QUATERNARY SYSTEM

Recent Series

The Quaternary is represented by stream gravels, terrace gravels, and alluvium, which are not associated with the iron ores.

STRUCTURE

In general the sedimentary rocks of the western Highland Rim lie horizontally. Although they have been elevated and depressed a number of times since their deposition, these sedimentary beds have retained practically their original attitude. There are, however, some slight flexures and gentle folds, having a general northeast-southwest trend. The dips, where measurable, seldom exceed a few degrees.

Fig. 2. Tuscaloosa gravel cemented into a conglomerate by brown iron ore. Specimen found in the Aetna mines, Hickman County.

The most marked exception to the horizontality of these beds is the uplift in the Wells Creek basin, just southwest of Cumberland City. Miser[7], in his geologic mapping of the Waynesboro quadrangle, has noted several gentle anticlinal and synclinal folds, which he has shown by means of structure contours on the Chattanooga shale. As yet no relationship has been worked out between this folding and the deposits of iron ore.

[7]Miser, H. D. 1921. *Op. cit.*, geologic map.

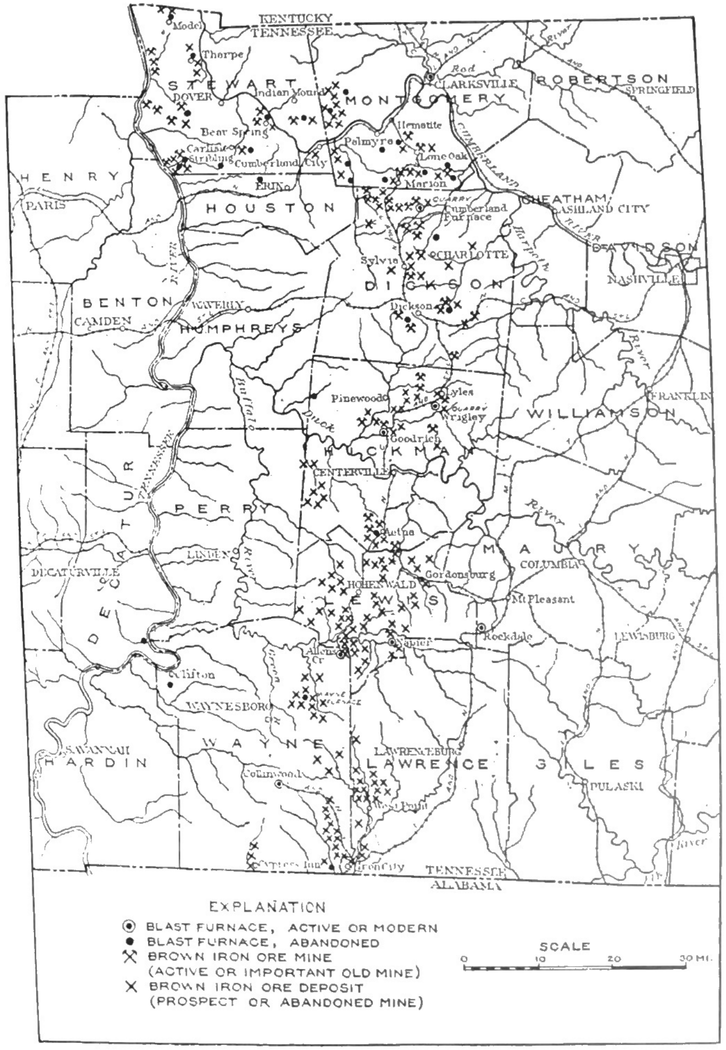

Fig. 3. Map of the western Highland Rim area of Tennessee, showing the location of the iron ore deposits, mines, quarries, and blast furnaces. (Used by courtesy of the United States Geological Survey).

The Brown Iron Ores

GENERAL DISTRIBUTION

The brown iron ores of the western Highland Rim lie in a north-south belt, lying west of the Central Basin and east of the Tennessee River (Fig. 3). The north-south extension of this ore belt is approximately 120 miles, the Kentucky state line roughly marking the northern boundary, and the ore workings in the vicinity of Iron City—just a few miles from the Alabama state line—the southern boundary. The width of the iron ore area varies from about 15 miles in the central part of the region to 35 or 40 miles in Stewart and Montgomery Counties.

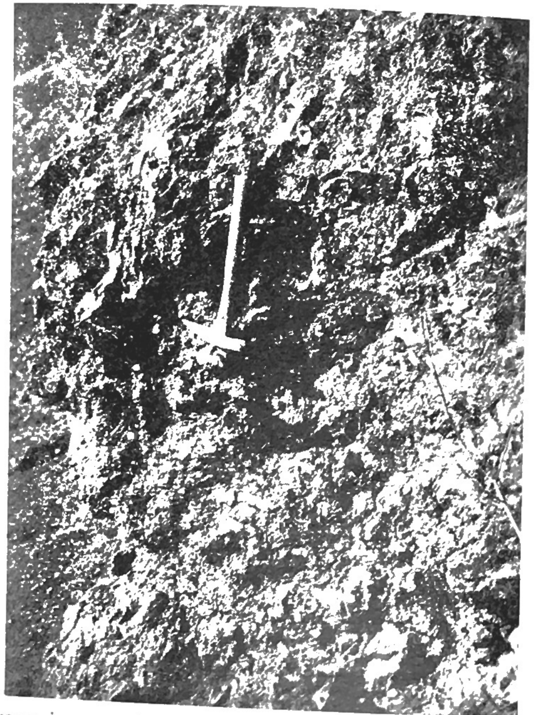

Fig. 4. Brown iron ore-chert breccia. From near Aetna, Hickman County.

It must not be thought that the northern and southern boundaries of the iron ore belt are marked abruptly by the Kentucky and Alabama state lines respectively. Brown iron ore of the same character has been described in western Kentucky, and Burchard[8] has reported

[8]Burchard, E. F. 1907. *Brown Iron Ores of the Russellville District, Alabama.* U. S. Geol. Surv., Bull. 315, pp. 152-160.

ore, very similar to that of western Tennessee, just across the Alabama line in Franklin County.

The counties of the Rim visited by the writer in his field work, beginning at the northwest, are: Stewart, Montgomery, Dickson, Hickman, Lewis, Wayne and Lawrence. Iron ore has also been noted farther to the west in Houston, Humphreys, Benton, Perry, Decatur, and Hardin counties, but these counties have never been important producers of ore.

OCCURRENCE AND FORM OF THE DEPOSITS

Throughout the Rim region the ore is found in concentrated zones, which the miners call banks. These banks occur rather consistently on the crests of the ridges and spurs of the highly dissected Highland Rim. In many places the ore outcrops at the surface, while in other localities barren overburden overlies the ore in depths ranging from a few feet to 25 or 30 feet. This overburden of top clay is extremely red in color and has been used in prospecting for ore. Much of the ore occurs in the form of a breccia with chert (Fig. 4).

That the ore occurs in pockets of different richness is evidenced by the irregular appearance of the pits at present. The open ore pits near Nunnelly in Hickman County and Pinkney in Lawrence County are excellent examples of the segregation of the iron ore in certain areas (Fig. 5). In these pits the best ore was mined out, leaving high pinnacles of clay and debris here and there throughout the pits.

Most of the ore has been removed by strip mining. At first, hand methods were used, but later steam shovels were employed in the open pits. There has been some tunnel mining in the area, but only to a limited extent. The ruins of the old tunnels may still be seen in the Aetna workings in Hickman County and in the vicinity of the old Wayne Furnace in northern Wayne County.

The size and depth of the deposits are extremely variable. Some of the banks in the western iron region occupy an acre or less, while others cover more than a square mile. Pits such as those at Stribling, Allens Creek, and Nunnelly are particularly extensive (Fig. 5). The depth of the ore varies greatly, even within the same bank. Workings at the Napier mines in Lewis County have extended to nearly 50 feet in depth, and the bottom of the ore has not been reached. At the Nunnelly mines in Hickman County the pits are now practically 60 feet deep, and it has been reported that a shaft was sunk 60 feet farther and was still in the ore body. In other places in the region, such as the Van Leer mine near Iron City, the workings are relatively shallow (Fig. 6). In all probability, the depth of the ore in the western Highland Rim area will average about 35 to 40 feet.

TYPES OF ORE

The brown iron ores of the western Highland Rim consist chiefly of the hydrous iron oxide, limonite, which occurs in a great variety of forms, the more important of which are listed below:

1. *Shot ore.* Shot ore is the term applied to the fine-grained, more or less rounded pieces of limonite, a part of which has been formed by the disintegration of larger pieces of ore. It usually occurs in the overlying clay and is often considered as a surface indication in prospecting for ore.

2. *Iron ore-chert breccia.* In many places angular pieces of chert have been cemented together by limonite forming a true breccia. A certain amount of replacement of the chert by the limonite may be noted in these breccias (Fig. 4).

3. *Replacements in chert.* When limonite fills a fissure or serves as a cement in chert, there is generally a partial replacement of the chert by the ore. In some specimens this replacement is almost complete (Fig. 7-A).

Fig. 5. View of the extensive ore workings near Nunnelly, Hickman County. Some of these pits reach a depth of more than 60 feet.

4. *Limonite-gravel conglomerate.* In localities in which the iron ore is found associated with Cretaceous gravels and sands, a conglomerate is formed with the iron ore serving as a cementing agent (Fig. 2).

5. *Fissure filling in chert.* Small fissures in chert are often filled by the iron ore. As was the case in the ore-chert breccia, some of the chert is replaced by the hydrous iron oxide along the sides of the fissures (Fig. 7-A).

6. *Honeycomb ore.* This variety has been formed by the action of water and other weathering agencies on the hard ore. The more soluble portions of the ore are dissolved, leaving a porous structure, consisting of thin webs and shells of limonite (Fig. 7-B).

7. *Replacements in clay.* In a few instances limonite has replaced clay with the formation of a low-grade ore.

8. *Bombshell ore.* Many large lumps of limonite are hollow resembling geodes. These represent limonite surrounding clay or other material which may have been later removed by solution.

9. *Pot ore.* Pot ore is the miners' term for that type of compact, massive, iron ore, which often exhibits a botryoidal surface (Fig. 8-A).

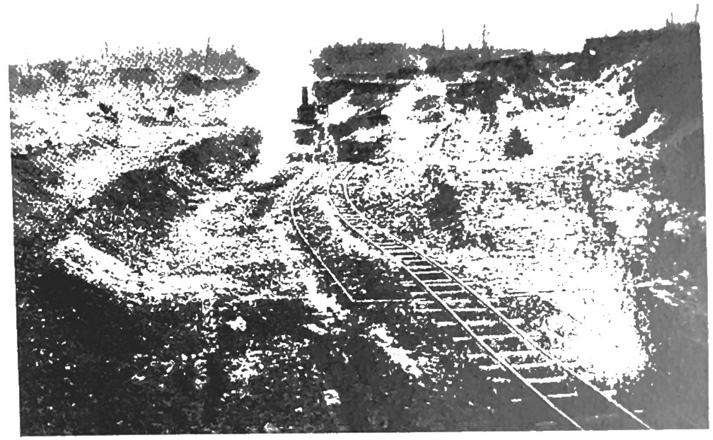

Fig. 6. Steam shovel at work in a shallow brown iron ore pit. Van Leer mines, near Iron City, Lawrence County.

The texture of the iron ore ranges all the way from the dense, compact variety such as pot ore, to the porous type described above as honeycomb ore. In many places, especially in the highly weathered zone near the top of the pits, the iron ore is decidedly earthy in character. There is also a wide variation in color. Where the ore has been exposed to long weathering it is an ocher-yellow, and grades from that color through several shades of brown to nearly black. The massive, compact variety is generally dark brown in color.

MINERAL COMPOSITION

The iron ore minerals of the western Highland Rim are all hydrous iron oxides. They resemble hematite in that their iron is in the ferric state, but differ essentially from that mineral in that they contain varying amounts of chemically combined water. In ordinary usage the brown iron oxides are indiscrimately called brown iron ore, brown ore, brown hematite, or limonite.

The brown iron oxides form an almost perfect isomorphous series, since with an increase or decrease in iron content or water of hydration, they grade from one into the other. They range from the almost anhydrous turgite to limnite which contains over 25 per cent chemically combined water.

Eckel[9] has tabulated these hydrous oxides of iron in the following manner (Hematite has been included by the author in order to complete the comparison):

Mineral	*Chemical Formula*	*Iron Oxide*	*Water*
Hematite	$2\ Fe_2O_3$, $0\ H_2O$	100.0 per cent	0.0 per cent
Turgite	$2\ Fe_2O_3$, $1\ H_2O$	94.7 per cent	5.3 per cent
Goethite	$2\ Fe_2O_3$, $2\ H_2O$	89.9 per cent	10.1 per cent
Limonite	$2\ Fe_2O_3$, $3\ H_2O$	85.5 per cent	14.5 per cent
Xanthosiderite	$2\ Fe_2O_3$, $4\ H_2O$	81.6 per cent	18.4 per cent
Limnite	$2\ Fe_2O_3$, $6\ H_2O$	74.7 per cent	25.3 per cent

Both the chemical and physical properties of these iron oxides are very similar.

It is certain that limonite ($2Fe_2O_3$, $3H_2O$) is the principal hydrous iron oxide in the brown iron ores of the western Highland Rim. However, there is a possibility that the amount of other members of the brown iron ore series has been underestimated. Both Burchard[10] and Miser[11] call attention to this fact in their publications. C. S. Ross made a microscopic examination of several specimens for Burchard and found the presence of a crystalline mineral which corresponded with the indices of refraction for goethite. There is every reason to believe that there is more goethite and turgite present in the ores of this region than has been previously supposed.

The chemical analysis of some brown iron ores of the Rim region indicate the presence of other iron oxides, which have a higher iron percentage than limonite. For example, D. F. Farrar, chemist for the Tennessee Geological Survey, made an analysis of an ore near Slayden in Dickson County, and found that it showed 59.35 per cent iron. Since limonite, free from all impurities, contains only 59.8 per cent iron, the question arises as to the true mineral composition of this ore. Later investigation by C. S. Ross proved this specimen to be limonite, along with mixtures of goethite and turgite. The presence of the last two minerals would naturally increase the percentage of the iron in the ore under consideration.

In several localities the writer noted a bright red mineral coating the limonite, and in the Napier pits a pinkish mineral was observed

[9]Eckle, E. C. 1914. *Iron Ores: Their Occurrence, Valuation and Control.* McGraw-Hill Co., New York, page 25.
[10]Burchard, E. F. 1927. *Op. cit.*, page 67.
[11]Miser, H. D. 1921. *Op. cit.*, page 49.

along with the brown iron ores. Both minerals were brought back to Vanderbilt University for identification. Qualitative and quantitative analyses for iron and chemically combined water were determined in an effort to identify the unknown minerals. The following results were obtained:

RED MINERAL

	Sample No. 1	Sample No. 2
Percentage of iron	69.67	69.59
Percentage of chemically combined water	5.29	5.05

PINK MINERAL

	Sample No. 1	Sample No. 2
Percentage of iron	62.48	62.62
Percentage of chemically combined water	10.01	10.05

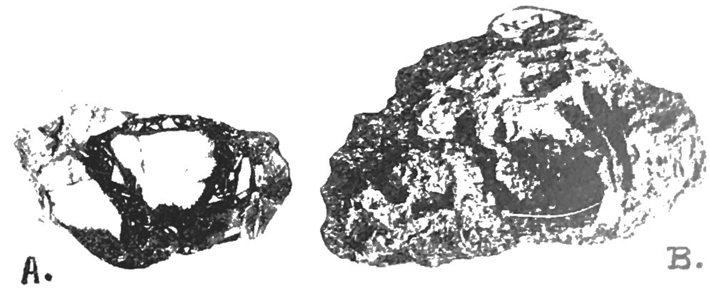

Fig. 7. A. Polished specimen showing replacement of white chert by brown iron ore. The faint gray areas show fragments of chert in various stages of replacement. The dense brown areas have resulted from almost complete replacement of the chert by the iron ore. From the Cumberland Furnace mines, Dickson County. B. Honeycomb ore, a porous variety of brown iron ore. From the ore pits near Nunnelly, Hickman County.

The results obtained from the analyses of the red mineral show that it is turgite. Turgite theoretically has 66.2 per cent iron and 5.3 per cent water of hydration. The fact that the red mineral analized 69.67 per cent iron suggests that it may contain a small amount of hematite in solid solution, which would increase the iron content. This is further substantiated by the fact that the combined water is 5.29 and 5.05 per cent, which is very near the theoretical percentage of chemically combined water in turgite. The presence of a small amount of hematite would not affect the percentage of water of hydration, since pure hematite contains no combined water.

The pink mineral is goethite. Theoretically, goethite contains 62.9 per cent iron and 10.1 per cent water of hydration. It will be noted that the above analyses by the writer of the pink mineral closely approximate these percentages. The physical properties of both the red and pink mineral correspond very closely to those described by Dana for turgite and goethite respectively.

No xanthosiderite or limnite were noted by the writer in the field, but in all probability these minerals are present in small amounts. The presence of hematite in the ores of the western Highland Rim in appreciable quantities is extremely doubtful. Burchard, Miser, Rogers, and others who have worked on the iron ores of this region have failed to observe it.

CHEMICAL COMPOSITION

The quantitative chemical composition of the brown iron ores varies considerably within the area. An endeavor was made to collect as many analyses of the ores of the western Highland Rim as possible

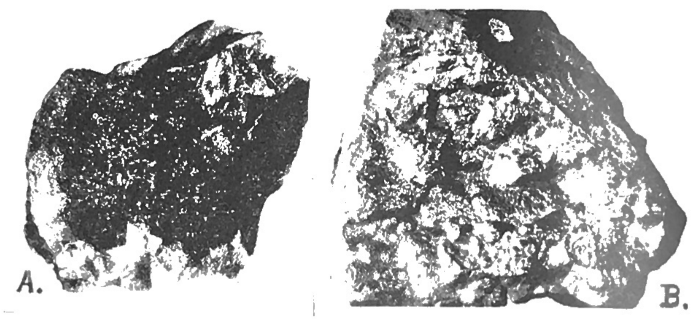

Fig. 8. A. Pot ore; a dense compact variety of brown iron ore. Note the botryoidal structure on the surface. Specimen from Stewart County, in the mineral collection of the Department of Geology, Vanderbilt University. B. A polished specimen of a highly sandy variety of iron ore. From the Napier pits, Lewis County.

from the available sources. An inspection of about 150 chemical analyses, which were compiled by the writer, show the following approximate averages of the constituents of the brown iron ores:

Metallic iron (Fe)—ranges from less than 40 to nearly 50 per cent with an average of about 45 per cent.
Insoluble (Al_2O_3 and SiO_2)—ranges from 10 to about 25 per cent with an average of more than 20 per cent.
Phosphorus (P)—ranges from mere traces to nearly 2 per cent with an average of between 0.4 and 0.5 per cent.
Manganese (Mn)—ranges from less than 0.1 per cent to more than 2 per cent with an average of about 0.4 per cent.
Chemically combined water—ranges from about 8 to 14 per cent with an average of about 10 per cent.

Analyses of the ores in the southern counties list sulphur (S), which occurs in minor amounts, at generally less than 0.1 per cent.

J. H. Walker, Consulting Engineer for the Tennessee Products Corporation, has supplied the writer with average analyses of the brown iron ores of the western Highland Rim by counties. Most of the analyses which compose these averages have been made on prospect samples, and are therefore higher in iron content and lower in insoluble constituents than the washed ore at the mine would average. The Tennessee Products Corporation owns several large ore workings in the region, and therefore the writer feels that Walker's averages are fairly representative of the ores:

Average Chemical Composition of the Brown Iron Ores of the Western Highland Rim by Counties

STEWART COUNTY	
Iron	53.00%
Insoluble	7.80%
Phosphorus	.36%
Manganese	.55%
MONTGOMERY COUNTY	
Iron	48.50%
Insoluble	15.20%
Phosphorus	.44%
Manganese	.46%
DICKSON COUNTY	
Iron	50.00%
Insoluble	12.50%
Phosphorus	.18%
Manganese	.26%
HICKMAN COUNTY	
Iron	52.00%
Insoluble	7.30%
Phosphorus	.128%
Manganese	.34%
LEWIS COUNTY	
Iron	53.00%
Insoluble	5.20%
Phosphorus	1.00%
Manganese	.18%
WAYNE COUNTY	
Iron	53.00%
Insoluble	11.40%
Phosphorus	.58%
Manganese	.38%
LAWRENCE COUNTY	
Iron	52.00%
Insoluble	7.20%
Phosphorus	.65%
Manganese	.30%

The iron, insolubles, and manganese content appear to vary widely within the area. However, it will be noted that the phosphorus percentage is uniformly high in Lewis, Lawrence, and Wayne Counties, and an attempt to explain this high phosphorus content will be made later in the paper.

ASSOCIATED MINERALS

The most abundant minerals associated with the brown iron ores of the western Highland Rim are the different forms of silica and clay. The silica occurs as (1) minute particles of quartz sand which is disseminated through some of the ore (Fig. 8-B); (2) pockets and lenses of sand in ore bodies; (3) fragmental chert, which may be cemented by the iron oxide into an iron ore-chert breccia; (4) both angular and well-rounded chert pebbles, which may be cemented by the limonite into a conglomerate; (5) well-rounded pebbles of milky quartz.

As has been previously stated, the clay in association with the iron ore has been derived from the weathering of the Mississippian formations, and often contains fragmental chert, gravel, and sand. The clay is generally white, yellow, or red in color and when wet is extremely sticky and plastic.

Manganese occurs in the region to a limited extent as is shown by the chemical analyses of the ore. It is probably in the form of wad, a soft brownish-black impure oxide, and it is possible that some pyrolusite is present. Dendritic manganese oxide on chert was observed in the field in several places.

In Wayne and Lawrence Counties, especially in the vicinity of the Van Leer mine, three rather rare iron phosphate minerals, strengite, cacoxenite, and beraunite, have been described by Miser[12]. At the time of the writer's visit to the Van Leer mine none of these iron phosphates were noted, but the mineral collection of the Department of Geology, Vanderbilt University includes specimens from that locality.

TOPOGRAPHIC RELATIONS

It has been previously stated that the brown iron ores under discussion occur on the western Highland Rim which lies to the west of the Central Basin at a higher altitude ranging from 200 to nearly 500 feet. The topographic history of this plateau during Eocene and later time has also been discussed.

The altitude of the iron ore deposits varies from less than 350 feet in Stewart County, near Tennessee River, to well over 1,000 feet in the high inter-stream area in Lewis County. By far the majority of the deposits occur on the crests of the ridges, seldom more than 150 feet from the top. This remarkable topographic uniformity of the iron ores brings up the interesting point as to whether or not there is a definite relationship between the location of the present ore deposits and the peneplanation of the Highland Rim.

[12]Miser, H. D. 1921. *Op. cit.*, page 53.

Burchard[13] has compiled the following table based on his field work along with that of Rogers and Miser. It will be noted that the greater number of the deposits occurs at an altitude of more than 700 feet:

RANGE IN ALTITUDE OF DEPOSITS OF BROWN IRON ORE IN WEST-MIDDLE TENNESSEE

Area	Number of deposits	Altitude
Stewart County	22	365-650 feet
Montgomery County	10	475-700 feet
Dickson County	32	550-900 feet
Hickman County	20	600-900 feet
Lewis County	30	700-1050 feet
Waynesboro Quadrangle	90	750-1000 feet

This problem may also be attacked from the production standpoint. With the possible exception of Stribling in Stewart County, none of the deposits of less than 700 feet in altitude have ever been important producers of iron ore. However, the high-level deposits, 700 to 1,050 feet above sea level, have produced over 90 per cent of the ore which has been mined in this region. The important workings in Dickson, Hickman, Lewis, Wayne and Lawrence counties are all high-level deposits, and there is a probability that their yield is roughly proportional to their extent. Very probably erosion has reduced the size of the areas of iron ore that were once on the higher levels. It is also probable that solution and redeposition at lower levels are going on at present.

THEORY OF ORIGIN

The economic geologist is often confronted with many differences of opinion as to the origin of certain mineral deposits. The brown iron ores of the western Highland Rim of Tennessee are no exception to the rule. Several hypotheses as to the possible origin of these iron ores have been suggested. Safford[14] in his early work on the ores of this region regarded the ferruginous chert of the Lithostrotion Bed (Warsaw and St. Louis) as the source of the iron, with the matrix composed of weathered chert and clay from the Siliceous Group (Fort Payne and New Providence).

Since iron is the fourth most abundant element in the earth's crust, the amount present in many limestones is considerable. However, it has been clearly shown by Eckel[15] that the decay of a limestone, carrying disseminated iron material, can never of itself yield a deposit of brown iron ore, although it may add materially to the deposit.

It seems imperative, therefore, to seek a more important source of the iron than that found in the Mississippian limestones of the Rim

[13]Burchard, E. F. 1927. *Op. cit.*, page 71.
[14]Safford, J. M. 1869. *Geology of Tennessee.* Nashville, page 350.
[15]Eckle, E. C. 1914. *Op. cit.*, pp. 96-97.

region. An adequate source of the iron in the ore deposits of this region is believed to be the ferruginous sediments of Cretaceous and possibly Tertiary age, which formerly overlay the Mississippian rocks in the area, but are now represented on the western Highland Rim only by isolated remnants of the Tuscaloosa gravel and the Eutaw sand, both of Cretaceous age.

Many brown iron ore regions in the South have been observed and recorded by Burchard of the United States Geological Survey, and in each of these localities he has noted the influence of the ferruginous sediments of the Coastal Plain upon the formation of iron ore deposits. Chief among these localities are the brown iron ores at Woodstock and Russellville, Alabama; near Shreveport, Louisiana; and in northeastern Texas.

The presence of the Tuscaloosa gravel and the Eutaw sand in the Rim region is evidence of the extension of Cretaceous seas over this area, and it is very possible that other glauconitic formations, such as the Selma and Ripley beds, which are present in western Tennessee and northeastern Mississippi, extended over most of the western Highland Rim. The eastern limit of the Cretaceous seas is open to debate, but recent field work tends to extend it farther east. The writer noted a patch of Tuscaloosa gravel some 15 miles farther east than it had been mapped in Montgomery County, and it is possible that these Coastal Plain deposits extended to the edge of the Central Basin, but have later been removed by erosion.

It is an established fact that glauconitic members were present in many formations of Cretaceous and Tertiary ages, especially in the Gulf Embayment series. Jewell[16] has described considerable greensand, or glauconite, in the Coffee phase of the Eutaw sand in Hardin County. And there is every reason to believe that the formations above the Eutaw were even more glauconitic in composition. If the above be true, the glauconite of these members would provide an adequate source of the iron, which is now represented in the iron ore belt under consideration.

Glauconite, or greensand, is a hydrated silicate of potassium and iron and according to Clarke[17] is represented by the formula $Fe^{III}\,K\,Si_2\,O_6.\,n\,H_2O$, when in the pure state. Iron was contained in the ferric state as glauconite granules in the Mississippi Embayment series, and although the iron content was quite variable, according to Clarke's analyses it must have approximated 12 to 15 per cent.

It is interesting to note the chemistry probably involved in the formation of the hydrous iron oxides of the western Highland Rim. Considering these glauconite-bearing formations of the Coastal Plain phase as the important source of the iron, a definite progression of chemical reactions appears to have taken place.

[16]Jewell, W. B. 1931. *Geology and Mineral Resources of Hardin County.* Tenn. Geol. Surv., Bull. 37, page 92.
[17]Clarke, F. W. 1924. *The Data of Geochemistry.* (5th Ed.) U. S. Geol. Surv., Bull. 770, pp. 519-521.

With the withdrawal of the Cretaceous and lower Tertiary seas, these glauconitic formations were soon subjected to erosion and the action of ground water. These surface waters carried carbon dioxide in solution, derived from the atmosphere, the nearby carbonates, and decaying vegetation. It has been proved by laboratory research that hydrous silicates are rather soluble in waters charged with carbon dioxide. Therefore, downward percolating waters, carrying carbon dioxide, would tend to take into solution a considerable amount of the iron in the glauconite in the form of the normal carbonate, although it is possible that some of it was in the form of the bicarbonate or sulphate.

The descending iron-bearing waters were provided a relatively easy passageway by the porosity of the underlying, loosely consolidated formations, especially the Tuscaloosa gravel. A certain amount of the iron was precipitated in the gravels and clays of the Tuscaloosa, which is evidenced by the occurrence of the conglomerate of this gravel with clay and iron oxide. However, most of the iron-bearing solutions continued downward into the more impervious Mississippian rocks, where the iron was precipitated under favorable conditions. The probable complexity of this process has been noted by Burchard[18]:

> This process was not direct or simple, however, for it doubtless was closely related to the physiographic history of the region, and the iron oxides may have passed through several stages of concentration before arriving at their present condition and position.

It is quite possible that the relatively high phosphorus content of the brown iron ores of Lewis, Wayne, and Lawrence Counties, has a definite relationship to the Coastal Plain formations, which also served as a source of iron.

The present amount of Tuscaloosa gravel and Eutaw sand represented in the southern counties of the Rim indicates that the Mississippi Embayment series was thicker in that region. In the central and northern counties of the area the Eutaw is evidently absent, and the Tuscaloosa gravel occurs only in isolated patches capping the higher hills.

Analyses of the mineral glauconite reveal varying amounts of phosphorus. There is a possibility that the phosphorus was taken into solution along with the iron, and deposited with it. Since the Coastal Plain sediments were thicker in the southern counties, the source of the phosphorus would naturally be greater, and it is logical to expect a higher percentage of phosphorus in the brown iron ores of an area where the source was greater.

A very strong argument in favor of the Cretaceous and Tertiary formations as the important source of the iron is the absence of the brown iron ore deposits on the eastern Highland Rim. The writer had considered this absence as supporting the idea of the influence of the glauconite-bearing formations on the ore deposits before he

[18]Burchard, E. F. 1927. *Op. cit.*, page 75.

read Burchard's unpublished manuscript on the *Brown Iron Ores of the Western Highland Rim, Tennessee*. In this work Burchard also cites the absence of ore on the eastern Highland Rim to substantiate his opinion that the iron originally came from overlying Cretaceous and Tertiary formations. It seems most logical since the deposits of the Coastal Plain did not extend across the Nashville Dome, that the brown iron ores would not be found in the part of the Highland Rim which lies east of the Central Basin. In fact, these glauconite-bearing formations lying on the west flank of the Nashville uplift would be situated in a most favorable position for westward drainage and concentration of the iron-bearing solutions.

AGE OF THE DEPOSITS

The presence of the iron ores in association with the Tuscaloosa gravel points strongly toward the age of the deposits as Tertiary. Eckel[19] has stated that most of our brown iron ores were deposited during the Tertiary. He cites definite proof that the ores near Russellville, Alabama, are of Tertiary age, because of their intimate relation with the Lafayette gravel. Since the brown iron ores deposits of the Russellville district have been generally considered as a southern extension of the western Tennessee belt, it seems logical to consider the ore of the Highland Rim to be Tertiary in age.

Jewell[20] in his work on the iron ores of eastern Hardin County considers the limonite there to be of Tertiary age:

> It has generally been assumed that the conditions most favorable for the formation of ore deposits of this nature are long, deep weathering in a temperate or tropical climate where the land surface is close to sea level and consequently much of the work of rock disintegration is of a chemical nature. It is generally believed that such conditions existed in this part of Tennessee in early Tertiary time. The logical conclusion is that the bulk of the iron deposits were formed then. This is perhaps essentially true but the fact that a few of the deposits occur near the bottom of the stream valleys as much as 300 feet below the general level of the Highland Rim peneplain shows that the process responsible for the formation of the iron deposits continued up to recent times and is probably in operation today to a certain extent. This is further shown by the fact that many of the terrace gravels, some of which are less than 60 feet above the flood stage of the Tennessee River, are strongly cemented by iron oxides. These lower gravels are probably not older than Pleistocene. It is thus clearly evident that iron-bearing solutions have been precipitating their salts to fairly recent times and certainly for many tens of thousands of years since the early Tertiary peneplain first started to rise.

BROWN IRON ORE RESERVES OF WESTERN TENNESSEE

The quantity of iron ore produced in the western Highland Rim area of Tennessee from 1797 to 1926 is estimated to have been about

[19]Eckel, E. C., in Burchard, E. F., Butts, Chas., and Eckel, E. C. 1910. *Iron Ores, Fuels, and Fluxes of the Birmingham District, Alabama.* U. S. Geol. Surv., Bull. 400, page 149.

[20]Jewell, W. B. 1931. *Op. cit.*, page 55-56.

8,420,000 gross tons, and the pig-iron, including ferrophosphorus, produced in the same period is estimated to have been about 3,940,000 gross tons[21].

Notwithstanding the fact that much of the richer deposits of brown iron ore have been mined out of this region, it appears that the western Highland Rim of Tennessee contains valuable reserves of ore. It will, however, require a greater expenditure of capital than that expended during the early days of the industry, since a lower grade of ore must be mined. Iron ore competition is keen at the present, and with the opening of new fields, promises to remain that way in the immediate future at least.

Most of the people interviewed by the writer during his work in the field were optimistic regarding the return of the iron ore mining industry in western Tennessee, but if this is to be brought about it is certain that more modern methods of mining and concentration of the ore will be necessary. The factors which have a definite effect on the accessibility of the ore will have to be carefully considered. Chief among these are the situation of the banks with regard to mining and concentration, and the location with respect to transportation facilities. The economic factor, the strategic position in respect to the markets, which governs supply, demand, and price, is also very important.

Since the writer's work on these ores was largely reconnaissance in nature, no estimate has been attempted regarding the possible reserve of iron ore in this region. In fact, no definite figure has ever been given as to the amount of unmined ore. Because of the irregular nature of the banks, the difficulties confronted in making a satisfactory estimate of reserve ore tonnage are obvious.

However, Burchard[22], utilizing his personal data along with the field observations of Rogers and Miser, has constructed the following table of the brown iron ore reserves of this region:

ESTIMATED RESERVES OF BROWN IRON ORE IN WESTERN HIGHLAND RIM AREA, TENNESSEE, BY COUNTIES, IN GROSS TONS
(Subject to Revision)

Stewart	450,000
Montgomery	400,000
Dickson	600,000
Hickman	750,000
Lewis (North of Allens Creek)	700,000
Wayne and Lawrence	6,000,000
Total	8,900,000

[21]Burchard, E. F. 1927. *The Western Tennessee Valley Iron Region.* Manufacturers Record, page 69.

[22]Burchard, E. F. 1927. *Brown Iron Ores of West-Middle Tennessee.* U. S. Geol. Surv., Bull. 795-D, page 112.