IRON AND MANGANESE.

TONNAGE ESTIMATES OF CLINTON IRON ORE IN THE CHATTANOOGA REGION OF TENNESSEE, GEORGIA, AND ALABAMA.

By Ernest F. Burchard.

INTRODUCTION.

In the summer of 1906 and the autumn of 1908 the writer made a brief reconnaissance of the productive and possibly productive Clinton iron-ore fields within a radius of 80 miles of Chattanooga, Tenn. It is difficult to assign any definite limits to the Chattanooga region. In one sense it comprises the so-called Rockwood district and may be considered to extend as far southward as Gadsden and Attalla, Ala., and will be so considered here. The data gathered regarding the thickness, quality, and probable extent of the ore beds have been used in making preliminary estimates of tonnage of Clinton ore for the report of the Conservation Commission, which was submitted to the President in December, 1908.[a] In preparing these estimates the ore beds have, because of their broadly lenslike shape, been considered to be tabular bodies of varying thickness. In all estimates the average thickness used has been derived from as large a number of measurements as were available. The structure and attitude of the beds have been considered as determining their workability for given distances down the dip. A vertical depth of 1,000 feet below the level of the outcrop has been considered as the limit to which the ore might be regarded as workable under present conditions. Beds dipping uniformly at an angle of 25° would reach a depth of 1,000 feet at about 2,300 feet from the outcrop. With steeper dips, the distance would be much less; for instance, beds dipping at 50° would reach the 1,000-foot level at about 1,400 feet from the outcrop. For dips less than 25° the distances would be very much greater. The other factors that were considered besides the length, breadth, and average thickness of the

[a] The complete statistics of iron-ore reserves embodied in the conservation report are given in the paper by C. W. Hayes, reprinted in Bull. U. S. Geol. Survey No. 394, 1909.

prisms of ore were the content of metallic iron and the percentage of probably recoverable ore. Some ore is invariably left for roofs or pillars in mining operations, and much is necessarily impossible of recovery on account of faults. About 80 to 90 per cent has been regarded as the recoverable proportion. The percentage of metallic iron controls not only the value of the ore, but also its specific gravity or number of cubic feet contained in a ton of ore. Ores are here considered as workable under present conditions that ten years ago were not mined owing to their low content of iron. With the exhaustion of the soft ores of the region, leaner and leaner hard ores have been utilized, owing to their high content of lime and low silica, which renders the material a suitable flux for brown ore or limonite. It is characteristic of the Clinton ores of this region that the hard ore is generally high in lime. Such ore, though originally low in iron, yields on weathering a soft ore rich in iron, and this accounts for the unusual richness of the soft ores that have been found in the region.

In the following pages is given an outline of the main facts on which are based the estimates of tonnage given on page 187. The figures given are, however, very much generalized and can not be regarded as at all close. Some of them may be too high, but it is believed that they are in the main conservative. They are the best that can be offered as a result of a very hasty and incomplete investigation, and it is hoped that what has been done may be only preliminary to a comprehensive study of the question of the origin and extent of the Clinton iron ores in the southern Appalachians.

ROCKWOOD DISTRICT.

LOCATION AND EXTENT.

The Rockwood district lies in the Tennessee River valley between Harriman and Dayton, Tenn., and extends eastward from the base of the Cumberland escarpment, or Walden Ridge, for about 10 miles. The area is principally in Roane County. Ore has been mined in many places along the west side of the valley between Spring City and Harriman, a distance of 25 miles. Adjacent to and underlying the river bed near the mouth of White Creek is a strip of Clinton (Rockwood) formation about 9 miles long. Ore has been mined at five or six places in this strip. The nearest post-office at present is Euchee. Six miles east of Euchee occurs another strip of Clinton (Rockwood) formation about 10 miles in length from northeast to southwest. Ore is mined at the upper end of this strip near Welker post-office.

Geologic maps of the district are contained in the Kingston folio (No. 4) of the Geologic Atlas of the United States.[a]

[a] The edition of this folio is exhausted, but the folio is on file in many public libraries, colleges, and engineering offices.

The ore along Walden Ridge is within one-fourth to one-half mile of the Queen and Crescent and the Tennessee Central railroads. The ore at Euchee is carried by boat down Tennessee River to a point opposite Dayton, and the ore at Welker is also dependent on favorable conditions of the river for transportation from Seven Islands down to Caney Creek. Where the ore is carried partly by water private railways have been built to the river.

ROCKWOOD-CARDIFF AREA.

Along the southeast base of the Cumberland escarpment outcrop strips of the Clinton (Rockwood) formation, broken in places by faults which have interrupted the continuity of the formation and wedged in masses of Carboniferous rocks. The Clinton (Rockwood) formation is composed of shale, sandstone, and iron-ore beds. It forms generally a low ridge or line of foothills in front of the Cumberland escarpment. The beds dip to the northwest, passing below the Mississippian chert and limestone, which in turn are overlain in the Cumberland escarpment by masses of sandstone, shale, and beds of coal. Underlying the Clinton (Rockwood) formation to the southeast is the Chickamauga limestone, below which occurs the Knox dolomite, underlain by shale and sandstone of Cambrian age. The formation contains one bed of ore that is workable between Harriman and Rockwood, also at a few points south of Rockwood as far as Glen Alice. The normal thickness of the ore bed ranges from 2½ to 4 feet. The degree of dip of the Clinton (Rockwood) rocks and their inclosed ore beds varies greatly from place to place along the outcrop, and it is not at all uniform at right angles to the outcrop. In places the bed at the outcrop dips very steeply 75° to 80° NW. Where followed underground for distances of 20 to 100 feet along the dip, it may be found to be faulted and offset several feet. Commonly the broken edges of the bed are found to be shoved past each other so as to overlap, giving the impression that there are two beds of ore in the section. The dip of the ore beyond such a fault generally grows less until the bed is nearly flat, and in places the dip is reversed so that the bed rises to the northwest. Beyond such a rise, the bed is usually found to pitch down steeply or vertically for 40 to 60 feet and then to flatten again, and so on. A series of such folds has been encountered in the area between Rockwood and Cardiff, and some of them are overturned toward the southeast. From crest to crest the distances range between 40 to 100 feet, and in height the folds range from 15 to 60 feet. There is some variation in the strike of the beds, due to the fact that the axes of the folds are sinuous and, instead of lying flat, plunge at a low angle to the southwest. As a result of the plications in the strata, the ore bed has been squeezed in places to less than its normal thickness, and in others it is swelled to more than its normal thickness. The thickest portions occur generally along the axes of the troughs or at the tops of the arches. Where the bed is pinched down, it may be less than 18 inches in thickness; in the thickened places as much as 6.25 to 8 feet of ore has been observed. There are reasons for believing that this close folding took place below a great thickness of cover. The fact that movement has taken place between the particles of ore is plainly shown by the slickensided condition of ore fragments. The ore is also minutely jointed. Since the close folding took place the superincumbent beds have been largely removed by erosion and later adjustments of stresses have resulted in the faulting and overthrusting of beds near the surface.

Between Rockwood and Cardiff the normal thickness of the ore ranges from 2½ to 4 feet, including a few local shale partings or lenses one-half to 1 inch thick. The ore is fossiliferous red hematite. In places it is somewhat granular, resembling oolitic ore. On the outcrop the ore is "soft," the lime having been dissolved out; but below cover it is "hard" and contains lime. The soft ore has nearly all been mined from the outcrop by stripping and trenching and from shallow drifts. The hard ore now being mined carries 33 to 40 per cent of iron, 6 to 15 per cent of silica, 4 to 8 per cent of alumina, 10 to 17 per cent of lime, 2.5 to 3.5 per cent of magnesia, 0.15 to 0.3 per cent of manganese, 0.5 to 0.6 per cent of phosphorus, 0.015 to 0.2 per cent of sulphur, and 1.8 to 4 per cent of water. The specific gravity of the hard ore, as determined at the laboratories of the Roane Iron Company, ranges from 3.29 to 3.36, which corresponds to 10.9 and 10.68 cubic feet per ton of 2,240 pounds. South of Rockwood the ore becomes thinner, a bed 15 to 30 inches thick having been worked on the outcrop and from shallow drifts near Spring City and Glen Alice.

The principal mining development in this area is along a strip extending from Rockwood northeastward to Emory Gap, a distance of about 7½ miles. On this strip there were in October, 1908, eight slope mines in operation and eight slopes inactive. The slopes range in length from 150 to 1,000 feet. They are not driven so as to follow the ore, a course that would be physically impossible, owing to the folding of the beds. The slopes are consequently driven in rock below the ore at a pitch of 28° to 32° in a westerly direction, diagonal to the directions of both dip and strike of the ore bed. At intervals of 100 feet entries or "lifts" are turned off through the rock so as to intersect the ore from the foot-wall side. From each lift air ways or rooms are turned up to the lift above, a vertical distance of 30 feet, leaving a pillar of 20 feet between the rooms. Most of the ore is robbed from the pillars finally. The greatest distance from the outcrop in the direction of the dip that the ore has been opened is about 765 feet, but the actual number of feet of ore, measured on the ore bed, is much greater than this, owing to the folds. Mining under these conditions is difficult, but has been so well systematized here that very little ore is lost. The mines from Rockwood to Cardiff are operated by the Brown Mining Company, which supplies ore to the two furnaces of the Roane Iron Company, at Rockwood, the owner of the ore lands, besides selling some ore to the Citico Furnace at Chattanooga.

No prospect drilling has been done between the ends of the present slopes and the escarpment of Walden Ridge, so that the character of the ore beyond the present workings is unknown. Apparently there has been no diminution in the thickness of the beds at right angles to the outcrop so far as explored, and it is probable that the ore bed extends northwestward under the coal field to distances and depths too great for mining. It is understood that some of the present inactive slopes have been driven about to the limit of profitable mining under present conditions. To judge from the dip of the coal beds in the Cumberland Plateau, the ore should become less steep and less sharply folded where it passes beneath the coal measures, and therefore it is possible that conditions would be favorable for the extraction of some ore from the Cumberland area. As to the continuity of the ore for great distances below the coal measures, it may be stated that the Clinton (Rockwood) formation emerges in the anticlinal Sequatchie Valley, and that it does not carry workable ore in its north end opposite Spring. Conditions observed in many other Clinton areas indicate that the ore will deteriorate more abruptly in the direction of the dip than along the outcrop.

On the assumption that the ore which extends for 38,000 feet on the outcrop can be worked under present conditions for 2,000 feet from the outcrop, and under remote future conditions for 5,000 feet farther, there should be a supply of ore here approximating 15,000,000 long tons immediately available, and of 40,000,000 long tons in reserve. Considered in the same light, the thinner beds between Glen Alice and Rockwood possibly contain 2,500,000 long tons within the 1,000-foot limit and 7,500,000 long tons additional between the 1,000-foot limit and the 4,000-foot limit measured from the outcrop.

EUCHEE (CRESCENT).

The strip of Clinton (Rockwood) formation near Euchee extends along Tennessee River for about 9 miles, lying partly in Roane County and partly in Rhea County. Much of this strip is in the bottom land of Tennessee River and, as the river in its windings crosses the strip four times besides following the formation for some distance, much of the Clinton (Rockwood) area is below the river level. On the east side the Clinton (Rockwood) strip is bordered by a fault for about 5 miles. Near the county line on the outcrop the rocks dip 20° to 30° SE. The ore bed, as observed at the Crescent mine, is 5 to 6 feet thick. From 10 inches to 1 foot of lean ore at the top is left for a roof. The ore that is worked is seamed with shale and calcareous material so that the content of iron is rarely above 30 per cent in the hard ore and the lime content is greater than is necessary for blast-furnace practice. In the Crescent mine many small folds, diagonal to the strike of the beds, have been encountered. The faults are apparently all normal; that is, the rocks have slipped downward on the side toward which the fault plane inclines. The throw of the faults is very small, ranging from a few inches to about the thickness of the ore bed—5 or 6 feet. At right angles to the dip there are a few shallow rolls in which the ore becomes horizontal in places and rises slightly for a short distance toward the southeast. There are also a few strike faults within the mine, and one of these has been overthrust so that the ore bed is duplicated in the section at one point in the mine. Where the two portions of the ore bed that are overlapped are in contact the thickness of the minable ore is from 8 to 10 feet.

Soft ore has been mined in six or eight places along this strip on both sides of the river, and it is understood that nearly all the available soft ore has been obtained. The Crescent mine of the Dayton Coal and Iron Company was the only place visited in this area during the recent investigation. Hard ore is mined here from an underground slope about 600 feet long. The ore is shipped by boat down Tennessee River to a point opposite Dayton, and thence carried to the furnaces by railroad.

If this bed of ore averages 5 feet in thickness and extends for 16,000 feet on the outcrop and 1,000 feet on the dip, as the observed facts indicate, there should be approximately 3,500,000 long tons of hard ore available here.

WELKER.

Extending south-southwestward from Tennessee River, at a point about 3 miles above the mouth of Clinch River, is a prominent ridge, the crest of which is formed of sandstone of the Clinton (Rockwood) formation. About 4½ miles from the river the ridge is cut in two by a branch of Riley Creek which follows a low anticline whose axis is transverse to the major axis of folding. In the east slope of both parts of this ridge is a fairly thick bed of Clinton ore with a shale parting. The measures carrying the ore are folded into a syncline, having dips of 15° to 30° on the northwest limb and very steep to vertical dips on the southeast limb. The ore thus lies in two long, canoe-shaped synclinal basins, 4 to 4½ miles in length and about one-fourth to one-third mile wide. It outcrops on the limbs and at the ends of the synclines.

The ore in the northeast basin consists of two benches, the upper 5 feet thick, and the lower 2 feet thick, parted by 1 to 2 feet of shale. On the east limb of the syncline, where the beds are nearly vertical, the ore is soft to a depth of 150 feet in places. On the west limb the ore is soft on the outcrop for 300 to 400 feet where the cover is thin. The soft ore is very rich, carrying 45 to 50 per cent of iron. The hard ore is fossiliferous, high in lime, and lean in iron. The iron ranges from 25 to 36 per cent, the silica from 3.5 to 6 per cent, the alumina from 3 to 4 per cent, and the lime from 22 to 25 per cent.

In the southwest basin the ore lies in similar relations, having dips of 10° to 20° on the west limb and being vertical or overturned on the east limb. The ore occurs in two benches, the upper of which is 3 feet thick and the lower 2 feet thick. The shale parting is thicker here than in the area to the northeast, being about 6 feet thick. On the west limb the ore dips at nearly the same angle as the slope of the surface, so that it is under thin cover, and there is a large area underlain by soft ore that can be obtained by moderate stripping. The soft ore is of high grade, running in places above 55 per cent of iron. The ore in the lower bench is mostly hard and of lean to fair quality. Owing to its position, below 6 feet of shale, it can hardly be mined along with the upper bench, and probably would not be considered minable under present conditions.

Mining operations have been carried on only in the upper strip from a point near Tennessee River southwestward for about 3½ miles. A great deal of mining by stripping has been done here through a period of more than twenty years, and this form of mining is still in progress. Shale is being stripped to a maximum thickness of 30 feet near Hacklers Gap, although some of the ore thus uncovered is hard and rather lean. Ore is mined from the vertical or "upright" bed on the east limb of the syncline, adits being driven on the strike of the bed from both ends of a hill until they meet; then the ore is milled down through air ways into the adits. At the extreme north end of the basin, where the syncline "spoons" up to the surface near Tennessee River, the overlying shale has been removed from the ore beds. In October, 1908, the ore bed was still in place in the basin for 300 feet along the strike, showing most perfectly the nonsymmetrical synclinal structure that is characteristic of the whole deposit. The ore in this locality is owned and mined by the Roane Iron Company. The product is carried on the company's railroad from Welker to Tennessee River, where the cars of ore are transferred to a barge and towed by steamboat down the river to a point near the mouth of Caney Creek. Here they are picked up by a locomotive and hauled over a branch of the Cincinnati, New Orleans and Texas

Pacific Railway as far as Cardiff. From this point the ore is carried over the main line of the same railway to the furnaces at Rockwood.

As the northeast basin contains an ore bed probably averaging 7 feet thick and extending 23,500 feet long on the strike and 1,650 feet at right angles to the strike, there should be 18,000,000 long tons of ore here available under present conditions. It is possible that in the middle of the basin the ore extends to a depth sufficient to increase the average distance on the total dip to more than 1,650 feet, and if so, the total tonnage will be increased proportionately. In the southwest basin, on the assumption that the upper bench averages 3 feet of ore for 20,000 feet on the strike and 1,700 feet on the dip, there should be 7,400,000 long tons available. Perhaps 1,000,000 tons, or possibly considerably more, of this total will be found to be soft ore. If the lower bench is found to average 2 feet of ore, it should contain about 4,775,000 long tons of ore in reserve. These estimates are all very rough and subject to revision.

CHATTANOOGA DISTRICT.

LOCATION AND EXTENT.

For the sake of convenience in subdividing the region, it will be here considered that the Chattanooga district comprises the ore-producing localities within the area limited by Sequatchie Valley on the west, Whiteoak Mountain on the east, Dayton, Tenn., on the north, and Rising Fawn, Ga., on the south.

The structure and distribution of the Clinton (Rockwood) formation and its ore-bearing areas in this district are shown on the economic geology maps of the Chattanooga (No. 6), Ringgold (No. 2), Rome (No. 78), Stevenson (No. 19), and Sewanee (No. 8) folios of the Geologic Atlas of the United States.

The areas containing workable ore are well supplied with railway facilities. The Southern Railway passes through the Ooltewah area; a branch of the Nashville, Chattanooga and St. Louis Railway extends up Sequatchie Valley; the Alabama Great Southern Railroad passes along the west border of the Lookout Mountain area; and the Chattanooga Southern and Central of Georgia railways are adjacent to the ore outcrops east of Lookout Mountain and Pigeon Mountain.

NORTH CHATTANOOGA.

At North Chattanooga, or Hill City, Clinton ore occurs in thin beds. The ore is inclosed in shale of the Clinton (Rockwood) formation, having very irregular structure. The beds are closely folded and considerably faulted, making deep or extensive mining practically impossible. One bed of ore, about 2.7 feet thick, has been mined to some extent on the outcrop and from shallow drifts. From a hasty inspection of this locality, it appears doubtful whether the ore can be considered available for more than 500 feet on the dip and for more than 1 mile on the outcrop, if all the available pieces of ore are placed end to end. This would provide 400,000 long tons of ore which would, for the most part, consist of soft or semihard material. The material can hardly be placed in the category of ore available under present conditions. Small quantities of ore have been obtained here in the past, and it is understood that mining is still in progress in a small way, the shipments being made by team to the furnace of the Citico Iron Company at Chattanooga.

INMAN.

On the east side of Sequatchie Valley, about 9 miles above the confluence of Sequatchie and Tennessee rivers, the outcrop of the Clinton (Rockwood) formation has been found to carry ore that is workable where soft. The beds dip at a low angle to the southeast below the Mississippian rocks that form the base of Walden Ridge. At this point mining operations were active for ten to fifteen years prior to 1903. At the time the old openings were visited in 1906 it was impossible to enter the mines for any great distance, owing to the badly caved-in condition of the workings. A limy ore bed, apparently about 4½ feet thick, but carrying only 2½ to 3 feet of good ore, has been worked here and more than 2,000,000 long tons of ore has been shipped, principally to the now abandoned blast furnaces of the Tennessee Coal, Iron and Railroad Company at South Pittsburg, Tenn. The surface workings extended for 2 miles along the outcrop and for more than 500 feet underground. Apparently little ore can be considered to be available under present conditions in this area. It is probable that with the future exhaustion of the supplies of higher-grade ore throughout the United States the hard ore in this locality will be considered of value at some time in the remote future, and on the strength of this probability a very general estimate has been made. The ore bed may be considered to average 2½ feet in thickness and to extend for 5,000 feet on the dip and for perhaps 15,000 feet on the outcrop, and these dimensions would indicate an ore reserve of 8,850,000 long tons. From such information as is available it seems probable that the hard ore will carry between 22 and 28 per cent, averaging about 24.5 per cent, of iron and an average of 30.7 per cent of lime.

OOLTEWAH.

About 2 miles east of Ooltewah, Tenn., ore-bearing strata of the Clinton (Rockwood) formation outcrop on both sides of a narrow syncline, the edges of which are exposed in Whiteoak Mountain and a smaller ridge lying about 2 miles east of it. The lower part of the formation here consists largely of hard brown sandstone, but the upper part contains more shale. Ore is present in the shale on the east slope of Whiteoak Mountain, the ore dipping 22° to 25° SE. There are, however, many minor crumplings in the strata that vary the dip considerably and make mining uncertain and difficult. The ore is very thin here, ranging from 14 to 18 inches in thickness, and in places having shale streaks included. Twenty years ago soft ore was obtained in large quantities from surface workings near the cuts of the Southern Railway through Julian Gap and McDaniel Gap and shipped to the furnaces at Chattanooga. At present, however, no ore for blast-furnace use is obtained here. Shallow surface workings are being operated by hand for the purpose of obtaining ore for the manufacture of metallic paint. In the ridge on the east limb of the Whiteoak Mountain syncline, north of Hinch's switch, red ore occurs apparently in two beds, but geologic examination has shown that a single bed of ore has been repeated by a close, overturned fold. Locally the same bed is displaced and repeated by an overthrust fault, and 1 mile south of Hinch's switch the entire Clinton (Rockwood) formation on the east limb of the syncline has been buried in a fault. The ore north of the railroad in this ridge averages about 12 inches in thickness, although in places it reaches 16 inches. Within the seam are a few partings of shale. From Hinch's switch northward for about 4 miles soft ore has been stripped for iron making in former years. At present the ore is mined by underground drifts and slopes at a point 1 mile north of the railroad. The product is shipped to the works of the Chattanooga Paint Company for use in the manufacture of metallic paint. If it is considered that the beds here have a total length of 35,000 feet on the outcrop, average 1¼ feet in thickness, and can be worked for 200 feet on the dip, there should be a reserve of 500,000 long tons of ore still in the ground. It should be noted, however, that this ore is not available for mining on a large scale under present conditions, and its principal value will probably remain, as at present, for its use as a paint material.

LOOKOUT CREEK.

Along the ridge lying just between Lookout Creek and the Alabama Great Southern Railroad, the Clinton (Rockwood) formation outcrops on what is structurally the west limb of the Lookout Mountain syncline. From Pudding Ridge northward through Trenton, New England, and Wildwood, Ga., to a point beyond the Tennessee-Georgia line the formation has been found to carry beds of iron ore that were workable on the outcrop. A bed of ore 2 to 2½ feet thick, dipping from 10° to 25° SE., has been mined on the outcrop near New England and at Wildwood. The ore obtainable by trenching or stripping is exhausted and mining activities are temporarily suspended. At Wildwood, however, where the soft ore has been found suitable for paint manufacture, there is still some ore available for that purpose. Geologic conditions indicate that there should still be a considerable reserve of hard ore in this locality, although there is practically no information at hand as to its quality. Persons familiar with the ore report that it carries only 22 to 30 per cent of iron. If the strips of ore between Wildwood and New England are considered as having a total length of 20,000 feet on the outcrop, as extending for 5,000 feet on the dip, and as averaging 2.37 feet thick, there should be an ore reserve here of approximately 12,650,000 long tons of ore; this is not available, however, under present conditions.

RISING FAWN.

In Johnson Crook, at the headwaters of Dry Creek, the Clinton (Rockwood) formation outcrops around the northeast end of a plunging anticline. The dips of the formation are to the north, northeast, and east into the synclinal Lookout Mountain area. Ore has been mined for many years in this vicinity to supply the blast furnace at Rising Fawn, Ga. Practically all of the soft ore has been exhausted from open-cut workings and the ore most recently mined (in 1906) was a rather lean, hard ore. The ore bed mined at that time averages about 4½ feet in thickness, and if it is considered to extend for 10,000 feet on the outcrop and 5,000 feet on the dip, there should be a reserve of about 12,500,000 long tons of ore at this place. The ore may in the near future possibly be worked to a depth of 1,000 feet by slope mining, and in this event 2,500,000 long tons of the amount just given should be available in the near future. West of Rising Fawn, at the Southwest end of Pudding Ridge, there is considerable low-grade hard ore present in the Clinton (Rockwood) formation. The ore has been prospected extensively, exposing a bed about 2½ feet thick that carries seams of shale and calcareous material. This bed can probably be worked in the remote future for 7,500 feet on the outcrop and 700 feet on the dip, and on this basis there should be a reserve of 850,000 long tons in the Pudding Ridge area west of Rising Fawn.

CHATTANOOGA CREEK.

On the east side of Lookout Mountain in Georgia, from Eagle Cliff southward for 10 miles, the Clinton (Rockwood) formation contains ore beds that have been worked at a few places for the soft ore that could be obtained on the outcrop. The formation dips at steep angles to the northwest or else stands vertical. At present no ore is being mined in this locality, but formerly some soft ore was obtained on the outcrop and from shallow slopes. Between Eagle

Cliff and High Point the ore is about 2¼ feet thick and owing to its steep dip can not be mined to any great distance from the outcrop. On the assumption that there may be workable ore for 7,500 feet on the outcrop and extending to a depth of 1,200 feet, there should be an ore reserve here of 1,000,000 long tons, which can not be mined under present conditions.

About 2 miles east of Eagle Cliff a V-shaped area of the Clinton (Rockwood) formation is exposed by folding. Ore was being mined in this locality in 1906. There was still a little soft ore remaining which could be obtained by extending the stripping beyond the limit of former workings, and some hard ore was being taken from shallow slopes. This area can hardly be considered as containing any important amount of ore that is available under present conditions, but if the ore extends for 15,000 feet on the outcrop and 1,800 feet on the dip and maintains an average thickness of 2½ feet, there should be a reserve of 4,000,000 long tons of ore, not at present available. The iron content of the hard ore is understood to range between 22 and 23 per cent.

PIGEON MOUNTAIN.

Pigeon Mountain is a spur extending northeastward from Lookout Mountain in the southern part of Walker County, Ga. The rock structure in Pigeon Mountain is synclinal, the formations outcropping around the base of the mountain and dipping toward its axis. At Estelle the ore dips in general to the south and southeast. At the northeast end of the mountain, west of Copeland, the rock lies nearly flat, and where the formation swings around the southeast side of the ridge the dips are toward the northwest.

Near Estelle, for about 1 mile to the northeast and about 3 miles to the southwest of the Chattanooga Southern Railroad, the ore has been mined to a considerable extent on the outcrop and also from a number of drifts and tunnels. This area has been a large producer of soft ore in the past, most of it having been shipped to the furnace of the Southern Steel Company at Chattanooga. At present the mines are understood to be idle, owing to the suspension of operations by this company. Three beds of ore occur just below the middle of the Clinton (Rockwood) formation. They are about 25 feet apart, but only the lowest bed, which is 2½ feet thick, can be considered of much importance. The workable ore appears to extend at Estelle for at least 30,000 feet on the outcrop, and if it maintains an average thickness of 2½ feet for 2,500 feet on the dip, there should be about 13,000,000 long tons of ore available under present conditions. The geologic conditions indicate that this is a fairly safe estimate. If the ore should be exploited for 5,000 feet farther, there should be a tonnage of 25,000,000 long tons in reserve for remote future use. The hard ore here carries from 28 to 32 per cent of iron.

At the northeast end of the Pigeon Mountain syncline, about 2 miles west of Copeland Station on the Central of Georgia Railway, there is a large outcrop area of the Clinton (Rockwood) formation, which lies nearly flat around the end of the syncline. Several thin beds of shaly, limy, fossiliferous ore are present here. The thickest bed carries about 2.7 feet of ore parted by five or six seams of shale. The iron content ranges from 25 to 32 per cent. If this ore could be cleaned of its shale by means of picking or washing, the grade would be very materially improved. Although the beds lie flat and comparatively near the surface, there does not appear to be much soft ore in this locality. On the assumption that there is an outcrop at least 18,000 feet in length and that the ore could be mined for 2,500 feet on the dip, there should be a reserve of about 8,000,000 long tons available for future use.

On the southeast limb of the Pigeon Mountain syncline, in the vicinity of Bronco, the dip of the Clinton (Rockwood) rocks is rather steep toward the northwest and the outcrop is narrow. Soft ore has been mined along this outcrop from Sharpe to Chamberlain, a distance of more than 3 miles. At Bronco some underground work has been done and ore mined by means of shafts and slopes driven on the strike of the ore bed. The bed averages apparently about 2½ feet thick and if it maintains this thickness for 18,000 feet on the outcrop and 1,000 feet on the dip there should be a reserve of about 3,000,000 long tons in this locality available for future use.

TAYLOR RIDGE.

About 3½ miles southeast of Summerville, Ga., on the east slope of Taylor Ridge are beds of the ore-bearing Clinton (Rockwood) formation. These rocks dip about 24° SE. An ore bed about 18 inches thick occurs here, the soft ore of which has been mined by stripping. Some hard ore remains and can be obtained from drifts along the strike of the ore bed from its outcrop in ravines that cut the flank of the mountain. The geologic conditions indicate that the bed extends for 12,000 feet or more on the outcrop, and if it were possible to mine this bed for 1,500 feet on the dip there should be, approximately, about 1,800,000 long tons of ore here available for future mining.

DIRTSELLER MOUNTAIN.

At the north end of Dirtseller Mountain, 2 to 3 miles southwest of Lyerly, Ga., red ore has been obtained from surface workings for many years. The structure of the Dirtseller Mountain Clinton (Rockwood) area is synclinal, the ore dipping southeastward from the crest of the ridge toward Panther Creek and rising again to the southeast to form the crest of a lower ridge. The synclinal axis rises to the northeast so that the ore outcrops around the end of the syncline at a point about 2 miles west of Lyerly. The dip of the beds and the slope of Panther Creek are very nearly the same, and the ore bed is overlain, for the most part, by a comparatively thin cover, so that it has been possible to strip the ore for several miles along its outcrop and for several hundred feet on the dip. Mining is still in progress after this fashion, and a large tonnage of soft ore has been obtained here. The ore in reserve, however, is mainly lean, hard, fossil ore, carrying from 25 to 30 per cent of iron. The soft ore carries from 45 to 55 per cent of iron. It is probable that the whole tonnage of hard ore that remains may be mined under present conditions, providing the price of ore remains high enough to warrant the cost of mining. The ore bed as measured in about a dozen places averaged about 1½ feet thick. If it extends for 30,000 feet on the outcrop and to a distance of 1,000 feet on the dip, there should be about 3,000,000 tons of ore still available in this locality.

GADSDEN DISTRICT.

LOCATION AND EXTENT.

The area here included in the Gadsden district extends from Gadsden and Attalla, Ala., northeastward to the Alabama-Georgia line. On the northwest and southeast borders of the Lookout Mountain syncline, the Clinton (Rockwood) formation outcrops along Little Wills Valley and Wills Valley from Attalla to Battelle and in Shinbone Ridge from Gadsden northeastward, except where cut up by faults. Ore from mines in these strips of the formation is, for the most part, shipped to furnaces at Gadsden and Attalla, although some of it goes to furnaces at Chattanooga and Rome. The Alabama Great Southern Railroad passes along the west border of the Lookout Mountain area within about 1 mile of the outcrop of the ore, and on the east border the Chattanooga Southern Railroad lies even closer to the ore outcrop. Transportation facilities are entirely adequate to the development of the red-ore resources in this portion of the Clinton ore-bearing territory.

Maps of portions of the area are included in the Gadsden and Stevenson geologic folios (Nos. 35 and 19), and other portions are shown on the Fort Payne topographic map.

SHINBONE RIDGE.

From Gadsden northeastward the Clinton (Rockwood) formation in Shinbone Ridge carries ore, some of which is workable under present conditions and some of which can be considered workable only under remote future conditions. Near Gadsden the dips are steep—45° to 80° NW. Under a synclinal area, the opposite limb of which lies to the northeast of Attalla, the workable ore bed averages about 3.3 feet thick, and it has been mined by slopes which have been driven for 200 to 300 feet. The ore carries 30 to 40 per cent of iron, and if it extends for 6,000 feet on the outcrop and 2,000 feet on the dip, maintaining the same quality and thickness as is found in the mines, there should be approximately 2,900,000 long tons still available under present conditions.

If the various localities containing ore in the east border of the Lookout Mountain syncline or Shinbone Ridge, northeast of Gadsden, are considered, there is still a large tonnage of undeveloped ore that can be had for future use in this locality. The ore through much of the area carries 25 to 35 per cent of iron and will perhaps average 3 feet in thickness, but the structure is very irregular. Not only is the dip steep, but many faults occur which cut out the ore in places and will make mining difficult and expensive. If such strips of ore-bearing territory as are thought to be productive were placed end to end, there would be a linear extent of ore aggregating 10 miles on the outcrop, which can safely be considered to extend for 3,000 feet on the dip. The total ore contained in a mass of this extent would aggregate 31,821,000 long tons, but this amount must not be considered as available under present conditions.

WILLS VALLEY.

On the west border of the Lookout Mountain syncline from Rising Fawn, Ga., to Attalla, Ala., the Clinton (Rockwood) formation shows a narrow outcrop, with generally medium dips to the southeast. There are places, however, where the dip is 45° or greater. At Battelle, Ala., about 3½ miles from the Georgia state line, occurs a workable bed of ore 3.3 feet thick, dipping 23° to 45° SE. The soft ore has been stripped from the outcrop and the hard ore has been mined within the last four years on three slopes 200 to 300 feet long. It is not known definitely how far this ore may extend in workable thickness and character on the outcrop, but it is possible that 20,000 feet of ore may be considered as available. If it should continue for 2,000 feet on the dip with the thickness indicated above, there should be a reserve of 8,839,000 long tons available in the Battelle locality. It is understoood that the ore carries 24 to 32 per cent of metallic iron.

Near Portersville, Ala., ore of character similar to that at Battelle occurs in shale of the Clinton (Rockwood) formation, dipping about

15° SE. Hard ore has been mined here from a slope that was about 400 feet long in 1905. The ore carries 25 to 38 per cent of metallic iron. The geologic conditions indicate that there should be at least 6,000 feet of ore on the outcrop averaging 3.3 feet in thickness and running 2,000 feet or more on the dip. This would give a reserve of 2,650,000 long tons of ore available under present conditions.

Near Crudup, Ala., about 7 miles northeast of Attalla, workable ore occurs in shale of the Clinton (Rockwood) formation, dipping about 26° SE. There are two beds of ore, the upper of which has been found to be workable. Soft ore has been mined on the outcrop and hard ore was mined in 1906 from two slopes about 1 mile apart. On the south slope the bed averages about 3¼ feet in thickness and on the north slope about 3¾ feet. The hard ore carries from 25 to 35 per cent of metallic iron. If it is considered that the ore at this locality extends for 7,500 feet on the outcrop and 1,500 feet on the dip and maintains an average thickness of 3¾ feet, there should be 2,280,000 long tons of ore here available under present conditions.

Near Attalla what is apparently the same bed of Clinton ore that occurs at Crudup has been mined for many years. All the soft ore has been mined from the outcrop and the hard ore is now obtained from two slopes about 2,000 feet apart that extended at the close of 1908 about 1,300 and 1,500 feet from the outcrop. The ore dips 30° to 35° SE., and ranges from 3 to 4 feet in thickness, averaging about 3½ feet. The geologic conditions indicate that the ore extends in workable condition for 7,500 feet or more on the outcrop, and 2,500 feet on the dip, which would give a tonnage of 5,000,000 long tons here available under present conditions.

As to the quantity of ore that may be obtained in the remote future from the west border of the Lookout Mountain syncline, there is room for great difference of opinion. Theoretically the ore should extend below the coal measures and emerge on the east side of the syncline and it undoubtedly does so, as is shown by the outcrops in Shinbone Ridge and Pigeon Mountain. The distance across the syncline is 10 miles or more in places, and it is likely that below the center of the syncline ore would lie comparatively flat and be freer of faults and other structural disturbances than along the outcrop. There are, however, probably changes in the character of the ore from the outcrop toward the center of the syncline. Beds which, on the outcrop, appear to thin out and change in quality may do likewise along the dip, and in the direction of the dip the change is probably more abrupt than it is along the outcrop. This statement is borne out by general observations of Clinton ore beds in various parts of the Appalachians. Strong evidence of the abrupt change of beds in the direction of the dip has been afforded by deep drill holes recently made in the Birmingham district. It is very evident that the beds on the east side of the Lookout Mountain syncline can not be correlated absolutely with those on the west side, and it is fair to presume that each bed thins out and gives place to succeeding beds of ore in the formation somewhere below the coal measures, so that the formation in reality contains several overlapping flattened lenses of red ore. The vertical depth at which the ore lies below the greater part of the Lookout Mountain syncline ranges between 1,300 and 3,500 feet. This fact of itself would preclude its consideration in this connection beyond the limits indicated above, and until mining conditions are such that ore can be mined at vertical depths exceeding 1,000 feet all the ore below that depth in the many synclines of the Appalachians in Tennesssee, Georgia, and Alabama must be regarded as completely beyond the present available limit. It is, however, fair to presume that there are at least 25 miles of outcrop of Clinton (Rockwood) formation that would carry a bed averaging 3 feet thick for 10,000 feet on the dip, without regard to the vertical depth that it would reach. A mass of ore having these dimensions, deducting 20 per cent for loss in mining, should carry 280,000,000 long tons. As the total outcrop of ore-bearing measures between Battelle and Attalla is more than 50 miles, and as 10,000 feet is but a fraction of the distance between the west border of the Lookout Mountain syncline and the east border, it is apparent that such an estimate as this can be considered conservative, especially with reference to ore beds that are not regarded as workable under present conditions.

ANALYSES.

In the following table are given analyses of ore from nearly all the workings mentioned above.

Analyses of Clinton iron ores in the Chattanooga region.

Locality.	Authority.[a]	Fe.	SiO_2.	Al_2O_3.	CaO.	MgO.	Mn.	P.	S.	H_2O.
Rockwood-Cardiff:										
Hard ore—										
Wright slope	R.	35.10	8.08	5.27	14.00	2.59	0.15	0.60	0.84	......
Patton slope	R.	40.55	7.88	6.03	9.90	3.49	.18	.59	.08	......
Howard slope	R.	33.35	15.35	8.60	6.88	......	.15	.60	.15	3.92
Warner slope	R.	38.00	4.61	5.85	10.85	4.23	......	......	.12	......
Cardiff slope	R.	35.60	10.46	5.70	10.90	......	.15	.59	.08	......
Baker slope	R.	39.25	6.46	4.28	11.60	3.16	......	......	.08	......
Suddath slope	R.	34.65	6.85	4.01	17.11	2.80	.36	......	.07	......
Glen Alice:										
Hard ore, Dyke slope	R.	38.08	10.60	......	10.13	......	.18	.56	.16	......
Soft ore, surface	R.	50.19	12.58	9.82	1.15	.92	......	......	Trace.	......
Euchee:										
Hard ore—										
Crescent slope	D.	26.50	9.10	6.28	22.25	1.43	......	.416	......	......
Do	D.	29.80	5.42	5.06	21.78	1.60	......	......	......	......
Do	D.	32.00	7.69	5.58	18.45	1.48	......	.446	......	......
Soft ore—										
River mines	D.	45.80	11.72	7.10	......	......	......	......	......	......
Do	D.	47.40	14.76	8.70	......	......	......	.268	......	......
Welker:										
Hard ore	R.	25.20	3.48	3.25	25.15	1.84	......	......	......	......
Do	R.	36.90	6.10	3.01	14.10	1.83	.12	.38	.07	......
Do	R.	29.06	7.00	3.79	22.97	1.20	......	......	.07	......
Do	U.S.	36.30	7.92	3.07	13.77	1.71	.25	.57	.05	6.11
Do	U.S.	28.20	5.00	2.82	24.84	1.63	.23	.431	.05	5.61
Soft ore	R.	50.25	10.90	5.75	......	......	......	......	......	......
Do	U.S.	52.45	7.62	4.31	.40	.47	.23	.532	.02	10.01
Do	U.S.	49.76	7.63	3.64	1.68	.50	.44	.736	.07	8.99
North Chattanooga:										
Hard ore	R.	25.00	[b]11.+	......	......	......	......	......	......	......
Soft ore	R.	45.+	[b]24.+	......	......	......	......	......	......	......
Inman, hard ore	B.	27.93	7.07	......	18.11	......	......	.282	......	......
Ooltewah:										
Soft ore	B.	56.00	16.45	......	......	......	......	.28	.10	......
Do	B.	48.36	14.78	......	......	......	......	.63	......	......
Rising Fawn:										
Hard ore	O.	24.12	10.17	2.15	22.10	2.66	.21	.51	.005	......
Do	O.	28.40	7.83	3.30	22.80	2.16	.40	.23	......	......
Pudding Ridge, hard ore	O.	33.25	5.30	......	19.60	......	......	......	......	......
Cenchatt, hard ore	O.	32.38	8.24	......	21.52	......	......	......	......	......
Eagle Cliff, semihard ore	D.	35.30	11.20	6.70	15.39	......	1.60	.453	......	......
Estelle:										
Hard ore	R.	31.00	18.00	......	......	......	......	......	......	......
Soft ore	R.	48.00	13.00	5.00	......	......	......	......	......	......
Dirtseller Mountain, soft ore	S.	49.55	15.87	5.87	2.61	......	......	......	......	......
Battelle:										
Hard ore—										
Upper bed	L.	27.50	11.80		22.08	2.50	......	......	......	......
Do	L.	29.30	9.40		22.87	......	......	......	......	......
Do	L.	31.18	7.20		22.54	......	......	......	......	......
Do	L.	24.15	15.60		23.45	......	......	......	......	......
Do	L.	23.25	12.90		26.05	......	......	......	......	......
Bottom bed	L.	31.77	10.10		20.54	......	......	......	......	......
Portersville:										
Hard ore	S.	25.52	5.60		30.82	......	......	......	......	......
Do	S.	30.35	6.42		25.88	......	......	......	......	......
Do	S.	33.72	4.94		22.90	......	......	......	......	......
Do	S.	38.00	9.18		19.04	......	......	......	......	......
Crudup: Hard ore	C.	39.07	10.58	3.30	14.13	......	.13	.42	......	......
Attalla: Hard ore	W.	38.05	8.40	......	27.00	......	......	......	......	......

[a] Authorities: B, W. M. Bowron, Chattanooga, Tenn.; C, Central Coal and Iron Co., Holt, Ala.; D, Dayton Coal and Iron Co.; L, Lookout Mountain Iron Co.; O, owners of property; R, Roane Iron Co.; S, Southern Steel Co.; U. S., United States Geological Survey.

[b] Insoluble.

SUMMARY OF TONNAGE ESTIMATES.

The following table gives a summary of the estimates of tonnage of ore in this region and of the data on which these estimates are based:

Extent, thickness, and estimated tonnage of Clinton ore beds in Chattanooga region.

Subdivision.	Length (feet).[a]	Width (feet).[b]	Thickness (feet)[c].	Iron (per cent).[d]	Ore (long tons). Available.	Ore (long tons). Not at present available.
Rockwood-Cardiff	38,000	2,000 5,000	3.5 3.0	33–40	15,000,000	 40,000,000
Glen Alice	15,000	1,000 3,000	.... 2.5	h. 30–38 s. 40–50	2,500,000	 7,500,000
Euchee	16,000	1,000	5.0	h. 26–32 s. 45–50	3,500,000	....
Welker (northeast basin)	23,500	1,650	7.0	h. 25–36 s. 40–50	18,000,000	....
Welker (southwest basin)	20,000	1,700	3.0 2.0	s. 40–55 h. 25–30	7,400,000	 4,775,000
North Chattanooga	5,000	500	2.7	h. 25–30 s. 38–45	....	400,000
Inman	15,000	5,000	2.5	22–30	....	8,850,000
Ooltewah	35,000	200	1.25	h. 30–35 s. 50–58	....	500,000
New England-Wildwood	20,000	5,000	2.37	22–30	....	12,650,000
Rising Fawn	10,000	1,000 4,000	4.5	20–30	2,500,000	 10,000,000
Pudding Ridge	7,500	700	2.5	20–33	....	850,000
Cenchatt	7,500	1,200	2.25	25–32	....	1,000,000
Eagle Cliff	15,000	1,800	2.5	25–33	....	4,000,000
Estelle	30,000	2,500 5,000	2.5	28–35	13,000,000	 25,000,000
Copeland	18,000	2,500	2.7	20–32	....	8,000,000
Broncho	18,000	1,000	2.5	25–30	....	3,000,000
Taylor Ridge	12,000	1,500	1.5	20–30	....	1,800,000
Dirtseller Mountain (Collyarton)	30,000	1,000	1.5	h. 25–30 s. 45–55	3,000,000	....
Shinbone Ridge	6,000 52,800	2,000 3,000	3.3 3.0	h. 30–40 h. 25–35	2,900,000	 31,821,000
Battelle	20,000	2,000	3.3	24–32	8,839,000	....
Portersville	6,000	2,000	3.3	25–38	2,650,000	....
Crudup	6,500	1,500	3.5	25–35	2,280,000	....
Attalla	7,500	2,500	3.5	32–40	5,000,000	....
Battelle to Attalla	132,500	10,000	3.0	25–30	....	280,000,000
	....	....	....	....	86,569,000	440,146,000

[a] Total length of outcrop.

[b] Distance down the dip to which the ore bed may be regarded as workable, either under present or future conditions. Where two distances are given the upper one represents the distance probably workable under present conditions.

[c] Average thickness of the ore bed.

[d] h, Hard ore; s, soft ore.

THE TAYLOR PEAK AND WHITEPINE IRON-ORE DEPOSITS, COLORADO.

By E. C. HARDER.

INTRODUCTION.

The detailed work on which this report is based was done during the latter part of the summer of 1906 by Freeman Ward and the writer, under the direction of C. K. Leith, who during the summer before, in company with C. R. Van Hise, made a general reconnaissance trip through the region.[a] The Taylor Peak deposits are situated in the Elk Mountains, near the boundary line between Gunnison and Pitkin counties, Colo.; the Whitepine deposits lie about 40 miles to the southeast, in the southeastern part of Gunnison County. Detailed maps of the ore bodies were made, to show their relation to the associated igneous and sedimentary rocks. The deposits consist of igneous contact ores of the same general type as those recently described from the Iron Springs district in Utah,[b] but they are very much smaller than the Iron Springs deposits, and are of no great commercial importance.

The Taylor Peak deposits occur in sedimentary rocks at or near the contact of an intrusive diorite; the Whitepine deposits are at the contact of sediments and Archean granite and are generally associated with small masses of an acidic intrusive.

TAYLOR PEAK DISTRICT.

LOCATION AND GENERAL GEOLOGY.

The Taylor Peak district lies in the eastern part of the Elk Mountains on the boundary between Pitkin and Gunnison counties, Colo. The nearest railway station to the north is Aspen, about 18 miles distant, on the Denver and Rio Grande and Colorado Midland railways, which may be reached by way of Ashcroft. To the south are St. Elmo, Quartz, and Pitkin, about 45 miles distant, on the Colorado and Southern Railway, which may be reached by way of Dorchester and Tincup. The northern part of the district is covered by the Aspen topographic sheet of the survey and the southern part by the

[a] Leith, C. K., Iron ores of the western United States and British Columbia: Bull. U. S. Geol. Survey, No. 285, 1906, p. 196.

[b] Leith, C. K., and Harder, E. C., Iron ores of the Iron Springs district, southern Utah: Bull. U. S. Geol. Survey, No. 338, 1908.

Crested Butte sheet. In the Anthracite–Crested Butte folio[a] the general geology and petrography of the rocks of the district are adequately discussed. The ore deposits are located on the north, east, and south sides of Taylor Peak, about 10 miles west of the junction of the Elk and Sawatch ranges. They are all above timber line, ranging in elevation between 12,000 and 13,000 feet.

Geologically the district is composed of Cambrian, Silurian, and Carboniferous sediments resting on pre-Cambrian granite and irregularly intruded by a fine-grained diorite of Tertiary age. As given

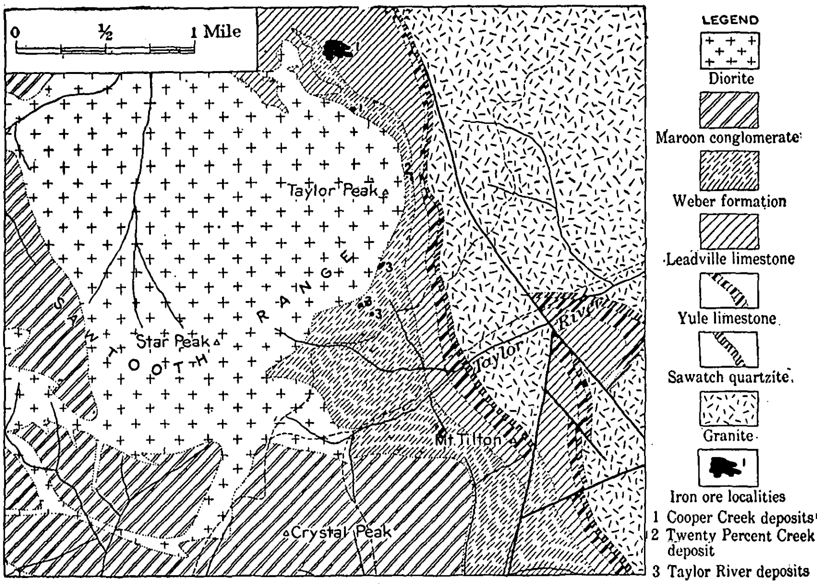

FIGURE 9.—General geologic map of Taylor Peak district, Pitkin and Gunnison counties, Colo., showing location of iron-ore deposits. (From Anthracite–Crested Butte folio, with additions and revisions.)

in the Anthracite–Crested Butte folio the sediments have the following succession:

Carboniferous:
- Maroon conglomerate, 4,500 feet. Conglomerate and sandstone, with local limestone layers.
- Weber formation, 100 to 550 feet. Dark shale, with limestone layers.
- Leadville limestone, 400 to 525 feet. Blue limestone.

Silurian:
- Yule limestone, 350 to 450 feet. Limestone with upper shale bed.

Cambrian:
- Sawatch quartzite, 50 feet. Quartzite with thin conglomerate at base.

Pre-Cambrian:
- Granite, gneiss, and schist.

In general the distribution of formations is as shown in figure 9.

[a] Emmons, S. F., Cross, W., and Eldridge, G. H., Anthracite–Crested Butte folio. Geol. Atlas U. S., folio 9, U. S. Geol. Survey, 1894.

The pre-Cambrian granite occupies the eastern part of the district and the intrusive diorite the western part; between them is the belt of Paleozoic sediments, the oldest on the east, narrowing to a thin strip on Taylor Peak. The sediments have a general westward dip of 25° to 45°. To the west of the district the diorite is in contact with the Maroon conglomerate, the uppermost Carboniferous formation of this region, but near Taylor Peak it comes into contact with the underlying Weber formation and is very near the Leadville limestone. On account of the proximity of the intrusive rock, the Leadville limestone and the limestone layers in the Weber formation are locally recrystallized and replaced by iron ore.

The Leadville limestone is very coarsely crystalline in places near the diorite contact, showing large cleavage rhombs of calcite. Where it is not so coarsely crystalline it shows numerous needle-like crystals of tremolite. These crystals are especially abundant near chert concretions, around which they form a fibrous matting, due to the presence of abundant silica which has combined with the surrounding lime. Except for the formation of ore deposits the shales of the Weber formation show but slightly the effect of the intrusion. The limestone layers in the Weber, however, have been recrystallized, though not so coarsely as the Leadville limestone. Near the ore deposits both formations are deeply stained by iron.

STRUCTURE OF THE ORE DEPOSITS.

The ore deposits are situated at or near the contact of the sediments with the intrusive diorite, the actual location being determined by the kind of rock and probably by fracturing and faulting. The largest single deposit (fig. 10) lies near the head of Cooper Creek, on the northwest slope of Taylor Peak, about 3½ miles south of Ashcroft. It is located near the contact of the Weber formation and the Leadville limestone, being a replacement of both, and is 500 feet from the diorite contact. This deposit is very irregular, containing horses of quartzite, shale, and limestone and having stringers that extend into the surrounding limestone area. The deposit is situated on a slope of 35° to 45° and is opened by several horizontal tunnels, three of which, having a length of 70, 110, and 120 feet, end in limestone. Whether this limestone is merely a horse or whether it is wall rock is not known, but if it is wall rock a large part of the present body of ore is merely a surface covering. In the limestone area surrounding the deposit there are numerous veins of iron ore and bodies of limestone and shale partly replaced by iron.

The ore is mainly a dark-blue, glossy magnetite with calcite, quartz, pyrite, kaolin, siderite, barite, and chlorite as gangue minerals situated in cavities or disseminated. The gangue minerals are most abundant near the limestone contact. Locally pyrite is present in such quantities as to become injurious. In places the ore is soft and friable, but mainly it is dense and hard. Near the surface it becomes more porous, owing to the leaching of gangue minerals, and is stained by limonite. The limonite originates partly from the oxidation and hydration of magnetite, but mainly from the oxidation and hydration of pyrite; indeed, considerable partly altered pyrite is present near the surface.

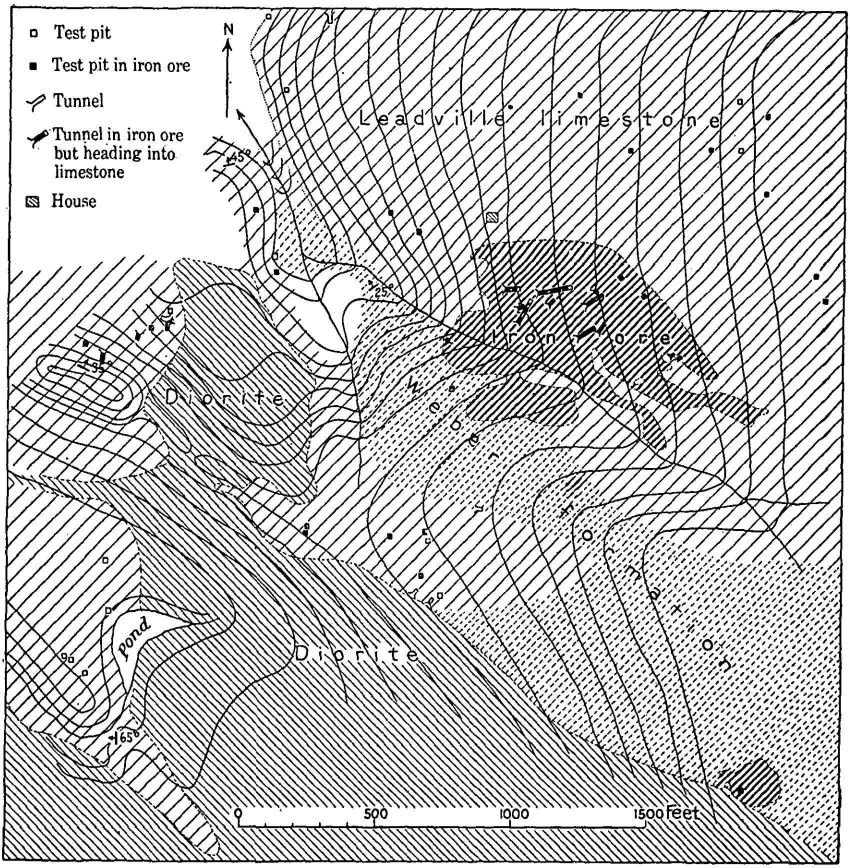

FIGURE 10.—Detailed map of the Copper Creek iron-ore deposits, Taylor Peak district, Colorado.

The contact of iron ore and limestone has commonly a very steep dip—from 70° to 80° toward the iron—but in places the dip is as low as 35°. The limestone is hard and crystalline within a few feet from the contact, and much of it contains veins of calcite. At the contact it is soft and friable and is mixed with gangue minerals and seams of magnetite and limonite. On the iron-ore side of the contact the gangue minerals gradually become less abundant and within a short distance give place to solid magnetite. Near the contact the ore is generally soft, but the main part of the ore body is dense and hard.

The sediments surrounding the ore deposits contain veins and stringers of iron ore for a distance of several hundred yards, and close to the deposit they are deeply stained and here and there partly replaced by iron.

Halfway between the main deposit and the summit of Taylor Peak is a small deposit at the contact of the diorite and the Weber formation. (See fig. 10.) This deposit contains two kinds of ore—a dense blue magnetite and a mixture of magnetite and limonite with partly replaced sedimentary material. Both kinds are present at the surface; the former probably represents the replacement of a pure limestone, and the latter shows the less thorough replacement of a shaly limestone. The surrounding sediments are stained and partly replaced by iron, but the diorite shows little or no change near the contact. The gangue minerals here are mainly calcite and quartz.

Another small deposit lies at the contact of the diorite and Weber formation on the east side of Taylor Peak, near the head of Twenty Percent Creek. (See fig. 11, *a*.) This deposit is similar in every respect to the one just described, being the replacement of a local limestone area in the shale-limestone formation.

On the southeast slope of Taylor Peak, above Taylor River, there is a series of small deposits in the Weber formation at or near the diorite contact. (See fig. 11, *b*.) The character of the ore here is the same as in the deposits previously described, but the association of gangue minerals differs in some of them. In the deposit farthest to the north, a short distance southeast of the summit of Taylor Peak, the ore is heavily impregnated with chlorite and contains some calcite, and directly at the contact there is an association of pyroxene, amphibole, garnet, epidote, and pyrite in a cherty matrix. The diorite at the contact is finer grained than usual and contains seams and specks of pyrite.

Other deposits of similar character occur along the contact at intervals between Taylor Peak and Star Peak. A few are exposed, but for the most part they are concealed by diorite talus. Several tunnels have been run underneath this talus mantle in search of silver ore and have penetrated limestone and iron-ore deposits. Small amounts of silver and antimony ore also were encountered.

The iron ore is intimately associated with sedimentary material, occurring as local replacements, stains, and small veins. Where the original rock was sandstone or shale the ore is very sandy, some of it being so lean as hardly to be called an iron ore. Most of the deposits, especially the replacement deposits, are very near the diorite contact, but veins of magnetite, limonite, and locally pyrite occur in the sediments at some distance from the igneous rock.

Near Star Peak in the Sawtooth Range the diorite contains included masses of siliceous shales from the Weber formation which have been deeply stained and contain little seams of magnetite a few inches in thickness and one or two local areas of ore a few feet in diameter at the contact with the diorite. On account of the color the whole mass has been considered iron ore—the so-called Iron Mountain deposit.

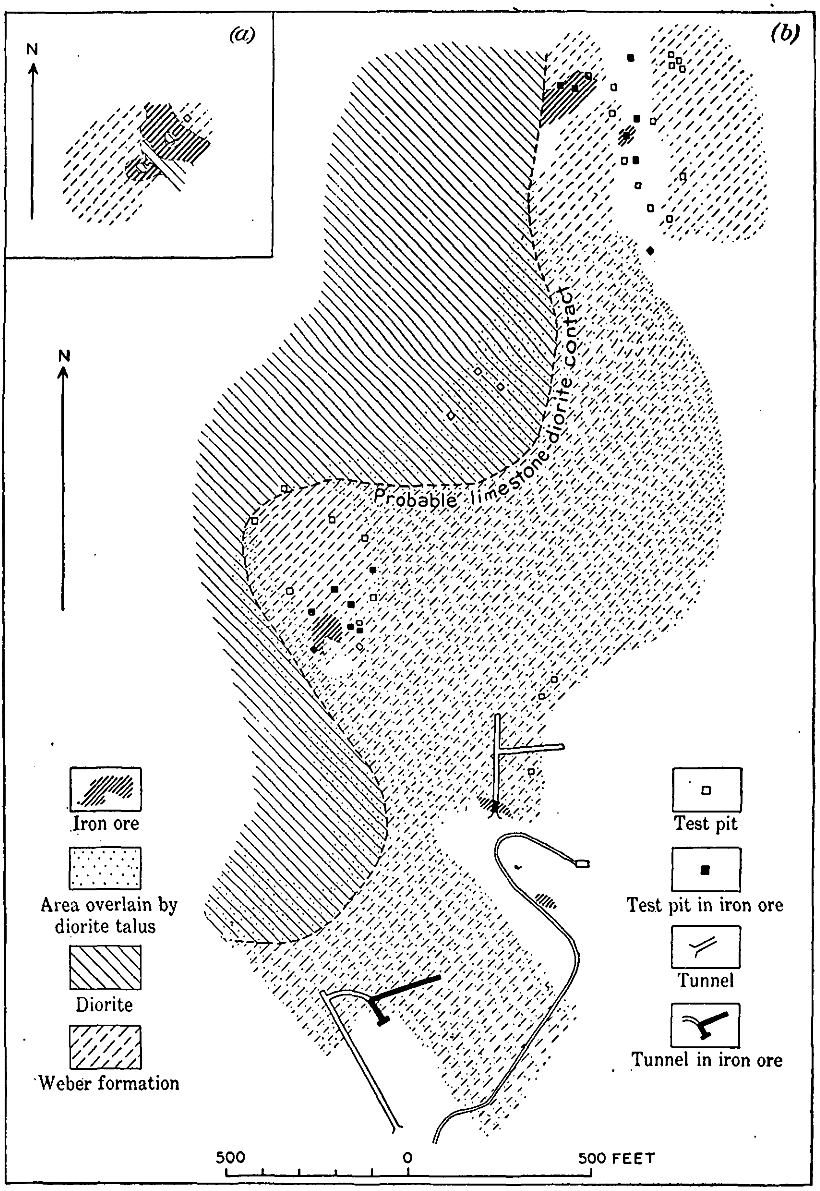

FIGURE 11.—Detailed map of the Twenty Percent Creek (*a*) and Taylor River (*b*) iron-ore deposits, Taylor Peak district, Colorado.

In general, then, the ore follows the diorite contact, replacing the calcareous portions in the adjacent Weber formation or the Leadville limestone where this is close enough. This association shows that the ore-bearing solutions were derived from the diorite, and the nature of the gangue minerals shows that they had a deep-seated source.

COMMERCIAL IMPORTANCE.

The iron-ore deposits of the Taylor Peak district are unfortunately situated with regard to topography and railroads. Aspen, the nearest railroad station, is 18 miles north of and 4,000 feet lower than the iron ores. Under great difficulty a branch line might be constructed to a point within a few miles of the Cooper Creek deposits if they were extensive enough to warrant the expenditure, which is not the case. The Taylor River deposits are several miles beyond Cooper Creek, on the other side of the Elk Mountain divide, and would have to be transported by way of Taylor River to the Colorado and Southern Railway. It is practically impossible to construct a railroad nearer than 2 miles from either of these deposits, as they are well up on the slope of the mountains and can hardly be reached by wagon. Unless the price of ore rises so as to make a 15 or 20 mile haul by pack animals and wagon profitable or a cheap method of transportation is installed these deposits will probably not be utilized.

The Cooper Creek deposit is by far the largest in the Taylor Peak district. Measured on the slope (35° SW.) it has an average width of 450 feet north and south and an average length of 750 feet east and west. Three horizontal tunnels have been driven through it into limestone, so apparently a large part of the deposit is merely a surface blanket. With the average depth as shown by the tunnels, the quantity of ore may be estimated as being between 3,000,000 and 4,000,000 tons. Doubtless, however, portions of the deposit go to a much greater depth than the explorations indicate, so that a larger tonnage than that may be expected. All the other deposits should be measured in thousands rather than millions of tons.

Some of the ore contains considerable pyrite, making its sulphur content so high that roasting may be necessary. Locally silicates also are very abundant, especially near the diorite contact, and elsewhere iron has only partly replaced the sediments and the ore contains considerable sand. On the whole, therefore, it is not of very high grade, and this fact, together with the unfortunate location of the deposits, will prevent its utilization for some time to come.

WHITEPINE DISTRICT.

LOCATION AND GENERAL GEOLOGY.

The Whitepine district lies on the west slope of the Sawatch Range, about 10 miles north of Marshall Pass, in the southeastern part of Gunnison County, Colo. It is readily reached from Sargents, on the narrow-gage line of the Denver and Rio Grande Railroad, a distance of about 12 miles. The principal deposits lie on the east slope of the valley of Little Tomichi Creek, about half a mile northeast of Whitepine, at an elevation of about 9,500 feet.

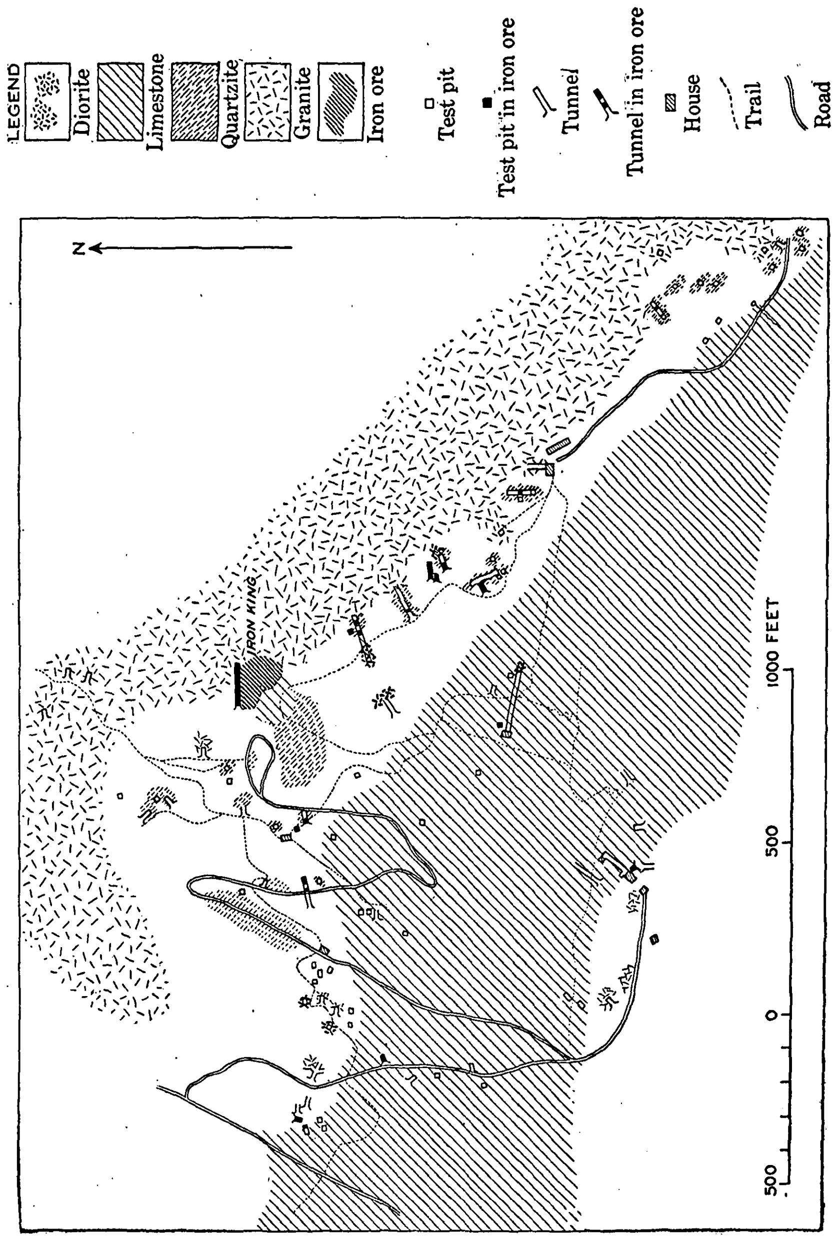

FIGURE 12.—Detailed map of the Whitepine iron-ore deposits, Gunnison county, Colo.

The ore-bearing area has a northwest-southeast trend (see fig. 12), lying along the contact of a granite with shale and limestone. The granite, which is on the northeast and occupies the upper part of the slope, is directly connected with the great pre-Cambrian granite mass forming the Sawatch Range. The sediments are presumably Paleozoic, being lithologically very similar to those of the Taylor Peak district. Next to the granite there is generally a layer of vitreous quartzite, of varying thickness up to 30 feet, which may represent the Cambrian. The iron ores occur locally between this quartzite and the overlying rocks. Outside of the quartzite and ores, where these are present, there is a strip of dark-colored limestone and shale, chiefly the latter, and outside of this is a blue or white crystalline limestone, which occupies the lower and principal part of the slope. This limestone is very similar to the Carboniferous limestone of Taylor Peak.

Besides these rocks a light-gray rhyolite is present as an intrusive into the dark shale formation and along the granite contact. It is composed mainly of a light-gray compact groundmass containing phenocrysts of quartz, feldspar, and biotite, the quartz being by far the most abundant. The rhyolite has been intruded in disconnected masses, whose forms could not be determined from the exposures found. The rocks are much fractured and faulted, but the details have not been worked out.

STRUCTURE OF THE ORE DEPOSITS.

The iron-ore deposits of this district are of two kinds—limonitic bog ores and replacement deposits of magnetite and limonite ores. The former occur in a small deposit along Little Tomichi Creek within the granite area, about a mile above the principal deposits. The latter are found in small irregular masses in the limestone-shale formation near the granite contact. In some places only a few feet of vitreous quartzite intervene between ore and granite; in others a mass of rhyolite and layers of the dark limestone-shale formation are present in addition to the quartzite. No place is known where the iron is immediately in contact with the granite. In the Iron King cut, the largest deposit in the district, no quartzite is exposed between ore and granite, but the direct contact can not be seen. As a rule the dip of the contact is steeply toward the iron.

The principal deposits vary in thickness from 5 to 40 feet, and extend along the contact for a distance of several hundred yards. Beyond in either direction is merely a local staining and a few small veins. Ore occurs also in small bodies where the rhyolite has intruded the sediments away from the granite contact, especially where the sediments are limestones, and a few deposits are found in the limestone away from the intrusive masses. The deposits along the granite contact and in association with the rhyolite consist largely of magnetite, but those entirely within the limestone, at some distance from the igneous rocks, are composed of dark-brown porous limonite.

The ore associated with the igneous rocks is mainly a glossy, black, compact magnetite with seams and specks of limonite. Locally this ore grades into blue, fine-grained magnetite with chlorite, quartz, and calcite disseminated through it, similar to some of the Taylor Peak ore. In the Iron King cut masses of serpentine and quartzite are interlayered with the magnetite. Large masses of brown ocherous material, which probably represent partial replacements of the limestone-shale formation, occur between the sediments and the ore bodies. This partly replaced border varies in thickness and degree of alteration; in some places it consists merely of stained quartzite, but elsewhere it is soft and friable and contains numerous veins of magnetite, limonite, chlorite, and kaolin. Here and there masses of partly replaced sandstone and shale occur as lenses surrounded by ore or as bands between adjacent ore deposits. The sediments near the ore deposits are heavily impregnated with contact minerals, among which the most conspicuous are epidote, chlorite, amphibole, pyroxene, garnet, pyrite, and magnetite.

From the foregoing statements it is clear that the iron ores are replacements of the calcareous parts of the limestone-shale formation. The nature of the gangue minerals shows the solutions to have had a deep-seated source, but the distribution of the deposits does not show as clearly as the Taylor Peak deposits the nature of this source. The fact that the deposits lie along the granite contact seems to point to the granite as the source, yet that rock is presumably much older than the overlying rocks that contain the ores. The association of the intrusive rhyolite with the granite contact and hence with the ores appears more significant. It is probable that the rhyolite intruded at this horizon, because it was easier of access, on account of the fracturing, and that the ore-bearing solutions were associated with it. Direct evidence for this hypothesis is not everywhere plain, yet the ore bodies and the rhyolite are closely associated and the sediments become altered and iron stained as the intrusive rock is approached.

The limonite ore within the limestone occurs as veins, breccia deposits, and small irregular replacement masses and is clearly of a different type from the contact ores. It was probably deposited by iron-bearing meteoric waters along open channels and replaced the adjoining rocks. The deposits are of small size and of no importance, few of them being more than 15 or 20 feet in diameter.

The bog-ore deposit occurs in the valley bottom along Little Tomichi Creek, about 1½ miles northeast of Whitepine. The granite contact crosses the creek between it and the contact deposits, and the bog ore is a considerable distance within the granite area. The deposit is 3 or 4 feet thick and perhaps 2 or 3 rods square and consists of successive layers of ore several inches in thickness. The ore is light and porous and is made up largely of evergreen needles and other vegetation, replaced by limonite.

At several places along Little Tomichi Creek, between this deposit and Whitepine, where the valley bottom is boggy, bog ore is being formed at the present time. This process is especially noticeable below the slope where the contact deposits occur.

COMMERCIAL IMPORTANCE.

So far as present developments show the Whitepine deposits can be considered of but small economic value. They occur in a narrow contact zone, and although they may go to a considerable depth, they are probably too thin to make mining profitable.

The thickness of the deposits varies within short distances. It may be 40 feet at one point and narrow down to 10 feet within a distance of 100 feet. At many places along the contact it pinches out altogether. Moreover, a large proportion of the ore is of low grade, containing clay, sand, silicate minerals, and other impurities.

Transportation facilities are not altogether unfavorable, however, as the narrow-gage line of the Denver and Rio Grande Railroad is only 12 miles distant, and without great difficulty a branch line could be constructed to a point within a short distance of the deposits if their size warranted such an expenditure.

THE HANOVER IRON-ORE DEPOSITS, NEW MEXICO.

By Sidney Paige.

INTRODUCTION.

During the latter part of July, 1908, the writer made a rapid reconnaissance of the iron-ore district near Hanover, N. Mex. But a week's time was given to the work and necessarily only the major geologic relations of the field could be studied. Considerable time was spent in the actual tracing of the igneous-sedimentary contact, and attention to those details of petrographic interest which might have been studied by means of systematic collections from the area was impossible. Though copper and zinc are both of economic importance in this district and though their geologic occurrence is intimately associated with that of the iron, time was not available to investigate them and they are not considered in this report.

Two topographic maps including this area have been prepared by the United States Geological Survey; one, the map of the Silver City quadrangle, scale 1:125000, contour interval 100 feet; another, in more detail, the Santa Rita special map, scale 1:24000, contour interval 20 feet. These maps will be ready for general distribution within a few months, and may be obtained for 5 cents each from the Director of the Survey.

Acknowledgment is due to Mr. B. F. Baker, of Hanover, for courtesies extended to the writer.

GEOGRAPHY AND TOPOGRAPHY.

The Hanover district is in Grant County, N. Mex., 12 miles N. 70° E. from Silver City and 2 miles northwest of Santa Rita. It may be reached from Deming, N. Mex., by the Atchison, Topeka and Santa Fe Railway.

The area studied is just within the borders of the mountainous district lying between Gila River on the north, the desert on the south, and Mimbres River on the east. The general elevation of the district is about 6,500 feet, with peaks rising 800 to 2,500 feet higher. The drainage is toward the south, and after passing beyond the mountain border all streams are lost in the desert sands. The district proper is drained by a southward-flowing stream fed by many mountain gulches, which in times of heavy rainfalls, such as are characteristic of the region, becomes a raging torrent, carrying in its

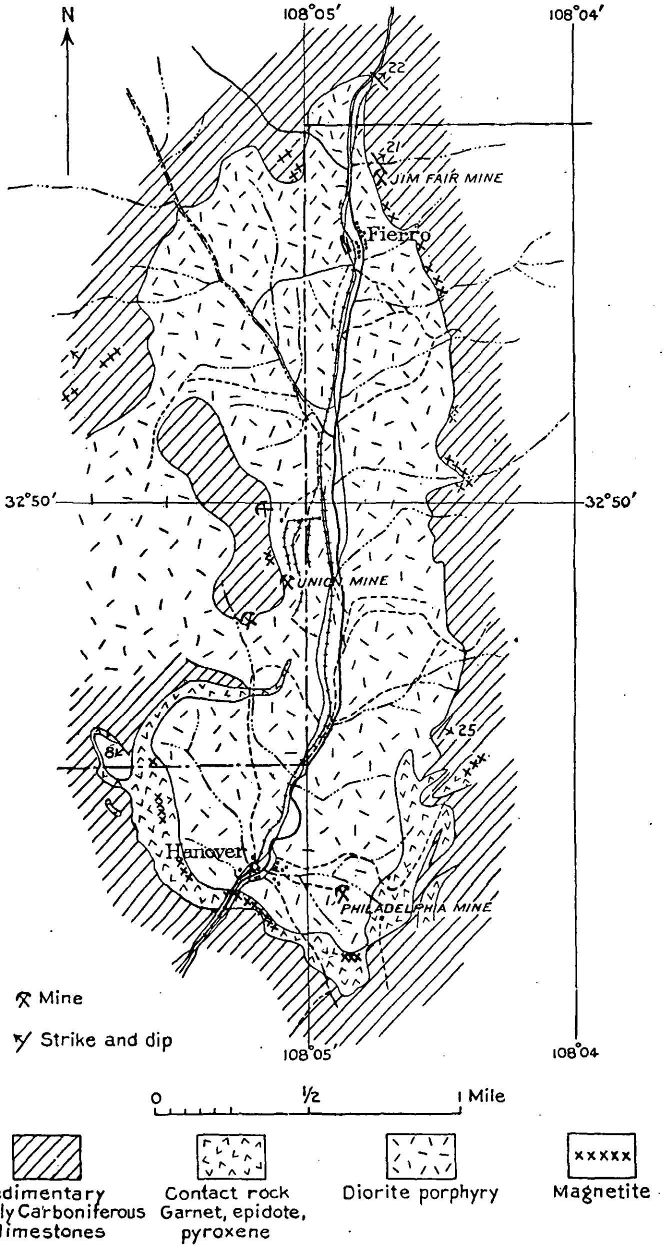

FIGURE 13.—Map showing geologic relations in the Hanover iron-ore district, New Mexico.

waters a large amount of detrital material to be spread out in a great alluvial fan at the edge of the mountains. The general lack of trees and shrubs on the hills facilitates this work of denudation, and the region, broadly considered, is a marked example of rapid interior erosion and deposition.

As a geologic unit the district may be described as a narrow basin occupying the upper valley of Hanover Creek, the iron ores being arranged more or less regularly around the edges of an intrusive mass of quartz diorite porphyry. (See fig. 13.) The basin is, roughly, 2½ miles long in a north-south direction and averages three-fourths of a mile in width. On its west side the ores occupy the summits of the ridges; on the east side they are formed along the slopes of a higher ridge. Hanover Creek occupies a central position, flowing southward and exposing in its valley the intrusive quartz diorite porphyry.

GEOLOGY.

GENERAL STATEMENT.

The broad relations of geologic structure in this basin are simple. A mass of quartz diorite porphyry has intruded Carboniferous sedimentary strata, in large part limestone. On a portion of the west side the areal boundaries of the mass are not known. (See fig. 13.) Its general contact determines, at least on the southwest side, the configuration of the hills, which are capped by iron ledge or contact rock. At many localities the determination of bedding is impossible, but so far as could be observed the limestone beds tend to dip away from the mass. In the southern third of the area the intrusive mass has caused extensive metamorphism of the strata. Along this contact zone and also along the contact where metamorphism has been far less pronounced ores of iron, copper, and zinc have been deposited. The iron ore is principally magnetite at one locality with considerable hematite.

At the north end of the area sandstones are present, but their relations to the limestones are not certainly determined; faulting has probably occurred. From the nature of the intrusive mass, the attitude of the surrounding beds, and the prevalence of Carboniferous rocks in the surrounding region it is believed that beds stratigraphically higher than those now exposed formerly extended over the area, or at least buried the present ore deposits under a considerable depth of rock which has been removed by erosion. The isolated mass of limestone on the west side of the area (see fig. 13) and the great thickness of the strata to the east likewise tend to uphold this view.

Where exposed in the larger mines of the district, the contact between the porphyry and the limestone is nearly vertical. However, the manner in which the metamorphism has taken place in the southern portion of the area and the isolated position of the limestone mass surrounded by porphyry on its western border lead to the belief that the igneous mass in depth probably has a much greater horizontal extension than is revealed at the surface. This hypothesis is favored by the width of the contact-metamorphic zone, locally as great as 800 feet, excluding narrow bands of contact rock (see fig. 13); the presence of what is believed to be a residual portion of the original cover in the isolated mass on the west side of the area; and the fact that ores of metals other than iron are found at considerable distances from the contact.

SEDIMENTARY ROCKS.

GENERAL CHARACTER.

The prevailing sedimentary rock in the vicinity of the ore deposits is a fine-grained dark-blue limestone of Carboniferous age. Its thickness in this region was not determined. From the evidence derived from float in some of the gulches entering Hanover Creek from the east, it is believed that sandstone beds overlie the limestone, possibly alternating with more limy beds higher in the series. In the northwestern portion of the district siliceous beds were noted underlying limestone, and, still lower, black slaty sediments were observed near the contact. The strike at this point was N. 40° E. and the dip 30° NW. As the limestones are here overlain by a considerable thickness of quartzitic beds, this succession would seem to correspond to that indicated by the float in the creeks on the east side of the basin, where shaly members underlie the limestone. On this side, however, the strike is variably N. 30° W., with a dip of 21° NE. To explain this discrepancy a fault may be assumed to pass northeastward near the eastern base of Hanover Mountain,[a] and the dip of the beds would suggest that if this is the case, the break occurred near the crest of an anticlinal fold.

On the east side of the area, near its south end, shaly beds and in some places limestones are exposed at the base of the series, next to the porphyry contact. These beds strike N. 32° E. and dip 25° SE. The alternation of limestone and shale at the contact may be explained by the irregularity with which the magma intruded the various strata, though it is true that the determination of the original nature of certain beds is complicated by the metamorphism which has taken place within the contact zone. One-half mile northwest of Hanover, in the creek beyond the ridge, the limestone appears to strike N. 45° W. and dip 8° SW. It would seem, then, in general that the sedimentary rocks dip away from the igneous mass and that the doming expressed in their quaquaversal dips is definitely related to the intrusion.

[a] The summit of Hanover Mountain is one-third of a mile northwest of the northern point of the intrusive mass.

JOINTING AND FAULTING.

Fracturing of the sedimentary rocks is very general, and jointing, sheeting, and faulting have all occurred. Though more extended observation would probably show the prevalence of other directions than those recorded, sufficient data were collected to indicate the general dominance of the lines of breakage. Figure 14 clearly brings out the tendency for joints to form in a northeast-southwest direction and shows the great scarcity of joints in the northwest quadrant. The age of the jointing is difficult to determine, except for the obvious fact that it occurred in large part after the cooling of the intrusive rock. In one place aplite dikelets were observed clearly broken in an east-west direction. Their breakage was sharp, yet the fracture of the diorite porphyry was invisible, even with the aid of a

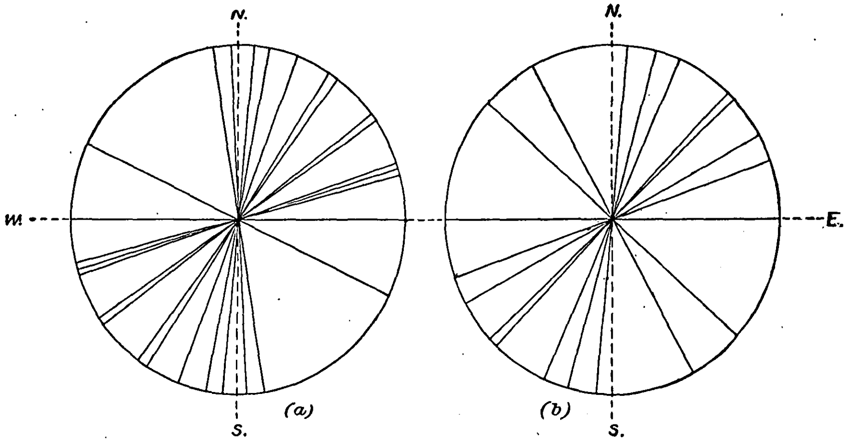

FIGURE 14.—Diagram showing relation of trend of dikes (*b*) to joints and sheeting (*a*) in Hanover iron-ore district, New Mexico.

hand lens. A suggestion that the magma was probably very brittle while still sufficiently hot to undergo recrystallization might explain this condition, for the aplite dike was not disturbed except by a clean fault. Locally pronounced sheeting was observed, trending in north-south and east-west directions. Faulting, except in displacements of very small throw, measured in inches, was observed in only a few localities. In the south pit of the Union mine a fault plane dipping 42° W. and striking nearly north and south can be plainly seen. Its throw is not known, nor is it safe to assume that a considerable movement is involved, for though rock is exposed in the bottom of the pit beneath the ore body its presence is not necessarily an indication of faulting; moreover, a porphyry dike at the north end of the same pit, so far as could be observed, was undisturbed.

On the east side of the area, a little less than a quarter of a mile east of the Philadelphia mine, porphyry dikes have been offset in an east-west direction in at least two steps, with a horizontal displacement of 50 and 75 feet. Neither the direction of the actual movement nor that of the fault plane was determined, but it is believed that at least part of the horizontal displacement is due to the dip of the dike on a normal fault.

The postulated fault at the foot of Hanover Mountain mentioned in the preceding section must await further studies for its elucidation, and for the present the suggestion is regarded as purely tentative.

IGNEOUS ROCKS.

MAJOR INTRUSIONS.

The deciphering of variations within igneous masses, the mapping of igneous transitional types, and the theoretical discussion of their origins always require careful detailed work, both in the field and in the laboratory. No such methods could be applied in the present investigation. Sufficient data were obtained, however, to recognize clearly the nature of the main intrusive stock and to note within its mass certain variations. One of these variations is purely textural, to be explained probably by differences in conditions of cooling or location; another is chemical, and for the present its geologic relations must remain unexplained.

The main mass is a quartz-bearing diorite porphyry, and to it or to the immediate results of its intrusion is ascribed the origin of the iron ores. Specimens were collected at various localities within the area and at only two, both in the southeast portion, near the limestone contact, were the rocks other than distinctly porphyritic. At these localities, however, the aspect was clearly that of an abyssal type—in one a quartz-bearing hornblende diorite, in the other a quartz monzonite. Their relation to the porphyritic phase was not determined, but the diorite, because of its definite mineralogical similarity to the porphyry and because of its association, is considered the parent magma. The main stock, the quartz diorite porphyry, must be considered a phase resulting from crystallization under conditions peculiar to the contacts of igneous masses with sedimentary formations. In very general terms such a texture would indicate a position near the top of the mass (in this instance) and this view accords with the hypothesis that the sediments extended over the area at an elevation somewhat near that of the isolated limestone mass on the western border. Megascopically, the quartz diorite porphyry is a light-gray, distinctly granitoid rock. Ferromagnesian minerals are pronounced and give an impression of what would be called a porphyritic diorite. It is only under the microscope, in thin section, that the distinctly porphyritic nature of the type becomes clear. The dominant phenocrysts are plagioclase feldspar (ranging from acidic andesine to normal labradorite), biotite, and common green hornblende; Carlsbad and albite twinning is characteristic and zonal growths are numerous. Quartz phenocrysts are of variable occurrence in the several specimens examined, and mica, though not so abundant, is perhaps larger in its development and striking in hand specimens. The groundmass is a microgranitic growth of feldspar and quartz. Magnetite is abundant and titanite, zircon, and some apatite were observed.

The diorite is a holocrystalline, coarse granitoid rock consisting of plagioclase (andesine labradorite), abundant quartz, hornblende, and mica. Augite occurs in small grains and magnetite and titanite are accessory.

The other rock of granitoid texture, whose relations to the main diorite porphyry mass were not determined, may be called a quartz monzonite. The single specimen collected consists of orthoclase, plagioclase, and quartz, in fairly equidimensional development, with ferromagnesian minerals forming a very subordinate part.

To sum up—by far the larger portion of the mass is a quartz-bearing diorite porphyry, within which was found at one locality a true diorite; at another a quartz monzonite. The diorite is regarded as an abyssal parent magma; the relation of the monzonite is not known.

MINOR INTRUSIONS.

As may be seen from figure 14, the dikes of the region are variable in their trend. There is, however, a marked tendency (so far as observations have shown) for their directions to be confined to the northeast and southwest quadrants; and it is possibly significant that the joint systems of the area seem more pronounced along similar lines.

Both granite and diorite porphyries are represented by the dikes, also granite-aplites and some plagioclase-hornblende rocks of diabasic texture.

The granite porphyries are light gray and of variable degrees of fineness. Porphyritic structure is pronounced in some of them, the feldspars attaining a length of three-quarters of an inch. They consist essentially of alkaline feldspar, partly orthoclase, partly plagioclase, with quartz and hornblende. Corrosion of the quartz is marked in one specimen. The feldspars have in several places been greatly altered to sericite and earthy matter. The hornblende commonly alters to chlorite and epidote.

Aplitic dikes of granitic composition are common. In one a granophyric texture was finely developed. This same texture was also observed where chill selvages had been formed along the edges of intruding granite-aplites, which in their main mass were of granular texture. This fact suggests an explanation for the existence of such a texture at a distance from a contact—that is, rapid cooling.

The diorite porphyries are likewise variable in texture and range in color from light to dark gray. One is a dense, dark grayish green, finely crystalline rock with an abundant sprinkling of pyrite. Under the microscope, plagioclase and hornblende phenocrysts are prominent in a groundmass of plagioclase.

A second type of diorite porphyry has a light gray-blue aphanitic groundmass and prominent phenocrysts of plagioclase. In thin section both plagioclase and mica are prominent as phenocrysts and the groundmass is seen to be a microgránitic mass of feldspar and quartz with accessory magnetite.

Two dikes somewhat different from the common examples seen may be described. One consisted of well-crystallized, even grains of plagioclase feldspar. In the hand specimen a green powder between the grains suggested the weathering out of a ferromagnesian mineral, probably hornblende, as this mineral was segregated in bunches in the dike. A little magnetite and titanite were present. This may have been a typical diorite dike. The second dike may be termed a hornblende diabase porphyry—that is, a proterobase porphyry—as, in place of augite, hornblende was present, occupying the interstices between interlocking laths of plagioclase feldspar. Large phenocrysts of hornblende were scattered throughout this mass.

Taken as a group the above-described rocks seem the natural resultants of a period of solidification of the parent magma, when, as openings occurred, magmatic material was thrust into them. Except for the rather abundant occurrence of granite-aplites, there is not much evidence of differentiation into alkalic and ferromagnesian types. It is quite possible that further studies will reveal rocks of a more basic nature, complementary to the aplites. The proterobase porphyry described may be the intrusive accompaniment of certain extensive flows that can be observed a few miles to the south.

Mineralization probably followed or accompanied the intrusion of these more basic types, but it can not be discussed in this report.

METAMORPHISM.

The intrusion of the diorite porphyry mass into the overlying sediments was accompanied or closely followed by intense local metamorphism of the intruded rocks and by less though marked local alteration of the intrusive body itself. This metamorphism was distinctly a contact phenomenon and was definitely confined to the border zone or such localities as are probably near igneous material.

The geologic sketch map (fig. 13) shows clearly that the nature of the metamorphism in different parts of the area was not the same.

The southern part is especially characterized by a definite border zone, of varying width, occupied by a typical contact rock, in large part epidote, garnet, and pyroxene (augite), with quartz, calcite, pyrite, magnetite, and zinc blende. Though it is hardly safe, in view of the meager amount of time given to the area, to speak definitely of the distribution of these several minerals, the broad fact seems to be clear that magnetite occupies a position at or near the inner border, that garnet and epidote lie next, and that toward the outer edge the pyroxene is most pronounced. Naturally there are transitions, and one or all of these minerals are apt to occur together in any single locality. On the outer edge of the contact zone on the west side the change from pure limestone to pure pyroxene (accompanied by garnet) is markedly abrupt. A knife blade can be placed on the line of demarcation. The limestone seems to have been saturated with a silicate solution which traveled a certain definite distance from the contact beyond which its influence ceased. The pyroxene occurs in crystalline aggregates of radiating augite, in which masses of garnet were seen. Near the contact with the igneous rock a thin section revealed a mass of crystalline epidote, quartz, and some titanite, as a replacement of limestone. The above-described condition is characteristic of that portion which has been mapped as contact rock, though the presence of pyroxene is more pronounced on the western border. Locally the garnet zones are extremely pronounced, the material being composed of large, beautifully crystalline masses of the pure mineral, generally with rhombic dodecahedral development.

Toward the north metamorphism is exhibited in a different manner and may possibly be more dominantly transformative than replacement. Silicification is more pronounced and epidote-garnet zones are rare and only of slight development. The beds nearest the contact, however, show the similarity of the metamorphism to that in the southern part of the area, sedimentary beds of extremely fine texture showing under the microscope crystalline aggregates of epidote and garnet, locally with abundant apatite. On the north some beds that probably were originally shales are composed of extremely fine grains of quartz and feldspar, with an abundant sprinkling of pyrite, and are of the nature of hornfels. On the eastern border, near the center of the area, a distinct banding of the metamorphic minerals is evident, following the stratification of the sediments. Here magnetite, quartz, and abundant apatite were observed, and needles of rutile in the quartz were numerous.

On the northwestern border of the area certain iron bands of considerable thickness are overlain and underlain by rocks representing the more sandy or shaly members of the sedimentary series, and are here cited as a probable example of selective metamorphism—that is, a limy layer has been replaced by magnetite.

Metamorphism is not confined to the intruded rocks. The diorite porphyry has suffered changes of the same nature as those that have affected the limestones, though to a less degree. Epidote and garnet were noted as contact minerals in the diorite, but the greatest change seemed to be the acquisition of abundant magnetite, probably replacing hornblende, as this mineral was almost entirely lacking in a thin section. There is some evidence also that a finer crystallization has occurred nearer the borders, though this condition is believed to be variable. These points must be left open until further studies can be made. It is known that in some other areas the intrusive rock suffers changes quite as pronounced as those of the rock intruded. In the Velardeña district of Mexico [a] metamorphism was believed to have followed the intrusion and to have been produced by ascending hot solutions that took advantage of fractures in the solidified magma. In the Hanover district evidence is not at hand to prove whether or not this condition existed, and it is presumed that the sediments afforded an easy avenue of escape for circulating solutions, and that these solutions, concentrated along the contact, were more efficient in altering the limestones than they were in replacing the igneous rock.

It is believed from the results of numerous investigations that the important factors determining the nature of the metamorphism due to the contact of igneous masses with sedimentary strata are the chemical composition of the intruded and intrusive rocks, the size of the intrusive mass, the depth at which intrusion took place (a factor that directly affects the pressure and in less degree the temperature), and the condition of the intruded beds with respect to porosity, fracturing, etc. The importance of these several factors has varied in different localities to such an extent that rather diverse views have been put forward respecting their relative weight. The accumulating evidence tends undoubtedly to prove that variable conditions, though it may be difficult to understand their nature, determine the effects of an intrusion. Barrell [b] holds that one of the chief results of his studies is the proof that contact metasomatism is dependent on a temporary permeability of the affected rocks, this permeability being due to a minute fracturing or parting, evidence of which has been in many places nearly destroyed by the metasomatic recrystallization.

He also holds [c] that the siliceous limestones are the strata most readily metamorphosed. This is directly the opposite of what Lind-

[a] Spurr, J. E., and Garrey, G. H., Ore deposits of the Velardeña district, Mexico: Econ. Geology, vol. 3, 1908, p. 698.

[b] Barrell, Joseph, Geology of the Marysville mining district, Montana: Prof. Paper U. S. Geol. Survey No. 57, 1907, p. 117.

[c] Op. cit., p. 147.

gren[a] finds to be true in the Clifton-Morenci district, Arizona, where the greatest contact effects have been produced in almost pure limestones. Moreover, Lindgren shows[b] that in the main the alteration has no dependence on fissures or veins, and that the only factor which seems to have any influence is the proximity of intrusive bodies.

In regard to volume changes also there are diverse views, but this subject can not be treated here further than to state that in the Hanover district the limestones have received great accessions of iron, sulphur, copper, and zinc, with ferric oxide and silica in the garnet zones.

In summing up, attention may be called to four points. First, the intrusive involved is distinctly a quartzose diorite porphyry and its contact effects have been marked. Second, there is evidence that metamorphism has been selective, the more calcareous sediments suffering the most. Third, evidence of fracturing as an explanation of intense metasomatism is lacking. Fourth, volume changes, if they have taken place, are not observable. It may be added that in those beds which were less susceptible to pneumatolytic changes the alteration has been more in the nature of a recrystallization, with possible siliceous additions. It would seem reasonable to suppose that the purer limestones, as carbon dioxide was driven out, were invaded by magmatic solutions of high temperature, and that any tendency toward shrinkage was overcome by further accessions from the magma. In other words, those elements native to the intruded rock which were of a proper nature to form contact minerals (such as lime and silica) combined with materials from the magma, the whole forming a solution from which the present minerals originated.

IRON ORES.

INTRODUCTION.

The iron ores occurring in the vicinity of Hanover, N. Mex., have been worked since 1899. In 1904 work was suspended because of labor difficulties, but since that time has proceeded nearly continuously.

The principal mines are the Union and the Jim Fair. They are leased by the Colorado Fuel and Iron Company and all the ore is shipped to Pueblo, Colo.

[a] Lindgren, Waldemar, The copper deposits of the Clifton-Morenci district, Arizona: Prof. Paper U. S. Geol. Survey No. 43, 1905, p. 154.

[b] Op. cit., p. 127.

DISTRIBUTION AND CHARACTER.

The map (fig. 13) shows clearly that the ores are arranged about the periphery of an intrusive stock, at or near its contact with sedimentary beds. With the exception of two localities, one in the northwestern part of the area and the other in the northeastern part (not shown), where the ore deposit is believed to occupy former limestone beds between more siliceous layers, the ore bodies are immediately next to the contact. They are, in the main, irregular lenticular masses of magnetite, in one place partly hematite. Where exposed at the northern and southern pits of the Union mine they are decidedly long as compared with their width and depth. At the Jim Fair mine a shorter, comparatively thicker lens is exposed. All three bodies pinch out in length, and in the northern pit of the Union mine ore has failed in depth. Besides these large bodies numerous outcrops may be observed, indicating the same mode of occurrence; that is, lentils of varying width and thickness, swelling and pinching in horizontal extension and, it may be safely presumed, presenting similar, though uncertain, irregularities in depth.

A second class of ore, which for convenience may be termed "soft ore," likewise occurs along the contact. It is characterized by the disseminated nature of the magnetite, which exists as finely and coarsely crystalline material with a considerable admixture of limestone, and depends for its commercial value on local concentration, whereas the value of the hard ores depends more directly on the size of the deposits and their freedom from impurities. Of the hard ores three bodies have been worked on a large scale, the two pits of the Union mine and the Jim Fair mine (see fig. 13); in the soft ores the principal work has been done immediately south of the southern Union pit, though soft ore, whose commercial value remains to be proved, occurs along the eastern border.

MINERALOGY AND CHEMISTRY.

The principal ore of the region is magnetite, though at the Jim Fair mine considerable hematite has been extracted. Varying amounts of chalcopyrite and zinc blende are associated with the iron ore, but figures are not at hand to express their relation, which is variable. Limestone and contact rock form the most abundant gangue material. In the hard ores the magnetite is generally massive and granular, but the magnetite of the soft ores presents in many places a fine development of crystal form, usually the rhombic dodecahedron.

The following data form part of a report by John Birkinbine on the iron ores of the United States published in 1897.[a] The iron con-

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, pp. 48–50.

tent shown by these figures probably does not express the facts when the mining operations of several years' duration are considered. A variable content of iron, between 53 and 57 per cent, with lime and silica also variable but correspondingly higher, would probably be nearer correct.

The extract from the report follows:

The following analyses by Messrs. Booth, Garrett, and Blair are of samples taken by Mr. Barringer, each being a sampling across the vein of about 25 pounds in weight. The subsequent shipment of 20,000 or 30,000 tons of ore has verified the correctness of the samples:

Analyses of samples of iron ore taken from the Hanover mines, New Mexico, supplied by D. M. Barringer, M. E.

No.	Metallic iron.	Silica.	Phosphorus.	Character of ore.
	Per cent.	*Per cent.*	*Per cent.*	
1	64.623	3.93	0.021	Specular.
2	63.673	.75	.021	Do.
3	65.979	2.43	.017	Do.
4	65.655	1.16	.028	Specular and magnetic.
5	64.258	1.10	.018	Do.
6	65.167	1.33	.017	Do.
7	62.450	.36	.019	Do.
8	64.578	1.20	.028	Do.
9	64.20	.49	.014	Do.
10	67.311	.63	.001	Magnetic.
11	60.132	2.42	.004	Do.

The sulphur determinations have been made in a few instances only, giving an average of 0.041 per cent, but this element is present in such small proportion that it was not considered necessary to have many determinations made. The ore contains no titanium or any other deleterious ingredient. It carries from 0.5 to 1.5 per cent of manganese, some lime, some alumina, and some magnesia, there being rather more of the latter than of lime or alumina. Some of the strictly specular ore, however, contains considerable quantities of lime. Some 4,000 tons of iron ore which were shipped to the Colorado Fuel and Iron Company at Pueblo, Colo., showed the following composition, being the average of 80 carloads:

Analysis of 80 carloads of Hanover, N. Mex., iron ore.

	Per cent.
Iron peroxide	76.00
Iron protoxide	12.85
Phosphoric acid	.041
Titanic acid	Nil.
Manganese oxide	.95
Alumina	.73
Lime	.58
Sulphur	.020
Combined water	2.32
Copper	.085
Iron	63.20
Phosphorus	.018
Silica	4.32
Manganese	.60

Highest 10 cars, 65.50; lowest 10 cars, 60.05 per cent of iron.

Highest 10 cars, 0.018; lowest 10 cars, 0.015 per cent of phosphorus.

Highest 10 cars, 8.85; lowest 10 cars, 1.65 per cent of silica.

Mr. T. W. Robinson, M. E., of Pueblo, Colo., also made an examination of this deposit, and analyses of samples which he took from nearly all parts of the property are as follows:

Analyses of iron ores from Hanover, N. Mex.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Ferric oxide	72.21	....	86.00	90.43	81.00	76.07	71.20	69.00	61.86
Ferrous oxide	....	....	....	....	8.48	11.05	....	16.07	17.48
Phosphoric acid	.332	....	.12	.112	.011	.256	....	.121	.13
Water	10.02	....	4.24	2.60	3.39	2.62	....	2.59	....
Alumina	.78	....	2.69	2.10	1.95	.75	....	1.67	....
Magnesia	1.25	....	1.06	.05	1.50	.95	....	6.20	....
Lime	.37	....	.40	.34	.15	.16	....	.31	....
Peroxide of manganese	2.61	....	1.26	1.49	.55	2.42	....	.79	1.07
Silica	12.89	....	4.36	2.19	2.46	4.74	....	2.90	....
Titanium oxide	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Trace.	Trace.
Zinc	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
Copper	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
	100.462	....	100.13	100.312	99.521	99.016	....	99.651	80.54
Iron	50.55	54.00	60.20	63.30	63.30	61.85	63.35	60.80	56.90
Phosphorus	.145	.058	.057	.049	.018	.112	.033	.053	.057
Sulphur	.009	....	.019	.018	.070	.015	....	.05	....

GENESIS OF THE ORES.

In view of the foregoing discussion of the probable changes involved in metamorphism but a word is necessary regarding the origin of the ores. Primarily they must be considered as part of the "effects" of the quartz diorite porphyry intrusion. Leith and Harder[a] have shown that in some localities contact metamorphism without much doubt precedes the deposition of magnetite, and that the latter is distinctly an "after effect."

The form of the ore bodies is suggestive. Most of them are irregular lenses occurring at or near the contact. Barrell and others have pointed out the possibility of shrinkage in sedimentary strata due to metamorphism. Leith and Harder,[b] to cite a concrete example, estimate that a horizontal radial shortening of 200 to 500 feet, depending on the depth of the laccolith, was possible as a result of cooling in the Iron Mountain mass. This mass is of the same order of magnetite as the one involved at Hanover. It might be argued, therefore, that lenses, large and small, represent the filling of such shrinkage spaces, and that therefore the magnetite is distinctly an "after effect."

Certain other relations may be significant. For example, where metamorphism is not especially pronounced in the limestones—that is, where zones of garnet, epidote, and pyroxene are lacking—soft ores have formed; in other words, ores which because of their dis-

[a] Leith, C. K., and Harder, E. C., Iron ores of the Iron Springs district, southern Utah: Bull. U. S. Geol. Survey No. 338, 1908, pp. 25–27.

[b] Op. cit., p. 20.

seminated character and perfect crystallization suggest an emanation of very highly heated solutions of volatile magnetite, precipitated by reduced pressure and temperature. On the other hand, where contact rock occurs these soft ores are lacking. The first inference might be that they were unable to form in such places because of the compact nature of the walls, and the second, that they were, therefore, later than the metamorphism.

Though magnetite filling undoubted fissures in either limestone or porphyry was nowhere noted, at certain localities the magnetite occurs as lenses surrounded entirely by contact rock.

Leaving open, then, for further study the consideration of the precise time relation of the magnetite to the contact metamorphism, we may tentatively suppose the following condition to have existed. On coming to place, the heated magma, by solutions probably above the critical temperature of water, impregnated certain strata of the surrounding rocks. Adjustments, due to cooling of the porphyry, to possible volume changes in the intruded sediments, and to gravity, served to make of the contact zone a favorable locus of superheated gases. Magnetite, a mineral which several investigators have shown might be precipitated from iron silicates by reactions with lime,[a] collected, replacing limestone, filling openings that may have gradually grown, and replacing in part the porphyry mass. The concentration might also be conceived to have been influenced by those laws which regulate the selective growth of mineral masses where abundant material is supplied.

MINING METHODS.

With the exception of some ore extracted recently from the southern part of the Union mine by underground methods, the ore has been mined by open-cut methods. The Union mine is located on a steep hillside and the Jim Fair is sufficiently elevated to permit hauling by gravity. Tunnels in the Union mine and an open cut in the Jim Fair, driven through the contact wall, serve as a roadway for the ore, and trams convey the product to bunkers at the railroad. Mexican labor is used almost exclusively.

STATISTICS.

As was stated in the introduction, mining in the Hanover district has been in progress continuously since 1899, except in 1904 and a part of 1907–8, when labor difficulties closed the mines. Figures segregating the production from the several mines are not at hand, nor are they available for the years 1899 and 1900. The following

[a] Clarke, F. W., The data of geochemistry: Bull. U. S. Geol. Survey No. 330, 1908, p. 283.

data are found in "Mineral Resources of the United States" for the respective years given:

Production of iron ore from the mines in the Hanover district, New Mexico.

	Long tons.
1901	61, 160
1902	132, 940
1903	137, 843
1904	210, 945
1905	113, 838
1906	161, 555
1907	192, 488
	1, 010, 779

THE IRON ORES OF THE APPALACHIAN REGION IN VIRGINIA.

By E. C. Harder.

INTRODUCTION.

The work of the United States Geological Survey on the iron ores of Virginia was begun in 1905 by E. C. Eckel, assisted by R. J. Holden and J. S. Grasty, with a survey of the Oriskany ores of western Virginia and the "mountain" and "valley" ores of the New River district. Subsequently the work was discontinued for several years, but was recommenced in the fall of 1908 by the writer, with a detailed examination of the ores of the Blue Ridge and a general reconnaissance of the Oriskany ores and the ores of the New River district.

Preliminary reports of the former surveys were published in 1906,[a] and the present paper will be a general summary of the results so far obtained. It is expected that a more detailed report on the brown ores of the entire Appalachian province will be published in the future.

IRON ORES OF VIRGINIA.

CLASSES AND DISTRIBUTION.

Iron ores and minerals of three types—hematite, magnetite, and brown ore—play an important part in the iron industry of Virginia. Iron carbonate and sulphide occur at many places, but are of no great commercial importance. The iron-ore deposits of Virginia may be separated geographically into two groups—those of the Piedmont region and those of the Appalachian region. The ores of the Piedmont region occur in pre-Cambrian crystalline and metamorphic rocks; those of the Appalachian region occur in Paleozoic sediments

[a] Eckel, E. C., The Oriskany and Clinton ores of Virginia: Bull. U. S. Geol. Survey No. 285, 1906, p. 183. Holden, R. J., The brown ores of the New River-Cripple Creek district, Virginia: Idem, p. 190.

or residual material derived from them. Both of these groups contain ores of several types, which may be classified as follows (see fig. 15):

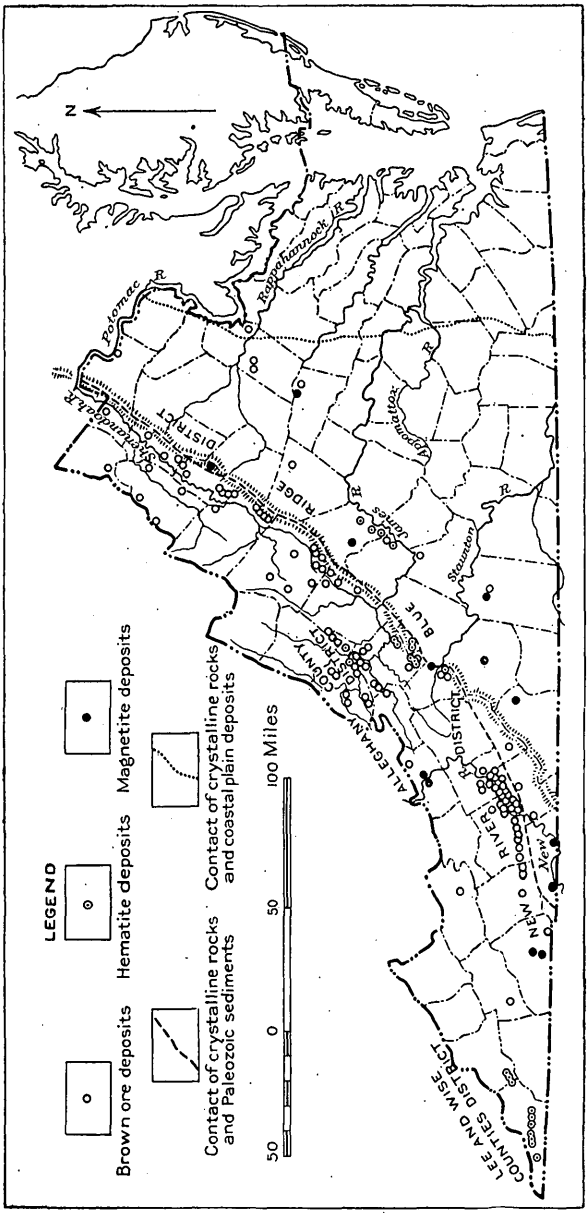

FIGURE 15.—Map showing the distribution of various classes of iron ores in Virginia.

Piedmont region:

1. Hematite. Specular hematite associated with nontitaniferous magnetite in the James River valley.
2. Brown ore. Gossan ore forming a capping of pyrrhotite deposits in southwestern Virginia and pyrite deposits in northern and central Virginia.

Piedmont region—Continued.

3. Magnetite—
   a. Nontitaniferous magnetite associated with gneisses, schists, and crystalline limestones in central and southwestern Virginia.
   b. Titaniferous magnetite associated with basic intrusives in the Blue Ridge.
4. Iron sulphides. Pyrite and pyrrhotite, used largely in the manufacture of sulphuric acid, the waste product (iron oxide or "blue billy") being used for its iron.

Appalachian region:

1. Hematite—
   a. Siliceous specular hematite interbedded with lower Cambrian shale and quartzite in the Blue Ridge.
   b. Fossil hematite interbedded with shale and sandstone of Clinton (Rockwood) formation in western and southwestern Virginia.
2. Brown ore—
   a. "Mountain" ores of the Blue Ridge and of the New River district, associated with lower Cambrian quartzite and with residual material above it derived from the quartzite and from the overlying formations.
   b. "Valley" ores associated with residual material of the Shady limestone in the New River district. A few deposits of this nature occur with other limestones of the Shenandoah group along the Blue Ridge.
   c. Oriskany ores replacing the Lewistown limestone directly underneath the "Monterey" (Oriskany) sandstone in the western part of the Appalachian region.
3. Magnetite. Magnetite and hematite associated with limonite and iron carbonate in the upper part of the Shenandoah group locally in southwestern Virginia.
4. Iron carbonate. Iron carbonate occurring with limestone magnetite in the upper part of the Shenandoah group locally in southwestern Virginia and as ironstone concretions in the Martinsburg and Romney shales.
5. Iron sulphide. Pyrite found locally in the Shady limestone in southwestern Virginia and used in the manufacture of sulphuric acid. The waste product, iron oxide or "blue billy," is used in blast furnaces for the manufacture of pig iron.

IRON ORES OF THE PIEDMONT REGION.

The iron ores of the Piedmont region are not of very much importance commercially, though small quantities of brown ore and magnetite are produced annually. The brown ore is derived from the upper portion of pyrrhotite veins; the magnetite is of the nontitaniferous variety and is associated with schists and crystalline limestone. None of the other ores are being produced at present except sulphides, which are used in the manufacture of sulphuric acid.

Specular hematite[a] and martite occur in crystalline schist in the James River valley, associated with nontitaniferous magnetite. In some places these two types are intermixed; elsewhere they occur in

[a] Benton, E. R., Iron mines of Virginia: Tenth Census, vol. 15, Mining industries, 1886, p. 263.

separate deposits. They are found in association with mica and talc schists, quartzite, and limestone. The following table gives analyses of specular hematite:

Analyses of specular hematite (natural state) from the James River valley.[a]

[By F. A. Gooch.]

	1.	2.	3.	4.
Fe	53.02	40.51	48.92	49.89
P	.049	.095	.033	0.139

1. Greenway mine, near Greenway, Nelson County.
2. Adams, Scott & Co., mine No. 11, near Riverville, Amherst County.
3. Naylor & Co., mine No. 6½, near Riverville, Amherst County.
4. Maud vein, near Stapleton, Amherst County.

Pyrrhotite and pyrite gossan consisting of limonite resulting from the oxidation of the sulphides is widely distributed through the Piedmont region. Pyrite gossan [b] formed the basis for the first iron industry in Virginia, but it has not been mined for a long time. It is found in the pre-Cambrian schists in many places east of the Blue Ridge, occurring in the upper oxidized portion of the pyrite lodes. Pyrrhotite gossan [b] occurs in southern and southwestern Virginia as a capping of the pyrrhotite lodes in crystalline schists. The principal deposits are in Grayson, Carroll, Floyd, and Franklin counties. The lodes are more or less continuous and dip with the schistosity of the rocks—about 35° SE. Locally they are workable for a distance of several miles, and in many places they have a constant width of 10 to 20 feet for several hundred yards. The maximum width of the lodes is about 175 feet. The gossan grades below into pyrrhotite associated with chalcopyrite, talc, calcite, hornblende, and quartz. The weathered portion extends to a depth of 10 to 60 feet, and consists of porous light-brown or yellow limonite. The lodes are frequently mined for copper, which generally occurs as black oxide at the junction of the gossan and the unweathered pyrrhotite.

The following table gives analyses of gossan ore.

Analyses of Virginia gossan ore.[c]

	1.	2.	3.	4.
Fe	44.54	42.81	36.15	47.00
SiO_2	....	....	16.36	12.25
P	.850	.478	.12	.85
Mn	....	....	1.40	2.70

1. Brown hematite mine, near Old Elk Creek furnace, Amherst County. Analysis by F. A. Gooch.
2. Stonewall mine, near Stapleton, Amherst County. Analysis by F. A. Gooch.
3. Betty Baker mine, near Betty Baker, Carroll County. Analysis by Virginia Iron, Coal and Coke Co.
4. Barr limonite mine, near Pittsville, Pittsylvania County. Analysis from J. H. C. Barr.

Nontitaniferous magnetite [d] is widely distributed through the crystalline schist of the Piedmont region, but occurs most abundantly in

[a] Benton, E. R., op. cit., pp. 264, 265, 268.
[b] Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, p. 419.
[c] Analyses 1 and 2 from Benton, E. R., op. cit., pp. 474, 476; 3 and 4 from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, pp. 265, 269.
[d] Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, p. 421.

the James River valley northeast of Lynchburg, near Pittsville in Pittsylvania County, and in Franklin and Patrick counties. The James River valley area was the principal iron-producing district in the State a hundred years ago, and was again exploited in 1880. Specular hematite constitutes most of the ore, but magnetite is associated with it. Near Pittsville the ore is magnetite and occurs as a lode between crystalline limestone and mica schist having a maximum thickness of 12 feet. In Franklin and Patrick counties magnetite occurs in hornblende schist in lodes varying up to 12 feet in thickness.

The following table gives analyses of nontitaniferous magnetite:

Analyses of Virginia nontitaniferous magnetite.[a]

	1.	2.	3.	4.	5.	6.
Fe	44.96	38.43	59.83	64.25	53.59	59.93
SiO_2	....	....	....	4.52	14.67	7.72
P	.051	.118	.086	.008	.018	.08
Mn	....	....	....	....	....	.17
S	....	....	....	....	.364	.19

1. Adams, Scott & Co., mine No. 13, near Riverville, Amherst County. Analysis by F. A. Gooch (specular hematite and magnetite).
2. First vein east of Old Furnace vein, near Old Elk Creek furnace, Amherst County. Analysis by F. A. Gooch (specular hematite and magnetite).
3. Pittsville mine, near Pittsville, Pittsylvania County. Analysis by F. A. Gooch.
4. Barr magnetite mine, near Pittsville, Pittsylvania County. Analysis from J. H. C. Barr.
5. Rocky Mount mine, near Rocky Mount, Franklin County. Analysis by F. A. Gooch.
6. Hairston mine, near Philpot, Patrick County. Sampled by W. W. Davis.

Titaniferous magnetite occurs at several localities in the Blue Ridge region in different associations. About 3 miles southeast of Marksville, Page County, it occurs as small bodies segregated locally in a basic syenite (unakite).[b] The ore contains considerable foreign material, mostly minerals common in the inclosing rock. These are generally in the form of rounded specks and vary in abundance in different parts of the deposit. Similar ore is reported from other places along the Blue Ridge. Near Roseland, Nelson County, and near Vinton, Roanoke County, ore of this type occurs with different associations. It consists of a mixture of ilmenite and apatite[c] and occurs in the form of a dike cutting the inclosing rocks. In Nelson County it occurs in schists and gneisses; in Roanoke County it is near the contact of gneisses with Cambrian sediments.

The following is an analysis of titaniferous magnetite:

Analysis of titaniferous magnetite from Marksville, Va.[d]

[By Booth, Garrett & Blair.]

Fe	51.44
TiO_2	16.76
P	.97

[a] Analyses 1, 2, 3, and 5 from Benton, E. R., op. cit., pp. 265, 266, 270, 273; 4 and 6 from Holden, R. J., op. cit., pp. 473, 475. All but 4 in the natural state.

[b] Phalen, W. C., Copper deposits near Luray, Va.: Bull. U. S. Geol. Survey No. 285, 1906, pp. 140–143.

[c] Watson, T. L., Phosphates, in Mineral resources of Virginia, 1907, pp. 300–302.

[d] Holden, R. J., op. cit., p. 433.

Pyrite and pyrrhotite occurring in the unoxidized portions of deposits described with reference to gossan ores are mined in a few places for the manufacture of sulphuric acid. After roasting out the sulphur the residue is in the form of a cinder consisting of iron oxide with 4 to 7 per cent of sulphur.[a] This is clinkered in kilns and the resulting product contains 52 to 56 per cent of iron and 0.05 per cent of sulphur, as compared with 45 to 52 per cent of iron and 27 to 32 per cent of sulphur in the crude ore. It is mixed with iron ore and used by iron blast furnaces.

IRON ORES OF THE APPALACHIAN REGION.

GENERAL STATEMENT.

By far the most important iron ores in Virginia are the brown ores of the Appalachian region, including "mountain," "valley," and Oriskany ores, and of them the Oriskany ores form the principal part. Second in importance are the specular hematites of the Blue Ridge, and, third, the Clinton fossil ores. The remaining types are of minor importance.

The mountain and valley brown ores of Virginia form part of a continuous belt of these ores extending from Vermont to Alabama. The Oriskany ores are confined largely to Virginia and West Virginia, though ores are found locally at this horizon in Kentucky and Pennsylvania. The specular hematite of the Blue Ridge belongs to the same class and occurs at approximately the same horizon as the specular or gray ores of Georgia and Alabama. The fossil ore belongs to the general type of Clinton ores found in the Birmingham and Chattanooga districts and in New York.

The rocks of western Virginia range in age from pre-Cambrian to Pennsylvanian. The former compose the eastern part of the Blue Ridge and extend eastward, and the latter cap the Allegheny escarpment and extend westward. The Appalachian Valley occupies a northeast-southwest belt between these boundaries and contains rocks ranging in age from Cambrian to Mississippian. The areal distribution of the rocks of the valley is very irregular, owing to the great amount of folding and thrust faulting. In general, however, the formations occupy discontinuous northeast-southwest strips, the older rocks being more abundant on the east side and the younger on the west side of the valley. The following sections show the latest classification of the rocks for the Appalachian region in Virginia:

[a] Iron and zinc deposits in southwestern Virginia: Eng. and Min. Jour., Nov. 7, 1908, p. 908.

Geologic sections for the Appalachian region in Virginia.[a]

Northwestern Virginia.		West-central Virginia.		Southwestern Virginia.	
Formation.	Thickness (feet).	Formation.	Thickness (feet).	Formation.	Thickness (feet).
Mississippian:		Mississippian:		Mississippian:	
Greenbrier limestone	325– 410	Pocono sandstone	700	Pennington shale	1,250–1,350
Pocono sandstone	85– 700			Newman or Greenbrier limestone	1,500
				Pulaski shale	0– 300
				Price sandstone	0– 300
Devonian:		Devonian:		Devonian:	
Hampshire formation	1,600–2,200	Hampshire formation	1,000–1,400	Grainger shale	1,000–1,500
Jennings formation	2,100–3,800	Jennings formation	2,800–3,400	Chattanooga shale	400– 800
Romney shale	1,000–1,300	Romney shale	600–1,000		
Silurian:		Silurian:		Silurian:	
"Monterey" (Oriskany) sandstone	200– 300	"Monterey" (Oriskany) sandstone	0– 300	Giles formation	30– 200
Lewistown limestone	700–1,250	Lewistown limestone	300– 500	Clinton (Rockwood) formation	20– 400
Clinton (Rockwood) formation	65– 550	Clinton (Rockwood) formation	120– 500	Clinch sandstone	100– 250
Cacapon sandstone	200– 350	Massanutten sandstone	500– 600 (with Massanutten sandstone below)		
Tuscarora quartzite	300±				
Ordovician:		Ordovician:		Ordovician:	
Juniata sandstone	200±	Massanutten sandstone		Bays sandstone	250– 350
Martinsburg shale	1,600–1,800±	Martinsburg shale	800–1,400	Sevier shale	1,250–1,350
Chambersburg limestone (Shenandoah group)	400	Liberty Hall limestone (Shenandoah group)	1,000±	Moccasin limestone, 0–400 feet; Tellico	
Stones River limestone (Shenandoah group)	900	Murat limestone (Shenandoah group)	100– 150	sandstone, 300 feet	0– 400
Undifferentiated Shenandoah (Shenandoah group)		Natural Bridge limestone (Shenandoah group)		Chickamauga limestone, 0–1,000 feet;	
				Athens shale, 300–1,200 feet	0–1,200
				Holston marble lentil	0– 190
	1,200–1,500		3,500	Knox dolomite	
Cambrian:		Cambrian:		Cambrian:	100–2,400
Undifferentiated Shenandoah (Shenandoah group)		Natural Bridge limestone (Shenandoah group)		Knox dolomite	
(Sequence broken.)		"Buena Vista" shale (Shenandoah group)	600– 900	Nolichucky shale	0– 175
Antietam sandstone	500	Sherwood limestone (Shenandoah group)	1,600–1,800	Honaker limestone	900–1,000
Harpers shale	1,000+	Lower Cambrian quartzite	800	Watauga shale	1,000–1,100
Weverton sandstone	100– 900	Lower Cambrian shale and quartzite	3,000	Shady limestone	750– 800
Loudoun formation	0– 800			Erwin quartzite	500– 700
				Hampton shale	600– 800
				Unicoi sandstone	1,500–2,500
Algonkian:		Pre-Cambrian:		Pre-Cambrian:	
Catoctin schist	1,000+	Crystalline and metamorphic rocks.		Crystalline and metamorphic rocks.	

[a] Bassler, R. S., Cement materials of western Virginia: Econ. Geology, vol. 3, No. 6, 1908, p. 510. Campbell, H. D., The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia: Am. Jour. Sci., 4th ser., vol. 20, 1905, p. 445. Keith, Arthur, Geol. Atlas U. S., folios 10 (Harpers Ferry) and 90 (Cranberry). Darton, N. H., Geol. Atlas U. S., folios 14 (Staunton), 32 (Franklin), and 61 (Monterey). Campbell, M. R., Geol. Atlas U. S., folios 26 (Pocahontas), 44 (Tazewell), and 59 (Bristol).

The iron ores are distributed through the Cambrian, Ordovician, and Silurian rocks, as shown in the accompanying general section (fig. 16). The lowest ore stratigraphically is the siliceous specular hematite of the Blue Ridge. It is associated with the lower Cambrian shale and quartzite shown in the west-central Virginia section, but in what part of this series it occurs is not definitely known. Next above it is the mountain brown ore. Along the Blue Ridge this ore is found in pockets in residual material along the contact of the lower Cambrian quartzite and the overlying formations, and as fault deposits and replacements in the quartzite. Several formations come into contact with the quartzite at different places along the Blue Ridge on account of extensive faulting. In the New River district mountain ores occur in residual material along the contact of the Erwin quartzite and the overlying Shady limestone. Locally, mountain brown ores are known to occur in Tertiary or Pleistocene variegated clays associated with the residual clay mentioned above. The valley brown ore is found mainly in the New River district in residual clay derived from the Shady limestone. In the Blue Ridge region small, scattered deposits occur in residual material overlying the Natural Bridge limestone. All the valley ores rest on an eroded limestone surface. The pyrite deposits are associated with the Shady limestone.

The upper part of the Shenandoah group contains limestone magnetites with associated limonite and carbonate. These ores occur in limestone and in residual clays derived from it. Their exact stratigraphic position has not been determined, but it is probably at the horizon of the Chickamauga limestone.

The fossil ore beds occur in the Clinton (Rockwood) formation, interbedded with shales. The Oriskany iron ores are found at the horizon of the Lewistown limestone, occurring as a replacement of the upper portion of this limestone directly underneath the "Monterey" (Oriskany) sandstone.

The following analyses are typical of the various classes of ores:

Analyses of type specimens of various classes of Virginia iron ores.

[By Lerch Brothers, Virginia, Minn. Determination at 100° C. (212° F.).]

	1.	2.	3.	4.	5.	6.	7.	8.
Fe	44.00	56.70	49.18	53.86	59.81	32.59	56.12	53.75
P	.465	.428	.376	.958	.081	.068	.095	.191
Mn			.32	.27	.61	.12	.14	.57
SiO_2	29.90	6.83	13.73	6.83	3.06	45.24	6.46	10.31
Al_2O_3	2.73					6.30		
CaO		.12						
Loss by ignition (largely H_2O)			10.33	10.45	10.78		11.55	10.48

1. Siliceous specular hematite, Arcadia mine, near Buchanan, Botetourt County.
2. Clinton fossil hematite, Horse Mountain mine, near Low Moor, Alleghany County.
3. Earthy mountain brown ore, Bare Bank mine, near Greenville, Augusta County.
4. Black glossy mountain brown ore, Dixie mine, near Vesuvius, Rockbridge County.
5. Needle mountain brown ore, Mine Bank mine, in Augusta County, near Vesuvius.
6. Red shaly mountain brown ore, Buena Vista mine, near Buena Vista, Rockbridge County.
7. Valley brown ore, Buck Hill mine, near Midvale, Rockbridge County.
8. Oriskany brown ore, Rich Patch mine, near Low Moor, Alleghany County.

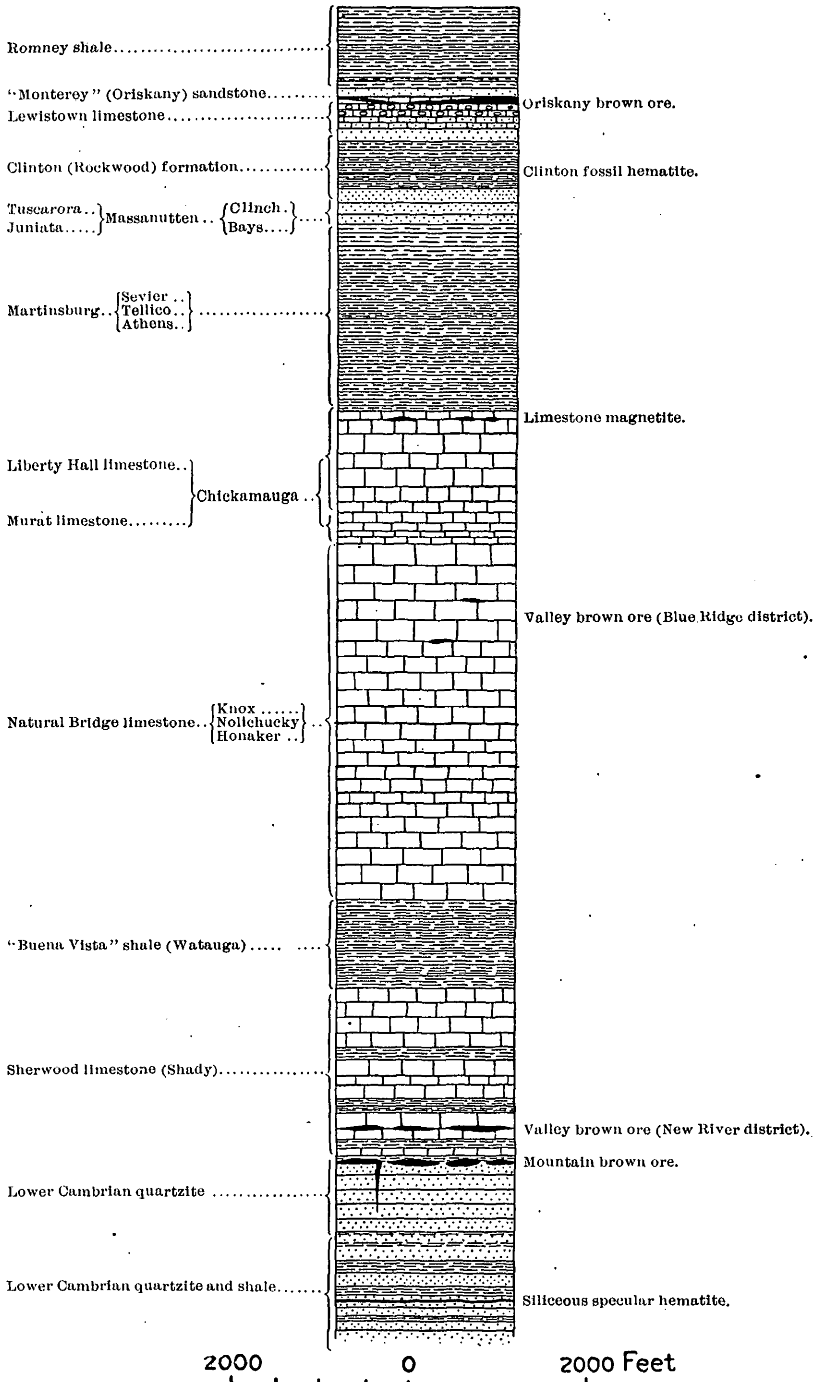

FIGURE 16.—Generalized section showing the stratigraphic position of the various classes of iron ore in the Appalachian region of Virginia.

Analyses 1 and 2 represent hematite (Fe_2O_3; theoretical percentage of iron, 70); the rest represent hydrous oxides consisting of various mixtures of limonite ($2Fe_2O_3.3H_2O$; theoretical percentage of iron, 59.8) and göthite ($Fe_2O_3.H_2O$; theoretical percentage of iron, 62.9). Turgite ($2Fe_2O_3.H_2O$) may be present in small quantities, but for the most part the ores contain too much water to make its presence seem likely.

In the following table are given the iron and water content of limonite, göthite, and turgite and of the five typical brown ores represented by analyses 3, 4, 5, 7, and 8, above. Specimen 6 is not a typical ore, but simply a partial replacement product. As the above determinations were made in a commercial laboratory, it was impracticable to obtain the combined water. The carbonaceous material present is so small, however, and the amount of moisture so slight that for practical purposes the loss by ignition may be regarded as combined water.

Percentage of iron and water and ratio of iron to water in hydrous iron oxides and brown ores.

	Percentages.		Ratio of iron to water.
	Iron.	Water.	
Limonite	59.8	14.5	4.12:1
Göthite	62.9	10.1	6.23:1
Turgite[a]	66.0	6.0	11.00:1
Earthy mountain ore (3)	49.18	10.33	4.76:1
Glossy black mountain ore (4)	53.86	10.45	5.15:1
Needle ore (5)	59.81	10.78	5.55:1
Valley ore (7)	56.12	11.55	4.86:1
Oriskany ore (8)	53.75	10.48	5.13:1

[a] The composition and ratio for turgite are only approximate.

From this table it is apparent that the ores are intermediate in composition between limonite and göthite and that they vary from three-fourths limonite and one-fourth göthite to one-fourth limonite and three-fourths göthite. The needle ore, which is the purest variety, is most nearly like göthite in composition. The valley ore, which contains considerable ocher, is more nearly like limonite in composition. All the brown-ore analyses show a decided difference from that of turgite, so it may be concluded that this mineral, if present in the mixture, is negligible.

SILICEOUS SPECULAR HEMATITE.

Location and geology.—The specular hematite of Virginia occurs interlayered with the lower Cambrian quartzite and shale as a bed of varying thickness. Workable portions of it outcrop along the Blue Ridge in Botetourt, Bedford, and Roanoke counties, from Buchanan on the north to a point about 5 miles south of Roanoke.

North of Buchanan the bed changes gradually to a ferruginous sandstone, and as such has been found west of Buena Vista, and is reported as far north as Basic City. Southward from the main outcrop it apparently loses its identity.

The associated rocks are Cambrian shale, sandstone, and quartzite in beds having a general northeast-southwest strike. The dip is variable, being about 50° SE. near Buchanan and 30° NW. near Blue Ridge Springs. Near the surface the rocks are considerably weathered and have a yellow, brown, or gray color. In depth they are hard and quartzitic and their color is dark green.

Ore bed.—The ore bed has been worked at eight localities along its principal outcrops. The distribution of the mines is as follows, from northeast to southwest: The Arcadia and Wood mines, about 4 miles southeast of Buchanan; the Ironville and Dewey mines, near Montvale; the Lemon, Grubb-Specular, and Edith mines, about 3 miles northwest of Blue Ridge Springs; and the Griffin-Specular mine, about 5 miles south of Roanoke. Of these the Arcadia, Wood, Dewey, and Edith mines are at present in operation.

Between the mines near Buchanan and those near Montvale there is a distance of 6 miles in which the bed has hardly been exploited, but through a considerable portion of which it is known to exist. Between the mines near Montvale and those near Blue Ridge Springs there is apparently an offset in the bed, and southwest of the latter place it disappears for a distance of 12 or 15 miles, reappearing at the Griffin-Specular mine.

At the Arcadia and Wood mines the ore bed is well up on the northwest slope of the Blue Ridge, being at an elevation of about 2,000 feet above sea level, or 1,000 feet above the valley to the west. The lower portion of the slope and the valley are formed by lower Cambrian quartzite, Sherwood limestone, and "Buena Vista" shale. The ore bed apparently continues at this elevation and on this slope of the Blue Ridge for several miles to the southwest to a point where it crosses over to the southeast slope and probably connects with the exposures at Montvale or Blue Ridge Springs. Nothing definite is known about its location in this intervening area.

At the northernmost mines the ore occurs in two beds, an upper one having an average thickness of 4½ feet and a lower one having a thickness of about 6 inches. (See fig. 17.) These beds are separated from each other by a 6-inch bed of yellowish or greenish brown fine-grained sandstone. The upper bed varies in thickness from 3½ to 6 feet, but the thickness of the lower bed is fairly uniform. Only the upper bed is mined, the lower one being too thin to pay for the removal of the intervening sandstone layer. The beds have a general strike of N. 40° E. and an average dip of 50° SE. Near the surface they are locally almost vertical and in some places even dip to the northwest.

The Arcadia mine is at present working the ore bed on its most northerly workable outcrop, and the Wood mine adjoins it on the south. On both properties the bed has suffered some folding and a great deal of faulting, so that locally, especially at its north end, there are two or three parallel outcrops within a distance of less than 100 yards. At the north end of the present workings of the Arcadia mine a ravine cuts across the strike of the strata and here the ore bed was found to end abruptly. Recent exploration has succeeded in revealing the presence of the bed about half a mile to the northwest and operations have begun along this extension, which is said to have the same strike and dip as the bed at the present workings. The old workings of the Arcadia mine and the operations of the Wood mine extend along the outcrop of the bed for a distance of nearly a mile.

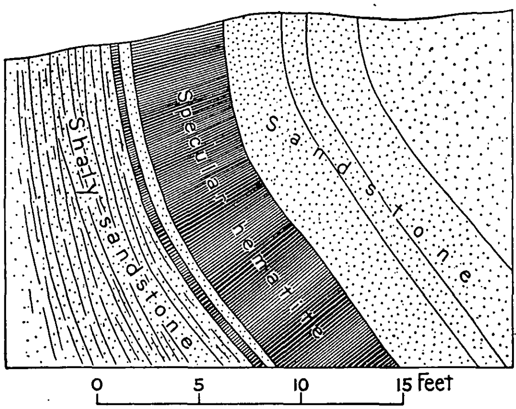

FIGURE 17.—Vertical section showing the structure and position of the specular hematite beds at the Arcadia mine, near Buchanan, Va.

The ore consists of dark-red, very siliceous hematite, the silica being present in the form of sand grains. Locally the ore contains small quartz pebbles or small balls of clay, called "frog eyes" by the miners; but as a rule the bed has a uniform texture throughout. The lower ore bed is somewhat more siliceous than the upper bed. The ore is sharply differentiated from both the hanging wall and the foot wall. The hanging wall consists of thick-bedded dark-green fine-grained quartzite, locally containing an abundance of disseminated crystals of pyrite. Near the surface it shows brown spots of iron oxide derived from the oxidation of the pyrite. The brownish-green sandstone between the two ore beds generally consists of a single bed, but locally it is divided by bedding planes into several layers. The foot-wall rock underneath the lower ore bed is a thin-bedded bluish-green shaly sandstone, fairly hard and in places finely laminated. It also contains some pyrite but not as abundantly as the hanging wall. The foot wall is part of a great thickness of brown, green, yellow, and gray sandy shales with interbedded sandstone which occupy the slope of the mountain below the ore bed. Above the ore bed the rocks are in general more sandy and heavier bedded. The strike and dip of the sediments are the same as those of the ore bed, in fact the ore layer is simply one of a series of beds.

The mines are operated as open stopes and trenches, and workings have gone but slightly deeper than the level of the bottoms of cross-cutting ravines.

The mines near Blue Ridge Springs are on the southeastern slope of the ridge at about the same elevation as those near Buchanan. The ore bed is traceable here for a distance of about 3 miles and is from 4 to 12 feet in thickness. It strikes approximately N. 60° E. and has a general dip of 30° NW., a dip opposite to that of the bed at Buchanan.

Three mines have operated along this bed, the Edith mine occupying the northeastern portion, the Grubb-Specular the center, and the Lemon mine the southwestern portion. The ore at this locality is confined to one bed, the 6-inch bed present at Buchanan having disappeared. The ore is similar in character to that farther to the north, though in general it is more siliceous and therefore of a somewhat lower grade. The sand grains are larger and more abundant and are in many places interspersed with tiny quartz pebbles. Locally thin lenses of shaly material are embedded in the ore, but sharply separated from it. The associated rocks are sandstones, quartzites, and sandy shales of lower Cambrian age which have the same strike and dip as the ore bed. The hanging wall for several feet above the ore bed consists of shaly sandstone very much fractured and stained by limonite near the surface, but green and solid underground. The foot wall is more compact near the surface and consists of thicker beds. Both hanging and foot walls are brownish green near the surface but underground they are a deep bluish green and are hard and quartzitic. Pyrite crystals occur disseminated in the hanging-wall rock.

In the Edith mine the ore is taken out through a tunnel crosscutting the ore bed. Formerly the mining operations were conducted in open trenches and stopes from the surface, but the old workings have now been abandoned. The ore bed is faulted underground, and locally the dip is apparently opposite to that at the surface.

The Dewey and Ironville mines are situated near Montvale, about 3 miles east of the Edith mine. The ore bed here has the same variations in thickness as at the Edith mine and has a nearly vertical dip. The strike is approximately east-northeast.

The Griffin-Specular mine is situated on the north slope of Buck Mountain. The ore bed has a thickness of about 2 feet at this locality and strikes approximately east and west.

Character and origin of the ore.—As has been stated the ore is a very siliceous dark-red hematite, the silica being present in the form of sand grains and small quartz pebbles. Along cracks there is in many places a thin selvage edge composed of a dark-green mineral, probably chlorite. Besides this, there are present locally small gray or reddish clay balls. For the most part, however, the ore is hard and dense. The iron content ranges from less than 35 per cent to 45 per cent, and the silica content from 30 to 40 per cent. The following are analyses of ore from various mines.[a] (See also analysis 1, p. 222.)

Analyses of siliceous specular hematite from the Blue Ridge.[a]

	1.	2.	3.	4.	5.	6.	7.	8.
Fe	44.06	33.34	39.52	42.64	37.09	34.66	36.90	40.97
SiO_2	....	41.14	....	....	36.91	39.06	34.85	31.16
P	.462	....	.393	.409	.37	.39	.28	....
Mn	....	....	....	....	.27	.15	.23	....

[a] Analyses 1, 3, and 4, from Benton, E. R., op. cit., pp. 277, 278; 2, 5, 6, 7, and 8, from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, pp. 444, 445, 447, 472. All but 2 and 8 in the natural state.

1. Arcadia mine. Analysis by F. A. Gooch.
2. Arcadia mine. Analysis by R. J. Holden.
3. Arcadia mine. Analysis by F. A. Gooch.
4. Wood mine. Analysis by F. A. Gooch.
5. Edith mine. Analysis by Virginia Iron, Coal and Coke Co.
6. Ironville mine. Analysis by Virginia Iron, Coal and Coke Co.
7. Dewey mine. Analysis by Virginia Iron, Coal and Coke Co.
8. Griffin-Specular mine. Analysis by R. J. Holden.

The bedded character of the ore layer, its conformity in strike and dip with the associated rocks, its sharp contact with these rocks, and the presence of sedimentary material in the ore itself point to the conclusion that, like the Clinton fossil ores, the specular hematite ores of the Blue Ridge are the result of original deposition. There is this difference, however, that whereas the Clinton ores were deposited in association with calcareous material the specular ores were deposited with quartz sand.

CLINTON FOSSIL HEMATITE.

Distribution and geology.—The fossil hematite ores occur as beds in the Clinton (Rockwood) formation of the Silurian system. The rocks of this formation are widely distributed through the western and southwestern parts of Virginia, but only in two localities are ores present in workable quantities—in Alleghany County, in the western part of the State, and in Wise and Lee counties, in the southwestern part.

In Alleghany County fossil ore has been produced at two localities—at the Horse Mountain mine, on the southeast slope of Horse Mountain, 3 miles southwest of Low Moor, and at the Iron Gate mine, at Iron Gate, on the face of the bluff northeast of Jackson River. The Horse Mountain mine is in operation at the present time. Clinton ore beds are known to outcrop also along many ridges elsewhere in this vicinity and to the southwest, but for the most part they are too thin and of too low grade to be mined at the present time.

In Wise and Lee counties the ore is found along outcrops of the Clinton (Rockwood) formation, extending southwestward from Big Stone Gap for about 25 miles.[a] There are two principal localities where ore is being mined. The first of these is on Wallen Ridge and in Powell Valley, extending for 3 or 4 miles south of Big Stone Gap. It embraces four mines, the Yeary, Irondale, Keystone, and Oreton. The second locality is along Poor Valley Ridge, extending for a distance of about 15 miles southwest from Pennington Gap, which is about 10 miles southwest of Big Stone Gap. There are eight mines along this belt—the Pennington, Lavine, Ben Hur, Truro, Noes Siding, Grabill, Boones Path, and Ewing mines, most of which are on the north slope of Poor Valley Ridge.

The rocks of the Clinton (Rockwood) formation are largely sandstone and sandy shales. Fossil ores occur interbedded with the latter. In the Alleghany County region the formation has a thickness of 300 to 600 feet, the average being about 450 feet.

Eckel gives the following section, measured by E. O. Ulrich, of the Clinton (Rockwood) formation at Iron Gate:

Section of the Clinton and associated formations at Iron Gate, Va.[b]

	Feet.
Lewistown ("Helderberg") limestone, thin-bedded, shaly limestone shales	322
Rockwood ("Clinton"):	
Heavy sandstone	42
Alternating sandstone and shale	125
Sandstones and shales overlying a red mottled shale, with a heavy ferruginous sandstone (block ore) near the base	115
Shales with fossil ore bed near top	170
Clinch ("Medina") hard massive, white sandstone	50

The section on Horse Mountain is somewhat different from this, for there a heavy bed of white, quartzitic sandstone more than 30 feet thick immediately overlies the ore-bearing shales, there being only from a few inches to 2 feet of shale between it and the ore bed. Only one ore bed is present in the Alleghany County region, but locally there are in addition one or two thin beds of red ferruginous fossiliferous sandstone closely approaching the ore bed in appearance.

In the fossil-ore district of Wise and Lee counties the Clinton (Rockwood) formation consists of shales and sandstones of variable

[a] Holden, R. J., op. cit., pp. 463–467. Campbell, M. R., Geol. Atlas U. S., folio 12 (Estillville).

[b] Eckel, E. C., Oriskany and Clinton iron ores of Virginia: Bull. U. S. Geol. Survey No. 285, 1906, p. 185.

thickness and composition and has an average thickness of 400 to 600 feet. Here and there outside of the ore-bearing area, as on Clinch Mountain, the thickness decreases to less than 100 feet, but at such localities the ore beds are generally absent. Three workable ore layers occur in this area, known as No. 2, No. 3, and No. 4. Bed No. 2 is the lowest, stratigraphically. About 175 to 225 feet above it lies bed No. 3, and bed No. 4 is about 80 to 90 feet above this. The middle bed has been mined most extensively, and the lowest the least extensively. At very few localities are all three beds productive.

Ore beds.—The strata at Iron Gate have been sharply folded into a northeast-southwest anticline, overturned to the northwest, so that the east limb describes a gentle arc across the upper half of the bluff. The Clinch sandstone forms the lower or inner portion of this limb,

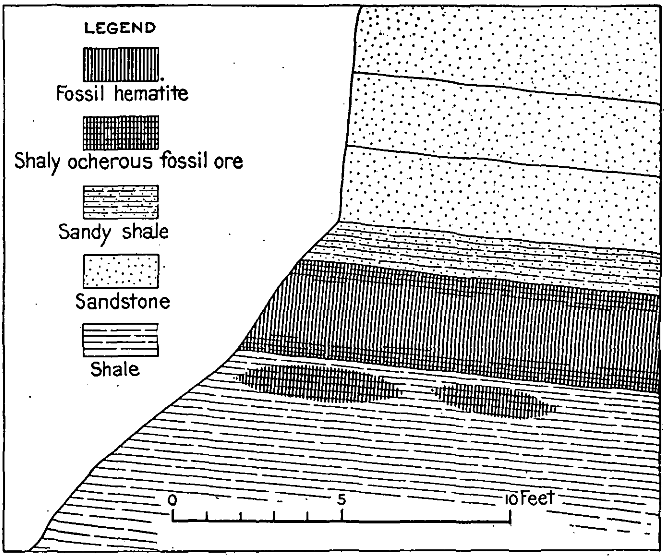

FIGURE 18.—Vertical section through the fossil hematite bed and adjacent rocks at the Horse Mountain mine, near Low Moor, Va.

and immediately above it are Clinton (Rockwood) shales containing near the top the ore bed, which is generally less than 1½ feet thick and irregular. The leached surface ore (soft ore) has all been removed and the unleached ore (hard ore) is of low grade.

At the Horse Mountain mine the ore bed is exposed along the southeast face of the ridge. The main workings are near the summit, but to the north the bed appears lower on the slope. It dips about 10° to 20° NW., into the ridge. The ore bed has an average thickness of somewhat less than 2 feet and generally consists, near the surface, of a hard red layer, with blocky fracture, which above and below grades into soft brown ocher. (See fig. 18.) The middle layer is, as a rule, over a foot in thickness. Above the ore bed is a layer of shale from a few inches to a foot and a half in thickness, succeeded by a heavy-bedded brownish-white quartzite 30 to 35 feet thick, which forms a very marked bluff near the crest of the ridge. The following is a detailed section taken in one of the eastern slopes.

Section of the fossil ore bed and adjacent formations on Horse Mountain, Va.

		Feet.	In.
Heavy-bedded brownish-white quartzite		30+	
Brownish-gray sandy shale		1	3
Ore bed	Soft yellow and dark-brown ocher		5
	Solid blocky red hematite	1	3
	Compact yellow and brown ocher		9
Gray shale with ocher lenses several feet thick near the top. Some of the lenses are connected into a layer 5 or 6 inches thick		10+	

The following sections, taken by Eckel[a] show slight variations from the above.

Sections of the fossil ore bed and adjacent formations on Horse Mountain, Va.

1.

	Ft.	In.
White quartzite	35	
Shale		2
Sandstone		3
Shale		½
Sandstone		3
Shales and thin sandstone		10
Fossil ore, brown and porous		7
Fossil ore, red and fairly hard	1	2
Ochery clay		6
Shales	2	

2.

	Ft.	In.
White quartzite	30	
Shales		2
Red fossil ore	1	4
Ochery shales and thin sandstones	1	
Shales and sandstones	2	

In a few places a 3-foot bed of red ferruginous sandstone with fossils like those in the ore bed is exposed about 15 feet stratigraphically below it. This sandstone is interbedded with gray shales.

The Clinton (Rockwood) strata immediately south of Big Stone Gap are on the southeast limb of a northeast-southwest anticline. The beds containing the ores therefore dip to the southeast. Wallen Ridge is formed by the Clinch sandstone, which stratigraphically is immediately below the Clinton (Rockwood). On the slope of this ridge and in the valley to the southeast the Clinton (Rockwood) formation carries ore beds Nos. 3 and 4. The formation extends southwestward along the southeast slope of Wallen Ridge for nearly 20 miles into Lee County, but ore of workable thickness has been found at only a few localities along this belt.

[a] Eckel, E. C., op. cit., p. 188.

The ore beds on Poor Valley Ridge are on the opposite side of the anticline from those just mentioned and for the most part dip steeply to the northwest. Three ore beds (Nos. 2, 3, and 4) are present, associated with sandstones and sandy shales. The strata extend southwestward into Tennessee, where they connect with the beds of the La Follette district.

Character and origin of the ores.—The Clinton ore of Virginia is largely of the variety called fossil ore, though some oolitic ore is found. The fossil ore varies in texture from very coarse to fine, according to the nature of the fossil fragments composing it; these consist largely of pieces of brachiopods, crinoid stems, and mollusks. The ore mined in Alleghany County is all of the soft variety from which the calcium carbonate has been removed by leaching of surface waters. It varies in color from yellowish brown to reddish black, but generally is of a dark-red color. The following table gives analyses of ore from Alleghany County. (See also analysis 2, p. 222.)

Analyses of Clinton ore from Alleghany County, Va.[a]

	1.	2.	3.	4.
Fe	57.00	44.82	41.71	46.5 -46.0
Mn	.15			
P	.678		.444	.49- .48
SiO_2	7.12	15.51		
Insoluble				19.90-20.24
CaO	1.46			

[a] Analyses 1 and 4 from Eckel, E. C., Oriskany and Clinton iron ores of Virginia: Bull. U. S. Geol. Survey No. 285, 1906, p. 188. Analysis 2 from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, p. 442. Analysis 3 (natural state) from Benton, E. R., Iron-ore mines of Virginia: Tenth Census, vol. 15, Mining industries, 1886, p. 281.

1, 2. Horse Mountain mine. Analyses by Low Moor Iron Co.
3. Horse Mountain mine. Analysis by F. A. Gooch.
4. Iron Gate mine. Analysis by Longdale Iron Co.

The ore of southwestern Virginia is of a lower grade and more siliceous than the Horse Mountain ore, as shown by the following analyses:

Analyses of Clinton ore from Lee and Wise counties, Va.[a]

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Fe	44.90	40.14	42.34	50.50	43.20	34.01	36.00	42.30	40.91	34.09
SiO_2	15.81	27.98	18.36	18.75	22.31	34.50	33.37	27.60	16.70	6.58
P	.29	.32	.29	.18	.34	.27	.23	.19	.45	.58
CaO	.22	.61	.11		.56			.10	5.18	7.72
MgO									.93	3.95
Mn						.16	.16			

[a] Holden, R. J., op. cit., pp. 464–467.

1. Oreton mine. Analysis by Union Iron and Steel Co.
2. Irondale mines. Analysis by Union Iron and Steel Co.
3. Yeary mine. Analysis by Union Iron and Steel Co.
4. Pennington mine. Analysis by A. S. McCreath.
5. Lavine mine. Analysis by Union Iron and Steel Co.
6. Ben Hur mine. Analysis by Virginia Iron, Coal and Coke Co.
7. Truro mine. Analysis by Virginia Iron, Coal and Coke Co.
8. Noes Siding mine. Analysis by Union Iron and Steel Co.
9. Boones Path mine. Analysis by Union Iron and Steel Co.
10. Ewing mine. Analysis by Union Iron and Steel Co.

The foregoing analyses show that most of the ore mined is of the "soft" variety, nearly all of the lime having been leached out. Nos. 9 and 10 still contain some lime and approach hard ore in composition.

The origin of the Clinton ores has been a matter of much controversy, but it is now almost universally agreed that they are original sedimentary deposits. This subject is adequately discussed by Burchard [a] with regard to the ores of the Birmingham district in Alabama.

MOUNTAIN BROWN ORES.

Distribution and geology.—Mountain brown ores are found in Virginia in two narrow belts. One extends along the west slope of the Blue Ridge from Front Royal, Warren County, on the north, to a point about 10 miles south of Roanoke, Roanoke County, on the south. The other belt is an extension of this one in the New River district, in southwestern Virginia. It extends from a point about 5 miles east of Allisonia west-southwestward to a point south of Marion. Between the two belts there is a barren area about 40 miles in length. At few places is either belt more than a few miles wide.

The ores are associated with the lower Cambrian quartzite and with residual material overlying it. They occur in small irregular deposits of a variety of types and are scattered at intervals along the belts mentioned. There is a marked grouping of deposits locally along the Blue Ridge belt, illustrated by the groups of mines at Shenandoah, Grottoes, Vesuvius, and Buena Vista and south of Roanoke.

In northwestern and west-central Virginia the Blue Ridge lies on the boundary between the crystalline and metamorphic rocks of the Piedmont region and the Paleozoic sediments of the Appalachian Valley belt. South of Roanoke, however, the line of contact and the Blue Ridge separate, the contact running along a series of low ridges until it reaches the Iron Mountains, which it follows southward into Tennessee, and the Blue Ridge, running farther to the southeast, across the crystalline area. (See fig. 15.) The ore belts follow the line of contact very closely.

By far the larger number of ore deposits occur in residual material above the lower Cambrian quartzite in the Blue Ridge region and above the Erwin quartzite in the New River district. A few occur in the solid quartzite, but very rarely are any ores found in the series of shales and quartzites between this formation and the crystalline rocks.

Along the Blue Ridge area the quartzite as a rule forms the western slope of the mountains, and clay, sand, and fragmental material, partly residual and partly fluviatile, form a gently sloping bench at

[a] Burchard, E. F., The Clinton iron-ore deposits in Alabama: Trans. Am. Inst. Min. Eng., vol. 39, 1908, pp. 997–1055.

the base. On this bench, near the base of the ridge, are located most of the iron-ore deposits. The Sherwood limestone and "Buena Vista" shale do not outcrop very abundantly along the Blue Ridge. In many places they are doubtless hidden under the residual material forming the bench just mentioned, and elsewhere they are cut out by faulting. In the valley to the west are the Natural Bridge and overlying limestones of the Shenandoah group.

In the New River district the distribution of the rocks is also complicated on account of folding and faulting. The valleys of New River and Cripple Creek are in the Shady limestone;[a] the ridges north and south of them consist of the Erwin quartzite, except Draper Mountain, at the northeast end, which is made up of Devonian and Silurian sediments. Locally, within the New River valley, there are minor ridges of the Erwin quartzite, such as Roaring Falls Mountain. The distribution of the mountain ore deposits is in general coextensive with the areas of the Erwin quartzite. The ores occur mainly along the north slope of the quartzite ridge south of New River and Cripple Creek, but also on both sides of the quartzite ridges within the valley, and in a few places, as south of Marion, on the south slope of the ridges north of the valley.

Tertiary or Pleistocene sediments are associated with the ore in many of the deposits. In some places they consist of variegated, much decomposed, angular conglomeratic material; elsewhere of a mixture of bright-colored clays; and in still other places of a mixture of sand, pebbles, and bowlders, largely of quartz and to some extent roughly stratified. At one locality near Buena Vista variegated clays containing lignite and rounded pebbles and bowlders are associated with soft, finely laminated gray shales, containing an abundance of fossil leaves, of both conifers and hard-wood trees. It is very difficult to distinguish the Tertiary or Pleistocene clays from the residual clays, except where the former contain pebbles and carbonaceous material. Therefore it is impossible to say with which clay most of the mountain ores are associated.

Ore deposits.—The mountain ore deposits are distinguished from the valley ore deposits by their structure, by the grade of the ore, and by the material with which they are associated. The valley ores are of higher grade than the mountain ores and are invariably disseminated through dark-red and ocherous-yellow, porous, crumbly clay lying on the uneven surface of the Shady or other limestones. The mountain ores, on the other hand, are associated with sandy, pebbly, or compact variegated clays, in which they occur as large bodies or as pockets of angular fragments. They are always found at or near the contact of the lower Cambrian or Erwin quartzite with

[a] Keith, Arthur, personal communication.

overlying formations, in residual material which appears to be largely derived from the quartzites. In some places the contact is normal; elsewhere it is marked by a fault. In the Blue Ridge district faulting is extensive, and the lower Cambrian quartzite may be in contact with the Sherwood limestone, "Buena Vista" shale, or Natural Bridge limestone. In the New River district the faulting is pronounced, but not as extensive as along the Blue Ridge, so that the Erwin quartzite always remains in contact with the Shady limestone. Many deposits are found in brecciated zones along the fault plane, either in the bed rock or in residual material above it. Other deposits, however, occur along this contact where faulting is not evident and appear to be simply concentrations on the upper surface of the quartzite.

The mountain brown-ore deposits are of many different types, chief among which may be mentioned the following:

1. Pocket deposits in clay, either residual or fluviatile.
    (*a*) Irregular replacement masses of large size.
    (*b*) Mammillary masses associated with bright-colored clay.
    (*c*) Angular fragments of various sizes, replacements along seams, etc., scattered through brown and variegated clay.
2. Deposits in shale. Small replacements along seams and fractures.
3. Deposits in quartzite.
    (*a*) Breccia deposits accompanied by replacement.
    (*b*) Vein deposits along faults.

1. The deposits in clay range in size from single pockets hardly more than a few hundred feet in diameter to large deposits consisting of a group of pockets or masses several hundred yards in extent. Such groups are in many places connected into a series extending along the strike of the rocks for 5 miles or more, causing the grouping of mines already mentioned. The greatest depth to which the deposits have been operated is about 200 feet, but most of the deposits are probably shallower than this, though it is not at all certain that some may not be deeper. The pocket deposits in clay are by far the most abundant of the mountain ores.

As each deposit is generally made up of a group of pockets, so each pocket is made up of several ore masses or of many fragments embedded in clay. Several different types of ore generally are associated in a deposit.

(*a*) The most important deposits, though the fewest in number, are composed of large, irregular ore masses from 20 to 150 or 200 feet in diameter. They are apparently replacements of limestone, as is indicated by the following facts: Limestone has been found in association with the deposits, and in a few places, as at the Grubb mines, has been known to occur in the unaltered interior of large fragments of iron ore. In a great many places chert, a characteristic associate of limestone, is found with the iron ore. These large masses are not solid ore, but are much broken up and fractured so that they consist of many angular fragments of varying size, intermixed with considerable clay and sand. They generally have a longer axis running in the direction of the strike of the rocks. Such deposits occur at the Happy Creek mine, near Front Royal, Warren County; at the Buena Vista mine, near Buena Vista, Rockbridge County; and at the Grubb mine, near Blue Ridge Springs, Botetourt County.

(*b*) The mammillary masses are perhaps the most characteristic forms in which the mountain ores occur. (See fig. 19.) These masses vary in length from about 10 to 100 feet and have a width equal to about one-third of their length. Many of them are irregular in outline, but all have one feature in common, namely, a rounded,

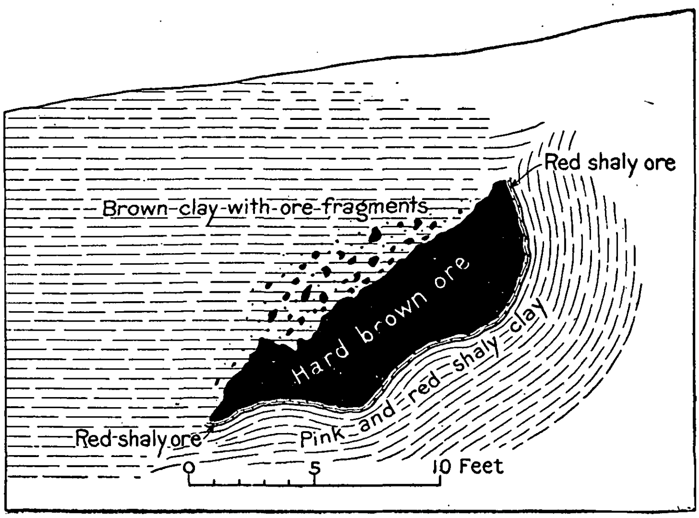

FIGURE 19.—Vertical section showing the structure of mountain brown ore occurring as a mammillary mass in clay at the Mary Creek mine, near Vesuvius, Va.

bulging surface. As a rule, the ore composing such masses contains many impurities, chief among which are sand and clay. Much of the ore is highly manganiferous, the manganese being present as psilomelane or pyrolusite and generally occurring in cavities associated with needle limonite. The ore in the interior of the masses is generally of a brown color and is in many places of a fairly good grade (see analysis 3, p. 222); the ore which occurs on the outside is red in color from half an inch to several inches from the surface, contains a great deal of sand and clay, and is of low grade. In some places the entire mass consists of red low-grade ore. (See analysis 6, p. 222.)

Generally the ore which composes these masses is hard and solid and not much broken up or fractured. The masses appear to have no regularity of position in relation to the underlying rocks. Their form and structure suggests the deposition of iron in clay by meteoric waters along trunk channels of circulation. Replacement and alteration progressed as more material was added, and the interior ore became of higher grade than the surface ore. The clays associated with the deposit are locally bright red, especially near the contact with the mammillary surfaces. The best examples of the deposits of this class are found at the Bare Bank and Mine Bank mines, in Augusta County, near Vesuvius; at the Mary Creek mine, in Rockbridge County, near Vesuvius; and at the Buena Vista mine, near Buena Vista, Rockbridge County.

(*c*) The third class of pocket deposits in clay consists of angular fragments of various forms and sizes scattered through variegated or brown clays. The fragments were probably at one time parts of larger masses, which have been broken up by the slumping of the clay. These masses were mostly small veins and replacements along lines of fracture or bedding planes, as is shown by the fact that many of the fragments are still arranged along such planes. Here and there fragments are grouped in little pockets, and in such places they were probably originally parts of small disconnected masses. The fragments vary from a fraction of an inch to more than a foot in diameter, though for the most part they are small. They are in numerous places associated with angular rock fragments, such as chert and quartzite.

The fragmental deposits consist mostly of hard brown ore, but locally contain pockets and stringers of soft sandy ore.

This class of mountain ore is very abundant, the following being among the typical occurrences: The Fox Mountain mine, near Elkton, Rockingham County; the Mount Vernon group of mines, near Grottoes, Rockingham County; the Crozier mine, near Greenville, Augusta County; the Buena Vista mines, near Buena Vista, Rockbridge County; the Troutville mine, near Troutville, Botetourt County; the Farris mine, near Allisonia, Pulaski County; the Foster Falls, Tipton, and Crawford mines, near Foster Falls, Wythe County; the Poplar Camp, Gregory, and Bailey Crockett mines, near Ivanhoe, Wythe County; and the Currin Valley mine, near Attoway, Smyth County.

2. In a few localities brown iron ores occur as a direct replacement of shale, layers of which are abundant locally in formations overlying the quartzite along the Blue Ridge. They are of no commercial value, the deposits being small and the ore of low grade. The replacement takes place along certain layers, so that the deposits generally consist of alternating layers of shale and ore. The layers are generally not more than 1 or 2 inches in thickness and are discontinuous, so that in reality they are flat lenses, the ends of which dovetail with other lenses. It is probable that the layers that have suffered the most alteration are those which originally contained the greatest amount

of calcareous material. Deposits of this type occur at the Lock property, near Front Royal, Warren County; at the Garrison mine, near Shenandoah, Page County; and at the Black Rock mine, in Augusta County, near Vesuvius.

3. The deposits in the quartzite are not very abundant, and only a few of them have been mined.

(*a*) The breccia and replacement deposits are usually of very low grade on account of the excessive amount of sand and quartzite fragments which they contain. In some of them the principal deposition has taken place along a brecciated zone, and replacement has occurred in the surrounding rocks, with this zone as a center. A mass of rock, perhaps several hundred feet in extent, suffers replacement and staining; but while some layers may be thoroughly replaced, others are merely stained with limonite. In some deposits of this type there is no brecciated center, but the entire deposit consists of a single pocket of replaced quartzite altered to different degrees, or of several distinct masses of such material grouped together. Typical deposits in quartzite occur at the Rileyville mine, near Rileyville, Page County; at the Midvale mine, near Midvale, Rockbridge County; and at the Morris mine, near Foster Falls, Wythe County.

(*b*) The fault and vein deposits in quartzite form a distinct type, very easily recognized and distinguished from all that have so far been described. Only two such deposits of sufficient importance to be mined have been found—the Big Ike mine, in Warren County, near Overall, and the Dixie mine, near Vesuvius, Rockbridge County. Similar deposits of small extent are found near Vesuvius and near Buena Vista, Rockbridge County. The deposits may occur along either dip or strike faults, but the largest deposit, that at the Dixie mine, is in a dip fault. This deposit (see fig. 20) strikes a little east of north and dips about 65° W., while the adjoining rocks strike N. 70° E. and dip about 60° N. It has been worked for a distance of several hundred yards and to a depth of about 250 feet and has been found to vary in thickness from 2 to 20 feet. Its center generally consists of pure glossy black limonite, and along the sides there are many partly replaced angular quartzite fragments. The quartzite next to it contains numerous small veins of limonite along the contact. The ore is very high in phosphorus, some of it containing several per cent. (See analysis 4, p. 222.) This has been traced to the mineral dufrenite, a green hydrated iron phosphate, which is locally present in such amounts as to give a green tint to the ore. The other deposits of this type are similar to the Dixie deposit, though of much smaller extent.

Character and origin of the ore.—As regards texture, the mountain ores are of three very distinct types—(1) black, glossy amorphous ore, (2) needle ore, and (3) brown, earthy amorphous ore. The first occurs as a cavity filling, especially along fault planes or in small veins and in breccia zones in quartzite. It is usually very hard and breaks with a conchoidal fracture. The needle ore also occurs as a cavity filling, but is more usually associated with the pocket deposits in clay, where it lines small cavities in the ore masses. It consists of fine, parallel needles grouped at right angles to the wall of the cavity. The color is usually dark brown. The third type is by far the most common form of mountain ore, as nearly all the deposits in clay and shale and part of those in the quartzite have this texture. It is the

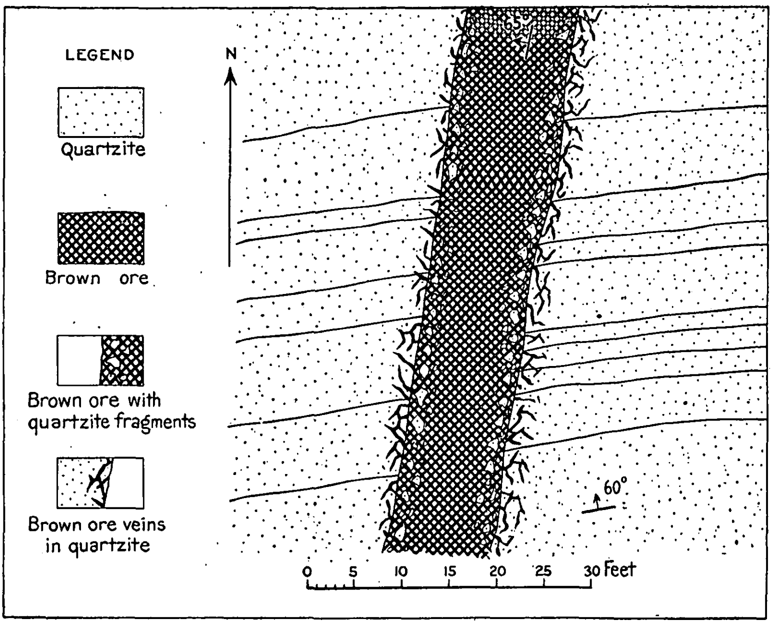

FIGURE 20.—Horizontal plan showing the structure of the brown-ore vein occurring along a fault in quartzite at the Dixie mine, near Vesuvius, Va.

form which limonite assumes when it replaces other materials, such as limestone, clay, or shale. There is a slight variation in texture, according to the material replaced. The ore is most pure and has a dark-brown color where it replaces limestone; but as the impurities increase it becomes lighter, so that ore which replaces shale and clay is generally of a rather light-brown color. The needle ore is the highest grade of brown ore. The glossy black ore, though rich in iron, generally contains considerable phosphorus, which makes it of low grade. The brown replacement ore, as a rule, contains a good many impurities, mainly in the form of sand and clay. (See analyses 3, 4, and 5, p. 222.)

The mountain brown ores are impure hydrated oxides, varying in composition between göthite and limonite and yielding on the average between 35 and 50 per cent of metallic iron. The impurities chief in quantity are silica and alumina, derived from included sand and clay. The silica content varies from 10 to 30 per cent. Phosphorus is the most injurious of the impurities present and varies in quantity from 0.10 to 2 per cent, thus making all the ore of non-Bessemer quality. The manganese content varies from 0.1 per cent upward. Where 1 or 2 per cent of manganese is present the ore produces a high-manganese pig iron which is used for special purposes. Ore containing a considerable percentage of manganese (about 10 per cent and upward) is used in the manufacture of spiegeleisen.

The following are analyses of mountain ores (see also analyses 3, 4, 5, and 6, p. 222):

Analyses of Virginia mountain brown ores.[a]

	1.[b]	2.[c]	3.[c]	4.[b]	5.[b]	6.[b]	7.[b]	8.[b]	9.
Fe	49.48	41.35	37.08	41.17	41.15	45.41	45.34	52.50	38.95
SiO_2	....	21.95	25.37	20.03	....	....	....	....	....
Insoluble	....	....	....	....	....	....	....	....	28.29
P	.59	.33	1.82	.215	.231	.274	.206	.229	.10
Mn	.75	.60	....	....	....	....	....	....	....

	10.	11.	12.[b]	13.[b]	14.	15.[c]	16.[b]	17.[b]	18.
Fe	41.13	48.50	41.20	38.68	47.80	39.59	40.38	40.67	35.61
SiO_2	....	....	14.08	20.91	13.40	....	20.11	18.09	28.50
Insoluble	14.83	14.46	....	....	....	....	....	....	....
P	.26	....	1.23	1.14	.14	.39	.55	.53	.069
Mn	8.22	....	1.13	1.20	.44	.48	.47	1.24	.30

	19.[c]	20.[b]	21.	22.	23.	24.[b]	25.	26.
Fe	43.60	35.96	40.77	47.91	49.89	35.63	42.65	40.00
SiO_2	....	17.10	13.92	9.69	11.40	20.21	....	15.00-20.00
P	.74	.25	1.19	1.98	1.22	.72	.12	.25- .35
Mn	1.56	4.52	6.80	1.23	.85	.60	....	2.00- 5.00

[a] Analyses 1, 2, 3, and 9 to 26 from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, pp. 430–461.
Analyses 4 to 8 from Benton, E. R., Iron-ore mines of Virginia: Tenth Census, vol 15, Mining industries, 1886, pp. 286–287.

[b] Natural state.

[c] Dried at 212° F.

1. Happy Creek mine, near Front Royal, Warren County. Analysis from H. J. Siebel, jr.
2. Boyer mine, near Shenandoah, Page County. Analysis by Alleghany Ore and Iron Co.
3. Rileyville mine, Rileyville, Page County. Analysis by Alleghany Ore and Iron Co.
4. Fox Mountain mine, near Elkton, Rockingham County. Analysis by F. A. Gooch.
5. Raines mine, near Grottoes, Rockingham County. Analysis by F. A. Gooch.
6. Miller mine, near Grottoes, Rockingham County. Analysis by F. A. Gooch.
7. Mount Torrey mine, near Lyndhurst, Augusta County. Analysis by F. A. Gooch.
8. Kennedy mine, near Stuart's Draft, Augusta County. Analysis by F. A. Gooch.
9. Black Rock mine, Augusta County, near Vesuvius. Sampled by A. S. McCreath.
10. Mine Bank mine, Augusta County, near Vesuvius. Sampled by A. S. McCreath.
11. Dixie mine, near Vesuvius, Rockbridge County. Analysis by Alleghany Ore and Iron Co.
12. Grubb mine, near Blue Ridge Springs, Botetourt County. Analysis by Virginia Iron, Coal and Coke Co.
13. Rorer mine, near Roanoke, Roanoke County. Analysis by Virginia Iron, Coal and Coke Co.
14. Tasker mine, near Hiwassee, Pulaski County. Analysis by West End Furnace Co.
15. Farris mine, near Allisonia, Pulaski County. Analysis by Pulaski Iron Co.
16. Morris mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
17. Hurst mine, near Reed Island, Wythe County. Analysis by Virginia Iron, Coal and Coke Co. (Semilimonite.)
18. Crawford mine, near Patterson, Wythe County. Analysis by Virginia Iron, Coal and Coke Co. (Semilimonite.)

19. Tipton mine, near Tipton, Wythe County. Analysis by Pulaski Iron Co.
20. Foster Falls mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
21. Poplar Camp mine, Poplar Camp, Wythe County. Analysis by R. J. Holden.
22. Indian Camp mine, near Poplar Camp, Wythe County. Analysis by New River Mineral Co.
23. William Jackson mine, near Ivanhoe, Wythe County. Analysis by New River Mineral Co.
24. Gregory mine, near Ivanhoe, Wythe County. Analysis by New River Mineral Co.
25. Norma mine, near Cripple Creek, Wythe County. Analysis by Pulaski Iron Co.
26. Currin Valley mine, near Attoway, Smyth County. Analysis from Dr. J. S. Apperson.

The mountain brown iron-ore deposits are clearly concentrations by meteoric waters. The iron was derived largely from the overlying limestone and shale formations, though perhaps partly from the underlying quartzite. The materials composing these formations were transported from the Piedmont region, where they were originally in the form of crystalline and metamorphic rocks. The shale formations contain a large quantity of undecomposed ferrous silicate minerals and in many places also considerable pyrite; the limestone formations contain pyrite and probably also iron carbonate; and the quartzite locally contains an abundance of pyrite. On weathering the iron in these formations is carried downward and precipitated as ferric oxide where conditions are favorable. Such favorable conditions are afforded by fault planes and an impervious basement of quartzite, and it is here that the deposits occur. The iron is carried downward through the shale and limestone residuum by successive precipitations until it reaches the underlying relatively impervious quartzite and is there concentrated. It replaces limestone and clay beds, forming pocket deposits in residual clay, and where possible penetrates fractures in the quartzite below, forming breccia and fault deposits. The presence of deposits in both residual and Tertiary or Pleistocene clays points toward a continuous concentration. Apparently this process is going on at the present time, for chalybeate springs are found in the neighborhood of many iron-ore deposits. The location of the deposits depends partly on the structure of the rocks and partly on the location of the original iron minerals in the overlying formations.

The ores in the limestone residuum which have not reached the underlying quartzite are generally in a porous and disseminated condition and constitute the valley or limestone ores described later.

VALLEY BROWN ORES.

Distribution and geology.—The valley ores (also called limestone limonites) extend along the same general area as the mountain ores, being distributed through a belt adjoining the mountain ores on the west and northwest. The belts generally overlap on the borders, especially in the New River region.

In the Blue Ridge belt valley ores are not very abundant, being scattered at intervals through the limestone area in the valley west of the Blue Ridge from the Maryland boundary on the north to Roanoke on the south. Only about six or eight deposits have been worked. In the New River district, however, the valley ore deposits are as numerous and important as the mountain ore deposits, if not more so. In this district the valley ore deposits are distributed through the valleys of New River and Cripple Creek between the quartzite ridges on the north and south. The maximum width of the valleys is about 6 or 7 miles, but the ores are confined to a somewhat narrower limit. The length of the combined valleys is about 55 miles. As has been mentioned, quartzite ridges carrying mountain ores occur in these valleys locally, though for the most part the mountain ores are confined to the southern border.

The valley ores occur as porous masses and disseminated particles in residual material derived from the Shady limestone in the New River district and from the Natural Bridge limestone in the Blue Ridge belt. It is possible that a few valley ore deposits along the Blue Ridge may be associated with the Sherwood limestone, but such a connection has not been established. The Sherwood is absent for considerable stretches on account of faulting, and where it is present its structure is generally unfavorable for ore concentration on account of the steep dips.

In the New River region the Shady limestone is nearly horizontal and only the lower portion of it is present, the upper part having been eroded. The bed rock is but a short distance below the surface and outcrops are abundant.

Ore deposits.—The valley ore deposits are not of the variable nature that characterizes the mountain ore deposits, but preserve great constancy with regard to both the form of the deposits and the character of the ores.

The valley ore deposits in the Blue Ridge are small and generally unimportant. They occur in clay on the surface of the Natural Bridge limestone or in crevices extending down into it. At the Buck Hill mine, near Midvale, Rockbridge County, there is a crevice 30 to 40 feet deep and 20 to 30 feet wide. The ore occurs in clay, in fragments or porous masses mixed with considerable ocher. In most of the valley ore mines along the Blue Ridge the ores are disseminated through dark-red clay on the surface of the limestone and do not extend to a great depth.

The valley ore deposits in the New River district, though associated with a different limestone formation, are similar in structure to those along the Blue Ridge. They are much greater in horizontal than in vertical extent, few deposits being more than 50 feet deep, though they may cover an area of 15 to 20 acres. The bottom of the deposits rests on the uneven surface of the limestone. (See fig. 21.)

Numerous horses of limestone extend up into the overlying clay, some of them even rising above the surface of the ground. Between these horses there are abrupt depressions filled with clay through which the iron ores are disseminated. In many places there is a difference of elevation of 20 feet or more between the top of the horses and the bottom of the depressions. After the removal of the ore and clay the limestone knobs and horses present an appearance very similar to that of forms produced by wind erosion in the western United States.

The residual clays have a prevailing dark-red color and are of porous and crumbly rather than plastic character. On approaching the contact with the underlying limestone the color changes to an ocherous brownish yellow. Locally dark-brown and even black clays occur, but light-colored variegated clays are conspicuously absent.

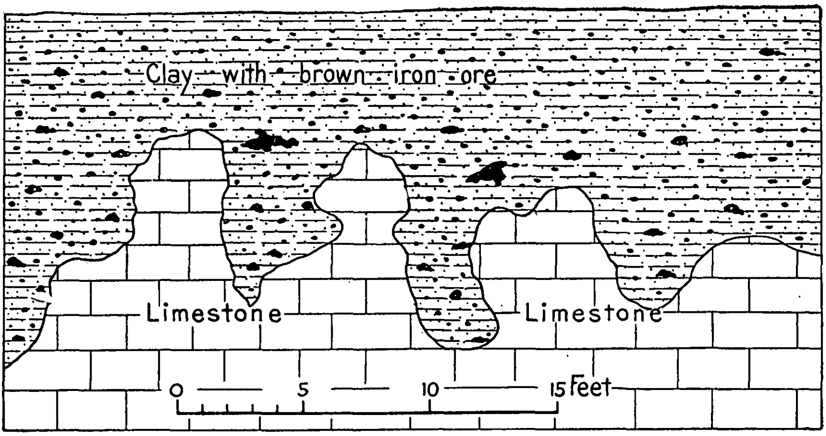

FIGURE 21.—Vertical section showing the structure of the valley brown ore deposits at the Rich Hill mine, near Reed Island, Va.

The ore is in the form of disseminated particles or large porous masses. The former vary from the size of a pea to fragments several inches in diameter; many of the latter are several feet in extent. Some of the masses and fragments are in the form and place that they were originally deposited, but elsewhere the original masses are broken into fragments and displaced by slumping of the clay beds. The ores are invariably more or less porous, and in many deposits ocher is associated with them, especially where they occur in large masses.

The large porous masses are more abundant in the ocherous clays near the limestone horses; the disseminated or gravel ore is more abundant in the dark-red clay. Much of the dark clay also contains numerous rounded pebbles of quartz and limonite in layers within a few feet from the surface.

In the valley ore deposits the ores are not gathered into local pockets as they are in the mountain ore deposits, but are scattered throughout the clay in varying abundance. The proportion of clay to ore varies from 5 to 1 to 25 to 1 in the workable deposits, but ore is present less abundantly throughout the area of limestone residuum.

The typical valley brown ore mines in the Blue Ridge region are the Hieston mine, near Luray, Page County; the Lofton mine, near Lofton, Augusta County; and the Buckhill mine, near Midvale, Rockbridge County. Those of the New River region are the Rich Hill, Reed Island, and Underock mines, near Reed Island, Pulaski County; the Barren Springs, Bertha, Walton, Carter, Sanders, Cedar Run, Hematite, Posey, and Foster Falls mines, near Foster Falls, Wythe County; and the Sisk & Gray, Simmerman, and Ivanhoe mines, near Ivanhoe, Wythe County.

Character and origin of the ores.—The valley ores are in general richer than the mountain ores and contain fewer impurities. They are porous and to some extent honeycombed, and locally considerable quantities of ocher are mixed with them. The cavities are generally filled with clay. Needle ore is rare in these deposits, the ore for the most part being in the amorphous form and yellow or brown in color. The valley ores, like the mountain ores, consist of a mixture of various hydrated oxides. They range in iron content from 40 to 55 per cent and in silica content from 5 to 20 per cent. Phosphorus is present in sufficient quantities to make a non-Bessemer ore, but it is by no means as high as in the mountain ore, ranging from 0.1 to 0.2 per cent. Manganese is generally below 1 per cent. Sand grains and quartz pebbles are not as abundant as in the mountain ores, but the sand is common where the original limestone was sandy. Locally chert occurs in small masses and bands.

The following table gives analyses of valley brown ores (see also analysis 7, p. 222):

Analyses of Virginia valley brown ores.[a]

	1.[b]	2.	3.	4.	5.	6.	7.	8.	9.	10.
Fe	52.50	43.81	56.22	42.42	56.29	44.27	44.98	55.04	46.03	41.17
SiO_2	5.59	14.65	....	18.92	....	12.50	....	....	10.90	19.31
P	.15	.18	.034	.17	.083	.14	....	.113	.15	.22
Mn	.46	.66	....	.37	....	.47	.53	....	1.09	.97

	11.	12.	13.[b]	14.	15.	16.	17.	18.	19.	20.
Fe	41.90	58.58	49.86	42.90	45.04	43.92	42.00–44.00	44.36	42.75	44.13
SiO_2	13.80	....	....	19.17	19.36	16.83	14.00–18.00	14.79	13.77	20.91
P	.13	.051	....	.09	.11	.14	.15	.11	.25	.17
Mn	1.03	....	.30	.67	.36	.73	.40– 1.00	.39	.32	....

[a] Analyses 1, 2, 4, 6, 7, 9 to 11, and 13 to 20 from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, pp. 448–463. Analyses 3, 5, 8, and 12 from Benton, E. R., Iron-ore mines of Virginia: Tenth Census, vol. 15, Mining industries, 1886, pp. 274–276.

[b] Dried at 212° F. All others in natural state.

1. Clark's bank, near Allisonia, Pulaski County. Analysis by New River Mineral Co.
2. Rich Hill mine, near Reed Island, Pulaski County. Analysis by Virginia Iron, Coal and Coke Co.
3. Rich Hill mine, near Reed Island, Pulaski County. Analysis by F. A. Gooch.
4. Reed Island mine, near Reed Island, Pulaski County. Analysis by Virginia Iron, Coal and Coke Co.
5. Reed Island mine, near Reed Island, Pulaski County. Analysis by F. A. Gooch.
6. Barren Springs mine, near Barren Springs, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
7. Bertha mine, near Barren Springs, Wythe County. Analysis by Pulaski Iron Co.
8. Carter bank, near Foster Falls, Wythe County. Analysis by F. A. Gooch.
9. Sanders mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
10. Cedar Run mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
11. Walton mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
12. Walton mine, near Foster Falls, Wythe County. Analysis by F. A. Gooch.
13. Patterson mine, near Patterson, Wythe County. Analysis by Pulaski Iron Co.
14. Hematite mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
15. Posey mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
16. Ivanhoe mine, near Ivanhoe, Wythe County. Analysis by New River Mineral Co.
17. Ivanhoe mine, near Ivanhoe, Wythe County. Analysis by Ivanhoe Furnace Co.
18. Sisk & Gray mine, near Ivanhoe, Wythe County. Analysis by New River Mineral Co.
19. Little Wythe mine, near Cripple Creek, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
20. Hall mine, near Castlewood, Russell County. Analysis by Union Iron and Steel Co.

The analyses of the ore from the Rich Hill (2 and 3), Reed Island (4 and 5), and Walton (11 and 12) mines show the difference in composition of the ores mined about thirty years ago and those mined at present, the latter being of much lower grade.

The valley brown ores are derived from the limestones in which they occur and from overlying formations, the iron being carried downward in successive stages and becoming more concentrated as it approaches the base of the limestone. They are not very distinctly localized, but such localization as does exist is probably due to the greater abundance of iron minerals in different areas of the overlying formations, such as local pyrite deposits, rather than to the structure of the underlying beds. The solution of the iron oxides and consequent downward movement is probably largely accomplished through the agency of organic acids, as suggested by Holden.[a] The porous and disseminated nature of the ores is due to the porous condition of the limestone clays. The valley deposits are simply deposits which have not yet reached the basement quartzite and become concentrated into large bodies, like the mountain ores. The original source of the materials is the same for both classes, so that the statement of the origin given under mountain ores applies here as well.

ORISKANY BROWN ORES.

Distribution and geology.—The Oriskany brown ores are so called on account of their association with the "Monterey" (Oriskany) sandstone. They are replacements in the upper portion of the Lewistown limestone and extend underground for variable distances from the outcrop. They are directly overlain by the "Monterey" (Oris-

[a] Holden, R. J., The brown ores of the New River-Cripple Creek district, Virginia: Bull. U. S. Geol. Survey No. 285, 1906, p. 192.

kany) sandstone or by the Romney shale where the sandstone is absent.

Deposits of this type occur locally in the western portion of the Appalachian belt, from Maryland to southwestern Virginia. The principal district is that of Alleghany County and vicinity, nearly all of the Oriskany ore produced being mined there. Minor deposits occur on Draper Mountain, in Pulaski and Wythe counties, south of Pulaski and Max Meadows; on Peters Mountain, Giles County; in the Buffalo Gap area, Augusta County; on Massanutten Mountain, Shenandoah County; and on North Mountain, in Shenandoah and Frederick counties.

In all these districts the ore occurs along the outcrop of the upper part of the Lewistown limestone wherever favorable conditions for concentration prevailed. The following is the upper portion of the Iron Gate section measured by Ulrich, part of which was given on page 229:

Section of the "Monterey" and Lewistown formations at Iron Gate.[a]

	Feet.
Romney black shale.	
"Monterey" (Oriskany):	
Sandstone and siliceous limestone	209
Calcareous sandstone	50
Siliceous limestone with many beds of chert	54
Bluish-gray limestone, with sandy beds in upper part	65
Quartzitic sandstone with two shaly beds	40
Lewistown (Helderberg) thin-bedded shaly limestone shales	322

One of the favorable conditions for the formation of the Oriskany ore deposits is a thin layer of "Monterey" (Oriskany) sandstone. Where ore deposits are present the sandstone is rarely more than 20 or 30 feet in thickness and is usually much less than that. In many places it is absent altogether, and there the Devonian shale overlies the ore.

In the Alleghany County region the Ordovician, Silurian, and Devonian rocks have been thrown into a series of parallel folds trending northeast and southwest. The folds are unsymmetrical,[b] the beds on the southeast side having low dips (5°–25° SE.), while those on the northwest side have steep dips (from 60° NW. to vertical), and in places are even overturned. After the folding erosion removed the softer rocks, as the Devonian shales, "Monterey" (Oriskany) sandstone, and Lewistown limestone, from the tops of the anticlines, exposing the hard Clinton (Rockwood) and Clinch sandstones which now form the summits of the ridges. The "Monterey" (Oriskany) sandstone and Lewistown limestone are now found on the middle slopes of the ridges and the Devonian shales lie on the lower slopes and in the

[a] Eckel, E. C., Oriskany and Clinton iron ores of Virginia: Bull. U. S. Geol. Survey No. 285, 1906, p. 185.
[b] Eckel, E. C., op. cit., p. 185.

intervening valleys. The ore deposits, therefore, occur along the slopes of the ridges and dip at varying angles toward the valleys. For the most part the workable deposits are confined to the southeast slopes, where the dips are fairly low, for reasons which will be given later.

In the other districts containing Oriskany ores, although the general structure of the rocks differs from that of the Alleghany County rocks, yet wherever ore deposits occur they occupy the slopes of mountains and the rocks containing them dip at medium low angles away from the ridges.

Ore deposits.—The ore deposits are formed as replacements in the Lewistown limestone, in the upper portion, which consists of pure, heavy-bedded limestone. Above them is the "Monterey" (Oriskany) sandstone or Romney shale, and below them the cherty middle portion of the Lewistown limestone. (See fig. 22.) The following is a typical section of the "Monterey" and Lewistown formations at the principal ore deposits in the Alleghany County district:

Typical section of the ore-bearing and associated formations in Alleghany County and vicinity.

	Feet.
Romney shale:	
Black shale	600+
Grayish blue clay	1–5
"Monterey" (Oriskany) sandstone, dark colored and iron stained	0–20
Lewistown limestone:	
Pure heavy-bedded limestone	10–60
Cherty limestone	20–60
Limestone and sandstone	200+
Clinton (Rockwood) formation	150+

Near the surface the rocks are all disintegrated except the "Monterey" (Oriskany) sandstone and here and there the cherty portion of the Lewistown limestone. At greater depth the disintegration is confined to the portions of the rocks near the contact of the ore deposits. In general the ores lie on clay containing numerous fragments of chert and are overlain by a dark-colored sandstone or by blue clay. Locally where the middle portion of the Lewistown limestone is very cherty it has remained undecomposed, and in such places the ores rest on a solid, uneven bed of chert, as at the old Rich Patch workings. The foot wall is considerably stained by iron, many of the chert masses being covered with a dark-brown or red coating. The "Monterey" sandstone contains numerous small veins of limonite and portions of it are largely replaced by iron. Where it is absent the ore bodies are overlain directly by a few feet of dark-colored plastic clay derived largely from the overlying shales. The shales are black and contain a considerable percentage of iron. They are solid and undecomposed within a few feet of the ore body. Where the "Monterey" sandstone is present the blue clay apparently occurs between it and the overlying shale. The mixture of chert and clay on the foot wall has a variable thickness and when it is penetrated the solid cherty limestone is found underneath. Locally a lens of chert may be interbedded with an ore deposit and divide it into two limbs. This was probably originally cherty limestone interbedded between two layers of pure limestone.

At a considerable depth, perhaps about 300 or 400 feet, the ore deposit begins to get thinner and limestone appears on both hanging and foot walls until finally, at a reported depth of about 600 feet, the ore gives place to solid limestone.

The ore deposits vary in thickness from a few feet to 75 feet, with an average of about 15 to 25 feet. They may extend along the strike of the formations in a series of pockets for half a mile or more, in which distance there is generally a great variation in thickness, and locally the deposit may pinch out altogether.

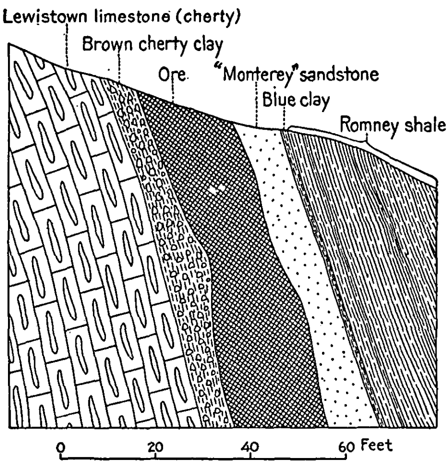

FIGURE 22.—Vertical section showing the structure of the Oriskany brown ore deposit at the Wilton mine, near Glen Wilton, Va.

The principal Oriskany brown ore mines in Virginia are the Liberty and Van Buren Furnace mines, in Shenandoah County; the Buffalo Gap and Ferrol mines, in Augusta County; the Victoria and Longdale mines, north of Longdale, Alleghany County; the Dolly Ann, Iron Mountain, and Stack mines, near Covington, Alleghany County; the Low Moor and Rich Patch mines, near Lowmoor, Alleghany County; the Jordan mines, on Potts Creek, Alleghany County; the Callie, Wilton, and Circle mines, near Glen Wilton, Botetourt County; the Oriskany and Fenwick mines, in Botetourt and Craig counties, near Oriskany; the Gala mines, near Dagger Springs, Botetourt County; the Clayton and Peak Knob mines, near Pulaski, Pulaski County; and the Locust Hill mine, near Max Meadows, Wythe County.

Character and origin of the ore.—The Oriskany ores are very similar to the mountain ores in that they are high in silica and manganese. The phosphorus content in general ranges between that in the mountain and that in the valley ores. Most of the ore is dark brown and amorphous, and much of it contains sand grains and partly replaced clay. Needle ore occurs in cavities, but it is not very abundant.

Fragments and porous masses of chert are common associates of the ore, representing unreplaced portions of the original limestone bed. The ore is usually hard and solid, but locally porous and cellular masses are found, and these contain clay in the cavities.

The iron content of the Oriskany ores ranges between 35 and 50 per cent. The phosphorus ranges from 0.06 to 0.5 per cent, silica from 10 to 25 per cent, and manganese up to 3 or 4 per cent. The following table gives analyses of Oriskany iron ores (see also analysis 8, p. 222):

Analyses of Oriskany iron ores from Virginia.[a]

	1.[b]	2.[c]	3.[c]	4.[c]	5.[c]	6.[c]	7.	8.[c]	9.	10.[c]	11.	12.[c]
Fe	41.10	43.90	35.26	40.14	41.51	46.19	44.32	51.77	48.20	51.66	45.67	43.71
SiO_2	16.32			21.58						9.97		
Insoluble							24.15		13.83		19.72	
P	.35	.076	.066	.36	.310	.289		.428	.42	.463		.380
Mn	3.40			1.06								

	13.	14.[c]	15.	16.	17.[c]	18.[c]	19.	20.	21.	22.[b]	23.[b]	24.[c]
Fe	46.52	43.84	42.90	41.10	45.62	37.39	45.88	40.37	44.60	41.12	53.46	37.54
SiO_2		22.87	25.60						22.30		4.58	18.79
Insoluble	17.60			24.41			16.29	21.81				
P		.636	.33	.43	.067	.395	.12	.43			1.22	.34
Mn			.78	.69			2.18	.69		.51	.40	1.55

[a] Analyses 1, 4, 7, 9, 11, 13, 15, 16, and 19 to 24 from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, pp. 431–459. Analyses 2, 3, 5, 6, 8, 10, 12, 14, 17, and 18 from Benton, E. R., Iron-ore mines of Virginia: Tenth Census, vol. 15, Mining industries, 1886, pp. 279–288.

[b] Dried at 212° F.

[c] Natural state.

1. Liberty mine, near Liberty Furnace, Shenandoah County. Analysis by Shenandoah Iron and Coal Co.
2. Hollow Bank, near Liberty Furnace, Shenandoah County. Analysis by F. A. Gooch.
3. West mine, near Van Buren Furnace, Shenandoah County. Analysis by F. A. Gooch.
4. Pit Spring mine, near Shenandoah, Page County. Analysis by Alleghany Ore and Iron Co.
5. Buffalo Gap mine, near Buffalo Gap, Augusta County. Analysis by F. A. Gooch.
6. Ferrol mine, near Ferrol, Augusta County. Analysis by F. A. Gooch.
7. Dolly Ann mine, near Covington, Alleghany County. Analysis by Low Moor Iron Co.
8. Dolly Ann mine, near Covington, Alleghany County. Analysis by F. A. Gooch.
9. Longdale mines, near Clifton Forge, Alleghany County. Analysis by Longdale Iron Co.
10. Longdale mine, near Clifton Forge, Alleghany County. Analysis by F. A. Gooch.
11. Stack mine, near Covington, Alleghany County. Analysis by Low Moor Iron Co.
12. Stack mine, near Covington, Alleghany County. Analysis by F. A. Gooch.
13. Low Moor mine, near Lowmoor, Alleghany County. Analysis by Low Moor Iron Co.
14. Low Moor mine, near Lowmoor, Alleghany County. Analysis by F. A. Gooch.
15. Rich Patch mine, near Lowmoor, Alleghany County. Analysis by Goshen Iron Co.
16. Potts Valley mine, near Covington, Alleghany County. Analysis by Alleghany Ore and Iron Co.
17. Callie mine, near Glen Wilton, Botetourt County. Analysis by F. A. Gooch.
18. Wills mine, near Covington, Alleghany County. Analysis by F. A. Gooch.
19. Oriskany mine, near Lignite, Botetourt County. Analysis by Alleghany Ore and Iron Co.
20. Ried mine, near Oriskany, Botetourt County. Analysis by Alleghany Ore and Iron Co.
21. Fenwick mine, in Craig County, near Oriskany. Analysis by Low Moor Iron Co.
22. Clayton mine, near Pulaski, Pulaski County. Analysis by Pulaski Iron Co.
23. Peak Knob mine, near Pulaski, Pulaski County. Analysis by New River Mineral Co.
24. Locust Hill mine, near Max Meadows, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.

The iron composing the Oriskany ores is derived from the overlying Devonian shales, which are black and very rich in iron minerals. Upon weathering the shales are decomposed and the iron is carried downward in solution by meteoric waters. The solutions have penetrated the underlying "Monterey" (Oriskany) sandstone, in which iron oxide has been deposited along fractures and has abundantly replaced the cement between the sand grains. Where the sandstone is sufficiently thin and fractured the solutions have penetrated into the underlying Lewistown limestone, and have replaced the calcium carbonate by ferric oxide, and thus formed iron-ore deposits. The extent to which the limestone is replaced depends on its purity; only the upper pure beds are replaced, the lower cherty beds being stained and partly decomposed. It is only where the layers have a moderately shallow dip that downward-moving waters can reach the limestones, and so the ores are confined largely to localities where such structural conditions prevail. Where the strata are steep or overturned ore deposits are rare.[a]

That the solution and deposition of iron is still going on is shown by the fact that waters percolating through the Romney shale carry an abundance of iron which is deposited as limonite on the walls of tunnels and drifts cutting the shale. This is especially noticeable at the Wilton mine, near Glen Wilton, Botetourt County.

Favorable conditions for the formation of Oriskany ores therefore are (1) nearness to the surface, (2) a thin and fractured bed of "Monterey" (Oriskany) sandstone, (3) a thick bed of pure limestone immediately underlying the sandstone, and (4) a moderately shallow dip of the beds.

LIMESTONE MAGNETITE ORES.

Limestone magnetite deposits[b] occur in the upper formations of the Shenandoah group and in clays derived from them. The principal deposits are found near Big Stony Junction, Giles County, and near Abingdon, Washington County; smaller deposits occur elsewhere in the southwestern part of the State. In Washington County the deposits are near the top of the Chickamauga limestone, not far from the border of an area of Athens shale. The ore consists of magnetite and hematite, the former in many places making up a dark steel-gray skeleton in which earthy red hematite fills the interstices. Locally in the limestone iron carbonate superficially altered to limonite is associated with the magnetite and hematite. The magnetite usually occurs as beds in the limestone and in lumps of a few pounds each in the clay and is farther from the surface than the associated minerals. It is of high grade.

So far as present developments show, the deposits are small, being only a few rods in extent and about 30 feet deep, though indications

[a] Johnston, J. E., jr., The origin of the Oriskany limonites: Eng. and Min. Jour., vol. 76, 1903, p. 231.

[b] Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, p. 422.

of ore occur over a wider area. Holden believes that these ores are secondary concentrations from the overlying shale.

The following table gives analyses of limestone magnetite:

Analyses of limestone magnetite from southwestern Virginia.[a]

	1.	2.	3.	4.	5.
Fe	63.55	48.82	58.30	56.05	62.00
SiO_2 or insoluble	5.21	19.76		7.76	5.50
P	.05	.05	.027	.036	.02
S	.002	.16		.06	
Mn				None.	Trace

1. Johnson mine, near Big Stony Junction, Giles County. Analysis by A. S. McCreath.
2. Porterfield mine, near Rifflemead, Giles County. Analysis by A. S. McCreath.
3. Semi-Magnetic mine, near Wytheville, Wythe County. Analysis by F. A. Gooch.
4. Galleher mine, near Abingdon, Washington County. Analysis by A. S. McCreath.
5. Holston mine, near Abingdon, Washington County. Analysis by Ivanhoe Furnace Co.

IRON CARBONATE.

Iron carbonate occurs sparingly in Virginia, being present in minable quantities at only one locality, near Abingdon, Washington County.[b] Here it occurs in a brecciated zone in the Chickamauga limestone near the border of the overlying Athens shale. It is associated with the limestone magnetite deposits and is superficially altered to limonite. At a few localities ironstone concretions occur abundantly in the Romney and Martinsburg shales.

The following is an analysis of iron carbonate associated with limestone magnetite:

Analysis of iron carbonate from Holston mine, near Abingdon, Washington County, Va.[b]

[By Ivanhoe Furnace Co.]

Fe	35.00
Insoluble	7.00
P	.03
CaO	12.00
MgO	5.00

PYRITE DEPOSITS.

Pyrite occurs in disseminated form in most of the Cambrian formations, but has been found in workable deposits only in the Shady limestone in the New River district. Here it occurs in separate deposits and also in association with lead and zinc sulphides. The pyrite is used in the manufacture of sulphuric acid, like pyrrhotite, and the iron oxide residuum is sent to the blast furnaces to be used

[a] Analyses 1, 2, 4, and 5 from Holden, R. J., op. cit., pp. 447–448, 461–462. Analysis 3 from Benton, E. R., Iron-ore mines of Virginia: Tenth Census, vol. 15, Mining industries, 1886, p. 277.

[b] Holden, R. J., op. cit., p. 462.

in the manufacture of pig iron. Little or no pyrite is being mined in the New River district at the present time.

THE IRON INDUSTRY IN VIRGINIA.

In 1907 Virginia ranked as the ninth State in the production of iron ore, producing a total of 786,856 tons, of which 696,518 tons was brown ore, 89,867 tons hematite, and 471 tons magnetite. These figures illustrate the relative importance of the different classes of ores. The brown ores are derived largely from the Alleghany County region and the New River district. In the Blue Ridge region only six mountain brown ore mines and four specular hematite mines are in operation. In the New River region 25 mines or more are producing brown ore, about two-thirds of this number operating on valley ore deposits and the rest on mountain ores. About a dozen mines are producing Oriskany ores, all except one or two of these being in Alleghany County and vicinity, in west-central Virginia.

Nearly all the ore mined is used in local furnaces, all except four or five mines being worked by mining companies who operate their own furnaces. The following are the principal mining companies:

The Virginia Iron, Coal and Coke Company has specular hematite and brown-ore mines near Blue Ridge Springs and Roanoke, brown-ore mines in the New River district, and fossil hematite mines in the Lee and Wise county area. Its furnaces are at Bristol, Washington County; Roanoke, Roanoke County; Pulaski, Pulaski County; Graham, Tazewell County; Max Meadows, Wythe County; Radford, Montgomery County; Foster Falls, Wythe County; and Reed Island, Pulaski County. The last two are charcoal furnaces; all the others are coke furnaces.

The Oriskany Ore and Iron Company has brown-ore mines at Vesuvius and in the Alleghany County district and coke furnaces at Iron Gate, Alleghany County; Buena Vista, Rockbridge County, and Shenandoah, Page County.

The Low Moor Iron Company has fossil hematite and brown-ore mines in the Alleghany County district and coke furnaces at Low Moor and Covington, Alleghany County.

The Pulaski Iron Company has a specular hematite mine near Buchanan and brown-ore mines in the New River district. It has coke furnaces at Pulaski, Pulaski County.

The Ivanhoe Furnace Company has brown-ore mines in the New River district and a coke furnace at Ivanhoe, Wythe County.

The Longdale Iron Company has brown-ore mines in the Alleghany County district and coke furnaces at Longdale, Alleghany County.

The Princess Furnace Company has brown-ore mines and a coke furnace at Glen Wilton, Botetourt County.

The Goshen Iron Company has brown-ore mines at Buena Vista and in the Alleghany County district and a coke furnace at Goshen, Rockbridge County.

The West End Furnace Company has brown-ore mines in the New River district and a coke furnace at Roanoke, Roanoke County.

The Union Iron and Steel Company has fossil hematites in the Lee and Wise County district and a coke furnace at Big Stone Gap, Wise County.

Besides the companies above named there are a few mining companies not at present operating who own charcoal or coke furnaces, and a few companies who do not own furnaces but are operating mines and selling their ore.

The above-named companies as a rule operate their own limestone quarries, from which flux for the furnaces is obtained, and a few companies also own coal mines. Limestone suitable for flux is plentiful throughout western and southwestern Virginia and is generally quarried near the furnaces. Fuel is shipped in from the neighboring coal fields.

The Oriskany ore deposits give greater promise than the other iron deposits of Virginia because of their extent, continuity, and depth, combined with the fact that they yield a fair grade of ore. Numerous deposits probably remain to be discovered, and it may be pointed out that the regions most favorable for exploitation are the Massanutten Mountain district and the area to the southwest of Alleghany County, with adjacent parts of West Virginia.

The valley ores, which are second in importance to the Oriskany ores, have probably reached their greatest development. Few new deposits remain to be discovered, and the productive capacity of most of those which are being operated is already on the decline. Considerable areas are being left unworked because the proportion of the ore to clay is so low that they can not now be mined at a profit. It is probable that in the future such deposits may be profitably worked, and if they are, large areas will become available.

The mountain ores for the most part occur in small discontinuous deposits. In many places a number of such deposits are grouped together and become of commercial importance. The mountain ore deposits along the Blue Ridge have been worked on a small scale for many years, but they have been found to be unreliable. This fact, together with the somewhat low grade of the ore, is preventing their development. A few deposits, however, are being operated regularly and are yielding good returns, and others are being worked intermittently. The mountain ores of the New River district, though of low grade, appear to be more continuous than those of the Blue Ridge and here eight or ten deposits are being worked regularly.

The hematite deposits, which constitute the other important class of iron ores of Virginia, are of moderate extent. The fossil hematite, though of good grade, generally occurs in beds which are too thin to be mined at a profit, and where beds of sufficient thickness occur they are not very extensive. At present a number of mines in Lee and Wise counties and the Horse Mountain mine, in Alleghany County, are being operated. The specular hematite beds are of considerable thickness and are of greater extent than the fossil ore beds. They would be of great value if composed of high-grade ore, but unfortunately the ore is very siliceous and can be used in furnaces only with great difficulty without the addition of other ores. Three or four mines, however, have been producing this ore regularly for a number of years, and the furnaces are using it in connection with brown ore.

The valley ores are mined exclusively from large open cuts, but the mountain and Oriskany ores are mined both from open cuts and from underground workings, the former method generally preceding the latter in the history of a mine. Specular and fossil hematite ores are mined from stopes and underground workings.

All the brown ores require washing and concentrating in order to free them from associated clay, sand, gravel, and rock fragments. The ore as it comes from the mines is crushed into fragments an inch or two in diameter and sent through a series of log washers. In these most of the clay is removed, and after passing through them the mixture of ore and rock fragments is screened so as to separate the small from the large fragments. The small pieces are cleaned by sending them through concentrating jigs; the large ones are passed over picking belts or tables, and the rock fragments are removed by hand picking. The jigs are far from perfect and allow a considerable quantity of rock fragments to pass through, thus lowering the grade of the ore. This is especially true in the case of mountain ores, in which gravel and rock fragments are more abundant than in the other varieties. Specular and fossil hematite ores are supplied to the furnaces in the form in which they come out of the mines, without preliminary concentration.

MANGANESE DEPOSITS OF THE UNITED STATES.

By E. C. HARDER.

INTRODUCTION.

In the winter and spring of 1908 the writer made an examination of the principal manganese districts in the United States and during the summer prepared a general report on manganese,[a] which will soon be ready for publication. The present paper is a brief digest of the principal portions of that report.

The manganese mining industry of the United States has been on the decline during recent years, owing to the extensive importation of high-grade ores from India, Brazil, Cuba, and the East Indies. The average grade of the domestic ores is much lower than that of the imported ores and they require considerable treatment, such as washing and sorting, to prepare them for the market. Besides, the domestic ores occur mostly in small scattered pockets, whereas the foreign ores are found in extensive beds and large deposits. All these circumstances have decreased the demand for the American manganese ore.

SOURCES OF MANGANESE.

Manganese has been obtained from four different classes of materials in the United States—manganese ore, manganiferous iron ore, manganiferous silver ore, and manganiferous zinc residuum.

Manganese ores may consist of any of the oxides or of the carbonate of manganese, but only the oxides occur in commercial quantities in the United States. Pyrolusite and psilomelane are by far the most important. Wad and braunite are of some importance, but manganite is rare. Pyrolusite has a theoretical manganese percentage of 63.2 and psilomelane of 45 to 60. As they occur in nature, however, the ores generally range from 40 to 50 per cent in metallic manganese. Psilomelane and pyrolusite are usually intermingled, being generally found as nodular concretions in which the two minerals form concentric layers, the psilomelane being amorphous and the pyrolusite

[a] Harder, E. C., Manganese deposits of the United States; with sections on foreign deposits, chemistry, and uses: Bull. U. S. Geol. Survey (in preparation).

occurring in small parallel needles. In many places nodules of pure pyrolusite occur with similar concentric layering, the successive layers being made up of granular and crystalline or needle-like pyrolusite. Pyrolusite and psilomelane locally have small admixtures of iron oxides and such ores are used in the steel industry. When free from iron they are very desirable for oxidizing and coloring purposes, but are extensively used in the steel industry also.

Deposits of manganese ore occur in many parts of the United States, but are most abundant in the Appalachian and Piedmont regions, in the southern Mississippi Valley, and on the Pacific coast. Small deposits occur in the New England, Rocky Mountain, and Great Basin regions. The principal producing districts up to the present time have been the James River valley and Blue Ridge regions in Virginia, the Cave Springs and Cartersville districts in Georgia, the Batesville district in Arkansas, and the Livermore-Tesla district in California. Of minor importance are the New River region in Virginia, the northeastern Tennessee region, the McCormick area in South Carolina, and the Little Grande district in Utah. Besides these there are minor deposits in many parts of the country which have produced small quantities of ore intermittently. During recent years operations have been confined to the Blue Ridge region, the James River valley, the northeastern Tennessee region, the McCormick area, and the Livermore-Tesla district. The manganese ore produced at present is being used in the manufacture of spiegeleisen and ferromanganese, and as a coloring material for bricks, pottery, and other articles.

Manganiferous iron ores consist of a mixture of any oxide or the carbonate of iron with any oxide or the carbonate of manganese. In this country manganiferous iron ores consist largely of limonite or hematite mixed with psilomelane, wad, or pyrolusite, a mixture of limonite and psilomelane being the most common. The iron and manganese oxides may be intimately intermingled or they may be coarsely mixed, so as to be easily distinguished from each other. In places good-sized pockets of manganese ore occur in deposits of iron ore, which are otherwise free from manganese. High-grade manganiferous iron ores are used in the manufacture of spiegeleisen and ferromanganese. Most of the low-grade manganiferous iron ores are not utilized for their manganese, which is generally considered an undesirable constituent.

Manganiferous iron ores occur in the United States chiefly in the New England, Appalachian, and Lake Superior regions, but minor deposits are found in the southern Mississippi Valley and in the Rocky Mountain region. High-grade manganiferous iron ore occurs in the Appalachian region, but there has been only a small production in recent years, the principal manganiferous iron ores produced at present being low-grade ores from the Appalachian and Lake Superior districts, which are so low in manganese that they are classed as iron ores. In the blast furnace they yield a "high-manganese" pig iron which is used for special purposes.

Manganiferous silver ores consist of a mixture of manganese and iron oxides, with small amounts of silver sulphide and lead carbonate, and in some places of gold. As a rule the iron content exceeds the manganese content, though here and there manganese may be in excess and rarely it may replace the iron altogether. These ores occur as a capping or gossan above metalliferous sulphide deposits which consist largely of iron, lead, zinc, and silver sulphides in a gangue of quartz or calcite. Locally rhodonite and rhodochrosite are present in the unaltered ores.

Manganiferous silver ores are divided into four classes, according to their uses. The greater portion of the ores are used for their silver and lead content. The manganese and iron content often insures these ores a higher price because of their fluxing value. The second class of manganiferous silver ore is too low in silver and lead to be used as a source of these metals, but is sufficiently high in manganese and iron to be used for the manufacture of ferromanganese and spiegeleisen, like the high-grade manganiferous iron ores mentioned above. At some localities the ore of this class is too low in manganese to be used in the manufacture of iron-manganese alloys and is used simply as an iron ore, like the low-grade manganiferous iron ores. A fourth class of manganiferous silver ore is too low in silver and lead to be used primarily for these metals and too low in iron and manganese to be used for the manufacture of iron-manganese alloys. This ore is sold to the smelters as flux, the iron and manganese becoming waste products, while the silver and lead content is recovered during the smelting.

Manganiferous silver ores occur in the Rocky Mountain and Great Basin regions, the principal producing localities being Leadville, Colo., and Tintic, Utah. Some of the Leadville ores are used in the manufacture of spiegeleisen. All the other localities produce these ores for fluxing only.

Manganiferous zinc residuum is obtained from zinc volatilizing and oxidizing furnaces using New Jersey zinc ores. The residuum consists largely of iron and manganese oxide, the zinc having been removed by volatilizing and collected as zinc oxide. The crude ores consist of franklinite, zincite, and willemite and are obtained only from the Franklin furnace district, in New Jersey. Small quantities of zinc residuum are used annually in the manufacture of spiegeleisen.

DISTRIBUTION AND OCCURRENCE OF THE ORES.

MANGANESE ORES.

VERMONT.

Manganese ore occurs near the towns of South Wallingford and Brandon, in Otter Creek valley, Vermont. In both localities the deposits are on the west slope of the Green Mountains at or near the contact of a lower Cambrian quartzite, which forms ridges along the west slope, and an overlying limestone of approximately the same age, which underlies the valley to the west. The deposits are mainly brown iron ore, with subordinate manganese.

The South Wallingford deposit[a] consists of pockets of iron and manganese ores, occurring separately or mixed in all proportions. The manganese ore is massive black psilomelane, with nests of crystalline pyrolusite. The ore occurs at intervals in a bed of yellow, red, and variegated clays at the contact of the quartzite and the limestone. The bed is almost vertical, dipping slightly to the west, and has a strike a little east of north. It has a probable average thickness of several hundred feet.

The Brandon deposit[b] is composed mainly of brown iron ore and subordinately of manganese ore in brown and white surface clays adjacent to the limestone-quartzite contact. In similar clays in the same locality lignite and Tertiary fossils have been found; hence it seems possible that the ore-bearing clay is a surface deposit derived from an underlying clay bed equivalent to that found at South Wallingford. The manganese ore is mainly in the form of black amorphous psilomelane kidneys, in some places containing nests of pyrolusite crystals. These kidneys are of various sizes and occur in pockets scattered through the clay, being locally associated with masses of iron ore.

VIRGINIA.

Manganese deposits occur in Virginia in the Piedmont region and in the Appalachian Valley.

The ore of the Piedmont region occurs in the James River valley northeast and south of Lynchburg. There are a number of old mines in this district, but only that of the Piedmont Manganese Company, near Mount Athos, and the Theresa mines, near Otter River, are at present producing ore. The deposits occur in residual clay and sand derived from ancient crystalline rocks. This material is still in place, and much of it is only partly decomposed, so that the texture and structure of the original rocks are clearly distinguishable. In general the ore occurs in nodular masses, ranging in weight up to

[a] Penrose, R. A. F., jr., Manganese: Ann. Rept. Arkansas Geol. Survey, 1890, vol. 1, p. 392.
[b] Idem, p. 395.

500 pounds and scattered through a yellowish-brown micaceous clay forming a nearly vertical layer between decomposed granite and quartzose mica schist residuum. The original nature of this ore-bearing layer is unknown.

The Piedmont Manganese Company's mine is situated on Beaver Creek, in Campbell County, about 1½ miles southeast of Mount Athos. In the present workings the ore occurs in masses in a yellow and brown micaceous clay bed dipping steeply to the southeast and having a general northeast-southwest strike. This layer is between a decomposed granite on the hanging wall and a residual micaceous clay on the foot wall. The latter is very similar to the ore-bearing clay and grades into it, the ore increasing in quantity toward the granite contact. The hanging wall also grades into the ore deposit through a zone partly replaced by manganese oxide. The ore-bearing layer, as exposed, varies from 5 to 10 feet in thickness, but ore apparently occurs at intervals for 50 feet from the hanging-wall granite. In places the ore masses are closely grouped, and the clay forms a very small part of the bed; elsewhere the clay may make up more than half of the layer. The length of the deposit is not known, but surface outcrops occur at intervals along the strike for a quarter of a mile to the northeast. The presence of ore-bearing layers parallel to the one now worked has been shown by surface pits.

In general the same conditions prevail in the old, unworked mines of the district. In the Leets mine, about 1½ miles northeast of the Piedmont Company's mine, ore occurs in a similar brownish-yellow micaceous clay between decomposed granite and schist and as a replacement of the adjacent part of the granite. Surface workings on the Saunders property, 2 miles east of Evington, show nodular ore in a red and yellow residual clay having a decomposed mica schist as foot wall. In the Cabell and Piedmont mines, about 2 miles north of Warminster, granite and schist are again to be seen, but their relations are somewhat obscured by the age of the workings.

A characteristic associate of many manganese deposits in the Piedmont region is a manganese-stained earth or clay known as "umber," which is a residuum of some formation as yet unknown. Crystalline limestone [a] has been found with it and may be a clue to its origin as well as to the origin of the deposits.

The Appalachian Valley may be conveniently divided into two districts, the Blue Ridge region and the New River region. The chief deposits of the Blue Ridge region occur on the west slope of the ridge from Front Royal on the north to Roanoke on the south. Through this area manganese deposits are found at irregular intervals near the foot of the mountains. The same region includes the Blue Ridge iron-ore mines, many of which contain some manganese ore, locally

[a] Watson, Thos. L., personal communication.

in such quantity as to form a manganiferous iron ore. Similarly, most of the manganese deposits contain some iron, especially near the surface.

The Blue Ridge extends along the contact between the ancient crystalline rocks of the Piedmont region and the Paleozoic sediments. The latter, although nearly vertical, have a general westward dip on the west slope of the mountains. The following section shows the succession of formations:

Section for the middle valley of Virginia.

Ordovician: Natural Bridge limestone.
Cambrian:
  "Buena Vista" shale.
  Sherwood limestone.
  Lower Cambrian quartzite (contains manganese).
  Lower Cambrian shale and quartzite (not manganese bearing).
Pre-Cambrian: Crystalline and metamorphic rocks.

The lower Cambrian quartzite occupies the main west slope of the mountains; the Sherwood limestone (believed to be the same as the Shady limestone farther south) and "Buena Vista" shale (believed to be the same as the Watauga shale farther south) lie on a gently sloping bench at the base; and the Natural Bridge limestone occurs in the valley to the west.

The manganese deposits occur in the limestone area near the contact with the underlying quartzite. With a few exceptions they are pockets of local concentration occurring in residual clay. With regard to texture the ore is of four varieties: (1) Kidneys of black psilomelane embedded at intervals in clay. (2) Irregular masses, many of them porous, of psilomelane with numerous layers or nests of crystalline pyrolusite, embedded in clay. This form is commonly assumed by local ore segregations in a manganiferous clay. (3) Breccia ore in large masses, consisting of sandstone or chert fragments, with either psilomelane or pyrolusite as cementing material. (4) Replacement and cavity fillings in sandstone or sandy clay. The ore of this type is composed largely of crystalline and granular pyrolusite with associated psilomelane.

The manganese ores are widely distributed along the Blue Ridge ore belt, but it is only here and there that they are sufficiently concentrated to form a workable deposit. In such deposits there are alternating layers, lenses, or irregular bodies of barren and ore-bearing clays. In many places one body of clay carries ore of a certain type, and an adjacent mass carries ore of another type. Of the numerous mines along this belt only the Dry Run, Crimora, Lyndhurst, and Vesuvius mines are at present in operation.

The Dry Run mine has recently been opened on an old manganese tract about 1 mile south of Compton, Page County. The ore is largely psilomelane in botryoidal forms occurring as cement in a brecciated pocket in solid lower Cambrian quartzite. Quartzite fragments form the principal part of the deposit, the manganese ore seams between them varying in width up to 3 or 4 inches. Cavities lined with botryoidal forms are numerous.

The Crimora mine is in Augusta County, about 2 miles east of Crimora station, on the Shenandoah Valley division of the Norfolk and Western Railway. The ore deposit is located in an elliptical basin in a canoe-shaped syncline of the lower Cambrian quartzite. The basin has a general north-south trend and is about a half a mile long, a few hundred yards wide, and about 200 feet deep. It is filled with yellow, red, and variegated clays. The ore is hard and of three varieties—(1) kidney ore of black psilomelane, (2) replacement and cavity fillings of psilomelane and pyrolusite in sandy clay, and (3) irregular pockets in manganiferous clays. The ore masses are segregated in local layers, lenses, and irregular bodies of clay, separated by barren areas. Near the surface the ore is somewhat ferruginous. In the eighties and early nineties the Crimora mine consisted mainly of underground workings. About 1895 these were abandoned and operations were begun for a system of hydraulic mining. A tunnel over a mile in length was cut westward from the lower part of the basin through the western rim, thus draining the entire basin above it. Water was brought to the mine by flumes from several points in the surrounding mountains. This system, however, has never been put fully into operation. The Crimora mine at present consists of a large open pit, near the center of which there is a shaft connecting with the long drainage tunnel. Operations are conducted on a very small scale and consist in taking out the ore left between the old levels. There is still about 135 feet of workable ground left between the bottom of the pit and the level of the tunnel, and nearly half of this is untouched by former workings.

The Lyndhurst mine is in Augusta County, about 2½ miles south of Lyndhurst, on the Shenandoah Valley division of the Norfolk and Western Railway. This deposit consists of scattered kidneys and irregular masses in clay. The former occur in small, irregular nodules averaging an inch or two in diameter, but in places reaching 5 or 6 inches. They are scattered through horizontal layers or lenses of red, brown, and variegated clays at intervals of a few inches to a foot or more. Mingled with the light-colored clays are layers and lenses of dark manganiferous clays which contain the ore of the second type. This varies from seams to irregular masses of different sizes and is either hard or soft. The ore is scattered at irregular intervals in a pocket which has been tested to a depth of about 60 feet and for a horizontal extent of about 300 yards. On account of the scattered location of the ore masses, much dirt has to be washed to get a small quantity of ore. The extent of the deposit, however, seems to be such as to warrant this expense. The mine consists of several shafts, with drifts at five levels.

The Vesuvius mine also is in Augusta County, about 1½ miles northeast of Vesuvius. The deposit is in a pocket, whose extent has not yet been determined, at the foot of the Blue Ridge. The workings consist of some old open pits, a shaft with underground workings recently abandoned, and a new shaft started west of the old workings. The ore is of two varieties—(1) breccia ore, occurring in large masses, with chert or sandstone fragments and either psilomelane or pyrolusite as cement, and (2) kidneys of ore from 3 to 6 inches in diameter, embedded in clay. Many of the breccia ore masses have a thick coating of botryoidal psilomelane.

Besides the mines mentioned, there are many unworked mines in this belt. Among them are the Fronk property near Kimball, Page County; the Eureka Manganese mine, southwest of Stanleyton, Page County; the Kimball mine and Garrison bank, east of Shenandoah, Page County; the Kendall and Flick mines, near Elkton, Rockingham County; the Seller mine, near Islandford, Rockingham County; the Shaver mine, near Port Republic, Rockingham County; the Old Dominion mine, which occupies the southern part of the Crimora basin, Augusta County; the Watt property, east of Dooms Crossing, Augusta County; the Kennedy and Mount Torry tracts, east of Stuarts Draft, Augusta County; the Midvale mine, east of Midvale, Rockbridge County; the Gowen and White banks, southeast of Lithia, Botetourt County; and the Houston banks, northeast of Troutville, Botetourt County. The ore deposits in Page and Rockingham counties all contain considerable brown iron ore. The manganese is largely in the form of nodular psilomelane, as at the Eureka Manganese and Kendall and Flick mines, but soft granular pyrolusite is common, as at the Fronk property, Kimball mine, and Garrison bank. The ore mined on the Old Dominion property has been mainly ferruginous surface ore. At a greater depth ore similar to that found in the Crimora mine will probably be obtained. The ore on the Watt property consists of masses of mixed psilomelane and pyrolusite with sandy clay fragments. On the Mount Torry and Kennedy properties the surface ore consists of ferruginous botryoidal and porous masses. The Kennedy open pit contains psilomelane kidneys near the bottom. The Gowen bank contains soft, blue ore; and the manganese ore shown in the Houston banks is mainly blue granular pyrolusite occurring as seams and replacements in sandstone horses. Some irregular masses of psilomelane and pyrolusite occur in the clays together with brown iron ore. Besides the occurrences noted above both manganese and manganiferous iron are found in most of the iron-ore mines. The deposits at some of the latter, like Mine Bank, 6 miles northeast of Vesuvius, consist almost entirely of manganiferous iron ores; at others, like the Happy Creek mine, near Front Royal, Warren County, they consist largely of iron ore, but the mines produce intermittently small quantities of manganese ore.

The manganese deposits of the New River region occur in several belts south of Pulaski, Wytheville, and Marion. The ores are found in the lower part of the Shady limestone and the upper part of the underlying Erwin quartzite, and almost invariably iron ores are associated with them. In the deposits visited the ores do not seem to have the form of kidney-shaped bodies, which are so prevalent elsewhere in Virginia, but rather to occur in large, porous masses, containing varying quantities of brown iron ore and much included clay and sand. Very little ore has been produced in this district, most of it coming from the Umbarger and the Currin Valley mines, southeast of Marion.

The Umbarger mine is about 1½ miles east of Sugar Grove, Smyth County. The main ore deposit consists of large masses of mixed porous psilomelane, limonite, and sandy clay. These masses range in size up to 6 or 8 feet, are of irregular shape, and occur in yellow or red clays. Ore has been taken out from a few cuts near the surface. Some ore is also scattered through a considerable area as small, irregular nodular masses, mainly psilomelane with some included pyrolusite, in yellow and red clay.

The Currin Valley mine is about 1½ miles south of Attoway, Smyth County. The workings consist of a large open pit from which considerable brown iron ore has been taken. The ore is in large masses and is a mixture of manganese ore, brown iron ore, and sand or clay, occurring locally in variegated clay. Manganese ore is also present at the Atkins mine, southeast of Attoway; on the Walker and Tate properties, north of Sugar Grove; at the Eagle Cliff mine, near Ivanhoe, Wythe County; near Allisonia, Pulaski County; and at several localities south of Wytheville.

Manganese ore is found outside of the three districts mentioned at several localities in Virginia, among which are some in the Oriskany iron-ore area in Shenandoah and Frederick counties, near Seven Fountains and Cedar Creek. Small deposits associated with Oriskany iron ores occur near Dagger Springs, Botetourt County, and at other localities to the southwest.

TENNESSEE.

The manganese ores of Tennessee are the southward continuation of the Appalachian Valley deposits of Virginia. As in Virginia, they occur near the eastern border of the valley. The best known of the Tennessee deposits occur in the vicinity of Newport and Del Rio, Cocke County; near Unicoi, Unicoi County, and in Shady Valley, Johnson County.

The Yellow Springs mine on English Mountain, 5 miles southwest of Newport, consists of an open pit in brown and red clays and sand, residual material derived from a lower Cambrian quartzite. Both soft and hard ores are present, the former generally occurring in irregular pockets and seams associated with manganiferous clays, and the latter in small kidneys and irregular masses scattered through the clay and the soft-ore pockets. There are numerous surface indications of manganese for several miles east of this mine, but little or no development work has been done.

The ore deposits at Del Rio and near Unicoi were not visited, but are reported to have similar associations.

In Shady Valley [a] manganese deposits occur associated with brown iron ore in residual clays probably derived from the Shady limestone. They are situated in the northern part of the valley, north of Cross Mountain.

Irregular masses of granular blue pyrolusite occur with iron ores in residual red clays of the Knox dolomite about 1½ miles northeast of Sweetwater, Monroe County.[b]

NORTH CAROLINA AND SOUTH CAROLINA.

In North and South Carolina manganese ores occur in two districts—the Kings Mountain region, on the boundary of the two States, and the McCormick area, Abbeville County, S. C. In the Kings Mountain district manganese oxides occur as stains, small veins, and replacements in a series of black schists extending as a narrow belt for about 50 miles in a northeast-southwest direction, crossing the boundary line near Blacksburg, S. C., and Kings Mountain, N. C. The deposits near McCormick consist of manganese oxides in association with residual clays derived from micaceous schists.

GEORGIA.

Manganese ores occur in Georgia at three horizons—(1) the ancient crystalline rocks, (2) the Weisner (Cambrian) quartzite, and (3) the Knox (Cambro-Ordovician) dolomite. The following is a general succession of rocks for northwestern Georgia:

[a] Penrose, R. A. F., jr., op. cit., p. 414.
[b] Burchard, E. F., personal communication.

Succession of rocks in northwestern Georgia.

Cambro-Ordovician: Knox dolomite.
Cambrian:
- Conasauga shale.
- Rome formation.
- Beaver limestone.
- Weisner quartzite.

Pre-Cambrian: Crystalline and metamorphic rocks.

In the crystalline and metamorphic area[a] ores occur at Mount Airy, Habersham County; Bowersville, Hart County; Blue Ridge, Fannin County; and Draketown, Haralson, and Paulding counties. All these deposits are small and none of them have been worked to any extent.

Northeast, east, and southeast of Cartersville, Bartow County, in the area underlain by the Weisner quartzite and Beaver limestone, there are extensive deposits of manganese in residual clays. In late years none of the mines have been operating, and no ore is being produced at present. The larger deposits of the district are the Chumbler Hill and Moccasin mines, east of Whites; the Dobbins mine, the Milner-Harris mine, lot 274, the Mayburn mine (lot 303), and lots 305 and 306, northeast of Cartersville; lots 460 and 465, east of Cartersville; and the Stegall property, near Emerson.

The ore is of four varieties—(1) kidney ore, either amorphous blue psilomelane or a succession of concentric layers of psilomelane and crystalline and granular pyrolusite; (2) irregular masses, either psilomelane or a mixture of psilomelane and pyrolusite; (3) breccia and replacement ore with chert or sandstone fragments; and (4) seams and irregular pockets of soft ore with local hard masses. The clays of the district are yellowish brown or red, according as they are derived from the Weisner quartzite or the Beaver limestone. The ores are generally associated with the yellowish-brown clays, and signs of manganese are present throughout the area covered by them, although only locally are there deposits rich enough to work. The breccia ores occur in residual sandstone or chert masses in the clays.

The Chumbler Hill mine is a large circular open pit in yellow, brown, and variegated clays containing local concentration of kidney ore. The fragments range in size from a few inches to a foot, but, as a rule, are 3 or 4 inches in diameter. They are embedded in yellow and brown sandy clay and are composed of concentric layers of psilomelane and crystalline pyrolusite. The Moccasin mine, a quarter of a mile to the east, contains ore of the same type.

[a] Watson, Thos. L., Preliminary report on the manganese deposits of Georgia: Bull. Geol. Survey Georgia No. 14, 1908, p. 158.

The Dobbins mine consists of a shaft and several open pits in yellow and brown clay, with local masses of darkly stained manganiferous clay. The main pit contains a large mass of breccia ore, but the principal deposits are seams and pockets of soft blue crystalline ore with local hard masses. These deposits are distributed through sandy clay and range in size from mere seams to masses several feet in extent. The latter generally contain small pockets of sandy clay.

The Milner-Harris mine consists of abandoned shafts and underground workings. The ore on the dumps appears to be of the same type as the Dobbins ore.

Lot 274 and the Mayburn mine are northeast of the Milner-Harris and Dobbins mines. The workings consist mainly of old open pits. The ore occurs in kidneys or in irregular masses, composed of psilomelane, of pyrolusite, or of a mixture of both. The kidneys are embedded in yellow or brown clay; the irregular masses commonly in dark manganiferous clay. Kidneys of beautiful needle ore (pyrolusite) are abundant in the Mayburn mine. Lot 274 contains considerable manganiferous iron ore near the surface.

Lot 460 is about 1 mile east of Cartersville. The ore occurs in porous, irregular ferruginous masses distributed along bands through reddish-brown clay.

Lot 465 is about 1½ miles south of lot 460. The ore here also is ferruginous and very much like that on lot 460. This lot also contains some deposits of breccia ore and kidneys of amorphous blue psilomelane.

These are the best-known deposits, but others of smaller extent occur in surrounding and intervening areas and contain ores similar in form and manner of occurrence to those described.

The areas where manganese ores occur in residual clays of the Knox dolomite are those around Cave Spring and Rome, Floyd County, and at Tunnel Hill, Whitfield County. These clays are generally dark red in color where derived from the Knox dolomite, and of lighter variegated color where residual from the associated shale. In the dark-red clays the ore occurs (1) as cement in residual masses of chert breccia, (2) in porous irregular masses ranging up to a foot in diameter, and (3) as pellet ore. In the lighter-colored clays the ore occurs as (1) cement in sandstone breccia or (2) blue psilomelane kidney ore. The main mines of the Cave Spring district are the Reynolds Mountain, Lowe, Scarborough, and Sanders.

The Reynolds Mountain deposit is about 7 miles north of Cedartown. The workings consist of several pits, most of which have caved in. The ore is dark-blue, partly crystalline pyrolusite, and occurs as cement in large masses of brecciated chert and as irregular porous fragments in the surrounding red clay.

The Lowe mine, about 2 miles southeast of Cave Spring, consists of a large open pit in dark-red clay. The ore occurs mainly in the form of small pellets, ranging up to one-third of an inch in diameter, with local larger masses of porous ore. Below the red clay is a variegated clay which contains ore associated with large areas of manganiferous clay.

On the Scarborough tract, about 4½ miles southwest of Cave Spring, there are several pits in light-colored variegated clays in which the ore occurs in breccia masses and kidneys of blue psilomelane. In the breccia the fragments form but a subordinate part, the main mass being a mixture of psilomelane and pyrolusite.

The Sanders property is about 2½ miles south of Cave Spring. The workings consist of several pits in variegated clays, in which the ore occurs as soft-ore pockets and small kidneys of hard ore. Both forms commonly occur in manganiferous clay, many of the former containing hard, irregular, partly crystalline masses. The kidneys are commonly only an inch or two in diameter and are composed of psilomelane.

At Tunnel Hill[a] the ore occurs in kidneys, separately and in nests, in dark-red clay. The ore is both massive and crystalline. Irregular masses of manganiferous iron ore are abundant.

Small deposits of little or no commercial importance are found in the vicinity of Rome and Lindale.

ARKANSAS.

Manganese ores of commercial importance have long been known and mined in the Batesville district, in northern Arkansas. Smaller deposits occur in the west-central part of the State, but have not been mined up to the present.

The Batesville district is north of Batesville and east of Cushman, Independence County. The country rock ranges from Cambrian to Carboniferous in age and is in horizontal beds. The following is the general succession of rocks for the district:

General section in manganese region in northern Arkansas.

Mississippian: Boone chert with St. Joe limestone member.
Silurian: St. Clair limestone.
Ordovician:
- Cason shale.
- Polk Bayou limestone.
- Izard limestone.
- St. Peter sandstone.

Manganese ores occur in three different associations in the Batesville district, but all of them are at very nearly the same geologic

[a] Watson, Thos. L., loc. cit.

horizon, between the Boone chert and the Polk Bayou limestone, or, where that is absent, the Izard limestone.

(1) The Cason shale locally becomes red and sandy and contains an abundance of small lenticular manganiferous iron ore nodules constituting a deposit of low-grade manganiferous iron ore. This bed where exposed is 10 feet or more in thickness. (2) In most of the mines of the district the interval normally occupied by the formations given in the section between the Boone chert and the Polk Bayou limestone is occupied by a manganese-bearing bed of varying nature, which appears to be partly residual material from the erosion of other rocks formerly occurring at this horizon and partly new material derived from deposition. This bed also is called the Cason shale, and although occupying a wider interval is presumably equivalent to (1). It varies in thickness from a few inches to many feet because of the irregular surface of the underlying Polk Bayou limestone. The formation consists in some places of clay with manganese ore fragments, in others of a solid bed of sandy, low-grade ore with associated sediments, and in still others of a partial replacement of sediments. (3) The remaining forms of manganese deposits are associated with residual clays on the slopes of hills below the main manganese bed above mentioned. These deposits consist of masses of psilomelane, pyrolusite, wad, and braunite, and are reconcentrations from the manganese bed above. Only a few deposits have been worked recently, among them the Cason, Reeves, Bales, Roach, and Meeker mines. The principal old mines are the Southern, Polk-Southerd, Turner, Adler, Trent, Baxter, and Montgomery mines.

The Cason, located about 3½ miles north-northeast of Batesville, is the only mine in the district which has worked the nodular manganiferous phases of the Cason shale. This is really a manganiferous iron ore and not a manganese ore, but it is included here on account of its associations. The ore is quarried rather than mined from two large cuts, the bed worked being about 10 feet thick and lying horizontal. It consists largely of red sandy shale with lenticular manganiferous iron pebbles lying in the plane of stratification and averaging between half an inch and 2 inches in larger diameter and from one-fourth to one-third of an inch in thickness. They are very closely spaced, making up more than half of the formation.

The Reeves mine is on Cave Creek, about 6 miles north-northeast of Batesville. The ore occurs in large and small masses scattered through horizontally bedded manganiferous earth. The ore masses are compact or spongy, the former being largely braunite and the latter psilomelane or wad.

The Bales mine is on Cave Creek, about 2 miles northeast of the Reeves mine. The ore occurs in manganiferous earth in irregularities on the surface of the Polk Bayou limestone, on the upper slopes of ridges capped by the Boone chert. The ore is mainly of the spongy blue variety. A considerable amount of the underlying limestone has been partly replaced by manganese.

The Meeker mine is on the horizon between the Boone chert and the Polk Bayou limestone, half a mile west of Cushman. The bed here consists of a few feet of sandstone and shale underlain by a ferruginous manganese formation varying in thickness from a few inches to 6 or 8 feet, the irregularity being due to the undulating surface of the underlying limestone. The material is fairly hard and consists of interlaminated manganese and iron oxides with sandy and shaly material, the whole forming a low-grade ore bed. Here and there are pockets of richer ore.

At the Roach mine, about 9 miles north of Batesville, the deposit occurs on a hill which lies in a basin of the St. Peter sandstone. It consists of a mixture of breccia ore, kidney ore, and manganiferous earth replacing clay, and occurs in dark-brown and chocolate clays. The breccia ore forms large masses, many of which are 5 or 6 feet in extent, composed of chert fragments cemented with manganese oxide. The kidney-ore masses average about 3 or 4 inches in diameter and are imbedded in chocolate-colored clays. Many of them contain chert fragments, and, on the other hand, some of the breccia masses have pure nodular psilomelane on the surface. The manganiferous earth occurs in large quantities with the other forms.

The Baxter and Montgomery mines are about half a mile east of the Roach mine. The ore at these mines occurs in red and brown clays on the surface of either the Polk Bayou or the Izard limestone. Dark-red masses, which appear to be decomposed shale and limestone, are seen in the clays. The ore is of two kinds—(1) thin layers of porous blue ore, apparently sedimentary or replacements of sedimentary material, interbedded with red shaly clay containing (2) small lenticular ore nodules similar to those of the Cason mine.

The Adler mine is about three-quarters of a mile north of the Reeves mine. Some of the pits are in the main manganese layer between the Polk Bayou limestone and the Boone chert; others are on the slopes below. The workings are old, and no ore could be seen in them at the time of the writer's visit.

The Trent mine is about 1 mile west of the Reeves mine. The ore is in dark clay on the Polk Bayou limestone, horses of which extend up into the clay. The ore consists of irregular masses of gray crystalline or amorphous braunite and psilomelane.

The Turner mine is about 2½ miles northeast of Cushman. The ore is spongy blue psilomelane and gray crystalline braunite in irregular masses scattered through reddish-brown clays on the surface of the Izard limestone. The Polk Bayou limestone appears to be absent, but the Boone chert is present locally above the clay.

The Polk-Southerd mine is about half a mile southwest of the Turner, but the pits are old and nothing could be seen except that the Boone chert formed the upper part of the walls.

The Southern mine is about 1 mile northeast of Cushman. It consists of a number of old open pits and shafts. The latter go through the Boone chert into the underlying manganese-bearing layer. The rock underlying this layer is the Polk Bayou limestone, as shown in the Grubb cut, a little to the northeast. In the pits ocherous and manganiferous clay is exposed under the Boone chert. This clay contains manganese ore masses here and there.

The deposits of west-central Arkansas are associated with brown-iron ore deposits. They lie on a novaculite bed of Silurian or Devonian age, immediately underneath a heavy Carboniferous shale series. Neither the iron nor the manganese deposits are of sufficient size to be considered of importance commercially.

UTAH.

Several deposits of manganese are known in Utah and others are being discovered. The best-known deposits are in Grand County, about 10 miles south of Little Grande, a station on the Rio Grande Western Railway. The ore here occurs as a replacement of calcareous layers along a certain horizon in the Triassic sandstone series. Above this horizon are beds of white and gray quartzite; below it are red thin-bedded limestones and calcareous sandstones grading downward into the massive red sandstone (presumably the Vermilion Cliff sandstone). The ore, consisting of blue granular and crystalline pyrolusite, is found abundantly as float and as replacements of layers and in pockets in the bed rock near the surface, where the overlying rocks have been eroded.

NEVADA.

A small deposit of manganese ore occurs 2 miles east of Golconda, Nev. It is bedded and varies in thickness from a few inches to 3 feet and is interstratified with calcareous and siliceous tufa. There is good evidence that this is a hot-spring deposit in a small basin in the tufa, as supposed vents of the springs are seen on the slopes of the hills above it. The ore is mainly wad in black powder or small fragments, slightly consolidated.

CALIFORNIA.

Manganese ore occurs in California in two different associations. (1) Near Meadow Valley, in Plumas County, and at other localities in the Sierra Nevada pyrolusite and psilomelane occur in veins in the Calaveras formation; (2) near the coast, north and south of San

Francisco, ore occurs as local small, thin lenses interbedded with jaspers of the Franciscan formation. Deposits of the first class have not figured as active producers up to the present time and in general are too small to be considered of importance. The principal deposits belonging to the second class so far found are located southeast of Livermore in Alameda and Santa Clara counties. Among these deposits are the old Ladd, the Fable, Pennsylvania, and Isler Mountain mines and the Overacker property. The ore is supposed to be largely in the form of manganite [a] and an impure oxide.

In the Ladd mine the ore occurs in what appears to be a fault fissure, having a general direction of N. 80° W. and dipping very steeply to the south. The fissure averages about 4 or 5 feet in width, with a hanging wall of massive pink jasper and a foot wall of thin-bedded gray jasper and clay. It has been mined to a considerable depth in open cuts along the strike. The ore occurs as cavity fillings, as infiltration and replacement deposits in red and yellow clays in the fissure, and as veins and breccia cement in the massive south wall. It is black in color and hard or soft according as it is associated with clays or with the jasper wall.

Along the strike of this fissure about half a mile to the west is a more recent opening consisting of an incline and stopes. The associations here are the same as at the Ladd mine.

The other deposits of the Livermore district are of a different nature. They consist of small lenses ranging up to 100 or more feet in length, and from a few inches to 5 feet or more in thickness. These lenses appear to be interbedded with the jasper layers and consist of black porous ore with seams of quartz. Along the edges there is considerable replacement of chert by manganese oxide.

Manganese indications are found throughout the Franciscan jasper areas of west-central California, and small deposits occur locally. Among them are those of Red Rock Island and Sausalito, near San Francisco, those of the Russian River valley, and a few deposits east of Tres Pinos, San Benito County, and near San Luis Obispo, San Luis Obispo County. So far, however, these deposits have not been found to be of commercial importance.

OTHER STATES.

Small quantities of manganese ore occur in Massachusetts, Connecticut, New York, and Pennsylvania in association with brown iron ore. The deposits are of the same nature as those of Vermont and Virginia. Locally there are veins of rhodonite in the New England crystalline area. Franklinite, willemite, and zincite, with some tephroite and rhodonite, occur near Franklin Furnace and Ogdensburg,

[a] Penrose, R. A. F., jr., op. cit. p. 481.

N. J., in crystalline limestone associated with gneiss. All these minerals contain some manganese, but the ores are used largely in the manufacture of zinc oxide and spelter. The residuum left after the volatilization and oxidation of the zinc, however, from those ores which are richest in manganese, is used in blast furnaces for the manufacture of spiegeleisen. In Alabama manganese ores are found at several horizons. They are continuations of the Georgia deposits, but are of much smaller extent. In Custer County, S. Dak., wad occurs in fissures and beds in Carboniferous limestone in association with cave deposits. The central Texas crystalline area locally contains veins of manganiferous garnet and tephroite, which are, however, of no commercial value.

MANGANIFEROUS IRON ORES.

APPALACHIAN VALLEY.

The manganiferous iron ores of the Appalachian Valley include deposits or parts of deposits of brown iron ore rich in manganese and manganese deposits rich in iron, in the States of Vermont, Massachusetts, Connecticut, New York, Pennsylvania, Virginia, Tennessee, North Carolina, Georgia, and Alabama. The most important are those in Vermont, Virginia, and Tennessee, which have been mentioned in the descriptions of manganese deposits. These ores vary from a coarse, easily separated mixture of manganese and iron oxides to a mixture indistinguishable to the eye. The principal minerals are limonite and psilomelane, but pyrolusite is of common occurrence.

ARKANSAS.

The manganiferous iron ores of Arkansas occur in the manganese horizons in the Batesville and west-central Arkansas districts and are described with the manganese deposits of that State.

LAKE SUPERIOR DISTRICT.

Much of the ore of the Lake Superior district contains between 1 and 10 per cent of metallic manganese. It is in the form of oxide, largely pyrolusite, occurring locally as small patches intimately mixed with red hematite.

Most of the manganiferous iron ores of the district have come from the Gogebic, Menominee, Mesabi, and Marquette ranges. At present, however, numerous deposits of manganiferous iron ore are being discovered on the Cuyuna Range of central Minnesota, where it occurs as local bodies in iron-ore deposits. A few deposits have also been found in the Baraboo Range in southern Wisconsin. Bog ores consisting of limonite and wad occur locally in northern Wisconsin.

COLORADO.

Manganiferous iron ores are found in the Cebolla district in Gunnison County, Colo. Manganese oxide is here associated with limonite in clay, a surface alteration of an iron carbonate in localities adjacent to a trachyte capping.[a]

UTAH.

A deposit of manganiferous iron ore has recently been discovered in western Utah near Joy, Juab County. It is said to occur along the contact of a limestone and granite, the latter being on the foot wall. There has been no production from this area because of lack of railroad facilities.

OTHER STATES.

Low-grade manganiferous iron ore occurs in both the hematite and the brown-ore deposits of Missouri. The hematite deposits that have manganese associated with them are chiefly those occurring in the porphyry. Bog deposits of limonite and wad occur at Wickes, Jefferson County, Mont.

MANGANIFEROUS SILVER ORES.

COLORADO.

Manganiferous silver ores occur at Leadville, Colo., in large deposits at or near the contact of porphyry and blue limestone, replacing the latter. These deposits consist of a black mixture of manganese and iron oxides with lead carbonate and silver. The manganese content varies from 10 to 40 per cent, being high where the iron is low and conversely. Manganese and iron oxides are associated only with the oxidized portions of the Leadville deposits. In the lower unoxidized portions the minerals are mainly pyrite, sphalerite, and galena. Manganese minerals are conspicuously absent and it is believed that the large quantity of manganese oxide in the oxidized ore is due to infiltration from the porphyry.[b] The ore is used both in the steel industry and for fluxing.

MONTANA.

Manganiferous silver ores occur in veins in the Butte granite at Butte, Mont. These veins traverse the area north, west, and south of Butte, nearly surrounding the copper area, in which little or no silver ore occurs. The outcrops and upper portions of the silver

[a] Leith, C. K., Iron ores of the West: Bull. U. S. Geol. Survey No. 285, 1906, p. 17.

[b] Emmons, S. F., and Irving, J. D., Downtown district of Leadville, Colo.: Bull. U. S. Geol. Survey No. 320, 1907, p. 34.

veins are black, and consist of a mixture of quartz and manganese oxides, mainly wad carrying silver. At greater depths the veins are white and pink and consist of silver and lead sulphides, with some pyrite, chalcopyrite, and locally sphalerite, in a gangue of quartz, rhodonite, and some rhodochrosite. In the Black Rock mine, where the veins are typically developed, the change takes place at a depth between 150 and 300 feet. The veins vary in width up to 100 feet or more, a large part of them generally being made up of included lenses of granite. The veins are branching and anastomosing, but all have a general east-west direction, ranging between northeast-southwest and southeast-northwest.

The manganese ores of Butte have been of little value commercially. In a few places the oxidized ore has been mined in former years, mainly for its manganese content for use as flux in smelting; but as a rule the ore is mined for its silver.

Manganiferous silver ores similar to the Leadville ore occur at Neihart, Cascade County, and Castle, Meagher County. The ores are in the form of brown and black oxides and occur in the upper portions of veins which grade down into unaltered sulphide ores of silver.

NEW MEXICO.

Manganiferous and ferruginous silver ores occur in southwestern New Mexico at Kingston and Lake Valley, Sierra County.

ARIZONA.

Manganese ores are abundantly developed in the oxidized portions of the metalliferous deposits at Tombstone, Cochise County, Ariz. The deposits are in the form of veins or chimneys, the manganese occurring as pyrolusite and earthy black wad, with some psilomelane in the upper portions, in a calcareous and siliceous gangue.

UTAH.

Manganiferous silver ores occur near Modena, Iron County, and in the Tintic district, Utah. The ores of the Tintic district are used for flux in the local smelters. The ore at Modena consists of a mixture of iron and manganese oxides, the latter largely wad, and occurs in the decomposed limestone on the foot wall of an igneous dike.

NEVADA.

Manganiferous and ferruginous silver ores are found at Pioche, Lincoln County, and at Eureka County, Nev.

USES OF MANGANESE.

The uses of manganese in the industries may be classified as follows: (1) Metallurgical, in the manufacture of alloys and in copper and silver reduction; (2) chemical, as an oxidizer and as a coloring material.

The manganese ores used in the manufacture of alloys are dependent in value on the percentage of metallic manganese present and on the absence of injurious substances like phosphorus and sulphur. The latter condition is especially important in the manufacture of the alloys with iron. Spiegeleisen, ferromanganese, silicomanganese, and silicospiegel are alloys of iron and manganese. Spiegeleisen contains below 20 per cent of manganese; ferromanganese has a manganese content ranging from 20 to 90 per cent, above which the alloy becomes unstable. Silicon and carbon are present in varying quantities. Silicomanganese and silicospiegel contain a large percentage of silicon. Spiegeleisen and ferromanganese are used in the manufacture of steel in the following ways: (*a*) As reducers of iron oxide in the final melting, the manganese oxide formed going into slag; (*b*) as recarburizers of steel, in which their carbon content is utilized; (*c*) for counteracting the effects of phosphorus and sulphur by the formation of manganese compounds with these elements; (*d*) in the manufacture of manganese steel, used for railroad and street-car rails on curves, burglar-proof safes, car wheels, ore crushers, dipper teeth for steam shovels, cover plates for lifting magnets, agricultural implements, such as plow and cultivator points, railway-car couplers, dredger pins, and many other appliances in which hardness and toughness are special requisites. The addition of small quantities of manganese gives to steel hardness, ductility, and strength.

Manganese is also used to form alloys with copper, zinc, aluminum, tin, lead, magnesium, and silicon, and with combinations of these elements. Manganese bronze is used for steamboat propellers and other alloys are used for coins, statuary, and ornamental purposes. Certain alloys of manganese, aluminum, and copper, known as Heusler's alloys, have come into prominence recently on account of their magnetic properties, and extensive experiments are being made with them.

Manganese oxides are used to a slight extent in copper and silver reduction as a substitute for iron oxides.

Manganese oxide is used as an oxidizer in the manufacture of chlorine, bromine, and oxygen and of disinfectants like potassium permanganate; as a drier in paints and varnishes; as a decolorizer of glass; and in the manufacture of the Leclanche battery and of dry cells. In these uses the value of the ore depends on its available oxygen content—that is, on its percentage of pyrolusite or manganese peroxide. A considerable tonnage of manganese oxide is used yearly in the manufacture of dry cells.[a]

As a coloring material manganese is used in calico dyeing; for coloring bricks, glass, and pottery; and in the manufacture of green and violet paints.

Compounds of manganese are used in a small way for medicine, and the mineral rhodonite, a silicate of manganese, is used rarely for ornamental purposes on account of its beautiful pink color.

THE MANGANESE INDUSTRY IN THE UNITED STATES.

The quantity of manganese ore mined in the United States is at present, as for several years past, very small. Of the important manganese districts—the Blue Ridge and James River valley districts in Virginia, the Cartersville and Cave Spring districts in Georgia, and the Batesville district in Arkansas—only the first two produced manganese ore in 1907. Of a total of 5,604 tons mined, 4,604 tons was produced in Virginia, 800 tons in South Carolina, and 100 tons each in Tennessee and California. About one-sixth of the above production was used in the manufacture of spiegeleisen and ferromanganese, the rest being consumed in the brick, pottery, and chemical industries.

Virginia has always been the principal manganese producer, with Georgia and Arkansas as second and third, respectively. Of the total production of 396,623 tons of manganese ore in the United States, these three States furnished about 95 per cent, Virginia alone furnishing more than 55 per cent.

The manganese ores of the United States generally occur in small discontinuous pockets, few of which contain more than 25,000 tons and most of them much less. A large proportion of the ore is of low grade, containing considerable iron, silica, and phosphorus. The eastern ores are embedded in clay and must be washed and sorted before they are fit for the market. The small extent of the deposits discourages the erection of expensive concentrating plants; hence mining is carried on only on a small scale.

The quantity of manganiferous silver ore produced in 1907 was very much larger than that of manganese ore, 67,514 tons being mined in the Leadville region for use in the manufacture of iron-manganese alloys and 40,000 tons or more being mined at Leadville and other localities in the West for use as flux in the silver and copper smelters. A large quantity of the iron ores produced also contained

[a] Burgess, C. F., personal communication.

an appreciable quantity of manganese, but not sufficient to make them of use in the manganese industry.

By far the larger part of the manganese ores consumed in the United States is imported from foreign countries, chiefly from India, Brazil, Cuba, and the East Indies. In 1907 the imports amounted to 209,032 tons, as compared with which the 5,604 tons produced in the United States may be regarded as insignificant. Most of the imported ore is used in the steel industry. A small percentage is used for chemical purposes, chiefly in the manufacture of dry cells and for coloring bricks and pottery.

SURVEY PUBLICATIONS ON IRON AND MANGANESE ORES.

A number of the principal papers on iron and manganese ores published by the United States Geological Survey or by members of its staff are listed below. The United States publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.; the monographs from either that official or the Director of the Survey. In addition to these papers, several geologic folios contain descriptions of iron-ore deposits of more or less importance.

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ALUMINUM ORES.

SURVEY PUBLICATIONS ON ALUMINUM ORES—BAUXITE, CRYOLITE ETC.

The following reports published by the Survey or by members of its staff contain data on the occurrence of aluminum ores and on the metallurgy and uses of aluminum. The United States publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.; the folios from either that official or the Director of the Survey.

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