GEOLOGICAL SURVEY OF OHIO

WILBUR STOUT, State Geologist

FOURTH SERIES, BULLETIN 45

The Iron Ore Bearing Formations of Ohio

By

WILBER STOUT

COLUMBUS

1944

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(Compiled from Various Sources)

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PREFACE

This report contains little new material but is simply a preliminary survey leading to a more detailed treatment in the future. Thus it is largely a compilation of data gathered by many workers over a long period and largely during the active days of the early furnaces when the deposits were well exposed for observation and measurements. The data are assembled in an orderly fashion, the various members and units being treated in an ascending order. It is hoped the report will serve a useful purpose until much new material may be gathered for a more elaborate treatise.

The Iron Ore Bearing Formations of Ohio

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THE IRON ORE BEARING FORMATIONS OF OHIO

by

WILBER STOUT

INTRODUCTION

In Ohio some utilization for the smelting of iron has been made of iron ores and of ferruginous rocks found in a wide expanse of strata, ranging through certain beds from the Brassfield limestone in the Silurian system to the Creston Red beds in the Permian system and on even to the bog ores laid down since the retreat of the Wisconsin glacier. The ores that were of prime importance, however, fall in the Pottsville and Allegheny series of the Pennsylvanian system and were smelted in the furnaces in the belt extending from Scioto and Lawrence counties on the Ohio River to Mahoning and Columbiana counties on the Ohio-Pennsylvania state line. Various deposits were used in other areas. The native ores thus supported the charcoal iron industry of the State—eighty-six furnaces in all—that began with the erection, in 1804, of Hopewell furnace on Yellow Creek in Mahoning County and closed with shutting-down, at 3 P. M. December 26, 1916, of Jefferson furnace near Oak Hill in Jackson County. Also throughout most of the active life of the fifty-six coal furnaces erected between 1845, Mary at Lowellville, and 1887, New York at Shawnee, the ferruginous part of the burdens consisted entirely or largely of ores gathered not far distant from the stacks. Further, many of the more modern coke furnaces built between 1863 and 1895 used some native ores along with that from outside sources. The smelting of Ohio ores thus ceased about 1923. Of the total of 226 blast furnaces built in Ohio all but about 60 have smelted native ores, over one-half nothing else. The period of such utilization was thus about 119 years, from 1804 to 1923. The Ohio ores still have a future.

KINDS OF ORES

SIDERITE OR IRON CARBONATE ORES

The siderite or iron carbonate ores, definitely of sedimentary origin, were laid down under marine, brackish and fresh water conditions where organic matter provided the carbonate (CO_2) radicle. Many of them contain fossil shells, plant impressions, etc., indicating their origin. Such ores may occur as regular stratified beds with a wide distribution, as nodules and concretions of various sizes in shales, or as oolitic-like shot cemented into irregular masses. The ferruginous matter was precipitated from the

soluble bi-carbonate $Fe<^{HCO_3}_{HCO_3}$ by the extraction or removal of H_2CO_3, thus rendering the $FeCO_3$ (siderite) insoluble. The factors of precipitation are adjustments of temperature, pressure, concentration of carbon dioxide, stagnation or circulation of water, and others. In the coal formations of Ohio the cycles of deposition are:

Complete	*Incomplete*
Shale and sandstone	Shale and clay
Iron ore	Iron ore
Marine limestone	Shale
Coal	Coal
Clay	Clay

Thus the ore may lie directly on the limestone or be placed in the shales above the coal. These ores vary much in color but are usually some shade of bluish gray, light gray to very dark gray, depending on the quantity of organic pigments present and on their dispersion. The siderite ores are dense and often break with an immature conchoidal fracture. The common range of specific gravity is from 3.00 to 3.80 depending on the purity of the material. The chief deleterious materials are silica and clay matter. Pure siderite contains 48.20 per cent iron. In the natural state the content of iron in the ores varies from 25 to 45 per cent but usually ranges between 30 and 40 per cent. The carbonate ores were all roasted before use in both the charcoal and coal furnaces. This reduced them from $2FeCO_3$ to Fe_2O_3 and thus increased the yield of metal.

LIMONITE OR BROWN ORES

As a class the limonite ores are derived from the alteration of siderite ores, from the decomposition of impure limestones and dolomites with enrichment of ferruginous matter, and by direct precipitation under oxidizing conditions of soluble iron salts in bogs, swamps, etc. They are amorphous in character and vary from soft putty-like ochers to hard, dense ores. The limonites consist essentially of the hydroxide limonite, $2Fe_2O_3 3H_2O$, bearing when pure 85.53 per cent iron oxide, Fe_2O_3, 14.47 per cent water, H_2O, and 59.82 per cent metallic iron, Fe. These ores vary much in color from light buffs through browns to dark shades, the changes being due to density, to texture, and to the effects of other coloring agencies as carbonaceous matter, manganese compounds, etc. The denser ores have a specific gravity usually around 3.6. Through weathering from other rocks, especially from siderite, the limonite ores take on distinctive forms known to the miners and furnace men as block ores, kidney ores, shell ores. and the like. Although they reduced readily even in the short stack of the charcoal furnace, commonly they were roasted to remove the combined water and to improve the physical properties. The limonite ores

were of vast importance in the iron industry in Ohio for over one-hundred years.

HEMATITE ORES

True hematite ores are not abundant in Ohio but nevertheless occur through a wide range of strata, from the Brassfield limestone in the lower part of the Silurian system to the Creston Red beds in the Washington series of the Permian system. They occur in both marine and fresh water formations. Their origin is variable and not well understood. Such hematites appear to have been formed as primary deposits from soluble $Fe<\frac{HCO_3}{HCO_3}$ through precipitation under oxidizing conditions and in the absence of active carbon dioxide, CO_2. They are not products of desiccation. Such ores occur most commonly as regularly stratified deposits in the limestone formations and as nodules in red shales. Each phase will be discussed more fully elsewhere. The hematite ores vary in color from bright red through brownish tints to very dark red. They are amorphous in character and assume wide textural differences fom soft, unctuous ochers to dense, hard stone. Further, oolitic structures are not uncommon. When pure the hematites range from 4.9 to 5.3 in specific gravity but the common ores, owing to impurities, have less relative weight. They are rich in iron and when pure yield 69.94 per cent metal. In former days the native hematites were used only in a small way in iron making in Ohio but in the future they may become of more importance.

BLACKBAND ORES

The blackband ores are directly associated with the coal beds, being found within or above such strata, usually the latter. In Ohio the known deposits fall in the Pottsville, Allegheny, and Conemaugh series of the Pennsylvanian system. The ore bodies are decidedly lenticular in nature, vary in extent from a few acres to several square miles, and change in thickness in different parts of the lens from a few inches to 10 feet or more. In the blackband ores the iron is in the form of the carbonate, $FeCO_3$. Along the outcrop, however, this may be changed to the limonite form. They may be considered as shales high in ferruginous matter and in organic residues which are in a fine state of division and act as the chief coloring pigment. The normal color is dark brown or brownish black. Commonly the ore has a definite banded appearance, hence the name blackband, through varying shades of color along the bedding planes. It thus presents a crude varve-like structure, the differences probably due to seasonal changes in the quantity of organic matter preserved during deposition. Owing to the presence of shaly matter, pyrite, organic matter, etc. the blackband ores are normally not rich in iron, the usual range of this metal in the natural ore being between 25 and 35 per cent and in the calcined product 40 to 53 per cent. The specific gravity of such ores

is low, 2.3 to 2.6. Some of the blackband ores are high in manganese compounds and most of them in the foundry grade in phosphorus. The blackband ores were of much importance in eastern Ohio and along with Sharon coal shaped up in iron industry of Youngstown, Hubbard, Warren and Massillon.

BOG ORES

"Bog iron ore is another rock formed through precipitation. It was deposited from shallow surface and spring waters in swales and swamps. The ferruginous component was gathered from the soils and consolidated rocks on the uplands through the action of acids from decaying organic matter, was held in solution as the soluble ferrous bicarbonate, $Fe<\begin{matrix}HCO_3\\HCO_3\end{matrix}$ and was precipitated in shallow water in the form of a yellow or orange-colored sediment which on consolidation became ore. This change came about through general chemical activity, aided possibly by 'iron bacteria.' In this reaction soluble ferrous bicarbonate oxidizes and hydrates to limonite. The reaction follows:

$$4Fe<\begin{matrix}HCO_3\\HCO_3\end{matrix} + O_2 = 2Fe_2O_3 \cdot 3H_2O + 8CO_2 + H_2O$$

"Bog ore is open and spongy in texture, generally yellowish brown in color, and usually more or less contaminated with impurities, chief of which is clay matter. The ore bodies are uncertain in lateral extent and variable in thickness. In size they vary from scattered nodules to sheets of several acres. The thickness ranges from a few inches to several feet but usually averages between 1 and 2 feet. In northern and especially northeastern Ohio the bog ores formerly played an important part in iron making. Such ore was most abundant along the Beach Ridges from Cleveland to the Pennsylvania-Ohio line."[1]

FERRUGINOUS TUFA OR FERRUGINOUS TRAVERTINE

Ferruginous tufa, ferruginous travertine, or ocherous deposits are commonly laid down from chalybeate or iron-bearing carbonate waters, with ions of ferrous oxide, FeO, by loss of carbon dioxide, CO_2, oxidation of the ferrous oxide, FeO, to ferric oxide, Fe_2O_3, and hydration of the ferric oxide to ferric hydrate or limonite, $2Fe_2O_3.3H_2O$. In steps the reaction may be written:

$$Fe<\begin{matrix}HCO_3\\HCO_3\end{matrix} = FeO + H_2O + 2CO_2$$
$$2FeO + O = Fe_2O_3, \text{ hematite}$$
$$2Fe_2O_3 + 3H_2O = 2Fe_2O_3 \cdot 3H_2O, \text{ limonite}$$

In many cases, however, the reaction does not proceed to limonite but only to hematite or to a mixture of the two.

[1]Stout, Wilber, Geol. Survey Ohio, Fourth Series, Bull. 41, pp. 10-11.

"Ferruginous deposits of this character occur around chalybeate springs where a constant supply of the ferruginous component is present. The precipitation of the iron mineral appears to be due to temperature changes, to evaporation of water changing the concentration, to oxidation from contact with air, and to precipitation through the formation of a stable insoluble compound.

"Such deposits of ferruginous tufa or travertine vary considerably in both physical and chemical properties. The common colors are dark buff, orange, reddish brown, and dark brown. Other shades as light yellow, greenish buff, nearly black, etc. are occasionally found. The coloring pigments include the various oxides and hydroxides of iron, peaty or carbonaceous matter, and small quantities of manganese salts, ferrous carbonate, and sulphur impurities. In texture the ferruginous tufas and travertines vary from soft spongy through open porous, earthy and grainy to hard dense rock. The compactness depends on original precipitation and on secondary cementation after deposition. Such tufas and travertines have found little application economically in Ohio."[1]

MINERS' TERMS OR LOCAL NAMES OF ORES

Practically all stratified beds are regularly jointed thus dividing the strata into rectangular blocks. The spacing of the joints is dependent in a way on the thickness of the bed and on the character of the material. With the ores the rectangles are approximately about equal to the thickness in width and one and one-half that in length. The form of the ore thus gave rise to such names as Big Red Block, Little Red Block, Sand Block, etc. Such ore may be carbonate or limonite in character depending on the state of weathering.

With the kidney ores the form again gave rise to the name. These are nodular or concretionary ores oval or kidney shaped. They are found bedded along a definite horizon or may be scattered indiscriminately in shale. Such ore may be carbonate or limonite in character. In general the kidney ores are thin, not over a few inches in thickness. The Red Kidney ore found below the Middle Kittanning coal is a good example.

Shell ores, as the name implies, are limonites that through long and intensive weathering have been reduced to an outer shell of more or less concentric layers loosely cemented. The inner cavity may be hollow or filled with soft ocherous ore. Such ores are most common along the outcrop of the deposits and may be derived from either block or kidney ores.

With the nodular ores the term again is self explanatory. They occur as nodules, irregular in size and in form, scattered heterogeneously in shales or confined to certain bands or zones in such rock. The size of the nodules may vary from fine shot to several inches in diameter. The

[1]Stout Wilber, Geol. Survey Ohio, Fourth Series, Bull. 41, pp. 11-12.

nodules may be siderite, limonite, or most typical hematite in character. A good example of such an occurrence is the hematite nodules in the Round Knob red shales in the Conemaugh series.

"Concretions are developed after the formation of strata. They are balls or irregular lumps of material differing from that of the stratum in which they occur. They are not pebbles, which are older than the stratum which contains them and which were embedded just as we find them, but are younger than the stratum and were formed subsequently. This is shown by the fact that the planes of stratification may often be traced through the concretion, and that fossils are sometimes found partly within and partly without the nodule. In shape the concretions vary greatly, from almost true spheres, to grotesque aggregations, but always with rounded form, and almost as great a variety of material is found among them. Very often a foreign body, like a fossil shell or leaf, forms the center or nucleus of the nodule, which has been built up, often in concentric layers, around the nucleus. One form of concretion, known as *septarium,* is divided internally by radial cracks, which were subsequently filled up with some mineral deposited from solution by percolating waters."[1] The most outstanding example of concretions in Ohio are those in the basal portion of the Ohio shale. The material is largely impure siderite.

In the cycles of deposition in the Pennsylvanian system, especially in the Pottsville and Allegheny series, the succession of strata in ascending order in some cases is clay, coal, limestone, iron ore, and shale or sandstone. The association of limestone and iron ore holds particularly true with the Lower Mercer, Upper Mercer and Vanport limestones. The last is well developed from central to southern Ohio and was readily recognized by miners and furnacemen, hence the associated ore was known simply as the "Limestone" ore. This is only a substitute name for Ferriferous ore which economically was the most prominent bed in Ohio supporting most of the charcoal furnaces in the old Hanging Rock Iron District and some of the coal furnaces in the Hocking Valley.

"From the fact that this ore is only found in the tops of the hills, it is sometimes designated as the 'Mountain' ore; and the limestone [Mahoning], from its ferruginous character, assumes, on weathering, a brownish color, and is hence often referred to as the 'buff' limestone, to distinguish it from the blue limestone [Putnam Hill] below. These ore beds are detached outliers of a great ferruginous sheet which once covered much of Stark, Carroll and Tuscarawas counties. Patches of this ore sheet, separated from their connections by the erosion of the valleys of the Sandy, Conotton, and Tuscarawas, occur in the isolated hills of Osna-

[1]Scott, William B., Introduction to Geology, The Macmillan Company, 1905, pp. 227-229.

burg and Paris townships, Stark County, Rose Township in Carroll, and Sandy and Fairfield townships in Tuscarawas."[1]

The term "flag" ore was applied by the miners to ferruginous deposits derived through weathering and enrichment from rather uniformly, bedded limestones or calcareous sandstones. In general the "flag" ores worked in Scioto, Lawrence, and Jackson counties were low in iron content but occurred with fair volume. They were utilized only in a small way.

The "Clayband" ores occur along definite zones in the soft clays or shales of the coal formations. The normal ore was a siderite but on weathering this changed to limonite. The "clayband" ores were of little importance in iron making in Ohio.

Various local names were also applied to ore bodies throughout the State. Such names may be derived from the description of the place, from the character of the material, from the property owner, from some chance expression, etc. As examples: the "Snow Fork" ore was named from the stream, Snow Fork, in the Hocking Valley area; the "Sour Apple" was a nodular ore on the horizon of the Bolivar clay and worked near Moxahala furnace in Perry County; the "Hallelujah" ore of Mt. Vernon furnace was present at about the level of the Mahoning limestone; the Boggs ore received its name from the Boggs farm near South Webster in Scioto County, etc.

[1]Newberry, J. S., Geol. Survey Ohio, Vol. III, pp. 175-176.

SILURIAN SYSTEM

INTRODUCTION

In Ohio the Silurian system contains only small quantities of iron ores and ferruginous materials other than the common quantities of iron oxides normally present in the dolomites and limestones which make up the great mass of rocks in this geological section. However, three furnaces in Adams County were supported by ore gathered from the top of the Niagara dolomite and one pocket furnace in Clinton County smelted some ore from the Brassfield limestone. In Ohio the Elkhorn formation is red in color and ferruginous in character but too lean to be considered more than pigmented shale.

ELKHORN MEMBER

The Elkhorn shale of Ohio is the Red Medina of the driller and the Queenstown of New York. The formation is regional in distribution but variable in thickness even locally. The common measurements in western Ohio are between 30 and 90 feet. The color of the shale is quite distinctive, being red or brownish red. The dominant pigment is hematite, Fe_2O_3. In the Tennessee and Alabama fields to the south this formation, a part of the Rockwood, appears to provide some iron ore. In Ohio one analysis shows:[1]

Ferric oxide,	Fe_2O_3 = 2.44 per cent	= 1.71	per cent Fe
Ferrous oxide,	FeO = 1.46 " "	= 1.13	" " "
Pyrite	FeS = 0.15 " "	= 0.07	" " "
	Total	2.91	

BRASSFIELD MEMBER

"The Brassfield limestone is present at the surface in an extended area in southwestern Ohio. The trend of its outcrop is northeastward from the Indiana-Ohio line near Fairhaven across Preble and Montgomery counties into central Miami County, thence southeastward across Clark, Greene, Clinton, Highland, and Adams counties to the Ohio River near Rome. The name Clinton was originally given to deposits in New York by Vanuxem, in 1842. Then, Orton, in 1873, applied the term to limestone deposits in Ohio occupying approximately a similar position in the geological column.

"In Ohio the thickness of the Brassfield member is from 20 to 60 feet with an average around 30 feet. . . . Locally in Adams, Highland, and

[1]Geol. Survey Ohio, Fourth Series, Bull. 42, pp. 388-396.

Clinton counties one or more layers in the middle portion of the formation becomes very ferruginous and conspicuously oolitic and closely resembles the famous Clinton ore of both the New York and the Tennessee-Alabama fields. Its use for iron smelting was attempted at the Todd pocket furnace in 1851, on Todd Fork north of Wilmington."[1]

The intention of the Clinton Furnace Company was to make iron from the thin layers of lean calcareous ore in the Brassfield limestone. The ore was mined along the south wall of the stream from the furnace eastward to the Xenia Highway. It is of the "fossil" oolitic type and much resembles that worked at Olympia, Kentucky, at Rockwood, Tennessee, and at Birmingham, Alabama.

These ferruginous layers in the Brassfield member are present in western Highland County and are conspicuous along Rocky Fork south of Hillsboro and along Ohio Brush Creek in the southeastern part of the area. The hematite-bearing layers are from 4 inches to 1 foot 8 inches in thickness. These beds continue with some variation along Ohio Brush Creek in Adams County and may have been used to a small extent by the furnaces there. The richest ore observed is that at the surface and loose blocks found along the streams. The geology of the ferruginous stratum is shown in the following record taken in a road cut on Route 41 just south of the bridge over Ohio Brush Creek, one mile southwest of Jacksonville, western Meigs Township, Adams County. Samples were taken March 22, 1940, by Wilber Stout and Walter Stout. The rock section is given below:[2]

Brassfield formation	*Ft.*	*In.*
Limestone, light, medium to massive layers, with only thin partings	5	10
Shale, calcareous, with a few layers of limestone, 2 to 6 inches in thickness	5	2
Shale, calcareous, with widely spaced layers of limestone, 2 to 6 inches in thickness	9	10
Iron ore, brownish red, oolitic, massive, sample 264	1	2
Limestone, thin to medium bedded with shale partings	9	0
Shale, bluish gray, with thin limestones	1	7
Limestone, thin to massive layers, hard, very fossiliferous, some thin shale partings	12	0
Limestone, massive, with much chert, fossiliferous	4	4
Limestone, thin to medium bedded with shale partings	6	2
Shale, calcareous, with thin layers of limestone	6	0
Limestone, shaly, drab to bluish gray, hard, a few fossils	3	6
Shale, calcareous, bluish gray	3	4
Limestone, very shaly, bluish gray	2	2
Shale, calcareous, gray	..	8

[1]Geol. Survey Ohio, Fourth Series, Bull. 42, p. 88.
[2]Geol. Survey Ohio, Fourth Series, Bull 42, pp. 49-51.

Elkhorn formation		
Shale, calcareous, pinkish, with thin layers of shaly limestone	7	0
Road level	..	..

"The chemical composition of the Brassfield iron ore is given below: Analyst Downs Schaaf.

Silica, SiO_2	1.95
Alumina, Al_2O_3	1.45
Ferric oxide, Fe_2O_3	13.03
Ferrous oxide, FeO	1.54
Pyrite, FeS_2	<0.01
Magnesium oxide, MgO	0.72
Calcium oxide, CaO	42.90
Sodium oxide, Na_2O	0.01
Potassium oxide, K_2O	0.03
Water, hydroscopic, H_2O-	0.90
Water, combined, H_2O+	1.70
Carbon dioxide, CO_2	35.24
Titanic oxide, TiO_2	0.09
Phosphorus pentoxide, P_2O_5	0.25
Sulphur trioxide, SO_3	<0.01
Manganese oxide, MnO	0.20
Carbon, organic, C	0.02
Total	100.03

"The mineral components in the ferruginous layer of the Brassfield limestone, Sample 264, as determined by calculation (Stout) from the analysis, are as given below:

Sericite, $(K, Na)_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$				0.36
Kaolinite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$				8.31
Quartz or free silica, SiO_2				0.25
Limonite, $2Fe_2O_3 \cdot 3H_2O$				8.43
Hematite, Fe_2O_3				5.82
Pyrite, FeS_2				0.00
Rutile, TiO_2				0.09
Apatite, $3CaO \cdot P_2O_5$				0.55
Anhydrite, $CaO \cdot SO_3$				0.00
Limestone	Main components	$MgO \cdot CO_2$ 1.51; $CaO \cdot CO_2$ 76.03		77.54
	Parts in solid solution	$FeO \cdot CO_2$ 2.48; $MnO \cdot CO_2$ 0.32		2.80
Water, hydroscopic, H_2O-				0.90
Hydrocarbons, $C_N H_{2N+2}$				0.02
Unbalanced parts (excess CO_2, H_2O)				—0.04
Total				100.03

Metals	
Iron, Fe	10.31
Manganese, Mn	0.15
Phosphorus, P	0.109
Fluxes	
Magnesium oxide, MgO	0.72
Calcium oxide, CaO	42.90
Parts to be slagged off	
Silica, SiO_2	1.95
Alumina, Al_2O_3	1.45
Titanic oxide, TiO_2	0.09"

Today such an ore would be useful as flux stone if the quantity available was not so small. In an investigation of these ores for the Columbus Iron and Steel Company, 1910, the richest ore found contained about 22 per cent iron.

Examination of well cuttings shows that these ferruginous layers in the Brassfield limestone are present at least locally under deep covering in central and eastern Ohio. Where found throughout the southwestern part of the State these ores are definitely oolitic in character and the iron largely in the form of hematite. On general correlation they are certainly related to the Clinton ores of New York, the Olympia ores of Kentucky, and the Rockwood ores of Tennessee and Alabama. In Ohio the Brassfield ores are of more interest for their geological relationships than for their economic value.

NIAGARA ORES

The Niagara ores are confined to the area of overlap in Adams, Highland, Pike, and Ross counties where the Monroe, Columbus, Delaware, and Olentangy formations are absent or where the Ohio shale rests on the Niagara dolomite. The chief deposits worked, however, were in Adams and Highland counties, in the so-called marl region, where the rock surface was long exposed and much weathered thus reducing the rock to a soft porous, marly condition. As described by Locke[1] the deposits are very pockety and uncertain and limited in extent. The ore bodies occur in large irregular masses in depressions in the upper surface of the dolomite. They vary in thickness from a few inches to 10 feet and in diameter from a few feet to many square rods. Along the outcrop and under shallow covering the ore is a soft limonite of moderate richness. It is decidedly open or cellular in texture, with thin plates or laminae forming the walls. The cell openings are commonly filled with ochre, bright yellow in color, and fine and plastic in grain. The common yield appears to have been about three tons of raw ore for one ton of metal. These ores supported three furnaces, Brush Creek, 1811-1837, Steam, 1814-1839, and Marble, 1816-1835, and provided some ore for Brush Creek, Steam, Rapid, and Benner forges.

[1]Geol. Survey Ohio, Second Annual Report, part by John Locke, 1838, pp. 252, 253. Also Vol. V, 1884, pp. 372, 448, 450.

DEVONIAN SYSTEM

INTRODUCTION

The Devonian system of rocks in Ohio contains little of interest to the iron manufacturer except limestone for fluxing purposes. No good iron ore is present in the entire formation. It is made up primarily of dolomite, limestone, and shale. The most ferruginous materials are the concretions in the Ohio shale.

FERRUGINOUS CONCRETIONS IN OHIO SHALE

The concretions in the Ohio shale are always ferruginous in composition but are not sufficiently rich to be considered as an iron ore. Westgate states:[1] "The concretions are found only in the lower part of the Ohio shale. . . . They are found entirely across the State of Ohio from the Ohio River to Lake Erie, and even beyond the State boundaries. A well-known locality outside the State is at Kettle Point, Ontario, where they have been described by Daly. They appear to be related in some unknown way to a water circulation through the Ohio shale just above the impervious Olentangy shale; under conditions, of course, entirely different from today, when the concretions are at the surface, in the zone of weathering and subject to disintegration.

"The following analysis of the rock was made for the Geological Survey of Ohio by Prof. D. J. Demorest:

Silica, SiO_2	9.08
Alumina, Al_2O_3	1.87
Ferric oxide, Fe_2O_3	5.03
Phosphorus pentoxide, P_2O_5	trace
Titanic oxide, TiO_2	0.12
Calcium oxide, CaO	27.29
Magnesium oxide, MgO	13.80
Manganous oxide, MnO	0.50
Carbon dioxide, CO_2	38.83
Carbon, C (organic)	2.25
Sulphur, S	0.675
Moisture at 105°C.	0.20
Total	99.645

"The mineral composition of the rock has been calculated from the chemical analysis and is given below. In this calculation the organic carbon, TiO_2, and MnO have been ignored, and the total calculated to 100 per cent.

[1]Westgate, Lewis G., Geol. Survey Ohio, Fourth Series, Bull. 30, p. 55.

Dolomite $(Ca,Mg)CO_3$	65.26
Calcite $CaCO_3$	15.07
Siderite $FeCO_3$	4.98
Kaolinite $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	4.82
Quartz SiO_2	6.91
Pyrite FeS_2	1.31
Limonite $2Fe_2O_3 \cdot 3H_2O$	1.65
Total	100.00

Calculating the metals alone this gives:

Iron, Fe	3.52
Phosphorus, P	trace
Manganese, Mn	0.39

Although these concretions in the Ohio shale have been suggested as a source of iron, they are entirely too lean in the metals and too high in slag components to be attractive. Other samples show up to 10 per cent iron. Further, the quantity of such material at any one place is small.

MISSISSIPPIAN SYSTEM

INTRODUCTION

The Mississippian system is made up largely of sandstones and siliceous shales. Locally the Maxville limestone appears at the top of the section and a thin stratum, 16 to 25 feet, of dark carbonaceous shale, the Sunbury, is found above the Berea sandstone. This great division of rocks is impoverished in iron ores.

FERRUGINOUS MATERIALS IN THE WAVERLY GROUP

The shales in the lower part of the Waverly group of rocks, especially locally in the State, contain abundant nodules or concretions of ferruginous matter. They may be spaced along certain zones or scattered promiscuously through the strata. In size they vary from 1 inch or less to several inches in length. The largest weighs several pounds. Unless weathered the material is impure siderite, blue gray in color. In the main these concretions were formed around fossil shells of marine types of life. Such material was especially abundant (now flooded by the dams in Ohio River) on the rock bar at Sciotoville. The material was low in iron, little of it containing more than 20 per cent iron. There is no record of this type of ore being used for iron making in the State.

In the upper part of the Waverly group, near the Allensville horizon, thin lenses of iron ore were locally present in parts of southern Ohio. These ore bodies occur on definite horizons, somewhat sheet-like in formation. The common thickness is 2 to 6 inches. The material is very fossiliferous with crinoid stems, brachiopods, etc. and along the outcrop is a soft limonite ore. Ores of this type were gathered along the outcrop and smelted to a small extent in Harrison furnace in central Scioto County. As a whole the ferruginous materials in the Waverly group of Ohio offer little for iron making.

EROSION INTERVAL

INTRODUCTION

A time break of some considerable length exists between the close of the deposition of the known Mississippian rocks in Ohio and the earliest of the deposits of the Pennsylvanian coal-bearing strata. The Maxville limestone in this State is only a remnant of the thick formations of like age found to the south and to the southwest in neighboring states. Further, especially in northeastern Ohio, much of the Waverly group is missing. The only representative of this lost interval is the Harrison ore.

Description of ore.	Analysis of ore in natural state in per cent.										Results of smelting 100 pounds of ore in the blast furnace on basis of smel										
	Iron.	Silica.	Alumina.	Lime.	Magnesia.	Phosphorus.	Manganese.	Sulphur.	Ignition loss.	Hydroscopic water.	Gases produced, in pounds.	Gases produced in cubic feet at 200°C.	Air required for smelting in pounds.	Air required for smelting in cubic feet at 20°C.	Pig iron produced in pounds	Slag produced in pounds.	Stone required for fluxing in pounds.	Coke required for smelting in pounds.	Ore used in pounds.	Coke required per 2268 pounds iron produced.	Gases in cubic feet at 200° C per pound coke used.
No. 1. Block ore, calcined.....	38.04	28.85	5.64	5.19	1.47	.576	.74	.89	.....	.23	308.06	6,310.61	219.74	2,924.25	42.178	75.39	58.08	48.05	100	2,584	131
No. 2. Block ore, raw carbonate.....	29.44	22.33	4.36	4.01	1.14	.445	.53	.69	24.38	.....	315.78	6,469.46	217.82	2,898.80	32.696	59.05	45.63	44.40	100	3,080	146
No. 3. Lake ore, Vivian.....	36.86	39.91	1.23	1.25	1.28	.019	.019	.....	.60	3.00	342.75	7,074.82	243.15	3,235.82	40.049	88.33	77.78	50.57	100	2,864	140
No. 4. Lake ore, Empire.....	39.01	39.37	.99	.48	.23	.072	.08	.....	.83	3.03	349.07	7,200.37	247.47	**3,293.26**	42.441	86.75	79.62	51.53	100	2,754	140
No. 5. Lake ore, Hanna No. 1.....	48.85	5.06	3.38	.25	.18	.073	.98	.....	4.81	14.81	261.56	5,634.55	176.05	2,342.31	53.350	17.13	14.52	41.80	100	1,777	135
No. 6. Block ore, calcined.....	42.13	21.98	5.10	4.82	2.16	.576	.74	.806	1.45	.....	292.54	5,994.55	209.43	2,787.09	46.453	58.97	41.94	47.01	100	2,295	128

[1] Result based on furnace practice at Ironton, Ohio, with over and above cost of $1.00 per ton of ore smelted, and cost of coke at $2.58 per ton. The ore used as standard is Ha

[2] Result based on furnace practice at Hanging Rock, Ohio, with over and above cost of $1.0936 per ton of ore smelted, and cost of coke at $3.05 per ton. The ores used as star

er Mercer or Block Ore to that of Lake Ores

TABLE I

ing 540 gross tons per day.						Costs per ton of 2240 pounds of ore. Basis of smelting 540 gross tons per day.[1] Hanna No. 1 ore used for comparison.									Costs per ton of 2240 pounds of ore. Basis of smelting 540 gross tons per day.[2] Hanna No. 1 and Empire ores used for comparison.							
Air in cubic feet at 20° C per pound coke used.	Analysis of gases by volume.					Over and above cost per ton 2240 pounds ore smelted.	Cost of ore per ton 2240 pounds at Ironton, Ohio.	Cost of stone for flux at 85 cents per ton 2240 pounds.	Cost of coke for smelting at $2.85 per ton 2000 pounds.	Total cost of smelting one ton 2240 pounds ore.	Cost per unit iron shown by analysis.	Cost per unit pig iron produced in smelting.	Cost per ton 2268 pounds pig iron produced.	Comparative value of ores, using cost of Hanna No. 1 as basis on pig iron produced in smelting.	Over and above cost per ton 2240 pounds ore smelted.	Cost of ore per ton 2240 pounds at Ironton, Ohio.	Cost of stone for fluxing at 85 cents per ton 2240 pounds.	Cost of coke for smelting at $3.05 per ton 2000 pounds.	Total cost of smelting one ton 2240 pounds ore.	Cost per ton 2268 pounds iron produced.	Comparative value of ores, using cost of Hanna No. 1 as basis on pig iron produced in smelting.	Comparative value of ores, using cost of Empire as basis on pig iron produced in smelting.
	Water.	Carbon dioxide.	Carbon monoxide.	Nitrogen.	Ratio $\frac{CO}{CO_2}$																	
61	1.41	14.30	25.72	58.56	1.8	$1.00	$1.98	$0.4937	$1.5338	$5.0075	$0.131638	$0.118723	$12.02	$2.11	$1.0936	$1.98	$0.4937	$1.6414	$5.2087	$12.50	$2.06	$2.91
65	2.12	14.74	26.52	56.62	1.8	1.00	1.98	.3879	1.4172	4.7851	.162537	.146351	14.82	1.18	1.0936	1.98	.3879	1.5167	4.9782	15.42	1.10	1.76
64	3.10	14.00	25.10	57.80	1.8	1.00	3.05	.6611	1.6142	6.3253	.171603	.157939	15.99	1.60	1.0936	3.05	.6611	1.7275	6.5322	16.51	1.54	2.35
64	3.00	14.00	25.20	57.80	1.8	1.00	2.65	.6768	1.6448	5.9716	.153079	.140704	14.25	1.85	1.0936	2.65	.6768	1.7603	6.1807	14.75	1.79	2.65
56	13.06	12.34	22.21	52.39	1.8	1.00	4.04	.1234	1.3343	6.4977	.133013	.121794	12.33	4.04	1.0936	4.04	.1234	1.4279	6.6849	12.69	4.04	5.12
59	1.40	14.23	25.62	58.75	1.8	1.00	1.98	.3565	1.5006	4.8371	.114814	.104129	10.54	2.80	1.0936	1.98	.3565	1.6059	5.0360	10.98	2.76	3.71

nna No. 1 at $4.04 per ton.

lards are Hanna No. 1 and Empire.

HARRISON ORE

The Harrison ore is unique in that it is the remnant left of that great erosion period at the close of Mississippian time and preceding normal Pennsylvanian deposition. The stratum is thus not comformable with the Mississippian rocks below or with the Pennsylvanian rocks above. It represents this lost erosion period. Such deposits are widely distributed in Ohio, being found locally from the Ohio River in Scioto County to the Ohio-Pennsylvania line in Mahoning and Trumbull counties. It is extremely variable in deposition, in character, and in thickness.

"Its composition is variable. In places it is composed of a brecciated mass of siliceous fragments cemented by iron compounds. This siliceous material appears to be what was once pieces of Maxville limestone as it contains imperfect impressions of marine animal life, and as it is usually present not far distant from Maxville areas. In general, these pieces are quite angular, which suggests their origin from shore deposits by wave action or from land areas by weathering agencies. These limestone fragments through solution lost their calcium and magnesium carbonate, and by replacement gained additional silica. In other words, such deposits are apparently the remains of deposits of Maxville limestone that were broken up by terrestrial and littoral forces, strewn over the eroded Mississippian plain by waves and currents, then covered by Pottsville sediments, and later cemented by iron compounds deposited from ground waters that circulated along this contact zone. At other places the Harrison member is a mixture of angular, siliceous fragments and of well-rounded quartz pebbles, the whole cemented by iron compounds. The pebbles are similar in every respect to those that compose the Sharon conglomerate which in many places lies directly above the ore or not far distant. In a few localities this ore is a rather pure ferrous carbonate or, where weathered a hydrous ferric oxide."[1]

Locally the Harrison becomes a fair grade iron ore and was worked, mainly through necessity, to a small extent by Harrison furnace in Scioto County, by Granville and Mary Ann furnaces in Licking County, and probably by a few others along this line of outcrop.[2]

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[1]Geol. Survey Ohio, Fourth Series, Bull. 31, p. 68.

[2]For references concerning the Harrison ore see:

Geol. Survey Ohio, Vol. V. *The Iron Ores of Ohio*, pp. 378, 379.

Geol. Survey Ohio, Fourth Series, Bull. 13, p. 47.

Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 28-29, 477, 481-484, 595-596.

Geol. Survey Ohio, Fourth Series, Bull. 21, pp. 48-49.

Geol. Survey Ohio, Fourth Series, Bull. 25, pp. 14-17, 139-145.

Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 68-69.

Geol. Survey Ohio, Unpublished report on Holmes County.

Thesis, Ohio State University, 1933, Edgar Lee Stephenson, *The Geology of the Youngstown Region*, pp. 62-63.

REGIONAL GEOLOGY

SCIOTO COUNTY

The Harrison ore is present locally in Harrison, Madison, Jefferson, Valley, Porter, and Green townships. A few sections are given to show the geological relations.

"The Harrison ore, which is somewhat fossiliferous, was found at the forks of the road, on Niner Ridge, in Section 20, Harrison Township. The measurement of the strata along this road is as follows:

	Ft.	*In.*
Pottsville formation		
Shale	12	0
Coal blossom, *Anthony*	..	..
Clay, impure, *Sciotoville* horizon	3	0
Sandstone, thin-bedded	11	0
Coal blossom	..	..
Shales, parts covered	32	0
Erosion interval		
Ore, *Harrison*	2	0
Logan formation		
Shales and sandstones	120	0"[1]

"On Nunn Hill, on the Scioto Fire Brick Company's property, in Section 32, Harrison Township, is shown the following section:

	Ft.	*In.*
Pottsville formation		
Sandstone, shaly	20	0
Coal, bony, *Anthony*	..	6
Clay, flint, *Sciotoville*	3	6
Shales and parts covered	38	0
Erosion interval		
Conglomerate zone, flint, boulders, shale, ferruginous clay, *Harrison horizon*	2	0
Logan formation	..	..",[2]

"The Maxville limestone was not found in Madison Township but the Harrison ore is present in several localities. In the eastern part of the area, where the Sharon conglomerate is present, this brecciated mass of flint and ore occurs directly below the base of the conglomerate, although the ore is not persistent by any means. The relation of the Harrison ore to other well recognized beds is shown in the following composite measurement, taken on the land of Samuel Shoemaker, in Section 26, Madison Township:

	Ft.	*In.*
Pottsville formation		
Shales and covered	30	0
Clay, flint, *Sciotoville*, outcrop exposure	3	0
Shales and covered	24	0

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, p. 482.
[2]Idem., p. 482.

	Ft.	In.
Shales	10	0
Shales and covered	9	0
Coal, *Sharon*	..	4
Clay, bluish, tough	2	0
Covered	6	0
Sandstone, light, fine-grained, *Sharon*	7	0
Erosion interval		
Ore, *Harrison*	1	0
Logan formation	..	..

"At this place the ore was formerly mined by stripping, for use at Harrison furnace."[1]

"In Jefferson Township the brecciated Harrison ore is well represented near the summits of the main ridges, and is often from 2 to 3 feet in thickness. It is found at the base of a thick sandstone, which is evidently the equivalent of the Sharon conglomerate. No sections were taken showing the relation of the ore to well known beds, for only the Sciotoville clay is present in the areas, and this is confined to a few isolated patches.

"The Harrison ore deposits extend westward along the main ridges from Jefferson Township into Valley, and have much the same character.

"In that part of Porter Township west of the Little Scioto River the Maxville limestone was not found, while the brecciated Harrison ore is present in only a few localities. In the part east of the above mentioned stream the ore was observed more frequently. . . . On the hill at the mouth of Sugar Run, on the farm of Joseph Jenkins, in Section 14, the following members were measured:

Pottsville formation	Ft.	In.
Shale	3	0
Covered	3	0
Ore, soft, siliceous, *Sharon*, very fossiliferous	1	0
Covered	3	0
Shale	6	0
Erosion interval		
Ore, with flint and pebbles, *Harrison*	1	0
Logan formation		

"The Sharon ore in the above section is remarkably fossiliferous, while the Harrison ore contains only a few poorly preserved remains."[2]

"The Harrison ore, in Green Township, has much the same general character as it has in the townships considered, but at a few places it has exceptional thickness. A composite section taken along Pattons Run shows the relation of the ore to other important members. The record follows:

Pottsville formation	Ft.	In.
Sandstone	7	0

[1] Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 482-3.
[2] *Idem.*, p. 483.

	Ft.	In.
Disconformity	..	..
Clay, flint, *Sciotoville*	2	0
Covered	10	0
Sandstone, irregular, *Sharon*	20	0
Erosion interval		
Ore, *Harrison*, brecciated mass of flint, ore, and clay	4	0
Logan formation		

"In this locality the brecciated material should hardly be called an ore, as it is only a conglomerate mass of flint, ore, and clay, in which the iron oxides constitute only a small part of the whole."[1]

"Harrison furnace used the Harrison ore in Scioto County to a limited extent. The deposits are uncertain, but often have good thickness, although the quality of the ore is generally poor, as it is siliceous or is admixed with cherty material."[2]

PIKE COUNTY

In eastern Pike County the Harrison ore is usually present in Union and Marion townships but it appears less frequently and in a more fragmentary form in Beaver and Jackson townships. Where observed the member is from 2 inches to 2 feet in thickness. Commonly in the thicker deposits the stratum is made up of a mass of brecciated flint, of quartz pebbles, and of iron oxides, the latter the chief bonding component. The best exposures are in eastern Union and western Marion townships. In general the deposits are too lean to be considered as iron ores.

JACKSON COUNTY

"The Harrison ore is found only in the southern part of Hamilton Township. The position of this ore is directly above the Maxville limestone when both are present, but the ore is found in a number of places where the limestone is absent. At some places this deposit is regular in structure and constant in thickness and composition, while at other places, where it represents the line of disconformity between the Mississippian and Pennsylvanian series, it is very irregular in structure, and is composed of a mixture of ore, flint, sandstone, and clay.

"In Section 24, Hamilton Township, the ore has been dug on the Amos Canter and adjoining properties, where the strata are as follows:

Pottsville series	Ft.	In.
Sandstone	3	0
Clay shale, light greenish	3	0
Erosion interval		
Limestone, with flint and ore, *Harrison*	1	0

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 483-4.
[2]Idem., p. 484.

Mississippian series		
Limestone, *Maxville*	9	0

"In Section 27, on the property of D. E. Ruth, the ore was seen in the bed of the stream along the road that leads from the Dever Valley to Mabee. The section is as follows:

Pottsville series	*Ft.*	*In.*
Coal, *Bear Run,* reported thickness	2	0
Covered, barometer measurement	75	0
Shale	10	0
Erosion interval		
Ore, very irregular, with sandstone and chert, *Harrison*	..	8
Logan formation		
Shale, siliceous	10	0

"The ore here is 85 feet below the Bear Run coal, while on the Canter property, where the ore is in its natural position above the limestone, it is only 21 feet below the same bed. The difference in interval is 64 feet, which gives some idea of the disconformity or the extent of erosion that took place at the close of Mississippian time. Near the center of Section 14, close to the bridge that crosses the Little Scioto, on the land of Philip Meldick, the strata exposed are as given below:

Pottsville series		*Ft.*	*In.*
Sandstone, coarse-grained, irony	*Sharon*	1	10
Shale, blue	conglomerate	..	1
Sandstone, coarse-grained, irony	equivalent	1	10
Erosion interval			
Ore, composed of small nodules, *Harrison*		..	10
Clay shale, light		2	0
Logan formation			
Sandstone, with parts covered		15	0
Shale, soft, yellowish		1	6

"About 200 yards west of this another section shows the following members:

Pottsville series	*Ft.*	*In.*
Sandstone	4	0
Shale, with *Guinea Fowl* ore in interval	5	0
Coal blossom, *Anthony*	..	6
Clay, plastic, *Sciotoville*	4	0
Shales and covered	18	4
Erosion interval		
Ore, small nodules of ore cemented by iron oxides, with light clay sandstone nodules and a few pebbles, *Harrison*	..	8
Logan formation		
Sandstone, shaly	11	4
Sandstone, ferruginous	..	8
Sandstone, light blue	3	0

"The quality of the Harrison ore is usually poor as it is more or less siliceous or flinty. Small amounts were mined in a few localities for the charcoal furnaces [Jackson, Monroe] during their periods of activity, but at present [1916] the ore is of no importance."[1]

VINTON COUNTY

"The distribution of the Harrison member is quite local in Vinton County as deposits were observed only in the western part of Richland Township. Near the head of Pleasant Valley in Section 30, small masses of typical material are present but poorly exposed at an elevation of about 800 feet, along the contact between shales of the Waverly and sandstones of the Pottsville. The deposits exposed vary in thickness from 3 inches to 1 foot 4 inches, and in character from loosely cemented breccia to very impure iron ore. The Harrison member is also well represented on the headwaters of Kelley Branch in Section 20. Along the road in the southeastern part of the area, the following rocks were measured:

	Ft.	*In.*
Pottsville formation		
Sandstone, soft, micaceous, cross-bedded	8	0
Erosion interval		
Breccia, with pebbles and sand, *Harrison*	..	8
Logan formation		
Sandstone, bluish-gray, argillaceous	3	0

"The elevation of the Harrison member at this place is approximately 780 feet, and the thickness of the bed is 4 to 10 inches. It is made up of angular fragments from decay of siliceous limestone, of quartz pebbles and of coarse sand similar to that in the Sharon conglomerate, and of iron oxides which are the chief bonding component. Other deposits were also observed along western tributaries of Kelley Branch in Section 20. The Harrison member in Vinton County has no qualities that fit it for use and it is of stratigraphic interest purely."[2]

HOCKING COUNTY

The Harrison member is locally present in Hocking County in Benton, Laurel, Falls, and Marion townships. It is generally an impure iron ore only a few inches in thickness. Probably it was utilized to a small extent by Union and Logan charcoal furnaces.

PERRY COUNTY

In Perry County in the areas in which the Maxville limestone is present the Harrison ore has fair continuity and separates the Maxville formation from the Pottsville strata. The material varies much from

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 28-29.
[2]Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 68-69.

place to place in composition and in thickness. The record given below was taken on the Frank Howdysell property south of the bridge across Little Monday Creek, east of the highway, in the northeast quarter of Section 20, Monday Creek Township, Perry County:

	Ft.	*In.*
Pottsville series		
Shale, gray	10	0
Coal smut, *Anthony*	..	3
Clay, plastic, siliceous, gray, *Sciotoville*	2	1
Shale, dark, somewhat fissile	2	2
Shale, dark gray	6	6
Erosion interval		
Ore, *Harrison*	2	3
Maxville formation		
Shale, calcareous	..	6
Limestone, thin to massive beds, gray, dense	8	5
Limestone, brecciated, conglomeratic, irregular	..	9
Logan formation		
Shales and covered	40	0

The Harrison member at this place consists of brecciated flint and limestone, some quartz pebbles, and iron ore, both as nodules and as cement. The bed appears again above the limestone on Jonathan Creek in Madison Township.

"On the top of the Maxville limestone iron ore was seen at several points. On the farm of Edward Danison, in Section 16, Madison Township, this ore was found from 4 to 8 inches thick. A sample of this ore was analyzed by Prof. Wormley. The results are given below:

Specific gravity	*3.600*
Protoxide of iron	37.36
Sesquioxide of iron	13.30
Manganese	4.30
Alumina	....
Lime	2.90
Magnesia	2.77
Foreign matter	5.32
Carbonic acid	28.10
Sulphuric acid	trace
Phosphoric acid	trace
Combined water	5.70
Loss	0.25
Total	100.00
Metallic iron	38.87

"This ore is interesting, as containing 4.30 per cent of manganese. No alumina was found, which is remarkable for a coal-measures ore, and ore overlaid by a shale containing much clay. Of sulphur and phosphorus it contains only a trace. The percentage of metallic iron, 38.87, added

to the unusual purity, would make this a desirable ore for making iron, if it can be obtained in sufficient quantity."[1]

Morse[2] shows that the Harrison ore is rather constantly present between the Maxville limestone and the basal Pottsville beds along Jonathan Creek in Perry and Muskingum counties. The thickness of the ore varies from 2 to 12 inches but averages close to 5 inches. The following record given by Morse and taken in the railroad cut in south central Section 15, Madison Township, Perry County, is representative and shows the geological features quite well:[3]

	Ft.	*In.*
Top of cut, soil	3	0
Sharon member		
Shales and talus	5	0
(Erosion interval)		
Iron ore	..	3
Maxville limestone		
Clay	..	5
Limestone, generally massive	4	0
Limestone, bluish to pinkish	1	8
Limestone, massive	2	0
Limestone, shaly	3	6
Limestone, shaly	1	9
Logan formation		
Shales and sandstones	12	1

MUSKINGUM COUNTY

The Harrison ore is represented locally along the contact of the Mississippian and Pennsylvanian rocks in western Muskingum County.[4] "The general features of the formation are illustrated in the following section taken on land of Frank Fink in the southeastern part of Section 13, Hopewell Township:

Pottsville formation		*Ft.*	*In.*
Shale, blue		3	0
Shale, dark, fissile		..	10
Clay, siliceous		1	10
Erosion interval			
Ore, siliceous		..	3
Shale	*Harrison*	..	1
Ore, siliceous		..	3
Maxville limestone		0 to 6	0

"In the above section the Harrison ore lies on the eroded surface of the Maxville limestone where this formation is present, and on the Logan

[1]Geol. Survey Ohio. Report of Progress 1869, pp. 121, 127.
[2]Morse, W. C., Geol. Survey Ohio, Fourth Series, Bull. 13, pp. 38-58.
[3]Idem., p. 41.
[4]Geol. Survey Ohio, Fourth Series, Bull. 21, pp. 48-49.

shales where the Maxville is absent. In Section 4, north, Hopewell Township, on the property of W. E. Tewksbury, the following strata were exposed for measurement:

	Ft.	*In.*
Pottsville formation		
Sandstone, massive, *Massillon*	20	0
Shale and covered	15	0
Erosion interval		
Ore, *Harrison*	..	10
Logan formation		
Shale	5	0

"At this place the Harrison ore lies between shales, but is irregularly bedded. This is the usual condition of the member, where observed, in Licking and Jackson townships. . . .

"The Harrison ore at its best is low-grade, ranking below the Mercer deposits. It is usually siliceous in character, uncertain in extent, and variable in thickness. The iron is in the carbonate form unless weathered to the oxide state. This ore was worked to a small extent for the early forges and furnaces in the region."

COSHOCTON COUNTY

"Northeast of Warsaw, in Coshocton County, the Harrison horizon is marked by local deposits of siliceous limestone fragments and quartz pebbles, partially cemented by iron compounds. These deposits are very similar in every respect to those found in Jackson and Scioto counties."[1]

"The ore has been found in nearly all parts of the region which have been studied [Jefferson and Bedford townships, Coshocton County] where the base of the Pennsylvanian system is exposed. Definite measurements have been made of its thickness ranging from 2 inches to 1 foot 2 inches. However, at two places, Tarkiln School in the northern part of Section 9, Jefferson Township, and in the eastern part of Section 8, Jefferson Township, the abundance of chert pebbles and cobbles weathered from the ore indicates a thickness greater than any definitely determined, possibly 2 to 3 feet.

"The following section is typical of some of the thicker exposures of the Harrison ore. It was taken along the east-west road, in the south central portion of Section 5, Jefferson Township.

	Ft.	*In.*
(Pottsville series)		
Limestone, dark, *Lower Mercer*	1	0
Coal smut, *Middle Mercer*	..	1
Clay	1	0
Covered interval	33	5
Sandstone and covered intervals	37	0

[1]Geol. Survey Ohio, Fourth Series, Bull. 21, p. 49.

	Ft.	In.
Sandstone, ferruginous, micaceous	5	10
Shale, sandy, micaceous	10	0
(Erosion interval)		
Sandstone, massive, very ferruginous with white chert nodules up to 4½ inches in diameter and containing Maxville fossils, Also ore nodules up to 5 inches in diameter, *Harrison*	1	2
Logan formation		
Sandstone	16	0

"The Harrison ore is a thin but persistent unit if one bears in mind the fact that it was developed by the advancing Pennsylvanian seas, largely from mantle rock, upon an uneven land surface that had developed by the beginning of the Pennsylvanian period. It, therefore, lines the erosional depressions in which the lower Pottsville sediments were deposited, and is the time equivalent of the several members within the depression." [1]

LICKING COUNTY

In Licking County the Harrison ore is represented locally in the eastern townships, Bowling Green, Hopewell, Franklin, Hanover, Newark, Perry, Mary Ann, Fallsbury, and Eden. Some ore from this member was supplied to both Mary Ann and Granville furnaces. It was stripped along the outcrop and hauled by wagon to the furnaces. Although the ore was a lean limonite, it made a good foundry iron.

HOLMES COUNTY

Across Holmes County the erosion interval between the Mississippian and the Pennsylvanian systems is marked locally by a few inches of Harrison ore. In general the ore is of fair quality but thus of small volume.

NORTHEAST OHIO

In northeastern Ohio in Medina, Summit, Geauga, and Portage counties, owing to the lack of good exposures through the glacial drift and to the meagerness of field work, the Harrison ore is not recorded. More detailed work will probably show its presence, at least locally.

TRUMBULL COUNTY

"The Harrison member is present about two miles west of Sharon, in Brookfield Township, Trumbull County, in the old Rose and Son quarry. . . . The Harrison ore in this quarry is a massive, coarse-grained, impure sandstone from 6 to 18 inches thick, which is heavily charged with yellow to brown iron oxide. The top of the sandstone is even, but the base is

[1] Thesis of Theodore Ralph Meyers, 1929, Ohio State University, *The Geology of Jefferson and Bedford Townships, Coshocton County, Ohio.*

quite irregular. In places the rock is a mass of sandy iron ore and iron nodules. There is much secondary silica deposited through the horizon and the rock is in general quite hard and firm. The ore contains numerous fossils, mainly fish teeth and spines. The section in the quarry is as follows:

	Ft.	*In.*
Pottsville series		
Sandstone, gray, coarse-grained, massive, in part conglomeratic, *Sharon*	50	6
Covered	6	0
Sandstone, yellowish gray, fine-grained, thin-bedded, with some interbedded shale	11	6
(Erosion interval)		
Ore, arenaceous, siliceous, fossiliferous, *Harrison*	1	0
Cuyahoga formation		
Sandstone and shale, blue-gray, thin-bedded, interbedded	30	0"[1]

Conclusions

Thus the evidence shows that the Harrison ore is wide-spread, extending across the State from the Ohio River in Scioto County to the Ohio-Pennsylvania state line in Trumbull County. The stratum lacks continuity, however, often being absent from the section. It is variable in composition, ranging from a ferruginous cemented mass of brecciated chert and quartz pebbles to an iron ore of fair purity, either carbonate or limonite, depending on the state of oxidation. In thickness it undergoes rapid changes, the range being from 2 inches to 4 feet. The ore is best when thin, 2 to 10 inches in thickness. It was smelted to a small extent in a number of the old charcoal furnaces and forges located close to the Mississippian-Pennsylvanian contact. The Harrison ore offers little for the future.

[1]Thesis, Edgar Lee Stephenson, Ohio State University, 1933, *The Geology of the Youngstown Region*, pp. 62-63.

PENNSYLVANIAN SYSTEM

In Ohio the Pennsylvanian system of rocks approximates 1,115 feet in thickness and 12,340 square miles in extent. It is made up of shales, sandstones, limestones, flints, clays, coals, and iron ores. Aside from that highly dispersed the ferruginous matter occurs in regularly stratified beds, commonly associated with the marine limestones, and in nodular forms and in irregularly bedded layers, most largely in the fresh-water formations. Ore is well distributed throughout the column but at no horizon does it occur in large quantities. The grade ranges from lean to rich in iron, and from low to high in secondary components, phosphorus, manganese and sulphur. Such ores were worked regularly and continuously for furnace burdens from the erection of Hopewell furnace, in 1804, on Yellow Creek in Mahoning County, to the closing of Jefferson furnace, in December, 1916, near Oak Hill in Jackson County. The iron produced was of good quality and was converted into a large variety of useful products for home consumption and for distant markets. During this long period native ore from the coal formations was used for the entire ore burden in some 62 charcoal furnaces and for all or a part of the ore burden in approximately 45 coal furnaces. Small contributions were also made to some of the more modern coke furnaces. The counties that thus provided ore in a large way were Scioto, Lawrence, Gallia, Vinton, Hocking, Athens, Perry, Muskingum, Licking, Coshocton, Holmes, Tuscarawas, Belmont, Jefferson, Columbiana, Stark, Mahoning, Trumbull and Summit.

SHARON BLACKBAND ORE

INTRODUCTION

The blackband ores are directly associated with the coal beds. They were either stratified with the coal, as the Sharon, or were deposited just above it, as the Freeport, more commonly the latter. Such ores were laid down in the presence of decaying vegetable matter where the carbon dioxide liberated was just sufficient to cause the precipitation of the soluble iron salts brought into the swamp area as ferrous carbonate.

The Sharon blackband ore was deposited within the coal, more in the form of a parting. It contains a high percentage of organic matter, much decomposed, which acts as the chief coloring pigment. The mineral residue consists largely of fine-grained silt or shaly matter, normal in texture and in composition for quiet water deposition. Pyrite, as may be expected from the organic content, is a constant component. The Sharon blackband ore is definitely but not prominently banded by brown and black layers. It shows a varve-like structure as if laid down under seasonal changes. The color of the unweathered ore is brown black, the shade

varying somewhat with the content of organic matter. The Sharon blackband ore and Sharon coal were of vast importance in the development of the iron and steel industries in the Mahoning Valley.

The deposits of blackband ore with the Sharon coal are confined to Trumbull and Mahoning counties. The story of the discovery of the ore in this area is given by Roy who states;[1] "The first coal mined at Mineral Ridge (Weathersfield Township, Trumbull County) occurred in the year 1835, the mines being opened at Coal Run, on the land of Michael Ohl. In 1833, Roger Hill, a Pennsylvanian, who had formerly mined coal in Beaver County, of that State, moved to Mineral Ridge. He pointed out a coal bed to Mr. Ohl, which, on being opened, proved to be 4 feet thick. Hill, who was employed to open the mine, in drifting into the hill, selected a square and heavy piece of the mineral, which differed in weight and appearance from the body of the seam, and carried it home to test its qualities. The piece refused to burn, and was pronounced bastard cannel, or black stone. It was afterward left unwrought in the mine, forming the floor of the excavation.

"In 1854 John Lewis, an English miner, who had mined blackband ore in the old country, settled at Mineral Ridge. One day, while digging up the floor of his room to set a prop, he was struck with the similarity of the floor to the backband ore in Victoria mines, in England. He informed the proprietors of the mine, Messrs. Ward & Co., that the floor of the mine was a deposit of blackband ore. The proprietors directed the English miner to mine and calcine some of the ore, which was done with promising results. All the workings were now reopened, and the blackband mined out. The stratum of ore ranged in thickness from 1 inch to 1 foot, and after being calcined yielded 50 per cent of iron. Several years elapsed before the full value of this discovery was appreciated; the art of calcining the ore, and mixing it judiciously not being properly understood. In 1868 the pig iron, made from a judicious mixture of the blackband and Lake Superior ores, produced an iron which was eagerly sought for, and since that time pig iron of the Mahoning Valley has taken the front rank in market, being known and prized as 'American Scotch'."

The Sharon blackband ore is limited to restricted areas in Trumbull and Mahoning counties. The ore bodies consist of lenses within the coal which in itself is confined to channel-like areas of no large extent in any particular basin. The larger deposits were in Trumbull County. This ore played an important part in the development of the iron and steel industry in the Youngstown district. The smelting of iron here began with the building of Hopewell furnace, on Yellow Creek, in 1804, changed to coal with the erection of Mary furnace at Lowellville in 1845, added blackband ore in 1854, and eventually turned to Lake ores and coke after 1860. The furnaces that used blackband ore to some extent were Mary, Eagle, Wood

[1]Roy, Andrew, Geol. Survey Ohio, Vol. V, pp. 320-321.

or Tod No. 1, Phoenix, Falcon, Porter, Grace No. 1, Himrod No. 1, Elizabeth, Ashland No. 1, Ashland No. 2, Grace No. 2, Himrod No. 2, Haselton No. 1, Himrod No. 3, Haselton No. 2, Thomas, and possibly a few others.

MINERAL RIDGE FIELD[1]

"Over a considerable area in the southern part of Weathersfield, in Trumbull County, and the north-western part of Austintown, in Mahoning —the Mineral Ridge belt, Coal No. 1 is accompanied with a stratum of blackband iron ore of good quality, which has been worked for many years, [since 1854] and has proved an important element in the economic resources of the Mahoning Valley. This iron ore is the upper part of a stratum of bituminous shale, highly charged with iron, and is clearly the carbonaceous mud that was deposited in a lake or body of open water which occupied a considerable portion of the area of one of the most important coal basins of this region. Usually the iron ore forms a continuous sheet from six to ten inches in thickness, capping a band of black shale two feet thick, both of which divide the coal seam into two benches. The lower bench, usually from one to two feet thick, is typical block coal of excellent quality; the upper bench, from two and a half to three feet thick, is considerably unlike most of the Mahoning Valley coal, breaking with more irregular fracture, having a pitchy luster and containing considerable more bitumen. These differences led to the impression that the Mineral Ridge coal was a different seam from that mined in the Mahoning Valley; and it was for a long time known as the 'Blackband coal.' Abundant evidence has, however, been gained that they are essentially the same, though it is quite possible that the lower bench in the Mineral Ridge coal is the only representative of the block coal, while the upper bench, accumulated a little later, and only in the district where it is found. That the blackband ore and its associated black shale were deposited in a lagoon or lake in the coal marsh, is proved by the great number of bivalve crustaceans, (*Estheria*) found in it. Similar fossils usually accompany blackband ore and are regarded as quite decisive as to its mode of formation.

"The history of the deposit of the Mineral Ridge coal seems to have been something as follows: A broad and shallow basin was for a time occupied by a sheet of vegetation from which a stratum of peat of limited thickness was formed. This, from the nature of the vegetation, or the prevalent physical conditions, produced an open-burning or block coal. When the growth of peat was sufficient to produce from one to two feet of coal, the basin was flooded with water, and at least a part of it became a lake. In this lake a carbonaceous mud was slowly deposited, and when two feet in thickness, iron began to be precipitated with it in considerable quantity. This formed the stratum of blackband ore. Subsequently the

[1]Newberry, J. S., Geol. Survey Ohio, Vol. III, pp. 790-791.

lagoon was invaded and occupied by vegetation, and a thicker bed of peat than the first was accumulated over the surface; this second peat bed—probably from its more constant saturation or submersion in water—produced a more homogeneous and bituminous coal, the thicker upper bench. The causes which operated to produce the deposit of iron in this lagoon, were probably the shallowing of the water, its more complete evaporation, and thus the deposition of the iron which before flowed away in solution as a part of the freer drainage."

The following section of the Tod, Wells and Company mine, located in Lot 21, Austintown Township, Mahoning County, at the southeast edge of the village of Mineral Ridge is representative:[1]

		Ft.	*In.*
"Earth		13	0
Sand-rock [Massillon]		26	0
Shale, gray		15	0
Shale, black		20	0
Coal, [Quakertown]		1	10
Shale, gray		15	0
Shale, brown		12	0
Shale, black		24	0
Sand-rock		7	0
Coal, top		3	0
Ore, blackband	*Sharon*	..	6
Shale, black	*Sharon*	2	0
Coal, block	*Sharon*	..	10"

An analysis of the blackband ore from Mineral Ridge was made by Dr. Wormley.[2] The results follow:

Specific gravity	2.494
Volatile matter	30.50
Siliceous matter	11.84
Carbonate of iron	43.26
Sesquioxide of iron	9.94
Alumina	trace
Oxide of manganese	1.00
Phosphate of lime	trace
Carbonate of lime	1.87
Carbonate of magnesia	2.03
Sulphur	0.18
Total	99.62
Metallic iron	27.12
Phosphoric acid	trace

[1]Section from Geol. Survey Ohio, Vol. III, pp. 800-801.
[2]Geol. Survey Ohio, Vol. III, pp. 813-814.

The analysis of a sample of blackband ore by N. W. Lord from the John Henry mine of Austintown Township follows:[1]

"Silica	7.15
Iron sesquioxide	31.26
Iron sulphide	2.52
Alumina	4.62
Lime	1.36
Magnesia	1.31
Oxide of manganese	0.55
Phosphoric acid	0.33
Sulphur	1.44
Volatile and combustible matter	47.56
Moisture	1.85
Total	99.95
Metallic iron	24.40
Phosphorus	0.145
Sulphur	1.44"

Present status

The main quantity of both ore and coal from the Sharon member of the Mineral Ridge field was exhausted by 1885. However, both minerals were of importance for a period of some forty years and helped shape up the iron and steel industry of the Mahoning Valley. Modern mining methods will yet recover small quantities of both coal and ore.[2]

SHARON ORE

INTRODUCTION

Owing to the restriction of the Sharon coal, in Ohio, to rather local fields and to variation of deposits following coal deposition, the Sharon ore at best is poorly represented. The only utilization of the material for iron smelting was in Jackson County.[3]

JACKSON COUNTY FIELD

"The horizon of the Sharon ore is close above that of the Sharon coal. In some cases the ore lies directly on the coal, while at other places it may be 15 or 20 feet above it. In Jackson County the member is uncertain and is found in only a few localities. As a usual thing the ore is fossiliferous, which character is thus of some aid in the correlation of the members near the base of the Pottsville. In a local area, west of Jackson, a blackband ore is found on this horizon.

[1]Geol. Survey Ohio, Vol. V, 1884, p. 388.
[2]For fossils of Harrison ore see Geol. Survey Ohio, Fourth Series, Bull. 25, pp. 14-17.
[3]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 71-72.

"In Section 28, Liberty Township, at the Decatur No. 1 mine, on the N. B. Wood property, the section obtained shows this ore and the relation to the coal below. The record follows:

	Ft.	In.
Sandstone, with small kidney ore nodules	1	0
Sandstone, coarse-grained, with pebbles	2	4
Ore, nodular, *Sharon*, irregular, present in places only	..	6
Shale, blue	2	6
Coal, good } *Sharon* {	2	11
Coal bony } *Sharon* {	4	0
Clay	1	0
Conglomerate, *Sharon*, not measured	..	..

"At the Glen Nell mine, in Section 20, Washington Township, the Sharon ore lies close to the Sharon coal, as shown by the following section:

	Ft.	In.
Sandstone, coarse-grained, interbedded	12	0
Ore, *Sharon*, irregularly bedded, with pebbles in places, fossiliferous	..	7
Shale, dark, carbonaceous	..	4
Coal, *Sharon*	3	1

"In some parts of the mine the ore is reported to lie on the coal while in other parts it is a foot or two above. It is also reported very uncertain. The relation of the ore to the coal below is shown in a section taken on land of J. L. Goodrich in Section 16, Washington Township. The section is given below:

	Ft.	In.
Shale, sandy	6	0
Ore, *Sharon*, with some pebbles, fossiliferous	..	0
Sandstones, shaly, and shales, sandy	14	6
Coal, *Sharon*, part bony	2	0

"The Sharon ore was found along the road that leads from Ray to the ridge in the northern part of Section 12, Jackson Township. The ore and its relation to other members are shown in the following section:

Pottsville formation	Ft.	In.
Sandstone, *Massillon*, highly cross-bedded, coarse-grained, same as seen at Richland furnace	48	0
Covered	4	0
Coal blossom, *Anthony*	..	6
Clay, part plastic and part flinty, *Sciotoville*	1	6
Sandstone and covered	4	0
Shale, part sandy	7	0
Covered	9	0
Shale	4	0
Ore, *Sharon*	..	4
Shale	3	8
Shale, dark, carbonaceous, *Sharon* coal horizon	4	0
Clay and clay-bonded sandstone, light	2	0

Sandstone, coarse-grained	3	0
Sandstone and sandy shales } *Sharon* conglomerate, equivalent	15	0
Erosion interval		
Conglomerate, pebbly with flint, brecciated, *Harrison* ore horizon	2	0
Logan formation		
Sandstone	3	0
Conglomerate, fine-grained, *Allensville*	2	0
Shales and sandstones	140	0

"The Sharon ore has been worked at only a few places in Jackson County. The old charcoal furnaces obtained small amounts of ore from this horizon, and the present furnaces [1916] have used some obtained as a secondary product from coal mines. The ore is low in iron, usually siliceous, and variable in composition."

The quality of the ore is shown by the analysis given below of a sample taken on the land of Hon. George M. Parsons, E. ½ of S. W. ¼ Section 6, Lick Township:[1]

"Specific gravity	2.685
Water, combined	8.40
Siliceous matter	38.06
Iron sesquioxide	49.34
Alumina	0.90
Manganese	1.40
Phosphate lime	0.75
Phosphate magnesia	0.75
Carbonate of magnesia	0.11
Sulphur	trace
Total	99.71
Metallic iron	34.54
Phosphoric acid	0.76"

"A partial analysis of the blackband ore from the mines of the Star Furnace Company was furnished by Mr. H. L. Clay, and is as follows:[2]

Iron	31.00
Silica	6.20
Alumina	4.28
Phosphorus	.152
Manganese	0.65
Lime	0.95
Magnesia	1.08

"The supply of these ores is limited, but small amounts may be obtained in the future in restricted areas as a secondary product from mining the Sharon coal."

[1]Geol. Survey Ohio, Report of Progress in 1870, p. 143.
[2]Geol. Survey Ohio, Fourth Series, Bull. 20, p. 72.

SCIOTO COUNTY FIELD[1]

"A kidney ore, the position of which is above that of the Sharon coal, and below that of the Sciotoville clay, was observed at a few places in Scioto County. Usually the ore lies on the coal, or within 15 feet of it. . . The Sharon ore is generally wanting, but, when present, may have a thickness of 10 inches or more.

"Three exposures of the ore were noticed along the roadside in Section 24, Madison Township. Its position was just above the thin blossom of the Sharon coal, and the stratum measured 6 inches in thickness. A composite section on the land of George Winters, Section 22, is as follows:

	Ft.	*In.*
Pottsville formation		
"Clay, plastic, lower part 'pink eye,' *Sciotoville*	2	0
Covered	12	0
Ore, *Sharon*	..	10
Shale, blue	2	0
Shale, dark, tough	1	0
Waverly group		
Sandstone, *Vinton*	..	..

"The ore has been mined on lands of George Winters, Samuel Kronk, and James Coburn, and is reported to be from 6 to 10 inches in thickness. On the Francis Warren property, in Section 11, Madison Township, the relation of the ore to the Sharon coal and to the Sciotoville clay is shown by the record given below:

	Ft.	*In.*
Pottsville formation		
"Coal, *Anthony*	1	3
Clay, dark, plastic, *Sciotoville*	3	0
Covered	16	0
Shale	2	0
Ore, *Sharon*	..	10
Covered	8	0
Sandstone	2	0
Coal blossom, *Sharon*, reported thickness of coal and partings	3	0
Covered	5	0
Conglomerate, *Sharon*	65	0
Waverly group		
Covered	5	0
Shale	2	0
Conglomerate, *Allensville*	1	0

"On the farm of Joseph Jenkins, at the mouth of Sugar Creek, Section 14, Porter Township, the Sharon ore is well developed, and is very fossiliferous. The ore affords good collecting, as the fossils are well pre-

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 493-494.

served and easily obtained.[1] The measurements taken at this place follow:

	Ft.	In.
Pottsville formation		
Ore, *Guinea Fowl*	..	6
Shale	3	0
Covered	3	0
Ore, soft, siliceous, *Sharon*, very fossiliferous	1	0
Covered	3	0
Shale	6	0
Erosion interval		
Ore, with flint and pebbles, *Harrison*	1	0
Waverly group		
Sandstone, *Vinton*	22	0

"The Sharon ore was noted at other places in this locality, and it also appears, but in a less developed state, in restricted areas along the Pine Creek Valley.

"The chief value of the Sharon ore in Scioto County is for stratigraphic work, as it is an aid in correlating the members near the base of the Pottsville formation. . . . The Sharon ore was mined at a few places, however, for use in the old charcoal furnaces."

PIKE COUNTY FIELD[2]

"Only a few small pockets of ore, which were placed with some confidence on this horizon, were found in Pike County. In Section 23, Marion Township, on land of W. M. Lyons, ore was formerly mined for the Star Furnace Company, Jackson, Ohio. Mr. Lyons reports the stratum to vary in thickness from 4 inches to 1 foot 6 inches, and the ore to be of good quality compared to other native ores. . . . Here the Sharon conglomerate is wanting and the stratum lies close to the Logan sandstone. . . . The same ore was also mined for the above company south of this on lands of William Ehrman and G. W. Keller. Here the stratum is reported to have a thickness of 10 inches to 1 foot 6 inches."

Economic Value

Even in the days of the charcoal and coal furnaces the Sharon member was only locally of value for an ore supply. Its utilization was most justified where the ore was taken from the roof of the Sharon coal mines. The quality of the ore was about average and was of foundry grade.

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[1]For fossils of Sharon ore see Geol. Survey Ohio, Fourth Series, Bull. 25, pp. 17-21.
[2]Geol. Survey Ohio, Fourth Series, Bull. 20, p. 455.

GUINEA FOWL ORE

Introduction

From the detailed field work so far done on the rocks of the basal Pottsville formation the Guinea Fowl ore appears to be confined to rather local areas. The type deposits are in Scioto County but others are also known in Vinton County. Further work may extend the field over a wide area.

"An iron ore to which the name Guinea Fowl was applied by the miners who worked such deposits for Scioto Furnace, operated from 1829 to 1892 in Bloom Township, Scioto County, is occasionally present in the lower part of the Pottsville formation of southern Ohio. It represents an ore horizon rather than an ore stratum, as the deposits occur at various positions in a shale stratum and are widely scattered. The position of the ore may change from 1 to as much as 20 feet above the Anthony coal, but the usual interval is between 5 and 15 feet. The member varies in thickness from 1 inch to 2 feet but averages nearly 6 inches. It may be represented by a single ore stratum or by two or even three benches separated by shale." [1]

"Often the distinguishing feature of this ore is the presence of quartz pebbles, varying in size from one-eighth to three-fourths of an inch, with some admixed sand. The ore is not a true conglomerate with the interstitial space filled with iron compounds, but a blue iron carbonate, when under cover, with a varying amount of pebbles. Usually the iron carbonate and not the pebbles make up the body of the ore. In some places it is practically free from pebbles." [2]

REGIONAL GEOLOGY

SCIOTO COUNTY[3]

"The Guinea Fowl ore occurs above the flint clay of the Sciotoville member, but in some localities it is found in or below the plastic clay [Huckleberry] that lies above the flint clay. The interval from the flint clay to the ore varies from a few inches to 20 feet. A few sections only, showing the relation of the ore to the coal, will be given.

"In Section 36, Harrison Township, on the property of Jacob Bauer, the following section was exposed:

		Ft.	*In.*
Ore, blackband	*Guinea Fowl*	2	6
		0	6
Shale		10	0
Coal, one block, *Anthony*, reported thickness		1	8
Clay, flint, *Sciotoville*		2	0

[1] See Geol. Survey Ohio, Fourth Series, Bull. 31, p. 76.
[2] Geol. Survey Ohio, Fourth Series, Bull. 20, p. 548.
[3] Idem., pp. 546-550.

"In the clay mines of the Buckeye Fire Brick and Clay Company at Scioto Furnace, the relation is shown in the section given below:

		Ft.	In.
Ore, *Guinea Fowl*		..	4
Coal, *Anthony*		..	½
Clay, flint	*Sciotoville*	1	6
Clay, semi-flint	*Sciotoville*	1	6
Clay, pink eye, seen	*Sciotoville*	3	0

"On the property of Henry Moore, in Section 21, Bloom Township, the section exposed was as follows:

		Ft.	In.
Shale, black, with thin coal bands	*Quakertown*	..	4
Coal, solid block	*Quakertown*	1	5
Shale and covered		31	0
Ore, *Guinea Fowl*		..	6
Shale		6	6
Coal, *Anthony*		..	2
Clay, flint	*Sciotoville*	3	0
Clay, semi-flint	*Sciotoville*	..	..

"In Section 13, Madison Township, on land of Oliver Powell, the rocks seen and reported are as given below:

	Ft.	In.
Ore, *Guinea Fowl*	..	6
Shale	6	6
Coal, *Anthony*, thickness reported	1	6
Shale and covered	32	0
Covered	15	0
Conglomerate, *Sharon*	53	0

"The Guinea Fowl ore in Scioto County is generally very siliceous owing to the admixed quartz pebbles and sand. Small deposits are found in Harrison, western Bloom, and eastern Madison townships. It was worked but little by the charcoal furnaces. . . . An analysis of this ore from a layer seen in the bed of the stream near Gephart's Station is as follows:

Specific gravity	3.321
Siliceous matter	14.60
Sesquioxide of iron	10.50
Carbonate of protoxide of iron	42.58
Alumina	1.50
Manganese	trace
Calcium phosphate	13.40
Calcium carbonate	10.04
Magnesium carbonate	2.73
Water and loss	4.65
Total	100.00
Phosphoric acid	6.14
Metallic iron	26.69

"The partial analysis of a sample from the William Tripp property, in Section 4, Bloom Township, where the ore is 18 inches in thickness is as follows:

In upper 6 inches	iron, Fe	25.40	per cent
	siliceous residue	51.30	" "
In lower 12 inches,	iron, Fe	18.20	" "

"The ore has more value for the phosphoric acid content than for the iron."

JACKSON COUNTY[1]

The Guinea Fowl ore is poorly represented in Jackson County. The deposits observed are local, thin, and low in quality.

VINTON COUNTY

In Vinton County the Guinea Fowl ore is locally present in Richland, Harrison, Eagle, and Jackson townships. The deposits, however, are uncertain but are sufficient to mark the horizon. The ore is largely carbonate in kind but low in quality. A few sections are given to show the geology of the member.

"At the forks of the road east of the Darby School in Section 35, Richland Township, the Guinea Fowl ore, 4 to 6 inches thick, is exposed at an elevation of 765 feet. Its position is nearly 120 feet below the Lower Mercer limestone. Small quantities of this ore were formerly mined by stripping near the forks of the road in central Section 25, where the bed is about 6 inches thick and approximately 8 feet above the Anthony coal. The following record, taken near the forks of Little Raccoon Creek in southeastern Section 23, shows its position with reference to the Sciotoville clay.[2]

	Ft.	*In.*
Sandstone, ferruginous, hard	2	0
Ore, *Guinea Fowl*, altitude 765 feet		4
Shale, dark, part covered	14	0
Clay, flint, *Sciotoville*	1	4
Covered	4	6
Stream bed.		

"Along the road that leads from the head of the hollow to the ridge east in southeastern Section 24, the Guinea Fowl ore was well exposed at an elevation of 890 feet. The ore is siliceous and sparingly fossiliferous. Its thickness here is 1 foot 4 inches and its position 37 feet above the Allensville conglomerate and 45 feet below the Bear Run coal. An outcrop of this member at an elevation of 850 feet was observed along the road in the east-central part of Section 35. The bed is 8 inches thick and lies

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 89-90.
[2]Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 77-79.

only a few feet above the Sciotoville clay. The Guinea Fowl member is locally made up of two or more ore benches as shown in the following measurements obtained along the ridge road near the forks in northeastern Section 26:

Forks of road, elevation 950 feet.			*Ft.*	*In.*
Shale, gray			6	0
Shale, dark, siliceous			5	0
Shale, black, fissile, *Bear Run* coal horizon			6	0
Shale, gray, parts covered			15	0
Shale, soft			1	0
Coal, rotten, *Quakertown*			2	0
Shale, dark, carbonaceous			1	6
Clay, light, siliceous			3	8
Clay, dark, shaly			1	0
Clay shale, light to dark			3	6
Shale, dark			2	6
Ore, kidney			..	1
Shale, dark	}	*Guinea Fowl*	..	10
Ore, siliceous, blackband	}	*Guinea Fowl*	..	7
Shale, dark	}	*Guinea Fowl*	3	4
Ore, kidney			..	3
Shale, dark			1	0

"The Guinea Fowl member was also observed on a knob of the ridge near the road forks in southeastern Section 27. The bed is 4 to 6 inches thick and siliceous in character. It bears a few fossils which are not well preserved. Its position is directly above the Anthony coal and 73 feet above the Allensville conglomerate.

"In Eagle Township, the lower Pottsville members are poorly represented, some through lack of deposition and others through replacement by the thick Massillon sandstone. The Guinea Fowl ore with good development was observed at only one place which is on the high knob north of High Hill School in southeastern Section 27. The record secured is given below:

Pottsville formation			*Ft.*	*In.*
Ore, siliceous, sparingly fossiliferous	}	*Guinea Fowl*	..	7
Shale and covered	}	*Guinea Fowl*	3	11
Ore, made up of small concretions about pea size	}	*Guinea Fowl*	..	8
Covered			9	0
Logan formation				
Shale and sandstone			12	0
Sandstone, shaly			15	0
Sandstone, shale and covered			27	0
Shale and covered			32	0
Conglomerate, *Allensville*			1	8

"At this place the upper layer of ore is sparingly fossiliferous but the

specimens are mostly fragmental. The Guinea Fowl ore is poorly developed in Jackson Township.

"This ore, even in the days of the charcoal furnaces, was of little value in Vinton County. It has fair thickness and extent but is lacking in quality as it is everywhere siliceous. In this locality the bed was mined at only a few places and there only in a small way, and its use was confined to Richland Furnace."

HOCKING COUNTY

Through the work so far done in Hocking County the Guinea Fowl ore appears to be present in local areas in thin deposits. It was little worked for iron smelting in either the charcoal or the coal furnaces.

The following record was taken south of the Till School in the western part of Section 1, Falls Township:

	Ft.	*In.*
Shale, sandy	3	0
Coal blossom, *Quakertown*	..	4
Clay, siliceous	2	8
Shale, gray	3	0
Shale, dark	2	0
Coal smut	..	1
Clay, siliceous	4	0
Shale, dark	4	6
Ore, irregular, siliceous	..	6
Shale and covered	7	0
Coal smut, *Huckleberry*	..	2
Clay, light	3	2
Shale, dark	..	6
Clay, siliceous, part covered	2	6
Ore, nodular, *Guinea Fowl*	..	3
Shale and shaly sandstone	2	6
Clay, flint, *Sciotoville,* elevation 830 feet	1	6
Shale and covered	5	6
Erosion interval		
Sandstone, ferruginous, *Harrison*	..	6
Logan formation		
Sandstones, shaly and shales, siliceous	30	0

Locally the member becomes limy in character as well as ferruginous. This phase is shown in a section taken in a hollow in the north central part of Section 30, Falls Gore Township, and given below:

	Ft.	*In.*
Shale, gray	15	0
Limestone, blocky, fossiliferous, *Lower Mercer*	..	5
Shale, black, weathered, *Middle Mercer*	1	0
Coal, weathered, *Middle Mercer*	..	6
Clay, plastic, light	3	0
Shale, gray, siliceous	20	0

Covered	25	0
Sandstone, massive, *Massillon*	29	0
Covered	5	0
Coal blossom, *Quakertown*	1	0
Shales and covered	30	0
Limestones, blue, fossiliferous, irregular masses in shale, *Guinea Fowl*	..	4
Shale, gray, siliceous	6	0
Shale, black, carbonaceous, fissile	1	3
Shale, black, very fossiliferous	..	7
Coal, fair, *Anthony*	..	6
Shale, carbonaceous	..	2
Clay, siliceous, *Sciotoville*	3	0

OTHER AREAS

North of Hocking County the Guinea Fowl ore has not been described definitely. The deposits are probably small in area and in thickness and more of the nodular form distributed in shales. Further search may show sufficient deposits to establish a continuity across the area.

LINCOLN, JACKSON SAND BLOCK ORE[1]

INTRODUCTION

"The Lincoln ore, which lies above the Bear Run coal, consists of irregular layers of limonitic kidney and carbonaceous shaly ores, occurring at different levels in the shales. The ore was worked, to a small extent, near Scioto Furnace, Scioto County, for making charcoal iron. . . . The Lincoln ore is found on the same general horizon as the Jackson Sand Block ore of Jackson County, but as both are erratically bedded and local in extent no definite correlation between the two deposits was established, further than that both occur in the interval between the Bear Run and Vandusen coals."

REGIONAL GEOLOGY

SCIOTO COUNTY[2]

"At 80 to 100 feet above the Conglomerate [Sharon] or the Sub-carboniferous limestone [Maxville], and at 100 to 125 feet below the Lower Mercer limestone, in the southern part of the field, and at 75 to 100 feet further northward, there is a series of small ore deposits. Not less than five distinct names have been given to ores that have been opened and worked about Scioto Furnace at this general level. The best known of these names is perhaps the Lincoln ore, or No. 4 of the Section." Other names were Blue ore, Thompson ore, Kidney ore, etc. Locally at Scioto Furnace the Lincoln ore bears plant fossils, a feature held in common with the Jackson Sand Block ore.

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, p. 557.
[2]Geol. Survey Ohio, Vol. V, p. 420.

JACKSON COUNTY[1]

"The productive field [1912] of the Jackson Sand Block ore is southwest of the town of Jackson, and includes the southwestern part of Lick, the southeastern part of Liberty, and the northeastern part of Scioto townships. The deposits, although somewhat isolated and irregular in structure, occur in the same general interval which is that between the Bear Run and Vandusen coals.

"Shales, thin to medium bedded sandstones with shales intervening, massive sandstones, or some combination of the above strata, make up the interval which is from 20 to 40 feet in thickness. Layers of the thin and medium-bedded sandstones, which have been enriched by iron compounds, constitute the ore beds. These deposits may occur interbedded in shales, or at the top or well down in the series of sandstones, but the richest beds are those in the shales, or in the upper part of the sandstone series. The position at which they occur in the interval varies from place to place; thus beds worked in one locality may not be on the same level stratigraphically as those worked at another.

"Under heavy cover the iron is in the form of the carbonate, while along the outcrop, or under shallow cover, where the weathering agents have been active, it occurs in the hydrated oxide forms. The sandstone strata are fine-grained, ripple marked, more or less ferruginous, and contain plant fossils. Apparently the iron compounds were deposited with the sands in shallow basins in which the waters were charged with iron salts and decaying organic matter. The deposits, as a usual thing, have a higher iron content along the outcrop, or under shallow cover, where local enrichment from percolating water has taken place.

"The Jackson Sand Block ore has been mined on the land of Martin Wastier, in Section 26, Scioto Township. The following section shows the strata that were exposed for measurement:

		Ft.	*In.*
Ore, kidney		..	4
Shales, part sandy		27	0
Ore, kidney		..	3
Shales, sandy		7	9
Covered		6	0
Shales		2	0
Coal, *Vandusen*		..	6
Sandstone, argillaceous		3	0
Sandstone, light		3	6
Ore, sandy	*Jackson Sand Block*	1	2
Shales		1	5
Ore, sandy		..	6

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 125-129.

"The deposit of Jackson Sand Block ore on the property of John M. Corn, in Section 2, Scioto Township, was being worked when the region was visited [1914]. The ore layers, which are quite variable in thickness and number, are interbedded in shales. A section of the mine is as follows:

		Ft.	In.
Shale		6	0
Ore		1	2
Shale	*Jackson Sand Block*	..	11
Ore, solid block	*Jackson Sand Block*	5	10

"Another section in the same mine, about 100 feet from the above, shows the variability of the deposit, hence the measurements are given below:

		Ft.	In.
Shale		..	..
Ore	[*Jackson Sand Block*]	..	6
Shale	[*Jackson Sand Block*]	1	0
Ore	[*Jackson Sand Block*]	..	8
Shale	[*Jackson Sand Block*]	1	8
Ore	[*Jackson Sand Block*]	..	6
Shale	[*Jackson Sand Block*]	2	10
Ore		5	4

"In Liberty Township, north of the Corn mine, on land of Howell and Jones, Section 34, the Jackson Sand Block ore is interbedded in sandstone. A section shows the following relations:

	Ft.	In.
Ore, seen, *Jackson Sand Block*	1	0
Covered	71	0
Sandstone, massive	12	0
Covered	18	0
Sandstone, massive	12	0
Ore nodules and finger coal in sandstone	1	0
Shale, sandy	..	10
Coal	*Sharon* coal horizon	..	2
Shale, dark, carbonaceous	*Sharon* coal horizon	..	6

"Near the summit of the hill just south of the old Hammertown mine, in Section 35, Liberty Township, the ore has been dug along the outcrop quite extensively. A section is as follows:

	Ft.	In.
Ore, *Jackson Sand Block*	2	0
Sandstone, thin to massive beds	20	0
Covered	110	0
Coal, *Sharon*	2	6

"In several localities in the southwestern part of Lick Township the ore has been mined also in a small way. On lands of the Jackson Iron

and Steel Company and Charles Ray, in Section 30, the following members were noted:

	Ft.	In.
Ore, *Jackson Sand Block,* thickness reported	2	0
Shales, sandy	10	0
Sandstone and covered	36	0
Covered	4	6
Coal, cannel, *Quakertown*	..	6
Clay and covered	2	0
Top of air shaft.		
Covered and shales	59	6
Coal, *Sharon,* reported thickness	3	6

"The Jackson Sand Block ore, as the name implies, is a sandy or siliceous ore with a blocky structure, as the beds are regularly jointed. The iron content varies from the lowest limit used for ores to about 45 per cent, but in the bulk of the ore mined it is from 30 to 35 per cent. The lime and magnesia, often amounting to several per cent, gives an additional value, as they flux directly part of the siliceous gangue of the ore, and as they tend to promote ease of fusion of the silicate impurities. The phosphorus, usually high, and the manganese about normal, make the ore a desirable constituent in the smelting of foundry iron. An analysis of the ore furnished by the Jackson Iron and Steel Company is as follows:

Iron, Fe	30.66
Silica, SiO_2	26.08
Alumina, Al_2O_3	7.56
Phosphorus	7.87
Manganese, Mn	0.51
Lime, CaO	5.16
Magnesia, MgO	trace
Moisture	6.00

The analyses of the Jackson Sand Block ore given below were furnished by Mr. H. L. Clay, superintendent of The Star Furnace Company:

	No. 1				*No. 2*		
Iron	From	25.00	to 35.70	From	23.00	to	35.50
Silica	"	21.85	" 28.50	"	24.35	"	33.00
Alumina	"	7.50	" 8.44	"	7.50	"	....
Phosphorus	"	0.614	" 0.875	"	0.88	"	1.09
Manganese	"	0.49	" 0.61	"	0.64	"	....
Lime	"	2.80	" 5.45	"	0.96	"	2.30
Magnesia	"	0.67	" 0.76	"	0.43	"	0.94
Sulphur	"	0.028	" 0.182	"	0.17	"	....

No. 1. Ore from Corn Mine.
No. 2. Ore from Hunsinger mine.

"The ore varies from 1 to as much as 8 feet in thickness, but usually averages from 2 to 3 feet. In some localities the ore is interbedded in

sandstone, while at other places in shale. So far [to 1914] most of the ore has been mined by stripping along the outcrop where the overburden is not heavy, but the general conditions for drift mining are favorable. Also the demand by the furnaces for outcrop ore has been greater as the iron is in the form of the oxide, and the metal content usually higher. There are large quantities of this ore yet available, but the cost of mining and the low market value, when compared to the siliceous Lake ores on a unit basis, have seriously impeded its utilization."

VINTON COUNTY[1]

"The Lincoln ore, mined to a small extent near Scioto Furnace during the days of the charcoal iron industry, is, in a general way, correlative with the Sand Block ore of Jackson County and with thin, isolated deposits in Vinton County. Such strata are found above the Bear Run coal and represent more an iron ore horizon than a definite bed. The beds vary in position, thickness, and composition. In Vinton County such deposits are poorly developed and have little or no economic value."

BOGGS ORE

INTRODUCTION

Orton states:[2] "The next ore of the section, holds a very different place from those last described. It is a new ore, but it makes a valuable addition to the stock already known. In Bloom Township, Scioto County, which is [1884] the most important center of its development, it is known as the Boggs ore, from the name of the farmer on whose lands it was first opened, but at Howard Furnace, in Vernon Township and also at Scioto and Bloom furnaces, the same seam has been worked on a small scale for many years as the Flag ore. This term suggests the nature of the ore. It is a stratified deposit, occurring in sheets or "flags" like sandstone or shale. It is not a blackband, as there is no coal and but little carbonaceous matter in the seam, nor does it agree in appearance with the clay-bands of the Upper Freeport horizon. It consists mainly of gray carbonate of iron, interleaved with gray shale. The ore has excellent volume, reaching in the drifts a maximum thickness of 6 feet, and holding a thickness of 4 to 5 feet over considerable territory. . . . The chief center of production [1884] is at and about South Webster, Bloom Township, Scioto County. All of the ore from this field is taken by the Jackson and Wellston furnaces."

"This member was known in southern Hocking County as the 'Union Furnace' ore and in southwestern Perry County as the 'Junction City' ore. Northward from there through Licking, Muskingum, Coshocton, and

[1]Geol. Survey Ohio, Fourth Series, Bull. 31, p. 97.
[2]Geol. Survey Ohio, Vol. V, pp. 421-422.

Tuscarawas counties the member is in more places represented by limestone or flint than by ore. The limestone and flint and locally the ore and associated shales bear an abundant fauna of marine origin. Normally the position of the Boggs member is about 25 feet below the Lower Mercer limestone and 3 feet above the Lower Mercer coal." [1]

REGIONAL GEOLOGY

SCIOTO COUNTY[2]

"The Boggs ore in southern Ohio lies from 40 to 55 feet below the Little Red Block ore, the position of which is close above the Lower Mercer limestone. The average interval from the Boggs to the Little Red Block ore is about 47 feet. The ore is best represented in Bloom Township near South Webster, but it is also found in Vernon Township, where it is known locally as the Flag ore. It is an argillaceous or shaly siderite ore usually low in iron, but often carrying appreciable amounts of lime and magnesia. The ore is not persistent, but is found only in isolated pockets. Where present, the thickness may vary from a few inches to as much as 6 feet, but the average measurement is about 2 feet. The appearance and composition of the ore suggest swamp origin, or that it was laid down in shallow water where the ferrous carbonate was precipitated, and where also argillaceous and arenaceous materials were accumulating as sediments. The Lower Mercer coal is closely associated with the Boggs ore. Its position is a few feet below the ore, and, in fact, several thin coals are found on this general horizon.

"The following measurement was taken in Section 25, Bloom Township, on the property of John Slack:

	Ft.	*In.*
Coal, *Webster Block*	1	6
Clay, plastic	3	0
Covered	8	6
Ore, *Little Red Block* or *Lower Mercer*	..	4
Shale and covered	43	0
Sandstone, plant marked	1	0
Ore, *Boggs,* 1 foot thick, seen across hollow on this horizon.		
Shale	3	0
Coal blossom, *Lower Mercer*	1	0

"In the northwest corner of Section 22, on the properties of W. E. Ranchous and others, the ore was worked by drifting for the Jackson furnaces. The bed was reported to be from 1 to 4 inches in thickness, and to lie 44 feet below the Lower Mercer ore. In Section 15, just west of

[1] Geol. Survey Ohio, Fourth Series, Bull. 31, p. 104.
[2] Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 567-570.

South Webster, a record taken on the property of Jefferson Mossbarger is as follows:

	Ft.	In.
Ore, *Big Red Block* or *Upper Mercer*	..	5
Shale and covered	27	0
Coal, *Webster Block* or *Upper Mercer*	1	4
Shale and covered	20	0
Ore, *Little Red Block* or *Lower Mercer*	..	4
Shale and covered	38	0
Ore, *Boggs*, reported thickness	1 to 6	0

"The ore has been opened on the property of James Haines, and also on that of S. H. Wiseman and S. G. Huffman, east of South Webster. On the property of William M. Galliger, south of Bloom Station, in Section 24, Bloom Township, the following strata were exposed:

		Ft.	In.
Sandstone, with finger coal at bottom		15	0
Shale, dark, tough, fissile		1	3
Ore	*Boggs*	..	4
Shale, blue		..	2
Ore		..	11

"On the land of Charles Dillon, in Section 2, Bloom Township, a record showing the Boggs ore and the underlying Lower Mercer coal follows:

	Ft.	In.
Ore, fossiliferous, *Little Red Block*	..	4
Shale and covered	53	0
Ore, *Boggs*, siliceous, fossiliferous	1	0
Shale and covered	3	0
Coal, *Lower Mercer*, reported thickness	2	0

"In Section 11, Bloom Township, on the property of John Kinker, one mile north of South Webster, where the ore was mined for the charcoal furnaces, the record obtained shows the following strata:

	Ft.	In.
Ore, *Little Red Block* or *Lower Mercer*	..	8
Covered	38	0
Sandstone	3	0
Shale, tough, dark, fissile	1	0
Shale, gray	4	0
Shale, dark	1	6
Coal	..	6
Ore, *Boggs*	2	6

"The Boggs ore extends south from eastern Bloom Township along Hale's Creek and along Pine Creek to the vicinity of Lyra, in Vernon Township. In this locality, however, the bed becomes more impure, and

finally breaks up into thin, irregular layers interbedded with shale. Here it was known as the 'Flag' ore.

"The weathered ore from along the outcrop of the deposit was first used by the old charcoal furnaces [Scioto, Jackson, Bloom, and Howard] in the region. Later the ore near South Webster was mined quite extensively and shipped to the coal furnaces at Jackson, Ohio. Many of the known ore pockets have been worked only along the outcrop, and as the stratum usually has excellent volume the quantity yet available is large. The method of mining would be by drifting.

"Analyses of Boggs ore collected from various sources:

Sample	*No. 1*	*No. 2*	*No. 3*	*No. 4*	*No. 5*
Metallic iron, Fe	31.12	31.75	34.7	25.05	20.95
Silica, SiO_2	7.88	12.61	22.4	41.00	
Alumina, Al_2O_3	1.25	3.03			
Lime, CaO	10.77	4.15	3.0		
Magnesia, MgO	0.95	0.59			
Manganese, Mn	0.51	0.46			
Sulphur, S	0.45		0.231		
Phosphorus	0.351	0.302	0.557		
Ignition loss	28.77	24.99	24.0		
Hydroscopic water	0.25	7.85	4.6		

Sample No. 1—Air dried, from William M. Galliger property, Section 24, Bloom Township.

Sample No. 2—Average sample of bed, natural state, same property as above.

Sample No. 3—Geol. Survey Ohio, Vol. 5, page 422.

Sample No. 4—Sample from outcrop, John Kinker property, Section 11, Bloom Township

Sample No. 5—Sample from outcrop, Smith Hayward property, Section 35, Bloom Township.

"All except No. 3 were sampled and analyzed by Wilber Stout for the Columbus Iron and Steel Company, and are given by its permission.

"The ore averages low in iron, consequently if used in the raw state it would give a small yield in the blast furnace. The siliceous content shown by some of the above analyses is not excessive, and the lime and magnesia increase the value somewhat. The phosphorus, which is high, restricts the use mainly for foundry iron, while the manganese content is about that found in the average ore. The main use of this ore should be to furnish the siliceous part of the ore desired in making high silicon and foundry iron, and to replace the highly siliceous Lake ores used at present [1914]. For this purpose the Boggs ore should produce fair results. As the ore is a blue carbonate, the volatile matter is exceptionally high; hence

calcination will increase considerably the non-volatile constituents. By calcination, samples No. 1 and No. 2 become as follows:

Sample	*No. 1*	*No. 2*
Metallic iron, Fe	45.78	47.28
Silica, SiO_2	11.58	18.78
Alumina, Al_2O_3	1.84	4.51
Lime, CaO	15.83	6.18
Magnesia, MgO	1.40	0.88
Manganese, Mn	0.75	0.69
Sulphur, S	0.66	....
Phosphorus	0.516	0.445

"The calcined ore is much richer than many of the siliceous Lake ores on the market."

LAWRENCE COUNTY[1]

"The Boggs ore, the position of which is only a few feet above the Lower Mercer coal, is poorly defined in Lawrence County. The bed is represented by kidney ores in the shales at a few places along Pine Creek. The position of the Boggs ore is shown in the following section, taken near the Kelley Mills School, in Elizabeth Township:

		Ft.	*In.*
Shale		4	0
Ore	*Boggs*	..	2
Coal	*Boggs*	..	2
Shale	*Boggs*	3	0
Ore, siliceous	*Boggs*	1	0
Shale		3	0
Coal, *Lower Mercer*		1	0

"The Boggs ore in this locality is siliceous in character, and irregularly bedded in the shales. It was mined but little even for the charcoal furnaces, and is of interest at present only for its stratigraphic features."

JACKSON COUNTY[2]

"The position of the Boggs ore is either directly or only a few feet above the Lower Mercer coal. Apparently the ore was laid down during the same general swamp period in which the Lower Mercer coal was deposited. The member was observed at only a few places in Jackson County.

"One measurement which was made along the road in Section 13, Washington Township, will be given in order to show the relation of this ore to other members. The section follows:

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, p. 292.
[2]Idem., pp. 141-2.

	Ft.	In.
Ore and blue fossiliferous, nodular limestone, *Upper Mercer*....	..	4
Shale	4	0
Shale with thin ore layers.....	3	0
Coal blossom, *Upper Mercer*.....	..	8
Clay, light	1	4
Shale, sandy	4	10
Ore, irregular	..	2
Sandstone, shaly	11	0
Shale and covered.....	8	0
Clay shale, light and pink.....	6	0
Shale and covered.....	..	3
Ore }	0	3
Shale } *Lower Mercer*	1	0
Ore }	..	10
Shale, very fossiliferous	1	6
Shale	2	1
Limestone, *Lower Mercer*.....	..	10
Clay shale	2	0
Coal blossom, *Flint Ridge*	..	2
Shaly sandstone and covered.....	14	0
Ore, *Boggs*	..	6
Shale and sandstone.....	3	0
Sandstone	..	3
Coal, *Lower Mercer*.....	1	1

"The deposits of Boggs ore in Jackson County are too small and the ore too impure to have any considerable value at present, but the bed was formerly worked in a small way by stripping for use in the old charcoal furnaces."

VINTON COUNTY[1]

"The Boggs member in Vinton County, as elsewhere in southern Ohio, is characterized by its lack of continuity, by its variability in thickness, and by its change in composition. It was formed in basins in which only locally were the conditions favorable for the precipitation of ferruginous sediments as rather pure deposits of siderite, as bonding material of sands, and as a component of blackband. In general, the matter was so dissipated through the body of the sediments that it is unnoticed. In the area under consideration the Boggs member is only occasionally present as a well-defined ore stratum. Neither limestone nor flint was observed on this horizon at any place within the county. The bed varies in thickness from 1 inch to 2 feet but in the thicker deposits it is very impure, more a ferruginous sandstone than an iron ore. The Boggs member is generally low in iron and on this account was not extensively used in the old charcoal furnaces.

[1]Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 104-108.

Brown Township

"Iron ore representing the Boggs member is locally present in Brown Township along Raccoon Creek in Sections 36, 35, 34, 33, and 32, and along Twomile Run in Section 29. The deposits are generally thin and are in many places divided into two or even three layers. Along the outcrop the ore is a limonite but under cover it is a siderite. The stratigraphy of the member is well shown by the record given below and taken along the stream in west central Section 35:

	Ft.	In.
Limestone, shaly, very fossiliferous, *Lower Mercer*	3	2
Coal smut, *Middle Mercer*	..	2
Clay, siliceous	2	0
Shale, gray	7	0
Coal, shaly, *Flint Ridge*	..	4
Shale, gray	7	6
Ore, kidney — *Boggs*, altitude 795 feet	..	2
Ore, very siliceous — *Boggs*, altitude 795 feet	..	4

"In the ditch at the east end of the bridge that crosses Raccoon Creek near the mouth of Twomile Run, fossiliferous shale is present on the Boggs horizon. No good section was obtained here as the overlying rocks were all covered. Along the road a short distance east of this, the following beds were measured:

		Ft.	In.
Limestone, blue, blocky, fossiliferous	*Lower Mercer*	1	1
Shale, limy, very fossiliferous	*Lower Mercer*	..	10
Shale, fossiliferous	*Lower Mercer*	..	8
Coal smut, *Middle Mercer*		..	4
Clay, light, siliceous		1	2
Sandstone, massive, soft		14	0
Covered		4	0
Ore, *Boggs*, elevation 733 feet		..	2
Shale and covered		8	0

"The Boggs member was also exposed in the south bank of Twomile Run in central Section 29. The ore is only a few inches thick and poor in quality. This stratum is present in the bed of Raccoon Creek just above the bridge in southern Section 34, where it is an impure carbonate about 3 inches thick and sparingly fossiliferous. Its position is nearly 30 feet below the Lower Mercer ore. Along the road about one-half mile south of New Plymouth and at an elevation of 760 feet, the Boggs member is marked by 6 inches of dark shale bearing a few fossils. It is overlain by 15 feet of gray shale and underlain by 1 foot of siliceous shale.

Swan Township

"The Boggs member is widely distributed in Swan Township, being due above drainage along all the larger streams. The bed, however, is not

persistent or well developed. In some areas it is wanting through lack of deposition and in others it is replaced by massive sandstone. At a few places shale-bearing marine fossils are associated with the ore or are present alone on the horizon. A general section is sufficient to show the main stratigraphic features. Along the road west of Orland in Section 2, the following beds were exposed:

		Ft.	In.
Ore, kidney	*Lower Mercer*	..	3
Shale	*Lower Mercer*	..	4
Ore, siliceous	*Lower Mercer*	..	2
Shale, dark, *Middle Mercer* coal horizon		..	2
Clay, light, siliceous		3	0
Shale, dark, chip		2	8
Shale, dark		1	4
Coal, cannel, *Flint Ridge*		..	5
Clay, light, siliceous		2	3
Shale and shaly sandstone		3	10
Shale, dark gray, chip		1	6
Ore, small kidneys, *Boggs*, elevation 825 ft		..	3
Clay, light, shaly		..	7
Shale, gray		6	0

"Along Brushy Fork in the northern part of the area, the horizon is marked by iron ore, ferruginous sandstone, or ferruginous shale. The deposits lie 15 to 35 feet below the Lower Mercer ore. In southern Swan Township, the Boggs member is largely replaced by sandstone.

Jackson Township

"Lack of continuity and variability in thickness, character, and position are general features of the Boggs member in Jackson Township, where it is locally present along the main ridges in the eastern and central parts. The position of the ore is 25 to 30 feet below the Lower Mercer limestone and its character a siliceous siderite or limonite, depending on the state of weathering. The following measurements, taken near the forks of the road in southern Section 29, are representative of the bed and its stratigraphy:

		Ft.	In.
Limestone, shaly, fossiliferous	*Lower Mercer*	7	11
Limestone, blue, fossiliferous	*Lower Mercer*	..	7
Clay and covered		15	0
Shale, dark, siliceous		3	2
Shale, dark, carbonaceous		3	10
Sandstone and siliceous shale, gray		5	0
Ore, very siliceous, *Boggs*, elevation 955 ft		..	5

"In this locality the position of the Boggs member is 1 to 5 feet above the Lower Mercer coal. East of this along Middle Fork and its tributaries,

the bed is only locally present, in many places being replaced by sandstone. The thickness is from 2 to 6 inches.

Richland Township

"In Richland Township the Boggs member is poorly represented, its place being taken by dark, carbonaceous shale or by gray, argillaceous sandstone. Thin local lenses, however, are found along the ridges in sections 28, 32, 33, and 34, where it was mined at a few places for use at Richland Furnace. Where observed it is a siliceous limonite about 3 inches thick.

Elk Township

"The areas in which the Boggs member is above drainage in Elk Township are small and are confined to the valleys of Elk Fork and Puncheon Fork. The deposits are thin and irregular.

Clinton Township

"In Clinton Township, the Boggs ore appears at the surface only in the western part along Little Raccoon Creek. Its position with reference to other well-recognized beds is shown in the following record taken along the road in southwestern Section 19:

	Ft.	*In.*
Ore and blue, fossiliferous, nodular limestone, *Upper Mercer*...	..	4
Shale	4	0
Shale with thin ore layers	3	0
Coal blossom, *Upper Mercer*.....	..	8
Clay, light	1	4
Shale, sandy	4	10
Ore, irregular, kidney.....	..	2
Sandstone, shaly	11	0
Shale and covered.....	8	0
Clay shale, light and pink.....	6	0
Shale and covered.....	6	6
Ore, kidney } *Lower Mercer* {	..	3
Shale } *Lower Mercer* {	1	0
Ore, kidney } *Lower Mercer* {	..	10
Shale, very fossiliferous } *Lower Mercer* {	1	6
Shale, gray } *Lower Mercer* {	2	1
Limestone, fossiliferous, blue } *Lower Mercer* {	..	10
Clay shale	2	0
Coal blossom, *Flint Ridge*.....	..	2
Sandstone, shaly and covered.....	14	0
Ore, irregular, kidney, *Boggs*.....	..	6
Shale and shaly sandstone	3	0
Sandstone	..	3
Coal, *Lower Mercer*.....	1	1

Economic Value

"The Boggs ore in Vinton County has no value at present and was little used even in the days of the charcoal furnaces. Small quantities were obtained at a few places by stripping along the outcrop. The bed is generally thin and uncertain, in many places giving way to shale or sandstone. The measurements vary from 1 to 8 inches but average only 3 inches. The ore is siliceous in character and in places changes to a ferruginous sandstone. Under cover the material is a siderite but where weathered along the outcrop it is a soft limonite. It belongs to the foundry class of ores as it is high in phosphorus."

HOCKING COUNTY

In Hocking County the Boggs member, known locally as the Union Furnace ore for its utilization at this furnace, is rather regularly present in Benton, Starr, Washington, Laurel, Falls, Green, Marion, and Falls-Gore townships. It was utilized to some extent by the charcoal furnaces, Union or Five Mile, Logan, and Hocking or Hayden, and by the coal furnaces, Winona, Monday Creek, Ogden or Helen, Gore, and Crafts. In this area the Boggs member begins the gradation from the truly iron ore phase of Southern Ohio to the ferruginous, flinty limestone phase of the Muskingum Valley. As an iron ore the member was most useful in Hocking and Perry counties. The position of the ore is from 15 to 20 feet below the Lower Mercer limestone, the chief bench for reference. The thickness of this block ore varies from 2 to 10 inches but averages only about 4 inches. The chief producing fields were in Falls, Green, Starr, and Washington townships. The largest contributions came from Green and Starr townships. The ore was worked largely along the outcrop by stripping where the siderite or carbonate form had been changed by weathering to a soft limonite.

The following record was secured near the cross-roads in the southeastern part of Section 5, Washington Township:

	Ft.	*In.*
Coal blossom and weathered shale, *Clarion*	4	0
Clay, part covered	5	0
Shale and covered	45	0
Limestone, blue, very fossiliferous, *Lower Mercer*	1	0
Coal and shale, *Middle Mercer*	2	0
Clay and covered	5	0
Covered	29	0
Flint, black, *Boggs*	..	6

In this locality ore had been stripped from above the flint. Its thickness was not ascertained. The Boggs ore was mined along the streams in northwestern Starr Township for smelting at Union Furnace. At this

place the Lower Mercer limestone has an elevation of 810 feet. Both Boggs ore and Lower Mercer limestone are due along the Hocking River south of Haydenville.

The Boggs member is rather persistent in Falls Township but shows considerable variation. Ore was mined at numerous places. Some of the geological features are shown in the record given below and taken near the road forks in the northeastern part of Section 26, Falls Township.

	Ft.	In.
Forks of road, elevation 1,009 feet	..	..
Covered	8	0
Coal blossom, *Clarion*	1	0
Clay, light, siliceous	3	0
Shale and shaly sandstone	15	0
Shale and covered	20	0
Limestone, shaly, fossiliferous } *Lower Mercer*	3	4
Limestone, blue, blocky, fossiliferous } *Lower Mercer*	..	5
Shale, calcareous, fossiliferous	..	4
Coal, shaly, *Middle Mercer*	..	5
Clay and covered	12	0
Shale and covered	4	0
Ore, siliceous, *Boggs*	..	5
Shale, dark, horizon of *Lower Mercer* coal	1	1
Clay and covered	5	6
Shale, gray, siliceous	16	0
Ore, kidney	..	4
Shale, dark	..	3
Coal, weathered, *Bear Run*	..	1
Clay, light, plastic	5	4
Shale, dark	..	10
Shale, argillaceous	1	0

Considerable ore was mined from this horizon in Green and Falls-Gore townships where the deposits were present not far above drainage level. Logan, Hayden, Crafts, Gore, and Winona furnaces drew a part of their supplies from this field. The ore where mined varied in thickness from 2 to 10 inches and averaged about 5 inches. It was mined along the outcrop by stripping where weathering had reduced the carbonate to a soft limonite. The yield of the roasted ore is reported to be about 45 per cent iron of a foundry grade.

PERRY COUNTY

In Perry County the Boggs or Junction City ore rated about fourth in importance in the group of ores ranging from the Harrison at the Mississippian-Pennsylvanian contact to the Whitlock ore at the general horizon of the Upper Freeport coal. The Boggs deposits supplied considerable ore for Baird and Bessie furnaces and some ore for Fannie, two stacks, New York, two stacks, XX, and Moxahala. The chief deposits

were in Monday Creek, Jackson, and Reading townships but some mining was also done in Hopewell and Madison townships.

The succession of thin coals and iron ores in the interval below the Lower Mercer limestone is shown in the record given below and taken in a ravine west of the road in the west central part of Section 8, Monday Creek Township:

		Ft.	*In.*
Sandstone, massive		10	0
Shales and covered		20	0
Limestone, blue, blocky, fossiliferous	*Lower Mercer*	..	9
Shale, blue, fossiliferous	*Lower Mercer*	..	2
Limestone, blocky, blue, fossiliferous	*Lower Mercer*	..	6
Shale, dark, carbonaceous, *Middle Mercer* coal horizon		1	5
Clay, light, plastic, part covered		6	0
Shale with thin sandstone layers		4	6
Ore, nodular, irregular		..	2
Shale, siliceous		..	4
Ore, nodular, irregular		..	2
Shale, siliceous		..	2
Ore, nodular, irregular		..	2
Coal, impure		..	1
Clay and covered		3	1
Shales, siliceous		6	6
Ore, nodular, irregular, *Boggs?*		..	2
Sandstone, dark		..	2
Shale, dark, carbonaceous, siliceous		1	8
Coal, bony, *Lower Mercer*		..	1
Clay, dark, siliceous		2	0
Clay, very siliceous, light		2	6
Coal, irregular		..	1
Clay, light		1	1
Coal, bony		..	4
Clay, light, siliceous		1	0
Shale, very siliceous		9	0
Valley floor, elevation 915 feet		..	..

At Crossenville in the southwestern part of Jackson Township the Putnam Hill limestone is present at an elevation of 1,027 feet and the Lower Mercer limestone at 960 feet. About 20 feet below the limestone an iron ore, apparently Boggs, has been mined by stripping. An analysis of this ore is recorded below:[1]

"Water	10.00
Siliceous matter	17.92
Iron sesquioxide	69.90
Alumina	0.60
Manganese	0.00
Lime phosphate	0.41
Magnesium phosphate	0.96

[1]Geol. Survey Ohio, Vol. III, pp. 859-860.

Magnesium carbonate	0.73
Sulphur	0.02
Total	100.60
Metallic iron	48.97
Phosphoric acid	0.63"

The position of the Boggs or Junction City ore is well shown in the record given below and taken in the pit of the Junction City Sewer Pipe Company just north of that village:

		Ft.	In.
Shale and soil		6	0
Limestone, weathered, *Lower Mercer*		1	3
Clay, *Middle Mercer*		3	0
Shale, dark		10	0
Coal	*Flint Ridge*	..	2
Shale	*Flint Ridge*	..	2
Coal	*Flint Ridge*	..	4
Clay, light to dark	*Flint Ridge*	4	6
Clay, dark, flinty	*Flint Ridge*	1	2
Clay, dark, plastic	*Flint Ridge*	..	6
Clay, light, very siliceous	*Flint Ridge*	8	6
Clay, siliceous, dark blue	*Flint Ridge*	2	0
Sandstone, massive		1	10
Shale, gray		5	0
Ore, *Boggs*		..	5
Clay, plastic, *Lower Mercer*		8	6

Ore was mined rather extensively along Rush Creek and its tributaries in northern Jackson Township. Part of this ore was shipped to the furnaces at Zanesville.

MUSKINGUM COUNTY[1]

"As has been previously stated, the Boggs member lies at most only a few feet above the Lower Mercer coal and on the average about 22 feet below the Lower Mercer limestone. In ascending order it is the second distinctly defined limestone horizon in the Pottsville formation of Muskingum County. The member is best developed in Hopewell, Falls, Muskingum, Cass, and Jackson townships, although it is also represented in Newton, Licking, Jefferson, Madison, and Washington townships.

"The Boggs horizon may be marked by limestone, flint, iron ore, or almost any combination of these rocks. Further, fossiliferous shales are often present. Lithologically this limestone in many respects resembles the Lower Mercer limestone and the flint is similar to that found on the Upper Mercer horizon. At its best this limestone is hard, dense, bluish-gray, and rather siliceous. It is usually ferruginous, and in places so

[1]Geol. Survey Ohio, Fourth Series, Bull. 21, pp. 70-75.

much so that the weathered blocks are highly colored by hydrated forms of iron oxide. In fact it gradates through these stages of ferruginous limestone to calcareous iron ore of the carbonate type. On the other hand it also gradates from siliceous limestone to calcareous flint, or even to that carrying practically no lime. The flint is usually highly colored from iron oxide and carbon, the colors vary from nearly white through grays to black. Limestone and flint are often directly associated, the flint usually occupying the upper position. The iron ore is an impure ferrous carbonate under heavy cover, but along the outcrop, or where severely weathered, it belongs to the limonite class. The limestone and flint are very fossiliferous, but the iron ore has fewer fossils. In the main the types are very similar to those shown in the marine life of the overlying Lower Mercer limestone, although so far the fossils have not been carefully studied and compared.

"The term Boggs is applied to the member, as it is correlated with confidence with an iron ore of that name formerly worked extensively for the early furnaces in Scioto County. Its position below the Lower Mercer limestone is approximately the same in Muskingum County as it is in southern Ohio. Further, the associated coal bed, which is well defined in both areas, also agrees stratigraphically, but the marine life preserved in the rocks of the two fields has not been studied.

Newton Township

"Although due over the entire area, the Boggs is not a conspicuous member in Newton Township. The horizon, however, is marked locally by deposits of siliceous iron ores or of nodular flinty material, lying approximately 20 feet below the Lower Mercer limestone.

Hopewell Township

"The Boggs member is above drainage in the northern part of Hopewell Township and is especially conspicuous along Poverty Run and its tributaries. It is often typically defined at this place, as it is a bed of fossiliferous limestone occasionally overlain by a bed of iron ore. At other places only iron ore or calcareous flint mark the horizon and in some localities the member is not represented or is replaced by thick sandstones. The following record taken on the land of Delard Fink, in Section 18, shows the relation of the Boggs member to the Lower Mercer limestone:

		Ft.	*In.*
Limestone, blue, fossiliferous	*Lower Mercer*	..	10
Limestone, blue, fossiliferous	*Lower Mercer*	1	4
Covered		10	..
Shale and covered		15	4
Limestone, blue, hard, fossiliferous	*Boggs*	..	10
Limestone, siliceous, ferruginous, fossiliferous	*Boggs*	..	10

"In the above locality the Boggs member is a siliceous limestone containing ferrous carbonate. On weathering the iron minerals in the lower bed are converted into an impure iron ore. Lithologically the upper stratum strongly resembles the Lower Mercer limestone and both beds are very fossiliferous. On the land of Della Wise, near the Wise School, the member is represented by iron ore, dark flint, and hard sandstone, the total thickness of which is about 10 inches. In Section 19, on the farm of Ralph Terry, the Boggs member is composed of 3 inches of ferruginous sandstone and 3 inches of light flint. It lies 17 feet 6 inches below the Lower Mercer limestone. East of the Wise School, on the property of Harrison Shuey, 10 inches of a siliceous, ferruginous, fossiliferous limestone on the Boggs horizon was exposed in the stream bed. In the northern part of Section 14, on the land of H. Drumm, the Boggs member is represented by a true black band ore in which *Lingulae* and *Orbiculoideae* are especially abundant. Along the Licking River in this township, the member is more often represented by iron ore or calcareous flint than by limestone.

Falls Township

"In Falls Township the Boggs member is above drainage along the Licking River and along Big, Bartlett, and Timber runs. The volume of the bed expands in local areas to 1 foot 6 inches, and the composition varies from a true limestone to a ferruginous flint or to a siliceous iron ore. The member is only moderately constant. The following section, taken on the J. Butler farm, 1 mile north of the mouth of Bartlett Run, shows the thickness and structure of the Boggs member:

			Ft.	*In.*
Flint, light, ferruginous Sandstone, flinty, ferruginous Shale, dark	*Boggs*	....	1 .. 1	.. 6 6

"The flinty phase of the Boggs member reported in the above section is common in the northern part of this township. The flint is sparingly fossiliferous and is usually of a dark color. The interval to the Lower Mercer limestone is about 35 feet, which is considerably greater than the average. Near the mouth of Big Run, on the M. A. Russel farm, the member is represented by 1 foot 6 inches of a ferruginous, cherty limestone, and west of this, along the Licking River, it has thinned to only 8 inches. Along Timber Run only thin deposits of iron ore were seen.

Licking Township

"The Boggs member is readily traced across Licking Township, but at few places is it more than a thin bed of flint or iron ore. It lies well

above drainage, especially in the western part, where it is found near the summits of the main ridges.

"The following section, taken along the road south of Claypool School, shows the position of the Boggs member in relation to the Flint Ridge coal:

			Ft.	In.
Coal, bony, *Flint Ridge*			..	8
Clay and clay shale, light			4	..
Flint, light, irregular	*Boggs*		..	5
Sandstone, hard			..	5
Shale, light			1	..

Muskingum Township

"In Muskingum Township the Boggs member is often a true limestone, strongly resembling the Lower Mercer. The range in composition, however, is from limestone to flint and from limestone to iron ore. The member is above drainage in the entire township, but it lies close to the flood plain along the Muskingum River. In the southern part of Section 6, along the road, 1 foot 2 inches of a dark, fossiliferous flint was exposed on this horizon. Along Blunt Run the Boggs member is exceptionally well exposed in the stream bed. For collecting, this is one of the best localities in the county. The typical stratum is a true limestone which is only slightly ferruginous and not especially siliceous. The overlying shales are calcareous and belong to the same deposition period, whereas the thin kidney ore is also directly related, its position with reference to the higher limestones being about normal. North of this, on Beech Run, the Boggs limestone has changed to one very flinty and generally ferruginous, and along the Wheeling & Lake Erie Railroad, north of Rock Cut, it gradates from a flinty limestone to calcareous flint or to siliceous iron ore.

Cass Township

"In Cass Township the Boggs member is well above drainage and exhibits the various phases of limestone, flint, and iron ore, all of which are fossiliferous. In local areas it has excellent thickness. Along the road south of Elberson School the Boggs horizon is marked by a few inches of light, calcareous flint, whereas along the road 1 mile west of Dresden it is represented by a blocky iron ore usually about 4 inches in thickness. North of the preglacial Newark Valley iron ore commonly marks the horizon.

Jefferson Township

"The Boggs member in Jefferson Township lies near the base of the hills and about 20 feet below the Lower Mercer limestone. The horizon is generally marked by iron ore.

Washington Township

"In Washington Township the Boggs member is very prominent along the cliff facing the Muskingum River in the vicinity of Ellis Dam, where it lies 20 feet above water level. The exposures in this locality were the only ones observed in Washington Township. The following section, taken near the dam, shows the relative positions of the Boggs member and the Lower Mercer limestone:

		Ft.	In.
Limestone, shaly	*Lower Mercer*	1	..
Limestone, hard	*Lower Mercer*	..	7
Shale	*Lower Mercer*	..	2
Limestone, hard	*Lower Mercer*	1	8
Shale		..	4
Coal, bony, *Middle Mercer*		..	8
Clay, siliceous, with sandstone layers		6	..
Sandstone, shaly		10	..
Shale, blue		1	6
Flint and hard sandstone, *Boggs*		1	..
Clay, light, very siliceous		3	..

"The Boggs member in this locality is made up of flint and hard sandstone in varying proportions. The flint, which is dark-colored and sparingly fossiliferous, occurs in the upper part of the bed, and gradates with no true line of demarcation into the sandstone, which is light-colored, and contains no impressions of marine life. Limestone and iron ore were not observed on that horizon.

Madison Township

"The Boggs member in Madison Township is present near the base of the hills along the Muskingum Valley, but it is so deeply covered that few exposures were observed. However, it occurs above drainage along Symmes Creek from its mouth to that of its largest tributary, North Fork, where the bed appears to be very steady and exceptionally well developed, showing all the phases from limestone to flint and iron ore. The Boggs limestone at Symmes Ford is dark-blue and moderately fossiliferous, in general appearance closely resembling the Lower Mercer limestone. The intervals to the Lower Mercer limestone and to the Poverty Run limestone are unusually short, the one to the Poverty Run limestone being only 16 feet. On the farm of Mrs. Agnes Compton, on Symmes Creek, about 1 mile from its mouth, there is only one layer of Boggs limestone, which is about 8 inches thick, and lies 17 feet below the Lower Mercer limestone and 18 feet above the Poverty Run limestone. Another good exposure of the Boggs member occurs in the bed of Symmes Creek near the mouth of North Fork, where it is composed of 4 inches of dark limestone overlain by 4 inches of red ferruginous limestone, both of which carry fossils. This lies only 19 feet below the Lower Mercer limestone, which is the

shortest interval found in the county. In the northern part of the township the Boggs member often has exceptional thickness and appears to be very persistent. Along the road one-half mile east of the Little School the bed measured 1 foot 8 inches in thickness, and is a dark, fossiliferous limestone, the upper part of which is more or less flinty. At this place it lies 17 feet above a blue siliceous ore, which represents the Poverty Run member, and approximately the same distance below the Lower Mercer limestone. The Boggs limestone was also observed at other places along the Muskingum Valley east of this. The following record, taken on the farm of James Scott, in the northeastern corner of the township, is given in order to trace the bed as far east as possible, and to show the general character of the member as it passes into Coshocton County:

		Ft.	In.
Limestone }		..	9
Limestone } *Lower Mercer*		..	11
Limestone }		1	11
Coal, bony, *Middle Mercer*		..	5
Clay		1	..
Sandstone, light, shaly		9	6
Shale, blue, siliceous		6	..
Limestone, flinty, dark, *Boggs*		..	9
Clay, siliceous		2	..

"The Boggs member at this place is a true limestone; it is somewhat flinty and dark-colored, but in other respects resembles the Lower Mercer. This limestone is moderately fossiliferous and the types of marine life are similar to those in the overlying Mercer limestone.

Jackson Township

"South of the Newark River Valley in Jackson Township, the Boggs member is generally marked by a bed of ferruginous flint or cherty limestone, whereas north of this valley it is more often characterized by deposits of iron ore, which were formerly mined to a small extent for iron smelting. Limestone, however, was seen at a few places north of the valley. The Boggs ore is very persistent along the main ridge north of Frazeysburg, where it is reported to vary in thickness from 6 inches to 3 feet. The average measurement, however, in this locality is approximately 10 inches. In places the ore is partially or completely replaced by flint. Like the limestone and flint, the ore is fossiliferous.

Economic Value

"The Boggs member is unimportant in estimating the mineral wealth of Muskingum County. The deposits of relatively pure limestone on this horizon are local and seldom reach 2 feet in thickness. The rock is too impure for caustic lime and too hard to be crushed cheaply for agricul-

tural use. However, it may be employed locally for road making where the stratum outcrops along stream beds and is thus readily available. The limestone often gradates into flint, in fact flint or cherty limestone is the most common representative of the member. Further, the limestone and also the flint often change to iron ore, which had considerable value during the early period of iron making in Ohio, but which has little worth at present. Analyses of this ore formerly mined north of Frazeysburg follow:[1]

"Specific gravity	3.152	3.464
Water, combined	2.40	10.05
Silicic acid	26.72	3.66
Iron sesquioxide	13.57	79.07
Iron carbonate	43.08	....
Manganese	.60	1.70
Alumina	2.00	2.60
Calcium phosphate	2.64	1.13
Calcium carbonate	4.18	....
Magnesium carbonate	4.24	.65
Magnesium phosphate	....	.70
Sulphur	.53	.23
	99.96	99.79
Metallic iron	30.28	54.65
Phosphoric acid	1.21	.89"

EASTERN OHIO

From Muskingum County on northward and eastward to Trumbull and Mahoning counties the Boggs member, if represented, is usually a limestone, a ferruginous flint, or a fossiliferous shale. Only locally is the horizon marked by iron ore. Small quantities were mined in western Coshocton County for the old charcoal furnaces, Mary Ann and Granville, and possibly some in the Mahoning Valley for Maria, Mill Creek, and Montgomery.

LOWER MERCER OR LITTLE RED BLOCK ORE[2]

INTRODUCTION

"The Lower Mercer ore, mined rather extensively in Scioto, Jackson, and Vinton counties for iron smelting in the charcoal furnaces, was called by the miners the 'little red block,' 'fine kidney,' and 'blue limestone' ore. In the report of 1870 it is described by E. B. Andrews as the 'little red block' ore. It extends from Mahoning County on the north to Scioto County on the Ohio River but it is subject to many wants. Moreover, the bed is everywhere thin, in few places expanding to more than a few inches. The member was mined most extensively in southern Ohio where it has fair continuity and good quality for a native material."

[1]Geol. Survey Ohio, Vol. III, p. 244.
[2]Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 131-132.

REGIONAL GEOLOGY

SCIOTO COUNTY[1]

"The Lower Mercer or Little Red Block ore lies on or only a few feet above the Lower Mercer limestone when both are present. In Scioto County the ore is far more persistent than the limestone, for the former is found in Green, Vernon, eastern Porter, and Bloom townships, while the latter was noted in good development only in Vernon Township along Pine Creek, south of the village of Lyra. These members lie about 45 feet above the Lower Mercer coal, 22 feet below the Upper Mercer coal, and 52 feet below the Upper Mercer or Franklin ore. Both the Lower Mercer ore and the limestone are fossiliferous, but the ore contains fewer specimens than the underlying limestone. Sections will be given in order to show the relation of these members to other well-known beds.

"In Vernon Township the Lower Mercer ore is moderately persistent, and the limestone is present in force along Pine Creek south of the village of Lyra. A record obtained along the road that leads from Poplar Fork to Clinton Ridge, in Section 28, Vernon Township, shows the following general positions of the Lower Mercer ore and other members. The record is given below:

	Ft.	*In.*
Limestone, *Vanport*	2	0
Sandstone and covered	54	0
Coal, *Brookville*	1	0
Shales and covered	32	0
Ore, *Upper Mercer*	..	4
Shales and covered	22	0
Coal blossom, *Upper Mercer*	1	0
Sandstone and covered	19	0
Ore, *Lower Mercer*	..	3
Covered	55	0
Coal, *Lower Mercer*	1	8"

"A combined section near Howard Furnace reveals the following strata."[2]

	Ft.	*In.*
Sandstone	12	0
Coal, reported, [*Lower Kittanning*]	3	0
Covered	10	0
Clay shales	7	0
Ore, [*Ferriferous*]	..	6
Limestone, *Ferriferous,* [*Vanport*]	5	0
Shale	..	6
Coal, [*Clarion*]	3	0
Under-clay	..	..
Not exposed	58	0
Sandstone, shaly	8	0

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 570-574.
[2]Geol. Survey Ohio, Report of Progress 1870, p. 173.

Coal, [*Brookville*]	1	8
Under-clay	..	..
Not seen	38	0
Ore, 'red block' [*Upper Mercer*]	1	0
Not seen	10	0
Ore, *'sand block,'* not measured	..	..
Sandstone, shaly	50	0
Ore, *'little block,'* [*Lower Mercer*]	..	4
Not seen	55	0
Ore, 'Flag' [*Boggs*]	..	6"

"The Lower Mercer ore is quite steady in Bloom Township, but the Lower Mercer limestone was nowhere observed. The ore was mined by stripping, for use in the charcoal furnaces, and is rather rich in iron. . . . It is usually somewhat fossiliferous, but not nearly so much so as the limestone. . . . On the land of the South Webster Brick Company in Section 24, Bloom Township, the following record was secured: [1]

	Ft.	*In.*
Ore, *Big Red Block* or *Upper Mercer*	..	4
Shale and covered	8	0
Sandstone	6	0
Ore, *Sand Block*	..	8
Shale and covered	14	0
Coal, *Webster Block* or *Upper Mercer*	1	4
Clay, good	4	6
Sandstone, shaly, part covered	7	0
Sandstone	7	0
Shale and covered	11	0
Ore, *Little Red Block* or *Lower Mercer*	..	4"
Shale and covered	1	0
Coal smut, *Middle Mercer*	..	1
Clay, siliceous	2	0
Shales and covered	12	7
Sandstone, shaly, blocky	1	0
Shales, sandy	4	0
Sandstone, shaly	..	4
Coal, fair, *Flint Ridge*	..	3
Shales and clay shales	2	3
Sandstone, ferruginous	..	7
Sandstone, hard	..	3
Shales, gray	2	5
Shale, blue	1	0
Shale, dark, bony, tough	..	4
Shale, blue, tough	1	7
Shale, dark, bony, tough	..	7
Clay, siliceous	1	0
Shale, blue	6	8
Shale, bony, *Boggs* ore horizon	..	1
Clay shale, blue, siliceous	1	7
Coal, bony, *Lower Mercer*	..	4

[1] Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 572-574.

Clay, dark, plant marked	1	0
Clay, light	2	0
Shales	35	0
Coal, *Vandusen*	..	10

"The Little Red Block or Lower Mercer ore was used to a considerable extent and liked very much by the operators of the charcoal furnaces [Bloom, Howard, Scioto, Franklin, Junior, Clinton, Ohio, Empire]. Under heavy cover it is a blue carbonate, but along the outcrop the ore has weathered to the hydrated oxide forms which were the types most desired for charcoal furnace work. The bed, usually from 2 to 4 inches in thickness, and with a maximum measurement of 8 to 10 inches, is quite persistent when the interval is composed of shale. This ore was extensively mined by stripping in Bloom Township, although it was also worked in Porter, Vernon, and Green townships. . . . A partial analysis by the writer [Wilber Stout] of a sample obtained from near Scioto Furnace is as follows:

Metallic iron, Fe	42.30
Silica, SiO_3	15.05
Alumina, Al_2O_3	2.20
Phosphorus, P	0.265
Manganese, Mn	0.34

LAWRENCE COUNTY [1]

"The outcrop of the Lower Mercer ore and limestone is restricted to the Pine Creek Valley, and to the Ohio River hills west of Hanging Rock. . . . These members are about 55 feet below the Upper Mercer ore, and about 25 feet below the Upper Mercer coal. The Lower Mercer ore was worked but little in Lawrence County during the days of the charcoal furnaces, as the Upper Mercer and Ferriferous ores were much better developed. This ore is of good quality, and in the natural state has from 40 to 50 per cent iron."

JACKSON COUNTY [2]

"The interval from the Lower Mercer or Little Red Block ore to the Lower Mercer limestone, when both are present, varies from 1 to 18 feet but the average interval is about 8 feet. The ore in the southern part of Jackson County, although wanting in large areas, is far more constant than the limestone which is seldom present. . . . In the northern part of Jackson County both ore and limestone are relatively constant, but vary in character and thickness. The ore is not a part of the limestone formation but a separate and distinct stratum, deposited under somewhat similar conditions, yet differing in composition and date of origin. The

[1] Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 292-293.
[2] Idem., pp. 142-151.

ore was deposited as ferrous carbonate, while the limestone was laid down as a calcium carbonate, yet both are of shallow sea origin. The ore was also formed somewhat later than the limestone, as the two are often separated by several feet of rock material. Both limestone and ore are fossiliferous and contain the same types of life.

"In Jackson County the interval from the Lower Mercer limestone to the Lower Mercer ore averages almost 8 feet; to the Upper Mercer coal the interval varies from 23 to 35 feet, but averages about 27 feet; to the Sand Block ore the interval varies from 30 to 45 feet, but averages about 36 feet; and to the Upper Mercer ore the interval varies from 43 to 60 feet, but averages 51 feet. The order and average intervals found are as given below:

	Ft.	*In.*
Ore, *Upper Mercer*	..	..
Interval	15	0
Ore, *Sand Block*	..	..
Interval	9	0
Coal, *Upper Mercer* or *No. 3a*	..	..
Interval	19	0
Ore, *Lower Mercer*	..	..
Interval	8	0
Limestone, *Lower Mercer*	..	..

"On land of Fred Raymond, Section 36, Hamilton Township, the following members were seen:

	Ft.	*In.*
Limestone, *Ferriferous,* seen on outcrop	3	0
Covered	47	0
Shale	8	0
Covered	6	0
Sandstone, massive	24	0
Covered	26	0
Ore, *Sand Block*	..	5
Shale and covered	11	0
Coal blossom, *Upper Mercer*	1	0
Clay and covered	3	0
Sandstone	12	0
Covered	12	0
Ore, *Lower Mercer*	..	4

"A section taken on land of Andrew Yinger, in Section 13, Scioto Township, shows the following members:

	Ft.	*In.*
Ore, *Upper Mercer,* fossiliferous	..	5
Sandstone, ferruginous	..	8
Coal, [*Bedford*]	..	6
Shale and covered	22	0
Coal, *Upper Mercer*	1	0
Shale and covered	12	0

Coal blossom	..	5
Clay shale	1	9
Ore, *Lower Mercer*	..	3
Coal blossom, [*Middle Mercer*]	1	0
Clay	3	0
Shale	27	0
Covered	3	5
Shale, bony	..	7
Sandstone, light	6	0
Shale, blue	34	2
Shale, sandy, blue	3	0
Coal, *Vandusen*	..	10
Clay and sandy shale	4	0

"On land of James Mayhew, in Section 5, Franklin Township, the Lower Mercer ore with three coals below were seen and measured. The section follows:

	Ft.	*In.*
Ore, *Lower Mercer* blocks seen	..	4
Covered	13	0
Shale, gray	8	0
Shale, blue, tough	6	0
Coal blossom, [*Flint Ridge*]	..	2
Shale, gray, sandy	6	10
Coal blossom, *Lower Mercer*, part cannel	1	6
Clay shale	2	6
Shale	13	0
Sandstone	24	0
Shale, sandy	3	0
Coal good	..	11
Clay shale *Vandusen*	..	3
Coal	..	1

"East of the Grace mine, Section 10, Coal Township, the limestone was exposed in the creek bed, and the ore seen in the road above. The section measured is as given below:

	Ft.	*In.*
Ore, *Upper Mercer*	..	4
Covered	10	0
Coal blossom	..	2
Clay shale	1	10
Shale and covered	11	0
Clay shale, sandy	2	0
Sandstone, shaly	7	0
Shale and covered	8	6
Coal blossom	..	6
Clay	2	0
Shale	4	7
Ore, *Lower Mercer*	..	5
Shale	3	0
Covered	5	3
Shale, blue	5	0

Limestone }		..	11
Shale, dark } *Lower Mercer*		1	10
Limestone }		1	0
Covered		9	0
Coal, cannel, [*Flint Ridge*]		..	6
Covered		1	0
Top of shaft, Grace mine		..	..
Covered		97	0
Coal, *Quakertown*		3	0

"Along the road west of Hamden, in Section 13, Washington Township, the Lower Mercer limestone and ore are well represented, and the horizon of the Upper Mercer limestone is marked by dark flinty limestone nodules and kidney ore. The section measured at this place is given below:

	Ft.	*In.*
Sandstone	11	0
Ore and flinty limestone, *Upper Mercer*	..	4
Shale	4	0
Shale with thin ore layers	3	0
Coal blossom, [*Bedford*]	..	8
Clay, light	1	4
Shale, sandy	4	10
Ore, kidney, *Sand Block*	..	2
Sandstone, shaly	11	0
Shale and covered	8	0
Clay shale, light and pink	6	0
Shale and covered	6	6
Ore }	..	3
Shale } *Lower Mercer*	1	0
Ore }	..	10
Shale, very fossiliferous	1	6
Shale	2	1
Limestone, *Lower Mercer*	..	10
Clay shale	2	0
Coal, [*Middle Mercer*]	..	2
Sandstone and covered	14	0
Ore, [*Boggs*]	..	6
Shale and shaly sandstone	3	0
Sandstone	..	3
Coal, *Lower Mercer*	1	1
Clay and covered	..	..

"The Lower Mercer limestone and ore are of more interest for their utilization in the manufacture of iron during the charcoal furnace period [Jackson, Jefferson, Monroe, Washington, Cambria, Latrobe, Lincoln] than for their present value. The ore is rich, easily reduced, and contains the elements necessary for making a soft, high-grade foundry iron; hence it was always in demand for charcoal iron. Although the stratum is thin the ore was worked along the outcrop and under shallow cover by benching, the rule being to strip a foot of dirt for an inch of ore. . . . The iron

content of the ore in the natural state runs from 35 to 50 per cent, the phosphorus from 0.250 to 0.400, and the manganese from 0.30 to 0.60."

VINTON COUNTY[1]

"In Vinton County the Lower Mercer ore is locally present across the central part or in northwestern Brown, Swan, eastern Jackson, eastern Richland, Elk, and western Clinton townships. It was mined most extensively in Richland Township where it was used for smelting in Cincinnati furnace. Where both the ore and the Lower Mercer limestone are present, the position of the ore is 2 to 10 feet above the limestone. The mean intervals to the overlying Sand Block and Upper Mercer ores are 23 and 34 feet respectively and to the underlying Boggs 31 feet. The member varies from 1 to 9 inches in thickness but averages about 3 inches. Usually it is represented by a single stratum but locally it may be divided into two or even three layers. Most of the deposits are sparingly fossiliferous, the fauna being of marine origin and similar to that in the underlying limestone. However, the species are fewer and the forms more impoverished.

"The Lower Mercer ore is poorly represented in northwestern Brown Township. At the forks of the road in southern Section 34, the following measurements were secured:

	Ft.	*In.*
Ore, kidney, *Lower Mercer,* elevation 760 feet	..	3
Clay and covered	8	8
Coal blossom, *Flint Ridge*	..	1
Clay, siliceous	1	0
Shale, argillaceous	6	0
Shale and covered	20	0
Ore, carbonate, siliceous, sparingly fossiliferous, *Boggs*	..	3
Shale	2	0
Water level, Raccoon Creek.		

"Formerly the member was mined in a small way by stripping along the outcrop in many places in Swan Township. Along the road in the southwestern part of Section 2, at an elevation of 841 feet, the deposit consists of two benches of ore, 2 and 3 inches thick, respectively, separated by 4 inches of shale. The structure and thickness of the member are much the same also in the vicinity of Mt. Pleasant in Section 4. Near the forks of the road in eastern Section 6, the following rocks were exposed:

		Ft.	*In.*
Ore blocky	*Upper Mercer*	..	5
Ore, impure, weathered, flint	*Upper Mercer*	..	4
Clay, siliceous		2	0
Shale and covered		12	6
Coal blossom, *Upper Mercer*		..	6

[1]Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 132-134.

Clay, light, plastic	1	6
Sandstone, shaly, parts covered	10	6
Ore, kidney, in two layers, *Lower Mercer*, elevation 972 feet	..	8
Clay, light, plastic, *Middle Mercer*	2	0
Shale, gray, siliceous	7	0
Ore, kidney, stray bed	..	3
Clay, impure, plastic, *Flint Ridge*	2	0

"The Lower Mercer ore is 3 inches thick near the Ebenezer School in northern Section 7. It shows little change in the central and the southern parts of the township, usually being present but everywhere thin.

"The position of the member is about midway up the slopes of the hills in the eastern part of Jackson Township and near the summits of the ridges in the central part. The development is not above the average in any part of the area. Its elevation above tide is about 1,030 feet in Section 1, 1,095 feet near the Chestnut Grove Church, in Section 5, 920 feet in Section 36, and 1,015 feet in Section 32.

"A part of the ore supply for Cincinnati furnace was drawn from the Lower Mercer member in Richland Township where the bed is moderately persistent over most of the area. Along the road in central Section 11, the ore is 2 inches thick and lies 2 feet 4 inches above the top of the Lower Mercer limestone which measures 5 feet 6 inches. Its relation to the Upper Mercer member is shown in the following record taken along the line in the southeastern part of Section 16:

	Ft.	*In.*
Coal blossom, *Brookville*	1	0
Clay, plastic, light	3	0
Covered	15	0
Shale, siliceous	3	0
Flint, siliceous, light gray to dark, *Upper Mercer*	..	4
Shale and covered	21	0
Clay, poorly exposed	2	0
Shale and shaly sandstone	8	0
Ore, kidney, siliceous, *Lower Mercer*, elevation 930 feet	..	3
Clay, shaly, light, *Middle Mercer*	1	6
Shale, gray	6	0
Coal, weathered, *Flint Ridge*	..	3
Clay, light, shaly	2	0
Shale	5	0

"In southeastern Section 13 and northeastern Section 24, from 2 to 4 inches of ore is present just above the Lower Mercer limestone which is well developed. Along the ridge in central Section 34, the bed was formerly mined by stripping. The thickness of the member is 2 to 6 inches. Old ore benches are also present at an elevation of 930 feet on the ridge in the central part of Section 33 and south of this in Section 4. Some deposits were also worked along Jackman Ridge in Sections 34 and 3. The ore is regularly broken by joint planes into blocks which weather into

concentric layers known to the miners as kidneys. Along the outcrop it is a limonite but under cover it is a hard siderite.

"The Lower Mercer ore is not a prominent bed in Elk Township for in many localities it is wanting and where present the stratum is thin and impure. It is present above drainage only in the western half. The member is also lacking in continuity and is variable in thickness and quality along Little Raccoon Creek and McConnel Run in the western part of Clinton Township.

Economic Value

"At present the Lower Mercer ore is of interest chiefly for its stratigraphic features although formerly in the days of the charcoal furnaces it was considered one of the important iron-bearing strata of southern Ohio. It belongs to the block or kidney type of ores, depending on its thickness and state of weathering. On the outcrop the material is a soft shelly limonite but under cover it is a dense siderite. Analysis of the ore usually shows from 25 to 45 per cent iron, from .200 to .400 per cent phosphorus, and .30 to .60 per cent manganese. It belongs to the class of ores well fitted for making foundry iron. Owing to its soft and porous nature, it smelted readily in the short stacks of the charcoal furnaces. In Vinton County the Lower Mercer ore was mined largely in the vicinity of Cincinnati furnace in Richland Township and near Creola in Swan."

HOCKING COUNTY

Throughout central and eastern Hocking County the Lower Mercer limestone has remarkable continuity, seldom being absent from the section. The hard blue limestone is commonly overlain by calcareous, highly fossiliferous shales from a few inches to a few feet in thickness. Under such conditions this shale has apparently supplanted the ore, except in very local areas. Where present the ore is nodular or blocky in structure and seldom over 3 inches in thickness. The Lower Mercer ore adds little to the iron resources of the area.

PERRY COUNTY

In Perry County the Lower Mercer ore is due across the western and central parts of the area but in general the stratum is wanting, through lack of deposition, from the section. Where observed the ore lies closely above the hard blue limestone and is only a few inches in thickness. The ore is of the limonite or siderite form and of fair purity.

MUSKINGUM COUNTY[1]

The Lower Mercer ore is poorly represented in Muskingum County for it was observed at only a few places. Where present the member lies

[1]Geol. Survey Ohio, Fourth Series, Bull. 21, pp. 90-91.

about 1 foot above the Lower Mercer limestone, and where measured, it was from 3 to 5 inches in thickness. Under cover the ore is a siderite or ferrous carbonate, but along the outcrop, where subjected to weathering agencies, it is a limonite or ferric hydrate. On the hill just south of the village of White Cottage, in Newton Township, the Lower Mercer ore was well exposed in a ravine where the record given below was obtained:

	Ft.	*In.*
Ore, *Lower Mercer*	..	4
Shale	1	10
Limestone, *Lower Mercer*	1	2

"At the mouth of the Licking River at Zanesville both the Lower Mercer limestone and ore were uncovered near the water level, and the ore measures 3 inches. The ore was observed at a few places along the Licking River west of this, and along the Muskingum River in the vicinity of Rock Cut. Along the road in the northeastern part of Section 20, Hopewell Township, the member measures 5 inches.

"At present the value of this member in Muskingum County is trifling, and even during the days of the charcoal furnaces its rating was low owing to its limited extent. It is one of the rich coal formation ores varying from 40 to 50 per cent iron in the raw state. The content of phosphorus is sufficiently high to place the ore in the foundry class, whereas the manganese is usually about 1 per cent. The ore carries varying quantities of lime and magnesia, which are present as carbonates."

COSHOCTON COUNTY

In Coshocton County the Lower Mercer limestone shows high development across the western part of the area. The member is made up usually of both hard blue limestone and fossiliferous shale. Throughout most of the area the associated ore is absent, its place being taken by siliceous shales. From the records no ore was mined within the area for metallurgical purposes.

HOLMES COUNTY [1]

"The Lower Mercer ore in Holmes County is of no economic and of very little stratigraphic importance. In this area the ore, if it is present, lies directly on top of the Lower Mercer limestone. The usual thickness, where present, is from 1 to 2 inches. The ore is a shaly, calcareous siderite, which, on the outcrop, has been weathered to a limonite. The greatest thickness of this member observed in Holmes County was 1 foot in central south Richland Township at the Holmes-Coshocton county line at the southeast corner of Section 23 and the southwest corner of Section

[1] White, George W. Unpublished manuscript on the Geology of Holmes County.

22. Here it overlies 7 feet 2 inches of calcareous shale which represents the Lower Mercer limestone at this place. The ore here was observed to be irregular and nodular."

WAYNE COUNTY[1]

The Lower Mercer limestone is well developed and persistent in Wayne County but the associated Lower Mercer ore appears to be absent except in very local areas.

The ore is best developed in Paint Township where it appears with normal development and at its proper position in the section. The following record was obtained near the road corners in the northern part of Section 17, Paint Township:

	Ft.	*In.*
Limestone, gray, *Putnam Hill*	3	8
Coal, fair, *Brookville*	2	4
Clay, gray, siliceous	7	6
Coal, smut, *Tionesta*	..	1
Clay, gray, siliceous	3	0
Covered	36	8
Shale, gray	7	0
Ore, blocky, *Lower Mercer*	..	4
Shale, gray	..	5
Limestone, hard, blue, *Lower Mercer*	1	9
Shale, dark, carbonaceous	1	2
Coal, bony } *Middle Mercer*	1	3
Shale, bony }	..	2
Clay, light, siliceous	5	5
Clay shale, dark	1	10
Coal, bony, *Flint Ridge*	..	2
Clay shale, dark	1	0
Clay, light gray, siliceous	2	0

TUSCARAWAS COUNTY

Although due throughout local areas in the western part of Tuscarawas County the Lower Mercer ore is rarely present and then appears only in a thin nodular form. It was not worked for iron smelting.

STARK COUNTY

The Lower Mercer limestone is widely distributed in Stark County and appears with good development. The Lower Mercer ore is not recorded in the scattered sections taken in the area.

[1]Geol. Survey Ohio, Fourth Series, Bull. 24, pp. 100-105.

MAHONING COUNTY [1]

"The Lower Mercer ore lies directly over the Lower Mercer limestone, but it has been found at only two localities in the Youngstown region. In Grindstone Run the Lower Mercer ore is represented by a layer of flat, kidney-shaped concretions, separated from the limestone by two inches of soft, fossiliferous shale. The ore nodules are blue when fresh, but the surface quickly turns brown when they are exposed to the air.

"The Lower Mercer ore is best developed in the ravine on the north edge of Lowellville. The ore has a dark bluish gray color when fresh, but weathers to colors varying from yellow through dark red to brown. The ore is divided into two parts. At the top there is a two-inch layer of fairly hard, dense, somewhat granular material which breaks with a rough, irregular fracture. When weathered, it is generally brown in color. This is underlain by about four inches of soft shaly material that looks like hematite, when weathered. . . . Below this there are two to four inches of dark blue, gritty, soft limestone which splits in rough, irregular layers, and is very fossiliferous. This layer directly overlies the hard limestone, which is 34 inches thick."

The geology of the Lower Mercer ore is well shown by the following section [Wilber Stout] taken in Furnace Hollow near Lowellville:

	Ft.	*In.*
Limestone, *Upper Mercer*	2	10
Coal, shaly }	..	11
Clay, dark } *Bedford*	..	2
Coal, good }	..	4
Clay, dark, with shaly coal bands	1	1
Clay, plastic, siliceous	1	6
Sandstone, shaly, part covered	13	3
Shale, gray	5	0
Ore, blocky, *Lower Mercer*	..	3
Limestone, hard, blue } *Lower Mercer*	2	1
Limestone, hard, blue }	..	6
Clay, dark	..	8
Clay, light, siliceous	2	0
Clay shale, siliceous, impure	4	0
Coal, shaly, *Flint Ridge*	..	5
Clay, siliceous, very impure	5	3
Shale, dark, carbonaceous, somewhat fissile	2	6
Clay, shaly, impure, light gray	4	0
Coal, fair, *Lower Mercer*	1	11
Clay, very siliceous, with ore nodules	5	0

Northeast of Poland the Lower Mercer limestone is well exposed in the bed of Yellow Creek. Lying directly on the limestone is 1 to 2 inches of iron ore, exceptionally well developed into the cone-in-cone structure.

[1] Thesis, Ohio State University, 1933, The Geology of the Youngstown Region, by Edgar Lee Stephenson, pp. 82-88.

SAND BLOCK ORE[1]

INTRODUCTION

"The Sand Block ore was formerly used in a small way by some of the charcoal furnaces in Scioto, Lawrence, Jackson, and Vinton counties. It was named Sand Block ore by the miners as it was blocky in structure and as it was more siliceous in character and rougher in appearance than either the underlying Lower Mercer or Little Red Block ore or the overlying Upper Mercer or Big Red Block member. It was considered least valuable of the three block ores. The general position of the Sand Block ore is about two-thirds of the way up in the interval between the Lower Mercer and the Upper Mercer ores, and only a few feet above the Upper Mercer coal."

REGIONAL GEOLOGY

SCIOTO COUNTY[2]

"Where present the Sand Block ore is found in the interval between the Upper Mercer coal and the Upper Mercer limestone or Big Red Block ore. In some places the ore lies close to the coal, while at other places it may be found as much as 30 feet above. The average interval is about 15 feet. . . . This deposit, found in Bloom, Vernon, and Green townships, contributed some ore for the old charcoal furnaces [Empire, Franklin, Junior, Scioto, Howard, Bloom] that formerly existed in the region. The bed averages from 4 to 6 inches in thickness and has a maximum measurement of about 12 inches. Under heavy cover it is a siliceous blue carbonate, but along the outcrop this has weathered to the hydrated oxides."

"The geology of the member is well shown in the following record taken on land of Smith Hayward, in Section 35, Bloom Township:[3]

	Ft.	*In.*
Coal, *Brookville*	2	0
Covered	18	0
Ore, *Big Red Block* or *Upper Mercer*	1	6
Covered	16	0
Ore, *Sand Block*	1	0
Shale	10	0
Coal, *Webster Block* or *Upper Mercer*	1	6"

LAWRENCE COUNTY[4]

"The Sand Block ore, which outcrops along the western edge of Lawrence County, lies between the Upper Mercer coal and the Upper Mercer ore. In some places the deposit is only a foot or two above the

[1]Geol. Survey Ohio, Fourth Series, Bull. 31, p. 139.
[2]Geol. Survey Ohio, Fourth Series, Bull. 20, p. 580.
[3]Idem., p. 579.
[4]Idem., p. 297.

coal, but usually it is from 10 to 15 feet. The ore, which varies from 4 to 12 inches in thickness, is quite siliceous, and has been worked at only a few places in Lawrence County."

The following record taken on Bear Run north of the plant of the Superior Portland Cement Company shows the position of the Sand Block ore with reference to the Upper Mercer coal:

	Ft.	In.
Sandstone, massive	15	0
Ore, irregular, *Sand Block*	1	0
Sandstone, very shaly	3	0
Shales, sandy	7	0
Coal blossom, *Upper Mercer*	2	0
Clay, good	4	0
Sandstone, thin bedded	6	0
Shale, gray, siliceous	16	0
Limestone, *Lower Mercer*	1	0

At this place the position of the Sand Block ore is 120 feet below the Vanport limestone.

JACKSON COUNTY[1]

"In Jackson County the next member above the Upper Mercer coal is the Sand Block ore, which was worked in a number of localities for the smelting of iron in the old charcoal furnaces, but it was then ranked far below the Ferriferous and the Upper Mercer ores. The ore is found more or less continuous in parts of Hamilton, Jefferson, Scioto, Franklin, Lick, Coal, Washington, Milton, and Bloomfield townships. In the townships south of Jackson the Sand Block ore lies from 10 to 20 feet above the Upper Mercer coal, and from 10 to 20 feet below the Upper Mercer ore, while north of Jackson these intervals are somewhat contracted, as the ore is often found lying just above the Upper Mercer coal. . . . The thickness of the ore varies from an inch or two to a foot or more in some localities, but the average measurement is about 5 inches. The ore is generally siliceous and low in iron, but in most cases the thicker the deposit the leaner the ore."

The general stratigraphy of the member is shown in the record given below and taken on land of George B. Wykle, north of the highway and Baltimore and Ohio Railroad, in the central part of Section 14, Lick Township.

Sandstone	15	0
Ore, *Zaleski* flint horizon	..	6
Covered	15	0
Limestone, shaly, fossiliferous, *Putnam Hill*	1	0
Covered	3	0
Coal blossom, *Brookville*	1	0
Clay, light	7	0
Shale	4	0

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, p. 160.

Sandstone	9	0
Coal blossom, *Tionesta*	1	0
Clay, sandy, dark	2	0
Shale, sandy	5	0
Ore, *Upper Mercer*	..	2
Coal stain, *Bedford*	..	1
Coal, light, sandy	2	0
Sandstone	8	8
Covered	5	0
Ore, *Sand Block*	..	2
Shale, siliceous	6	8
Coal, *Upper Mercer*	1	1
Clay, good	3	0
Shale, siliceous	9	11
Coal, shaly	..	4
Clay shale	2	8
Sandstone	3	0
Shale	3	0
Coal, shaly	..	9
Covered	5	3
Limestone, *Lower Mercer*	1	0

VINTON COUNTY[1]

"In Vinton County the Sand Block ore is an uncertain and variable element. It changes from a well stratified ore of blocky structure to concretionary nodules dissipated throughout several feet of shale. Further, in many areas it is completely wanting. The material varies also in character from a rather rich mellow ore to one decidedly siliceous or argillaceous. During this stage the conditions in the brackish water swamps were only locally favorable for the deposition of ferruginous sediments in sufficient quantities to form definite ore bodies. Under cover the ore is a siderite but along the outcrop, where weathering has been active, it is a limonite. The thickness of the ore varies from 1 to 8 inches but the usual measurement is about 3 inches. The general position of the Sand Block ore in Vinton County is 11 feet below the Upper Mercer ore, 4 feet above the Upper Mercer coal, 23 feet above the Lower Mercer ore, and 29 feet above the base of the Lower Mercer limestone.

"Formerly the Sand Block ore was mined in a small way at a number of places in Swan Township. It was worked most extensively along the ridges west of Creola. The main stratigraphic features are shown in the following measurements taken in southern Section 29:

	Ft.	*In.*
Ore, blocky, *Upper Mercer*	..	4
Shales and covered	13	6
Ore, irregular, siliceous, *Sand Block*	..	3
Shale and covered	1	9
Coal blossom, *Upper Mercer*	..	6

[1]Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 139-141.

Clay, part covered	4	0
Shale and covered	11	0
Ore, very siliceous, *Lower Mercer*	..	3
Shale, dark	..	3
Coal blossom, *Middle Mercer*	..	6
Clay, siliceous	2	0
Sandstone, shaly	4	4
Ore, kidney, local	..	2
Shale, gray	1	8
Coal and bone shale, *Flint Ridge*	..	6
Clay, light, plastic, very siliceous	2	0

"Local deposits of Sand Block ore are present along the ridges in eastern and central Jackson Township. Near Otterbein Chapel in Section 9, Jackson Township, this member, 4 inches thick, was exposed along the road. The elevation of the deposit is about 1,050 feet. Its position here is directly above the Upper Mercer coal, only a few inches thick, and 11 feet below the Upper Mercer member, represented by fossiliferous limestone and flint. Along the ridge in Section 10, Jackson Township, the conditions are much the same except that the ore thickens to as much as 6 inches and the coal to 1 foot or more. Other exposures were observed in the southeastern part of Jackson Township.

"The deposits appear to be thin and scattered in Richland Township and are not especially prominent in western Clinton. The member was formerly mined to a small extent in western Elk Township. The stratigraphic relation of the Sand Block ore to other members higher in the geological column is well shown in the following record taken along the road in central Section 7, Elk Township:

	Ft.	*In.*
Coal blossom, *Clarion*	1	0
Clay, plastic, light	5	0
Sandstone, light, soft, *Clarion*	30	0
Coal blossom, *Winters*	1	0
Clay, plastic, light	1	0
Covered	3	0
Shale, part dark	3	0
Coal blossom, *Ogan*	1	0
Clay, plastic, light	2	8
Ore, nodules in clay	..	4
Shale and covered	21	6
Coal blossom, *Brookville*	1	6
Clay, plastic, light, lower part siliceous	5	0
Shale, gray	10	0
Ore, blocky, *Upper Mercer*	..	4
Clay and covered	2	6
Sandstone, ferruginous, blocky	1	6
Shale, gray, siliceous	13	2
Ore, very siliceous, *Sand Block*	..	4
Shale, part dark	1	6
Coal blossom, *Upper Mercer*	1	0
Clay, plastic, light	2	0

"In the vicinity of Elk Fork, the Sand Block ore, known locally as the 'Dever block,' was formerly mined at a number of places. The member here lies about 13 feet below the Upper Mercer or 'Dunkel' ore which was worked very extensively throughout the area.

"The deposits of Sand Block ore in Vinton County are too thin and too lean to be of any special importance at present. Formerly also the member was regarded by the charcoal furnace operators as of less value than either of the associated Mercer ores as it was changed in a short distance from an ore of fair purity to one very rough and siliceous. Like most of the coal formation ores, it belongs to the foundry class, being high in phosphorus. The composition of the best Sand Block ore is approximately 25 to 40 per cent iron, .200 to .400 per cent phosphorus and .50 to 1.50 per cent manganese."

CENTRAL AND EASTERN OHIO

Although a detailed search of much of the area in central and eastern Ohio has not been made the evidence as now available indicates that the Sand Block ore is absent from the section or at least very poorly represented. In general the interval between the two Mercer limestones decreases some in their extension to the north and to the east. In so doing both the Upper Mercer coal and the Sand Block ore disappear or become poorly represented. The ore was not found in detailed work in Muskingum, Holmes, and Wayne counties and in local areas, through thesis work, in Coshocton, Stark, and Mahoning counties.

UPPER MERCER OR BIG RED BLOCK ORE[1]

INTRODUCTION

"The limestone now bearing the name Upper Mercer was described in 1858 by Rogers of the First Pennsylvania Survey as the Mahoning from exposures along the Mahoning River near Newcastle in Lawrence County, Pennsylvania . . . Twenty years later, or in 1878, the name was changed by White to Upper Mercer as the bed was traced by him to Mercer in Mercer County, the type locality for the underlying Lower Mercer limestone. In Ohio the stratum was first designated by Orton in 1878 as the Gore limestone from exposures near Gore Furnace in Hocking County. In 1884 the name used in Pennsylvania was adopted in Ohio.

"The Upper Mercer member, represented in some form, extends with only local wants across the State from Columbiana and Mahoning counties on the north to Scioto and Lawrence counties on the south. In the northern part of the field in Columbiana, Mahoning, Stark, Wayne, Tuscarawas, and Holmes counties, the horizon is marked largely by hard, blue limestone with or without flint nodules. Locally, however, the deposits are

[1]Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 142-143.

so flinty that the quantity of siliceous matter in them is greater than that of the calcareous component. But little iron ore is found associated with the limestone in this part of the field. In its extension southward into the central part of the State in Coshocton, Muskingum, Licking, Perry, and Hocking counties, the common material at this position in the geological column is a black flint, overlain occasionally with irregular lenses of gray flint or with thin deposits of iron ore. In southern Ohio in Vinton, Jackson, Scioto, and Lawrence counties, this stratigraphic unit is represented by iron ore with little or no flint or limestone. In general, the Upper Mercer member where traced across the State thus changes from hard, blue limestone to black flint and then to iron ore.

"The Upper Mercer, the thickest and most persistent ore bed in the Pottsville formation of southern Ohio, changes from a red or brownish yellow limonite on the outcrop to a bluish-gray siderite under deep cover. The bed is well stratified but is regularly broken by joint planes into variously shaped blocks. For these reasons the ore was named by the miners the Big Red Block. As it was the main reliance of Franklin Furnace in Scioto County, it was called by Brown the Franklin Block ore. The ore member is only sparingly fossiliferous."

REGIONAL GEOLOGY

SCIOTO COUNTY [1]

"The Upper Mercer limestone is seldom present in Scioto County, but the horizon is quite constantly marked by an iron ore which is known as the Upper Mercer, Big Red Block, or Franklin. It was the main reliance of Franklin Furnace, and was extensively used also at Junior and Ohio furnaces. Further, it was used but to a more limited extent by Scioto, Empire, Clinton, Howard, and Bloom furnaces. The Upper Mercer ore is found in Green, Vernon, and eastern Bloom townships. . . The average interval between the Lower Mercer and the Upper Mercer ore is approximately 52 feet. It is about 30 feet above the Upper Mercer or Webster Block coal and approximately 35 feet below the Brookville coal. The mean interval from the Upper Mercer ore to the Ferriferous ore is nearly 110 feet.

Green Township

"The Upper Mercer ore is much better developed in Green Township than it is in either Vernon or Bloom, although in these it often has good volume for a coal formation ore. This ore was regularly mined for many years by drifting at Ohio Furnace by the Hanging Rock Iron Company, although at present [1915] the mines are abandoned, owing to the influence of the more available and somewhat richer Lake ores. A section taken at

[1] Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 580-584.

the mines of the above mentioned company, located one and one-half miles north of Ohio Furnace, is given below:

		Ft.	In.
Shale		2	0
Ore, upper block	*Upper Mercer*	..	7
Shale		..	..
Ore, lower block		..	11
Coal, dense, hard, *Bedford*		..	2

"The Upper Mercer ore in this locality is sparingly fossiliferous and the lower part of the bed is quite calcareous also, often approaching limestone in composition, and in fact the rock should be called a ferruginous limestone. On the river hills, south of Ohio Furnace, John Norris reports that the Upper Mercer ore is only from 4 to 5 inches in thickness and is unsteady. This is the condition of the ore where noted in the hills south of Junior Furnace. North of this place, however, the ore has good volume and continuity, and is reported to vary in thickness from 6 inches to 1 foot 8 inches.

"The Upper Mercer ore is present only on the high knobs on the main ridges from Franklin Furnace north to Pine Creek. From observations and reports the usual thickness of the bed is from 6 to 10 inches. This ore has been mined rather extensively by stripping along Tick Ridge, where it is stated to have excellent volume for a coal formation ore. On the north end of Tick Ridge, on the property of J. D. Willis, the following measurements were obtained:

	Ft.	In.
Ore, *Upper Mercer*	..	7
Covered	25	0
Coal blossom, *Upper Mercer*	1	0

Vernon Township

"Although the Upper Mercer ore is represented in most of Vernon Township, it is best developed in local areas along Pine Creek, in the eastern part. Next to the Ferriferous ore it was the main reliance for the ore supply of the charcoal furnaces, Empire, Clinton, and Howard. The interval from the Upper Mercer ore to other members is shown in the following record, obtained along the road that leads from Poplar Fork to Clinton Ridge, in Section 28:

	Ft.	In.
Limestone, *Ferriferous*	2	0
Sandstone and covered	54	0
Coal blossom, *Brookville*	1	0
Shale and covered	32	0
Ore, *Upper Mercer*	..	4
Shale and covered	22	0
Coal, *Upper Mercer*	1	0

"The Upper Mercer ore has excellent volume on the land of T. Kern, and on the adjoining properties in Section 23. The ore is reported to have a thickness ranging from 1 to 3 feet, and it was formerly mined by drifting. The Upper Mercer ore was also mined north of the village of Lyra, along Pine Creek, but the bed is much thinner and quite unsteady.

Bloom Township

"The Upper Mercer ore is somewhat persistent in the eastern part of Bloom Township, but the limestone is not well represented. The normal volume of the ore is from 6 to 10 inches although at a few places it expands to as much as 1 foot 6 inches. This ore was well liked by the charcoal furnace operators, as it made a good grade of foundry iron; hence it was mined by benching quite extensively. The only place in Bloom Township that the Upper Mercer limestone was observed was at the foot of the incline of the Morgan and Horton mines, in Section 5, where the following composite section was measured:

	Ft.	In.
Limestone, *Vanport*	8	0
Coal and clod, *Clarion*	4	0
Covered	51	0
Sandstone, shaly	5	0
Shale, black	5	0
Coal, somewhat bony, reported thickness } *Brookville*	1	6
Coal, good, reported thickness } *Brookville*	1	6
Covered	4	0
Sandstone, massive, [*Homewood*]	35	0
Covered	4	6
Ore, *Big Red Block* or *Upper Mercer*	..	5
Limestone, *Upper Mercer*	..	8

"In Section 30, just west of the old stack of Bloom Furnace, the record is as given below:

	Ft.	In.
Coal blossom, *Brookville*	1	0
Clay, plastic	2	0
Shale	4	0
Sandstone	3	0
Shale	12	0
Covered	10	0
Ore, *Big Red Block*	..	6

"On the land of Smith Hayward, in Section 35, the Upper Mercer ore has good thickness, and is sparingly fossiliferous. The ore and other members were well exposed; hence the following measurements were obtained:

	Ft.	In.
Coal, *Brookville*	2	0
Covered	18	0

Ore, *Big Red Block* or *Upper Mercer*	1	6
Covered	16	0
Ore, *Sand Block*	1	0
Shale	10	0
Coal, *Webster Block* or *Upper Mercer*	1	6

"In Section 26, on the John Poetker land, the Upper Mercer ore has good volume, as is shown in the record given below:

		Ft.	*In.*
Ore, kidney, red	*Upper Mercer*	..	6
Ore, siliceous, gray	*Upper Mercer*	1	8

Economic Value

"In many places on the Upper Mercer horizon there are two ore benches which differ in quality and in physical appearance. The upper bench, usually thin, is much richer in iron than the lower bench, which often has excellent volume. The following analyses, made by the writer [Stout], are used through the courtesy of the Columbus Iron and Steel Company. The partial analyses of the Upper Mercer ore from the outcrop on the John Poetker land, are as given below:

	No. 1	*No. 2*
Iron, Fe	48.60	24.95
Siliceous material	14.95	46.10

Sample No. 1—Analysis of upper 6 inches of deposit.
Sample No. 2—Analysis of entire 2 feet 2 inches of ore.

"The Upper Mercer ore, which was formerly mined by drifting, on the Kern and McCallister properties, near Cornwall, south of Lyra, gave the following results: Analyst W. Stout.

	No. 3	*No. 4*
Iron, Fe	42.35	28.40
Silica, SiO_2	21.15	38.35
Lime, CaO	trace	....
Magnesia, MgO	trace	....
Manganese, Mn	0.63	....
Phosphorus, P	0.203	....
Ignition loss	11.60	....

Sample No. 3—Average sample of bed. Theodore Kern property, near Cornwall Station, Vernon Township.
Sample No. 4—Sample from outcrop. McCallister property. Same locality as No. 3.

"An analysis [Stout] of the deposit, 1 foot 6 inches in thickness, from the Smith Hayward land follows:

	Natural	*Roasted*
Iron, Fe	34.65	46.14
Silica, SiO_2	15.90	21.17
Alumina, Al_2O_3	3.34	4.45

Phosphorus, P	0.219	0.292
Manganese, Mn	0.57	0.76
Lime, CaO	2.05	2.73
Magnesia, MgO	1.48	1.97
Zinc, Zn	trace	trace
Ignition loss	24.90	....

"The above sample, which was taken from an entry, and thus under good cover, well represents the average composition of the ore."

LAWRENCE COUNTY [1]

"The Upper Mercer ore was exposed [1916] only at a few places, but the old benches from which it was taken can be followed for miles, as this bed was largely worked by the charcoal furnaces along the Pine Creek Valley, and along the Ohio River. The ore is above drainage in Hamilton, and in the western parts of Upper, Elizabeth, Decatur, and Washington townships. It goes under cover on Storms Creek, near the Kelly School, on Little Storms Creek, near the Lagrange Furnace, on Little Pine Creek near Lawrence Furnace, and on Pine Creek near the mouth of Youngs Branch. The maximum thickness of the ore is 2 feet, but in many places it is thin or wanting, as the ore has been replaced by sandstone. This ore lies on the horizon of the Upper Mercer limestone, and when the limestone is present the ore is found directly above it. In Lawrence County the limestone is wanting, but the ore is quite persistent. The interval from the Upper Mercer ore to the Ferriferous ore varies from 100 to 130 feet, but the usual measurement is from 110 to 120 feet.

Upper Township

"The Upper Mercer or Block ore is present along the lower parts of the valleys of Storms and Little Storms creeks. It was mined rather extensively for the charcoal furnaces. Just north of Ironton, in Kronnacker's spring house, the ore has the following structure:

		Ft.	*In.*
Sandstone, with finger coal at base		5	0
Shale, with ore nodules		1	10
Ore, kidney, good	*Upper Mercer*	..	6
Ore, siliceous	*Upper Mercer*	1	6
Clay, soft, plastic		1	..

"Along the lower course of Storms Creek this ore was worked considerably by stripping, and is reported to be from a few inches to 2 feet in thickness. The quality of the ore is stated to be best when the bed is thin. On Storms Creek it passes under cover just below the Kelly School, and on Little Storms Creek it disappears from view near Lagrange Furnace.

[1] Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 297-305.

Hamilton Township

"The outcrop of the Upper Mercer ore is readily traced on Osburn Run by the old benches which extend along the hillsides. Near the school, where the member was exposed along the bank of the stream, the ore measured 10 inches, and had clay for the covering stratum. West of this stream, on Norman Run, the ore, judging from the depth to which it was mined by stripping, is also well developed. In this locality the ore is reported to be from 6 inches to 1 foot 6 inches in thickness. The bed is very persistent also west of this stream, where the following record was measured in Section 3, on land of the Hanging Rock Iron Company:

		Ft.	In.
Ore, *Upper Mercer*		..	6
Sandstone, shaly		4	0
Covered		8	0
Shale		8	0
Coal, good		1	4
Clay, impure	*Upper Mercer*	..	6
Coal, good		..	8

Elizabeth Township

"The Upper Mercer ore was worked along the courses of the streams in the western part of Elizabeth Township where the bed has good continuity and volume. This ore constituted a part of the regular burden for the charcoal furnaces Center, Lawrence, Pine Grove, and Union. In this township, from measurements and reports, the ore varies in thickness from 4 inches to 2 feet. The mean thickness, however, is from 5 to 10 inches. On Little Pine Creek west of Lawrence Furnace the ore is reported by Thomas Coyer to vary from a few inches to 2 feet in thickness. Generally the roof is shale, but in some places it is a massive sandstone. In some of the workings he reports the ore as follows:

Red ore, upper block.....6 to 10 inches
Gray ore, lower block.....8 to 12 inches

"Near the pond at Lawrence Furnace the ore was exposed on the outcrop and measured about 6 inches.

"North of Kelleys Mills along Pine Creek the Upper Mercer ore has been mined in many places On the Fred Smith farm the ore measured 6 inches in thickness, while north of this on Cooney Branch, it was 8 inches thick where exposed along the banks of the stream. In both places the ore was siliceous in character.

Decatur Township

"The Upper Mercer ore is found along Bear Run and along Pine Creek, in the western part of Decatur Township. Here the bed is only

moderately steady, as it is often replaced by thick sandstones. In this township the member lies from 95 to 120 feet below the Vanport limestone, and it has an average thickness not to exceed 6 inches.

Washington Township

"The charcoal furnaces in Washington Township obtained a small quantity of ore from the Upper Mercer bed, which is present only along the stream courses in the western part of the township. The ore is usually thin, and the member unsteady.

Economic Value

"Next to the Ferriferous the Upper Mercer was the most important ore bed in Lawrence County in the days of the charcoal furnaces, but at present it is not utilized. Under deep cover this ore is gray or bluish-gray ferrous carbonate of the usual coal formation type, but where weathered along the outcrop, or under shallow cover, it has been changed from the carbonate to the oxide state. The charcoal furnaces were not able to smelt successfully the carbonates. If used, these ores were first roasted, which action expelled the carbon dioxide, and oxidized the iron to the ferric state. Even then the blue and gray ores were not liked, for often the calcined ore had unchanged cores, which were quite difficult to smelt in the short stacks of the charcoal furnaces. The red and yellow ores were also roasted before use. This was done, however, only to expel the combined water, which left the ore open, or porous, thus allowing the iron oxides to be reduced readily by the furnace gases. Owing to the difficulty of mining these thin ore beds, and to the demand for only the weathered material, the supply of ore for the charcoal furnaces was taken from along the outcrop; hence the main bodies of ore remain untouched, and may be of more importance in the future. The percentage of iron in the weathered or oxide ore is greater than it is in the unweathered or carbonate ore, but in either case the average content of metal is low. The upper block of the Upper Mercer bed contains a higher percentage of iron than the lower. This ore, mined near Ohio Furnace, and used for years by the Hanging Rock Iron Company, was generally roasted before use. Mr. W. M. Jefferys, superintendent of the furnace, reports the analysis of the ore as follows:

	Calcined	*Calculated to raw ore or carbonate*
Iron, Fe	38.04	29.44
Silica, SiO_2	28.85	22.33
Alumina, Al_2O_3	5.64	4.36
Lime, CaO	5.19	4.01
Magnesia, MgO	1.47	1.14
Sulphur, S	.89	.69

Phosphorus, P	.576	.445
Manganese, Mn	.74	.53
Ignition loss	.23	24.38

"An analysis of a leaner sample is given in Geological Survey of Ohio, Volume V, page 1,110. Assuming this ore, in the raw state, to be a blue carbonate, its calculated analysis would be approximately as shown in the second column.

	Calcined	*Calculated to raw ore or carbonate*
Iron, Fe	32.00	27.08
Silica, SiO_2	35.57	29.35
Alumina, Al_2O_3	6.10	5.04
Lime, CaO	2.85	2.35
Magnesia, MgO	1.12	.93
Sulphur, S	.93	.77
Phosphorus, P	.62	.51
Manganese, Mn	.84	.70
Ignition loss	2.11	21.57
Water, H_2O	.48	....

"The upper block of the Upper Mercer ore at many places is of good quality. An analysis reported by the Hanging Rock Iron Company gave the following results:

	Calcined ore
Iron, Fe	45.90
Silica, SiO_2	13.10
Alumina, Al_2O_3	2.61
Lime, CaO	15.55
Magnesia, MgO	.35
Sulphur, S	.39
Manganese, Mn	.538
Ignition loss	2.61
Water, H_2O	.17

"Mr. E. B. Willard reports the analysis of the calcined ore from the same locality from a large burnt kiln as follows:

Silica, SiO_2	21.98
Alumina, Al_2O_3	5.10
Lime, CaO	4.82
Magnesia, MgO	2.16
Iron—metallic, Fe	42.13
Sulphur, S	.806

"The value of the Upper Mercer ore, compared to that of siliceous Lake ores, determined by a method devised by the writer while at the furnaces, shows that this ore is worthy of consideration for iron smelting

in the modern blast furnaces.[1] The basis of comparison is on smelting 540 tons of ore per day with soft Pocahontas coke, and with limestone for flux. The average analysis of this coke for a number of years, as determined by the Columbus Iron & Steel Company, follows:

Ferrous oxide, FeO	1.17
Silica, SiO_2	2.35
Alumina, Al_2O_3	1.66
Phosphorus, P	.005
Lime, CaO	.41
Magnesia, MgO	.32
Sulphur, S	.63
Volatile matter	1.01
Fixed carbon	90.30
Moisture	2.09

"The flux stone used is as follows:

Ferric oxide, Fe_2O_3	.52
Silica, SiO_2	2.30
Alumina, Al_2O_3	.70
Phosphorus, P	.015
Calcium carbonate, $CaCO_3$	90.16
Magnesium, $MgCO_3$	5.90
Water, H_2O	.12
Combined water, H_2O	.25

"In these comparisons 2 per cent silicon and 4 per cent total carbon are figured to the iron. In ordinary practice about one-half the manganese found in the burden goes to the iron, while the remainder is carried out in the slag and this condition is used in the comparisons.

"The iron produced is made up of the following:

Total iron in burden of ore, stone and coke.
Total phosphorus in burden of ore, stone and coke.
One-half manganese in burden of ore, stone and coke.

The three above items equal 94 per cent of the total pig.

Silicon	2 per cent
Carbon	4 per cent
Pig iron produced	100 per cent

In the slag the ratio of acids to bases is held at 1:1, that is,

$$\left\{\begin{matrix} CaO \\ MgO, \text{ when low} \\ MnO, \text{ when low} \end{matrix}\right\} : \left\{\begin{matrix} SiO_2 \\ Al_2O_3 \end{matrix}\right\} : : 1 : 1$$

[1]Thesis, Ohio State University, 1915, A Heat Balance Method of Iron Ore Comparison, by Wilber Stout.

"The heat units required for the reduction of the ore, breaking up of stone, and slagging of the gangue of the ore and coke, together with the heat lost in the process, and also heat produced by the burning of the coke, are based on figures obtained from Richard's calculations. The ratio by volume of $\frac{CO}{CO_2}$ 1.8 is held, as this denotes economy of fuel. This ratio is easily reached in practice.

"Col. H. A. Marting of Ironton reports as follows:

The freight rate on Lake Ores from the docks at Toledo or Cleveland to Ironton is 90 cents per ton of 2,240 lbs. The average price of Pocahontas coke delivered at Ironton would be approximately $2.85 per ton of 2,000 lbs. This is taking the average price over a period of about ten years.

The general over and above cost including the labor, taxes, insurance, office expenses, maintenance of property, and cost of marketing, would be somewhere in the neighborhood of $1.00 per ton of ore smelted. This is on the basis of smelting approximately 540 tons of ore per day. The cost of native limestone per ton of 2240 lbs. is from 80 to 85 cents, delivered at Ironton.[1]

"Mr. W. M. Jefferys of the Hanging Rock Iron Company reports as follows:

Limestone, cost per gross ton at furnace, 85 cents. Average cost of net tons of coke at furnace, $3.05. Freight on Lake ore, 90 cents per gross ton. Over and above cost per ton of pig iron, including all labor and repair costs, taxes, insurance, etc., would be $1.0936; cost of native ore per gross ton delivered at furnace would be $1.92 for the 'Limestone' ore, and $1.98 for the Block ore.[2]

Oglebay, Norton & Co. quote Empire ore for season of 1912 at lower lake ports at $1.75 per ton.

Pickands, Mather & Co. quote Vivian for season of 1913 at lower lake ports at $2.15 per ton.

In these comparisons the following figures are used:

Over and above costs	$1.00 and $1.0936 per ton of ore smelted
Block ore per gross ton	1.98
Empire ore per gross ton	1.75
Vivian ore per gross ton	2.15
Coke per net ton	2.85 and $3.05
Stone per gross ton	.85
Freight on Lake ore per gross ton	.90

"The common practice of the charcoal furnace operators where carbonate ores were used was first to calcine them, which action was an

[1]Personal letter, dated Feb. 26, 1913.
[2]Personal letter. dated Feb. 27, 1913.

advantage, as the ores then reduced more readily in the short stacks. This same practice was also followed where the ore was used in the large coke furnaces. Mr. W. M. Jefferys reports, 'We have not attempted to use this ore in the natural state. It has always been calcined, but we are of the opinion that it could be used in the natural state by crushing.'

"In the breaking up and in the reduction of the ores the following heat units are required when the grams of the substances used are equal to the molecular weights.

$4FeCO_3 + (4x24{,}900 \text{ cal.} = 99{,}600 \text{ cal.}) = 4FeO + 4CO_2$
$4FeO + (4x65{,}700 \text{ cal.} = 262{,}800 \text{ cal.}) = 2Fe_2 + 2O_2$

362,400 cal.

"Thus the total heat required to break up $4FeCO_3$, and then reduce the $4FeO$ to $2Fe_2$ is 362,400 calories, or the calories per unit of iron are 1,618.

"Where the carbonate is first roasted to the ferric oxide and then reduced, the heat required is as follows:

$4FeCO_3 + (4 \times 24{,}900 \text{ cal.} = 99{,}600 \text{ cal.}) = 4FeO \times 4CO_2$
$4FeO + O_2 = 2Fe_2O_3 + (2 \times 64{,}200 \text{ cal.} = 128{,}400 \text{ cal.})$
$2Fe_2O_3 + (2 \times 195{,}600 \text{ cal.} = 391{,}200 \text{ cal.}) = 2Fe_2 + 3O_2$
Heat of reduction used = 490,800 calories.
Heat of oxidation given = 128,400 calories.

Heat required = 362,400 calories.

"It is seen from these calculations that the heat energy required is exactly the same. The results are different when the heat required to smelt the raw carbonate is compared with that required to smelt the calcined ore, as shown below:

4 $FeCO_3$ requires 362,400 calories for its complete reduction, while 2 Fe_2O_3 requires 391,200 calories for its complete reduction, or 28,800 calories more are required in the second case to produce $2Fe_2$ than in the first case. This is an excess of 129 calories per unit of iron, or 129 calories more are required to reduce one unit of iron from the oxide than from the carbonate, so that from this point of view there is no special economy in roasting the ore.

"When charged into the blast furnace and reduced, other effects must be considered also. The CO_2 produced carries out heat while the O_2 given up by the iron oxide combines with the CO gas to form CO_2 with evolution of heat. The temperature at which the gases leave the furnace is ordinarily 200° C. The specific heat of CO_2 at this temperature is

.414. When the carbonate ore is charged into the furnace, the heat items are as follows:

Heat used to break up $4FeCO_3$ = 362,400 calories
Heat carried out by $4CO_2$ (176x200x.414) = 14,753 calories
Heat given by oxidation $4CO + 2O_2$ = $4CO_2$ + (4x12x5,670) = 272,160 calories.
Heat carried out by $4CO_2$ (176x200x.414) = 14,753 calories

Heat used = 391,906 calories.
Heat given = 272,160 calories

Heat required = 119,746 calories

"This 119,746 calories must be furnished by the oxidation of C to CO by air.

1 unit C burned to CO gives 2,430 calories.
The gases produced carry out the following at 200° C.

$\frac{7}{3}$ units CO $= \frac{7}{3}$ x200x.3084 = 144 calories

$\frac{307.6}{69.3}$ units $N_2 = \frac{307.6}{69.3}$ x200x.2448 = 217 calories

Total 361 calories

Radiation losses are not considered in the above.
2,430 calories — 361 calories = 2,069 calories available heat.

$\frac{119,746}{2,069} = 58$ units carbon

"So total carbon units required are 58 + 48 = 106, which must be supplied by the coke. The units of iron reduced by 106 units of carbon are 224, or the carbon per unit iron is .473.

When calcined ore is charged the items are as follows:
Heat units required to break up $2Fe_2O_3$ = 391,200 calories
Heat given by oxidation $6CO + 3O_2 = 6CO_2$ (6x12x5,670 = 408,240 calories.
Heat carried out by $6CO_2$ (264x200x.414) = 21,859 calories

Heat used = 413,059 calories
Heat given = 408,240 calories
Heat required = 4,819 calories

"The 4,819 calories yet required must be supplied by the oxidation of C to CO by air, which gives 2,069 calories per unit C. The equation follows:

$$\frac{4,819}{2,069} = 2 + \text{units C}$$

"Total units carbon required are 72 + 2 = 74, so in this case 224 units iron are reduced by 74 units carbon or carbon per unit iron is .330.

The difference in carbon per unit between using the raw and calcined ore is .473 — .330 = .143, or 14.3 per cent of the weight of the iron. This saving of carbon will justify the calcining of the carbonates especially where it can be done with cheap fuel.

"The calcining of ore is also expensive for several reasons. The ore is handled once or twice more than if used raw, and while low grade fuels are generally used, these must be given a value. Considerable ore is lost in dust that results from the extra handling and calcination. Some of the ash from the fuel used is mixed with the calcined ore, thus increasing the gangue to be fluxed in the furnace.

"There are also several points against using the raw carbonate. In a normal working furnace the Fe_2O_3 is reduced to spongy metallic iron near the top. The $FeCO_3$ is broken up and reduced several feet lower or close to where the slag zone begins. The carbonates are dense; hence their impervious character retards greatly the reducing action of the gases, as the CO_2 must first be expelled and then the FeO reduced. If the ore is added in large pieces before this breaking up and reduction is complete, it may be carried far down into the slag zone, which generally causes trouble. If the ore is crushed to small pieces, the breaking up and reduction will take place in the proper zone. Magnetites for years were held in disfavor, as the furnace managers were trying to use them in too large pieces, but at present they are crushed and work very satisfactorily. The carbonates, if used raw, should also be prepared by crushing before use.

"In a measure the capacity of a furnace is limited; that is, the amount of stock which can be charged per day. The carbonate and oxide ores compare in weight as follows:

$2FeCO_3 = 232$; or ore per unit iron = 2.07
$Fe_2O_3 = 160$; or ore per unit iron = 1.43

"From the above it follows that, if carbonate alone were charged, the tonnage of iron produced from the furnace would be much less than where oxides alone are charged. In the table where the two are compared in this way, it shows that 3,080 lbs. of coke are required to smelt 2,268 lbs. of iron from the carbonate and only 2,584 lbs. of coke for the iron from the oxides. The difference is due to the capacity of the furnace and to the low yield of iron when the carbonate is used, as in both cases 540 tons ore were charged.

"These siliceous carbonate ores give a low yield of metal, but they may be utilized to good advantage to bring the silica in the burden up to the quantity required. Their value is considerably increased if the ore is calcined before use. On the whole, the Upper Mercer ore of Lawrence County is equally as valuable as the siliceous Lake ores. It belongs to the class of ores adapted for the smelting of foundry iron. The member is well worthy of consideration as a mineral asset of the county and is

of interest also in connection with the early history of iron making in the Hanging Rock Iron Region."

JACKSON COUNTY[1]

"The Upper Mercer limestone is seldom present in Jackson County, but the ore, except where replaced by the heavy sandstone, is quite persistent. . . . The horizon is found near the summits of the hills and ridges in the eastern parts of Hamilton and Scioto townships, and owing to the dip eastward it goes under cover in the eastern parts of Jefferson and Franklin townships. It is found in the eastern halves of Lick, Washington, and Coal townships, and, extending eastward, it goes below drainage in northern Bloomfield and eastern Milton along the courses of Little Raccoon Creek and its tributaries.

The relation of the Upper Mercer ore to other members and the average intervals separating them are given in the following general section for Jackson County:

	Ft.	*In.*
Flint and ore, *Zaleski* flint horizon	1	0
Shales and sandstones	21	0
Coal, *Brookville*	2	0
Shales and sandstones	27	6
Ore, *Upper Mercer*	..	6
Shales and sandstones	14	8
Ore, *Sand Block*	..	4
Shales and sandstones	8	6
Coal, *Upper Mercer, No. 3a*	1	6
Shales and sandstones	18	0
Ore, *Lower Mercer*	..	4
Shale and sandstone	7	8
Limestone, *Lower Mercer*	1	0

Hamilton Township

"In Section 35, Hamilton Township, on the land of Henry Comer, the position of the Upper Mercer ore with reference to other members is shown in the following record:

	Ft.	*In.*
Shales	..	..
Coal blossom, *Brookville*	1	0
Covered	25	0
Ore, *Upper Mercer*	..	6
Covered	17	0
Ore, *Sand Block*	..	3
Covered	45	0
Ore, *Boggs*	..	2

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 160-169.

"On the land of Joseph Woods, in Section 24, in the eastern part of Hamilton Township, the measurements were as follows:

	Ft.	In.
Ore, *Upper Mercer*	..	4
Covered	13	0
Ore, *Sand Block*	..	4
Covered	27	0
Ore, *Lower Mercer*	..	1

Jefferson Township

"The intervals from the Upper Mercer ore to other important members are given in the following section taken along the road just south of the Mound School, in sections 19 and 20:

	Ft.	In.
Sandstone, massive	15	0
Shales and covered	21	0
Shale, dark, *Brookville* coal horizon	3	0
Sandstone, massive	32	6
Ore, *Upper Mercer*	..	6
Sandstone, massive	20	0
Coal blossom, *Upper Mercer*	1	0
Clay	3	0
Sandstone, massive	13	0
Ore, *Lower Mercer*, old bench level	..	..
Sandstone and covered	17	0

"In Section 5, on the land of John H. Horton, the Upper Mercer ore was being mined, [1916], and the thickness of the bed was 10 inches. On the land of Evan Jenkins, Section 3, where the ore was also being mined, the following relations were noted:

		Ft.	In.
Sandy clay and argillaceous sandstone		3	0
Shale		3	0
Ore		..	4
Sandstone	*Upper Mercer*	..	1
Ore	*Upper Mercer*	..	2
Sandstone, cherty	*Upper Mercer*	..	1
Coal, *Bedford*		..	1
Covered		13	3
Shale		4	0
Ore, *Sand Block*		..	6
Shale, blue, tough		6	0
Coal, *Upper Mercer*		1	2
Clay		..	..

"South of the above along Black Fork and along the lower course of Hewitt Run, while the horizon is above drainage, the ore is wanting or is replaced by heavy sandstones.

Scioto Township

"In Section 36, Scioto Township, on the Anson Scurlock property, the Upper Mercer ore was being mined [1916] by stripping where it was 9 inches thick. The upper part of a measurement on land of Andrew Yinger, in Section 13, shows the Upper Mercer ore and its relation to other strata:

	Ft.	In.
Shale	8	0
Ore, *Upper Mercer,* fossiliferous	..	5
Sandstone	..	8
Coal	..	6
Shale and covered	22	..
Coal, *Upper Mercer*	1	..
Shale and covered	12	..
Coal blossom	..	5
Clay shales	1	9
Ore, *Lower Mercer,* fossiliferous	..	3
Coal blossom	1	..

Franklin Township

"In Section 31, Franklin Township, on land of Edward Gahm and P. E. Lanhart, the ore measured 8 inches, but is reported to be 2 feet in local areas. In Section 30, on the property of Alexander Jones, the thickness of the ore seen was 8 inches. The Upper Mercer ore, varying in thickness from 4 to 8 inches, was seen at a number of places in sections 32, 33, and 34. A composite section on the land of Everett Rice, in Section 8, shows the ore and other members:

	Ft.	In.
Ore, *Upper Mercer*	..	8
Covered	12	..
Ore, *Sand Block*	..	3
Covered	45	0
Ore, *Lower Mercer*	..	4
Covered	82	0
Shale, gray	14	0
Shales, dark blue, sandy	4	0
Coal, *Vandusen*	..	10
Shale, carbonaceous	1	0
Covered	2	0
Sandstone	10	0

"The Upper Mercer ore was also seen at several places in Section 7, where it has about the same thickness as in the above section, and has been worked for the Jackson furnaces. A composite section taken along the ridge near the home of W. L. Brown, Section 3, shows the following relations:

	Ft.	In.
Limestone, *Vanport*	..	..
Covered	42	0

Ore, *Zaleski* flint horizon		..	4
Covered		43	0
Ore, *Upper Mercer*		..	3
Covered		78	0
Coal, cannel	*Lower Mercer*	..	8
Shale	*Lower Mercer*	..	6
Coal, cannel	*Lower Mercer*	..	10

Lick Township

"The Upper Mercer ore has been mined by benching along the outcrop quite extensively in the eastern part of Lick Township. It has good thickness and is rather persistent. In Section 26, on land of Harrison Kesinger, the measurements which follow were taken:

	Ft.	In.
Ore, *Zaleski* flint horizon, reported thickness	..	6
Covered	58	0
Ore, *Upper Mercer*	..	4
Covered	15	0
Sandstone, shaly	8	0
Coal, *Upper Mercer*	1	8
Covered	..	..

"A composite section on the property of Michael Radcliff, in Section 23, shows the relation of several members as follows:

	Ft.	In.
Limestone, *Vanport*, weathered blocks on summit of knob	..	..
Covered	26	0
Coal, *Winters*, reported thickness	1	8
Covered	15	0
Ore, *Zaleski*, flint horizon	..	4
Covered	40	8
Coal, reported thickness, *Brookville*	1	4
Covered	10	0
Ore, *Upper Mercer*	..	4
Covered	20	8
Coal, *Upper Mercer*	1	0
Covered	48	0
Coal, *Lower Mercer*, cannel, reported thickness	1	3

"In Section 22, on land of Madison Wykle, the rocks measured as follows:

	Ft.	In.
Ore, *Zaleski* flint horizon	..	6
Covered	48	0
Ore, *Upper Mercer*	..	5
Covered	25	0
Sandstone	8	0
Shale	1	6
Coal	*Upper Mercer*	..	5
Clay	*Upper Mercer*	..	2
Coal	*Upper Mercer*	1	5

Covered	36	0
Coal, *Lower Mercer,* cannel nature	..	3

"In Section 14, on land of George B. Wykle, a section showing the important members from the ore on the Zaleski flint horizon to the Lower Mercer limestone was obtained. The section following thus defines the position of the Upper Mercer ore:

	Ft.	*In.*
Sandstone, *Clarion*	15	0
Ore, *Zaleski* flint horizon	..	6
Covered	15	0
Sandstone, calcareous, fossiliferous, *Putnam Hill*	1	0
Covered	3	0
Coal blossom, *Brookville*	1	0
Clay, light	7	0
Shale	4	0
Sandstone	9	0
Coal blossom, *Tionesta*	1	0
Clay, sandy, bluish	2	0
Shale, sandy	5	0
Ore, *Upper Mercer*	..	2
Coal stain, *Bedford*	..	1
Clay, light, sandy	1	11
Sandstone	8	8
Covered	5	0
Ore, kidney, *Sand Block*	..	2
Shale	6	8
Coal, *Upper Mercer*	1	1
Clay, good	3	0
Shale	9	11
Coal	..	4
Clay shale	2	8
Sandstone	3	0
Shale	3	0
Coal	..	9
Clay shale	2	0
Covered	5	3
Limestone, *Lower Mercer,* fossiliferous	1	0

Coal Township

"The Upper Mercer ore continues northward across Coal and Washington townships into Vinton County. A representative section showing the Upper Mercer ore and its stratigraphic position with reference to the Brookville and Upper Mercer coals and the ore on the Zaleski horizon, was outlined on land of G. N. House, in Section 3, Coal Township. The rocks exposed and measured follow:

	Ft.	*In.*
Covered	15	0
Ore, *Zaleski* flint horizon	..	8

Covered			25	0
Sandstone, shaly, calcareous, very fossiliferous			..	4	0
Shale, sandy, very fossiliferous		*Putnam Hill*	..	1	3
Shale, dark, very fossiliferous			..	..	4
Coal			..	1	2
Clay shale, with thin coal bands			..	..	6
Coal	*Brookville*		..	..	5
Clay, dark			..	..	11
Coal			..	..	10
Clay shale, dark				1	6
Covered				14	0
Ore, *Upper Mercer*				..	4
Sandstone, shaly				26	0
Shale				2	10
Coal, *Upper Mercer*				1	2
Covered				..	..

"Along the road south of the abandoned Superior No. 2 mine, in Section 35, the measurement obtained shows the interval from the Upper Mercer ore to the Lower Mercer ore and limestone below. The following rocks were measured:

	Ft.	*In.*
Ore, *Upper Mercer,* thickness reported	..	5
Covered	35	0
Ore, sandy, *Lower Mercer*	..	4
Clay shales, light	1	8
Shales and covered	16	0
Limestone, *Lower Mercer*	1	0

Washington Township

"On the land of W. R. Hamilton, Section 27, Washington Township, the ores have been mined by stripping. The section obtained shows the general relation of the Upper and Lower Mercer ores, and is given below:

	Ft.	*In.*
Ore, *Upper Mercer*	..	4
Sandstone and covered	10	0
Covered	20	0
Coal blossom, *Upper Mercer*	1	0
Clay and covered	7	0
Sandstone and covered	10	0
Ore, *Lower Mercer,* fossiliferous	..	6

Milton Township

"In Milton Township the Upper Mercer ore was mined by benching, first for the charcoal furnaces, and later for the modern coke furnaces. It is mined at present [1916] in a desultory way, but the amount produced is trifling. The section taken at the mine of the Wellston Colliery

Company, in Section 5, Milton Township, shows the position of the Upper Mercer ore with reference to the Vanport limestone above and the Lower Mercer ore and Quakertown coal below. The section measured is as follows:

	Ft.	In.
Limestone, *Vanport*	3	0
Covered	62	0
Ore, *Upper Mercer*	..	6
Covered	55	0
Ore, *Lower Mercer*	..	4
Shale	2	0
Sandstone, ferruginous	1	0
Covered	29	0
Top of shaft	..	..
Interval	78	0
Coal, *Quakertown*	2	6

"The following composite section taken at the mine of the Elk Fork Coal Company, in Section 3, shows the Upper Mercer ore and other important members:

	Ft.	In.
Coal blossom, *Brookville*	..	6
Clay, upper part dark	4	0
Covered	2	0
Sandstone	4	6
Covered	5	0
Sandstone	5	0
Ore, *Upper Mercer*	..	4
Shales	9	2
Coal, *Upper Mercer*	1	6
Sandstone, shaly	5	0
Top of shaft	..	..
Sandstone and covered	25	0
Limestone, *Lower Mercer*	1	0

"The Upper Mercer ore is exposed along the small stream east of Mulga, in Section 3, and on the hills east of this, on the land of the Superior Colliery Company, in Section 2, the Clarion coal was opened. In Section 8, the measurements taken from the hollow near the abandoned [1916] Superior No. 6 mine to the hill west on land of George Woodrow, show the Upper Mercer ore, the Clarion coal, and the Lower Mercer limestone. The record is given below:

		Ft.	In.
Coal	*Clarion*	1	2
Clay and bone coal		..	8
Coal		1	0
Clay-sulphur band		..	1
Coal		1	0
Covered		51	0
Coal blossom, *Brookville*		1	0
Covered		31	0

Ore, *Upper Mercer*	..	4
Covered	35	0
Shale, part sandy	16	0
Covered	5	0
Limestone, *Lower Mercer*	..	10

"The Upper Mercer ore here varies from 4 to 8 inches in thickness and has been mined by stripping. Along Mulga Run in Section 10, the ore has been mined, and the following section, taken on land of the Superior Colliery Company, shows the position of the ore and other important members:

	Ft.	*In.*
Sandstone, with finger coal, *Clarion* horizon	1	0
Sandstone, shaly and covered	29	0
Coal bony, cannel, *Brookville*	1	0
Sandstone and covered	27	0
Ore, *Upper Mercer*	..	6
Shale	12	0
Coal, *Upper Mercer*	1	6

"The ore where exposed along Mulga Run varies from 4 to 10 inches in thickness, but averages about 5 or 6 inches. The ore was exposed in the road near the bridge that crosses Little Raccoon Creek, in Section 15, and the rocks measured at this place are given below:

		Ft.	*In.*
Ore, *Upper Mercer*		..	4
Shale		3	0
Coal blossom		..	2
Clay shale	*Bedford*	..	6
Coal blossom		..	2
Clay shale		1	0
Shale, gray, sandy		6	6
Ore, *Sand Block*		..	4
Sandstone, ferruginous		1	0
Shale, carbonaceous, fissile, *Upper Mercer* coal horizon		2	0

"The Upper Mercer ore and the associated strata were exposed on the land of R. A. Fitzpatrick, east of Little Raccoon Creek, and in Section 16 along the road north of Middletown. Near Hogansville along the road between sections 18 and 19, the Upper Mercer ore and the Lower Mercer and Vanport limestones were exposed and measured. The record follows:

Limestone, flinty, *Vanport*		3	0
Shale, black, fissile		2	0
Coal		1	2
Coal, bony		..	4
Clay	*Clarion*	..	6
Coal		1	5
Clay		..	1
Coal		1	0

Clay and covered	13	0
Sandstone	9	0
Covered	10	0
Sandstone, soft	12	0
Shale	1	6
Ore, *Upper Mercer*	..	3
Clay, light	1	3
Sandstone	1	0
Covered	5	0
Ore, *Sand Block*	..	4
Sandstone, ferruginous	..	8
Sandstone, soft	10	0
Covered	5	0
Sandstone	11	0
Clay, light	2	0
Sandstone, shaly	3	0
Sandstone, coarse-grained	5	6
Shale	1	6
Limestone, *Lower Mercer*	1	0

"Along the road just below the mouth of Coal Run, in Section 23, the Upper Mercer ore was exposed, and on the hill nearby the cannel coal was formerly mined. The following rocks and intervals were recorded:

	Ft.	*In.*
Coal, cannel, *Brookville,* thickness reported	2	0
Sandstone and covered	32	0
Sandstone, coarse-grained	2	0
Shale, gray	3	0
Ore, *Upper Mercer*	..	4

"The Upper Mercer ore goes below drainage in the Little Raccoon Valley, in the southern part of Section 23, but it is exposed along the headwaters of Flint and Tarcamp runs.

Bloomfield Township

"Along the headwaters of Dickason Run, especially in the vicinity of Ridgeland, in Bloomfield Township, the Upper Mercer ore is again above drainage. It was mined by stripping here during the days of the charcoal furnaces, but the bed is not as thick or persistent as the ore on the Zaleski flint horizon.

Economic Value of Upper Mercer Ore in Jackson County[1]

"Next to the Ferriferous, the Upper Mercer ore was the main reliance for the ore supply of the charcoal furnaces. For the coke furnaces it now [1916] stands third, ranking below the Jackson Sand Block ore and the Ferriferous. The thickness of the deposit varies from a few inches

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 170-171.

to about 2 feet, but that usually observed is from 5 to 10 inches. Under heavy cover the ore is a ferrous carbonate, the usual coal formation type, but along the outcrop it is a ferric oxide with more or less combined water. The carbonate ore was not desired for charcoal furnace use, and even the gray or partially weathered material was often condemned. On this account, and owing to the ease of mining, the stratum was worked only along the outcrop or under shallow cover: hence the main ore body yet remains in the hills. The mining at present [1916] is done by stripping with pick and shovel, with plow and scraper, or, where the strata above are hard shales and sandstones, with explosives and scraper. No drift mines are operated [1916] in Jackson County for the Upper Mercer ore.

"The iron content of the ore compares favorably to that of the siliceous Lake ores, while the phosphorus and manganese are well proportioned for foundry pig. The general character of the Upper Mercer ore is shown by the following analysis, kindly furnished by the Jackson Iron and Steel Company:

Iron, Fe	41.14	per cent
Phosphorus, P	0.344	" "
Silica, SiO_2	22.10	" "
Alumina, Al_2O_3	4.92	" "
Manganese, Mn	0.78	" "
Lime, CaO	None	
Magnesia, MgO	None	
Moisture, H_2O-	6.80	" "

"The Star Furnace Company reports the Upper Mercer ore, which is mined on the Scurlock property south of Jackson, to contain from 51.10 to 54.30 per cent of iron. An analysis of the Upper Mercer ore from the vicinity of Jackson is as follows:[1]

Specific gravity	2.774
	....
Combined water	11.30
Siliceous matter	9.16
Sesquioxide of iron	74.63
Alumina	1.20
Manganese oxide	1.15
Carbonate of lime	0.52
Carbonate of magnesia	0.76
Phosphoric acid	0.83
Sulphur	*trace*
Total	99.55
Iron, Fe	52.24
Phosphorus, P	0.362
Manganese, Mn	0.73

[1]Geol. Survey Ohio, Report of Progress, 1870, p. 150.

"The ore smelts easily as the structure is porous, thus allowing the reducing gases to permeate the mass. Even when smelted in the coke furnaces the iron carbonizes somewhat similarly to that made by the old charcoal furnaces. The iron is soft and tough, hence it is a standard iron for all foundry work. When all points are considered, these ores surpass the siliceous Lake ores in value, and should be more extensively used."

VINTON COUNTY [1]

"The Upper Mercer is the most persistent and widely distributed ore in Vinton County and during the days of the charcoal furnaces it was more extensively mined than any of the other beds. It is present with some wants in northwestern Madison, western Brown, Swan, eastern Jackson, eastern Richland, Elk, and western Clinton townships. Flint or limestone accompanies the ore in a few places. The position of the member is, on the average, about 40 feet above the Lower Mercer limestone, 31 feet below the Putnam Hill limestone, and 54 feet below the Zaleski black flint, which are the main benches for reference. Considerable variations and irregularities, however, are found locally in these intervals. From more than 50 measurements, the mean thickness of the bed is 7 inches, the minimum 1 inch, and the maximum 3 feet 7 inches. Generally the ore is present in a single bed but locally it may be divided into two, three, or even more distinct strata, varying in both composition and texture.

Brown Township

"Along Raccoon Creek and Twomile Run in northwestern Brown Township, the Upper Mercer member is generally thin and in many localities it is wanting. Such deposits were mined in but few places.

Madison Township

"The Upper Mercer is due close to drainage level along Raccoon Creek near Zaleski and along Strong Run in northeastern Section 36. Near the forks of the hollow in the latter area this limestone and ore were exposed in the stream bed. The record secured is given below:

			Ft.	*In.*
Shale, gray, fossiliferous	*Putnam Hill*	.....	1	0
Limestone, shaly, fossiliferous	*Putnam Hill*	.....	..	9
Coal	*Brookville*	.....	1	2
Clay, dark	*Brookville*	.....	..	4
Coal	*Brookville*	.....	1	3
Clay, plastic, light		.....	3	6
Shale and covered		.....	11	6
Ore, nodular, reddish-brown	*Upper Mercer*	...	..	4
Limestone, shaly, blue, fossiliferous	*Upper Mercer*	...	..	8
Limestone, hard, blue, blocky, fossiliferous	*Upper Mercer*	...	..	7

[1] Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 143-151.

"The ore varies from a soft limonite to a hard siderite, depending on the state of weathering. The limestone affords fair collecting as the fossils are well preserved.

Swan Township

"The Upper Mercer ore was extensively mined for many years in Swan Township, especially in the southern and western portions. Most of it was loaded for shipment at Creola. In some of the deposit the ore is very rich and is much above the average in thickness. The usual measurement of the bed, however, is between 4 and 8 inches.

"Near Orland, the member is generally thin and locally wanting. Where observed in the southwestern part of Section 9, the deposit consists of 2 to 4 inches of iron ore underlain by 4 to 8 inches gray to dark, fossiliferous flint. Its position is about 960 feet above tide. Many old benches show where the ore was mined along the ridges in sections 5, 6, 7, and 8. Near the road forks in eastern Section 6, at an elevation of 1,010 feet, the deposit is made up of 5 inches of block ore underlain by 4 inches of rough, flinty ore. A record, taken just across the county line in southwestern Section 31, Washington Township, Hocking County, shows exceptionally well the composite nature of the member in places and also its stratigraphic relation to other well-known beds. The measurements are given below:

			Ft.	*In.*
Shale, gray			18	0
Shale, calcareous, very fossiliferous, *Putnam Hill*			1	8
Shale, dark, carbonaceous, *Brookville* coal horizon			1	1
Clay, dark, plastic			2	0
Shale, gray			3	4
Shale, block			..	1
Coal			..	1
Clay, light			1	6
Shale, gray			6	4
Coal, shaly	*Tionesta*		..	8
Shale, with thin coal bands	*Tionesta*		..	8
Coal, shaly	*Tionesta*		1	0
Clay, light, plastic, siliceous			3	4
Sandstone and sandy shale, light			7	0
Ore, kidney	*Upper Mercer*, elevation 995 feet		..	3
Sandstone, shaly	*Upper Mercer*, elevation 995 feet		..	3
Ore, blocky	*Upper Mercer*, elevation 995 feet		..	5
Ore, shelly	*Upper Mercer*, elevation 995 feet		..	7
Limestone, blue, fossiliferous	*Upper Mercer*, elevation 995 feet		..	9
Shale, siliceous	*Upper Mercer*, elevation 995 feet		..	11
Flint, black	*Upper Mercer*, elevation 995 feet		..	5
Shale, siliceous			7	8
Coal	*Bedford*		..	3
Sandstone	*Bedford*		..	2
Shale, coaly	*Bedford*		..	5
Clay, impure, siliceous			1	6
Sandstone, shaly			6	4

Shale, dark, carbonaceous, *Upper Mercer* coal horizon	..	6
Clay, light, siliceous	2	6
Shale, gray, siliceous	6	0
Ore, kidney, *Lower Mercer*	..	2
Shale, gray	..	8
Shale, dark, carbonaceous, *Middle Mercer* coal horizon	..	6
Sandstone, hard, dark	..	2
Clay, light, siliceous	2	7
Shale, dark, carbonaceous, *Flint Ridge* coal horizon	..	4
Sandstone, hard, dark	..	3
Shale, dark	..	3
Clay, light, plastic	3	0
Shale, gray, soft, part siliceous	15	2
Shale, dark	..	5
Coal, hard, *Lower Mercer*	1	8
Clay, plastic, light	1	0
Shale, gray, part covered	4	4
Shale, dark, siliceous	..	10
Shale, gray, siliceous	2	0
Sandstone, massive, *Massillon*	25	0
Covered.		

"Extensive mining by benching has been done along the ridge northwest of Creola in sections 19, 20, 29, and 28, where the ore is reported to be above the average in both thickness and quality. Locally it is underlain by black flint from a few inches to more than 1 foot thick. Many stripping operations are yet evident along the ridge in sections 31, 32, and 33, where the ore is reported to vary from 2 inches to 1 foot 10 inches in thickness. On the hill just east of Creola in Section 34, measurements show 6 to 10 inches of ore underlain by about the same thickness of dark flint. The deposit here has an elevation of 836 feet and lies 104 feet below the Vanport limestone. Along Raccoon Creek in the southeastern part of the area, the Upper Mercer member is generally thin and consists usually of ore alone. Near the road forks in east central Section 25, the bed lies 764 feet above tide and measures 3 inches in thickness.

Jackson Township

"Formerly the Upper Mercer member was mined at many places along the main ridges in the eastern and central portions of Jackson Township. It shows no unusual features. The ore is generally in one bench and 4 to 6 inches thick. Locally it is underlain by black flint or cherty sandstone.

"Along the ridge in western Section 10, both ore and black flint are present at an elevation of about 1,060 feet. Similar deposits were observed north of the Browns School in Section 9 and also in northeastern Section 16. Near the road forks in central Section 21, 4 inches of Upper Mercer ore was exposed at an elevation of 1,050 feet. South of the Shively School in Section 23, the member is divided into 3 to 5 inches of block ore

and 4 to 6 inches of black flint. The bed lies 990 feet above tide. On the George W. Hartley farm in southwestern Section 36, the following rocks were exposed for measurement:

		Ft.	In.
Shale, dark, very fossiliferous, *Vanport*		2	0
Coal, somewhat bony		1	1
Clay shale	*Clarion*	..	7
Coal		1	9
Clay		..	1
Coal		..	8
Clay, plastic, light		6	6
Covered		24	6
Limestone, very fossiliferous, *Putnam Hill*		..	5
Clay, shale, and covered		30	7
Ore, kidney	*Upper Mercer*, altitude 930 ft.	..	2
Shale, very siliceous		..	5
Ore, blocky, siliceous, sparingly fossiliferous		..	7
Shale, very siliceous		1	1
Ore, siliceous		..	3

"Nearby the lower ore stratum changes to gray or black flint 5 to 8 inches thick. Its position is about 45 feet above the Lower Mercer limestone which is well developed.

Richland Township

"A part of the ore supply for Cincinnati Furnace, later known as Richland, was drawn from the Upper Mercer member in the eastern and central parts of Richland Township. As elsewhere the deposits show considerable variation in thickness, character, and structure.

"Near the Pawpaw School in Section 1, the Upper Mercer member was mined extensively by stripping along the outcrop. The elevation of the deposits is approximately 920 feet. One to two benches of ore are present, the thickness of which is reported to be 3 to 10 inches. Locally the ore is underlain by flint or dark, ferruginous sandstone. The position of the Upper Mercer member in this locality is nearly 45 feet above the Lower Mercer limestone, 40 feet below the Zaleski black flint, and 65 feet below the Vanport buhrstone. The thickness of the ore where observed in central Section 12 is from 4 to 6 inches, at the Wyckoff Crossroads in Section 15 from 3 to 5 inches, and along the ridge in sections 16 and 21 the measurements are about the same. Near the Dolly School in Section 22, 3 to 5 inches of block ore is accompanied by 3 to 10 inches of black flint. At this place the elevation of the bed is 925 feet above tide and its position about 35 feet above the Lower Mercer ore. Deposits similar in character and thickness were noted also in sections 27, 28, 32, 33, 34, and 3, south.

Elk Township

"The Upper Mercer ore is moderately persistent in Elk Township and is present above drainage in all but a few sections in the southeastern portion. The most extensive mining was done in the northern and western parts, the ore being hauled to the railroad at McArthur and Elk Fork.

"Along the road in southeastern Section 3, the Upper Mercer ore is present at an elevation of 794 feet. The bed measures about 3 inches in thickness but near by it is reported to expand to as much as 8 inches. Formerly this ore was mined at a number of places in sections 4, 5, 6, and 7. The thickness observed is from 2 to 7 inches. Its relation to other members is well shown in the following record taken along the road in southeastern Section 8:

	Ft.	*In.*
Shale, gray	8	0
Shale, gray, fossiliferous, *Putnam Hill*	2	0
Coal blossom, *Brookville*	2	8
Clay, light, plastic	3	0
Sandstone, light, argillaceous	10	0
Covered	5	9
Ore, blocky, 3 to 5 inches, *Upper Mercer,* elevation 870 feet	..	3
Shale and shaly sandstone	14	7
Clay shale, dark	1	0
Coal, blocky, *Upper Mercer* or *No. 3a*	..	5
Clay, dark, siliceous	2	0
Shale and covered	6	4
Ore, siliceous	..	7
Shale, gray, parts siliceous	18	1
Shale, fossiliferous, *Lower Mercer*	1	0

"West of McArthur the ore locally has fair thickness and was mined at a number of places. Several exceptionally good deposits in the vicinity of the Hawk School were worked for shipment to furnaces in the Hocking Valley. Along the road in the northeastern corner of Section 26, the member is composed of two ore benches, of 3 and 4 inches respectively, separated by 8 inches of shale and underlain by a hard, ferruginous sandstone which locally changes to black flint. The bed lies 710 feet above tide. Locally along Elk Fork in this section, the ore is reported to thicken to 1 foot and to be of good quality. (See analysis, page 112.)

Clinton Township

"Both Hamden and Cincinnati furnaces drew a part of their ore supply from the Upper Mercer member in the western half of Clinton Township. This bed extends eastward to Dundas and Hamden Furnace before it disappears below the valley floors. Some of the deposits were far above the average in thickness and were mined extensively by stripping along the outcrop.

"In sections 5, 6, and 7, the bed appears to be thin and in places wanting. On the Craig farm in Section 8 the deposits are much above normal in both thickness and quality and were stripped to deep covering. Measurements of the ore and associated rocks are given below:[1] (See analysis, page 112.)

	Ft.	In.
Soil	4	0
Shale, light gray	2	6
Sandstone, soft, ferruginous	2	3
Clay shale, gray	1	2
Shale, dark blue, sandy	..	6
Ore, limonite, red, 10 inches to 1 foot } *Upper Mercer* {	..	10
Ore, sideritic, blue } *Upper Mercer* {	..	5
Coal	..	1
Clay	..	1
Sandstone.		

"The few exposures observed in sections 17 and 18 show 2 to 5 inches of block ore, usually of inferior quality. West of Hamden in Section 19, considerable stripping was also done on the Robbins farm where the deposit consists of two benches of ore of 6 and 9 inches respectively and where it lies about 40 feet above the Lower Mercer limestone. Near Hamden Furnace the member is locally well developed and was used for iron smelting. The following record, taken along the old road in north central Section 28, shows very well not only the thickness and structure of the ore but also its relation to other important stratigraphic units:

	Ft.	In.
Shale and covered	10	0
Sandstone and covered	46	0
Coal blossom, *Middle Kittanning*	2	0
Clay, light, plastic	1	0
Shale, shaly sandstone, and covered	25	0
Clay, plastic } *Oak Hill* {	3	0
Clay, flint } *Oak Hill* {	1	0
Coal blossom, *Lower Kittanning*	1	0
Clay and covered	6	0
Shale and covered	11	0
Limestone, *Vanport*	3	0
Covered	2	0
Coal blossom, *Clarion*	3	0
Clay, light, plastic	6	0
Sandstone, light, clay-bonded	7	8
Coal, weathered } *Winters* {	2	2
Clay } *Winters* {	..	3
Coal, weathered } *Winters* {	..	5
Clay, plastic, dark	3	6
Shale, gray, siliceous	13	6
Ore, irregular, local	..	6
Shale, gray	7	2

[1]Geol. Survey Ohio, Report of Progress, 1870, p. 121.

Coal, *Newland*		..	5
Clay, light, siliceous		1	6
Sandstone, soft, parts covered		43	11
Ore, with shale layers	*Upper Mercer*, altitude 765 feet	..	10
Ore, blocky		..	7
Sandstone, ferruginous		..	8
Ore, soft, siliceous		..	5
Ore, blocky		..	10
Shale, ferruginous		..	6
Sandstone, argillaceous		1	6
Shale and covered		4	0
Coal, bony		..	4
Clay, siliceous, upper part with coal bands		1	8
Sandstone, soft, massive, part covered		50	8

"At other places in this vicinity the ore measures 4 to 10 inches in thickness. Locally it is underlain by an irregular stratum of black flint.

Economic Value

"Although of little value at present, the Upper Mercer ore in Vinton County was formerly an asset of importance as it was worked for many years over a wide area. Mining activity began with the advent of the charcoal furnaces within the county in 1852 and continued briskly until 1888 when the native ores were largely replaced by those from the Great Lakes region. Upper Mercer ore was used extensively during their active periods in Richland, Hamden, and Vinton furnaces and in less amounts in Zaleski, Eagle, and Hope. Later large quantities of ore were shipped from McArthur, Elk Fork, and Creola to outside furnaces, Creola being the main center for this trade. Regarding the ore shipped from this place, Mr. A. B. Kirkendall states:[1]

'From 1880 to 1888 ore, both raw and calcined, was constantly being loaded at Creola. For months at a time the standing orders were for 25 cars per day which amounted to between 300 and 400 tons. One large pile on the yard in 1884 contained 19,000 tons. In the most active years from 1881 to 1884, the annual shipment was not far from 30,000 tons. The ore loaded here was largely block or Upper Mercer and was mined along the ridges west of this place. The bulk of the material was sold for smelting in the furnace at New Straitsville but some was shipped also at Winona, Gore, Orbiston, Buchtel, Greendale, and Floodwood. After 1888, the trade declined rapidly and soon ceased altogether.'

"Under deep cover the Upper Mercer ore is a siderite but along the outcrop, where affected by weathering, it is a limonite. These limonites smelted easily in the short stacks of the charcoal furnaces as they were open and porous. As the soft, oxidized ore was liked best for iron smelting, the main supply was obtained by stripping where the overburden

[1]Personal letter from A. B. Kirkendall, Creola, Ohio, Jan. 4, 1924.

was thin. The rule was that one foot of dirt could be removed for every inch of ore. Drift mining was not regularly practiced in Vinton County. From many observations, the mean thickness of the bed in this field is 7 inches but in local deposits the measurements range from 10 inches to as much as 3 feet and frequently average 1 foot 3 inches. Such a bed of ore will yield approximately 4,400 tons per acre.

"The iron content of the Upper Mercer ore is low compared to that of the better grades from the Great Lakes district as the Upper Mercer is not only more siliceous and argillaceous but also much higher in combined water and volatile matter. When calcined the difference is not so great. The quality of the Upper Mercer ore is shown by the following analyses:[1]

	No. 1	*No. 2*	*No. 3*
Moisture and ignition loss	7.50	33.38	8.75
Silica, SiO_2	6.49	3.93	43.46
Ferric oxide, Fe_2O_3	83.74	11.61	45.95
Ferrous oxide, FeO	....	43.51	....
Alumina, Al_2O_3	.70	....	....
Manganous oxide, MnO	trace	trace	.65
Lime, CaO	.07	2.30	.20
Magnesia, MgO	.14	2.95	.50
Phosphorus pentoxide, P_2O_5	.217	.42	.971
Sulphur, S	.06	.03	trace
Total	98.917	98.13	100.481
Iron, Fe	58.62	42.00	32.17
Manganese, Mn	trace	trace	.50
Phosphorus, P	.073	.183	.424
Specific gravity	2.814	3.516	2.682

No. 1. Limonite ore, upper part of bed, Craig mine, Section 8, Clinton Township

No. 2. Siderite ore, lower part of bed, Craig mine, Section 8, Clinton Township.

No. 3. Limonite ore, siliceous, McAllister mine, Section 26, Elk Township.

"The ores on the Upper Mercer horizon have a wide range in composition as they vary in the character of the ferruginous minerals from hydrated oxides to carbonates, and in the quantity of impurities such as sand, clay substance, and calcareous matter. In general, the ore in the upper part of the deposits is of better quality than that in the lower part and laterally the transition from good to poor ore may take place in a short distance. These ores are all in the foundry class as they are high enough in phosphorus to make an iron sufficiently fluid to pour well The manganese varies from a trace to 1.00 per cent but usually averages about .50 per cent. In some deposits the content of lime and magnesia is such that it aids substantially, during smelting, in fluxing the siliceous matter.

[1]Geol. Survey Ohio, Report of Progress, 1870, pp. 111, 122.

The weathered ore is generally low in sulphur. On the whole, the Upper Mercer, for a lean ore, has fair metallurgical properties."

HOCKING COUNTY

In Hocking County the Upper Mercer ore member is absent in rather large areas. In parts of the field only black flint appears on the horizon and in other parts neither ore, flint, nor limestone is present, to represent the member. The iron ore phase is most prominent in the southwestern part of the county in Benton and Washington townships. This ore helped in a small way to supply burden for Union, Logan, and Hayden charcoal furnaces and for Winona, Monday Creek, Helen, Gore, and Crafts coal furnaces.

In Benton Township the deposits are confined to the ridges in the southeastern part of the area. The member is found at an elevation of 1,030 feet in east central Section 36, 1,080 in northwestern Section 34 and 1,071 in southeastern Section 24. In this area the ore averages about 6 inches in thickness. Its position is about 25 feet above the Lower Mercer limestone and 80 feet above the Lower Mercer coal. Some ore was mined along the ridges, mainly by benching along the outcrop.

The Upper Mercer ore is far from persistent in Washington Township, in fact, the horizon is marked by ore in only a few localities. The best deposits are in the southwestern part of the area. The geology of the member is well shown in the record given below and taken along a ravine in the southwestern part of Section 31, Washington Township:

			Ft.	*In.*
Top of knob, elevation 1,045 feet			..	..
Shale, gray			18	0
Shale, calcareous, fossiliferous, *Putnam Hill*			1	8
Shale, dark, carbonaceous, place of *Brookville* coal			1	1
Clay, dark			2	0
Shale, gray			3	4
Shale, black			..	1
Coal, shaly			..	1
Clay, light			1	6
Shale, gray			6	4
Coal, shaly	*Tionesta*		..	8
Shale, coaly	*Tionesta*		..	8
Coal, shaly	*Tionesta*		1	0
Clay, light, siliceous			3	4
Sandstone and sandy shale			7	0
Ore, kidney	*Upper Mercer*		..	3
Sandstone, shaly	*Upper Mercer*		..	3
Ore, blocky	*Upper Mercer*		..	5
Ore, shelly	*Upper Mercer*		..	7
Limestone, fossiliferous, blue	*Upper Mercer*		..	9
Shale, siliceous	*Upper Mercer*		..	11
Flint, black	*Upper Mercer*		..	5

Shale, siliceous		7	8
Coal		..	3
Sandstone	*Bedford*	..	2
Shale, coaly		..	5
Clay, siliceous		1	6
Sandstone, shaly		6	4
Shale, dark, *Upper Mercer* coal horizon		..	6
Clay, light, siliceous		2	6
Shale, gray, siliceous		6	0
Ore, *Lower Mercer*		..	2
Shale, gray		..	8
Shale, dark, *Middle Mercer* coal horizon		..	6
Sandstone, dark, hard		..	2
Clay, light, siliceous		2	7
Shale, dark, *Flint Ridge* coal horizon		..	4
Sandstone, hard, dark		..	3
Shale, dark		..	3
Clay, light, plastic		3	0
Shale, gray, soft		15	2
Shale, dark		..	5
Coal, hard, *Lower Mercer*		1	8
Clay, light, plastic		1	0
Shale, gray, and covered		4	2
Shale, dark, siliceous		..	10
Shale, gray, siliceous		2	0
Sandstone, massive, *Massillon*		25	0

At this place all three phases of the Upper Mercer member, ore, limestone, and flint, are present and in characteristic development.

In Falls Township the Upper Mercer ore is very generally absent from the section and where found it is thin, often nodular. In Green Township black flint is the common material present at this horizon. Usually neither ore nor limestone is present with the flint. Some of the geological features are shown in the following record taken on the south tributary of Kitchen Run, one mile north of Greenland School, in east central Green Township:

		Ft.	*In.*
Shale, gray		3	0
Coal, weathered, *Tionesta*		..	6
Clay, plastic		5	0
Clay, siliceous		3	0
Flint, black, locally replaced by sandstone, *Upper Mercer*		1	1
Covered		14	10
Shale, gray		6	0
Limestone, blue, fossiliferous		2	0
Shale, blue, fossiliferous	*Lower Mercer*	..	11
Limestone, blue, fossiliferous		..	2
Coal, *Middle Mercer*		..	5
Shale, black, part bony		1	3
Coal, *Flint Ridge*		..	2
Clay, light, plastic		1	0

The Upper Mercer ore is much impoverished in western Ward Township and throughout Falls-Gore Township. Where marked flint is the common material on the horizon. The Lower Mercer-Putnam Hill interval is much contracted with the absence of several members. No mining for ore was found in this part of the county.

PERRY COUNTY

Throughout central and western Perry County the rock that marks the Upper Mercer horizon is, in general, black flint or flint and limestone. In few places does iron ore appear and then only in thin lenticular beds. Such deposits are due above drainage in Monday Creek, Jackson, Reading, Hopewell, Salt Lick, Pike, Clayton, and Madison townships. The Upper Mercer thus added little to the ore supply for the eight coal furnaces—Baird, Fannie No 1, Fannie No 2, XX, Mollie, New York, Moxahala, and Bessie—that formerly operated in Perry County.

The geology of the Upper Mercer member is shown in the record given below and taken along the road that leads from the head of Salt Run to the ridge west in the southeastern part of Section 3, Madison Township:

	Ft.	*In.*
Shale, gray	16	0
Coal blossom, ***Middle Kittanning***	4	0
Clay, light, siliceous	9	0
Sandstone, shaly, part light	10	0
Shales, gray, parts siliceous	36	6
Limestone, nodular, fossiliferous } *Putnam Hill* {	..	6
Shale, gray, very fossiliferous } *Putnam Hill* {	7	6
Shale, gray	8	0
Clay shale, light, part covered, ***Brookville*** coal horizon	7	0
Clay, plastic, part dark	5	6
Clay and covered	5	6
Shale, dark	..	6
Coal, shaly	..	1
Shale, weathered, with ore nodules	1	3
Coal, bony, ***Tionesta***	..	5
Clay, light	1	0
Clay shales and covered	7	3
Limestone, dark, flinty, ***Upper Mercer***	1	2
Coal, ***Bedford***	..	5
Clay, light, siliceous	2	5
Shale and covered	7	0
Coal, bony, weathered, ***Upper Mercer***	..	8
Shale, gray	1	4
Sandstone, shaly	10	0
Shale, dark blue, carbonaceous	1	11
Shale, gray	1	9
Coal, bony, ***Middle Mercer***	..	4
Clay, siliceous	4	0
Covered	8	0
Level of bridge, 890 feet elevation	..	..

MUSKINGUM COUNTY[1]

"The Upper Mercer ore, which is more generally known in southern Ohio by the name Big Red Block, or Franklin ore, lacks continuity in Muskingum County, as it was observed at only a few places. However, in these places the thickness of the deposit is about the same as it is in Jackson, Scioto, and Lawrence counties, where it was mined extensively for many years for iron smelting in the early charcoal furnaces. The measurements of the bed in Muskingum County vary from 3 to 6 inches. Its position is close to that of the Upper Mercer limestone or flint. In fact, in local areas the ore rests directly on the flint or limestone, whereas in other localities it is separated from this stratum by a bed of shale expanding from a few inches to several feet in thickness. The ore is often sparingly fossiliferous and the types present are about the same as those found in the underlying flint or limestone. In places the associated shales also bear impressions of the marine life that existed during this general period of deposition of ore, flint, and limestone. The member will be traced only in a general way, as the exposures are few and the value trifling. In a ravine just south of the flour mill at White Cottage the following relations between the Upper Mercer ore and Upper Mercer flint were noted:

	Ft.	*In.*
Shale	5	..
Ore, *Upper Mercer*	..	6
Shale	..	5
Flint, dark, *Upper Mercer*	1	5

"On the land of J. W. Beam, in the western part of Section 20, Newton Township, the Upper Mercer ore lies directly on the Upper Mercer flint, and measures 6 inches in thickness. Along the road in the northern part of Section 28, Newton Township, the Upper Mercer flint or limestone is absent. This condition, with only the ore present, was seldom observed in this county, although it is the characteristic arrangement in southern Ohio. Along the Licking River west of Zanesville, in Falls Township, the ore and flint appear either to be merged into one bed or the flint is very ferruginous and the ore wanting. The stratum is a mixture of flint and iron ore. This condition was noted at a number of places. On the land of J. Butler, 1½ miles north of Dillon Falls, the following structure was observed in a stream bed:

	Ft.	*In.*
Shale, gray	1	..
Ore, nodular, *Upper Mercer*	..	3
Shale	..	3
Flint, black, *Upper Mercer*	1	1

[1]Geol. Survey Ohio, Fourth Series, Bull. 21, pp. 114-115.

"At another exposure near-by the ore measures 6 inches in thickness. Along the road in Section 12, Muskingum Township, east of Township Hall, the ore varies from 2 to 8 inches in thickness, and is separated from the underlying limestone by several feet of shale. In the eastern part of this township the Upper Mercer ore is absent, or is merged with the flint, the upper part of which is often very ferruginous. This is the general condition noted also in Hopewell, Licking, Cass, and Jackson townships.

"The Upper Mercer ore was not utilized to any extent in Muskingum County, even during the days of the charcoal furnaces, as the deposits are local and the ore thickness small. It belongs to the siderite class of ores which is typical of the unweathered ores in the Pottsville rocks of Ohio. Along the outcrop of the bed chemical agencies have changed it from the carbonate to the hydrated oxide or to the limonite class. From general appearance the ore is somewhat siliceous, even where the bed is separated from the flint. It carries some lime and magnesia which, however, aid in smelting. The phosphorus content of the Pottsville ores usually fits them for the smelting of foundry iron. Owing to the limited quantity of the Upper Mercer ore in Muskingum County, and to the small demand for native ores, since the advent of the rich Lake ores, the bed has no value worthy of consideration at present." [1918]

EASTERN OHIO

Throughout eastern Ohio, through Coshocton, Holmes, Wayne, Tuscarawas, Stark, Portage, and Mahoning counties, the deposits of Upper Mercer ore are quite local, widely scattered, and generally thin. Flint or limestone or both mark the horizon. The associated ore lacks development and hence has no economic value.

PUTNAM HILL LIMESTONE HORIZON

Most of the marine limestone members in the Pottsville and Allegheny series carry iron ores in association. This is true of the Lowellville, Boggs, Lower Mercer, Zaleski, Vanport, Hamden, and Washingtonville. However, no regularly bedded stratified ore is present with the Putnam Hill member. The related stratum is calcareous shale, rich in fossils.

ZALESKI FLINT HORIZON[1]

INTRODUCTION

"Closely associated with the Winters coal, in parts of Jackson and Vinton counties, there are found deposits of black flint, calcareous shales, and kidney ores. When both the flint and coal are present the flint lies just below the coal. . . . East of Coalton and Jackson the flint and coal

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 179-187.

are seldom present, but a kidney ore is found which marks the horizon and which has been mined for the charcoal and coke furnaces."

REGIONAL GEOLOGY

JACKSON COUNTY

The ore is present locally in Lick Township. A carefully measured section which shows the important members between the ore on the Zaleski horizon and the Lower Mercer limestone was obtained on land of George B. Wykle, in Section 24, Lick Township. The record follows:

	Ft.	*In.*
Ore, *Zaleski*, flint horizon	..	6
Covered	15	0
Sandstone, calcareous, very fossiliferous, *Putnam Hill*	1	0
Covered	3	0
Coal blossom, *Brookville*	1	0
Clay, light	7	0
Shale, gray	4	0
Sandstone	7	0
Coal blossom, *Tionesta*	1	0
Clay, sandy	2	0
Shale, sandy	5	0
Ore, *Upper Mercer*	..	2
Coal, *Bedford*	..	1
Clay, light, sandy	2	0
Sandstone	8	8
Covered	5	0
Ore, *Sand Block*	..	2
Shale	6	8
Coal, *Upper Mercer*	1	1
Clay, siliceous	3	0
Shale, gray	9	11
Coal	..	4
Clay shale	2	8
Sandstone	3	0
Shale, gray	3	0
Coal	..	9
Clay shale	2	0
Covered	5	3
Limestone, *Lower Mercer*	1	0

"The upper part of a section measured along the road in the northeastern part of Section 23, Lick Township, shows the ore on the Zaleski flint horizon to be broken up into three benches. The record taken is as given below:

		Ft.	*In.*
Ore		..	4
Shale		2	0
Ore	*Zaleski* flint horizon	..	6
Shale		1	2
Ore		..	4

"This ore which is quite persistent in eastern Lick Township was mined at many places. The member varies in thickness and structure for it is often broken into two or more layers with shales intervening.

Coal Township

"The flint as well as the ore is present in a few places in the southern part of Coal Township, although both are rather unsteady. A section taken on land of G. N. House, in Section 3, Coal Township, shows the following relations:

			Ft.	*In.*
Ore, *Zaleski* flint horizon			..	8
Covered			25	0
Sandstone, shaly, very fossiliferous	*Putnam Hill*		4	0
Shale, sandy, very fossiliferous	*Putnam Hill*		1	3
Shale, dark, very fossiliferous	*Putnam Hill*		..	4
Coal, good			1	2
Clay shale with thin coal bands	*Brookville*		..	6
Coal, good	*Brookville*		..	5
Clay, dark	*Brookville*		..	11
Coal, good	*Brookville*		..	10

"Along the ridge south of this the ore has been mined by stripping. In the northern part of Coal Township the ore has been mined in a few localities, but no records were obtained. In Washington Township both flint and ore are present, but the Winters coal above was not seen.

Bloomfield Township

"While the ore on the Zaleski flint horizon is rather persistent in northwestern Bloomfield Township, where it was formerly mined by stripping for the charcoal furnaces, the flint was not observed, and the Winters coal above is poorly represented. East of Ridgeland, in Section 8, Bloomfield Township, on land of Albert W. Lackey, the ores on the Zaleski flint and Upper Mercer horizons have been mined and flinty Vanport limestone was seen on the hill above. The ore on the Zaleski flint horizon is reported to vary from 4 to 10 inches in thickness, and to average about 8 inches. In the western part of the same section, on the land of Harriet A. and W. L. Burris, the ore, formerly mined quite extensively by stripping, is reported to vary from 3 to 15 inches in thickness, and to average about 10 inches. The section taken is given below:

	Ft.	*In.*
Limestone, *Vanport*	4	0
Covered	49	0
Ore, *Zaleski* flint horizon	..	10
Covered	8	0
Shale, gray	3	0
Shale, sandy, fossiliferous, *Putnam Hill*	4	0

Shale, dark		4	0
Sandstone, dark		..	4
Shale, carbonaceous, fissile		2	0
Coal, good		..	10
Clay, siliceous	*Brookville*	..	10
Coal, good		1	2
Covered		8	2
Shale, sandy		9	0
Shale, soft		..	4
Coal, *Upper Mercer*		1	11

Economic Value

"The ore on the Zaleski flint horizon has been of some economic value as the bed furnished a part of the ore supply for the charcoal furnaces originally in operation in the Jackson and Wellston regions, and it has also contributed some ore for the later coke furnaces. In thickness the bed varies from a few inches to 2 feet, but averages about 8 or 10 inches. . . . The ore is not of wide extent as the bed is confined mainly to northeastern Franklin, northwestern Bloomfield, eastern Lick, and western Milton townships, although it has been mined at a few places in eastern Coal and eastern Washington townships. An analysis of the "Kidney ore" from the Zaleski flint horizon is as follows:

Specific gravity	*3.551*
Combined water	1.24
Siliceous matter	7.54
Sesquioxide of iron	9.66
Carbonate of protoxide of iron	73.38
Alumina	0.24
Manganese oxide	2.00
Carbonate of lime	2.50
Carbonate of magnesia	2.04
Phosphoric acid	0.207
Sulphur	0.36
Total	99.167
Percentage of metallic iron	42.29

VINTON COUNTY [1]

"The most characteristic material on the Zaleski horizon is a black or brownish black flint, hard and lustrous. . . . Aside from the true flint. the horizon also yields calcareous flint, siliceous limestone, calcareous shale, and iron ore. . . . The iron ore under deep cover is a siderite but near the surface this has been changed to limonite.

"In Ohio the Zaleski member with its associated Ogan and Winters coals has as yet been recognized only in southern Vinton and northern

[1]Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 181-186.

Jackson counties. The basin thus appears to be small, as now outlined, covering an area of not more than 130 square miles. . . . The stratigraphic position of the Zaleski member is, on the average, about midway between the Brookville coal and the Clarion coal, or 26 feet above the Brookville and 27 feet below the Clarion. These intervals, however, vary much and erratically from place to place. In general the ore is poorly developed in Vinton County.

"Near the Jackman School, in Section 34, Richland Township, the ore was mined by stripping for the charcoal furnaces, and the Brookville coal below, which has excellent volume, is mined for local use. The section obtained follows:

	Ft.	*In.*
Ore, *Zaleski* flint horizon	..	8
Shale	5	0
Shale and covered	19	0
Shale, very fossiliferous, *Putnam Hill*	4	0
Coal, *Brookville*	5	1

"In Madison Township the Zaleski member is above drainage only along Raccoon Creek, Elk Fork, and their minor tributaries in the western part. The bed is very unsteady being absent more often than present. It may be represented by flint, iron ore, or impure shale. Near Dundas in Clinton Township the horizon is locally marked by iron ore or shaly flint.

Economic Value

"The iron ore on this horizon was formerly mined in a small way at a few places near Dundas and near Hamden for smelting in the charcoal furnaces. It was worked only along the outcrop where the ore is a soft limonite. The deposits are local and variable and from 2 inches to 1 foot thick. The quality of the ore is generally poor as it is siliceous in character. The Zaleski member has not been definitely recognized north of Vinton County."

CANARY ORE

INTRODUCTION

The Canary ore is local in distribution and is confined to a few areas in southern Ohio, mainly Scioto County. Its position is at or close to the base of the Clarion clay. It may be correlative with the ore on the Zaleski flint horizon but appears to be slightly higher in position.

REGIONAL GEOLOGY

SCIOTO COUNTY [1]

"The Canary ore is found from 25 to 30 feet below the Ferriferous limestone, but the bed is quite unsteady, being developed only in restricted

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 589-590.

areas. In Scioto County it is best developed on Clinton Ridge in Vernon Township, where this ore was formerly mined in a small way for the charcoal furnaces. The bed extends along the ridge from Pine Creek to the Cadot Hill in Section 22. The Canary ore is also present at a few places near the summits of the main ridges in the eastern part of Green Township, but it was not observed in eastern Bloom as the horizon is taken by massive sandstones. The interval from the Canary ore to the Ferriferous limestone is shown in the following section, taken on Clinton Ridge near the head of Germany Hollow, in Section 26, Vernon Township:

	Ft.	*In.*
Limestone, *Ferriferous*	3	..
Clay and clay-bond sandstone	18	..
Clay shale, with scattered ore nodules	10	..
Ore, *Canary*	..	6

"The Canary is a concretionary ore of the carbonate variety, and is usually siliceous in character. It has no special value at present, although it contributed in a small way to the ore supply of the charcoal furnaces that operated in eastern Scioto County."

LAWRENCE COUNTY[1]

"The Canary ore lies at the base of the Clarion clay, and is found at only a few places in Lawrence County. It is a kidney ore of a yellowish color, and is low in iron. The bed was worked, to a small extent, by stripping, during the active period of the charcoal furnaces."

FERRIFEROUS ORE

INTRODUCTION

The Ferriferous ore, known by local names as Franklin, Baird, etc., but most commonly as Limestone ore, was the chief reliance for the 70 furnaces of the Hanging Rock Iron District. As defined by the iron masters, this area embraced the furnaces, furnace lands, and adjacent properties over which iron ore, limestone, and charcoal were gathered in a region of southern Ohio and northern Kentucky, particularly endowed by nature for the smelting of commercial iron. The region included parts of Carter, Boyd, and Greenup counties, Kentucky, and parts of Lawrence, Scioto, Gallia, Jackson, Vinton, and Hocking counties, Ohio. The area south of the Ohio River is roughly 510 square miles and that north of the stream 1,290 square miles.

North of Hocking County the Vanport limestone with the attendant ore are largely wanting or erratically developed to Mahoning County where the limestone appears again locally in force but seldom carries the

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, p. 316.

associated ore. The productive field for Ferriferous ore may thus be defined as southern Ohio in a narrow belt covering the outcrop of the Vanport limestone. The ore produced a high grade foundry iron suitable for the needs of that time. As the ore was mined mainly along the outcrop, large volumes still remain under deep covering in the hills. As this is one of the most important ore bodies in Ohio it will be described in a detailed way.

REGIONAL GEOLOGY

LAWRENCE COUNTY [1]

"The Vanport limestone and the Ferriferous ore have contributed much to the wealth of Lawrence County, and they bid fair to add materially to its revenue for many years to come. Early in the development of the State these rocks brought the Hanging Rock Iron District into prominence for its iron making as the 16 charcoal furnaces in this county drew all or a part of their supply of ore and flux stone from these members. Further, these beds have furnished, but to a more limited extent, a part of the burden for the 9 coal and coke furnaces that operated in the county.

Perry Township

"In the southern part of Perry Township the Vanport limestone and the Ferriferous ore pass below the bed of the Ohio River somewhere near the village of Sheridan. North of this a few small patches of limestone and ore are found along the lower course of Little Ice Creek and along Ice Creek east of the mouth of Sugar Creek. The limestone varies from 2 to 5 feet in thickness; while the ore on Ice and Sugar creeks is reported to measure from 4 inches to 1 foot.

Upper Township

"In Upper Township the Ferriferous limestone is very patchy and usually thin. The ore is somewhat more persistent than the limestone, but in the greater part of the area it is also replaced by sandstones. Near Coalgrove on the John Peters property the limestone is mined in a desultory way for road and other purposes. A general section of the rocks taken at this place and given below shows the relation of the limestone and ore to other beds:

	Ft.	*In.*
Ore, *Ferriferous*	..	6
Limestone, *Ferriferous*	5	..
Clay, siliceous, *Clarion*	8	..
Sandstone, ganister	8	..
Sandstone, *Clarion*	10	..

[1] Geol Survey Ohio, Fourth Series, Bull. 20, pp. 332-352.

"North of this along the lower course of Ice Creek the limestone and ore are somewhat steady. The Ironton Portland Cement Company used this limestone for several years in the manufacture of their product, but at present they use the Maxville which has great thickness and high purity. A. C. Steece reports that in this locality the Ferriferous ore varies from 6 inches to 1 foot 6 inches in thickness, and that the limestone measures from 4 to 6 feet. Along Sugar Creek south of the Marion Road the limestone and ore are normally developed. Near the road tunnel just north of Ironton a small outlying patch of these rocks is found, while along Storms Creek both beds are unsteady. The limestone is present in patches along the course of the stream in the northern part of the township, while the ore extends with some wants well towards its mouth. Much the same conditions as these are found along the course of Little Storms Creek, for both members are seldom present in force.

Hamilton Township

"The Ferriferous limestone is wanting in eastern Hamilton Township and in the western part it is represented more often by irregular masses of flint than by limestone. The ore, however, is somewhat more persistent than the limestone and has about normal volume. This bed varies in thickness from a few inches to 1 foot 6 inches, but in places it is admixed with irregular masses of flint.

Elizabeth Township

"As we pass from the river townships northward into Elizabeth, both the Ferriferous members are present in force and with the characteristic development for which they are noted, also in Jackson and Vinton counties. The beds extend in nearly an unbroken sheet over all the township except that part west of Pine Creek, and that part south of Little Pine Creek and west of Pine Grove Furnace, in which areas the members are marked only by isolated patches of ore and flinty limestone. About one mile north of Royer Station at the limestone mines of the Hanging Rock Iron Company, the following measurements were made under favorable conditions:

		Ft.	*In.*
Ore	*Ferriferous*	..	5
Ore, calcareous	*Ferriferous*	..	3
Limestone, *Ferriferous*		6	3

"In local areas in this vicinity the ore has exceptional volume as it expands to as much as 4 feet in thickness and appears to replace the entire bed of limestone. Analyses show that the ore is of exceptional quality also. In the vicinity of Pedro both limestone and ore are quite well developed, but in the extension of the members eastward to Storms Creek

the limestone in many places is flinty and thin, while the ore holds normal thickness. Where measured, the ore varied from 6 to 12 inches in thickness, but the limestone seldom exceeded 5 feet. Near Lawrence Furnace the limestone, where examined, was from 5 to 8 feet in thickness, while the ore was from 2 to 10 inches.

"One mile west of Lawrence Furnace, at the mines of W. R. Maxey, the limestone measured 7 feet 10 inches and the ore 8 inches. In this locality, also, two irregular layers of ore are present in the shale that overlies the regular deposit of Ferriferous ore. These upper beds each average about 5 inches in thickness. At the head of Darby Creek the rocks exposed measured as follows:

	Ft.	*In.*
Coal blossom, *Lower Kittanning*	3	..
Clay	5	..
Shale and covered	15	..
Limestone, *Ferriferous*	6	..
Clay, *Clarion*	7	..

"On Cannons Creek, east of Lawrence Furnace, the Ferriferous limestone is often flinty in character, but it has about normal volume. The ore varies in thickness from 1 inch to 1 foot. E. B. Willard mines the Ferriferous limestone by drifting near Bartles, where the following measurements were obtained:

	Ft.	*In.*
Ore, *Ferriferous*	..	8
Limestone, *Ferriferous*	6	..
Clay, *Clarion*	6	..

"Near Center Station both the Ferriferous members have good volume, and have been mined in a large way. The limestone is from 6 to 9 feet in thickness, while the ore varies from 4 to 12 inches. On the main ridge, south of Center Furnace, both members are generally present in force. In Elizabeth Township, west of Pine Creek, small patches of limestone and ore appear on the high knobs on the main ridge east of Irish Hollow.

Decatur Township

"The importance of the Ferriferous members in Decatur Township is attested by the fact that at least 6 charcoal furnaces drew all or a good part of their supply of ore and flux stone from the beds in this area. The volume and continuity of the members are excellent, and the direct association of the Clarion coal with them in the northern part of the township also increases their worth. The members will now be described in a more detailed way in order that the main features of these rocks may be rightly understood. At the mines of Michael Riley, near Center Station, the fol-

lowing record, which shows about normal volume of the members in this vicinity, was obtained in the mines:

	Ft.	In.
Sandstone	15	..
Ore, *Ferriferous*	..	10
Limestone, *Ferriferous*	8	6
Clay, plastic, *Clarion*	5	..

"In this locality the massive overlying sandstone forms an excellent roof for safety and ease in mining. These same general conditions also extend west of Center Furnace, where the following record was obtained at the mines of the Superior Portland Cement Company:

	Ft.	In.
Sandstone, massive	15	..
Shale	1	6
Ore, *Ferriferous*	..	7
Limestone, *Ferriferous*	7	..
Shale	..	8
Coal blossom, *Clarion*	..	1
Clay, *Clarion*	5	4

"In Branch Hollow, southwest of Moulton, the Ferriferous limestone is somewhat patchy, and varies in thickness, when present, from 3 to 7 feet. The ore is quite steady, and is reported by David McFann to be about 1 foot in thickness. Further, the condition of the beds near Moulton is somewhat the same, while along the pike, near the head of Pine Creek, the limestone measured 6 feet. Near the mouth of Painter Creek, north of Moulton, the following record was obtained:

	Ft.	In.
Ore, *Ferriferous*, reported thickness	..	10
Limestone, *Ferriferous*	7	..
Shale	..	2
Coal and partings, *Clarion*	3	8

"At the mines of the Buckhorn Coal Company, near the mouth of Nigger Creek, the ore, limestone, and underlying coal all have excellent volume. The record obtained follows:

	Ft.	In.
Ore, *Ferriferous*	..	10
Limestone, *Ferriferous*	7	..
Coal and partings, *Clarion*	3	10

"In Buckhorn Hollow the limestone is usually thin, while in places it is wanting. The ore is rather steady, and in local areas is reported to expand to 2 feet or even more. The mean measurement of the bed, however, is from 8 to 10 inches. Along Youngs Branch, and along Willow Run also, the general features of the members are much the same as they are in Buckhorn Hollow.

Symmes Township

"The Ferriferous members appear above drainage level in only one locality in Symmes Township, which is on Buffalo Creek, in the vicinity of the Rehmer School, where the following was measured:

	Ft.	*In.*
Ore, *Ferriferous*	..	4
Limestone, *Ferriferous*	5	9
Coal blossom, *Clarion*	..	3

Washington Township

"Activity in the mining of the materials from the Ferriferous horizon has been nearly continuous in Washington Township since the erection of Olive Furnace in 1833. At present the ore is not regularly mined, but the limestone is worked in a large way for road ballast and for furnace flux. The members extend entirely across the township, and with few exceptions have normal volume and quality. Along Olive Creek, east of Olive Furnace, the Ferriferous limestone has an average thickness of about 6 feet, while the ore is reported to measure about 8 inches. At Olive Station the following measurements were taken:

	Ft.	*In.*
Ore, *Ferriferous*	..	10
Limestone, *Ferriferous*	7	..
Shale	..	2
Coal and partings, *Clarion*	5	4

"In the first hollow west of the furnace stack the limestone measured 6 feet and the ore 4 inches, while on Brushy Fork the ore in places is replaced by a thick sandstone, but the limestone is present in force. On the main ridge north of this both members are rather steady, but the limestone is often flinty in character, and the ore replaced in restricted areas by the thick overlying sandstone. On Brady Creek, near the Town House, on the Ironton Road in Section 23, the beds have the following volumes:

	Ft.	*In.*
Ore, *Ferriferous*	..	6
Limestone, *Ferriferous*	6	..
Shale	..	3
Coal and partings, *Clarion*	5	5

"Other measurements taken west of this along Brady Creek show from 5 to 7 feet of limestone and from 1 to 10 inches of ore. In the central part of Section 16 the Bear Run Mining Company mines by drifting the Ferriferous limestone for flux stone at the Jackson furnaces,

and the Clarion coal for the general market. Measurements taken at the mine follow:

	Ft.	In.
Ore, *Ferriferous*	..	2
Limestone, *Ferriferous*	8	..
Shale	..	2
Coal and partings, *Clarion*	6	8

"Near the plant of the Portsmouth Refractories Company, in Section 10, the limestone measured 6 feet and the ore 6 inches. East of this, in Section 3, the measurements obtained follow:

	Ft.	In.
Ore, *Ferriferous*	..	4
Limestone, *Ferriferous*	7	3
Shale	..	3
Coal and partings, *Clarion*	3	9

"In Irish Hollow and along the headwaters of Black Fork Creek the Ferriferous members are very steady, and the limestone is mined for road ballast and flux stone. The bed varies from 4 to 9 feet in thickness; while the ore usually measures from 2 to 10 inches. A section taken near the plant of the Cambria Clay Products Company is given below:

	Ft.	In.
Ore, *Ferriferous*	..	4
Limestone, *Ferriferous*	9	..
Shale	..	1
Coal and partings, *Clarion*	4	..

Economic Value

"During the days of the charcoal furnaces the Ferriferous ore was the most important bed in Lawrence County, but owing to the influence of the Lake ores, and to the increased demands of the modern furnaces, it has gradually decreased in influence from that time, so that at present the member is an asset of small value. While the quality of the Ferriferous ore is inferior to the high-grade Lake ores, and while the stratum is thin and variable, yet its relation to the furnaces in this region is such that the bed is worthy of careful consideration. The ore lies directly above the Ferriferous limestone, which association is also of interest.

"The Ferriferous ore is a persistent deposit, but varies considerably in thickness in different localities. In the shale or clay above this deposit one or more layers of kidney ore occur in parts of the region. These are of the same general origin as the ore below, and consequently they are given as a part of the Ferriferous ore deposit. The section near Lawrence Furnace shows three rows of kidney ore which E. L. Lambert, who has had a very extended experience in the region, says will average

10 inches in thickness. At the mine of W. R. Maxey, west of Lawrence Furnace, two rows of these kidneys are found, but at the limestone mine of the Hanging Rock Iron Company, near Royer Station, only one layer is present.

"The Ferriferous ore was seen in 23 places in Lawrence County and the average thickness of the bed is 7 inches. On the whole, the bed is somewhat thicker than this, as some of the exposures noted were on the outcrop where the bed was thin and was worked but little during the days of the charcoal furnaces. Where the ore was heavy it was benched to deep cover, so that at present it is seldom seen under favorable conditions. The average thickness of the ore is reported by various parties who formerly mined it to be about 12 inches. The average thickness given in the chapter on Lawrence County in the Report of Progress for 1870 for 15 sections is 10½ inches, which is probably near the true thickness. In places the ore is very thin, only an inch or two being present, while in a few localities it expands to 3 or 4 feet over small areas.

"The ore is of swamp origin. It was deposited in quiet waters heavily charged with carbon dioxide, which precipitated the soluble ferrous salts brought in as ferrous carbonate. Under heavy cover the ore still exists as the carbonate, but along the outcrop or under light cover it has been oxidized more or less to ferric hydrates. The specific gravity of the limonite ore will average about 2.9; while that of the carbonate will run close to 3.5. Considering the ore 10 inches thick and 60 per cent available, the yield per acre will be 1,974 net tons for the limonite and 2,382 net tons for the carbonate. For the charcoal furnaces the ore was mined mainly along the outcrop by stripping. Some small entries were worked, but these extended only short distances under cover. Carbonate ores were difficult to smelt in the short stack charcoal furnaces, so that only the oxidized or limonite ores were desired. Consequently the main body of ore is scarcely touched as the deposit was followed only along the outcrop.

"This deposit is generally too thin to be worked for the ore alone with any economy. Too much material must be removed for entry ways in order to get sufficient height. Ordinarily the roof is shale or clay, either of which is hard to hold. Where the deposit will average 15 inches or more in thickness, and where the roof is of good quality, it may be mined advantageously. If the associated materials have a value, then the ore may be mined with these. The ore and limestone are worked together in a few places. In some cases the clay above is of excellent quality and it may be mined with the ore. At the present price of Lake ores, this deposit can be mined only in a secondary way, except in local areas where it is well above the normal thickness.

"The quality of the Ferriferous ore varies between rather wide limits,

yet the average composition compares favorably with that of the low grade Lake ores. The analyses given on Table II are instructive.

"These analyses show the general quality of the ore. It is non-bessemer and best suited for foundry, but it can be used to good advantage in making either basic or malleable iron.[1]

No. 1. Roasted ore from Pine Grove Furnace. Analysis furnished by the Hanging Rock Iron Company.
No. 2. Red ore from Etna Furnace. Analysis furnished by Mr. Wm. H. McGugin.
No. 3. Red ore from Etna Furnace. Analysis furnished by Mr. Wm. H. McGugin.
No. 4. Gray ore from Etna Furnace. Analysis furnished by Mr. Wm. H. McGugin.
No. 5. Gray ore from near Gallia Furnace. Analysis furnished by Mr. Wm. H. McGugin.
No. 6. Gray ore from near Howard Furnace. Analysis furnished by Mr. Wm. H. McGugin.
No. 7. Red ore from near Washington Furnace. Analysis furnished by Mr. Wm. H. McGugin.
No. 8. Red ore from near Center Furnace. Analyst, Mr. W. M. Barnett.
No. 9. Red ore from River Hills. Analyst, Mr. W. M. Barnett.
No. 10. Red ore from River Hills. Analyst, Mr. W. M. Barnett.
No. 11. Blue limestone ore, Washington Furnace. Report of Progress for 1870, Geological Survey of Ohio, pp. 182-3.
No. 12. Brown limestone ore, Washington Furnace. Report of Progress for 1870, Geological Survey of Ohio, pp. 182-3.
No. 13. Blue limestone ore, Cambria Furnace. Report of Progress for 1870, Geological Survey of Ohio, pp. 184-5.
No. 14. Limestone ore, Vesuvius Furnace. Report of Progress for 1870, Geological Survey of Ohio, p. 193.
No. 15. Gray limestone ore, Vesuvius Furnace. Report of Progress for 1870, Geological Survey of Ohio, p. 193.
No. 16. Calcined limestone ore, reported by Mr. E. B. Willard.
No. 17. Calcined limestone ore from Pine Grove Furnace, reported by Mr. E. B. Willard.

Ore Comparisons

"In the comparison of the value of the Ferriferous or native and the Lake ores, the following items are used:[2]

[1]See Table II.
[2]See Table III

Analyses from Various Sources of Ferriferous Ore TABLE II

Number.	Iron, Fe.	Siliceous matter, SiO_2.	Alumina, Al_2O_3.	Phosphorus, P.	Lime, CaO.	Magnesia, MgO.	Sulphur, S.	Manganese, Mn.	Ignition loss.	Water combined, H_2O.	Water hydroscopic, H_2O.	Manganese dioxide, MnO_2.	Phosphoric acid, P_2O_5.	Iron carbonate, $FeCO_3$.	Iron sesquioxide, Fe_2O_3.	Lime phosphate, $C_4P_2O_9$	Lime carbonate, $CaCO_3$	Magnesium carbonate, $MgCO_3$.	Specific gravity.
1	45.50	24.20	6.50	.155	1.50	.55	.580	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	54.81	7.27	.....	.108	trace.	.....	.063	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	47.90	6.25	.....	.116	.71	.....	.172	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	40.88	5.00	.....	.232	7.00	.....	.282	1.49	21.95	.....	4.00	.....	.....	.....	.....	.....	.....	.....	.....
5	30.26	22.24	1.69	.430	2.95	1.19	.79	.75	26.28	2.63	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	31.65	22.45	1.91	.740	2.77	1.08	.48	.83	26.22	1.72	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	47.81	7.00	1.32	.980	1.23	.....	.097	trace.	21.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	35.57	9.76	2.20	.260	5.15	.....	.....	.76	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	36.76	12.28	2.78	.120	5.65	.....	.....	.46	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	35.20	7.66	7.38	.176	14.74	.....	.....	.41	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	38.91	15.42	.75	.....	.....	.....	.12	.....	.....	1.10	.....	1.55	.38	63.27	7.20	.87	5.40	3.44	3.585
12	44.14	.62	3.03	.....	.....	.....	.95	.....	.....	.....	.....	3.10	.57	58.39	22.79	1.24	6.00	3.12	3.125
13	41.89	7.52	.51	.....	.....	.....	.15	.....	.....	.....	.....	.13	.35	68.44	13.51	.76	6.12	2.11	3.583
14	54.39	2.00	.....	.....	3.67	.....	trace	.....	.....	5.60	.....	1.90	.....	.....	77.70	.....	9.09	trace.	3.066
15	36.81	26.32	.60	.....	.....	.....	trace	.....	.....	.....	.....	1.05	trace.	40.91	24.37	.....	4.20	2.65	3.439
16	50.20	9.58	6.53	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
17	41.81	23.74	3.67	.155	5.53	.....	.784	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Amount of ore smelted per day, 540 tons.

Ratio by volume of $\frac{CO}{CO_2} = 1.8$ which is obtained with good practice.

Slag ratio $\frac{\text{bases}}{\text{acids}} = 1.$

Pocahontas coke used for smelting and a standard limestone for flux.

"The figures for value of coke and stone delivered at Ironton, and for the over and above cost used, are those supplied by Col. H. A. Marting.

Over and above cost per ton 2,240 lbs. of ore smelted	$1.00
Coke, per ton of 2,000 lbs.	2.85
Stone, per ton, 2,240 lbs.	.85
Freight per ton ore, 2,240 lbs., from Lake	.90

The Hanging Rock Iron Company reports the following costs:

Cost of limestone per gross ton, 2,240 lbs., at furnace	.85
Average cost of coke per net ton, 2,000 lbs. at furnace	3.05
Freight on Lake ore per gross ton, 2,240 lbs., at furnace	.90
Over and above cost per ton ore, 2,240 lbs.	1.0936
Cost of limestone ore per gross ton, 2,240 lbs. at furnace	1.92
Price of Hanna No. 1 ore used in comparison quoted by M. A. Hanna & Co. for season of 1913, delivered at Ironton per ton	$4.04

Prices of Negaunee and Clinton silica ores quoted by the Cleveland-Cliffs Iron Company, delivered at Lower Lake ports are $3.57 per ton for the former and $2.22 for the latter.

Cost of Negaunee ore at Ironton would be $4.47 per ton.

Cost of Clinton silica ore at Ironton would be $3.12 per ton.

The price of Adriatic ore quoted by Pickands, Mather & Co., delivered to Lower Lake ports is $3.28, which at Ironton, Ohio, would be $4.18 per ton.

It has been the common practice in southern Ohio not only to calcine the carbonate ores, but also the limonite or hydrate types. Where the ore is charged raw into the furnace the heat units used are as follows:

$Fe_2O_3\ 3H_2O + (214x4 = 856 \text{ calories}) = Fe_2O_3 + 3H_2O.$

$3H_2O + (54x592 = 31{,}964 \text{ calories}) = H_2O$ as gas.

$54x200x.457 = 4{,}936$ calories = specific heat carried out by gases at 200° C.

Total = 37,756 calories.

This is $\frac{37756}{214} = 176$ calories per unit of ore.

1 unit carbon gives 2,430 calories.

Description of ore.	Analyses of ore in natural state in per cent.										Result of smelting 100 pounds ore in the blast furnace on basis of									
	Iron.	Silica.	Alumina.	Lime.	Magnesia	Phosphorus.	Manganese.	Sulphur.	Ignition loss.	Hydroscopic water.	Gases produced in pounds	Gases produced in cubic feet at 200° C.	Air required for smelting in pounds.	Air required for smelting in cubic feet at 20° C.	Pig iron produced in pounds.	Slag produced in pounds.	Stone required for fluxing in pounds.	Coke required for smelting in pounds.	Ore used in pounds.	Coke required per 2268 pounds iron produced.
No. 1. Ferriferous, carbonate	37.96	4.76	3.22	3.96	.36	.220	.60	.....	28.88	3.32	266.35	5,492.05	178.91	2,380.94	41.343	16.50	6.39	39.10	100	2,145
No. 2. Ferriferous, limonite	48.25	4.42	3.76	.71	tr.	.260	1.11	.....	8.52	11.31	256.19	5,533.36	172.24	2,292.19	52.646	16.46	12.51	40.81	100	1,758
No. 3. Ferriferous, limonite	37.80	19.64	3.04	2.70	.29	.136	.64	.....	13.52	4.39	283.04	6,023.86	193.28	2,572.24	41.262	48.12	38.49	42.06	100	2,312
No. 4. Ferriferous, carbonate, gray	34.95	7.63	2.17	8.60	1.99	.182	.85	.68	24.10	3.20	243.12	5,020.73	166.49	2,215.65	38.184	21.30	Excess .36	36.68	100	2,179
No. 5. Ferriferous, limonite	42.79	12.97	3.13	3.84	.14	.207	.73	.44	8.49	7.68	269.31	5,717.71	184.32	2,452.90	46.640	34.42	24.18	42.14	100	2,049
No. 6. Adriatic, Lake ore	50.00	10.02	1.98	.33	.19	.0672	.247	.....	4.01	11.50	271.20	5,773.18	185.12	2,463.60	53.969	24.71	21.60	43.42	100	1,825
No. 7. Negaunee Lake ore	51.14	7.91	2.04	.67	.15	.081	.21	.....	3.50	12.15	265.89	5,664.52	181.50	2,415.36	55.157	20.27	17.09	42.99	100	1,768
No. 8. Hanna No. 1, Lake ore	48.85	5.06	3.38	.25	.18	.073	.98	.....	4.81	14.81	261.56	5,634.55	176.05	2,342.31	53.350	17.13	14.52	41.80	100	1,777
No. 9. Clinton Silica, Lake ore	45.24	17.24	1.78	.20	.16	.074	.20	.....	2.80	12.70	292.86	6,219.87	200.83	2,672.67	48.898	40.30	36.60	44.94	100	2,084

[1] Based on costs furnished by Col. H. A. Marting.

[2] Based on costs furnished by Hanging Rock Iron Company.

TABLE III

smelting 540 gross tons per day.							Costs per ton 2240 pounds ore. Basis smelting 540 gross tons per day.[1]								Costs per ton 2240 pounds ore. Basis smelting 540 gross tons per day.[2]					
Gases in cubic feet at 200° C. per pound coke used.	Air in cubic feet at 20° C. per pound coke used.	Analyses of gases by volume					Over and above cost per ton 2240 pounds ore smelted.	Cost of ore per ton 2240 pounds at Ironton, Ohio.	Cost of stone for flux at 85 cents per ton 2240 pounds.	Cost of coke for smelting at $2.85 per ton 2000 pounds.	Total cost of smelting one ton 2240 pounds ore.	Cost per unit iron shown by analyses.	Cost per unit pig iron produced in smelting.	Cost per ton 2268 pounds pig iron produced.	Comparative value of ores, using cost of Hanna No. 1 as basis on pig iron produced in smelting.	Over and above cost per ton 2240 pounds ore smelted.	Cost of ore per ton 2240 pounds at Ironton, Ohio.	Cost of stone for flux at 85 cents per ton 2240 pounds.	Cost of coke for smelting at $3.05 per ton 2000 pounds.	Total cost of smelting one ton 2240 pounds ore.	Cost per ton 2268 pounds pig iron produced.	Comparative value of ores, using cost of Hanna No. 1 as basis on pig iron produced in smelting.
		Water.	Carbon dioxide	Carbon monoxide.	Nitrogen.	Ratio $\frac{CO}{CO_2}$															
140	61	4.02	14.71	26.49	54.78	1.8	$1.00	$1.92	$0.0543	$1.2481	$4.2224	$0.111233	$0.102131	$10.34	$2.73	$1.0936	$1.92	$0.0543	$1.3357	$4.4036	$10.78	2.70
136	56	13.55	12.18	21.13	52.34	1.8	1.00	1.92	.1063	1.3027	4.3290	.089720	.082229	8.33	4.00	1.0936	1.92	.1063	1.3941	4.5140	8.68	4.00
143	61	10.26	12.78	23.01	53.95	1.8	1.00	1.92	.3272	1.3426	4.5898	.121423	.111236	11.26	2.36	1.0936	1.92	.3272	1.4368	4.7776	11.72	2.31
									Credit									Credit				
137	60	3.95	14.39	25.89	55.77	1.8	1.00	1.92	.0031	1.1708	4.0877	116959	.107053	10.84	2.48	1.0936	1.92	.0031	1.2530	**4.2635**	11.31	2.44
136	58	9.72	12.88	23.19	54.21	1.8	1.00	1.92	.2055	1.3451	4.4706	.104478	.095853	9.71	3.13	1.0936	1.92	.2055	1.4395	**4.6586**	10.11	3.11
133	57	10.30	12.80	23.00	53.90	1.8	1.00	4.18	.1836	1.3860	6.7496	.134992	.125064	12.66	4.00	1.0936	4.18	.1836	1.4832	6.9404	13.02	4.00
132	56	10.47	12.73	22.91	53.89	1.8	1.00	4.47	.1453	1.3722	6.9875	.136635	**.126684**	12.83	4.20	1.0936	4.47	.1453	1.4685	7.1774	13.18	4.20
135	56	13.06	12.34	22.21	52.39	1.8	1.00	4.04	.1234	1.3343	6.4977	.133013	.121794	12.33	4.04	1.0936	4.04	.1234	1.4279	6.6849	12.69	4.04
138	59	9.75	12.84	23.11	54.30	1.8	1.00	3.12	.3111	1.4345	5.8656	.129655	.119956	12.15	3.21	1.0936	3.12	.3111	1.5352	6.0599	12.55	3.19

The gases produced in combustion carry out at 200° C.

$$\frac{7}{3} \text{ units CO} = \frac{7}{3} \times 200 \times .3084 = 144 \text{ calories.}$$

$$\frac{307.6}{69.3} \text{ units } N_2 = \frac{307.6}{69.3} \times 200 \times .2488 = \frac{217}{361} \text{ calories.}$$

So from combustion of 1 unit carbon the available heat units are 2430—361 = 2069 calories. This means if the ore is charged raw an addition of $\frac{176}{2069}$ or .085 units of carbon are required.

Considering coke 90 per cent carbon the requirement for roasting 2,000 pounds of ore, radiation losses neglected, is 189 pounds.

Where calcined in kilns with carbon for fuel, and if burned with perfect economy, the results are as follows:

Total requirement for expulsion of water same as before, 37,756 calories or 176 calories per unit of ore.

1 unit carbon gives 8,100 calories.

The gases produced in combustion carry out at 200° C.

$$\frac{11}{3} \text{ units } CO_2 = \frac{11}{3} \times 200 \times .414 = 304 \text{ calories.}$$

$$\frac{615.2}{69.3} \text{ units } N_2 = \frac{615.2}{69.3} \times 200 \times .2448 = \frac{434}{738} \text{ calories.}$$

Available heat then is 8100—738 calories = 7362 calories. The fuel requirement is $\frac{176}{7362}$ or .024 units carbon per unit ore.

Considering the fuel 90 per cent carbon, the requirement for roasting 2,000 pounds of ore is 53 pounds. Radiation losses are not considered in the above, and the loss of heat due to air excess is neglected. The difference in fuel between calcining in the furnace, and in special kilns, is thus only 136 pounds per ton of ore. This saving is far overbalanced in loss of material, labor, etc., during calcination.

The common practice with furnace operators at present is to carry an 8 per cent water burden. This means 8 per cent of the total weight of the stock is water. The main reason is to keep the top of the furnace cool, which holds the reduction zone in the proper position. The water carries out the heat from the top of the furnace, thus keeping down the temperature. It is not important whether this is the hydroscopic or combined water from the stock. When dry stock is charged this zone is too near the top, which results in abnormal working of the furnace. So raw ore should give better results than the calcined. W. M. Jefferys, superintendent of The Hanging Rock Iron Company, reports:

'The ore located on our property in Lawrence County is what we

usually term limestone ore. It is found in two grades, the red and the gray. In former years this ore was calcined before using it in the furnace, but for the past year the Hanging Rock Iron Company has abandoned this method of treatment and is now using the ore in the natural state, and the results from same are excellent.'

The calcined ore is less firmly bonded than the raw ore. It is fragile, consequently considerable ore is lost in the form of dust, owing to the extra handling involved in calcination. The cost of preparing the ore for roasting either in piles or kilns must be considered, and also the interest on the money invested. Considering the points both for and against calcination, the latter outweigh the former. The best economy is obtained by using the ore in the natural state.

SCIOTO COUNTY [1]

"The Ferriferous ore, Vanport or Ferriferous limestone, and Clarion coal and clay, of the Allegheny formation are poorly represented in Scioto County, as they are found only on the high knobs and ridges in the eastern parts of Bloom, Vernon, and Green townships. The Vanport or Ferriferous limestone, which extends with some wants across eastern Scioto County from Jackson County on the north to the Ohio River on the south, is generally thin and often flinty. However, in local areas in northern Bloom Township, this member is present in force. The Ferriferous ore has better continuity, and has about the same volume throughout its extent. As these members are so closely associated, general sections showing their stratigraphy and extent will be given instead of considering each bed separately.

Bloom Township

"The Clarion coal and the Ferriferous ore and limestone in Bloom Township are confined to small areas on the main ridges in sections 1, 5, 6, 7, 8, 19, 20, 25, 29, 30, 31, 32, 36, and sections 5 and 6 south. The most important area is that west of Eifort where the members all have normal volume. The strata exposed at the mines of Morgan & Horton, west of Eifort, in Section 5, show about the average thicknesses and relations of the various members when normally developed. The measurements follow:

		Ft.	*In.*
Ore, Ferriferous		..	5
Limestone, *Ferriferous*		8	..
Shale, draw slate		..	4
Coal	*Clarion*	1	..
Clay	*Clarion*	..	4
Coal	*Clarion*	1	7
Clay, impure	*Clarion*	..	1
Coal	*Clarion*	..	5
Clay		2	..

[1] Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 590-593.

"The structure of the deposits in sections 1 and 6 is practically the same as the above. The small pockets of limestone and coal on this horizon, found in the high knobs in the southeastern part of Bloom Township, have been worked to a small extent, but the strata were not favorably exposed for measurement. The Clarion coal, however, in most of this area is thin or decayed, while the limestone is usually very flinty in character.

Vernon Township

"In Vernon Township the Ferriferous limestone with its associated ore, and the Clarion coal and clay are found on all the high ridges east of Pine Creek, but west of this stream the beds are present only along the main hill and spurs of what is known as Clinton Ridge as far west as the western part of Section 22. The Clarion coal is not well developed, however, in the areas south of Howard Run and east of Pine Creek, or in those on Clinton Ridge, while the Ferriferous limestone thins or becomes patchy in its extension southward and westward. The Ferriferous ore is far more persistent than the limestone, but it is often completely replaced by massive sandstone. The beds have only local value. In Section 1 the Clarion coal, which is mined for local use, and the Ferriferous limestone and ore have about their normal volume. The following record was obtained from an outcrop exposure:

	Ft.	*In.*
Ore, *Ferriferous*	..	4
Limestone, *Ferriferous*	8	..
Coal, *Clarion*, on outcrop	3	..

"On Clinton Ridge the Ferriferous limestone is stated to vary from 2 to 7 feet in thickness, while the Clarion coal is reported to be of no value, as it is thin and rotten. The Ferriferous ore is quite steady, and was formerly mined along the entire ridge. The thickness of the ore varies from a few inches to about 1 foot. The Clarion clay has good volume but is siliceous in character.

Green Township

"In Green Township the horizon of the Clarion coal, Clarion clay, Ferriferous limestone, and Ferriferous ore extends westward on the main ridge to about one mile west of Ohio Furnace. The Clarion coal is marked only by a smut streak, but the Clarion clay, although quite siliceous in character, is from 2 to 5 feet in thickness. The Ferriferous limestone is traced by scattered lenses of flinty or cherty material. The most constant of these members by far is the Ferriferous ore, which varies in thickness from 3 inches to about 1 foot 6 inches, and which was mined by stripping along its entire outcrop during the days of the charcoal furnaces.

Economic Value

"The Ferriferous ore was highly prized by the charcoal furnace operators, as it gave a good yield and as it made foundry iron of the very best quality. The most successful furnaces were those in this ore belt. The area of ore in Scioto County is small as the bed is confined to isolated tracts near the summits of the hills and ridges in the eastern parts of Bloom, Vernon, and Green townships. The quality of the ore has been fully described in the report on Lawrence County; hence the subject will not be considered here."

GALLIA COUNTY[1]

"The Ferriferous ore was the most important bed of rock in southern Ohio during the palmy days of the charcoal furnaces, for it was along the outcrop of this ore that the industry flourished best. It was the main reliance of the furnaces, and, when these ran, times were good, for work was plentiful and brought a fair reward, and trade was active, for the farmer and merchant found a ready market for their products. The iron produced commanded the highest market prices, for its excellence was known far and wide; hence fair returns on the money invested were realized by the stockholders. To the Ferriferous ore, then, much of the early activity and wealth of the area must be credited. Since this time, the importance of the Ferriferous ore has diminished, until at present it can be considered an asset of only small importance, for these furnaces, with one exception, are known only by abandoned stacks or by heaps of cinders.

"The Ferriferous ore lies directly above the Ferriferous or Vanport limestone. Usually the ore and limestone are separated by a thin parting, but in some localities the two beds have so coalesced that no line of demarcation is recognized. The thickness of the deposit is variable. Where observed in Gallia County the measurements show from 1 inch to 1 foot, but in restricted areas it is reported to have a thickness of 2 feet. On the outcrop the ore has a decidedly concretionary or blocky structure, but under heavy cover this is not so apparent. The iron was laid down as ferrous carbonate with a small amount of admixed argillaceous and calcareous ingredients. Along the outcrop or under shallow cover the ferrous carbonate has weathered to the hydrated ferric oxides. It is then classed as a limonite ore.

Greenfield Township

"The Ferriferous ore is found along Lefthand Fork, in Section 7, Greenfield Township. Here, as it was mined by stripping for use at Cambria Furnace, during its active period, the ore is not well exposed for

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 615-617.

measurement, but is reported to vary from 3 to 12 inches in thickness. The ore has good volume evidently in Kokeene Hollow, since it has been benched to deep cover. Wesley Clarkson states that, while the deposit varies in thickness from a few inches to 2 feet, the average measurement is from 6 to 10 inches. The thickness of the ore conforms in a measure to the irregularities of the upper surface of the limestone below, because, where there is a low depression in the limestone the ore is quite thick, and conversely, on the most elevated portions, it is thin. The thick deposits of ore are, with few exceptions, local. In Pokepatch Hollow the best deposits of ore are reported to have a thickness of about 1 foot. The ore is thin and flinty where it appears at the surface of Dirtyface Creek, in Section 29, Greenfield Township. In the mine of N. A. Wood, at Gallia, the Ferriferous ore is well exposed, and its thickness is probably typical of the entire locality. The thickness varies from a mere stain to 8 inches, but the average measurement is about 3 inches. North of Gallia, where exposed in the cut of the Cincinnati, Hamilton & Dayton Railway, the ore measures 5 inches. At the abandoned Black Diamond mine, in Section 9, Greenfield Township, the ore is again well exposed in the prospect mine, found near the base of the hill:

	Ft.	*In.*
Ore, *Ferriferous*	..	10
Limestone *Ferriferous*	3	..

Huntington Township

"The Ferriferous ore is found above drainage in one locality only, in Huntington Township, which is along Little Raccoon Creek, in sections 7 and 18. Because the bed was mined by stripping for use at Keystone Furnace, outcrop exposures were seldom seen, but from a few observations and reports, the thickness of the ore is estimated to vary from a few inches to 1 foot. No information is at hand in regard to the thickness and character of the Ferriferous ore under heavy cover.

Economic Value

"The economic value of the Ferriferous ore at present is small, for the great ore beds of the Northwest now supply at a low cost the necessary demands of the iron industry. The bed is too thin to be mined for the ore alone, but it has a fair value as a secondary product when mined with the limestone below. Under heavy cover the iron present is in the form of ferrous carbonate, hence the ore must be classed as a siderite, but along the outcrop and under shallow cover this compound has been oxidized to the hydrated ferric oxides, so the ore here belongs to the limonite class. The charcoal furnaces were able to smelt successfully the oxidized ores only, consequently mining was confined mainly to stripping, and hence the great bodies of ore in the hills are yet untouched. The quality of this

native ore compares favorably with that of the siliceous grades of Lake ores now on the market. The Ferriferous ore in the natural state carries from 30 to 55 per cent iron, from .10 to .35 per cent metallic phosphorus, and from .40 to 1.25 per cent manganese. It also contains small amounts of lime and magnesia, which therefore decrease the necessary addition of flux stone and promote early fusion of the slag. Thus its composition is such that it requires no mixing with other ores to produce, on smelting, foundry iron of the best quality. The ore has a high content of hydroscopic water and of volatile matter, which when expelled by heat leave the structure open or porous, a condition very favorable for ease of reduction by furnace gases. Owing largely to its physical condition, the Ferriferous ore was readily reduced in the short stacks of the charcoal furnaces while the Lake ores, which are more compact, were smelted with difficulty. The operators of today say the ore works well in the coke furnaces, but they complain that the amounts readily available are too small to form a regular part of the burden. The worth of the bed to future generations can not be predicted, but its value to the country during the days of the charcoal furnaces will scarcely be surpassed.

JACKSON COUNTY[1]

"The next members of value in the ascending scale are the Ferriferous or Vanport limestone, and the Ferriferous or Baird ore. They are directly associated, seldom more than a bedding plane or an inch or two of shale separating the two. The Ferriferous ore was the main reliance of the old charcoal furnaces, and is used at present [1916] by Jefferson Furnace, the only charcoal stack in the state in blast. The Ferriferous limestone was the principal source of flux stone for the charcoal furnaces, and is used some at present by the modern furnaces in the region. The history of the iron industry in the Hanging Rock District, both past and present, is interwoven with descriptions or references to these members. The Ferriferous limestone and the Ferriferous ore are found in a very small area in Hamilton Township, but they extend along the main ridges over most of Jefferson Township. The areas in which the members are present in the eastern parts of Franklin, Lick, and Coal townships are also very small. These beds are represented in force, however, in Madison, Bloomfield, and Milton townships. The following pages give a more detailed description of the areas, but contain only a few records, as many measurements in which the thickness of the beds are shown have already been given.

Hamilton Township

"The Ferriferous limestone and ore are found in Hamilton Township only in Section 36, where the beds are exposed near the summit of the

[1]Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 217-227.

main ridge in the extreme southeastern part. The limestone, which is from 5 to 7 feet in thickness, is generally flinty in character.

Jefferson Township

"In Jefferson Township the limestone and ore are present in 24 of the 36 sections, being absent in 8 sections in the northwestern part. These members are found near the summits of the main ridge and spurs running northeast from Section 31 to Jefferson Furnace, in Section 14. In the eastern part of the township the horizon lies about halfway up the hills, thus increasing the area of the deposits. At the mines of the Washington Coal Company near Monroe, the limestone has good thickness, but the ore is reported generally thin. The section taken at the mine follows:

		Ft.	In.
Ore, *Ferriferous*		..	3
Limestone, *Ferriferous*		7	..
Shale		..	4
Coal	*Clarion*	1	..
Clay		..	5
Coal		1	6
Clay, sulphur band		..	1
Coal		..	6

"On land of the Diamond Brick Company, Section 25, the strata measured as follows:

	Ft.	In.
Ore, *Ferriferous*	..	4
Limestone, *Ferriferous*	7	..
Coal and partings, *Clarion*	4	9

"On the land of the Jefferson Iron Company near Mt. Horeb Church, in Section 15, the ore is being mined for furnace use. The section taken follows:

	Ft.	In.
Ore, *Ferriferous*	..	10
Limestone, *Ferriferous*	5	..
Coal blossom, *Clarion*	3	..

Madison Township

"The Ferriferous limestone and ore are found well above drainage in the western part of Madison Township, but owing to the dip eastward they pass under cover near the central part. As no drill records are available the condition of the members in the covered area embracing Sections 1, 2, 11, 12, 13, 14, 23, 24, 25, 26, 27, 28, 33, 34, 35, 36 and Sections 1, 2, and 3 south are not definitely known, but both beds are somewhat steady

where they disappear below cover. In Section 6, on the land of Margaret Evans, the following rocks were measured:

	Ft.	In.
Ore, *Ferriferous*, reported thickness	..	3
Limestone, *Ferriferous*	6	..
Coal and partings, *Clarion*	3	4

"In the northwestern part of the township, in small areas, both the limestone and ore are wanting, while at other places only the ore is present. This condition, where the limestone is absent, but the ore considerably thickened, is shown in the following section, taken on land of F. H. Quick, near the center of Section 7:

	Ft.	In.
Ore, *Ferriferous*	1	6
Coal, *Clarion*, reported thickness	2	6

"In the northern part of the section on the same property the ore measured only 3 inches, while the limestone had a normal development. Near Madison Furnace, in Section 5, the thickness of the limestone is 7 feet, and of the ore 10 inches. The Ferriferous limestone and ore are usually present, but are often flinty in character in sections 3 and 4. The thickness of the limestone observed along the outcrop is from 5 to 7 feet, while that of the ore is from 2 to 10 inches. These conditions also hold true in sections 9 and 10. On the average the beds are somewhat thicker in sections 16, 17, and 18, but locally the limestone may be flinty in character. The following measurements illustrating the members when in good volume were taken along the road east of Moriah Church, in Section 16:

	Ft.	In.
Ore, *Ferriferous*	..	4
Limestone, *Ferriferous*, part flinty	10	..
Coal and partings, *Clarion*	4	..

"In the western part of Section 19, on the land of Arizona E. and Myrta L. Evans, the kidney ore in the shales above the Ferriferous ore was noted. This ore is found in many places in Lawrence County, but it was seldom observed in Jackson County. The section which follows shows its position:

	Ft.	In.
Ore, *Kidney*	..	4
Shale	3	..
Ore, *Ferriferous*	..	10
Flint / Limestone } *Ferriferous*	..	10
	5	..

"The usual thickness of the Ferriferous limestone, where observed in sections 20, 21, and 22, is from 5 to 7 feet, but in some localities it is

flinty, while in restricted areas it is wanting. The thickness of the ore where exposed for measurement was from 3 to 10 inches. Both limestone and ore are quite steady in sections 31, 32, and sections 4, 5, and 6 south.

Franklin Township

"The Ferriferous limestone and ore in Franklin Township are found only near the summits of the high ridges and hills east of the Franklin Valley. In the southern part of this territory they are found in sections 23, 24, 25, 26, 35, and 36. On the property of Albert Evans, in Section 36, the limestone exposed on the outcrop measured as given below:

	Ft.	*In.*
Limestone, *Ferriferous,* somewhat weathered, very flinty	3	..
Clay shale, soft	2	..
Coal and partings, *Clarion*	4	..

"On the property of James A. Hensen, in Section 23, the exposure of limestone and ore was measured with the following results:

	Ft.	*In.*
Ore, *Ferriferous*	..	5
Limestone, *Ferriferous*	7	..
Coal and partings, *Clarion*	4	..

"A small area of flinty limestone was found near the summit of the ridge in the southern part of Section 2, but no measurements were made In Section 1 small patches of limestone and ore were found, but the members are unsteady, as they are partially replaced by heavy sandstones.

Bloomfield Township

"The Ferriferous limestone and ore are well represented in Bloomfield Township, where the latter was formerly extensively worked for the charcoal furnaces. In the western part of the township the beds are found near the 800 foot contour. In the southern part they dip below drainage along the headwaters of the eastern tributaries of Symmes Creek, but in the northern part they disappear along the course of Little Raccoon Creek south of old Keystone Furnace. A few sections showing the thickness of the limestone and ore, measured where best exposed along the outcrop, will be given. A record obtained at old Limestone Furnace, in Section 32, is given below:

	Ft.	*In.*
Ore, *Ferriferous,* formerly mined, not seen.		
Limestone, *Ferriferous*	7	..
Coal, Clarion	4	4

"In Section 29 the Ferriferous limestone and ore have good volume. The general thickness of the limestone is from 5 to 8 feet, while that of the ore is from 2 to 10 inches. These members pass below drainage in the

western parts of sections 28 and 33, and in the northern part of Section 27. They are completely covered in sections 24, 25, 26, 34, 35, and 36. The following record obtained on the land of the Southern Ohio Portland Cement Company, in Section 20, shows the character of the beds in this locality:

	Ft.	In.
Ore, *Ferriferous*	1	..
Limestone, *Ferriferous*	7	..
Coal and partings, *Clarion*	4	5

"In this locality the ore has excellent volume in restricted areas as it thickens to 2 feet 6 inches. In sections 16, 17, 21, and 22, the limestone is from 6 to 8 feet in thickness, and is quite persistent. The ore usually measures from 2 to 8 inches, but it often exceeds this. The rocks noted on the land of Taylor Munyon shows good development of the limestone and ore. The record follows:

	Ft.	In.
Ore, *Ferriferous*	..	4
Limestone, *Ferriferous*	7	..
Shale	..	4
Coal and partings, *Clarion*	4	10

"In sections 13, 14, and 23, the Ferriferous limestone and ore are rather unsteady, although both are well developed in local areas.

"Only small pockets of limestone and ore are found on the highest knobs in sections 30, 19, 18, 7, and 6, and in sections 5 and 8 the areas are not large, and, where exposed, the limestone is usually somewhat flinty. The members are thin or wanting in parts of Section 4, but have medium thickness in Section 9. On land of Anna Dillinger, in Section 3, the rocks exposed gave the following measurements:

	Ft.	In.
Ore, *Ferriferous*	..	5
Limestone, *Ferriferous*	7	..
Shale	..	2
Coal and partings, *Clarion*	4	4

"On land of the Superior Colliery Company, in the same section, the limestone on the outcrop measured 7 feet in thickness, and under heavy cover it is reported to reach 10 feet, while the ore varies from an inch or two to over 1 foot, but it has an average measurement of about 6 inches. The heavy sandstone above replaces both ore and limestone in parts of sections 2 and 11, but, when present, the members have about the normal development. A section taken on land of W. L. Perkins, Jr., in Section 11, is given below:

	Ft.	In.
Ore, *Ferriferous*	..	4
Limestone, *Ferriferous*	6	6
Shale	..	6
Coal blossom, *Clarion*	4	..

"In sections 1 and 12 the limestone and ore are quite unsteady. At many places they are completely wanting, while in some localities the coal below has also been replaced by sandstone.

Lick Township

"The Ferriferous ore and limestone in Lick Township are confined to the high hills and ridges in the eastern part. The areas are generally small. Owing to shallow cover in much of the area the limestone is considerably weathered, but the ore has good thickness and quality. The members are confined to Sections 13, 14, 23, 24, 25, 26, 35, and 36. On the land of Luther D. Johnson, in Section 35, the following measurement was taken:

		Ft.	*In.*
Flint	*Ferriferous*	..	6
Limestone, flint, and ferruginous clay	*Ferriferous*	1	..
Shale, dark		1	4
Coal, *Clarion*, seen		3	..

Coal Township

"In sections 11 and 12, Coal Township, near the Walnut Grove School, the horizon is represented by thin, flinty, irregular pockets of limestone with nodular ore. The Ferriferous limestone and ore were not found in Washington Township.

Milton Township

"The beds are valuable again in Milton Township, for the Ferriferous ore or limestone is represented in every section except 6 and 31. They were extensively used during the early period of iron making in Milton Township by the charcoal furnaces Jackson, Latrobe, Buckeye, Cornelia, and Lincoln, and also later by the coal and coke furnaces Eliza, Milton, and Wellston, but at present neither the ore nor the limestone is regularly used. In Section 29, near Latrobe Furnace, the ore is reported to vary in thickness from 2 inches to 1 foot 6 inches, but to average from 5 to 8 inches. The limestone is from 5 to 7 feet in thickness, but in some localities the upper part is very flinty. This character is shown in the following section, which was taken at the mouth of a coal mine just south of the old furnace:

		Ft.	*In.*
Flint Limestone, good	*Ferriferous*	1 3	6 ..
Shale		1	5
Coal and partings, *Clarion*		4	11

"Along Tarcamp Creek, in sections 28, 33, and 34, the members are quite unsteady, but the ore is more persistent than the limestone, and this condition was found also in Section 35. On Greasy Run, in Section 36, on the land of the Superior Colliery Company, the rocks exposed and measured are given in the following section:

	Ft.	*In.*
Sandstone, shaly	20	..
Limestone, *Ferriferous*	8	..
Coal and partings, *Clarion*	4	11

"In sections 25, 26, 27, in some localities the massive overlying sandstone replaces the limestone and ore. Along the road west of Little Raccoon Creek, in Section 26, near Buckeye Furnace, the thickness of the beds observed is as given below:

	Ft.	*In.*
Ore, *Ferriferous*	..	4
Limestone, *Ferriferous*	5	6
Coal and partings, *Clarion*	5	..

"In sections 17, 18, 19, and 20, the upper part of the limestone deposit is often flinty in character, while in local areas the member is thin or wanting. The ore was mined along the outcrop for the charcoal furnaces, but is reported to have an average thickness of about 6 or 8 inches. On land of V. A. Pettinger, in Section 17, the limestone has about its normal thickness, and is of good quality. The record obtained follows:

	Ft.	*In.*
Ore, *Ferrifcrous*, reported thickness	..	5
Limestone, *Ferriferous*	6	..
Shale	1	6
Coal and partings, *Clarion*	4	6

"This flinty phase of the Ferriferous limestone is also noticeable in sections 16 and 21. On the land of J. H. Scurlock, in Section 16, the limestone member, where exposed for measurement, gave the following record:

		Ft.	*In.*
Flint / Limestone	*Ferrifcrous*	2	3
		3	5
Shale		1	8
Coal and partings, *Clarion*		4	3

"In sections 15 and 22 the members are again somewhat unsteady; further when present the limestone is often flinty in character. East of this in sections 14 and 23 the beds are seldom present. There is a belt extending from near Keystone Furnace northward to Lincoln Furnace, in which the Ferriferous limestone and ore are very uncertain, for the beds in much of the area are partially or completely replaced by massive

sandstone, the thickness of which varies from 10 to 50 feet. In some local areas this sandstone lies unconformably on the Clarion or Hecla below, thus replacing the Clarion coal also. In Section 24, along Buffer Run, the members are somewhat more persistent, which is the case also along the headwaters of Rich Run, in sections 12 and 13. Near the No. 10 mine of the Superior Colliery Company the following measurements were obtained:

		Ft.	In.
Ore, *Ferriferous*		..	4
Limestone, flinty	*Ferriferous*	1	..
Limestone, good		4	..
Shale		2	6
Coal and partings, *Clarion*		4	4

"Along Rich Run, in Section 11, the Ferriferous ore and limestone are generally wanting. In the northern part of Section 2, on the land of the Valley Coal Company, the members were exposed for measurement, and the record taken follows:

	Ft.	In.
Ore, *Ferriferous*	..	5
Limestone, *Ferriferous*	6	8
Shale	2	4
Coal and partings, *Clarion*	4	6

"In Section 10 only a few pockets of limestone and ore were seen while the members are also unsteady in Section 3. On the land of Adam Phillips, in the latter sections, the members are present, and measured as follows:

	Ft.	In.
Ore, *Ferriferous*	..	5
Limestone, *Ferriferous*	6	..
Shales	2	6
Coal and partings, *Clarion*	4	5

"West of this in sections 4, 5, 6, 7, 8, and 9, the members are quite persistent, but, as they are found high on the hills, the areas are small and the limestone usually much weathered. On a knob on the land of Jacob L. Tucker, in Section 9, the ore and limestone were exposed, and the following section was obtained:

		Ft.	In.
Ore, *Ferriferous*		..	4
Limestone, flinty	*Ferriferous*	1	..
Limestone, good		4	..
Shales		2	5
Coal and partings, *Clarion*		4	9

"The members are wanting in Section 31, and the areas are small in Section 32, but on the main ridge in the northern part of this section the ore was formerly mined by stripping, and the limestone, where exposed,

measured from 5 to 6 feet in thickness. In Section 33 the members are about normally represented for the limestone is from 5 to 7 feet in thickness, and the ore, where exposed, from 4 to 8 inches. Along the road in the western part of Section 34 the limestone exposed measured 5 feet in thickness, but it is probably thicker under cover. At the mine of the Minglewood Coal Company there is a local thickening of the ore, which in places is reported to reach 2 feet, while the limestone below is normal. The rocks exposed along the outcrop gave the following measurements:

	Ft.	*In.*
Ore, *Ferriferous*	1	6
Limestone, *Ferriferous*	5	..
Shale	2	..
Coal and partings, *Clarion*	3	6

"In Section 35 the limestone and ore are again uncertain, for they are often replaced by sandstone. The horizon drops below drainage along Mulga Run in the central part of Section 36, but here the massive sandstone above lies directly on the Clarion coal, having thus replaced both ore and limestone.

Economic Value

"The rich Ferriferous ore has been of vast importance in establishing the iron and steel industry in this state. It was the main dependence of about 100 charcoal furnaces in the Hanging Rock District, of which 16 were in Jackson County. The thickness of the deposit, the yield of metal, the excellent working qualities in the short stacks of the charcoal furnaces, and the natural composition for smelting foundry iron, placed this ore at the head of the list of native ores in importance. The ore varies in thickness from one inch to as much as 2 feet 6 inches, but the usual measurement is from 5 to 12 inches. The exceptional volumes noted are usually of local extent, somewhat in the nature of rolls, and they usually denote a decrease in the normal thickness in the surrounding areas. Under heavy cover the ore is of the normal carbonate type, but along the outcrop it has weathered to the hydrate forms with an increase in the iron content. The usual outcrop ore is porous blocks, but under extreme weathering it is soft and clay-like in character; especially is this the case in that found along the joint planes where the limestone below has weathered to widely separated blocks. This ore more nearly resembles colloidal precipitated hydrates.

"The quality of the Ferriferous ore is shown by the following analyses collected from various sources:

Sample	*No. 1*	*No. 2*	*No. 3*	*No. 4*	*No. 5*	*No. 6*	*No. 7*	*No. 8*
Specific gravity—								
dried at 212°.	2.980	2.868	2.983	2.704	4.872	3.375	3.245	....
Water combined.	10.40	11.90	7.40	11.10	3.25	3.33	3.20	....

Siliceous matter, SiO_2, etc.	5.84	1.62	3.44	23.64	31.56	8.84	23.36	20.90
Iron sesquioxide, Fe_2O_3	79.40	72.61	87.89	62.69	13.55	13.91	13.16	....
Iron carbonate, $FeCO_3$	....	....	....	....	34.01	55.99	48.44	....
Iron, metallic, Fe	55.58	50.83	61.52	43.88	25.91	36.77	32.59	38.10
Alumina, Al_2O_3 .	.40	.40	....	....	2.60	.30	.80	6.43
Manganese, Mn..	1.90	1.05	.10	.07	.45	.55	.25	.67
Calcium carbonate, $CaCO_3$	....	....	....	trace	9.25	4.70	4.90	....
Lime, CaO	.40	9.75	trace	trace	5.18	2.63	2.74	2.15
Magnesia, MgO.	.68	1.59	.62	.75	1.40	2.38	.81	trace
Phosphoric acid, P_2O_5	.642	.466	.414	.754	.894	.530	.065	....
Phosphorus, P...	.280	.203	.181	.329	.390	.231	.027	.134
Sulphur, S.....	.12	.14	trace	trace	.12	2.72	.16	....
Sulphuric acid, H_2SO_4	....	....	....	....	....	8.33	....	....
Water, hydroscopic	....	....	....	....	....	....	....	7.00

No. 1, labeled 'Best limestone ore,' Geol. Survey Ohio, Report of Progress, 1870, page 137.

No. 2, labeled 'Good limestone ore,' Geol. Survey Ohio, Report of Progress, 1870, page 137.

No. 3, labeled 'Dark red limestone ore,' Geol. Survey Ohio, Report of Progress, 1870, page 137.

No. 4, labeled 'Limestone ore, reddish gray, shaly,' Geol. Survey Ohio, Report of Progress, 1870, page 137.

No. 5, labeled 'Limestone ore, blue carbonate, best quality,' Geol. Survey Ohio, Report of Progress, 1870, page 137.

No. 6, labeled 'Limestone ore, blue carbonate, earthy, sulphurous,' Geol. Survey Ohio, Report of Progress, 1870, page 137.

No. 7, labeled 'Gray limestone ore,' Geol. Survey Ohio, Report of Progress, 1870, page 137.

No. 8, average analysis of Ferriferous ore, reported by the Jackson Iron and Steel Co., Jackson, Ohio.

"Owing to the thinness of the deposit, and to the more desirable quality of the weathered product, the Ferriferous ore has been mined mainly by stripping along the outcrop. In local areas where the thickness is exceptional, and the quality good, it has been mined by drifting. At present both methods are used to obtain the ore supply for Jefferson Furnace. Small amounts are also obtained from the limestone mines."

VINTON COUNTY[1]

"During the days of the charcoal furnaces in southern Ohio the Ferriferous ore was of great economic importance, leading directly to the establishment of the iron industry in the Hanging Rock district in

[1]Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 268-276.

1826, and being the main reliance of more than 60 furnaces in this and the Hocking fields. With few exceptions the furnaces that succeeded best were those located along the line of outcrop of the Ferriferous ore. The Ferriferous was superior in yield of iron and in smelting qualities, was more reliable in thickness and in continuity, and made a better grade of foundry iron than the other ores in the region. The mean thickness of the ore was nearly 10 inches and the yield of iron about 40 per cent. The bed was extensively mined in Lawrence, Jackson, and Perry counties and, less widely, in Scioto, Gallia, Vinton, and Hocking; but north of this in central and eastern Ohio the stratum so fails that it was little used for metallurgical purposes. In the southern counties the member was commonly called the 'Limestone' ore on account of its position directly above the Vanport or Ferriferous limestone. In the Hocking Valley region it was designated the 'Baird' ore as the deposits were especially important near Baird Furnace in Hocking County. The Ferriferous ore not only laid the foundation for the iron industry of southern Ohio, but was one of the chief factors in the development of the region.

"In Vinton County the Ferriferous ore, although very widely distributed, occurs more in the form of irregular, isolated patches than as a sheet deposit. The member is locally present in Brown, Swan, Jackson, Richland, Elk, Madison, Vinton, Clinton, and Wilkesville townships. The deposits that were mined the most extensively were those in Elk and Clinton townships. The member varies in thickness from one inch to three feet or more but averages not more than ten inches. The mean of about twenty measurements made by the writer is five inches; but this is less than the true average as the thicker ore was stripped to deep cover and is now obscured by slumping and farming. Under deep cover the Ferriferous ore is a siderite of a blocky structure, of a gray or bluish-gray color, of a grainy texture, and with free silica as the chief impurity. The content of sulphur is low but that of phosphorus is sufficient to classify the ore as foundry grade. Along the outcrop the siderite has been altered by weathering agencies to a limonite of a yellowish or brownish color. It still retains the blocky structure due to a shell of firmly cemented ore inside of which are concentric layers of similar material and a core of soft, mellow ore. In this form it is known as kidney or block ore.

"The Ferriferous ore was mined most largely by stripping along the outcrop as the unaltered carbonate under deep cover gave, in roasting, a ferrous silicate which was difficult to reduce in the short stacks of the charcoal furnaces. Where directly overlain by a sandstone instead of shale, the siderite is altered to limonite under much deeper cover, as the circulation of ground waters is along the base of the sandstone stratum. Under such conditions and with a good thickness of ore, the bed was then mined by drifting. In Vinton County such a method was employed in only a few small areas. The common practice in stripping was that

a foot of dirt could be profitably removed for an inch of ore. In general the depth of overburden removed was from 1 to 15 feet.

"The Ferriferous ore is separated ordinarily from the underlying limestone by a thin stratum of shale. Locally, however, the two beds are firmly cemented, the ore gradating somewhat into the limestone. In places the upper part of the limestone stratum is so enriched by iron oxides that it has a pink or brown appearance. Under thin cover and with advanced decay the cavities in the upper surface of the limestone and the wide spaces along the joint planes are filled with a soft clay-like ore formerly employed in a small way for pigment. It was too fine and dusty to be used in making charcoal iron.

Brown Township

"In Brown Township both the Ferriferous ore and the Vanport limestone are largely wanting, but on this general horizon small local deposits of ore are present in the shale overlying the Scrubgrass coal. The stratigraphic position of the bed is shown in the following record, taken along the road in the east central part of Section 19:

	Ft.	*In.*
Coal blossom, ***Middle Kittanning***	3	0
Covered	12	0
Shale and covered	21	0
Coal blossom, ***Lower Kittanning***	1	0
Clay and covered	10	0
Sandstone, massive, soft	8	0
Covered	10	0
Sandstone, massive, soft	13	4
Shale	1	0
Ore, nodular, *Ferriferous* horizon	..	4
Shale and shaly sandstone	7	4
Coal, *Scrubgrass*	1	4
Shale, black, fissile	6	10
Coal, *Clarion*	1	5
Clay, plastic	6	4

"In this locality the ore varies from 2 to 6 inches in thickness but is unsteady in extent. The quality is poor as it is siliceous in character. It was not mined even for the charcoal furnaces.

"In the shales between the Clarion and Scrubgrass coals irregular lenses and nodules of ore were observed at a few places. Such a deposit was well exposed in the cut of the Baltimore and Ohio Southwestern Railroad in the southwestern part of Section 8. The ore varies from 1 inch to 1 foot 2 inches in thickness and lies about 4 feet above the Clarion coal and 59 feet below the Lower Kittanning member. At this place the Scrubgrass coal is replaced by sandstone. The ore varies in kind from a siderite to a limonite and is siliceous in character. No fossils were observed either in the ore or in the associated shale. Directly above the

Clarion coal a body of blackband ore about 2 feet 6 inches thick appears on the Timothy Clifford property near Hope Station, but the deposit is local.

Swan Township

"Only small patches of Ferriferous ore are present in Swan Township and these are confined most largely to the southeastern part. The ore was mined in a small way along the ridge in Section 10, on that east of Creola in the central part of Section 34, and on the knobs in the east central part of Section 31. At the latter place the deposits are small but the bed is reported to be about 1 foot thick. Some flint is also present along with the ore. In Swan Township the Upper Mercer or Big Red Block ore was of far more importance and was extensively mined over a wide area.

Jackson Township

"Small deposits of Ferriferous ore and buhrstone are present on a few of the high knobs in Section 36, Jackson Township. The ore was little mined.

Richland Township

"The Ferriferous and Vanport members in Richland Township outcrop only along the summits of the high ridges in the eastern part. The deposits are small, being confined largely to sections 1, 13, and 24. The ore is frequently absent even where the limestone is present. It is also low grade and thin.

Elk Township

"In Elk Township the Ferriferous ore is widely, but on account of wants, erratically distributed over much of the area. The deposits most largely worked are those in sections 9, 10, 15, 16, 17, 22, 27, 30, 35, and 36. Locally the ore not only has good thickness but is above the average in purity.

"In sections 9 and 10 the ore bodies are small and were mined to only shallow covering. The thickness reported is from 4 to 6 inches. The stratigraphic position of the member is shown in the following record made in the eastern part of Section 15:[1]

Coal, *Middle Kittanning,* reported thickness	4	6
Covered	50	0
Coal, *Lower Kittanning,* reported thickness	3	6
Shale, gray	14	0
Ore, *Ferriferous*	..	6
Shale, gray, siliceous	1	3
Limestone and flint, *Vanport*	2	0
Clay	..	3
Coal blossom, *Clarion.*		

[1]Geol. Survey Ohio, Report of Progress, 1870, p. 107.

"The Ferriferous ore was mined rather extensively by stripping along the ridges in Section 16. Here it rests on the buhrstone of the Vanport and in places is more or less mixed with this material. The deposits in Section 22 are described as follows:[1]

"The Ferriferous limestone is found with a fine development of limonite ore over it and a bed of coal reported 3 feet 4 inches thick a little below. The ore is quite irregular, but at one place attains a very unusual thickness. It is reported to range from a few inches to 9 feet, the reported average being 2 feet 6 inches to 3 feet. This is one of the most celebrated developments of ore in all southern Ohio. It has been mined by drifts, and the quantity taken from less than two acres is reported to be 10,880 tons. At one place the limestone and ore are both wanting. The strata in this locality follow:"

	Ft.	*In.*
Coal, *Lower Kittanning.*		
Sandstone and shale	35	0
Ore, limonite, *Ferriferous,* average	2	6
Limestone, *Vanport*	7	0
Clay	..	7
Coal, *Clarion*	3	4

"Small quantities of ore were also mined at various places along the ridges in the southwestern part of the township in sections 28, 29, 30, 32, and 33. The association is ore and buhrstone, the latter replacing the Vanport limestone. The mining was all done by stripping. The best deposits are reported to be about 1 foot thick. In the eastern part of Section 26, the Ferriferous ore locally attained excellent thickness and was mined extensively. A section of the rocks follows:[2]

Coal blossom, *Lower Kittanning.*		
Sandstone and covered	33	0
Clay	..	5
Ore, *Ferriferous,* reported thickness	3	0
Limestone, *Vanport,* average	5	0
Clay	2	..
Coal, not opened, *Clarion.*		
Shale and sandstone	39	0
Coal, not opened, *Winters.*		
Shale	6	0
Ore, 'gray kidney'	..	4
Ore, 'Little fine block'	..	10
Shale and sandstone	32	0
Coal, reported, *Brookville*	3	6
Sandstone and shale	36	0
Ore, 'kidney' ..... } *Upper Mercer* {	..	2
Ore, 'big red block' }	..	10

[1]Geol. Survey Ohio, Report of Progress, 1870, pp. 108-9.
[2]Idem., p. 111.

"Samples of the Ferriferous ore were taken for testing. (For analyses, see pages 146, 147.) Small deposits of good ore were also worked in sections 27, 34, 35, and 36, but the thickness was at few places more than 1 foot and the average measurement much less.

Madison Township

"Both the Ferriferous ore and Vanport limestone are wanting in the northern part of Madison Township except for stray lenses of ore and flint, neither of which is of economic value. They improve in continuity and development in the southern part of the township along Elk Fork and Flat Run. The best ore is in the vicinity of Vinton Furnace where it was mined in many places. The following record, taken in the northwestern part of Section 31, shows the stratigraphic features very well:

	Ft.	*In.*
Shale and covered	10	0
Ore, *Ferriferous*	..	7
Limestone, *Vanport*	7	4
Shale and covered	19	8
Coal blossom, *Clarion*	4	0
Clay, light, plastic	3	0
Sandstone, massive	9	0
Covered	9	0
Coal, old mine, *Winters*	3	0

"Locally the ore thickens to 15 inches. In most places it lies directly above the Vanport limestone. Along Flat Run in Section 13 these members are present just above drainage level, but are uncertain in character and thickness. The ore was little mined.

Vinton Township

"In the main, deposits of Ferriferous ore in Vinton Township are confined to the valley of Pierce Run from Oreton to Radcliff and to that of Raccoon Creek from Arbaugh to Hawk. It is unsteady, in many places being replaced by sandstone. The ore is below normal in thickness but is of standard quality. The position of the member is as usual directly above the Vanport limestone but the ore is frequently wanting even where the limestone is present. The member was mined by stripping most largely in sections 10, 15, 16, 33, and 34.

Clinton Township

"The supply of ore for Hamden Furnace was drawn largely from the Ferriferous member in Clinton Township where the bed is found with fair regularity over the entire area east of the old valley that extends

from Dundas to Hamden. It was mined most extensively in sections 3, 9, 13, 16, 21, 23, 25, 26, 27, 28, and 29. The deposits are variable in thickness, character, and association. The ore may be absent or may expand to as much as 3 feet. Through weathering it changes from a hard, gray siderite to a soft, brown limonite. It may be associated with limestone, with buhrstone, or in their absence with shale and sandstone.

"The Ferriferous ore was mined in a number of places in the vicinity of Dundas in sections 3, 9, and 10. The thickness reported is about 1 foot with a maximum measurement in local swells of nearly 4 feet. The best developed deposits are those in the southern part of Section 9 where it was stripped to deep cover. In sections 1, 2, 11, and 12 the ore is very unsteady, in many places being replaced by sandstone. Likewise, for the same reason, the Vanport limestone and Clarion coal are absent from the section. Along the high ridge and its spurs in sections 13, 14, 15, 16, and 17, this ore is moderately persistent, has average thickness, 2 inches to 1 foot 4 inches, is underlain by Vanport limestone, and was mined at many places for the smelting of iron in Hamden Furnace. In the southern part of the township in sections 25, 26, 27, 28, and 29, the conditions are similar. The stratigraphic features are normal throughout the entire area.

Wilkesville Township

"The only areas in which the Ferriferous ore appears at the surface in Wilkesville Township are along Raccoon Creek from Hawk to Section 20, along Rockcamp Run in Section 30, along Indiancamp Run in Section 28, and along Karr Run in Section 27. In general the ore is poorly represented but the underlying limestone is well developed. The bed was little mined along Raccoon Creek and only locally along its western tributaries.

Economic Value

"From 1830 to 1870, the period of greatest activity of the charcoal furnaces, the Ferriferous ore was the most important bed in southern Ohio, far outweighing in value any of the coals, clays, or limestones. Conditions have so changed that now [1925] it is not utilized at any place in the entire area. In Vinton County mining of the Ferriferous ore in a large way began with the erection of Eagle, Cincinnati, Vinton, Hamden, Hope, and Zaleski furnaces, between 1852 and 1858, and lasted during their periods of activity. It is of foundry grade, making a soft iron well suited for a wide variety of castings. In yield of iron and in economy of smelting this ore compares favorably to the more siliceous ores from the Great Lakes region. The general quality of the Ferriferous ore in Vinton County is shown by the following analyses made during the time the bed was being actively mined:

	No. 1	*No. 2*	*No. 3*	*No. 4*
Ignition loss	12.65	8.90	7.50	16.85
Ferric oxide, Fe_2O_3	65.65	60.86	79.37	64.36
Silica, SiO_2	17.26	22.16	6.64	8.56
Alumina, Al_2O_3	.05	.00	.00	1.00
Lime, CaO	.55	.12	2.95	1.99
Magnesia, MgO	1.28	.83	.56	2.68
Phosphorus pentoxide, P_2O_5	.215	2.524	.91	.384
Manganous oxide, MnO	1.40	3.95	1.75	1.45
Sulphur, S	.10	trace	.00	2.53
Totals	99.155	99.344	99.68	99.804
Metallic iron, Fe	45.95	42.60	55.56	45.05
Metallic phosphorus, P	.094	1.102	.397	.168
Metallic manganese, Mn	1.09	3.06	1.36	1.12
Specific gravity	2.709	2.307	3.333	

No. 1 Ferriferous ore, lower part of bed. Section 26, Elk Township. Geol. Survey Ohio, Report of Progress, 1870, p. 111.
No. 2 Ferriferous ore, middle part of bed, same location. Idem.
No. 3 Ferriferous ore, upper part of bed, same location. Idem.
No. 4 Ferriferous ore, mixed siderite and limonite, same location. Idem, p. 112.

"The Ferriferous ore in southern Ohio fluctuates, like other coal formation rocks, through rather wide limits in composition and character. The average of many samples of ore used for metallurgical purposes and gathered over a wide area gave the following data:

	Variation per cent	*Average per cent*
Iron, Fe	25.00 to 56.00	41.87
Phosphorus, P	.025 to 1.100	.344
Manganese, Mn	.05 to 3.00	.91
Lime, CaO	.05 to 15.00	3.43
Magnesia, MgO	.05 to 2.70	1.13
Silica, SiO_2	1.60 to 32.00	13.42
Alumina, Al_2O_3	.05 to 7.50	1.77
Sulphur, S	.01 to 2.75	.46
Ignition	5.00 to 30.00	18.00

"The contents of lime and magnesia are usually higher in the siderite ore than in the limonite, for through weathering these components have been partially removed by the action of carbon dioxide in the circulating waters. In general this is also true of the silica as some desilication has taken place in the breaking down of the complex silicates. The quantity of sulphur is erratic in both the siderite and the limonite ores. In the siderite it is generally in the form of a sulphide, largely iron sulphide or pyrite, and in the limonite it is usually in that of a sulphate, such as gypsum or calcium sulphate. In the alteration the pyrite is first converted into ferrous sulphate and free sulphuric acid which readily combines with

any bases present. Through solution and substitution a part of these sulphates may finally be precipitated as gypsum. Such material is locally abundant in ores lying near the surface, especially those that have been penetrated by plant roots. The range in phosphorus is generally much larger in the oxide ore than in the carbonate. Through solution and chemical changes a part of the bed may be impoverished in this component and another part enriched. The entire ore body may also be affected at the expense of associated strata. Such enrichment is thus more or less local either within the ore deposit or within a small area.

"Before use in the charcoal furnaces the Ferriferous ore was calcined in order to remove hydroscopic and combined water, to convert the carbonates to oxides, to increase the porosity of the material, to increase the yield of the stack, and to save coke in the smelting operation. The treated ore was easily reduced by carbon monoxide in the upper part of the furnace, whereas the gray ore was more difficult to smelt. The fuel most used for calcination was wood, charcoal brands, and fine charcoal, as little deleterious materials such as sulphur and ash were thus added to the product. Coal was also used but with less favorable results. The ore was roasted in several ways, the most common of which were in piles built in the ground at the furnace, at the mine, or at the shipping point, and in kilns on the furnace yard.

"The Ferriferous deposits in Vinton County are too thin to be worked at present for the ore alone as the 'Lake' ores are far more economical. If mined as a secondary product in stripping the underlying limestone, the material has sufficient value to pay at least for its removal. Where the bed is 10 inches thick, the yield per acre is approximately 3,970 tons for the siderite and 3,290 tons for the limonite. In some localities Ferriferous ore, Vanport limestone, Clarion coal, and Clarion clay may be conveniently mined in this way. The overlying shale and Lower Kittanning clay are also of value for the manufacture of ceramic products. The combined section from the base of the Clarion clay to the top of the Lower Kittanning coal thus yields a variety of materials all useful for some purpose. The Ferriferous ore is not mined at present [1925] at any place in Vinton County and probably will never become important again for metallurgical use as the quantity is too small. The foundry iron made from it was of superior quality."

HOCKING COUNTY

In Hocking County both the Vanport limestone and the Ferriferous or Baird ore are very uncertain and in fact are absent in many areas. The ore is somewhat more stable than the limestone, which here is represented commonly by impure flint or flinty limestone. The Ferriferous ore is due in eastern Washington, Starr, Green, Ward, and Falls Gore townships.

Washington Township

In Washington Township the Ferriferous ore with the associated Vanport limestone and flint, black shale, and Clarion coal and clay are locally present along the high ridges and knobs in the central and the eastern parts of the area. The ore is due at an approximate elevation of 994 feet in south central Section 1, 950 feet in northeast Section 36, 1,065 feet in southwest Section 29, and 1,075 feet in northeast Section 5. Geologic relations to members higher and lower in the scale are given in the composite record given below and taken on the ridge north of the center of Section 12:

	Ft.	*In.*
Shale and covered	15	0
Coal blossom, *Middle Kittanning*	3	0
Shale and covered	15	0
Clay, plastic, light, *Oak Hill*	6	0
Shale, gray	16	0
Coal blossom, *Lower Kittanning*, elevation 1,000 feet	1	6
Clay, light, plastic	6	0
Shale, weathered	7	0
Ore, *Ferriferous*	..	8
Limestone, *Vanport*	1	4
Covered	30	0
Shale, gray	10	0
Shale, dark	2	0
Covered	2	0
Coal, old prospect mine, *Clarion*	..	..

Starr Township

Throughout Starr Township the Ferriferous member is due in the western and northern parts along the valley walls. In general both the Ferriferous ore and the Vanport limestone are absent from the section, their place being taken by shale or sandstone. No deposits of prominence are recorded.

Falls Township

The area sufficiently high to catch the Ferriferous ore is very limited in Falls Township, being confined to the ridges and knobs in the southeastern part of the area. The ore appears to be generally absent.

Green Township

Through wants and impoverishment both the Ferriferous ore and the Vanport limestone are poorly represented in eastern Green Township where they are due along the main ridges. At a few places old strip benches indicate small quantities of ore were mined from this horizon.

Falls Gore Township

Near Bessie and Gore furnaces in eastern Falls Gore Township small bodies of Ferriferous or Baird ore were worked along the summits of the high ridges. The ore is present at an elevation of 940 feet in the northeast corner of Section 27 and 880 feet along Monday Creek in the northwest part of Section 36. The ore is reported to be from 4 to 12 inches in thickness and of good quality.

Ward Township

The Ferriferous ore is generally wanting in Ward Township. The horizon is above drainage along Monday Creek and its tributaries in the western part of the area. No ore of value is reported.

PERRY COUNTY[1]

"The Baird ore of this district is the Limestone or Ferriferous ore of the Hanging Rock field. It occurs to a small extent in Reading and Clayton townships of northern Perry County. It becomes an element of real value in Pike, Jackson, and Monday Creek townships of southern Perry County.

"Throughout the territory now described, it has been worked on a large scale for many years. Not only the furnaces already named, (Union, Logan, Baird and Crafts) but three others in addition, viz., the Bessie, the Thomas Iron Company's [Gore], and Winona furnaces, have all obtained large amounts of ore from this thoroughly known and thoroughly approved seam. It retains all the characteristics that have given to it its excellent reputation in southern Ohio. It occurs in the same form, and in the same stratigraphical associations as there, but its thickness is a little less than in Lawrence and Jackson counties. It averages 8 inches here for the whole territory against 10 inches in the southern part of the field. Of course, it often rises to 12 inches, and sometimes to double this measure, but this extra volume has generally to be paid for by corresponding decrease in the surrounding territory.

"It is separated from the Lower Kittanning coal by a very white seam of clay (the Kittanning clay), which ranges between 10 and 20 feet in thickness. The ore has been mined by stripping only, and the benches of white clay, many miles in length, that mark the centers of production, are among the most conspicuous features of the country. The outcrop ore is naturally most valued and sought for, but the seam appears to hold quite steady under heavy cover. Its place in the series ranges from 30 to 50 feet below the Nelsonville [Middle Kittanning] coal, which is the standard element in all sections of this field. The usual interval between the coal and ore is 40 feet.

[1]Geol. Survey Ohio, Vol. V, pp. 413-414.

"The ore is almost entirely of the oolitic variety throughout the Hocking Valley, and, though not over rich in iron, and quite high in silica, it is so free from sulphur and phosphorus, and is otherwise so constituted, that it yields an iron of great tenacity and consequent value. The mill iron manufactured from it is noted for its strength, and finds market [1884] even where very rigorous demands as to this quality are made."

Coal Township

"The gray ore (Ferriferous) appears to be quite persistent, ranging in thickness generally from 1 to 3 feet, sometimes thinning down to a few inches, and in places disappearing altogether. It is largely developed and of excellent quality in the hills about Old and New Straitsville, and in nearly all the hills which reach its proper horizon, to the west line of Monday Creek Township. Separated in a few places by shale intervening between it and coal No. 5, (Lower Kittanning) its ordinary position is directly beneath the fire-clay of this coal, and it is often associated with a cherty drab limestone. When the ore is well developed it seems to take the place of the coal. Where drifts have been carried into the hill, the ore has been found, on an average, 9 feet below the coal, the interval being filled with fire-clay, and the ore resting on flint, limestone, and sometimes in sand-rock." [1]

Some of the geological features are shown in the record given below and along the road and gully north of Old Straitsville, Section 18, Salt Lick, and Section 19, Coal townships:

	Ft.	*In.*
Coal blossom, *Strasburg*	..	..
Covered	10	0
Coal blossom, *Lower Kittanning*	1	0
Clay and covered	16	0
Ore, *Ferriferous*	..	6
Covered	21	6
Sandstone and covered	32	0
Shale, gray, part siliceous	31	0
Limestone, blocky, gray, *Upper Mercer*	..	6
Clay and covered	5	10
Covered	30	0
Limestone, blue, hard, fossiliferous, *Lower Mercer*	..	6

Salt Lick Township

In Salt Lick Township the deposits of Ferriferous or Baird ore are confined largely to the valley of Monday Creek in the western part of the area. The ore was mined rather extensively by stripping for the furnaces at Shawnee and New Straitsville.

[1] Geol. Survey Ohio, Vol. III, p. 664.

Monday Creek Township

Baird furnace located in the northeast corner of Section 14, Monday Creek Township, drew much of its ore supply from the Baird or Ferriferous member in that general locality. These deposits were drawn upon also by Bessie, Gore, and Winona furnaces. The position of the stratum is well up on the knobs and ridges in the central and eastern parts of the area.

Some of the definite geological features are shown in the following section taken along the road in the south central part of Section 14, about one mile south of Baird furnace:

	Ft.	*In.*
Shale, gray	5	0
Clay, plastic, with ore nodules, *Oak Hill*	5	0
Sandstone, shaly	7	0
Coal blossom, *Lower Kittanning*	1	6
Clay, light, plastic	16	6
Ore, *Ferriferous*	..	10
Limestone, gray, fossiliferous, *Vanport*	1	6
Shale and shaly sandstone	30	0

Where observed in the northeastern part of the township the ore varies from 2 to 12 inches in thickness. It has been mined extensively by stripping. The geology of the bed is given in the following record measured along the road in the south central part of Section 2:

	Ft.	*In.*
Coal blossom, *Middle Kittanning*	3	0
Clay, shale, and covered	36	0
Ore, *Ferriferous*	..	3
Flint, gray, *Vanport*	..	8
Shale and shaly sandstone	36	0
Covered	21	0
Shale, gray	3	0
Ore, nodular	..	2
Shale, gray	..	6
Limestone, ferruginous, very fossiliferous, on outcrop weathered to shale, *Putnam Hill*	..	4
Clay, plastic, light, good, *Brookville*	5	0
Covered	13	0
Sandstone, parts covered	25	0
Coal and shale, weathered, *Bedford*	1	0
Clay, gray, plastic	2	0
Shales and covered	20	0
Limestone, blue, hard, fossiliferous, *Lower Mercer*, elevation 846 feet	..	6

Jackson Township

Considerable ore was mined by stripping along the outcrop on the main ridges in the eastern part of Jackson Township. The elevation of the

bed is close to 1,000 feet in the east central part of Section 23, 1,020 in the southeastern part of Section 33, and 950 feet in the central part of Section 36. The ore is reported to be of good quality and from 4 to 12 inches in thickness. Locally flint representing the Vanport limestone accompanies the ore.

Pike Township

Local deposits of Ferriferous ore are well distributed over Pike Township where considerable mining was done for the furnaces at Moxahala, Shawnee, and New Straitsville. The ore is accompanied most commonly with impure flint or with cherty limestone. Its stratigraphic relations are much the same as in the area to the south.

Reading, Clayton, Madison, and Hopewell Townships

In northern Perry County, in Reading, Clayton, Madison, and Hopewell townships, the Ferriferous ore fades from the section, becoming wanting over large areas and where present only poorly developed. No deposits of worth were noted.

Economic Value

The Baird or Ferriferous ore furnished a part of the burden for the coal furnaces, Baird, Fannie No. 1, Fannie No. 2, XX, Mollie, New York, Moxahala, and Bessie, that operated in Perry County from 1875 to 1920. The general quality of the ore is shown by the following analyses:

(1) Baird ore, Shawnee, by E. G. Love.[1]

Silica	13.99
Oxide of iron	40.67
Alumina	4.73
Oxide of manganese	0.42
Magnesia	2.87
Lime	4.40
Phosphoric acid	0.24
Carbonic acid	28.50
Sulphur	0.07
Metallic iron	31.63
Phosphorus	0.10

(2) Blue Limestone ore, Shawnee, by S. B. Newberry.[2]

Silica	10.11
Protoxide of iron	33.26
Sesquioxide of iron	15.60
Alumina	1.14

[1]Geol. Survey Ohio, Vol. III, p. 660.
[2]Idem.

Oxide of manganese	3.99
Magnesia	2.91
Lime	4.17
Carbonic acid	26.80
Sulphur	0.29
Moisture	0.78
Metallic iron	36.79
Phosphorus	0.21

(3) Thomas ore, Section 19, Monday Creek Township, by S. B. Newberry:[1]

Silica	9.47
Sesquioxide of iron	41.09
Alumina	8.24
Phosphate of alumina	1.82
Magnesia	1.45
Lime	4.92
Carbonic acid	28.05
Sulphur	0.13
Moisture	2.30
Metallic iron	37.72
Phosphorus	0.10

MUSKINGUM COUNTY[2]

"The Ferriferous ore, which has good thickness and continuity in the vicinity of Gore and Baird furnaces in Hocking County, where it was formerly extensively mined for charcoal iron, is poorly defined as it extends northward into Muskingum County. The ore is due in all the townships west of the Muskingum River, and in Wayne, Washington, Madison, Adams, and Monroe townships east of this stream. However, only a few scattered patches of Ferriferous ore from 1 to 5 inches in thickness were observed in the entire area. The normal position of the member is directly above the Ferriferous limestone or flint. The ore on the outcrop belongs to the limonite class and is somewhat siliceous in character. It has no value as the quantity is negligible."

NORTH CENTRAL AND EASTERN OHIO

The conditions of deposition were generally unfavorable for the laying down of iron ore and also for limestone on this general horizon throughout north central and eastern Ohio. The limestone is locally developed in Stark and Mahoning counties but the ore is everywhere patchy at best and thin or nodular. No ore of value is recorded.

[1]Geol. Survey Ohio, Vol. III, P. 660.
[2]Geol. Survey Ohio, Fourth Series, Bull. 21, p. 164.

NODULAR OR "ORE SLATE" ORE

INTRODUCTION

In the shale immediately overlying the Ferriferous ore in local areas in southern Ohio nodular ore was present in sufficient quantity to be mined during the days of the charcoal furnaces. It was worked mainly in stripping for the underlying Ferriferous ore to which the scattered nodules added from 2 to 10 inches of additional thickness. This ore was best developed in southwestern Lawrence County but was found to a small extent in eastern Scioto and southeastern Jackson counties. The ore occurred as scattered nodules and less commonly as bands of nodules in the shale. This shale, lying above the Ferriferous ore and below the base of the Lawrence clay, varies from 2 to 7 feet in thickness but measures commonly between 3 and 5 feet. Under covering the ore is a siderite but along the outcrop this has weathered to a limonite. Some of the nodules appear to be made up of an aggregate of fine shot. The ore was considered of good quality. A few sections are given to show the geological features.

REGIONAL GEOLOGY

On the north side of the low divide one-half mile southwest of Etna Junction in central Elizabeth Township, Lawrence County, the following strata were measured:

			Ft.	*In.*
Sandstone			30	0
Coal, good	*Lower Kittanning*		2	5
Clay, impure	*Lower Kittanning*		..	1
Coal, good	*Lower Kittanning*		..	10
Clay, siliceous, *Lower Kittanning*			1	6
Shales, siliceous, gray			2	0
Sandstone, shaly			1	6
Shale, siliceous			..	1
Sandstone, shaly			1	0
Shales, siliceous			1	6
Coal blossom, *Lawrence*			..	1
Clay, flinty, dark	*Lawrence*		1	0
Clay, plastic, dark, good	*Lawrence*		1	6
Clay, plastic, light, good, slightly siliceous	*Lawrence*		4	6
Shale, gray			..	6
Ore, nodular, layer in shale, not continuous	*"ore slates"*		..	6
Shale, dark gray	*"ore slates"*		1	6
Ore, blocky	*Ferriferous*		..	5
Ore, frozen to limestone	*Ferriferous*		..	3
Limestone, good, *Vanport*			6	3
Clay, very siliceous, *Clarion*			4	0

"On the Ironton-Oak Hill highway, nearly one mile north of Center Station in the northeast corner of Section 33, Decatur Township, Lawrence

County, many of the rocks are exposed from the Clarion clay to the Upper Freeport coal. A part of this section is given below:[1]

	Ft.	In.
Sandstone, massive	20	0
Shale, gray	6	0
Coal, smut, *Middle Kittanning*	..	1
Clay, plastic, gray, fair	5	6
Shale, gray, siliceous	1	2
Sandstone, massive	40	0
Shale, siliceous	2	0
Coal, weathered	1	5
Clay, impure	..	7½
Shale, dark, hard *Lower Kittanning*	..	4
Coal, good	..	9
Coal, bony	..	1½
Clay, light to dark, *Lower Kittanning*	1	7
Coal, bony, *Lawrence*	..	4
Clay, dark, flinty	..	9
Clay, plastic, light, excellent *Lawrence*	2	10
Clay, plastic, light, siliceous	1	9
Shale, with ore nodules, ['Ore Slate']	4	2
Ore, *Ferriferous*	..	4
Limestone, *Vanport*	5	6"

The deposits of this ore in Scioto County were small and were confined largely to Vernon Township. Most commonly in Jackson County the "ore slate" of the miner is replaced by siliceous sandstone. This is also true in northeastern Gallia County.

Economic Value

In the main this nodular ore was mined incidentally in stripping for the Ferriferous ore. Any nodules thus encountered were saved and combined amounted to a solid layer from 1 to 10 inches in thickness. The ore is of foundry grade and yields from 30 to 45 per cent iron.

ORES IN LOWER KITTANNING SHALES

INTRODUCTION

Iron-bearing strata of considerable importance during the days of the charcoal and coal furnaces are present in eastern Ohio in the shales lying between the Lower Kittanning coal and the Strasburg coal. Such ores were of most value in Columbiana and Tuscarawas counties but were worked to some extent in Mahoning, Stark, Carroll, and Holmes counties. Both blackband and nodular ores were present.

Along the horizon of the Hamden limestone, lying above the Lower Kittanning coal, iron ore appears in local areas in southern Ohio. It is

[1]Geol. Survey Ohio, Fourth Series, Bull. 36, p. 80.

usually more or less nodular in form and is bedded in clay shale or shale. The largest deposits of this ore are near Hamden in Vinton County. This ore is high in phosphorus and is of value chiefly for this component.

HAMDEN ORE

REGIONAL GEOLOGY

VINTON COUNTY[1]

"The Hamden is one of the unsteady and variable members in the coal formations of Ohio. It may be represented by a regularly bedded limestone, by nodular limestone, by calcareous shale, by iron ore, or by some combination of these. It occurs more in the form of lenses of small or medium size than in that of a sheet of wide extent. The areal range of the member as now known is from Beaver County, Pennsylvania, southwestward to Jackson County, Ohio. Future work may extend this both to the east and to the south . In this State the material in some form on the Hamden horizon appears in local areas in Columbiana, Mahoning, Stark, Carroll, Tuscarawas, Coshocton, Muskingum, Perry, Hocking, Athens, and Vinton counties.

"The limestone and calcareous shale are of marine origin as they bear an abundant fauna of that character, but the method of formation of the iron ore is not so clearly indicated. Most of it appears to have been laid down in shallow arms of the sea as a ferruginous limestone which, during the long period since the Alleghenian rocks were elevated into a land mass, has been so altered by ground waters, especially near the outcrop, that the rock has lost most of its calcium carbonate and gained in iron oxide. Such ore and in many cases the associated shale are sparingly fossiliferous with either salt or brackish water types. In the southern extension of the field in Vinton and Jackson counties, the few isolated bodies of Hamden ore appear to be of true bog or swamp origin. In the unaltered ore the iron is mainly in the form of ferrous carbonate or siderite and in the weathered material along the outcrop and under shallow cover it occurs largely as ferric hydroxide or limonite. The phosphorus is held both as calcium phosphate and ferric phosphate, but largely as the latter.

"The Hamden member lies either directly on or only a few feet above the Lower Kittanning coal and just below or in many places within the body of the Oak Hill clay. Where it forms the roof of the coal, the material is usually shale with more or less nodular limestone, both highly fossiliferous. In a few localities such deposits consist of bowldery limestone in irregular, lenticular layers, separated by shale partings. Where bedded within the clay, the horizon is less definitely marked, the most

[1]Geol. Survey Ohio, Fourth Series, Bull. 31, pp. 303-5.

common representative being concretions and ill-shaped bodies of ferruginous limestone and impure iron ore.

"In Vinton County the Hamden member is poorly developed except in a small area near Hamden Furnace in Clinton Township where it occurs as an iron ore, rather lean in iron but rich in phosphorus. In the old charcoal furnace at this place the ore was tried but soon condemned as the iron made from it was hard and brittle. Later a few thousand tons were shipped to Columbus and Buffalo to mix with lake ores in order to increase the phosphorus content of foundry iron. The ore bodies are present in the form of irregular lenses of small extent, but with excellent thickness. The following record, taken at a mine on land of the Puritan Brick Company in Section 16, shows the main stratigraphic features:

	Ft.	*In.*
Shale, weathered	3	0
Coal, *Middle Kittanning*	..	6
Clay, impure	1	0
Shales and sandstones	10	0
Sandstone, shaly, ferruginous	1	11
Ore, irregular, kidney, 1 to 5 inches, *Red Kidney*	..	2
Shale, gray	1	7
Coal, shaly	..	1
Clay, dark, part flinty, with scattered ore nodules, *Oak Hill*	2	6
Ore, *Hamden*	9	0
Shale, reported thickness	2	0
Coal, *Lower Kittanning*, reported thickness	1	6

"In this deposit the ore varies from 1 to 12 feet in thickness but measures usually between 2 and 4 feet. Its position is at the base of the Oak Hill clay and from 2 to 3 feet above the Lower Kittanning coal. Both the upper and lower surfaces of the ore are irregular in outline. The material varies from red to brown to gray, depending on the state of oxidation. It was mined entirely by stripping. Elsewhere in Vinton County the Hamden member is of no value economically and has little interest stratigraphically. In a few places in Elk, Madison, and Brown townships, the horizon is marked but poorly by scattered nodules of impure ore at the base of the Oak Hill clay. Neither the limestone nor the shaly phase was observed at any place within this area.

Economic Value

"Although the quantity yet available is small, the Hamden ore is of some interest commercially, more for its content of phosphorus than that of iron. The element phosphorus is very effective in increasing the fluidity of molten iron and in preventing the oxidation of other metals present. It thus assists in the production of sound castings in foundry work. It is combined with the iron as the phosphide, FeP. In the Hamden ore the phosphorus varies from 2 to 12 per cent but averages between

4 and 5 per cent. In general the ore richest in phosphorus is that in the lower part of the deposit. The fluctuation in iron in the material is from 25 to 55 per cent, but the average is approximately 33 per cent. This ore carries also nearly one-half the bases, lime and magnesia, needed for fluxing the silica and alumina present. Through the kindness of Mr. J. H. Frantz of the American Rolling Mill Company, Columbus, Ohio, the average analysis of 29 cars of ore is given below: (Percy Daines, analyst)

	Dry at 212°F.	Natural
Iron, Fe	33.09	28.87
Silica, SiO_2	9.20	8.03
Phosphorus, P	4.78	4.17
Manganese, Mn	.85	.74
Alumina, Al_2O_3	8.37	7.30
Lime, CaO	9.75	8.51
Magnesia, MgO	.90	.79
Ignition loss	11.60	10.12
Moisture	....	12.75

Under normal furnace practice the iron resulting from the smelting of Hamden ore alone would have the following approximate composition:

Carbon, C	4.00
Silicon, Si	2.00
Iron, Fe	81.21
Phosphorus, P	11.73
Manganese, Mn	1.06
Total	100.00

"The product is a ferro-phosphide iron, hard and brittle, and silvery in appearance. Such an iron is only slightly inferior to that now considered standard and used widely in foundry work. The Hamden ore has thus a special field of usefulness in a region where such material is frequently needed and not widely distributed."

CENTRAL OHIO

Nodules of ore derived from the weathering of the Hamden limestone are locally present in Perry, Muskingum, and Coshocton counties. At best such deposits are from 2 to 8 inches in thickness and are confined to outcrop conditions. The ore is of fair quality for foundry iron.

BLACKBAND ORE

REGIONAL GEOLOGY

HOLMES COUNTY[1]

"No better place will be found for a brief account of a stratum included in this general district that has provoked a good deal of discussion

[1]Geol. Survey Ohio, Vol. V, pp. 399-400-402.

within the last few years. [1884] It was first described by the late Professor E. B. Andrews in a report of an examination of the then projected line of the Cleveland, Canton, Coshocton and Straitsville Railway Company, now the Coshocton branch of the Connotton Valley Railway.

"The stratum in question is a so-called blackband deposit, immediately over the Lower Kittanning coal (No. 5), occurring at a few points in German township, in Holmes county, and perhaps also in contiguous territory. Professor Andrews describes it as follows:

'Quite to my surprise, I found very large deposits of blackband over coal No. 5. At one point where coals No. 6 and No. 5 are both well exposed, the shales between the two seams, here 18 to 20 feet apart, are very thickly studded with large nodular masses of ore, and hundreds of tons were exposed in the immediate neighborhood. But a half mile away, we find 10 feet or more of black bituminous shale over No. 5 so largely charged with iron in even diffusion as to constitute a blackband ore. . . . North about a mile and a half is an extensive and elevated ridge where the exposed blackband over No. 5 is 10 feet thick. It is of equal thickness at another exposure in the same ridge about a mile further north. About 2½ miles in a northwest direction from the last-mentioned point is another exposure where the blackband ore is equally thick, 7 feet 6 inches being in sight, with probably considerably more below.'

"Analyses were made of two of these deposits, one of the analyses being supposed to cover 7 feet 6 inches of ore, and the other 5 feet 6 inches. The samples yielded of metallic iron, 27.32 and 22.62 per cent., respectively. These figures place the ores, as Professor Andrews justly remarked, on a level with the Tuscarawas blackband.

"The table of analyses is given herewith from Professor Andrews' report:

'I give, in the following table, the results of the analyses of these ores over No. 5 coal. All the analyses were by Prof. Wormley.

'The analyses show that the blackband ores over coal No. 5 are of excellent quality.

No. 1 Blackband over coal No. 5.
No. 2 Blackband over coal No. 5.

Analyses of Blackband Ores

	1	2
Silicic acid	25.52	24.16
Volatile matter	13.30	20.06
Iron carbonate	45.86	33.60
Iron sesquioxide	7.40	9.14
Alumina	0.50	5.75
Manganese	2.10	1.85
Lime carbonate	1.50	0.95
Magnesia carbonate	3.26	4.20

Sulphur	0.17	0.30
Phosphoric acid	0.096	0.032
	99.706	100.042
Metallic iron	27.32	22.62
Phosphorus	0.043	0.018
Iron in calcined ore	43.94	35.08'

"Professor A. A. Wright, of Oberlin College, who made the review of the economic geology of Holmes county for the present report, was instructed to give special attention to these deposits. He did so, visiting all the accessible exposures. He sent in for analysis, samples of the 7 to 8 feet of ore on Christian Fisher's farm, German township, perhaps the best-known and most trusted of these deposits. The results are given below (No. 1). The average of the seam was taken.

"Afterwards I visited the Fisher bank in person, and selected two sets of samples, the first to show the average of the seam, and the second to show the composition of the most promising layers. These are given below in Nos. 2 and 3. In No. 4 the composition of the nodular ore from the same horizon is shown. The samples were taken from a heavy deposit in the Rowville cut of the Connotton Valley Railway.

"The ferriferous character of the horizon has been fully established by 100 miles of outcrop in the eastern counties. It is the same stratum, viz., the Kittanning shales, it will be remembered, that bears the shell ore and the blue block ore of Tuscarawas county, and the kidney ore of Columbiana county. It is therefore no surprise to find iron accumulated in force at this level in Holmes county, but blackband has not been heretofore reported from the Lower Kittanning seam. The Fisher bank, which is represented in the analyses given below, Nos. 1, 2, and 3, deserves the name of blackband ore. It has too much carbonate of iron to allow it to be called a bituminous shale. The results obtained by Professor Andrews would make the deposit a very valuable bed of ore. The results obtained by the Survey do not indicate any real economic value under present conditions of iron making. The disparity in the two sets of analyses, it is hard to explain. Professor Andrews' work is entitled to respect and certainly the Survey has not spared trouble to ascertain the facts.

	1	2	3	4
Silica	37.52	34.28	28.82	8.67
Iron protoxide	13.75	15.29	19.85	43.11
Iron sesquioxide	1.57	4.64	5.43	0.42
Alumina	....	...	13.31	4.47
Manganese oxide	....	....	0.04	2.07
Lime	....	....	2.95	5.15
Magnesia	....	....	0.94	2.09
Carbonic acid	....	....	15.46	32.74
Phosphoric acid	....	....	0.275	1.176

Sulphur	....	....	1.810	0.178
Water and organic matter.	....	....	8.95	0.25
Moisture	....	....	0.58	0.12
	....	....	98.41	100.44
Metallic iron	11.80	15.15	19.25	33.85
Phosphorus	0.160	0.071	0.120	0.513
Sulphur	0.699	.255	1.810	0.118

"The discussion can be summed up in few words. If there is any considerable body of ore, 3 feet in thickness, let alone the 6 to 10 feet reported, that will yield before calcination from 22 to 27 per cent. of iron, as shown in the above quoted tables, the work of iron manufacture may be begun immediately, and its success can be guaranteed, so far as ore is concerned. No such body of ore was found by the Survey. On the other hand, if the Fisher bank fairly represents the blackband of this district, then iron-making can not be successfully begun here in our day."

NODULAR ORE IN SHALES[1]

REGIONAL GEOLOGY

COLUMBIANA COUNTY

"The ore production of Columbiana County stands by itself among the mining interests of the State. Not a pound of ore is taken directly from the horizons that supply it, but the ore mining of the county is altogether placer mining. The gravel beds that fill the valley of the Middle Fork of Little Beaver constitute the present [1884] available ore deposits of the county. These gravel beds are dug over and sifted, and the ore is selected from the other materials by hand picking.

"The ores of the county all belong to the class of kidney ores. They are chiefly derived from two horizons, but additions are made from two others to a small extent. The main horizon is the shale between the Middle Kittanning and the Lower Kittanning coals.

"The kidneys between the Kittanning coals are gathered into a more definite horizon, and it may be possible to find localities in the county in which they can be worked with profit in their native beds, as in adjoining counties. So far, however, no such accumulations have been reported, and their whole production is confined to the placer accumulations of the valley of the Middle Fork.

"The ore exists in all cases as weathered ore. The crust, at least, of all the kidneys has been converted into limonite by atmospheric agencies. These ores are within reach of such agencies in the valley deposits, which are freely permeable, and it is also quite possible that a part of the process of oxidation was carried on before the kidneys were buried here. These

[1]Geol. Survey Ohio, Vol. V, pp. 384-386.

accumulations stand for the work of the ages, the separate blocks having been mined out by erosive agencies of the drainage streams through many thousands of years. Even if the work of accumulation should be limited to the time that has elapsed since the Glacial epoch, a vast period would be available for this history, but there does not appear to be sufficient reason for restricting the work to post-glacial time.

"It is believed that the best of these supplies has already been taken. A large acreage is exhausted, and no considerable territory remains to be attacked, at least under the same favorable conditions that have been found hitherto. The excavations are carried as low as 20 feet in extreme cases. Generally they do not go down more than half this distance.

"The field already worked lies along the West Fork Valley from a little below Teegarden's Mills as far south as Elkton. The southern territory has proved the best. It was not found possible to determine the percentage of yield in the worked deposits, nor to refer the kidneys as they occur to their several sources. Both these questions admit of answers, but the answers would require more time than was available.

"The character of the ore is excellent, as is to be expected from the horizons to which it belongs. Its use has been mainly confined to the Leetonia furnaces."

The following analyses are representative.[1]

"No. 1 Iron ore, Lisbon, sent by H. C. Bowman, shell of ore.
No. 2 Nucleus of iron ore.

	No. 1	No. 2
Specific gravity	3.211	3.658
Water combined	10.55	....
Siliceous matter	11.25	9.20
Alumina	1.20	1.60
Iron, carbonate	....	68.08
Iron, sesquioxide	71.88	7.62
Manganese, oxide	1.90	2.80
Lime, carbonate	1.96	5.20
Magnesia, carbonate	0.81	4.76
Sulphur	0.08	0.18
Total	99.13	99.44
Iron, metallic	50.32	38.21
Phosphoric acid	0.51	0.59

TUSCARAWAS COUNTY[2]

"The kidney and block ores of the counties now under consideration remain to be briefly noticed. They are limited to the two counties, Stark and Tuscarawas, and almost exclusively to the latter.

"The kidney ores will be first treated. Mention has been already

[1]Geol. Survey Ohio, Vol. III, p. 130.
[2]Geol. Survey Ohio, Vo. V, pp. 398-899.

made of the occurrence of many nodules and kidneys in the shales above the blackband, which are often mined with the latter. These require no further notice, and only one horizon needs to be named as a further source of kidney ore in this district. The Kittanning shales, or the 20 to 40 feet of clay and shale that separate the Lower and Middle Kittanning coals, have already been shown to be a chief repository of kidney ore in the territory to the southeast of this. The 'placer' mines of the Little Beaver Valley have obtained most of their ore from this source, as has been stated. But the same stratum proves even richer in ore as it is followed to the westward. At least the kidneys are gathered here into a distinct seam that justifies mining on a small scale.

"The ore is known in Tuscarawas county as shell ore. Its place is immediately under the thin seam of coal that comes into the section locally, midway of the Kittanning shales. This leaves the ore about 20 feet above the Lower Kittanning coal (No. 5) and about the same distance below the upper seam (No. 6). The ore occupies 4 or 5 feet of white and purplish clay, and will aggregate 12 to 18 inches in thickness. In quality it is excellent, only the mellow and aerated kidneys having been reached thus far in the simple style of mining followed. All the ore that has yet been dug, has come from the shallow benches cut down around the edges of the hills. It is only in the neighborhood of the furnaces, and along the lines of the railroads, that mining has been carried even as far as this. It is not known that a single drift has ever been carried under the hills in pursuit of the kidney ore.

"This horizon can scarcely maintain itself in present competition with the blackband hills where nothing less than 2 feet of ore is counted mineable, and where the average of entire acres will exceed 5 feet, but it is well to remember that the kidney ore is here, and that its aggregate in the county vastly exceeds the more conspicuous source which the isolated caps of 40 or 50 separate hills, scattered through 100 or more square miles of territory, contain. Small supplies can be continued to local furnaces for a long while to come."

The quality of the ore is shown by the analyses given below:

No. 1. Mineral Point, over coal No. 5, raw. (Wormley)
No. 2. Mineral Point, over coal No. 5, calcined. (Wormley)

	No. 1	No. 2
Specific gravity	3.434	4.076
Water	0.00	2.28
Iron, sesquioxide	7.60	75.00
Iron, carbonate	64.17	0.00
Siliceous matter	8.96	8.46
Alumina	2.60	0.60
Manganese	1.35	1.85
Lime, carbonate	7.35	....
Lime	....	5.94

Magnesia, carbonate	6.50	....
Magnesia	....	3.64
Phosphoric acid	0.863	1.26
Sulphur	0.18	0.12
	99.573	99.15
Metallic iron	36.31	52.50

Analyses of the nodular ore, both raw and calcined, from above the Lower Kittanning coal at Zoar and representative of the material are given below.[1] Analyst Downs Schaaf.

	Raw ore	*Roasted ore*
Silica, SiO_2	10.72	15.24
Alumina, Al_2O_3	4.45	6.20
Ferric oxide, Fe_2O_3	1.11	44.78
Ferrous oxide, FeO	38.08	13.66
Pyrite, FeS_2	0.42	0.05
Magnesium oxide, MgO	3.75	5.10
Calcium oxide, CaO	5.19	7.00
Sodium oxide, Na_2O	0.12	0.16
Potassium, oxide, K_2O	0.19	0.27
Water, hydroscopic, H_2O-	0.77	0.32
Water, combined, H_2O+	1.10	0.10
Carbon dioxide, CO_2	30.20	2.40
Titanic oxide, TiO_2	0.22	0.31
Phosphorus pentoxide, P_2O_5	1.83	2.50
Sulphur trioxide, SO_3	0.02	0.75
Manganous oxide, MnO	1.06	1.48
Zirconium oxide, ZrO_2	<0.01	<0.01
Carbon, organic	0.92	0.02
Hydrogen, organic	0.12	....
Metal components:		
Iron, Fe	30.48	41.96
Manganese, Mn	0.83	1.15
Phosphorus, P	0.80	1.09
Total	32.11	44.20
Slag components		
Calcium oxide, CaO	5.19	7.00
Magnesium oxide, MgO	3.75	5.10
Sodium oxide, Na_2O	0.12	0.16
Potassium oxide, K_2O	0.19	0.27
Total	9.25	12.53

SNOW FORK ORE

INTRODUCTION

"In parts of Columbiana County[2] a thin bed of fresh water limestone is found at or not far below the base of the Middle Kittanning clay

[1]Unpublished analyses in files of the Geol. Survey of Ohio.
[2]Geol. Survey Ohio, Fourth Series, Bull. 28, pp. 146-150.

and on or only a few feet above the Oak Hill clay where this member is present. . . . In Columbiana County the Salem limestone lies from 4 inches to 10 feet below the Middle Kittanning coal. The usual measurement, however is 1 to 3 feet. Where both limestone and Oak Hill clay are present, the limestone lies directly on or only a foot or two above the clay. The Salem member varies in thickness from 5 inches to 1 foot 2 inches but averages nearly 8 inches. . . . It is generally siliceous and ferruginous and in places changes into a calcareous sandstone and in other places into an iron ore. The fauna indicates that the limestone is of fresh water origin."

REGIONAL GEOLOGY

Locally in the Hocking Valley ore at this horizon was mined for a part of the burden of the coal furnaces. It was worked most extensively on Snow Fork for Akron furnace and was known locally as the Snow Fork ore. Andrews states:[1] "Nowhere have we found so persistent a horizon of ore as that found a few feet below the great coal seam [Middle Kittanning]. Scarcely anywhere was a section made of this part of the vertical range of strata without the discovery of this ore. It is in nodules, often small, but sometimes very large and heavy. Unfortunately, the nodules are generally too much scattered to make mining profitable, yet there are doubtless many places where this ore might be obtained by stripping, in sufficient quantity to serve a valuable purpose for mixture. A sample obtained on the land of James Hawkins, on Snow Fork of Monday Creek, in Ward Township, Hocking County, was analyzed by Prof. Wormley. The result is given below:

Specific gravity	3.200
Protoxide of iron	37.22
Sesquioxide of iron	3.64
Manganese	1.20
Alumina	0.60
Lime	2.40
Magnesia	2.16
Foreign matter	18.82
Carbonic acid	27.00
Combined water	4.40
Loss	2.56
Total	100.00
Metallic iron	31.50

"The ore is a siderite or carbonate of iron, and yields 31.50 per cent metallic iron. It is often filled with beautiful impressions of coal plants.

"On the farm of Benjamin Saunders, on the west bank of Monday Creek, the stream has cut its way below the great seam of coal [Middle

[1]Geol. Survey Ohio, Report of Progress, 1869, pp. 124-127.

Kittanning], and revealed the same range of nodular ores, found below the coal on Snow Fork and elsewhere. The ore is rich in iron, but the nodules are too much scattered to make mining profitable. Generally in the upper Sunday Creek valley, this ore would be several feet below the beds of the streams.

"Immediately below the Great Vein [Middle Kittanning coal] are frequent outcrops of a compact, very hard, blue carbonate, which appears of good quality, the nodules, sometimes, being of large size. . . . This horizon is accessible in most of the territory north of Moxahala Village, Perry County, and the indications of the presence of the ore are in all respects favorable." [1]

"On lower Monday Creek, and on Snow Fork, the ore is in flat discs, which contain coal plants in a state of beautiful preservation. The same nodular ore is seen under the Nelsonville coal, near the mouth of Meeker Run."[2]

YELLOW KIDNEY ORE

INTRODUCTION

"A much more valuable ore, and the only seam of the entire series that is worked at a considerable number of localities, [in the Hanging Rock Iron District] is the Yellow kidney ore. Its place is 90 to 100 feet above the Ferriferous or Vanport limestone, or from 40 to 50 feet above the ore last mentioned [ore below Middle Kittanning coal]. It belongs to the horizon of the Lower Freeport limestone, sometimes replacing it, and sometimes accompanying it. The kidneys are found scattered through 4 to 6 feet of shale, and when all are counted, the aggregate ranges from 6 to 10 inches in thickness. The ore is valued as highly as any that comes to the furnaces of the district [Hanging Rock]. It can be mined only by stripping, and consequently the ore is at its best. The diggings are nowhere extensive, but the seam is opened at a great number of places. This ore underlies the Lower Freeport or Hatcher coal by a few feet. It is most largely worked on Howard and Buckhorn furnace lands, but it is also mined in considerable amount at Centre, Olive, Mt. Vernon, Hecla, and Little Etna Furnaces." [3]

REGIONAL GEOLOGY

"Between the Middle Kittanning and Lower Freeport coals there occurs in places in Lawrence County a fresh water limestone [Lower Freeport] which is often very ferruginous. In fact, along the outcrop it is often an iron ore and is characterized by a high content of phosphorus, which makes it valuable for some grades of iron. This deposit is best seen

[1] Geol. Survey Ohio, Vol. III, p. 674.
[2] Idem., p. 866.
[3] Geol. Survey Ohio, Volume V, p. 433.

in small areas in Hamilton, Upper, and Elizabeth townships. The thickest deposit of ore noted on this horizon was in Mile Hollow, on Osborn Run on the property of the Hanging Rock Iron Company, where the following record was obtained:

	Ft.	*In.*
Clay, bluish, plastic	3	..
Ore, *Yellow Kidney*	3	6
Sandstone and covered	44	0
Sandstone	20	0

Coal horizon, *Lower Kittanning.*

"The Yellow Kidney is a calcareous, high phosphorus ore with sufficient iron to make it worth while for furnace use. As a general thing it is more than self-fluxing, which adds materially to its value. There are two benches of the ore, the upper one of which carries the largest percentage of iron. This ore was used to a small extent by the charcoal furnaces, and has also been used occasionally by the present furnaces. An analysis of the ore furnished by the Hanging Rock Iron Company follows:[1]

Iron, Fe	34.00
Silica, SiO_2	5.85
Alumina, Al_2O_3	3.66
Lime, CaO	10.50
Magnesia, MgO	0.38
Sulphur, S	0.068
Phosphorus, P	2.393
Manganese, Mn	0.94
Ignition loss	13.60
Hydroscopic water	2.00"

SOUR APPLE, STRAITSVILLE ORE[2]

INTRODUCTION

"In the Upper Sunday Creek region, and northward to New Lexington we find an ore horizon a little above the Norris coal [Lower Freeport]. This ore is locally called the 'Sour Apple' ore, from an apple tree near one of the exposures of this ore, the apples of which were quite disappointing to a party of explorers. It is about 15 feet above the Norris coal. [Lower Freeport].

REGIONAL GEOLOGY

"On the farm of Wesley Moore, in Pike Township, Perry County, this ore is nodular and embedded in white clay [Bolivar]. The nodules are scattered through 2 feet 8 inches of clay, and if in solid mass would form

[1] Geol. Survey Ohio, Fourth Series, Bull. 20, pp. 396-397.
[2] Geol. Survey Ohio, Vol. III, p. 857; Vol. V, pp. 409-410.

a layer of 8 to 10 inches in thickness. On the land of Mr. Harper, a little south of New Lexington, the same ore is in good development.

Analyses of 'Sour Apple' Ore

No. 1 Wesley Moore's.
No. 2 From Harper's farm.
No. 3 Ore reported seven feet above Norris coal at Moxahala.

	No. 1	*No. 2*	*No. 3*
Water	5.80	12.00	1.60
Silicic acid	15.32	14.96	15.96
Iron carbonate	....	....	44.91
Iron sesquioxide	66.66	66.44	28.57
Alumina	2.20	3.20	0.40
Oxide manganese	1.80	0.50	0.42
Lime phosphate	0.89	0.51	....
Lime carbonate	4.84	....	2.80
Magnesia phosphate	....	2.05	....
Magnesia carbonate	1.39	....	4.69
Phosphoric acid	....	....	0.32
Sulphur	0.13	0.08	0.33
	99.03	99.74	....
Metallic iron	46.66	46.57	41.68
Phosphoric acid	0.41	1.35	0.32

No. 1 and No. 2 by Prof. Wormley; No. 3 by E. S. Gregory.

"A partial analysis of a sample of this ore from Sunday Creek gave 43.06 per cent of iron. In places this ore will contain too much phosphorus, but it often appears promising. Where I have seen it, it is nodular, but further explorations may reveal it in a regular layer. South of New Lexington considerable quantities of it may be obtained by easy stripping."

The Straitsville ore belongs to the horizon of the Bolivar clay, underlying the Upper Freeport coal by 10 to 30 feet. Its position is thus 60 to 70 feet above the Middle Kittanning coal.

"The Straitsville ore has been mined in a large way at but a few points, viz., in the hills adjacent to New Straitsville, from which several thousand tons were taken out a few years since [1884] and from the vicinity of Moxahala, where many unsuccessful efforts have been made to find in it a safe basis for iron manufacture. It is known here as the Sour Apple ore, or as nodular ore." [1]

BUCHTEL OR BESSEMER ORE

INTRODUCTION

The Upper Freeport limestone maintains fair continuity across Ohio, but it undergoes variations in thickness, in character, and in

[1] Geol. Survey Ohio, Vol. V, p. 410.

position. It is of fresh water origin and therefore belongs below a coal bed, the Upper Freeport member. Usually the limestone is found from 1 to 10 feet below the coal, the two being separated by clay. The limestone is best developed in the eastern part of the State. In central and southern Ohio the limestone is less certain in development and the deposits become more ferruginous in character. Here, locally, the conditions have favored the weathering of the limestone, with the substitution of iron, FeO, for lime, CaO, to an iron ore. This condition prevails along the outcrop especially in parts of Athens, Hocking, and Perry counties, where formerly this ore was the main reliance for several furnaces.

REGIONAL GEOLOGY

In his report on the Hocking Valley, published in 1878, E. B. Andrews states as follows about the Bessemer ore:[1]

"The next ore of importance above the 'Sour Apple' ore is the Bessemer ore. This has its most marked development at Bessemer [now Buchtel], Athens County. At the Akron furnace, at Bessemer the ore is, by instrumental measurements, 83 feet above the floor of the Nelsonville [Middle Kittanning] coal. A little above the ore is seen at one point a seam of coal believed to be the Bayley's Run seam [Upper Freeport]. At the outcrop the ore is nodular, but a little drifting reveals a layer of blue carbonate, which, at one point, I found to be 2 feet 7 inches thick. Resting upon this layer are thickly packed nodules of ore, the mass averaging, according to Mr. Thomas Black, 1 foot 6 inches in thickness. The ore is generally more or less oxidized on the outcrop, but in the drifts becomes hard and blue. At first it was supposed that the overlying nodules were chiefly composed of carbonate of lime; indeed they were called "lime bowlders," and were to be used in the furnaces rather as a flux than as an ore, but it is reported that they have been found, by trial, to be a useful ore. I have no analyses of the Bessemer ore at this place. The ore is siliceous, and obviously not very rich in metallic iron. It doubtless contains phosphorus enough to make the iron cold-short; but it is abundant and near the furnace [Akron], and can be obtained very cheaply.

"The Ogden furnace, higher up the valley of Snow Fork, [southeast quarter of Section 2, Ward Township, Hocking County] obtains its native ore from the Bessemer seam. The ore is similar in appearance to the ore at the Akron Furnace. The lower bench is reported to be from 10 inches to 2 feet in thickness, with an estimated average of 15 inches. Upon this rests a layer of the so-called "lime bowlders," the mass ranging from 1 foot to 1 foot 8 inches in thickness. I have no analyses of the ore of the lower bench, but the nodules above are reported to yield from 8 to 20 per cent of iron.

"On the Cawthorn farm, on Monday Creek, near Bessemer, [Buchtel]

[1]Geol. Survey Ohio, Vol. III, pp. 868-872.

the Bessemer seam of ore shows a fine outcrop of nodules, in all from 4 to 5 feet in thickness. There is no drift opened [1884] to reveal the thickness of the lower bench of ore. Here the ore is, by Locke's level, 83 feet above the bottom of the Nelsonville [Middle Kittanning] coal, and 17 feet above the limestone, which, at this place, is from 3 to 4 feet thick. Some years since I obtained a sample of the outcrop ore, thoroughly oxidized, which Prof. Wormley analyzed with the following results:

Water	10.70
Silicic acid	36.45
Alumina	0.18
Lime phosphate	0.62
Magnesia carbonate	0.52
Magnesia phosphate	0.33
Iron sesquioxide	50.50
Sulphur	0.06
Total	99.36
Metallic iron	35.35
Phosphoric acid	0.48

"The ore contains an undesirable percentage of silica, but in other respects is of fair quality. When the mine is driven under the hills, the ore will become a blue carbonate, but probably much oxidized ore may be obtained by stripping along the outcrop. Here, as at the Akron Furnace, the ore, limestone, and coal are all in the same hill and can be put into a furnace at very small cost.

"On Meeker Run, below Nelsonville, the Bessemer ore, 1 foot 11 inches thick, is reported on the land of J. L. Gill, Esq. It is 76 feet above the Nelsonville [Middle Kittanning] coal. It is 11 feet 7 inches below the Bayley's Run [Upper Freeport] coal, here about 90 feet above the great seam. About 12 feet below the Bessemer ore is the limestone, 2 feet 10 inches thick.

"I have little doubt that the Bessemer ore will be found extensively, in the hills west of the Hocking River, in the vicinity of Nelsonville. I think I have seen traces of it on Floodwood, and it is reported at Salina [Beaumont], and as far north as Lick Run. In the hills between the Hocking River and Monday Creek it is often seen. W. B. Brooks, Esq. reports its existence, in fine thickness, on his coal lands in Section 19, Ward Township, Hocking County. It is said to be nodular above and in a solid layer below. This ore is about 85 feet above the Nelsonville [Middle Kittanning] seam of coal and 18 to 20 feet above the limestone. The Bayley's Run [Upper Freeport] coal, 3 feet thick, is found a little above the Bessemer ore.

"The Bessemer ore is reported by Mr. F. Baird on the lands of the Monday Creek Iron Company [Section 14, Ward Township, Hocking County], but at the time [1884] of my visit the test pits, which had re-

vealed it, were not open. The same ore is reported at Carbon Hill. On the coal lands of Peter Hayden, Esq., a somewhat remarkable deposit of ore is found in the horizon of the Bessemer ore, 87 feet above the floor of the Nelsonville [Middle Kittanning] coal.

"At several points the ore on the Bessemer level is well opened and exposed. It is generally a dark red ore, well oxidized. In one hill the ore ranges in thickness from 1 to 4 feet. Over it is a thin siliceous band 4 inches thick, and above this from 2 to 20 feet of clay, in which are occasional nodules of ore—some quite large. In another hill a pit revealed 1 foot 8 inches of the same red chalky ore.

"In a third hill the ore is nodular, but still red. The nodules are imbedded in a fire-clay and the clay sometimes forms a part of the nodules, giving them a peculiar mottled appearance. Over these nodules is a layer of light colored limestone, but this sometimes becomes nodular. There is evidently a large quantity of the red ore on the estate [Peter Hayden's]. Two analyses of the red ore have been made by Prof. Wormley, with the following results:

	No. 1	No. 2
Specific gravity	2.558	....
Water combined	3.00	1.70
Siliceous matter	28.20	24.52
Iron sesquioxide	43.51	44.29
Alumina	2.00	1.80
Oxide manganese	1.00	0.75
Lime carbonate	21.21	21.99
Lime phosphate	0.41	2.49
Magnesia carbonate	0.52	1.36
Sulphur	0.12	0.10
Total	99.97	99.00
Metallic iron	30.56	31.00
Phosphoric acid	0.19	1.14

"The phosphorus in one of the samples analyzed by Prof. Wormley is pretty large, but that in the other is quite small for an ore from our Ohio Coal Measures. The peculiarity of the ore is the large percentage of lime carbonate disseminated through it. Thus brought into immediate contact with the particles of silica, the lime will serve an admirable purpose for flux, and the ore will scarcely require any added lime in the furnace. The ore is a very peculiar one, and a little special practice with it may be needed to show the best manner of treatment in a furnace.

"On lower Sunday Creek, in Trimble Township, an iron ore found a little below the Bayley's Run [Upper Freeport] coal has been reported. The ore is nodular, but the nodules are often large. Further exploration may reveal its existence in a solid layer. A sample was analyzed by Prof. Wormley.

Water	6.15
Silica	18.44
Iron carbonate	31.16
Iron sesquioxide	26.68
Alumina	2.20
Oxide manganese	5.30
Lime phosphate	0.21
Lime carbonate	5.25
Magnesia carbonate	4.54
Sulphur	0.06
Total	99.99
Metallic iron	33.72
Phosphoric acid	0.10"[1]

"An entirely similar association of buff limestone and ore is met, for the third time, at 10 to 15 feet elevation above the last named bed, [Upper Freeport limestone], or at about 75 to 85 feet above Coal No. VI. The ore now to be considered is better known than either of the others [Norris and Straitsville ores] which it resembles so closely. It has had, heretofore, a very unfortunate designation, viz: the *Bessemer ore,* the name being derived from the site of the Akron Furnace Company on Monday Creek, in the Hocking Valley. It can well be substituted by the name of the enterprising head of the Akron Company, and the ore will be here known [named by Orton] as the *Buchtel ore.*

"Except the Great Coal seam [*Middle Kittanning*], no other stratum of the Hocking Valley has awakened [1884] so much interest and excitement as the Buchtel ore. Its outcrops in the vicinity of Akron Furnace show a wall from 3 to 6 feet in thickness, and it is evident that the ore may be quite lean and yet make a valuable contribution to the iron manufacture of the State. The ore contains from 20 to 30 per cent of iron under cover, the average of many analyses being about 24 per cent. The percentage of silica varies, being sometimes, though rarely, as low as 8 per cent, but the usual figures vary between 12 and 20 per cent. The average is not less than 15. It is to be remembered, however, that in the lime of which the ore carries a notable percentage, a part of the flux is contained, and the percentage of silica can accordingly be looked upon as the double one of ore and flux.

"The results obtained from Akron Furnace have been watched [1884] with great interest, as widely different views have been held in regard to the character and availability of the seam. On the whole, it can be said that a considerable value has been shown to belong to the seam in this immediate locality."[2]

"The Buchtel ore has by far its best development in the vicinity of Buchtel Furnace, where also it has been largely worked, and the location

[1]Geol. Survey Ohio, Vol. III, pp. 869-872.
[2]Idem., pp. 909-910.

of which was fixed in part by the presence of these deposits. The Buchtel ore is a lean carbonate of iron, always calcareous, and often passing by easy gradations into an impure limestone. The nodules or bowlders that compose it are of large size, and are very hard and heavy. They are imbedded in clay, and are light gray in color, sometimes inclining to blue. The thickness of the seam at its best is between 5 and 6 feet, and there are considerable areas where it exceeds 2 feet in thickness. The upper portion, where the seam is thickest, generally consists of a separate layer of nodules, more calcareous than the main seam, and called distinctively, bowlder ore. The outcrop ore is rough and unpromising for the most part, though an occasional mass of fair quality is found. Analyses of seven samples, selected from the stock pile of calcined ore at Akron Furnace, when the seam was first worked, showed an average of a little less than 21 per cent of metallic iron [Howard]. The bowlder ore was mined with the rest of the seam at this time. When this is left out, the percentage runs higher. The best of the calcined ore is said to yield 33 per cent in the furnace. There is a considerable amount of lime in it, but the proportions are entirely uncertain, and it can never be safely used for flux. There is no way of knowing what proportions of iron and lime go into the furnace top where the products of this seam are used.

"The same seam has been mined on a large scale at the new furnaces [1884] at Floodwood. The ore taken out was mainly outcrop ore, and it thus makes the best possible showing for the seam. . . . This stratum, though massive and conspicuous, is not, therefore, considered as adding to the resources of the valley [Hocking] in iron manufacture."[1]

BLACKBAND ORE, UPPER FREEPORT COAL HORIZON

INTRODUCTION

The Upper Freeport coal, marking the top of the Allegheny series, is one of the prominent fuel-bearing members in Ohio and crosses the State from Columbiana County on the Ohio-Pennsylvania line to Lawrence County on the Ohio River. The member is characterized by variations in thickness and in quality. The horizon may be marked by thick beds of coal, by mere soot streaks of carbonaceous matter, or by intermediate phases. The overlying shales, locally, are rich in ferruginous matter, thus becoming the blackband ores that formerly were so useful in iron smelting. Deposits of this character are most abundant and have been most extensively worked in Tuscarawas County. They are present also but to a less extent and with less purity in Stark, Carroll, Guernsey, Perry, and Gallia counties.

[1]Geol. Survey Ohio, Vol. V, pp. 410-411.

REGIONAL GEOLOGY

TUSCARAWAS COUNTY

"The Upper Freeport coal is quite a constant feature in the sections exposed in Tuscarawas County, but throughout the northern and central townships, it has little economic value. On entering the county from the north, it is first seen in the tops of the hills about Zoar Station, and thence southward, is continuous in all the highlands, to the Guernsey County line. It is locally known as the blackband coal, from the fact that the important blackband deposits of the county rest directly upon it, and hence, its place is well known to a large part of the inhabitants. On the old furnace tract at Zoar Station, Coal No. 7 is 3 to 3½ feet in thickness, soft, sulphurous, and poor. In the highlands, between the Conotton and the Tuscarawas, it is shown in all of the blackband ore mines, being usually taken out with the ore. It is here from 1 to 2 feet in thickness and generally quite sulphurous. In the highlands west of the Tuscarawas, in the townships of Salem, Bucks, Auburn, and Sugar Creek, quite a large territory lies above the horizon of coal No. 7, and it is opened at numerous localities, in connection with the important deposits of blackband ore found there. Throughout this region the coal is thin and poor."[1]

"The blackband ore of Tuscarawas County has been so fully investigated during the forty years [prior to 1878] through which it has been sought and worked, and so fully described in our reports, that comparatively little will need to be said of it here. It is already known to most persons that this variety of ore is simply a black bituminous shale impregnated with iron. The degree of impregnation varies greatly; most of our black shales contain some iron, but generally too little to have any value as ores. In these varieties which are classed as blackband ore, the quantity of metallic iron varies from 25 to 40 per cent.

"To an uneducated eye this material has very little the appearance of an iron ore, and would be, and doubtless has been, frequently passed as simply a black shale. It is highly charged with carbonaceous matter, and its specific gravity is usually not so high as to arrest attention. Its valuable properties are therefore so much masked that it was rather by accident than otherwise that Mushet in 1801, discovered the value of the blackband of Scotland, and laid the foundation of the great iron industry of that country. To a practiced hand the greater weight of the iron-bearing shales will serve for their detection, but where the quantity of iron contained can not be conveniently measured, a sufficient test will be afforded by burning a heap of shale in the open air or elsewhere, when, if it contains iron enough to be valuable, this will 'loop,' as it is said, that is, will agglutinate and form scoriaceous masses of great density.

"When subjected to the action of the weather the blackband ore decomposes like any other shale, and its carbonaceous matter being re-

[1]Geol. Survey Ohio, Vol. III, p. 72.

moved by oxidation, it falls into a mass of thin brown or rusty flakes, which, though looking no more like iron ore than the unchanged material, should be recognized by the explorer, for this is the only form of the ore which will be exposed to his examination in natural outcrops.

"The geological position of the blackband of Tuscarawas county is, as has been stated on a preceding page, immediately above Coal No. 7, and at the base of the Barren Measures. This is a strongly marked iron horizon, although the ore found here varies considerably in character.

"It would seem that this ferruginous deposit was made by the drainage from a surrounding land area into a circumscribed basin of comparatively shallow water. In some parts of this basin carbonaceous mud heavily charged with iron accumulated, which subsequently formed the blackband; in others clay without vegetable matter, but generally containing considerable iron, and this, as is usual in such cases, subsequently segregated to form nodules of kidney ore. In the deeper portions of this basin, where the water was clearer, a limestone was deposited, and this also, in some localities, contained enough to become a valuable calcareous ore, now known as *mountain ore*. These three kinds of material were precipitated almost simultaneously, and they are frequently found to alternate one with another, so that along a somewhat extended outcrop the ore worked will be in one place blackband, in another mountain ore, and in a third shell ore; and also on one side of a hill Coal No. 7 may be overlain by a sheet of blackband even eight or ten feet in thickness, while on the other side of the same hill no blackband occurs, but instead some other form of ore, or even barren material. Wherever blackband and mountain ore are found together, as they frequently are, the former is always beneath the latter, from which we learn that it was really deposited first. Generally, in such cases, the mountain ore is found to thicken in one direction, the blackband in the other, showing that the calcareous deposit extended from a lower level—a deeper portion of the basin—up over the carbonaceous mud which had previously partly filled it. From what we know of the formation of coal we can positively assert that Coal No. 7, accumulated in a marsh, precisely as peat now forms by a growth of vegetation in the open air; in other words, that it was practically a land surface. That this peat bed was subsequently covered with shale and limestone proves that it was depressed and covered, first with shallow water, in which carbonaceous mud and clay were first deposited, the former deriving its organic material from the disintegrated peat. As the subsidence progressed the water in the basin became clear enough to permit the formation of limestone, which was naturally purest and thickest in the deeper places, and thinned away to an edge on the muddy shallows.

"It has been reported that the blackband ore has in a few places been found to reach a thickness of twenty feet, but no such development of the deposit has come under my observation. It usually ranges from three to six feet, but at the mines of Mr. A. Wilhelmi, in Auburn town-

ship, and in the Patterson ore-bank near Port Washington—now owned by the Glasgow Port Washington Iron Company—I have seen ten and even twelve feet of solid ore.

"The iron found at this horizon, in the form of blackband, or mountain ore, where present in full force, constitutes by far the richest ore deposit of the State. Tracts of many acres might be specified underlain by a continuous sheet of blackband, eight feet in thickness, and since this contains twenty-five per cent of metallic iron, it is equivalent to a sheet of cast-iron over two feet in thickness of equal extent. The inhabitants of Tuscarawas county may, indeed, congratulate themselves that they are the possessors of nearly all this valuable deposit found in the State, and that so large an aggregate area of the county is underlain by it that it has already largely contributed to the wealth of the county, and is destined to be an important source of revenue for many years to come; but it is greatly to be regretted that only a small fraction of the original deposit now remains. This evidently was once continuous throughout the greater part of the county, but lying as it did high in the series, and near the surface of the plateau, which once occupied all this portion of the State, it has suffered terribly by the erosion that has carved the present varied topography out of that plateau, and only a meager remnant in the hilltops bordering the broad valleys mark its horizon.

"Outliers of the blackband stratum are found in the highlands of Osnaburg and Paris, in the central part of Stark county, in those of the western side of Carroll, and the northeastern part of Coshocton, while local representatives of the deposit are found in nearly all the townships of Tuscarawas county. It is evident, therefore, that the basin in which it accumulated once stretched over all the interval between those limits. It may have reached much further to the north and west, as in this direction all the old landmarks are cut away by the erosion of the surface; but on the south and east we are apparently able to trace its former boundaries: since with abundant exposures of the horizon where the blackband lies, no indications of its existence are found much beyond the line of Tuscarawas county.

"The blackband ore of this region was first discovered and utilized by the Zoar Community over forty years ago. The portion of their lands which lie in the northern part of Fairfield township, includes hills that run up into the Barren Coal Measures, and these were found to contain valuable beds of blackband and mountain ore. To work these, a charcoal furnace was erected nearby, where iron continued to be manufactured for twenty years. This is the most northern outcrop of the blackband in Tuscarawas county. Both varieties of ore occur here, varying much in their respective developments; the blackband from three to eight feet in thickness; the mountain ore from two and one-half to five, perhaps averaging three feet of good ore.

"From the Fairfield furnace the blackband deposits run through the

highlands toward Dover, and south between the Conotton and Tuscarawas. In this district the best known ore beds are those of Clover Hill, so long worked by Messrs. Tod & Rhodes, the Junkin bank, and the mine of the Tuscarawas Coal and Iron Company. Ore is also found on the farm of Benjamin Riggle, worked by Mr. Burton of Massillon. The blackband here is five feet in thickness, with three feet of mountain ore over it. On the farm of Hugh Kelley an outcrop of the blackband, thin and near the surface, is seen.

"The most important deposits of blackband ore in the county are in the townships of Auburn, Bucks, Salem, and Oxford. Of these, the first four lie on the highlands west of the Tuscarawas, and are drained by Sugar Creek, Stone Creek, and Oldtown and Buckhorn Creeks. Here the land in some places rises to the height of one hundred and twenty-five feet above the blackband horizon, and quite a number of more or less extensive basins, or patches of ore, are known to exist, some of which have been worked for twelve or fifteen years. The most important deposit seems to be that of Mr. A. Wilhelmi, in Section 24, Auburn township, where the ore has been taken from seven or eight acres, and thirty or more acres still remain. The average thickness of the ore here is from five and one-half to six feet, though a maximum thickness of eleven feet of good ore has been met within the workings.

"A section which I took at Wilhelmi's bank, is as follows:

	Ft.
1. Shale and sandstone	125
2. Fine black shale	1–3
3. Blackband ore	9
4. Coal No. 7	2
5. Fire-clay	1
6. Slope, covered, mostly shale	95
7. Coal No. 6	3
8. Fire-clay and shale to creek	15

"At another opening the section exposed is—

1. Shale	15
2. Mountain ore	2–2½
3. Blackband ore	2½
4. Coal	1½

Here the mountain ore is seen to run out to an edge.

"There are several limited deposits of blackband in the vicinity of Wilhelmi's mine, and between that point and New Philadelphia, belonging to Gabriel Shull, U. Shaw, and others. A large amount of ore has been taken from Wilhelmi's mine, for the most part manufactured in Massillon, and has been proved to be of excellent quality. Its composition in the natural state is given in the tables below. Like all blackband ore, it is calcined with great facility, scarcely requiring any other fuel than that

contained in itself. When so calcined, on an average two tons of ore will make a ton of iron which closely resembles Scotch pig, is used for the same purposes, and is equally esteemed.

"Three miles west of Phillipsburg a deposit of blackband is leased and mined by Mr. H. Andemann, and the ore is also found in some other hills in the vicinity. Farther south, on the farm of Jacob Rheinhart, I noticed the characteristic outcrop of the blackband in the road near Mr. R's house. No exploration has, however, been made in this vicinity to determine its thickness and extent.

"Still further south, in Salem township, west of Port Washington, are deposits of blackband ore, which have been already shown to be quite extensive, and some of them have been worked for a long time. The more important of these have been purchased by the Glasgow-Port Washington Iron and Coal Company, an organization of Scotch capitalists, attracted by the resemblance of the ores of this region to those of their own country.

"They have erected two large and fine furnaces, and but for the depression in the iron trade would now be producing a large quantity of first class iron. The purchases made by this company are supposed to include more than one hundred acres of blackband territory, and it is evident that if suitable fuel can be prepared from Coal No. 6, which is here from five to seven feet in thickness, this will become the theater of an active and successful iron industry.

"The southern limits of the blackband area have, up to the present time, not been well defined, and it was until recently supposed that no important deposits of it existed south of the Tuscarawas. Extensive explorations have, however, been lately made by Mr. A. Wilhelmi, in Oxford township, which have resulted in the discovery of 'basins of ore,' which rival in extent and value any before known. These are all located within two or three miles of what is called Post Boy Station, on the Marietta, Pittsburgh and Cleveland Railroad. The several tracts controlled by Mr. Wilhelmi and his associates are supposed to include one hundred and fifty acres of productive ore ground, where the blackband varies in thickness from three to nine feet. All these tracts are within easy reach of the railroad, and it may be confidently expected that a large contribution will be made from this district to the wealth of the county.

"I am informed by Mr. Wilhelmi that in his explorations for blackband, in Oxford township, he discovered by boring, an important body of ore unknown elsewhere, lying from forty to fifty feet below the blackband stratum. He reports it as a light-gray siliceous ore, shown by analysis to contain thirty-nine per cent of metallic iron, and consisting of closely approximating layers or plates, having an aggregate thickness of from three to nine feet.

"On a former page I have referred to the discovery by my associate, Prof. J. T. Hodge, of a well-marked stratum of blackband on the Still-

water, some eight or nine miles south of Uhrichsville. No effort has been made, so far as I can learn, to determine accurately the extent and value of this deposit, but it affords another indication of the southward reach of the blackband, and such as should encourage further exploration in this part of the county. In this connection I will mention that I am informed by Prof. J. J. Stevenson that a well defined, though perhaps not extensive development of blackband is found on the farm of Mr. Proctor, in Liberty Township, Guernsey county."[1]

"The Tuscarawas blackband is also less rich than the blackband of the Mahoning Valley, before alluded to. The following analyses of the ore used at the Dover Furnace will show the composition of the ore, both in its raw and calcined state:

	Raw	Calcined
Specific gravity	2.321	3.411
Carbonic acid	15.00	....
Water	....	0.25
Volatile matter	21.00	....
Siliceous matter	26.22	17.02
Iron peroxide	8.79	75.00
Iron protoxide	23.02	....
Alumina	0.70	0.60
Manganese	1.70	1.65
Lime	1.70	2.80
Magnesia	0.88	1.48
Phosphoric acid	0.492	0.773
Sulphur	0.11	trace
	99.712	99.573
Metallic iron	24.06	52.5

"The blackband has been mined chiefly by stripping the outcrop and quarrying on the face of the stratum. A wall of the ore thus exposed, 10 or more feet in height, and several hundred feet long, is a sight of no little interest. The ore has thus been very generally worked by simple quarrying, though now considerable is obtained by a regular system of mining by drifts and galleries, as in working a coal seam. The great thickness of the bed renders this method easily applicable, and in this manner the ore may be mined for 75 cents per ton, one man easily producing 3 tons per day. When mined the ore is usually calcined on the spot in heaps, and the burnt ore then transported to the smelting furnaces. In building the piles, the ore is placed on its edge, so as to facilitate the operation. Considerable quantities of fuel have been heretofore mixed with the ore in the heaps, though it seems that there is sufficient carbonaceous matter in the blackband itself to produce the calcination when once the combustion has been started. The fuel that has been used for this purpose is the underlying coal No. 7, which contains considerable sulphur, and hence

[1] Geol. Survey Ohio, Vol. III, pp. 74-80.

is disadvantageous, as it contaminates the ore with the ash and increases the amount of foreign matter. The fact of the coal thus adding impurities to the ore, which affect the quality of the iron, is becoming understood, and less is now being used, though any fuel beyond the amount required to start the pile seems hardly necessary. The ore is so easily reducible and fusible, that notwithstanding the care which may be taken in the hottest parts of the pile, and if the heat has been too high, these masses or 'loups' are so hard, as to require severe labor to remove and break them up. In calcining, the ore loses considerable as fine dust, which is separated by screening, but it becomes enriched by the expulsion of the volatile matter from an ore of 25 per cent to one containing 50 per cent of metallic iron. At the Massillon and Dover furnaces there are consumed about 2 tons to 2½ tons of ore to make a ton of pig-iron. The value of this ore, of course, varies, owing to different circumstances, but in 1879-80 it was worth in the neighborhood of $2.50 to $2.75 at the furnaces." [1]

STARK COUNTY[2]

"The chief interest which attaches to Coal No. 7 in Stark county comes from the fact of its association with the blackband ore which overlies it. This is a bituminous shale, highly impregnated with iron. It often, though not constantly, forms the roof of Coal No. 7, and where present attains a thickness of from three to eight feet. The blackband ore is generally, though not always, overlain by a ferruginous limestone, in which the quantity of iron is sometimes sufficient to render it a calcareous iron ore. From the fact that this is only found in the tops of the hills, it is sometimes designated as the *mountain ore;* and the limestone, from its ferruginous character, assumes, on weathering, a brownish color, and is hence often referred to as the 'buff' limestone to distinguish it from the blue limestones below. These ore beds are detached outliers of a great ferruginous sheet which once covered much of Stark and Carroll and all of Tuscarawas county. Patches of this ore sheet, separated from their connections by the erosion of the valleys of the Sandy, Conotton, and Tuscarawas, occur in the isolated hills of Osnaburg and Paris, the only portions of the county geologically high enough to include them. Such being the geological position of this important formation, it can not be expected to be found in any other portion of the county, even though the hills may there rise up to an equal relative or absolute height with those referred to. It is important to bear these facts in mind in order that time and money be not wasted in useless search for the blackband and mountain ore.

"I subjoin analyses of the raw and calcined blackband from Robertsville:

[1] Geol. Survey Ohio, Vol. V, pp. 465-466.
[2] Geol. Survey Ohio, Vol. III, pp. 175-6.

	Raw	Calcined
Water	18.60	....
Silica	31.40	12.88
Iron, oxide	18.75	69.94
Iron, carbonate	23.14	....
Manganese	1.80	3.15
Alumina	1.00	7.00
Lime, phosphate	0.72	2.35
Lime, carbonate	0.75	....
Lime	....	1.76
Magnesia	2.86	2.16
Sulphur	4.28	0.14
	99.30	99.37
Metallic iron	24.28	48.95
Phosphoric acid	0.31	1.08"

STARK, CARROLL, AND TUSCARAWAS COUNTIES[1]

"The blackband ore of this area is the most important source of iron in Northern Ohio. It is the second ore in general value in the State, ranking below the limestone ore of the Hanging Rock district alone in this respect. With the last-named ore it disagrees in almost every particular of geological occurrence. The limestone ore is both steady and persistent, covering hundreds of square miles almost continuously with its thin but excellent sheet. The blackband is extremely capricious in its occurrence, and treacherous in its development. It forms the cap of scarcely more than 50 hills, scattered through three counties, and in these hills it ranges from a maximum of 19 feet to zero, an acre or two being often sufficient to accomplish the whole range of changes.

"Throughout this field it everywhere deserves its name of blackband. There is almost always a foot or two of coal, generally poor in quality, underlying it, and thin streaks of coal generally extend through the ore itself. But whether coal is present in the body of the ore or not, carbonaceous matter is never wanting. There is nearly enough of this substance generally to calcine the ore. Its specific gravity for the same reason is light for an iron ore, ranging generally from 2.3 to 2.5. When calcined, the figure that represents its gravity is nearly a unit higher than the figures above given. The banded structure is very distinct in all portions of the ore, as much so as in ordinary bituminous shales.

"The raw ore ranges from 20 to 30 per cent in metallic iron, the calcined ore from 45 to 55 per cent. .

"Above the blackband proper there are frequently found other large accumulations of ore, which by strict classification would need to be considered in other divisions, but which can be dealt with to best advantage in the present connection. The mountain ore, so-called, is one of the

[1]Geol. Survey Ohio, Vol. V, pp. 886-898.

forms of limestone ore to which attention has already been directed, where carbonate of iron replaces locally the carbonate of lime in a stratum of the Freeport type. Many kidneys of ore also occur at the same general level.

"The geological place of the blackband has already been assigned. It is borne by and is part of the Upper Freeport coal seam. It is found only on the outer margin or outcrop of the formation, thus far, though notable accumulations of iron can often be found with the seam as it descends towards drainage. This marginal development of the ore needs to be distinctly recognized. The usual element to which we refer in establishing the sections in which the blackband occurs is the Middle Kittanning coal, or No. 6 of Tuscarawas county. Counting from this, the average intervals in different portions of the field are as follows: 110 ft., 114 ft., 117 ft., 118 ft., 120 ft., 120 ft., 120 ft., 125 ft., 130 ft., 132 ft., 143 ft., 145 ft., 147 ft., 148 ft., and 150 ft. In no single case does the measure fall to 100 feet. A difference of 20 feet can often be found for the level of the ore itself in different portions of the same basin. The ore generally lies on an uneven floor, and frequently in well-defined and quite limited basins.

"The first display of blackband as we enter this district from the east and north is found in the northeastern corner of Osnaburg township. An area of small extent, perhaps not an acre, is found capping a hill with not a dozen feet of cover at the highest point. It is owned and worked by the Grafton Iron Company, of Leetonia. The ore has a maximum thickness of 14 feet. Coaly streaks are distributed through the whole mass. Much of it is considerably weathered, and it splits into thin lamina, but the whole seam is taken for furnace use, and taken at the present time without calcination, being used raw in the furnace. The deposit is nearly exhausted. The interval from the Middle Kittanning coal to the blackband is here 118 feet, as outlined by a single measurement. A single analysis gives the following result:

Blackband from Grafton Iron Company's Mine—Osnaburg Township
(Average of 15 feet.) (Lord)

Silica	13.26
Iron protoxide	1.80
Iron sesquioxide	41.08
Alumina	7.93
Manganese oxide	1.42
Lime	2.07
Magnesia	0.65
Carbonic acid	3.47
Phosphoric acid	1.362
Sulphur	0.175

Water and organic matter	25.23
Moisture	2.13
	100.57
Metallic iron	30.15
Phosphorus	0.592
Sulphur	0.175

"A small area has already been entirely worked out by the Burton Ridgway Company, of Massillon, from the intersection of sections 11, 12, 13, 14 on a farm now owned by Thomas Tinkler. The maximum thickness of the ore, as reported by Mr. Tinkler, who superintended the mining, was 18 feet 11 inches. This is the highest measure recorded in the field. This body was also without cover, and the whole hill top was carried away in the workings.

"In Paris township, north of Robertsville, three small deposits have been worked for a number of years, at intervals. The ore does not rank as high in these areas as at some other points. The ore hills are known as the McNutt, Wolf, and Shull banks, respectively. Their combined acreage is small. A considerable body of the ore is still left in these deposits.

"In Sandy township, of Stark county, no valuable beds of the ore have yet been discovered. The horizon is very clearly displayed at many points, and on several farms the Upper Freeport coal has been worked on a small scale. On the land of David Stull, for example, on the west side of the township, a large body of lean ore, overlying the Upper Freeport coal, was mined and calcined many years ago, but the ore was pronounced unfit for iron manufacture, and it still lies in the kilns. Several other attempts have been made to find the ore in this township, but, though several banks have been opened, none of them has furnished ore of proper quality.

"Better fortune has attended the development of this horizon in the adjacent township of Rose, in Carroll county. Three separate but closely contiguous hills have been found to hold blackband ore of fair quality. They are situated on the Rhinehart, Creighton, and Newhouse (formerly Gibler) farms, respectively, and are all embraced in section 24. The interval from the Middle Kittanning coal, which is mined at the foot of the hills in which the ore banks are found, is 130 feet for the Rhinehart farm, and 147 feet for the Creighton farm. The Rhinehart bank has been entirely worked out. A little ore is left in the other areas. At the Newhouse bank it is 3½ feet thick. Considerable ore has been mined here, but it was pronounced too lean, and was consequently abandoned. Samples were taken from this rejected ore for partial analysis, the result of which is given below:

Analysis of Newhouse Blackband (Lord)

Silica	12.39
Metallic iron	25.63
Phosphorus	0.157
Sulphur	0.46

"The figures show an excellent ore, that ought to be handled with profit in any furnace that is using blackband. There is certainly nothing in the analysis to justify the discarding of the ore. It is quite up to the average of blackbands in metallic iron, and it is much lower in silica than most of the ores in this class. The only question is whether the samples fairly represent the bank. They were taken with this specific object from the piles that were mined, but never removed from the ore bank.

"The next deposits of ore in following southwestward are found in Tuscarawas county. This county is, by way of excellence, the blackband field of the State, and the seam is generally and justly known as the Tuscarawas blackband.

"The map of the county that appears on page 257 [Vol. V] indicates the positions of all the ore hills of the county. The observations already recorded in Stark and Carroll counties can be combined with these to show the area occupied by the seam (see map on page 65, Vol. V). It is confined in its characteristic development, according to present knowledge, to the townships of Osnaburg, Paris, and Sandy, of Stark county; Rose, of Carroll county; and Sandy, Fairfield, Dover, York, Auburn, Jefferson, Salem, and Oxford, of Tuscarawas county. A line drawn from the northeast corner of Osnaburg township to the northeast corner of Auburn township would mark approximately the western outcrop of the ore for the first portion of its extent. Such a line would be about 25 miles in length, and its direction would be nearly southwest. From the northeast corner of Auburn township, the field is continued to the southward, but the direction of its axis is abruptly changed. A line running from this point due south, and 20 miles in length, will mark the approximate western outcrop of the field in this direction. In both portions, a breadth of 6 miles, at right angles to the line of western outcrop, will reach every ore hill. The greatest developments of the ore are found in Auburn, Jefferson, and Oxford townships, and these are represented in a subsidiary map which will presently appear.

"Returning to the northern boundary of Tuscarawas county we find but little land in Sandy township high enough to receive the ore, but on at least one of these few points the ore is reported. On the farm of Wm. Gordon, one mile east of Mineral Point, the coal of the seam is 20 inches thick, and the blackband is developed also to some extent. As to its quality and quantity, there are conflicting statements. The hill has been

sold or leased as an ore property, but the contract is now before the courts.

"In Fairfield township two bodies of blackband are being mined at the present time, but a number of separate areas have already been exhausted, the credit for the discovery and first use of the ore belonging to this township (see Volume III, page 77).

"The two tracts now furnishing ore are the Labb hill, near Zoar Station, and the Kelly farm, a little more than 2 miles south of the former. The ore of the first is mined and used by the Tuscarawas Coal and Iron Company, of Dover; the Kelly ore is mined by a company from Massillon. This mine is under heavy cover, and the ore is wrought in rooms by regular methods. The seam ranges from 3 to 8 feet in thickness, and the probable average is 5 feet. It is in all respects a fine body of ore. It has been necessary thus far to follow the seam along the line of dip, and consequently the workings are constantly troubled with water. Both blackband and mountain ore are yielded by this mine, the proportions being two of blackband to one of mountain ore. The Riggle Hill, near by, has been entirely exhausted.

"Extensive stripping has been done on the Labb farm, the height of the bank sometimes reaching 25 feet, but part of the ore is also gained by drifting. There is not a large body of the ore left.

"The possible blackband territory of the township is quite extensive, and, though considerable exploration has been carried on by the drill and otherwise, it is not necessary to believe that the ore is all known at the present time.

"But two small tracts of blackband are known in Dover township. There is not a large amount of land in the town that is high enough to catch the ore.

"A mile south of Zoar Station, and nearly opposite to the Labb Hill already described, the Tuscarawas Coal and Iron Company, of Dover, own a small tract of blackband that has not been fully developed. No mining is done in this seam in Dover township at the present time.

"The two townships south and southwest of Dover, viz., Auburn and York, contain, or rather have contained, some of the noblest bodies of ore in the whole blackband field, but the ore has been chiefly mined out from York, all operations here having ceased. From Auburn, also, a large quantitiy has been taken, but a considerable acreage still remains, and the work of mining is going forward.

"The chief banks in York township were the Bear hill, in lot 32, N. W. ¼; the Burkholder hill, lots 12 and 13, N. W. ¼; Winkler's and Shull's hills, section 16, and lots 5 and 6, N. W. ¼.

"Considerable ore has been left in all of these deposits, but generally in such a condition that it can not be recovered with advantage. The earlier workings were without system, and were consequently wasteful.

"There is still an area which is supposed to hold the ore, on lots 30, 33, and 35. It is high enough, and surface indications are counted favorable.

"Three famous hills contain the known supply of Auburn township, viz., the Beller hill, the Shaw hill, and the Lahmer hill. All these are shown in the accompanying map of 'Blackband Deposits,' section C.

"The Beller hill contains an aggregate of perhaps 160 acres of blackband territory. Not less than six separate mining properties are established on it. They are named as follows: Beitzel's, Reif's, and Gribel's on the north side; Catcott's, Beller's, and Rock Island, on the south. Of these the Beitzel and the Beller workings are nearly exhausted. All the rest hold large bodies of ore.

"Both blackband and mountain ore occur here in their characteristic forms. They play fast and loose with the seam, and it is hard to estimate the proportions of each. The aggregate often reaches 8 feet, and sometimes 10 feet. The ore is not worked below 2 feet, as a rule. The ore is mined by system, in drifts, at the present time. About 2 feet of coal is expected with the ore. As much of it as is necessary for calcining the ore is brought out of the mine. A tram road runs from the hill to Blackband Station, on the Wheeling and Lake Erie Railroad. The ore from this region has been taken thus far by the Dover and Massillon furnaces.

"The Shaw hill is nearly exhausted, and needs no further mention.

"In Section 19, there is an area on which blackband ore is believed by some persons to occur, but it has not yet been proved to be present here.

"The distance from the Middle Kittanning coal (No. 6) to the blackband in this region is 120 feet, as shown by a single measurement on the Catcott hill.

"There are more ore hills in Jefferson township than in any other township of the blackband field. The dividing ridge between Stone Creek and Oldtown Creek, in particular, originally held the largest connected body of ore that we know at this horizon. Erosion has separated it into 8 distinct tracts at the present day. The Upper Freeport coal appears in all of these sections in fair condition. Its quality is better than in the townships already reported. It seldom exceeds 3 feet in thickness, however, and often falls to 2 feet. The ore alternates between blackband and mountain ore, and considerable nodular or kidney ore is found in the overlying shales.

"Much of the more promising territory has already been exhausted, but there are still large bodies of ore.

"Adam Baker, in lot 30, holds an undeveloped tract in which the mountain ore, at least, is good. The coal below is also in good condition. David Maughermann, in section 21, has 3½ feet of blackband, and a large amount of kidney ore in the shales above the blackband.

"The Harmon and Keffer hill, in section 10, has also 3½ feet of good ore. This is now worked for the Dover Furnace. The underlying coal ranges from 24 to 30 inches in thickness. There is also nodular ore above the blackband.

"In section 19, the Kutcher hill is also counted as blackband territory, but is now not worked. In the same section, another deposit has been mainly worked out.

"The Rhinehart deposit is limited in area, and is not now worked. The Millhofer hill, in section 16, is mainly exhausted. The Lorenz hill, in lot 36, contains but a small deposit of ore.

"On Benjamin Schwab's farm near Phillipsburg, good ore has been taken by drifting. Quite a large amount has been produced by this bank.

"The Meese hill has also a valuable bed of the ore, 3½ to 4 feet in thickness, underlain by 2 to 2½ feet of coal. The seam was mined quite largely by the Glasgow Furnace when it was in operation.

"This completes the list of the main banks of the township, so far as they are at present known, but the coal of this horizon holds a large area in addition to the hills above reported, and it is almost certain that many other bodies of ore will be hereafter found in connection with it. Perhaps the heavier deposits have been mainly brought to light already, but thinner sheets can certainly be worked to profit in connection with the coal that underlies them, if not now, at a future day.

"In Salem Township six ore hills are known.

"The most northerly of them is the Arth hill, in section 3. The ore has not been mined here, but it is known to be present. It is connected with the Rhinehart hill, of Jefferson township, in which the mountain ore predominates. It is therefore probable that this form of the ore will be found in the Arth farm.

"The Yackell hill, in section 2, is one of the best-known bodies of ore in the township. It is worked by the Burton-Ridgeway Company of Massillon. The ore is genuine blackband throughout, and it reaches a maximum of 9 feet in thickness. The quality is fully approved. All the ore thus far has been taken by stripping, but drifts will soon be required to reach the remainder. A large amount of kidney ore is now gained by stripping, none of which will be reached in drift mines. A tram-road connects the mine with the railroad, ½ mile distant. The underlying coal is 32 inches thick, and quite sulphurous.

"In sections 5 and 6, the Everhart hill has produced quite a large amount of ore for the Glasgow furnace. The haul was a long one, however, and the mine was thus at a great disadvantage. The ore was approved in all respects. The Wiandt hill, in section 14, is nearly exhausted. Its ore was taken by the Glasgow furnace.

"The J. S. Dye ore hills were owned by the Glasgow Furnace Company. There are two of them, and, as the map indicates, they are the only deposits of this kind within a radius of several miles. The ore is

not at its best in these banks, but it holds well in thickness, ranging from 3 to 11 feet. The underlying coal is 2 feet thick and sulphurous. . . .

"The next deposit of blackband, and the last in the Tuscarawas field, is found in the southeast corner of Oxford township, on the head waters of Bird's Run. The ore is hauled out to the railroad at Post Boy Station, and is consequently known to many as Post Boy ore. This basin was originally one of the largest of the fields as will be seen by inspection of the map (see page 392). Bird's Run and its minor tributaries have dissected it into ten separate but closely contiguous fragments.

"The general thickness of the ore, so far as it has been mined, ranges between 5 and 6 feet. It is not as rich in iron as some other bodies of the blackband, but it is highly approved in use. The Dover Furnace Company owns a large tract of it, and most of the remainder belongs to John Booth.

"The interval between the Middle Kittanning coal (No. 6) and the blackband, at this point, is 143 feet, as shown in a single measurement.

"The average composition of the ore of the Bird Run field is shown in the following analysis:

Bird Run Blackband—John Booth's Mine (Lord)

Silica	11.89
Iron sesquioxide	2.00
Iron carbonate	52.61
Alumina	6.04
Lime carbonate	2.57
Magnesia carbonate	2.72
Oxide of manganese	0.60
Sulphur	1.08
Phosphoric acid	0.451
Volatile and combustible matter	18.94
Moisture	1.12
Total	100.02
Metallic iron	26.80
Phosphorus	0.196
Sulphur	1.08

"The blackband deposit does not end abruptly with the Tuscarawas county line, but through northern Guernsey county, there is always a probability of more or less carbonate of iron being found above the Upper Freeport coal. These deposits have been examined in a number of instances by explorers for iron ore, but no valuable beds have yet been found.

"There are several heavy layers over Steele and Lanfesty's coal on the Ringer farm, near Cassell's Station. Analysis shows the following composition:

Iron Shale Over Upper Freeport Coal At Cassell's Station (Lord)

Silica	35.34
Protoxide of iron	.77
Sesquioxide of iron	17.15
Metallic iron	12.60
Phosphorus	0.166
Sulphur	13.02

"The deposit has no value unless as a possible source of sulphur.

"As already stated, the blackband carries enough carbonaceous matter to effect its own calcination when properly ignited. The chief difficulty in calcining it, in fact, arises from excess of fuel. A tough and flexible silicate of iron often forms into an 'iron hat' near the upper surface of the kiln, when the heat has been brought to too high a point. This covering is sometimes 12 to 18 inches thick, and very hard to dislodge or break through, and an extensive crust of it detracts very much from the value of a kiln.

"Kilns for calcining the blackband are generally made 120 x 30 x 7 feet. The height of the kiln must be proportioned to the amount of carbonaceous matter in the ore. Too high a heat, together with an insufficient supply of air, leads to the formation of the 'iron hat' already noticed. Kilns require 3 or 4 months time for burning, and after being once ignited, demand but little care. Each kiln yields about 600 tons of calcined ore, which overruns 50 per cent in metallic iron.

"The price for the raw ore in the hill usually ranges between 30 and 35 cents per ton.

"This completes the account of the Tuscarawas blackband field. No explorations of new territory have been attempted, but the sole aim of the present survey has been to indicate the present state of development of the field. The maps of the leading areas appear here for the first time, as does also the general blackband area of the county (page 257). Doubtless, many additions will be made to the tracts already known, but it is probable that the larger bodies have been already struck, as a good deal of intelligent and expensive proving has been carried on within the last 10 or 15 years throughout the available territory.

"Among those most prominent in these explorations, Mr. A. Wilhelmi, of Dover, the Dover Furnace Company, and the Ridgway Burton Company, of Massillon, deserve special mention."

Tests of blackband ore gathered from various sources are as follows:

	No. 1	*No. 2*	*No. 3*
Silica, SiO_2	22.20	30.63	15.36
Alumina, Al_2O_3	19.04	24.10	8.72
Ferric oxide, Fe_2O_3	49.24	32.17	....
Ferrous oxide, FeO	4.04	7.15	....
Pyrite, FeS_2	....	0.19	....
Magnesium oxide, MgO	1.29	0.27	1.95

Calcium oxide	1.25	0.56	2.80
Sodium oxide, Na_2O	0.18	0.16	....
Potassium oxide, K_2O	0.59	0.40	....
Water, hydroscopic, H_2O—	0.14	0.25	30.50
Water, combined, H_2O+	0.03	0.83	.....
Carbon dioxide, CO_2	0.04	<0.01	....
Titanic oxide, TiO_2	0.44	0.55	....
Phosphorus pentoxide, P_2O_5	0.65	0.95	....
Sulphur trioxide, SO_3	0.33	0.22	....
Manganese oxide, MnO	0.66	1.65	....
Zirconium oxide, ZrO_2	<0.01	<0.01	....
Sulphur, as sulphide, S	0.02	....	.569
Vanadium oxide, V_2O_5	....	<0.01	....
Carbon, organic	....	0.09	....
Metallic components			
Iron, Fe	37.58	28.15	29.40
Manganese, Mn	0.51	1.28	0.288
Phosphorus, P	0.284	0.415	0.338
Flux bases			
Calcium oxide, CaO	1.25	0.56	....
Magnesium oxide, MgO	1.29	0.27	....

Sample No. 1. Calcined blackband ore from a large pile on the property of Ernest Couts, central Section 20, Oxford Township, Tuscarawas County. Sampled by C. F. Euga, Feb. 26, 1938. Analyst, Downs Schaaf.

Sample No. 2. Calcined blackband ore from large ricks on the Frinfrock farm, southwest Section 18, Rose Township, Carroll County. Sampled Sept. 24, 1935, by Wilber Stout. Analyst, Downs Schaaf.

Sample No. 3, partial analysis from pile of calcined ore on property of Edward Zeigler, northeast part of Dover Township, Tuscarawas County. Sampled and analyzed by the Bailey Furnace Company, Canton, Ohio.

PERRY COUNTY [1]

"The first ore above the coal, and doubtless the most important, is the 'Shawnee ore.' This ore is best known from a fine development of it at Iron Point, a little northeast of the village of Shawnee, in Perry county. The elevation of the ore seam above the Nelsonville coal is probably not far from one hundred feet. This is about the average of many instrumental measurements, which, as reported, range from ninety-one to one hundred and ten feet. There are variations in the bedding of the ore, and no two measurements are exactly alike. At one exposure of the ore, where it was worked in open quarry, I took the following section:

	Ft.	*In.*
Yellow clay	6	..
Carbonaceous streak.		
Laminated ore	3	3
Coal	..	3
Clay.		

[1]Geol. Survey Ohio, Vol. III, pp. 873-877.

"A few rods distant the laminated ore was two feet four inches thick. The minimum thickness is reported by Mr. E. C. Pechin as fourteen inches, and the maximum as four feet. In places the ore is a hard blue carbonate, showing less lamination, and resembling the 'mountain ore' associated with the black band over Coal Seam No. 7, in Tuscarawas county. The laminated ore is, where I saw it, much oxydized. In its laminated structure it much resembles a black band, but is not like the typical blackband in being a bituminous shale highly charged with iron. There are, however, sometimes thin films of coal formed by isolated fragments of coal-forming plants buried in the ancient ferruginous mud. This mud was deposited in layers; hence the lamination of the ore. The ore is divided by vertical joints, and is readily split and removed. The following analyses of the Iron Point ore have been made:

	No. 1 Raw Ore	*No. 2 Raw Ore*	*No. 3 Calcined Ore*
Silica	33.44	....	10.60
Alumina	3.14	....	6.69
Oxide manganese	0.91	....	4.49
Lime carbonate	Trace	....	Lime 2.35
Magnesia carbonate	Trace	....	Mag. 0.60
Phosphoric acid	0.39	0.42	0.58
Sulphur	0.14	....	0.13
Water, contained	5.74	....	....
Iron sesquioxide	56.03	....	74.66
	99.79	....	100.10
Metallic iron	39.21	35.27	52.26

"No. 1 was made by Mr. E. S. Gregory, and furnished me by Mr. J. G. Chamberlain; No. 3 was given by Mr.. A. J. Long, of Akron, to Mr. Pechin; No. 2 was given by General S. Thomas, of Columbus. An analysis of the pig iron from the Fannie Furnace is quoted from Mr. Pechin as follows:

Iron	91.45
Silicon	3.89
Carbon graphitic	2.31
Carbon combined	0.24
Sulphur	0.03
Phosphorus	0.59
Manganese	0.85
Undetermined	0.64
	100.00

"There are four furnaces in operation at Shawnee all using the Iron Point ores. These are:

	Height	*Bosh*
	Ft.	*Ft.*
Fannie No. 1	48	12
Fannie No. 2	48	13½
XX or "Double X"	50	14
Vilas	50	14½

"The fuel used at all of these furnaces is raw coal from the Nelsonville seam. The limestone is from a seam generally found about sixty feet above the coal. It is here reported to be from two to two and one-half feet thick. Until drifts are required the stone may be obtained at little expense. All the raw materials are procured at a small cost, and pig iron is consequently made very cheaply. By admixture of the native ores with those from Lake Superior and elsewhere, iron adapted to meet different wants may be made. The area over which the Shawnee ore is known to exist in the Iron Point field is not very great, but new explorations will doubtless enlarge it."

"South of Iron Point several shafts have been sunk for the ore on the lands of the Straitsville Cannel Coal Company of New York. J. H. Lyons, Esq., the Superintendent, has kindly furnished me with the facts ascertained. About forty feet above the Bayley's Run coal he found at every point a thin seam of coal. This is doubtless the equivalent of a seam found from forty to fifty feet above the Bayley's Run seam, on Lower Sunday Creek. In one shaft he found a blue carbonate of iron twenty-six feet below this thin upper coal. Here the ore is two feet six inches thick. In the next shaft the section is very interesting and significant. The following is the section:

		Ft.	*In.*
1.	Thin coal	..	6
2.	Interval not reported in detail	27	..
3.	Blue ore	1	6
4.	Sand-rock	4	..
5.	Blue ore	1	6
6.	Shale, with nodular ore	5	..
7.	Coal, Bayley's Run seam	4	10
8.	Under clay and shale	8	..
9.	Sand-rock, etc.	74	..
10.	Nelsonville or Great seam.		

"Here the blue ores represent the Shawnee horizon. The upper ore is rich on the top, but grows more sandy until the sandstone is reached; while the lower ore begins sandy on the top and becomes rich at the bottom. The bottom of the ore is ninety-two feet above the Nelsonville coal, and five feet above the Bayley's Run seam, which is here in full

thickness. In another shaft, beginning with the upper thin coal, we find other ores.

		Ft.	In.
1.	Thin coal	..	6
2.	Shale, with nodular ore	3	..
3.	Clay shale	12	..
4.	Ore	1	..
5.	Interval	7	..
6.	Shawnee ore, blue	3	4

"In another shaft the Shawnee ore is composed of a layer of two feet of blue ore, with one foot five inches of nodular ore underneath. There are also nodules of ore filling a space of one foot three inches about ten feet below the thin coal, which is here twenty-nine feet above the Shawnee ore. By three instrumental measurements, Mr. Lyons made the interval from the Nelsonville coal to the Iron Point ore ninety-one, ninety-two, and ninety-three feet, respectively; but he found the ore varying in level ten feet in the space of six rods. These measurements appear to verify his conclusion that the blue ore from five to twelve feet above the Bayley's Run coal is the equivalent of the Iron Point seam, although it nowhere presents the laminated structure of the latter.

"Through the labors of the Moxahala Iron Company, the equivalent of the Iron Point ore has been found at several places in thickness varying from one foot to thirteen feet. The Hone ore, first discovered by Mr. Lewis Wolfe, is on a hill between Moxahala and New Lexington. It is reported to be by measurement a little over one hundred feet above the Nelsonville seam of coal. The ore rests upon a sand-rock, and no coal was seen below it. In this region the Bayley's Run coal is generally absent —replaced by sand-rock. The Hone ore is a local deposit, or pocket, on the summit of a knob, and covers from one and a half to two acres. It is seven feet thick, in the center of the deposit—in one place swelling to eight feet, but becoming thinner at the outcrop. It is covered with clay from one to ten feet thick, but the covering has admitted the air, and the whole body of the ore is thoroughly oxydized. There is little appearance of lamination, and no traces of carbonaceous matter were detected. The ore was doubtless originally a carbonate deposited in the form of a mud remarkably free from silica and alumina. The borings, where the ore is seven feet thick, were intimately mixed, and constituted a sample, which, analyzed by Mr. E. S. Gregory, of Youngstown, showed the following constituent elements:

Water combined	10.61
Iron sesquioxide	79.58
Silicic acid	4.22
Alumina	1.16
Oxide manganese	1.06
Lime carbonate	1.38

Magnesia carbonate	0.29
Phosphoric acid	1.03
Sulphur	0.07
Total	99.40
Metallic iron	55.71
Phosphorus	0.45

"The ore is rich in iron, and is easily smelted. It is easily dug, and is delivered by railroad to the furnace very cheaply. There are probably 15,000 tons in this single deposit.

"Another deposit of ore which is believed to be in the horizon of the Iron Point ore is found on the Whitlock farm, a little northeast of Moxahala. This deposit is irregular in outline, and the extent is not well ascertained. The ore where first opened is laminated with occasional films of coal formed from isolated fragments of coal plants. On the outcrop the ore is oxydized and dark red in color; but under cover it becomes a regular blackband, according to Mr. Chamberlain. I have no full analysis of this ore, but it appears to be of excellent quality, and has proved itself such in the Moxahala Furnace. A single determination of the iron in the oxydized portion of the ore, showed 44.50 per cent. of metallic iron.

"More recent developments of the Whitlock ore show a change from a blackband to the unstratified oxydized character of the Hone ore previously described. The ore thus changed is very fine, yielding over fifty per cent of iron in the furnace after it is calcined. Mr. Chamberlain also reports that in some places over the stratified or blackband portion of the Whitlock ore are considerable masses of nodular ore. Thus we have in the same horizon blackband, massive limonite, and nodular ore. As Mr. Chamberlain well says, the nodular ore may, in many places, serve to indicate the horizon, and further search may reveal the blackband itself.

"In the neighborhood of Bristol, in the same county, much larger areas of the Iron Point ore have been found. These areas, already proven, would make an aggregate of from one hundred and fifty to two hundred acres, in which the ore is believed to range from two to thirteen feet in thickness. The ore under impervious cover, will doubtless prove to be a typical blackband, with more than ten per cent of carbonaceous matter. Through the courtesy of Mr. Chamberlain, of the Moxahala Iron Company, I have received the following analysis, by Mr. Gregory, of this newly found ore. The sample analyzed was composed of borings obtained in sinking holes to test the deposit.

"Analysis of Blackband, Moxahala Furnace, from the large deposit near Bristol:

Silica	20
Iron carbonate	43

Iron sesquioxide	18
Lime and magnesia	4
Alumina	0.72
Sulphur	0.04
Phosphoric acid	0.83
Water and organic matter	8
	96.59
Metallic iron	33.80"

"The last point at which we found ore to be taken from the Upper Freeport or main blackband horizon in coming south and west is in Oxford Township, Tuscarawas County.[1] The counties of Coshocton and Muskingum have been passed without the report of a single deposit of this character. The ore is not likely to be found in central Muskingum county, as we know from the fact that the coal is already mined extensively through a number of townships here, and the horizon has thus been fully disclosed. If the ore had been present, it would certainly have been brought to light. It has been already shown that in the occurrence of the ore thus far, it has occupied the exterior margin of its field, the mineable coal being found farther within the basin. In other words, the landward side of the coal swamp received the supply of iron, probably in the waters of the drainage streams that found their way to it. The Stark and Carroll county deposits, for example, are found on the very westernmost outcrop of the Upper Freeport level, while the Dell Roy coal field lies a dozen miles or more from this outer margin. In the same way, the Tuscarawas ore-hills mark the outermost exhibition of the Upper Freeport horizon in that county. The Cambridge coal, on the other hand, lies 20 miles within this boundary. In parts of Muskingum county, as just stated, the coal is found of good thickness on the western outcrop of the seam, without the ore, but in central Perry county the conditions found in Carroll and Tuscarawas counties are repeated. Valuable beds of stratified ore mark the northwestern outcrop of the Upper Freeport seam, while a still more valuable seam of coal is found as the horizon dips down toward its final cover to the southward.

"The blackband ore of this region was first discovered in the neighborhood of Shawnee. The hill on which it was found was named Iron Point, and the ore has been generally known as the Iron Point ore, but sometimes as the Shawnee ore. It is confined to section 10, Pike township.

"The ore lies about 100 feet above the Middle Kittanning coal (No. 6) which is here the basis of all sections. The range of intervals is, however, considerable, the distance being sometimes reduced to 90 feet, and occasionally rising to 120 feet. The level of the ore in a mine

[1] Geol. Survey Ohio, Vol. V, pp. 406-410.

that covers even less than an acre will frequently be found to have a range of 20 feet. These facts are entirely in keeping with the general character of the horizon.

"In composition the ore is not in most cases a true blackband but much of it would rather come under that division of the stratified ores called clay-bands. Thin streaks of coaly matter are distributed between the drab-colored layers of carbonate of iron. Below it there is often found, as in the other fields, a foot or two of coal, generally poor in quality, and not enough can be depended on to effect the calcination of the ore.

"The blackband in the immediate vicinity of Shawnee is supposed to have occupied about 20 acres, but it is now practically exhausted, only a few small areas being left of the original deposits. Four furnace stacks were built, upon the discovery of the ore, and they have made, in their short career, quick work with what has been discovered up to this date. One furnace might have found a profitable life in the field, with the blackband for its main reliance, but four necessarily brought about a rapid exhaustion of the limited supply.

"The ore seldom rises above 3 feet in working height, and the average of the worked areas will not probably exceed 2 feet. It was largely mined by 'stripping' or 'tailing' at first, but that stage soon passed, and almost all is taken from regularly opened drifts at the present time. The calcined ore yields more than 50 per cent of metallic iron.

"In Section 14, Pike Township, about equally distant from New Lexington and Moxahala, the valuable deposit known as the 'Hone ore' was found. The bank covered less than 2 acres, and reached a maximum of 8 feet in thickness. It has been entirely mined out. It was a distinctly stratified ore, but contained no carbonaceous seams. It was quite light in color when under cover. The outcrop was a rich and mellow limonite. A question has been raised as to the true geological place of this ore, but there does not seem to be sufficient reason for rejecting the general conclusion that it lies at the blackband horizon.

"No such question exists in regard to the 'Whitlock ore' which is found in section 14, Bearfield township. This is certainly at the Upper Freeport horizon, and, moreover, it is a true blackband. A long and valuable section was measured in this vicinity, including the Whitlock bank. It is as follows:

Ames limestone	
Interval —not measured.	
Cambridge limestone	
Interval	50 feet
Brush Creek coal—No. 7a	
Interval	45 feet
Whitlock ore—Upper Freeport coal No. 7	
Interval	61 feet

Nodular ore and fire clay—Lower Freeport horizon?
Interval ..... 51 feet

Middle Kittanning coal—No. 6.
From lowest coal to ore, 117 feet; from same to Cambridge limestone, 212 feet.

"So far as worked, the seam has ranged between 1½ to 4 feet in thickness. It carries enough coal and carbonaceous matter to effect its calcination. It is under much heavier cover than most of the ore bodies of this horizon. In fact, not another occurrence of genuine blackband has been noted in the State directly beneath the Ames limestone. The area already mined will not exceed an acre, but the hills come down so abruptly that the possibilities of tailing or stripping the ore have already been exhausted. Drifts have been pushed under the hill, but they are not now open. According to what seems reliable testimony, the ore was left at full thickness at the head of the drifts. If this be true, there is still a considerable amount to be looked for in this region. The horizon can be marked through a large territory. All the ore that was mined here, was taken to Moxahala Furnace. The raw ore contains 36 per cent of iron.

"There is another important field near Bristol, in the southwestern corner of Pike township. Two bodies of the ore have been found and worked in sections 29 and 32, respectively. The former is known as the Clark ore from the name of the farm on which it occurs; the latter is, for a like reason, called the Bowman ore. Both have been worked quite largely, the former for Moxahala Furnace, and the latter for the Shawnee furnaces. The average thickness of the Clark ore is less than 15 inches. The Bowman ore covered originally about 22 acres, and probably two thirds of it have been mined out. It occurs in two benches, separated by about 15 inches of shale. The upper ore bench is 6 inches thick; the lower ranges between 12 and 15 inches. The ore is mainly mined by stripping. A tram-way conveys it from the mine to the railroad at McCunieville. These deposits are not equal in value to the Iron Point beds. They fall below in thickness, and perhaps also in quality, but they have already yielded many thousand tons of iron, and the supply is not exhausted.

"To the south of Moxahala, several large deposits of rough ore occur at the same general level, but experience does not warrant us in assigning to them any real value as sources of iron. One of them is so high in phosphorus that it would serve a better purpose as a fertilizer than as an iron ore.

"In section 2, Ward township, Hocking county, on the Helen Furnace lands, a blackband ore has been opened and worked to the extent, at least, of several thousand tons. It lies 93 feet above the main coal (Middle Kittanning or No. 6). It carries a foot or two of coal above it (Upper Freeport or No. 7) and below it there is also a sulphurous, car-

bonaceous deposit that verges toward coal. The Lower Freeport coal also appears in the section. The ore ranges from 6 to 15 inches in thickness. It lies under comparatively light cover. When calcined it yields fully 50 per cent of iron. It has been mined by drifts, and shows itself a persistent deposit, so far as it has been followed. It appears to hold a considerable area, being found in several tracts that are separated by valleys. It did not work as kindly in the furnace as could be desired, and since it cost as much, or nearly as much, as the Baird ore that the other furnaces of the valley were handling, it was found necessary to abandon its use, at least for a time."

MOUNTAIN ORE

INTRODUCTION

The Mountain ore appears to belong to the horizon of the Mahoning limestone, lying below the Mahoning coal. "This calcareous ore, which elsewhere is a non-ferruginous limestone [Mahoning], has been extensively mined in eastern Tuscarawas County, as on the property of the old Zoar Furnace, in Fairfield Township, and is known as the 'Mountain ore.'[1]

REGIONAL GEOLOGY

TUSCARAWAS COUNTY

"The Mountain ore is of but local importance and has been obtained chiefly in the eastern part of Tuscarawas County, in Fairfield Township. The ore is subjected to calcination in heap, as is usually done with ores of its class. As an ore it is highly valued."[2]

"The limestone ore [Mountain] shows equal irregularities of thickness to that of the blackband. At Wilhelmi's mine [Auburn Township] in one of the old openings, it is seen increasing from nothing to 3 feet in thickness, running down a slope of blackband ore, and practically taking its place. Throughout the area occupied by the limestone, that is, over parts of Stark, Carroll and much of Tuscarawas, the limestone [Mahoning] is met with at intervals, having, where present, a thickness of 4 to 5 feet. Even where not forming an iron ore, it contains so much iron as to assume, in weathering, a decided buff color, and it is frequently referred to in our [Newberry] notes and reports as the Buff Limestone."[3]

PERRY COUNTY

"About 4 feet above the upper or Stallsmith seam of coal, [Upper Freeport], is a deposit, apparently in very large nodules, of an earthy blue

[1]Geol. Survey Ohio, Vol. V, p. 464.
[2]Idem., p. 466.
[3]Geol. Survey Ohio, Vol. III, p. 76.

carbonate of iron or siderite. On the Latta farm, near Millerstown (Monroe Township, Perry County), the thickest nodule measured 2 feet in thickness. . . . On the Rogers farm, in the same neighborhood, the same earthy blue carbonate of iron was seen, grouped in three layers of nodules, measuring respectively 13 inches, 14 inches, and 6 inches, making in all 33 inches. To determine whether these nodules will prove sufficiently contiguous to constitute regular seams, will require additional excavation.

"As this was by far the largest development of ore seen above the horizon of the great seam of coal [Middle Kittanning], samples for analysis were taken from both the Latta and Rogers farms. The sample from the Latta farm yielded, according to Prof. Wormley's analysis, 26.12 per cent of metallic iron, and that from the Rogers farm 23.78 per cent."[1]

ATHENS COUNTY

E. B. Andrews, in Volume III, Geological Survey of Ohio, 1878, reports as follows:

"On lower Sunday Creek large bodies of ore are found above the Bayley's Run [Upper Freeport] seam of coal. The ores are, generally, nodular on the outcrop, but further exploration might bring to light localities where they form regular layers. The largest deposits, so far as I have seen, are found in a horizon ranging from 10 to 25 feet above the seam of coal referred to. The ore, is, in places, very abundant, and could be advantageously mined. At no point have I seen these ores assuming the character of blackband. The following analyses were made by Prof. Wormley of samples taken by myself from different localities:

Analyses of Lower Sunday Creek Ores

	1	*2*	*3*	*4*
Water	6.15	12.50	5.85	7.90
Siliceous matter	18.44	21.96	15.97	8.36
Iron sesquioxide	26.68	59.48	28.86	36.70
Iron carbonate	31.16	....	19.38	12.87
Alumina	2.20	0.80	0.90	1.60
Manganese	5.20	1.40	0.95	6.20
Lime phosphate	0.21	Trace	0.69	0.89
Lime carbonate	5.25	1.60	22.24	20.96
Magnesia carbonate	4.54	2.72	4.24	3.63
Sulphur	0.06	Trace	0.06	0.10
Total	99.99	100.46	99.14	99.21
Metallic iron	33.72	41.57	29.56	31.90
Phosphoric acid	0.10	Trace	0.31	0.41

"No. 1 was from Section 7, Trimble Township.
Nos. 2 and 3 were from the 'Dugway' in Trimble.
No. 4 from Laurel Fork, in the same township.

[1]Geol. Survey Ohio, Report of Progress, 1869, p. 125.

"Some of the ores are excellent. No. 2 is quite rich in iron, with only traces of sulphur and phosphorus. Taking the four analyses together it will be seen that the average phosphoric acid is only 0.21 per cent, which is quite low for Coal Measure ores. The average percentage of iron is 34.19. It is to be expected that the ores under impervious cover will be carbonates exclusively, and, consequently, a little less rich in iron."[1]

"A line of facts, similar to the foregoing in many respects, is found in what is called the Dugway ore. This is a deposit of the same general character as the Buchtel ore, but lying above the lower stratum of the Mahoning sandstone. . . . It lies from 15 to 30 feet above the Upper Freeport coal (No. 7), and about the same distance below the Brush Creek coal. [Mason]

"It occurs in massive blocks or bowlders that lie in a red and white clay. The bowlders will often make a thickness of 3 or 4 feet in an aggregate of 6 feet of outcrop. The horizon is quite steady, being shown in almost every section where it is due, especially along the Sunday Creek Valley. An analysis of a selected sample of the weathered ore from the farm of Joseph W. Jones, on Mud Fork, near the Blondin well, gives the following results:

Analysis of Dugway ore, Mud Fork, Trimble Township: Analyst, N. W. Lord.

Silica	11.97
Iron protoxide	29.01
Iron sesquioxide	14.43
Alumina	6.29
Manganese oxide	0.83
Lime	6.10
Magnesia	2.83
Carbonic acid	25.68
Phosphoric acid	0.828
Sulphur	0.024
Water and organic matter	2.41
Moisture	0.41
Total	100.84
Metallic iron	32.70
Phosphorus	0.361
Sulphur	0.024

"Iron could be made from an ore that would maintain this character and composition, but experience has shown a rapid reduction in the percentage of iron as soon as the outcrop is left. A few attempts have been made to mine and work the ore. At Corning several hundred tons were taken out of the seam, which is in full development and easily reached, but the use of the sample that was mined created no demand for more."[2]

[1]Geol. Survey Ohio, Vol. III, pp. 877-878.
[2]Geol. Survey Ohio, Vol. V, pp. 411-412.

"Ore about 15 feet above the Bayley's Run coal [Upper Freeport] is called by Prof. Weethee the 'Great Vein Ore' as it reaches a thickness in places of over 5 feet. One specimen of the unroasted ore yielded 42 per cent metallic iron, and the average of several analyses was 35 per cent. Its outcrop may be seen on Section 17, Trimble Township (Athens County); Section 11, on the Follet land; on the Moody farm in Fraction 36; on the Blonden, Johnson, and Hope lands, on Mud Fork; on Jones' Run, Fraction 1; on the Russell lot, in the village of Trimble; on the Jennings farm at the Dug Way of Trimble, on the mill-dam in Millfield in Dover township; also, on Section 5 and 18, Dover Township, etc. Its very numerous and heavy outcrops indicate that it may be found at this horizon throughout nearly the whole valley. It consists of layers of nodules, some of quite large size, bedded in shale, some of the nodules containing considerable siliceous matter, and others 20 to 25 per cent of carbonate of lime. The iron exists mainly in the form of a sesquioxide, but some of it as a carbonate.

"At the Dug way, north of the town site of Ewing [now Jacksonville], the ore is opened up so as to disclose in a vertical height of 6 feet the equivalent of 5 feet of solid ore, while above this are 5 feet of red ferruginous shales containing nodules of rich ore indicating valuable deposits above the massive nodules. The lower stratum is blue, but burns to a black oxide which is highly magnetic, and all the strata appear to lose their siliceous character, which marks some of them at the outcrop, as they are followed into the hill. This is a magnificent exposure of ore; and several other entries gave promise of an equal thickness. Different openings in Trimble and Dover townships give the following measurements of solid ore: Five feet, three feet, four feet, two and one-half feet, etc. There can be little doubt that this fine bed of ore is continuous through all the hills in this neighborhood and of sufficient thickness to mine by drifting. The ore rests upon a white fine clay, and is bedded in clay colored red by the iron. This ferruginous clay extends up to a thin seam of coal [Mahoning] five to ten feet above the ore, and is generally so compact as to constitute a good roof. The ore can be mined without blasting, but the nodules are sometimes so large as to make it difficult to handle them."[1]

GALLIA COUNTY

"On Dry Ridge, a few miles southeast of Gallia Furnace, a section was taken in order to get the approximate stratigraphical position of an iron ore. The section is as follows:

	Ft.	*In.*
Sandy limestone, fossiliferous [Cambridge]	1	3
Not exposed	86	0
Iron ore	1	3

[1]Geol. Survey Ohio, Vol. III, pp. 688-689.

Not exposed	90	0
Sand-rock	24	0
Sheridan [Middle Kittanning] coal, no opening	..	..

"The ore in the above section has been used with acceptance in the Gallia Furnace, but it is too far away to make its use profitable. The ore is a dark red limonite, but has a decided tendency to crumble, and hence can best be used as a mixture with other and harder ores."[1]

"Throughout the southern counties this horizon [Mahoning limestone] is always conspicuous as an ore or limestone horizon. It lies a little higher above Coal No. 6 than to the northward, its average height being about 130 feet. It yields an ore of large volume at Gallia Furnace, which has been worked to a considerable extent under the name of the Banda ore. At Hecla Furnace it is known as the Top Hill ore."[2]

LAWRENCE COUNTY

"The Hallelujah ore of Mt. Vernon Furnace lies, according to the best interpretations, a few feet above the blackband level, [above Upper Freeport coal], but upon this point there is room for difference of opinion. . . . Wherever it goes, will probably also go the Banda ore of Gallia Furnace, an ore once mined in considerable quantity, for a short time. Neither of these ores is distinctly stratified, and yet both agree with this class [Limestone group] more nearly than with any other.

"The Hallelujah ore has large volume for a Hanging Rock ore, ranging from 1½ to 2 feet in thickness. It is red on the outcrop, but under cover it is blue with a greenish tinge. Thus far [1884] it has been worked only in one hollow of Mt. Vernon land, but the same ridge that covers it reaches through to Buckhorn land, and it will probably be found here also when looked for.

"The ore imparts a peculiar character to the iron into the production of which it enters, causing it to crystallize in large plates, like spiegeleisen. For some time this character of the iron [high manganese] worked against it in market."[3]

The Oak Ridge ore belongs on the horizon of the Anderson coal, with its associated Portersville and Bloomfield limestones. The ore is very local in extent and has been worked in only one locality, near Oak Ridge Furnace in Lawrence County.

"About 20 feet above the Cambridge limestone, in Aid Township, Lawrence County, quite a heavy deposit of ore occurs. It was the main

[1]Geol. Survey Ohio, Report of Progress, 1870, p. 179.
[2]Geol. Survey Ohio, Vol. III, p. 911.
[3]Geol. Survey Ohio, Vol. V, P. 434.

reliance of Oak Ridge Furnace for the short time that it was in blast."[1]

"The last ore of the series scarcely deserves a place in the column. The Oak Ridge ore was discovered, it might almost be said, invented, to meet the demands of a newly built furnace [Oak Ridge built 1856-57] that was located outside of all the main ore belts. Something must be found from which to make a stock pile, and the Oak Ridge 'ore' answered that purpose, and it also served to use up the charcoal supply of Oak Ridge Furnace during its first and only blast. The ore lies about 20 feet above the Cambridge limestone. It is a lean and coarse deposit, known in but a small territory and not likely ever to be mined again as a source of pig iron."[2]

ORE IN ROUND KNOB SHALES

INTRODUCTION

The upper half of the interval between the Ames and Cambridge limestones is generally occupied by red shale, for which Condit proposed the name of Round knob from a hill of that name in Madison Township, Columbiana County. "The beds vary from structureless, purplish-red clay to deep red, even-bedded shale, which may alternate with bluish layers. The more sandy portions frequently show ripple-marks and sun-cracks. Lenticular siderite concretions are common in the bluish shales and nodules of limestone and hematite in the structureless red clay. The hematite is in dense, reddish nuggets of sub-metallic lustre, which contain 55 to 60 per cent of iron and would be of value as iron ore were the quantity greater."[3]

REGIONAL GEOLOGY

These shales are well marked across the State and usually bear ferruginous matter in the form of nodules of various sizes and shapes. Only where concentrated along stream beds and available through placer mining would the ore be of sufficient interest for working. Some idea of the quantity of ore in the shales may be gathered from the following:

"In the shale underlying the Crinoidal [Ames] limestone in Union, Lee, Center, and Monroe townships, Carroll County, there is always more or less iron ore, sometimes plate, sometimes blackband, but usually in small nodules or evenly disseminated throughout the mass, which is often 20 feet thick. When concentrated in one layer, the ore is rarely more than 4 or 6 inches thick."[4]

"This is called the Fulton ore because first opened on the farm of D. Fulton, Section 29, Dover Township, Athens County. Its position is a

[1]Geol. Survey Ohio, Vol. III, p. 911.
[2]Geol. Survey Ohio, Vol. V, pp. 434-435.
[3]Geol. Survey Ohio, Fourth Series, Bull. 17, pp. 35, 36.
[4]Geol. Survey Ohio, Vol. III, p. 197.

few feet below the Ames limestone, and indications of its presence in many places may be observed. It has been opened only on the Fulton farm and on Fraction 36, Trimble Township. On the Fulton farm the opening has been carried some 50 feet into the hill, but no roof reached. The maximum thickness at place observed is 18 inches, but the nodules and fragments of ore, some of considerable size, in the earth above, indicate a thicker stratum when the rock cover is reached. This is a remarkable Coal Measure ore, a yellow sesquioxide of iron, almost pure, yielding a fraction over 60 per cent of metallic iron, of sulphur a mere trace, and of phosphoric acid 0.19 per cent only." [1]

ORE IN "BIG RED" SHALES

INTRODUCTION

"In the interval between the Ames limestone and the Pittsburgh coal, which varies from 220 feet in Jefferson County to 155 feet in Meigs County, the predominating rocks are red ferruginous shales, gray marly shales, fresh-water limestones, and massive sandstones. The red shales are most always present and usually make up a fair part of the total strata. In these red shales the chief coloring pigment is hematite laid down as such, in fine dispersion and also in nodules varying in size from one-tenth inch or less to 3 inches or more. These nodules vary in shape from nearly round, to very irregular, to flat or oval. In general these nodules are quite pure hematite, varying from 45 to 60 per cent iron. Some of the larger nodules may also be pyritic in character. For the most part the nodules are scattered irregularly through the mass of shale. However, in some sections they are confined more or less to bands or zones, quite continuous. In general the ore-bearing shale is not sufficiently rich to be worked for the ore alone, except possibly in some restricted areas. Through erosion many valleys in eastern and southern Ohio are cut largely in these red ore-bearing shales, where the fine materials have been carried away and the coarse and heavy matter left along the streams as valley fill. Such conditions offer possibilities for placer mining of the ore." [2]

REGIONAL GEOLOGY

"In Stock Township, Noble County, on the land of Mr. Smith nodules of excellent iron ore were seen 135 feet below the coal. [Meigs Creek]. These nodules are generally rich in iron, but they are seldom found in sufficient quantity to warrant drifting for them. . . . Some ore of very superior quality was also seen on the farm of A. Enochs, in Section 36. . . . The ore is a sesquioxide of iron and slightly hydrated, the combined water

[1] Geol. Survey Ohio, Vol. III, p. 690.
[2] A Survey is now, 1944, being made of these deposits.

being only 4.60 per cent. The following is the analysis of the ore by Prof. Wormley:

Water	4.60
Silica	10.76
Sesquioxide of iron	80.51
Alumina	1.20
Magnesia	1.30
Lime	1.30
Phosphoric acid	Trace
Sulphur	0.00
Total	99.67
Metallic iron	56.36

"The ore is rich in iron, and its remarkable freedom from phosphorus and sulphur makes it the best possible material for an iron for conversion into steel. . . . In the slide of the hill-side were large, laminated blocks of ore 6 inches thick. It is an ore of very great promise." [1]

In a report on Noble County, in Volume II, Geological Survey of Ohio, page 516, E. B. Andrews writes as follows:

"Between Hiramsburg Station and Ava Station in Noble Township, Noble County [horizon of 'Big Red' shales] Col. Teeters, of Caldwell, to whom I am indebted for much intelligent aid, found some ore (but not, I think, in place) of a good quality as seen by the following analysis:

Water	12.85
Siliceous matter, etc.	20.04
Sesquioxide of iron	58.27
Alumina	Trace
Manganese	5.80
Phosphate of lime	1.30
Carbonate of lime	0.14
Carbonate of magnesia	1.21
Sulphur	0.10
Total	99.71
Metallic iron	41.78
Phosphoric acid	0.60

"The percentage of phosphorus is not large, and the amount of metallic iron is considerable. The manganese would make the ore valuable for certain purposes." [2]

Such ore is also found along Duck Creek in Aurelius Township, Washington County. Andrews states: [3]

[1] Geol. Survey Ohio, Vol. II, pp. 524-525.
[2] Idem., p. 516.
[3] Idem., pp. 489-90.

"Iron ore of excellent quality is often found in this [Aurelius] and adjacent townships. It is always in nodular form, and is derived from the disintegration of clay shales (in upper part of Conemaugh series) in the hill sides, from which it is washed out. Sometimes very large nodules are found. It is often difficult to trace the ore to its original bed, but where I have succeeded in doing this the nodules are too few to warrant drifting into the shales, for them. Doubtless other and better localities will be found where drifting may be profitably done. The following is an analysis by Prof. Wormley, of a sample of ore from the farm of James Dutton, in this township:

Specific gravity	4.554
Water, combined	1.20
Sesquioxide of iron	78.90
Alumina	7.70
Silica and insoluble matter	10.60
Sulphuric acid	0.25
Phosphorus	0.00
Total	98.65
Metallic iron	55.48

"This is a rich ore, and would make an iron adapted to Bessemer Steel. If it can be found in adequate quantity, it will be of inestimable value."

These red shales are prominent features of the Conemaugh series in southern Ohio in Lawrence, Gallia, Meigs, Athens, Morgan, Perry, and Muskingum counties where the thickness varies from 25 to 100 feet or more. The common measurement, however, is between 25 and 75 feet. Thick deposits are also present locally in Guernsey, Noble, Belmont, and Harrison counties and are found to a less extent in Washington, Tuscarawas, Carroll, Jefferson, and Columbiana counties. Some of the stratigraphic features are brought out in the following sections:

In Columbiana County the full thickness of the Conemaugh series is not present as the highest knobs contain only the Connellsville sandstone. The following record, taken along the road in the northern part of Section 21, Wayne Township, Columbiana County shows the detail of the shales between the Connellsville sandstone and the Harlem coal:[1]

	Ft.	*In.*
Sandstone, part covered, *Connellsville*	14	0
Shale, yellowish	4	0
Shale, red	2	0
Shale, yellowish	4	0
Clay shale, red	4	0
Sandstone, shaly	4	0
Clay shale, red, full of small limestone nodules, *Clarksburg*	13	0

[1]Geol. Survey Ohio, Fourth Series, Bull. 28, p. 354.

Shale, drab, part siliceous	22	0
Clay shale, red	14	0
Shale, drab	4	0
Covered	5	0
Shale, gray to drab	26	0
Shale, dark	1	0
Coal, weathered, *Harlem*	0	10

In Carroll County the conditions are not essentially different. In Jefferson County the deposits of red shales are irregular in thickness and in character. Only locally do they have good thickness. The following record taken along the road in the central part of Section 1, Salem Township, Jefferson County, shows one of the thicker deposits and its place in the column:[1]

	Ft.	*In.*
"Limestone	1	0
Shale and covered	33	4
Clay and covered	..	8
Limestone, nodular, *Summerfield*	..	8
Sandstone, shaly, with some sandy shale, *Connellsville*	26	0
Shale, red	88	0
Coal blossom, *DuQuense*	..	3
Clay	4	6
Shale, gray, arenaceous	7	10
Limestone, shaly at top, *Ames*	1	6"

In general in Harrison County the red shales make up from 30 to 60 feet of that part of the Conemaugh section lying between the Morgantown sandstone and the Summerfield limestone. Parts of it contain ore nodules in fair abundance. Such deposits continue without much change across northwestern Belmont County. The conditions in Guernsey County are represented in the section given below and taken in Section 11, Londonderry Township:[2]

	Ft.	*In.*
"Pittsburgh or No. 8 coal	..	..
Clay	3	0
Shale, sandy	5	0
Clay	13	0
Limestone, gray	2	6
Clay, colored red to gray, nodular limestone present	28	0
Shale	18	0
Limestone, *Summerfield*, having many minute fossils: color of rock, buff	2	10
Clay shale, with nodular limestone	25	0
Shale, sandy, with calcareous and ferruginous concretions, [ore horizon]	90	0
Clay shale	4	0
Limestone, *Ames*. A fossiliferous rock	1	10"

[1]Geol. Survey Ohio, Fourth Series, Bull. 35, p. 167.
[2]Geol. Survey Ohio, Fourth Series, Bull. 17, p. 171.

Red shales are conspicuous features in the upper half of the Conemaugh series in Noble County, but they show much variation from place to place both in thickness and in character. In general the deposits contain considerable ferruginuos matter in the nodular form. The following section taken near Senecaville, in Section 6, Wayne Township, Noble County, shows the general nature of the rocks between the Ames limestone and the Pittsburgh coal:[1]

	Ft.	In.
"Coal blossom, *Pittsburgh*	..	..
Clay	0	10
Limestone, dark gray	1	3
Clay	3	0
Limestone, dark gray	1	8
Clay shale	10	0
Limestone	2	0
Shale, sandy	33	0
Limestone, *Summerfield*.. There are several layers interlain with clay. Some of these consist of buff limestone having imbedded lumps of white limestone	4	0
Clay shale, with a few beds of sandstone and red clay, having concretions of limestone and hematite	82	0
Shale, sandy, with irregular layers of calcareous concretions and two layers of impure fossiliferous limestone, *Skelley*	43	0
Limestone, *Ames*, fossiliferous	2	3"

The area of outcrop of red shale is small in Washington County and is confined largely to Duck Creek in Aurelius Township.

In general a good thickness of red shale is present in the Conemaugh series in Muskingum County. A typical section is shown in the following record which was taken along the road in Section 4, Union Township.

			Ft.	In.
Shale, siliceous, gray			6	0
Coal blossom, *Pittsburgh*			0	6
Clay shales, mottled, calcareous			35	0
Shale, siliceous, gray			6	0
Clay shale, calcareous, mottled			11	0
Limestone, light	*Summerfield*	.....	1	0
Clay shale, calcareous	*Summerfield*	.....	4	0
Clay shale, with limestone bowlders	*Summerfield*	.....	7	0
Clay shale, mottled, with marly limestone			11	0
Clay shale, light, with marly limestone			4	0
Shale, gray			9	0
Clay shales, red and gray, with ferruginous and calcareous nodules			56	0
Clay shale, red, part covered			13	0
Shale, gray			14	0
Limestone, fossiliferous, *Ames*			1	4

[1]Geol. Survey Ohio, Fourth Series, Bull. 17, p. 159.

Shale, gray	14	8
Coal blossom, *Harlem*	1	0
Clay shale, mottled, parts covered, *Round Knob*	24	0
Sandstone, shaly	5	0
Shale, soft, gray	5	0
Shale, gray, siliceous	38	0
Shale, dark, fossiliferous, *Portersville*	5	0
Coal blossom, *Anderson*	2	0
Clay shale, light	12	0

Throughout western and northern Morgan County, thick conspicuous deposits of red shales with ore and limestone nodules are present in the upper Conemaugh Section, mainly between the Ames limestone and the Summerfield limestone. Locally these shales contain not only the highly diffused pigmental iron oxide but also hematite nodules, mainly small in size. The record given below was taken by C. N. Brown, east of McConnelsville in the southwest quarter of Section 12, Morgan Township, Morgan County:

	Ft.	*In.*
Limestone, light	16	0
Covered	5	0
Limestone, light	2	0
Covered	23	0
Coal blossom, *Meigs Creek*	1	0
Covered	12	0
Limestone, light	4	0
Covered	10	0
Limestone, light	1	0
Covered	13	0
Sandstone, shaly	10	0
Shale, with thin bands of coal, *Redstone*	1	0
Shale, dark	11	0
Shale, calcareous	7	0
Clay shale, light	5	0
Covered	7	0
Coal blossom, *Pittsburgh*	1	0
Covered	2	0
Limestone, light	5	0
Shale, sandy	28	0
Limestone, light, *Summerfield*	1	0
Covered	9	0
Clay shale, red, with red hematite ore	15	0
Limestone, rough, nodular	4	0
Shale	10	0
Sandstone, massive	14	0
Clay shale, red or drab	9	0
Shales, sandy	16	0
Covered	25	0
Shale, sandy	10	0
Covered	18	0
Limestone, *Ames*	2	0

A sample of iron ore, gathered by Pearl A. Miller, from the stream bed along the East Branch of Sunday Creek in Union Township, Morgan County, gave the following results: Analyst D. Edwin Morgan, Globe Iron Company, Jackson, Ohio.

Iron, Fe	59.20
Silica, SiO_2	8.15
Alumina, Al_2O_3	2.55
Phosphorus, P	0.112
Manganese, Mn	0.62
Ignition loss	1.75

These ore-bearing red shales are present locally in southeastern Perry County in Bearfield, Pleasant, and Monroe Townships. The Ames limestone is overlain by 50 to 75 feet of shale mainly red in color and along certain zones rich in hematite nodules.

Throughout western Athens County the upper half of the Conemaugh series consists of variable deposits of red shale, gray shale, sandstones, and fresh water limestones. Some of the red clay deposits contain hematite ore in the nodular form usually concentrated into bands or zones. The following record taken by Ellis Lovejoy southwest of Athens shows this condition:

	Ft.	*In.*
Clay, red, with heavy nodules of iron ore	23	0
Limestone, bouldery	2	0
Clay and clay shale, red, parts covered	23	0
Limestone, light	1	0
Clays, red	15	0
Clay, light, with nodules of limestone	11	0
Clay shale, red, with streaks of iron ore	19	0
Shale, sandy	19	0
Limestone, *Ames*	1	0

"Red beds" are prominent features of the Conemaugh series of rocks in the western part of Meigs County. Aside from sandstones the ferruginous shales are the outstanding deposits between the Ames limestone and the Pittsburgh coal. One or more layers or rather zones of hematite nodules are present with regional continuity.

"The following section was measured along an abandoned road leading southeastward from Hanesville [northeast Section 1, Salem township]. Strata above the Pittsburgh coal are also included:[1]

	Ft.	*In.*
"Sandstone, coarse, friable	18	0
Shale	5	0
Coal blossom, probably *Pittsburgh*	..	..

[1]Geol. Survey Ohio, Fourth Series, Bull. 17, p. 102.

Conemaugh formation

Shale, with white nodular limestone	25	0
Clay, red	11	0
Sandstone	4	0
Clay shale, red	31	0
Shale, calcareous	2	6
Sandstone, shaly	8	0
Clay shale, red, with nodules of hematite and limestone	41	0
Sandstone	3	6
Clay shale, red	14	0
Limestone, *Ames*, very impure, fossiliferous	1	6
Shale, calcareous	34	0
Limestone, white, with ferruginous layers at bottom	2	0
Sandstone	4	0
Clay, red, with many hematite nodules	13	0
Sandstone, shaly	22	0
Limestone, *Cambridge*	2	3
Shale	2	0
Coal, unmeasured [*Wilgus*]	..	..
Shale	12	0
Sandstone, thin bedded	11	0"

The Conemaugh series is widely distributed in Gallia County, being present to some extent at the surface in every township. Red clay shales appear at several horizons especially both above and below the Ames limestone. A section upward from the Cambridge limestone to the Pittsburgh coal in the hill to the south of Northup [Section 13, Green Township, Gallia County] was measured. The lower exposures were found along the ravine and the upper portion along the road leading southward from Northup:[1]

	Ft.	*In.*
"Coal, *Pittsburgh* or No. 8	..	..
Shale, with limestone nodules	24	0
Sandstone	4	0
Shale, bluish	3	0
Clay with limestone nodules	12	0
Shale, red	30	0
Sandstone	4	0
Clay, red	5	0
Clay, bluish	2	0
Sandstone	9	0
Clay, red	4	0
Sandstone, not well shown	9	0
Shale, red	10	0
Sandstone, shaly	3	0
Clay, red, with nodular limestone	29	0
Sandstone, shaly	9	0
Shale, calcareous, probable place of *Ames* limestone	13	0
Interval mostly covered, consisting largely of red clay with nodules of limestone and hematite	53	0

[1]Geol. Survey Ohio, Fourth Series, Bull. 17, p. 86.

Shale, reddish-brown, alternating with bluish gray beds	12	0
Shale, fossiliferous	2	4
Limestone, *Cambridge*	2	6
Clay shale, unmeasured	..	..

"The interval between the Cambridge limestone and Pittsburgh coal as shown by the above section, is about 237 feet, and since more than one-half of it consists of red beds, it is evident that red clay is a prominent feature in the hills of this region."

Much the same condition exists in eastern Lawrence County where the red beds are conspicuous geological features in Rome, Union, Windsor, and Mason townships. This is especially true along Greasy Ridge the slopes of which contain much red clay, soft and greasy when wet. The following section was taken on Greasy Ridge from the crossroads northwest to the valley in Southeast Section 9, Mason township:

	Ft.	*In.*
"Coal, *Pomeroy,* unmeasured	..	..
Clay	3	0
Shale, sandy	32	0
Clay, horizon of *Pittsburgh* coal	1	0
Interval, red clay, shale, and shaly sandstone	100	0
Limestone, non-fossiliferous	1	3
Shale, calcareous	3	0
Sandstone, *Morgantown,* coarse-grained, with a conglomerate at the base	40	0
Interval, partly covered, much red clay seen	50	0
Shale, sandy	40	0
Limestone, *Cambridge,* fossiliferous	1	0
Coal, *Wilgus*	2	11
Clay, unmeasured	..	..[1]

A partial analysis of a small sample of ore nodules picked up in a stream bed in southern Rome Township, Lawrence County, yielded slightly over 60 per cent iron. This sample was probably above the average in richness. The area is now (1944) being surveyed.

MONONGAHELA SERIES

The outstanding features of the Monongahela series across Ohio are the abundance of fresh-water limestones and calcareous shales, the continuity of great sandstone members, the presence of thick coal beds, and the impoverishment in iron ores, either bedded or nodular. Such ore deposits as exist are usually derived from the weathering of limestone beds along the outcrop or under shallow covering where the conditions are favorable for solution and exchange. Lean ores of this character were observed at a few places in Morgan, Athens, Meigs, and Gallia counties.

[1]Geol. Survey Ohio, Fourth Series, Bull. 17, p. 66.

DUNKARD SERIES OF PERMIAN SYSTEM

INTRODUCTION

"The Dunkard is a most variable series of rocks. There are sandstones, shales, beds of limestones, and coal; in fact, it includes nearly all the different varieties, of sediments from coarse sandstone and conglomerate to the finest grained shale. These change rather rapidly from one to the other so that it is often impossible to trace a horizon for any great distance. And then too there is considerable similarity between a number of beds at different stratigraphic elevations. This is especially true of the shales which are often featureless and devoid of any marks whereby they might be recognized. Shale is the most abundant rock in the series. The higher shales are often red in the northern part of the area, while to the south, red is the prevailing color of the shale throughout the whole series."[1]

One division of the Dunkard series is prevailing red in color throughout its entire range. It is known as the Creston Reds and occurs about 160 feet above the Waynesburg coal. "These red beds occupy the entire space between the Lower and Upper Marietta sandstones in the region about Marietta. They consist of thick beds of red shale with occasional layers of sandstone."[2]

Although the Dunkard series contains much shale both red and gray, these only locally carry iron oxide or carbonate in the nodular form. It is rich in diffused iron components but not in concentrated forms. However, these rocks have provided ore for one small furnace for a number of years.

REGIONAL GEOLOGY

In 1857 a small furnace using native ore and local fuel was built at Martins Ferry. Cyrus Mendenhall, a prosperous Quaker of Mount Pleasant, conceived the idea of utilizing for iron smelting the native ore on his 50 acres of farm and on that of his neighbor, Ellis Steele, located in Sections 1 and 36, Pease Township, Belmont County. Mendenhall and Jenkins built a small stone stack, 40 feet in height, at Martins Ferry in which the burden was native ore from their property, coal from the Lower Freeport member at Steubenville, and limestone from the Fishpot member in the hills nearby. The ore was mined by stripping and was hauled to the furnace mainly by wagons. The ore was a limonite derived from the weathering of a ferruginous limestone. The position of the ore was only a few feet above the Washington coal in the Dunkard

[1]Geol. Survey Ohio, Fourth Series, Bull. 22, p. 15.
[2]Idem., p. 19.

series. The venture proved a success and led to larger works in the district.[1]

Conditions found locally in the Washington formation are shown in the section given below and taken one and one-half miles south of Bethesda in the south central part of Section 22, Goshen Township, Belmont County.[2]

	Ft.	*In.*
"Argillaceous red and buff shale	12	6
Gray shale with numerous dark-gray nodules of limestone, *Upper Washington limestone*	5	0
Covered interval	16	0
Covered slope, probably argillaceous shale	26	8
Gray shales and nodular limestone, *Lower Washington limestone*	16	0
Gray shales, and thin bedded, gray sandstones	3	0
Gray shale containing one thin, lenticular bed of limestone	1	0
Coal blossom, *Washington coal*	2	0
Bluish gray shale containing large iron nodules	8	8
Covered interval	29	4
Buff shale full of small iron nodules	13	0
Partly covered buff sandstone and shale	20	0
Laminated, micaceous, gray sandstone	16	0
Transition beds from the coarse, friable sandstone below to the laminated sandstone above	5	4
Coarse grained, friable sandstone which weathers to buff, *Waynesburg sandstone*	21	6
Argillaceous buff shale	0	4
Coal blossom, *Waynesburg coal*	0	10"

"On the land of Edwin Guthrie Section 28, Belpre Township, Washington County, we find the following geological section, which reveals considerable iron ore:[3]

	Ft.	*In.*
"Shale, with kidney ore in nodules near top	5	0
Ore (1)	0	4
Shale	2	0
Ore (2)	0	3
Shale	1	8
Ore (3)	0	4
Shale	1	0
Ore (4)	0	3
Shale	2	6
Ore (5)	0	6
Shale	2	0
Sandstone, quarried	15	0
Sandy shale	20	0
Sandstone [Upper Marietta]	25	0

[1]Data from "Iron and Steel in Wheeling" by Henry Dickerson Scott, 1929, page 25, and from field notes of George W. White taken in 1943.

[2]Geol. Survey Ohio, Fourth Series, Bull. 22, p. 74.

[3]Geol. Survey Ohio, Vol. II, pp. 456-466.

"Samples of all the ores, except the nodular one at the top, were taken for analysis by Prof. Wormley. The numbers begin with the upper layer.

"Numbers 1, 2, and 3 gave only 12, 13, 18.03, and 18.00 per cent of metallic iron respectively. The detailed analyses of Nos. 4 and 5 are as follows:

	No. 4	*No. 5*
Specific gravity	2.916	2.924
Combined water	7.20	5.20
Siliceous matter	16.40	21.68
Iron sesquioxide	44.86	60.44
Alumina	3.60	0.00
Manganese	2.00	8.00
Phosphate of lime	1.50	0.54
Carbonate of lime	22.18	2.08
Carbonate of magnesia	1.43	2.04
Sulphur	trace	trace
Total	99.17	99.98
Metallic iron	31.40	42.31
Phosphoric acid	0.70	0.25

"No. 5 is a good ore, and worthy of some practical investigation. The layer is thick enough to be worked under favorable circumstances, and being near the Ohio River, it might be shipped to furnaces down the river."

In Athens and Meigs counties the Dunkard series contains much red and variegated shales, the dominant pigments of which are ferruginous components. Locally these shales bear nodular ores, some apparently rich in metallic iron. The nodules, however are scattered through the shales and so lack concentration necessary for working except possibly along stream beds as placer deposits.

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