

# IRON DEPOSITS IN SOUTHWESTERN INDIANA

*by*

WAYNE M. BUNDY

Indiana Department of Conservation

GEOLOGICAL SURVEY

Report of Progress No. 10

1956

STATE OF INDIANA  
George N. Craig, Governor

DEPARTMENT OF CONSERVATION  
Harley G. Hook, Director

GEOLOGICAL SURVEY  
Charles F. Deiss, State Geologist  
Bloomington

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# IRON DEPOSITS IN SOUTHWESTERN INDIANA

By Wayne M. Bundy

## ABSTRACT

Most of the iron deposits of Martin and Greene Counties, Ind. , are within the Mansfield formation (lower Pennsylvanian), but small deposits also occur in the Beech Creek limestone (upper Mississippian). Goethite, the major iron mineral, occurs as cementing material, concretions, bands along bedding planes, veins, irregular open-space fillings, and replacements of plants in sandstone and shale. Small replacement bodies of goethite are common in the limestone. Magnetite occurs as finely disseminated grains within the interior shells of concretions.

Iron deposits in Indiana probably were precipitated in swamps and lagoons in early Pennsylvanian time. The belief that the iron was deposited in bogs is substantiated by the following evidence: (1) the irregular and local distribution of the iron deposits in Indiana is characteristic of bog iron deposits; (2) the relative abundance of those plant fossils associated with iron deposits is similar for both the iron deposits in Indiana and bog iron deposits; (3) the chemical analyses of the iron deposits in Indiana are similar to other iron deposits that are known to be of bog origin; (4) clay that is similar in composition to underclay (indicative of swamp conditions) is present in the Indiana deposits; and (5) the syngenetic nature of the concretions and the abundance of concretions of the Indiana deposits are like those of other iron deposits that are known to be of bog origin. Shrinkage cracks and colloform texture indicate that the iron was largely a colloidal precipitate. Electrolytes, micro-organisms, oxidation, and supersaturation may have been active in precipitation of the iron. Iron content is too low and phosphorus content is too high to consider the deposits in Indiana as being of commercial grade for most purposes.

## INTRODUCTION

### PURPOSE OF THIS INVESTIGATION

Indiana was an important iron-producing state between 1834 and 1895 when a dozen blast furnaces were supplied by native ores. The furnaces ceased operating, however, when the rich iron ores of the Lake Superior district were developed.



Because iron ore was produced in Martin and Greene Counties for nearly 61 years, a reconnaissance survey of these counties was carried out in the spring of 1954 to determine the origin and economic possibilities of the iron deposits. Each ore locality noted by Shannon (1907, p. 373-422) was visited. Chip samples for chemical analyses and hand samples for petrographic examination were collected from outcrops where visual examination indicated a relatively high iron content.

#### LOCATION AND ACCESSIBILITY OF THE IRON DEPOSITS

The general area of study (fig. 1) includes the east-central portions of Greene and Martin Counties. The Illinois Central Railroad and Indiana State Highway 54 traverse the area in Greene County, and the Baltimore and Ohio Railroad and U. S. Highways 50 and 150 cross the area in Martin County.

The iron deposits in Greene and Martin Counties are within the physiographic province known as the Crawford upland (Malott, 1922, p. 98-102). The land surface is highly dissected, and narrow ridges capped by sandstone are separated by moderately to steeply sloped valleys underlain by either shale or limestone. Maximum relief is approximately 400 feet.

#### GENERAL GEOLOGY OF THE DEPOSIT AREA

##### STRATIGRAPHY

Outcrops in the immediate vicinity of the iron deposits are confined to the Chester rocks (upper Mississippian) and the Mansfield formation (lower Pennsylvanian). Underlying formations, depending upon pre-Pennsylvanian topography, may be either Beech Creek limestone, Golconda limestone, or Cypress sandstone (of Indiana usage). A stratigraphic column (fig. 2) shows upper Mississippian formations and the Mansfield formation.

The Beech Creek limestone rests on the Elwren sandstone and is overlain by either the Cypress sandstone or the Mansfield formation. The limestone is medium-grained, light brown to blue gray, and fossiliferous. Crinoid stems are exposed on weathered surfaces. Caverns exist locally in the limestone. Joints are abundant and seem to control cave development. Springs also controlled by joints issue from the base of the Beech Creek limestone. The Beech Creek is approximately 15 feet thick throughout the area (Malott, 1931, p. 223).

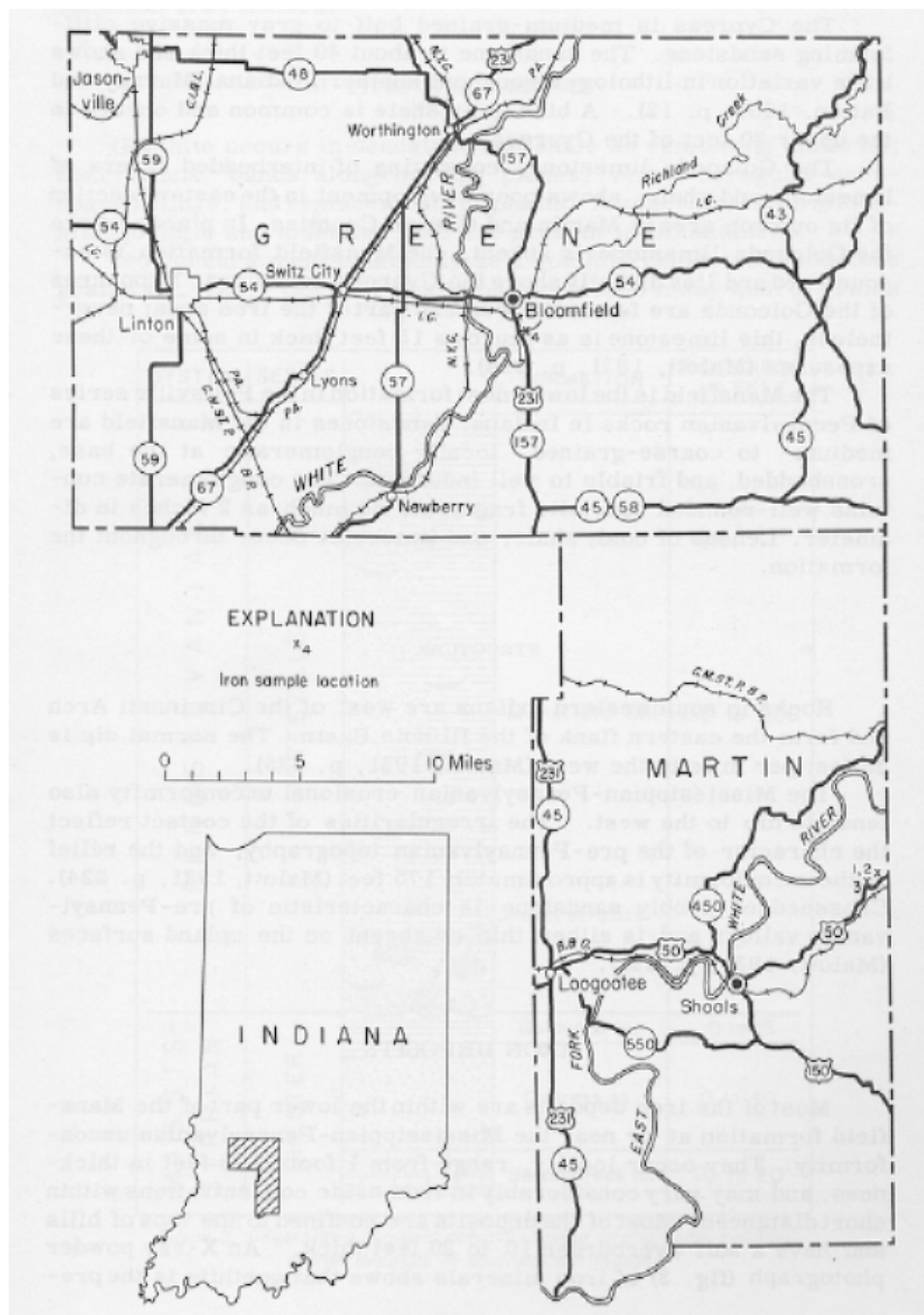


Figure 1. Map of Greene and Martin Counties, Ind., showing collecting localities of iron samples.

The Cypress is medium-grained buff to gray massive cliff-forming sandstone. The sandstone is about 40 feet thick and shows little variation in lithology throughout southern Indiana (Murray and Patton, 1953, p. 12). A blue-gray shale is common and occurs in the upper 20 feet of the Cypress.

The Golconda limestone, consisting of interbedded layers of limestone and shale, shows poor development in the eastern section of its outcrop area in Martin and Greene Counties. In places where the Golconda limestone is absent, the Mansfield formation is encountered and lies directly above the Cypress sandstone. Exposures of the Golconda are few in the western part of the iron area; nevertheless, this limestone is as much as 15 feet thick in some of these exposures (Malott, 1931, p. 224).

The Mansfield is the lowermost formation in the Pottsville series of Pennsylvanian rocks in Indiana. Sandstones in the Mansfield are medium- to coarse-grained, locally conglomeratic at the base, crossbedded, and friable to well indurated. The conglomerate contains well-rounded quartzite fragments as much as 2 inches in diameter. Lenses of coal, shale, and limestone occur throughout the formation.

#### STRUCTURE

Rocks in southwestern Indiana are west of the Cincinnati Arch and form the eastern flank of the Illinois Basin. The normal dip is 35 feet per mile to the west (Malott, 1931, p. 225).

The Mississippian-Pennsylvanian erosional unconformity also tends to dip to the west. The irregularities of the contact reflect the character of the pre-Pennsylvanian topography, and the relief on the unconformity is approximately 175 feet (Malott, 1931, p. 224). Crossbedded pebbly sandstone is characteristic of pre-Pennsylvanian valleys and is either thin or absent on the upland surfaces (Malott, 1931, p. 231).

#### IRON DEPOSITS

Most of the iron deposits are within the lower part of the Mansfield formation at or near the Mississippian-Pennsylvanian unconformity. They occur locally, range from 1 foot to 30 feet in thickness, and may vary considerably in iron oxide concentrations within short distances. Most of the deposits are confined to the tops of hills and have a soil overburden 10 to 20 feet thick. An X-ray powder photograph (fig. 3) of iron minerals shows that goethite is the pre-

dominant iron mineral.

#### TYPES OF OCCURRENCE

Goethite occurs in sandstone and shale as cementing material, concretions, bands along bedding planes, veins, irregular open space fillings, and replacements of plants. Replacement iron minerals, goethite and siderite, also are present in limestone.

Iron occurs most commonly as a goethite cement of sandstone grains (pl. 1A). Goethite has in part replaced many quartz grains

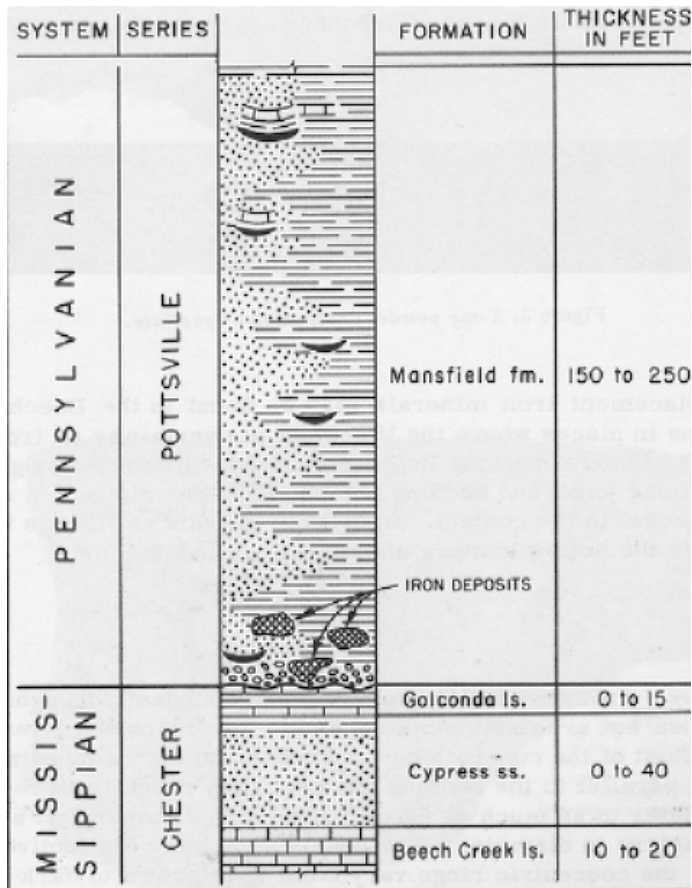


Figure 2. Generalized geologic column showing stratigraphic position of iron deposits in southwestern Indiana.

along fractures and crystal boundaries.

Concretions, which are abundant throughout the iron deposits, are described on page 12.

Relatively high concentrations of goethite occur in narrow bands along bedding planes. The bands are rarely more than half an inch wide, but are repeated vertically over short intervals. These high concentrations of iron stand out as resistant ridges on the outcrop surface in the sandstones of the Mansfield formation. The surfaces of many iron oxide masses display a colloform texture (pl. 1B).

Solution of much primary iron has resulted in its redeposition in highly permeable zones. Goethite veins (pl. 1A) and irregular open-space fillings are abundant throughout the iron deposits.

Plant fossils, replaced by goethite, are common and very abundant in the shale lenses. Carbonaceous imprints, however, are found in few shale lenses.

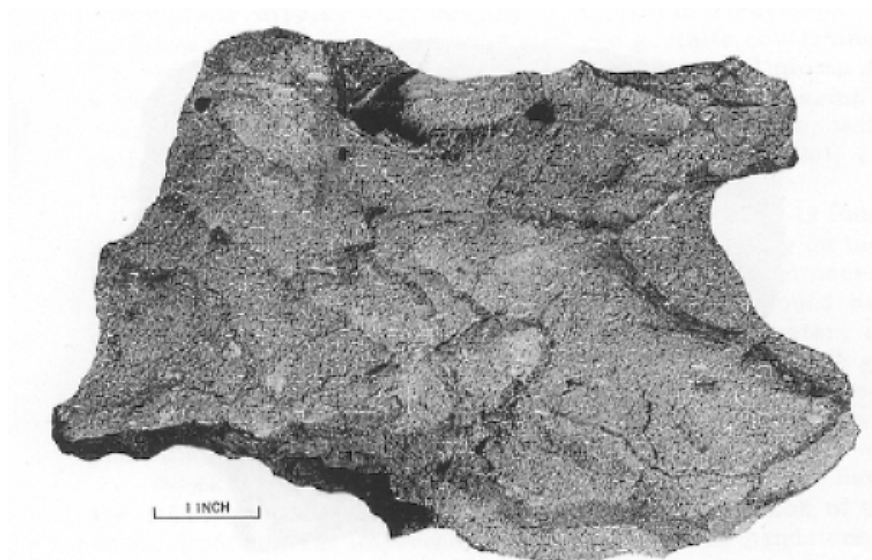


Figure 8. *X-ray Powder photograph of goethite.*

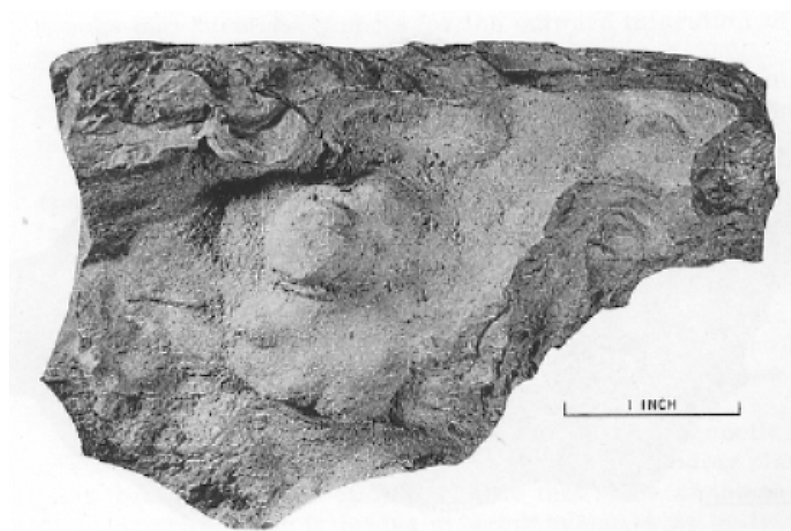
Replacement iron minerals may be found in the Beech Creek limestone in places where the limestone is overlain by an iron zone in the Mansfield formation. Replacement of the limestone by goethite occurs along joints and bedding planes and is restricted to a narrow zone adjacent to the contact. Siderite is present as fillings in open spaces in the hollow centers of concretions in limestone.

### CONCRETIONS

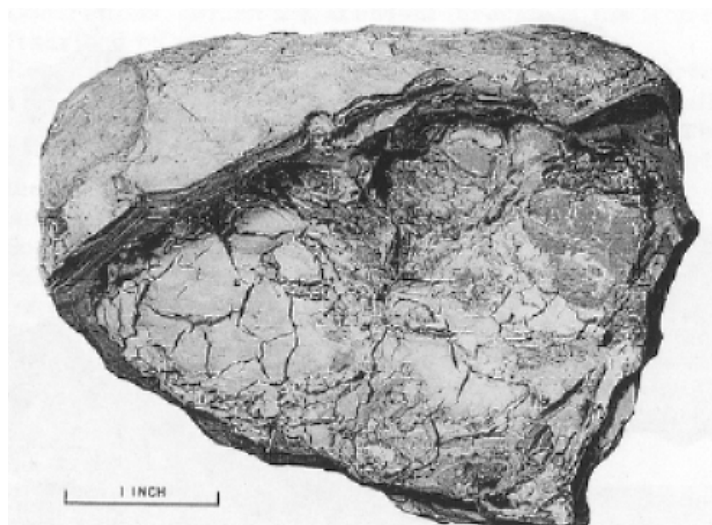
*Nature.* --Iron concretions (pl. 2A) are abundant throughout the iron zones but are most common within the interbedded lenses of shale. Most of the concretions are hollow and disc-shaped and are oriented parallel to the bedding planes. They range from less than 1 millimeter to as much as 60 centimeters in diameter and average 8 centimeters in diameter. The concretions show distinctive color banding; the concentric rings vary from light brown to dark brown. Shrinkage cracks are abundant; they are parallel to the concentric banding and radiate from the center of the concretions. Many, of the



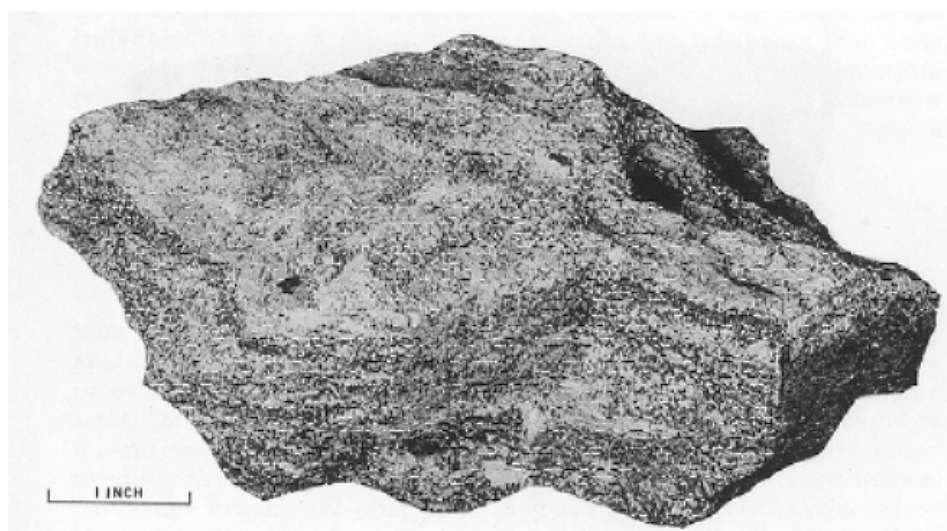
A. GOETHITE OCCURRING AS VEINS AND AS CEMENT OF SAND GRAINS.



B. GOETHITE DISPLAYING BOTRYOIDAL SURFACE.  
GOETHITE.



A. TYPICAL SYNGENETIC IRON CONCRETION



B. CLAY OVULES ALIGNED ALONG BEDDING  
PLANES,  
GOETHITE AND CLAY OVULES.

concretions display well-developed septarian structures. Inner surfaces of the concretions consist of red goethite containing finely disseminated magnetite. The goethite displays a colloform surface with abundant shrinkage cracks, which commonly resemble mud cracks. Black, blue, and greenish-black incrustations, which are believed to be organic material (Twenhofel, 1939, p. 390), coat the inner surfaces of most of the concretions.

Most of the concretions are hollow. White clay is found as a loose plastic ball within the open space or as a coating on the inner surface of some of the concretions. Clay balls are not necessarily confined to the cores of concretions; they may be found as small ovules, which average less than 1 millimeter in diameter, and are aligned parallel to the bedding planes (pl. 2B). Incipient growths of concentric goethite bands are associated with these ovules. The clay was identified by an X-ray spectrometer as illite, kaolinite, and minor chlorite (fig. 4).

*Origin.* - Clay balls and plant remains are believed to have been the materials which acted as nuclei for the formation of the iron concretions. Local impermeable zones within the sandstone, which contain abundant authigenic quartz, also have acted as nuclei. The hollow interiors displayed by many concretions are believed to have originated by at least two processes:

1. Dehydration and shrinking of flocculated precipitates of iron hydroxides. Outward migration of iron hydroxide along shrinkage cracks is indicated by abundant septarian structures. Because dehydration takes place from outside to inside, resultant shrinkage cracks may furnish channels for the outward migration of iron hydroxides.

2. Removal of clay and organic material by ground water. Circulating ground water has had adequate access to these nuclei through the abundant shrinkage cracks.

The hollow centers of the concretions provided accessible open spaces for the iron-bearing solutions. The colloform texture of the inner surface of the concretions indicates that the iron (goethite) was deposited in an open space. Bastin (1950, p. 25-26) stated that colloform textures commonly result from surface tension exerted on gels which have been deposited in open spaces. Organic material in the hollow centers of the concretions brought about the reduction of ferric iron to form fine-grained magnetite, which was disseminated through the goethite.

Most of the concretions are believed to be syngenetic, but concretions containing abundant detritus and relict bedding planes which pass through the concretions indicate that some of the concretions are epigenetic. The following evidence supports the belief that most of the concretions are syngenetic.



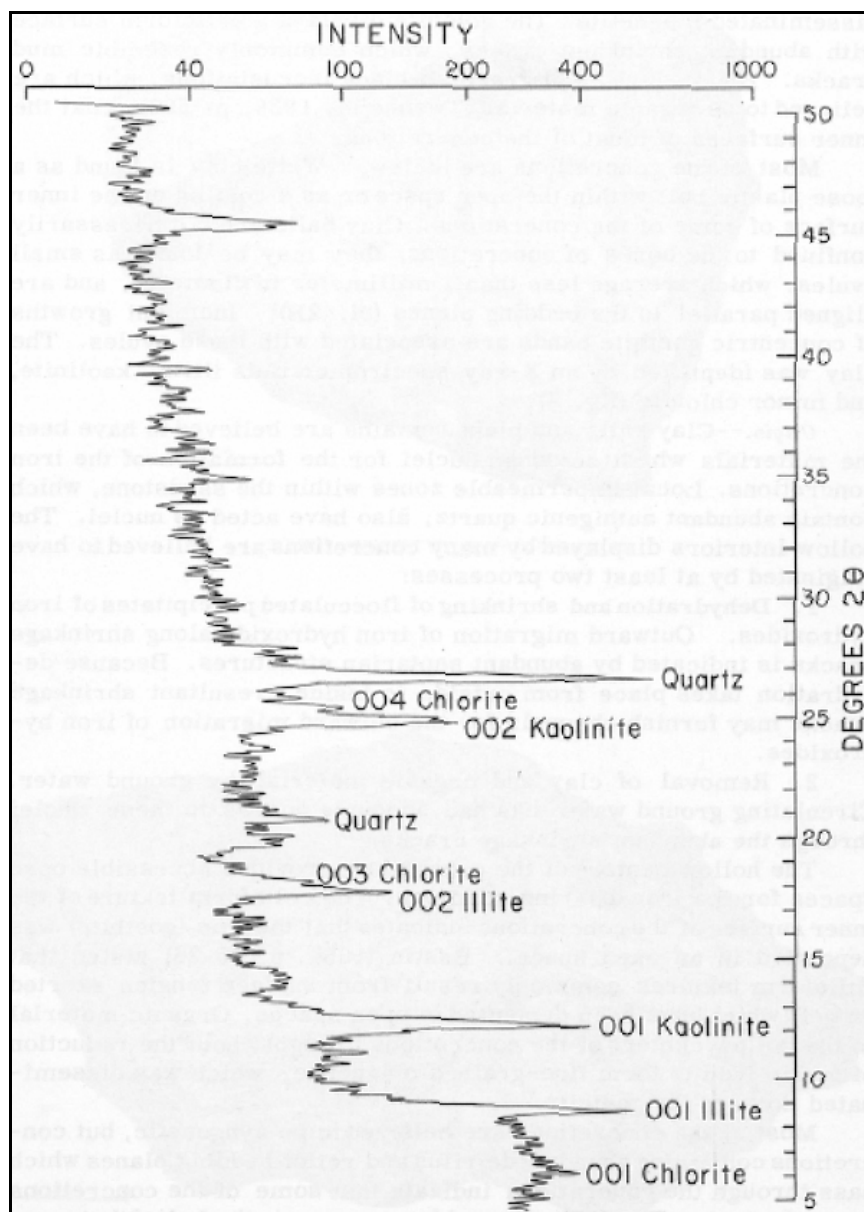


Figure 4. X-ray spectrometer curve of clay minerals.

1. Detrital material was not detected in those concretions believed to be syngenetic.
2. Bedding planes conform to the outline of the concretions rather than passing through, as observed in concretions of epigenetic origin.
3. The large size and abundance of the concretions and the particular abundance in relatively impermeable shale point to a syngenetic origin (Tarr, 1921, p. 383-384).
4. Organic nuclei are probably present in the syngenetic concretions. Undoubtedly, the organic debris was subjected to either putrefaction or oxidation or both. Thus it appears unlikely that the organic material would have persisted long enough to provide nuclei for the formation of epigenetic concretions.

## CHEMICAL ANALYSES

Three chip samples (nos. 1, 2, 3) from the Winfield D. Keely farm in Martin County and one chip sample (no. 4) along Richland Creek in Greene County were taken for chemical analyses.

Sample No.	Location	Thickness of sampled unit (feet)
1 - - -	NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 1, T. 3 N., R. 3 W.	7.5
2 - - -	NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 1, T. 3 N., R. 3 W.	5.5
3 - - -	SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 1, T. 3 N., R. 3 W.	11.0
4 - - -	NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 25, T. 7 N., R. 5 W.	10.0

Samples nos. 1 and 2 were taken from the same exposure; sample no. 1 represents the lowermost part of the outcrop. Samples nos. 1, 2, and 3 were taken from outcrops containing iron minerals largely in the form of concretions and cementing material. Sample no. 4 consists of sandstone containing iron oxides mainly as cementing material concentrated along bedding planes. Tables 1, 2, and 3 show the results of chemical analyses of the samples listed

above.

Table 1-- *Chemical analyses of bog iron deposits  
in Greene and Martin Counties, Ind.*<sup>1</sup>

[S. Ross Taylor, Analyst]

Constituent	Sample No.			
	1	2	3	4
SiO <sub>2</sub> -----	56.8	69.3	75.5	84.2
Fe <sub>2</sub> O <sub>3</sub> -----	34.2	23.0	20.3	10.9
Al <sub>2</sub> O <sub>3</sub> -----	2.3	2.6	.55	2.1
TiO <sub>2</sub> -----	.28	.23	.18	.13
MnO-----	.21	.22	.15	.21
P <sub>2</sub> O <sub>5</sub> -----	.85	.44	.37	.21
SO <sub>3</sub> -----	.04	.04	.06	.04
CO <sub>2</sub> -----	.35	.20	.30	.30
H <sub>2</sub> O and organic material lost at 1000°C.	5.5	3.7	2.9	2.1
Total-----	100.53	99.73	100.31	100.19

<sup>1</sup> Dried at 140°C.

Table 2.--Chemical analyses of bog iron deposits recalculated to express carbon dioxide ( $CO_2$ ), sulphur trioxide ( $SO_3$ ), and phosphorus pentoxide ( $P_2O_5$ ) as ferrous carbonate, sulfate, and phosphate respectively<sup>1</sup>

Constituent	Sample No.			
	1	2	3	4
SiO <sub>2</sub> -----	56.8	69.3	75.5	84.2
Fe <sub>2</sub> O <sub>3</sub> -----	32.1	21.9	19.1	10.0
FeCO <sub>3</sub> -----	.9	.5	.8	.8
FeSO <sub>4</sub> -----	.07	.06	.09	.07
Fe <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> -----	2.07	1.06	.90	.50
Al <sub>2</sub> O <sub>3</sub> -----	2.3	2.6	.55	2.1
TiO <sub>2</sub> -----	.28	.23	.18	.13
MnO -----	.21	.22	.15	.21
H <sub>2</sub> O and organic matter lost at 1000° C.	5.5	3.7	2.9	2.1
Total -----	100.23	99.57	100.17	100.11

<sup>1</sup>Dried at 140° C.

Table 3.--Chemical analyses of bog iron deposits showing water at 140° C., calcium oxide, magnesium oxide, and total iron as Fe

Constituent	Sample No.			
	1	2	3	4
H <sub>2</sub> O at 140° C. from samples as received -----	1.7	.85	.74	.43
CaO -----	.1	.1	.1	.1
MgO -----	.1	.1	.1	.1
Total iron as Fe ----	23.9	16.1	14.2	7.6

Shannon (1907, p. 423-424) reported a much higher iron content for these deposits. His analyses must have been of rich lenses or stringers, as they are not comparable to representative samples from the present outcrops.

Analyses of the samples from Greene and Martin Counties show a distinct relationship between the minor constituents TiO<sub>2</sub> and P<sub>2</sub>O<sub>5</sub>

and the major constituents  $\text{SiO}_2$  and  $\text{Fe}_2\text{O}_3$ . It is suggested, although not conclusively shown, that  $\text{P}_2\text{O}_5$  and  $\text{TiO}_2$  should be expected to increase in the samples having the highest iron content. If it may be assumed that phosphorus is present by virtue of organic material, it also may be concluded tentatively that abundant fossil plants would indicate a higher iron content.

Table 4 is a chemical analysis of a sandstone from the Mansfield formation, which is included for comparison with iron deposits in the Mansfield formation (tables 1, 2, and 3). The amounts of  $\text{Al}_2\text{O}_3$ ,  $\text{CaO}$ ,  $\text{MgO}$ , and  $\text{TiO}_2$  in the sandstone sample are comparable to those in the iron samples. As might be expected, the amount of  $\text{MnO}$  is much higher in the iron samples. Rankama and Sahama (1950, p. 673) pointed out that manganese is contained in various amounts in bog iron ores. Chemical analyses of bog iron ores from other localities (tables 5 and 6) commonly show a relatively high content of manganese.

Chemical analyses given in tables 5 and 6 are comparable for the most part to the analyses of the iron deposits in Indiana. Lindgren (1933, p. 263) stated that bog iron ores are always mixed with sand and clay and rarely contain as much as 50 percent iron (Fe). An increase in the amount of phosphorus with an increase in the amount of organic material is further emphasized in table 5. This relationship is in agreement with the assumption that an increase in the amount of phosphorus results in an increase in the amount of iron. The sulfur content is consistently low as would be expected in bog iron deposits (Lindgren, 1933, p. 263). The remaining minor constituents are comparable for the most part to those in the iron deposits in Indiana.

Table 4.--*Chemical analyses of a sandstone  
from the Mansfield formation*<sup>1</sup>

Oxide	Percent
SiO <sub>2</sub> - - - - -	97.30
Al <sub>2</sub> O <sub>3</sub> - - - - -	1.40
Fe <sub>2</sub> O <sub>3</sub> - - - - -	0.300
CaO - - - - -	0.05*
MgO - - - - -	0.031
TiO <sub>2</sub> - - - - -	0.290
Na <sub>2</sub> O - - - - -	0.05*
K <sub>2</sub> O - - - - -	0.20*
ZrO <sub>2</sub> - - - - -	0.06
MnO - - - - -	0.002

<sup>1</sup>Analyses made from composite of samples  
B52-32 and B52-33 (Murray and Patton, 1953, p.  
29).

\*Less than.

Table 5.--*Chemical analyses of bog ores recalculated as oxides*<sup>1</sup>

Constituent	Sample		
	A	B	D
SiO <sub>2</sub> -----	51.17	51.4	29.13
Fe <sub>2</sub> O <sub>3</sub> -----	28.82	29.69	52.04
Al <sub>2</sub> O <sub>3</sub> -----	.97	.21	.68
MnO- -----	2.60	.41	2.05
P <sub>2</sub> O <sub>5</sub> -----	1. 76	.83	3.41
SO <sub>3</sub> -----	.04	---	---
CO <sub>2</sub> -----	10.91	16.76	6.08
H <sub>2</sub> O, ignition -----	2.14	1.13	4.55
Organic matter ----	1. 63	.03	1.37
CaO -----	1.35	2.52	2.62
MgO -----	.08	.05	.11
KCl -----	.03	*	*
NaCl- -----	.24	*	*
Total- -----	101.74	103.03	102.04
Excess due to calculation of FeO as Fe <sub>2</sub> O <sub>3</sub> --	1.79	3.45	.90
Total- -----	99.95	99.58	101.14

<sup>1</sup>After Clarke, 1924, p. 538.

\*Trace.

Table 6.--Average percentage of oxides obtained from  
30 chemical analyses of Swedish  
bog iron ores<sup>1</sup>

Oxide	Percent
Fe <sub>2</sub> O <sub>3</sub> -----	62.57
Mn <sub>2</sub> O <sub>3</sub> -----	5.58
SiO <sub>2</sub> -----	12.64
Al <sub>2</sub> O <sub>3</sub> -----	3.58
CaO -----	1.37
MgO -----	0.19
P <sub>2</sub> O <sub>5</sub> -----	0.48
SO <sub>3</sub> -----	0.07
Ignition -----	13.53
Total -----	100.01

<sup>1</sup>Lindgren, 1933, p. 263.



GENESIS OF THE IRON DEPOSITS AND NATURE OF THE  
IRON-BEARING SOLUTIONS

The following evidence supports the belief that the iron deposits were precipitated in swamps and lagoons in early Pennsylvanian time:

1. The irregular and local distribution of these deposits is characteristic of bog iron deposits (Tyler, 1950, p. 517).

2. The relative abundance of those plant fossils associated with iron deposits is similar for both the iron deposits in Indiana and bog iron deposits.

3. Chemical analyses of iron deposits in Indiana are similar to chemical analyses of iron deposits of other localities that are known to be of bog origin.

4. The syngenetic nature of the concretions and the abundance of concretions of the iron deposits in Indiana are similar to those of other iron deposits that are known to be of bog origin (Pettijohn, 1949, p. 344).

5. Clay consisting of kaolinite, illite, and chlorite (the general composition of underclay found associated with coal seams) is present in the iron deposits in Indiana. The occurrence of thin coal seams in close proximity to the iron deposits indicates that swamps and bogs which had acidic and reducing conditions must have been abundant. This environment is favorable to the mobilization of iron. The dissolved iron then may have been precipitated in the ferric state by autotrophic plants or by the seasonal sinking of cold surface waters (Goldschmidt, 1954, p. 665).

Shrinkage cracks and colloform texture indicate that the iron of the Indiana deposits is largely a colloidal precipitate. Colloidal ferrous hydroxide is stable in acidic solutions; its stability is augmented by protective organic colloids (Mason, 1952, p. 149). Oxidation of ferrous hydroxide and the organic protective coating would have resulted in the precipitation of ferric hydroxide. Precipitating agents as listed by Rankama and Sahama (1950, p. 674) are electrolytes, micro-organisms, and oxidation.

In addition, supersaturation of iron-bearing solutions can act as a precipitating agent. All these precipitating agents may have been effective in the precipitation of the syngenetic iron deposits and except for micro-organisms also may have caused the precipitation of the epigenetic goethite. Goldschmidt (1954, p. 665) suggests that concentric zoning in many iron ores may be attributed to the seasonal supply of oxygen from sinking aerated waters. Silica sol which is negatively charged may have been effective in precipitating positively charged ferric hydroxide. Dissolved electrolytes contained in the environment of deposition and in the adjacent rocks also may have acted as precipitants of the colloids. Thus solutions

of calcium bicarbonate, an electrolytic solution, probably caused the precipitation of iron in the Beech Creek limestone.

## ECONOMIC CONSIDERATIONS

### SPECIFICATIONS

Lovering (1943, p. 181) stated that prices of iron ore depend upon iron content and freedom from deleterious impurities. Marketable ore should carry at least 50 percent iron, although ore containing as low as 25 percent iron may go to the furnaces under especially favorable conditions, such as a low freight rate to a commercial furnace. The standard grade of iron ore changes periodically. In the Lake Superior district the standard grade ore contains about 50 percent iron, less than 0.10 percent phosphorus, and less than 0.10 percent sulfur. Ore of this grade sells from \$4.00 to \$5.00 per ton.

According to McKinstry (1948, p. 595), oxygen, sulfur, and phosphorus are the main deleterious impurities contained in iron ores and must be removed before the iron can be used for steel. Ore of Bessemer quality must not contain more than 0.045 percent phosphorus, and non-Bessemer ores, which sell at a lower price, may contain as much as 0.18 percent phosphorus. Sulfur in excess of 0.025 percent is usually undesirable; however, iron ore containing as much as 0.20 percent sulfur may be acceptable. Titaniferous ores containing as much as 1.5 percent  $\text{TiO}_2$  and manganese ores containing as much as 10 percent manganese are usually marketable.

### IRON DEPOSITS IN INDIANA

The irregular and local distribution and lateral discontinuity of the iron deposits in Indiana appear to be unfavorable to expensive mining installations. As iron ore commands a relatively low price per ton, the amount of money that can be spent on concentration of ore is limited. A relatively low freight rate to a blast furnace would be required for a small mine to operate profitably.

As one can readily see from the chemical analyses, the iron content of the deposits in Indiana is too low and the phosphorus content is too high for most commercial purposes. Enrichment of these ores by higher grade iron ores from other localities would be necessary for most uses. Owing to the relatively high degree of consolidation of the iron deposits, the ore would have to be crushed.

## CONCLUSIONS

Iron deposits of southwestern Indiana are present predominantly at the base of the Mansfield formation. Chemical analyses and field study substantiate the belief that the iron deposits were formed in a bog environment. Chemical analyses indicate, however, that for most purposes the iron deposits are not of commercial grade.

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