary, and conglomerate ore—may be accepted in a broad way, although these three classes may be present in the same locality. So far as the analyses now available are concerned, the concretionary ores are of decidedly better quality than the laminated ores, and these in turn are better than the conglomerate ores. But few of the conglomerate ores now appear to be worth working.

The overburden in the best districts is light and it is probable that a steam shovel would operate to less advantage than plows, scrapers, and pick and shovel. We are inclined to think that a steam shovel will not prove to be the most economical method of handling the greater part of the material in many of the ore districts. It will doubtless find its use here and there, but by no means to the extent now to be seen in Alabama, Georgia, Tennessee, and Virginia.

MINING ORE.

Mining operations in the northern counties have been confined for the most part to the richest outcrops of concretionary ore, and simple hand methods of mining have prevailed. The largest-scale stripping has been done with wheel scrapers. Water is too scarce to render hydraulicking possible. Cheap methods of handling the stripping and the ore are needed, and now, as a result of extensive prospecting in Cass County, there seems to be a fair possibility that steam shovels may be used to advantage over large tracts. This method of mining must, however, be supplemented by concentration of the ore-bearing material, and it is upon the success of this part of the work that the possibility of large-scale mining operations in Cass and the adjoining counties seems most to depend.

Mining of the bedded ore near Rusk, Cherokee County, at present not being worked, was carried on as follows: The cover, which is mainly loose sand, was removed by means of wheel scrapers and dumped into ravines or piled in banks on ground from which the ore had been mined. Areas of several acres were thus stripped at one time. The thickness of the cover stripped rarely exceeded 7 or 8 feet, but a maximum of 10 feet was noted. After the loose cover was stripped off, the "sand cap," or scale of ferruginous hard sandstone, half an inch to 4 inches thick, was split loose from the top of the ore and piled up where it would not interfere with the workings. Then the ore was blasted loose from the bed and the lumps were pried up and broken to smaller sizes with sledges and picks and piled ready for shipment. The ore was loaded into carts by means of forks, and consequently much good ore in fine sizes was left on the ground. The ore of "curly" structure lying in the bed below the laminated top portion tends to crumble on weathering and is commonly referred to as the "buff, crumbly" ore. Probably much ore was thus lost by being allowed to weather too long before it was carried to the furnace. The use of forks appears at first thought to be a wasteful method, but when it is considered that this ore contains a high percentage of alumina, the importance of getting it up free of any underlying clay, even at the sacrifice of some fine ore, is readily apparent. The State mines were operated by convict labor and when in operation were connected with the blast furnace by railroads and tramroads. The method of mining at the other mines near Rusk was similar to that at the State mines, but on a much smaller scale.

CONCENTRATION OF ORE.

The profitable exploitation of the nodular, concretionary, and residual ores in Cass and adjoining counties probably depends more on the successful concentration of these ores than on any other factors connected with their development. Heretofore handpicking of the lump ore from the surface has been about the only method of maintaining a high-grade product, but this method is wasteful and altogether too slow and expensive to be continued. What is needed is a method or a combination of methods of ore concentration that will make it possible to work on a large scale the maximum thickness of ore-bearing ground, and deliver ore concentrates of high grade at a cost commensurate with the value of the ore recovered.

Experiments are under way in Cass County which involve washing the mine-run ore in revolving screens, picking the oversizes on a picking belt, and crushing and jigging the residue when separated from the loose sand and clay. In commercial operations the ore will first be run through log washers. The final step consists in calcining the ore to drive off the combined water from the limonite and the carbon dioxide from the carbonate ore. The washing and jigging experiments which have been carried on in a small but well-equipped plant have been designed mainly to ascertain the ratio of ore to dirt removed from the test holes, and although they were not made on a commercial scale they seem to demonstrate that the ore can be fairly well cleaned by this method, the percentage of silica being materially reduced and the percentage of iron proportionately increased.

Surface water is none too abundant in this region at certain seasons of the year, and the maintenance of steady and adequate supplies of water for large-scale operations may prove one of the most serious problems to be solved. There are many small creeks in the region which might be utilized to supply reservoirs, and the water after having been used once can be conserved for further use by means of settling basins. Deep wells are also expected to play a part in furnishing water for ore washing.

For calcining ore northeastern Texas is well supplied with fuel. There is an abundance of wood at present, lignite occurs in many places, and the Caddo oil and gas field is near by and already supplies natural gas to several towns in Cass County.

In 1914 an investigation was undertaken by William B. Phillips to ascertain whether the Goltra beneficiation process is applicable to the brown iron ores of northeastern Texas. By the Goltra process the use of water is dispensed with, the ore is cleaned by means of a current of hot air and properly located screens, and the fines are separated magnetically. Phillips[1] describes the process as follows:

> The material from the bank of ore, containing ore, sand, clay, earth, chert, sandrock, etc., is fed into a steel cylinder partly lined with fire brick. This cylinder is 125 feet long and 10 feet in diameter. It is inclined three-quarters of an inch to the foot and makes one complete revolution per minute. The travel of the material down and through this cylinder is at the rate of about 2 feet per minute, so that it reaches the lower end in from 45 to 60 minutes after feeding.
>
> At the lower end of the cylinder a blast of ignited pulverized coal is blown in by an Aero pulverizer, the fineness of the coal being from 80 to 100 mesh. At the upper end of the cylinder a large fan is installed, with a capacity of 35,000 cubic feet of air per minute, and this draws the heated air through the cylinder and discharges it, with the fine dust, into a dust catcher. During the drying of the material the temperature of the lower part of the cylinder is kept at about 300° F., the temperature at the upper end being about 200° F., or even less.
>
> The material is thus dried very slowly and completely, and during the drying the fine clay, sand, earth, etc., are swept out of the cylinder by the current of heated air. From this first cylinder the thoroughly dry material is sent to a gyratory crusher, set for 2 to 2½ inches. From the crusher the material goes to a revolving three-size screen, the inner openings, punched round, being three-

[1] Phillips, W. B., Concentration by the Goltra process: Iron Age, Nov. 12, 1914, pp. 1148–1150.

fourths inch, and the second screen, with round openings, being one-half inch. The outer screen has $\frac{1}{16}$-inch slotted openings.

The material over $\frac{3}{4}$-inch screen is hand picked on a picker belt and goes with all of the stuff, except such as passes the $\frac{1}{16}$-inch outer screen, into storage bins. The material through the $\frac{1}{16}$-inch outer screen goes into a reject bin.

The material from the revolving screen, all sizes above one-sixteenth inch, is conveyed to a storage bin which discharges into a second cylinder 125 feet long and 9 feet in diameter, partly lined with fire brick. This cylinder has the same slope as the first cylinder and the same revolutions per minute. It is heated in the same manner as the first cylinder, but the temperature is much higher, so that the material reaches the lower end at a bright-red heat—about 1,000° F. The heated air is drawn through this cylinder in the same manner as through the first cylinder, and the fine dust, etc., is discharged into a dust chamber.

From the lower end of this second cylinder, which may be termed the calciner, as distinguished from the dryer, the red-hot ore is screened over a revolving screen with $\frac{1}{2}$-inch punched round holes. The "overs" from this screen are cooled and hand picked over a picker belt and go direct to the loading bins above the railroad tracks. The red-hot material through the $\frac{1}{2}$-inch screen just mentioned goes to what is known as the reducer. This is a closely sealed steel cylinder, in which the ore is sprayed with crude petroleum and rendered highly magnetic. From this reducer the magnetized fine ore goes to screens where it is classified to one-fourth and one-sixteenth inch, these separate sizes being sent to Ball-Norton magnetic separators.

This, in brief, is the Goltra process. It is an air-washing process, instead of a water-washing process, and employs magnetization and magnetic separation of the fine material, instead of jigging it.

A Goltra plant has been built at Waukon, Iowa, in an attempt to render marketable the brown ore occurring near that place. In order to test the Texas ores Phillips shipped 14 carloads of Texas brown ore, aggregating about 338 tons in weight, to Waukon and put it through this concentrating process. The following analyses show the average composition of the ore at various stages:

Average composition of Texas brown ore concentrated at Waukon, Iowa, by Goltra process.

	1	2	3
Metallic iron [Fe]	32.74	42.36	55.23
Silica [SiO_2]	26.77	26.80	14.80
Alumina [Al_2O_3]	6.65	9.89	10.43
Sulphur [S]	.041	.003	Trace.
Phosphorus [P]	.075	.085	.098
Free water	11.33	....	....
Combined water	8.70	....	....

1. Average of samples of raw ore from each of 14 cars when unloaded at Waukon.
2. Average composition of ore after drying.
3. Composition of ore after calcining (excluding magnetic concentrates).

Of these analyses Phillips says:

The meaning of these figures is that a comparatively worthless material, the raw ore, is changed into an excellent product, well adapted for blast-furnace use.

The mere statement of the composition of the calcined ore does not convey the full sense of its merits. Its physical qualities, especially the porosity so essential for easy reduction in the furnace, are of equal if not greater importance. It would seem to be practically impossible to take a raw brown ore of similar character and make from it a better product than this calcined ore. In quantity it comprises 22.22 per cent of the dried ore and 38.76 per cent of the material from the calciner, which is to be classed as ore.

Embodying the results of the detailed analyses [both physical and chemical] of each separation in one general statement, we have:

Dry ore to be accounted for, 267.32 tons.

Ore recovered.

	Per cent of dry ore.	Per cent of material to be classed as ore.	Per cent of iron.
(a) Size, ½ inch and over, not magnetic	22.22	38.76	55.23
(b) Magnetic heads, partly oversize	4.39	7.55	55.23
(c) Magnetic heads, ½–¼ inch	.52	.90	63.33
(d) Magnetic tails	4.04	7.00	34.05
(e) Unfinished material, ½ inch and under	26.87	35.87	52.36
(f) Clean-up at separator	3.42	5.89	50.00
(g) Leakage at reducer feed	2.73	4.03	51.58
		100.00	

What has been done, therefore, is to take a raw ore containing 32.74 per cent of iron and bring 46 per cent of it up to 52 per cent of iron. Taking the free and combined water as material which has to be removed and which represents no possibilities of concentration, being a detriment to the ore, we have taken a material which in the ground carries 32.74 per cent of iron and have brought the iron up to 52 per cent. At the same time the physical nature of the ore has been greatly improved. The loss in weight during the operation, extending from the ore "bank" to the loading bins at the plant, is 54 per cent, of which 20 per cent is free and combined water. This leaves 34 per cent, or 115.13 tons of material, a portion of which may be suitable for further concentration.

Looking at this matter from the standpoint of clean ore, it is very satisfactory. The free and combined water are completely removed, the clay is almost completely removed, and the physical condition of the finished ore leaves nothing to be desired.

The greatest success is reached in preparing calcined ore over one-half inch in size. This product carries over 55 per cent of iron, and its physical condition is ideal.

Where the process is weak at present is in the treatment of the calcined ore through a ½-inch screen, this material being sent to the "reducer" for magnetization and then to magnetic separators.

While some of the magnetic heads carry 63 per cent of iron, yet the intermediate products and the tails carry too little iron as chargeable against the cost of concentration.

The finished product obtained by this process is excellently adapted for use in the blast furnace. The free and combined water are completely, and the clay, sand, etc., almost completely, removed. The sulphur, except in the case of some magnetic concentrates, is eliminated. The physical nature of the ore is greatly improved, particularly in respect to its porosity and easy reducibility in the blast furnace.

The loss in free and combined water in the ore tested was 20 per cent. From the ore received at Waukon we removed 67.83 tons of water, or 16,279 gallons. Good brown ore of 47 per cent iron as sent to the furnaces in Alabama will carry 14 per cent of water (free and combined) per ton of ore, and this water goes into the furnace and must be evaporated by the heat within the furnace, which otherwise would be used in smelting the stock.

UTILIZATION OF THE ORE.

GENERAL CONDITIONS.

The brown ores of northeastern Texas have been utilized to a minor extent for the manufacture of iron in small local forges or furnaces in almost every county in which a good-sized deposit of ore occurs. Some of these furnaces have already been mentioned. This form of industrial activity existed mainly between 1856 and 1870. Between 1870 and 1909 iron was manufactured from time to time in five or more small charcoal blast furnaces, notes on which are given below. Since the last of these furnaces went out of blast several plans have been made to establish iron and steel works on the Gulf coast, as well as at points between the ore field and the Oklahoma coking-coal field. A movement is now under way to establish an iron and steel industry at Texas City, Tex. The recent conditions of the iron and steel markets and the general financial situation have not, however, been favorable for the furtherance of such enterprises, and in the meantime some attention has been given to the shipment of iron ore to blast furnaces in Alabama and on the Atlantic seaboard.

Phillips,[1] who has given much thought to the utilization of the Texas brown ore, has stated his belief that the ore should be utilized in the northeastern part of the State rather than an attempt be made to build iron and steel works on the Gulf coast. With reference to the practical iron and steel plant he says:

Iron and steel works of the size to make profitable use of by-product ovens are not now needed in Texas or the Southwest. Instead, it seems to us that a blast-furnace plant producing 250 to 300 tons of pig iron a day, with a steel plant whose product would enter into the lighter finished forms, is much more to the point. The initial investment would be much less and the character of the product could be kept in closer touch with actual demands. The logical location for such a plant would be in east or northeast Texas, in close proximity to the ore fields and within reach of the coking coal of Oklahoma and Arkansas. So far as known there is no good coking coal in Texas and the nearer an iron furnace is to regular supplies of coke the better. Coking coal or coke will have to be brought from some other State. * * * The most favorable outlook in Texas and the Southwest for the manufacture of iron and steel is in the direction of a blast furnace with auxiliary steel plant, not operated so much with reference to the demand for the heavier forms, such as structural shapes, plates, or rails, as to the demand for cotton ties, wire

[1] Phillips, W. B., Iron and steel making in Texas: Iron Age, Jan. 4, 1912, pp. 14–16.

fencing, wire nails, perforated metal, pipe, and light steel castings. That such an enterprise would succeed here, under proper management is, we think, well within the bounds of probability.

TEXAS BLAST FURNACES.[1]

One of the early blast furnaces to utilize the local ores was the Loo Ellen furnace at Kelleyville, Marion County, 5 miles north of Jefferson, which was put into blast in 1870. The stack was originally square, but was rebuilt in round form in 1874. The height, originally 34 feet, became 45 feet; the bosh diameter was 9 feet, and the capacity of the furnace was 10 tons of metal a day. The product was at first hot-blast charcoal soft foundry iron, and later a hard iron especially suitable for chilled castings, such as car wheels, was made. Limestone for flux was obtained near Dallas.

A larger and more modern charcoal blast furnace was put into blast March 15, 1891, on the north edge of the town of Jefferson, and for several years this furnace was supplied with ore from deposits in Cass, Marion, and Morris counties adjacent to the railroads. Its annual capacity was rated at 13,500 tons. The plant has been inactive for 10 or 12 years.

There are three small blast furnaces in the vicinity of Rusk, Cherokee County, that were built to utilize the brown ore of the plateau, but all are now idle. The oldest furnace and the one which has had the most useful history is the property of the State of Texas. It was originally called the Old Alcalde, and was first put into blast in February, 1884, with a stack 55 feet high and a bosh diameter of 9½ feet. It was designed for an output of 25 tons a day, or 7,000 tons a year. It stands about three-quarters of a mile northeast of the center of Rusk, just outside of the walls of the State penitentiary, and has trackage connections with the Texas & New Orleans Railroad and the Texas State Railroad. The blast furnace and the associated ore mines were operated by convict labor, and considerable of the pig iron produced was remelted and cast into iron pipe at an adjoining pipe foundry, also owned and operated by the State. The furnace was originally built to use charcoal, but later it was rebuilt and ran on coke. The furnace has been out of blast since December, 1909, but in 1913 it was relined and put in good shape by the Texas Iron Association, which had leased the furnace and planned to revive operations. Owing to unfavorable business conditions and other reasons the lease was permitted to lapse.[2]

[1] Dumble, E. T., Reports on the iron-ore district of east Texas: Texas Geol. Survey, Second Ann. Rept. (for 1890), p. 15, 1891.
Walker, J. B., idem, pp. 293–294.
Phillips, W. B., The iron resources of Texas: Western Pennsylvania Proc., vol. 18, No. 2, p. 77, 1902.

[2] See Min. and Eng. World, June 27, 1914, p. 1210.

The Tassie Belle furnace, 2 miles southeast of Rusk, was put into blast in November, 1890. This furnace stands on the east side of the St. Louis Southwestern Railway and during its few years of activity was surrounded by a flourishing town known as New Birmingham. It was operated as a charcoal furnace and two of the old charcoal kilns still stand. The capacity was rated at 13,500 tons a year. The furnace is now in a very dilapidated condition, the top house and elevator ways have fallen down, the machinery has been allowed to rust and to be dismantled, and the ground is covered by second-growth pine.

The last furnace to be built in Cherokee County was the Star and Crescent, which was put into blast in November, 1891. It stands on the south side of the St. Louis Southwestern Railway about three-quarters of a mile east of Rusk. This furnace is said to have been operated as late as 1907. The equipment is in better shape than that of the Tassie Belle, and 31 brick charcoal kilns remain standing. The capacity was rated at 18,000 tons of pig iron a year.

SHIPMENTS OF ORE TO OTHER STATES.

About 1907–8 approximately 2,200 tons of brown ore (mostly from Marion and Cass counties) was shipped to the Birmingham district, Ala., a distance by rail of about 500 miles. The ore was mostly in selected lumps, and its average content of metallic iron was above 57 per cent, with phosphorus ranging from 0.10 to 0.20 per cent. It was reported to be well adapted for the production of basic open-hearth steel. The freight rate was $2.20 a ton.[1]

In 1910 a sample lot of 568 tons of brown ore was shipped to Philadelphia by way of Texas City, on Galveston Bay. The rail haul was about 300 miles. The ore was similar in quality to that sent to Birmingham. A rate of $2.30 a ton to Philadelphia is reported to have been quoted to one of the companies.[2]

Two steamer cargoes of high-grade brown ore were shipped from northwestern Marion County to Philadelphia, by way of the Port Bolivar Iron Ore Railway and the Atchison, Topeka & Santa Fe Railway to the Gulf, in the summer of 1913. The analyses of this ore are given on page 88. It is reported by the shippers that the ore gave excellent satisfaction in the Alan Wood Iron & Steel Co.'s furnaces, where it was used.

Concerning the supply of the highest grade of ore Phillips[3] says:

> While it may not be possible to secure large and regular shipments of 57 per cent ore from east Texas, yet we believe there are very large supplies of 50 per

[1] Phillips, W. B., Iron and steel making in Texas, I: Iron Age, Jan. 4, 1912, p. 14.
[2] Linton, Robert, Texas iron-ore deposits: Eng. and Min. Jour., Dec. 20, 1913, pp. 1154–1156.
[3] Phillips, W. B., op. cit., p. 15.

cent ore which can be mined and loaded for 85 cents to $1 per ton. Such ore could be laid down in the stockyard of a furnace at Jefferson for $1.25 a ton and at Texarkana for $1.50 a ton. The ore cost of a ton of pig iron should not exceed $3 at either of these localities.

PAPERS ON GEOLOGY AND IRON-BEARING DEPOSITS OF EASTERN TEXAS AND NORTHERN LOUISIANA.

BIRKINBINE, JOHN, The iron industry of Texas: U. S. Assoc. Charcoal Iron Workers' Jour., vol. 6, pp. 168–172, June, 1885.

DEUSSEN, ALEXANDER, Geology and underground waters of the southern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, 364 pp., 1914.

DUMBLE, E. T., KENNEDY, WILLIAM, and others, Reports on the iron-ore district of east Texas; Texas Geol. Survey Second Ann. Rept. (for 1890), pp. 7–326, 1891.

ECKEL, E. C., Iron industry of Texas: Iron Age, vol. 76, pp. 478–479, Aug. 24, 1905.

——— The iron ores of northeastern Texas: U. S. Geol. Survey Bull. 260, pp. 348–354, 1905.

GORDON, C. H., Geology and underground waters of northeastern Texas: U. S. Geol. Survey Water-Supply Paper 276, 78 pp., 1911.

HARRIS, G. D., Oil and gas in Louisiana: U. S. Geol. Survey Bull. 429, pl. 13, 1910.

JOHNSON, L. C., Report on the iron regions of northern Louisiana and eastern Texas: Fiftieth Cong., 1st sess., House Doc. 195, 54 pp., 1888.

KENNEDY, WILLIAM, Iron ores of east Texas: Am. Inst. Min. Eng. Trans., vol. 24, pp. 258–288, 862–863, 1895.

LINTON, ROBERT, Texas iron-ore deposits: Eng. and Min. Jour., Dec. 20, 1913, pp. 1153–1156.

——— East Texas iron: Los Angeles Min. Rev., Dec. 25, 1909, pp. 12–13.

PENROSE, R. A. F., jr., The iron ores of east Texas: Texas Geol. Survey First Ann. Rept., pp. 65–84, 1890.

——— A preliminary report on the geology of the Gulf Tertiary of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., pp. 3–101, 1890. (The iron ores of east Texas, pp. 65–86.)

——— The Tertiary iron ores of Arkansas and Texas: Geol. Soc. America Bull., vol. 3, pp. 44–50, 1892.

PHILLIPS, W. B., The iron resources of Texas: Eng. Soc. Western Pennsylvania Proc., March, 1902, pp. 64–79.

——— Iron and steel making in Texas: Iron Age, Jan. 4, 1912, pp. 14–16; Jan. 11, 1912, pp. 141–143.

——— The new iron-ore dock at Port Bolivar (Galveston Bay, Tex.): Iron Age, April 18, 1912, p. 974.

——— The iron situation in east Texas: Min. World, November 26, 1910, p. 994.

WALKER, J. B., Reports on the iron-ore district of east Texas: Texas Geol. Survey Second Ann. Rept., pp. 293–294, 1891.

ANON., Texas as an iron-producing State: Manufacturers' Record, February 22, 1912, pp. 110–111.