POSSIBILITIES FOR MANGANESE ORE ON CERTAIN UNDEVELOPED TRACTS IN THE SHENANDOAH VALLEY, VIRGINIA.

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SCOPE OF INVESTIGATION AND REPORT.

Studies of ore deposits aim to interpret the associations of ores, in order that the systematic exploitation of known deposits or the search for unknown ones may be carried on intelligently. Such studies attempt to determine the source of the materials that make up the ore and associated minerals, the conditions that determine the favorable places for accumulation, the processes by which the accumulation has been accomplished, and the subsequent processes that have affected the deposit or brought it to view at the surface.

It is apparent that any attempt to determine areas that may contain ore deposits now unknown must be based upon a sound even if incomplete hypothesis concerning the origin and mode of occurrence of the ores, and such a hypothesis can be formulated only after many deposits of the particular ore sought have been thoroughly explored and studied.

Manganese minerals are widely distributed in Virginia, and a fairly complete explanation of the origin of the large deposits, which are sources of ore, will be possible only when many deposits have been examined in detail. Although much remains to be learned in future work, it is believed that sufficient is now known concerning some types of these deposits in Virginia to warrant the direction of effort toward exploration in areas where unknown deposits may be found.

This report aims to present briefly the results of field work in a part of Virginia where many manganese deposits are known. The examination was directed toward the discovery of areas likely to contain manganese, with the aid of data gathered in a study of the geologic relations of known deposits. The field work was done in cooperation with the Geological Survey of Virginia. As it has brought forth much information concerning the nature and structure of the rocks associated with the manganese ores, which may greatly aid the operators of producing mines, a more detailed report will be published later by the Virginia Survey.

AREA EXAMINED AND METHODS EMPLOYED.

Northwestern Virginia has long been the source of much of the manganese ore mined in the United States, and at times it has been the scene of active prospecting in the hope that other extensive deposits like that at the Crimora mine might be discovered. The manganese deposits lie along the east side of the Shenandoah Valley, at the foot of the Blue Ridge. For the present investigation a narrow belt was selected extending from Front Royal at the north to a point about 10 miles southwest of Waynesboro at the south. (See fig. 26.) This strip is about 85 miles long and averages 4 miles

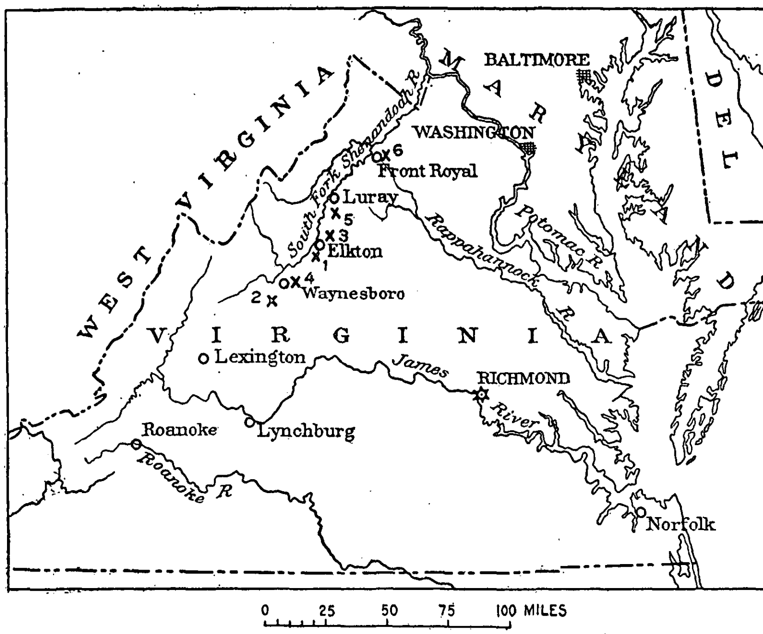

FIGURE 26.—Index map of northern Virginia, showing location of undeveloped tracts recommended as favorable for prospecting for manganese. Tracts are numbered in the order of prospective promise.

wide, and the Crimora mine occupies a central position in it. A preliminary geologic map of the area has been prepared, and this will be published in the report of the Geological Survey of Virginia.

The method of study was very similar to that which would have been employed in making a detailed areal map of the region. Traverses were run along the roads and up the streams that cross the belt nearly at right angles to the trend of the bedded rocks. By this means the attitude of the beds was determined and the boundaries of the rock formations were located. The adjacent mountains were climbed where more information was needed or where a general view was desired for the purpose of location. This was essential in many places on account of the inadequate exposures of the rocks in the lowlands and the necessity of resketching the topographic base map where it was inaccurate. Where the rocks were found so broken by weathering or so covered by rock waste that the bedding could not be determined, the structure was inferred by the study of surface forms and the distribution of distinctive débris derived from the several formations.

In addition to the traverses for the purpose of making the map and determining the structure of the rocks, manganese and iron mines, prospect pits, and holes of any sort where information as to the relation of the ore to the bedrock might be observed were examined. At only a few places was the unaltered limestone in the mine pits visible, but the relation of the ore to the residual clay and to the wash was carefully scrutinized. The clay in most of the deeper mines and in some of the shallow pits was found to preserve the original bedding of the impure dolomite and limestone, so that the structural relations of the ore to these rocks could be determined.

THE MANGANESE DEPOSITS.

GENERAL FEATURES.

The known manganese deposits of this part of Virginia are masses of oxides that are associated with rocks of several different types and have diverse structural relations. Some bodies of the oxides are rather large and so pure that they may be mined and shipped without prelminary treatment. Other masses are composed of nodules disseminated through clay in proportions that have a wide range. The material from such deposits must be washed to procure ore of high enough grade to warrant shipping.

A complete discussion of the origin of the deposits should include geologic data of several kinds, such as the distribution of manganese-bearing rocks and minerals, the chemical properties of manganese compounds and natural minerals, the character of the ground water of the region, the characteristics and stratigraphic relations of the rocks with which the ores are associated, the local structure of the rocks, and the surface features resulting from the erosional processes that have affected the region. Brief statements concerning data of the last three kinds only are presented in this report, as they are used in outlining favorable areas for the accumulation of the ores.

ROCKS WITH WHICH THE ORE IS ASSOCIATED.

The rocks which occur in the vicinity of the manganese deposits of the Blue Ridge and adjacent part of the Shenandoah Valley include sandstone, shale, limestone, and dolomite and the older crystalline rocks on which these rest. The oldest crystalline rock present in the area is granite. The other crystalline rocks are greenstone, greenstone schist, and sericite schist, which were originally molten lavas. The massive greenstone is very resistant to weathering—that is, it is not readily soluble in water nor easily broken up by frost and rain—and therefore it forms the highest summits of the Blue Ridge throughout this area.

Immediately overlying the crystalline rocks are sandstones and quartzites, composed in part of unassorted débris derived from the disintegration of the older crystalline rocks. These beds range from soft arkose through harder arkosic sandstone to hard gray sandstone and dark ferruginous quartzite. With them are associated beds of slaty argillaceous sandstones. Some of the basal beds have rounded grains and small pebbles of quartz, which are usually clear and transparent, though some have an opaline blue color. Besides quartz there are grains of feldspar, generally chalky white from weathering, and considerable clay and iron oxide. A spotted sericite schist, representing a thin amygdaloidal lava flow, occurs at several places interbedded with the lowest sedimentary beds. These rocks have been called the Unicoi formation in northern Tennessee, and that name will be used in this report. They are equivalent to the Weverton sandstone and Loudoun formation of Maryland and northern Virginia. Their thickness in this area is estimated to be 1,750 to 2,000 feet. The formation is best exposed in the cuts of the Southern Railway 4 miles east of Front Royal but is also well shown on the Simmons Gap road south of Elkton and elsewhere in the belt between the main Blue Ridge and the front foothills.

Overlying the Unicoi formation are dark-gray shales, slates, and thin sandstones which in northern Tennessee constitute the Hampton shale. The shales and slates are mostly sandy and weather to hackly outcrops, so that in many places their original character and bedding can not be clearly discerned. Some of the shale is dark and banded but weathers to soft buff rock. The formation is the same as the lower part of the Harpers shale of northern Virginia. It is estimated to be about 400 feet thick in this area but may be much thicker, as it is in general highly folded. Typical rocks of the Hampton and Unicoi formations are easily distinguished, but the two formations were not separately mapped everywhere in the field, because there are shaly rocks in the Unicoi and hard sandstones and arkoses in the Hampton. All these rocks weather more easily than either the underlying greenstone or the overlying massive white quartzite, so that they form depressions or subordinate ridges between the main Blue Ridge on the east and the outer foothill ridges on the west.

The next higher formation is a massive white quartzite, the outcrops of which make prominent ridges in this region. It is here called the Erwin quartzite. The western foothills of the Blue Ridge throughout most of the area are composed of this rock, and in many places it forms the front ridges. The formation in this region is generally made up of three massive cliff-making ledges separated by thinner-bedded sandstones. The thickness in the measured section given below, the best-exposed section in this region, is 500 feet, but it appears elsewhere to be much greater, possibly 1,000 feet.

Section of Erwin quartzite in Blue Ridge near Stanley, Va.

	Feet.
White sandstone full of scolithus; crumbles readily to sand. Rarely exposed in place. Upper layers harder; weather red to rusty and porous	120
Upper cliff: Hard white thick-bedded vitreous quartzite. Contains some scolithus	40
Partly covered, probably crumbly white sandstone	90
Middle cliff: Hard thick massive beds of bluish-white vitreous quartzite	80
Covered, probably crumbly sandstone	70
Lower cliff: Hard white vitreous quartzite. Contains some scolithus	100
	500

The cliff-making ledges consist largely of massive beds of dense white quartzite, some of which are 15 to 20 feet thick without a visible trace of bedding. Many of the beds contain casts of worm tubes (scolithus), and as these were vertical when the sediments were deposited they may be used to determine the bedding of the rocks, which is at right angles to them. This formation is the same as the Erwin quartzite of northern Tennessee and has also been correlated with the Antietam sandstone of northern Virginia. It is believed, however, to represent not only the Antietam but also a lower quartzite, the Montalto quartzite of southern Pennsylvania, which is a member of the Harpers shale.

In the Shenandoah Valley the Erwin quartzite is overlain by a great thickness of limestone and shale, but only those beds immediately adjacent to the mountain front need here be considered. The formation that normally lies above the Erwin quartzite—the Shady dolomite—is composed largely of coarse dolomite containing chert nodules and beds of impure shaly limestone. Because of the solubility of the dolomite it readily breaks down into grains and finally weathers into red clay and is generally not visible at the surface. It therefore forms a deep-red granular and clayey soil containing chert fragments and underlies low valleys. Some yellow laminated clay or ocherous layers at the base represent banded argillaceous limestones. Unallotted dolomite has been exposed only in a few shafts and tunnels in the region. The formation is the same as the Shady limestone of northern Tennessee and is equivalent to the Tomstown limestone of southern Pennsylvania and Maryland. It is reported to be 1,800 feet thick in the vicinity of Natural Bridge, and it has probably about the same thickness here.

The next recognized formation of the limestone group is a shale called Watauga in northern Tennessee. Its characteristic color is reddish purple, but in this area it is generally so much weathered that it is buff colored. In places it is weathered to purple and buff banded ocherous clay, as at the ocher mine 10 miles southwest of Luray. It contains thin calcareous shales and blue limestone beds and in places thinly laminated ripple-marked sandstone, which is best displayed east of Front Royal. It is the equivalent of the Waynesboro shale of southern Pennsylvania and Maryland, which is conspicuously purple and sandy. The thickness in this area could not be determined, because of poor exposures. The formation is reported to be 900 feet thick in the vicinity of Natural Bridge, where it is better exposed, but it does not appear to be so thick in this area. Above the Watauga

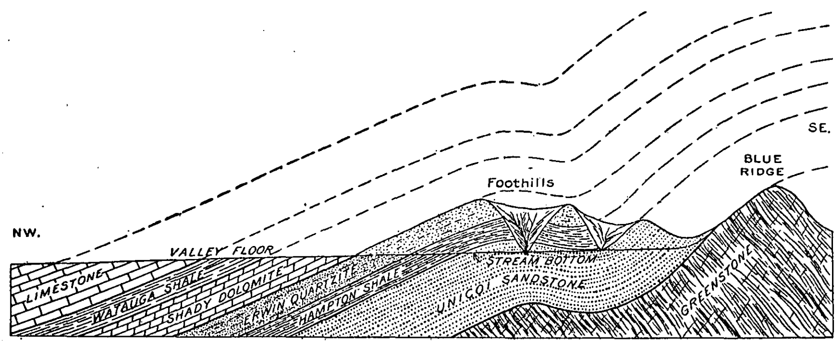

FIGURE 27.—Generalized structure section of the west front of the Blue Ridge and the adjacent part of the Shenandoah Valley, showing the normal relations of the rocks and their former extent (dashed lines) before removal by erosion.

shale are limestones and dolomites that have not been differentiated in this area, and as they need not be considered in the present connection, they will not be described.

All the sedimentary rocks above described are geologically very old. No fossils, except the worm tubes in the Erwin quartzite, were found in them in this area, but casts of shells and other fossils have been found in the equivalent formations elsewhere, and they are therefore known to belong in the Cambrian and to be among the oldest fossiliferous rocks known in the eastern part of the continent.

The sediments were nearly horizontal when they were laid down in the sea. The beds are now in most places steeply inclined and folded into long troughs (synclines) and arches (anticlines) whose axes are parallel to the northeasterly trend of the mountain ridges. (See fig. 27.) After being folded and wrinkled the rocks were worn down by processes of atmospheric erosion, and the softer and more soluble rocks were removed from the higher regions. The underlying quartzites, shales, and greenstones were thus exposed and, because of their resistance to erosion, now form the mountains, whereas the limestone underlies the valleys. A generalized cross section showing the rocks of the region as they are now and their extent before they were eroded is given in figure 27.

The manganese deposits are not confined to a single thin group of beds but lie in or over beds that range from the upper part of the Erwin quartzite to the lower part of the Watauga shale, stratigraphically 2,000 feet higher. Most of the deposits, however, occur in banded clays that are believed to have been derived by weathering in place from the lower 200 feet of the Shady dolomite.

RELATION OF DEPOSITS TO STRUCTURAL FEATURES.

Manganese oxides are widespread in the Shenandoah Valley, but as most of the rocks near by are deeply decayed, the structural associations of many small bodies of the oxides are obscure. Studies of a number of deposits that were large enough to warrant extensive exploration, however, show that at least five structural types may be recognized and that in most places the local structure of the adjacent rocks has determined the form of the deposits and in large measure their areal extent and their persistence below the surface.

The five types of deposits will be briefly described. Figure 28 shows cross sections of four deposits which have been studied recently and which probably include those types that are sources of most of the ore now mined in northwestern Virginia.

1. The commonest type of deposit in the belt under consideration is that represented at the old Kendall & Flick shaft, south of Elkton, but also shown at the Vesuvius mine, 1½ miles northeast of Vesuvius, Rockbridge County, and elsewhere in the region (fig. 28, B). These deposits occur in a 200-foot zone of decomposed shale and cherty dolomite that overlies the upper beds of the Erwin quartzite, where the beds dip toward the Shenandoah Valley at angles that range from 30° to 60°. The structure near these deposits may be termed monoclinal, as all the beds are similarly inclined. In such localities the upper surface of the Erwin quartzite forms the slope of a conspicuous straight ridge, and float ore from the deposits is found over the gentle slopes near by on the northwest. Under these structural conditions irregular bodies of manganese oxides are found here and there in a narrow belt of decomposed shale and dolomite parallel to the outcrop of the Erwin quartzite. The bodies of manganese oxides appear to have no relation to the transverse ravines that rise in the Blue Ridge and cross the quartzite. So far as available records show, no deposits of manganese ore or manganiferous iron ore occurring under these conditions in this area have yielded more than 25,000 tons, and many have been abandoned before producing as much as 5,000 tons.

2. Deposits of another type occur in clays that fill troughs formed by the upper surface of the Erwin quartzite. The best illustration

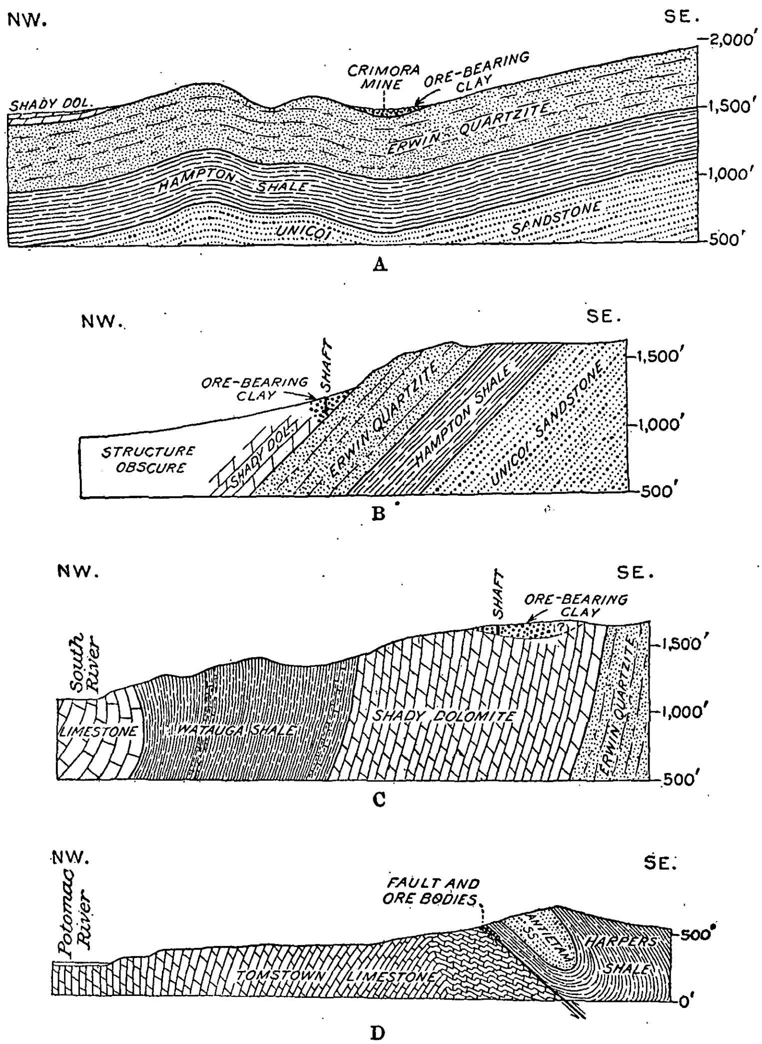

FIGURE 28.—Sketches showing vertical cross sections of four manganese mines in the Shenandoah Valley-Blue Ridge region, representing four types of deposits. A, Cross section S. 48° E. through the Crimora manganese mine, Augusta County, Va., in which the ore lies in a trough in the Erwin quartzite; B, cross section S. 52° E. through the old Kendall & Flick mine, south of Elkton, Va., in which the ore occurs as pockets in clay immediately above the top of the Erwin quartzite, which has a monoclinal structure; C, cross section S. 65° E. through the Midvale mine, Rockbridge County, Va., in which the ore occurs in gravel in a stream channel cut on nearly vertical limestone; D, cross section S. 65° E. through the mine at Dargan, Md., near Harpers Ferry, W. Va., in which the ore occurs in clay along a fault zone.

of this type is the deposit worked at the Crimora mine, Augusta County.[1] (See fig. 28, A.) A detailed study of the Crimora mine

[1] Hall, C. E., Geological notes on the manganese deposits of Crimora, Va.: Am. Inst. Min. Eng. Trans., vol. 20, p. 46, 1892.

was made by one of the present writers in May, 1917, and a report is now in preparation. Near Elkton[1] manganese ore was mined from a U-shaped trough in the Watauga shale, but no other deposits with such associations are known.

At the Crimora mine over 300,000 tons of manganese ore has been recovered from a deposit about 20 acres in extent that lies in a trough formed by the Erwin quartzite. The trough trends N. 40° E. and is therefore slightly inclined to the ridges adjacent to the Blue Ridge, which limit it, and it plunges southwest under the low plain that here forms a part of the Shenandoah Valley. The trough is bounded on the northwest by an anticline, which also plunges southwest into the valley. Much ore has been recovered at depths ranging from 100 to 200 feet below the surface, but the limits of ore toward the southwest end of the deepening trough are not known. Explorations of the deposit at the Crimora mine, which has yielded more manganese than any other in the region east of the Allegheny Mountains, and of other deposits that have similar relations confirm the tentative conclusion that troughs in which the beds have low dips are the most favorable sites for the accumulation of ore.

Other deposits of manganiferous iron and manganese ore which occupy troughs in the Erwin quartzite occur at the Mount Torry mine, near Sherando, and the Red Mountain mine, 5 miles east of Pekin siding, on the Norfolk & Western Railway, Augusta County.

3. In the deposits of the third type manganese oxides replace porous sandstone along crushed zones in the Erwin quartzite. One deposit of this type has been prospected in the southeastern part of the Mount Torry tract, south of Sherando, and another on Dry Run, 9 miles northeast of Luray, is being actively mined by the Compton Manganese Co. Such crushed zones appear to be irregular in distribution. They yield siliceous ore and, as they occur in hard rocks, are expensive to exploit.

4. A fourth type of deposit is represented by that explored near Dargan, Washington County, Md.[2] (fig. 28, D). This deposit occurs along a fault zone in clay derived in part from the decomposition of limestone (Tomstown) on one side and shale (Harpers) on the other. Such deposits appear to be uncommon, and no others are known in the belt from Potomac River to Vesuvius, Va. They appear to yield small quantities of ore.

5. The fifth type of deposit in this region of which the structural relations are known is represented by that at Midvale, explored by the Rockbridge Manganese & Iron Co.[3] (See fig. 28, C.) Another of

[1] Hewett, D. F., Some manganese mines in Virginia and Maryland: U. S. Geol. Survey Bull. 640, pp. 42, 61–67, 1916.

[2] Idem, pp. 42, 69–71.

[3] Idem, pp. 42, 54–60.

this type is now being explored on the Kennedy property, 3 miles southwest of Sherando, Augusta County. In these deposits manganese oxides replace the clay zones of sediments that fill an ancient river channel (Midvale) or that form an ancient alluvial fan or gravel terrace (Kennedy). It is a coincidence that the Kennedy deposit is near the outlet of an ancient stream that rose in the high ridges several miles to the south and flowed in a trough directed toward the deposit. Such deposits are flat masses that conform to the depressions in which the sediments were laid down. Exploration by drilling at the Kennedy mine is reported to show the presence of a large quantity of ore, and it is possible that here, as with deposits in troughs, the size may depend upon favorable local structural features.

The field work on which this report is based was directed especially toward the interpretation of the structure of the beds making up the Erwin quartzite, Shady dolomite, and Watauga shale. The tracts in the belt examined that are considered favorable to the accumulation of manganese or manganiferous iron ore are those which are underlain by troughs of the upper beds of the Erwin quartzite, from the surface of which the products of decay of the overlying Shady dolomite have not been removed. The six tracts that are described in the following pages fulfill these conditions, but the troughs are considered favorable in proportion to the size of the area that has drained into them, or to the abundance of float ore present and the thoroughness of the decay of the rocks over the Erwin quartzite.

A number of faults have been recognized in this belt, but as the factors which determine the parts of the fault zones that are favorable to accumulation of ore are not known, and as the only deposit known to lie along a fault is not large, it would not be wise to direct exploration along such faults.

RELATION OF DEPOSITS TO SURFACE FEATURES.

In a recent report[1] it has been suggested that several manganese deposits in the region between Potomac River and Midvale, Rockbridge County, Va., occur under conditions that make it appear that they were formed during or soon after the period in which the valley-floor peneplain was being established. This peneplain has been considered to be of early Tertiary age and for brevity it will here be referred to as the early Tertiary peneplain. It was also noted that several deposits crop out at the level of this plain, without regard to the extent to which the plain was locally dissected. The present investigation has shown that the outcrops of a number of additional

[1] Hewett, D. F., op. cit., pp. 37–71.

deposits lie close to the position of this peneplain, but also that the lowest point of one deposit—that at Red Mountain, northeast of Vesuvius—occurs 400 to 500 feet above the level of this plain, and that the surface near the Lyndhurst mine is not 50 feet below the early Tertiary plain, as stated in a previous report by the senior author,[1] but nearly 250 feet below it. Therefore, while the conditions during or soon after the early Tertiary peneplanation appear to have been particularly favorable to the accumulation of certain deposits of manganese and possibly of iron ores, others were probably formed at an earlier and some at a later period.

Evidence collected during this investigation shows that although four periods of planation may be recognized,[2] the recent physiographic history has probably been even more complex.

Although field work has shown that the Midvale and Kennedy deposits are in alluvial material laid down near the level of the early Tertiary plain and the region contains many remnants of gravel on this plain, there is no way of recognizing, in advance of exploration, the places where these gravels may contain deposits of manganese ore.

According to the hypothesis previously stated, that troughs present the most favorable structure for the accumulation of manganese ores, those troughs which pitch at a low angle under the early Tertiary plain would be the most favorable, and the parts of the troughs most likely to receive the deposits should be those where the top of the Erwin quartzite is not more than 300 feet below the present surface of the ground.

ORIGIN OF THE DEPOSITS.

A hypothesis of the origin of the manganese deposits of the region is here presented briefly, in so far as it bears on the conditions that are most favorable for the accumulation of manganese oxides. The purpose of this report does not permit the presentation of evidence bearing upon some phases of the hypothesis.

Definite evidence concerning the source of the manganese that now makes up the workable deposits is lacking; but, from the data at hand, it appears that the manganese was originally widely disseminated as carbonate in the dolomite and limestone and possibly in silicates in other rocks found in the neighborhood of the deposits. The manganese was dissolved as bicarbonate and transported along established channels of circulation to the places where the oxides are now found, in clays produced by the previous decay of sericitic shales, limestone, and dolomite. The oxides were probably deposited when and where the solutions containing manganese bicarbonate

[1] Hewett, D. F., op. cit., p. 61.
[2] Watson, T. L., Drainage changes in the Shenandoah Valley region of Virginia: Virginia Univ. Philos. Soc. Bull., Sci. ser., vol. 1, p. 355, 1913.

met oxygen-bearing waters. Manganese oxide appears to have been deposited largely by replacing the clay, although small quantities were deposited in open spaces. The largest deposits of manganese were formed in places where the maximum amount of manganese in solution met the most favorable conditions for deposition. Most complete rock decay and, therefore, solution of the maximum proportion of manganese in the rocks are probably attained in regions of low relief having a thick cover of vegetation, under the influence of a warm, moist climate. As the process of solution would be most active in those parts of the region above the average level of streams and above ground-water level, more manganese should be delivered in solution to the belt of country where the ridges and hills meet the plains than elsewhere.

If not diverted by the local rock structure the maximum flow of solutions near the surface would have occurred near or directly under surface stream channels. Where oxidation was possible deposits formed in the stream channels themselves As deeper circulation of surface waters was controlled by rock structure, troughs would have received the maximum circulation, although fault zones might have been locally favored. According to this hypothesis structural troughs were the most favorable channels for circulation, and if suitable conditions for oxidation and deposition existed they should be the most favorable places for accumulation.

Many reports have been published which describe briefly the associations of manganese ore in certain mines in Virginia, but most of the available information concerning the stratigraphic and structural relations of the deposits in Virginia is contained in reports that are based on comprehensive studies of many deposits in a large area.[1] The relation of the hypotheses of origin of the manganese deposits set forth in these reports will be discussed in a later report.

TRACTS RECOMMENDED FOR EXPLORATION.

BASIS OF RECOMMENDATIONS.

Descriptions of six undeveloped tracts along the west front of the Blue Ridge are presented below. These tracts appear to present features favorable for the accumulation of deposits of manganese and manganiferous iron ores, and prospecting with the view to dis-

[1] Penrose, R. A. F., Manganese, its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 401–412, 1891.

Hall, C. E., Geological notes on the manganese ore deposits of Crimora, Va.: Am. Inst. Min. Eng. Trans., vol. 20, pp. 46–49, 1892.

Watson, T. L., Mineral resources of Virginia, Virginia Geol. Survey, 1907.

Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, 1910.

Hewett, D. F., Some manganese deposits in Virginia and Maryland: U. S. Geol. Survey Bull. 640, pp. 37–71, 1916.

covering such deposits is recommended. Formerly such deposits were prospected by means of pits and trenches, but recently improvements in methods of employing the churn drill make it most useful for this purpose, and several operators use it extensively. Even if deposits should exist under these tracts, they may be covered by gravel or wash from the neighboring slopes, as at the Crimora mine, and exploration by drilling is peculiarly adapted to such conditions.

These tracts are regarded as favorable for exploration largely because they have the same structural and stratigraphic features as other areas within which large deposits of manganese and manganiferous iron ores are known and bear a similar relation to the surface. They are described in the order of greatest promise, the one in which the conditions are believed to be most favorable first. Fragments of manganese minerals have been found on the surface of many tracts, but as such fragments are widespread in this region they are not especially significant. Positive assurance that these tracts contain workable deposits of ore can not be given, but to those interested in searching for unknown deposits of these ores the tracts should offer an attractive field.

TRACT 1.

Tract 1 lies 2 miles southwest of Elkton, within a mile of the Norfolk & Western Railway. (See fig. 29.) The west front of the mountains in the vicinity of Elkton has many sharp offsets in its general southwest course. From Swift Run this course is a little south of west for 1½ miles to a point where the mountain front is slightly offset to the northwest. From that point the front runs west-southwest across Hawksbill Creek for 1¼ miles to a sharp offset to the east of about half a mile. The southwestward course then continues for three-fourths of a mile but is interrupted by a second sharp offset to the east of about a quarter of a mile. At Gap Run, three-quarters of a mile beyond, the mountain front is slightly offset in the opposite direction, to the west, but the southwest trend is maintained. At Swift Run the mountain front is offset to the southeast, and beyond Elk Run the front ridge breaks down to low knolls for over a mile.

Along the west flank of the mountains, immediately west of the line just traced, there are gravel-covered terraces that slope toward Shenandoah River and are deeply trenched by cross streams. No rock exposures occur in the gravel-covered belt, but several mine shafts and test pits show that it is underlain by lower members of the Shenandoah group of limestones (Shady dolomite and Watauga shale). The gravel-covered area is 1 to 1¼ miles wide, except for a short stretch at the mouth of Hawksbill Creek, where it is reduced in width to about a quarter of a mile by the eastward bend of Shenandoah River. West of the gravel terraces at the mouth of Hawksbill Creek, especially along Shenandoah River, there are exposures of the Watauga shale and overlying beds of limestone.

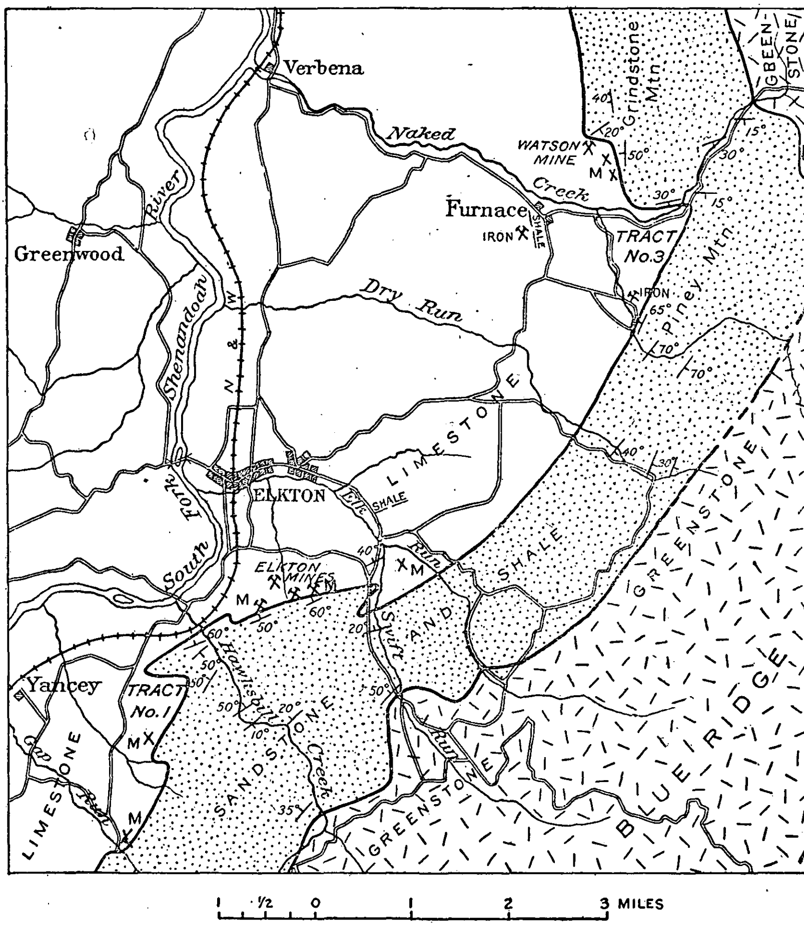

FIGURE 29.—Sketch geologic map of region near Elkton, Va., showing location of tracts 1 and 3.

The western foothills of the Blue Ridge are made up of white quartzite (Erwin), whose structure determined the irregular course of the mountain front. Thus from Swift Run westward for 1½ miles, where the mountain front is straight and trends west-southwest, the quartzite beds strike about parallel to the mountain front and dip 50°–60° NW., passing under the limestone of the valley. The small offset in the mountain front at Hawksbill Creek and the larger one east of Yancey are produced by a detached anticlinal ridge of quartzite which is separated from the main quartzite ridge by a shallow synclinal valley. Both the anticline and the syncline plunge sharply northeast just east of Hawksbill Creek, and the quartzite abruptly passes under the limestone of the valley. Southwest of Hawksbill Creek the folds plunge more gently southwestward, and the quartzite again passes below the level of the gravel-covered plain in that direction. The syncline widens in this direction, as the main ridge of the mountain here strikes more southerly and diverges from the outlying ridge, and the limestone embayment is therefore large and open. The offset in the mountain front three-quarters of a mile farther south is apparently produced by two similar though smaller folds, which plunge south, and the northwest offset at Gap Run is formed by two other flat, gentle folds, which plunge north. The offset east of Swift Run is apparently produced by a northeastward-plunging anticline and syncline, for, although the bedding in the sandstone was not observed, the rocks seen along the road crossing the syncline are believed to be the basal sandy beds of the limestone group. Beyond this offset the mountain front is straight, although the front ridge breaks down beyond Elk Run, where the quartzite is weakened by crushing and probable minor faulting.

Although the white quartzite beds have a general steep westerly dip on the front foothills they flatten out toward the east and cap the tops of several spurs and ridges some distance back from the front, where they are nearly horizontal or even lie in gentle synclines. To the east of and therefore beneath the white quartzite there are shales and arkosic sandstones which are somewhat folded and form a belt half a mile to 1½ miles wide. These basal Cambrian beds rest upon pre-Cambrian greenstone and greenstone schists which generally form the main mass of the Blue Ridge.

There is a group of manganese mines about 1 mile south of Elkton, which will be referred to as the Elkton mines. The old workings are known as the Kendall & Flick mines and include the Niesswaner shaft and Bartell shaft, which have been described by Harder[1] and Hewett.[2] One of the mines is now being worked by the United States Manganese Co. These mines are on a terrace at the base of the quartzite ridge between Swift Run and Hawksbill Creek. Three of the mines, including the easternmost, which alone is active at present, lie close to the top of the northwestward-dipping quartzite, and apparently there is no synclinal structure of the bedrock that determined the concentration of these deposits of ore. As the outer mine, which is about 1,200 feet from the base of the mountain, struck the purple Watauga shale in its deep shaft, the steep

[1] Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, 1910, p. 57.

[2] Hewett, D. F., Some manganese mines in Virginia and Maryland: U. S. Geol. Survey Bull. 640, pp. 61–67, 1916.

westward dip of the beds probably continues out that far, and the small syncline at Hawksbill Creek must therefore plunge steeply northeastward. Just east of Swift Run there is a manganiferous iron prospect which is in strike with the three Elkton mines, but the embayment to the south, between the prospect and the quartzite ridge, which is covered with mountain wash, has not been prospected so far as known and may be worthy of investigation, as the structure of the inclosing rocks is apparently synclinal and favorable for the accumulation of ore.

Southeast of Yancey a manganese prospect north of the small run has been opened by J. H. Crawford and another south of the run by W. B. Yancey. These two prospects have direct bearing on the tract to which particular attention is here directed. The Crawford prospect shaft, which is 75 feet deep, is on the south side of the embayment in the mountain front 1½ miles east of Yancey station on the Norfolk & Western Railway. This embayment is a triangular area about half a mile long and covers about 180 acres. It lies in the reentrant angle between the white quartzite ridges locally called Little Piney Mountain (on the northwest) and Big Piney Mountain (on the southeast). In the saddle between these hills the upper quartzite beds of the Erwin formation lie horizontal in the bottom of the syncline. The quartzite hills diverge toward the southwest, and the syncline plunges in the same direction, so that the trough between the hills incloses the overlying Shady dolomite. At the Crawford shaft, half a mile south of the head of the trough, manganese nodules occur in red clay with chert fragments, which is the characteristic residuum of the Shady dolomite. The entire embayment, therefore, is probably underlain by the Shady dolomite, but it is completely covered by wash from the quartzite mountains. The only means of determining the thickness of the wash and the presence of manganese ore beneath the alluvial covering is by drilling or by digging test pits. The synclinal structure of the quartzite in the surrounding mountains, the favorably located basin filled with wash and underlain by gently dipping beds of the Shady dolomite or its residual clay, and the known presence of manganese ore in the trough justify the recommendation that this triangular area be thoroughly prospected for manganese.

The conditions in the embayment in the mountain just south of this tract are not so well determined. The structure of the quartzite hills around the offset at the north end of the embayment is obscure and is inferred chiefly from the topography, but at the offset at the south end, just north of Gap Run, the quartzite lies in a very shallow, broad syncline. The alluvial filling in this embayment appears to be heavy, but the Shady dolomite or its residual red clay is probably present, as the manganiferous nodules in the Yancey prospect pits occur in red pebbly clay, although chert fragments, such as are characteristic of the Shady dolomite were not seen in it. This area, though not as promising as the embayment east of Yancey, still has sufficiently favorable indications to suggest that further prospecting should be done in it.

TRACT 2.

Tract 2 lies between two spurs of the Blue Ridge about 3 miles southwest of Sherando and 6 miles south-southwest of Lyndhurst, in Augusta County. (See fig. 30.) It is about midway between the Kennedy mine, to the northwest, and the Mount Torry mine, to the southeast, and is drained by Mills Creek. A lumber railroad over which ore from these two mines is shipped passes just north of the tract and joins the Norfolk & Western Railway near Lipscomb. A spur of the lumber road formerly ran southwestward up Mills Creek, but the rails and ties have been removed.

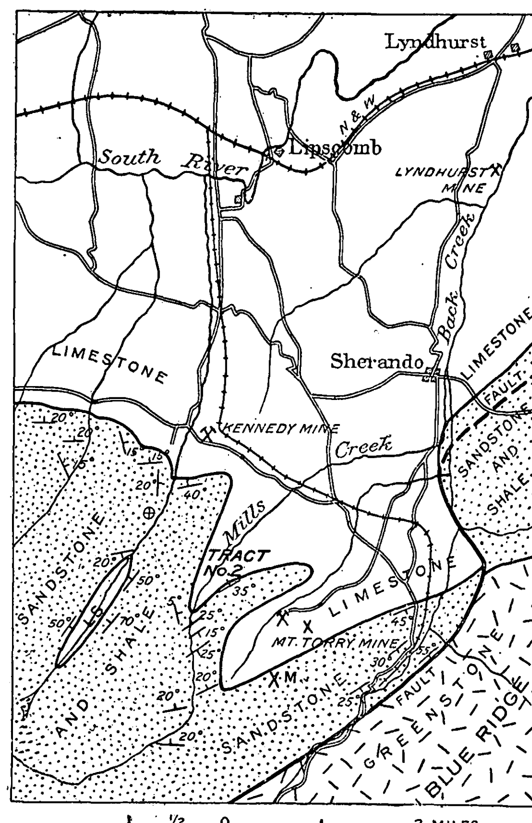

FIGURE 30.—Sketch geologic map of area south of Lyndhurst, Va., showing location of tract 2.

The mountain spurs on both sides of the tract are composed of white quartzite (Erwin), and the structure of each is anticlinal. Both anticlines plunge northeastward, so that in this direction the quartzite descends below the limestones and shales of the Shenandoah Valley. (See fig. 30.) The area between the spurs is a northeastward-plunging syclinal trough and therefore is probably underlain by limestone and possibly some shale, but no outcrops are to be seen, as the surface is covered with quartzite wash from the mountains. The anticlinal spurs on both sides of the plunging synclinal trough diverge to the northeast, so that the limestone belt widens in this direction, forming a wedge-shaped area which is about 1 mile long in a northeasterly direction and about three-quarters of a mile wide between the points of the spurs. This wedge-shaped area merges on its northeast side with the great limestone and shale belt of the Shenandoah Valley.

This synclinal embayment closely resembles the adjacent embayment on the southeast, in which the Mount Torry mine is situated and which also is a synclinal trough. This mine produced a large amount of iron ore 40 or 50 years ago and was abandoned because of the manganese in the ore. Later it was extensively prospected for manganese ore, and some ore was shipped. Both the manganiferous iron ore and the manganese ore are now being mined by a company which has leased the property. This embayment is larger than that on Mills Creek and the syncline is deeper, and although bedrock is not exposed at the surface within the basin, fresh Shady dolomite was encountered in a shaft near the head of the valley.

West of tract 2 there is a smaller embayment of limestone in the mountain front. This embayment occupies a northeastward-plunging synclinal trough, at the mouth of which the Kennedy mine is located. Back in the mountain the syncline deepens and forms a narrow valley which once inclosed limestone between two high, rocky quartzite ridges. This limestone has probably all been removed by erosion, but some may still be present, deeply covered by the quartzite wash. Even if limestone or its residual clay is present, the area is too narrow to expect any large deposit of ore to occur in it, for the ore was probably largely carried out to the mountain front by the former underground drainage and deposited in the clays in which the Kennedy mine is located.

The accumulation of ore in the deposits in which the Mount Torry and Kennedy mines are located was greatly aided by the synclinal structure of the quartzite and overlying limestone. The ore is found in the undisturbed residual clay from the limestone and in overlying clay mixed with quartzite gravel and boulders, where solutions deposited the manganese oxides in crevices or bedding planes, and in nodules and masses replacing the clay. The structural conditions in tract 2 appear to be equally favorable for the accumulation of manganese ore in commercial quantity, and although no manganese ore has been reported there, possibly because of the deep filling of the basin with wash, the favorable structural relations warrant search for the ore. It is therefore recommended that the tract be thoroughly prospected by drilling.

TRACT 3.

Tract 3 lies between Grindstone and Piney mountains, two foothills of the Blue Ridge about 5 miles northeast of Elkton. (See fig. 29, p. 284.) It is chiefly in Rockingham County, but partly in Page County. Naked Creek, which flows near the north edge of the tract, forms the boundary line between the two counties. So far as known, no prospecting for manganese has been done within the area, but the Watson mine is about 1 mile to the north-northwest, and a number of manganese prospects are scattered along the west base of Grindstone Mountain, between it and this tract.

White quartzite (Erwin) is exposed on the crest and most of the west slope of Grindstone Mountain. In general its strike is parallel with the mountain, which trends N. 10°–20° W., and it dips 40°–50° W., passing beneath the limestone and shales that are exposed in the Shenandoah Valley. A small embayment near the south end of Grindstone Mountain is formed by a steeply plunging syncline. No limestone is exposed at the surface in this syncline, but residual clay from the limestone was observed at the Watson mine and in the prospects near by, all of which are in the syncline. This residual clay retains the original bedding of the limestone and incloses decomposed chert that is characteristic of the Shady dolomite. The clay is overlain by and at the top is partly mixed with quartzite boulders, which are especially numerous on the flat wooded spurs that extend southward from the base of the mountain.

Grindstone Mountain ends abruptly at Naked Creek, where the mountain front is offset about a mile to the east and thence continues south in Piney Mountain. The crest and most of the west slope of Piney Mountain are formed of the same white quartzite, which strikes S. 25° W. and dips at a high angle toward the Shenandoah Valley. This offset is caused by an anticline and associated syncline, which are similar to but larger than those at the Watson mine, a mile to the north. The folds are so broad and open and plunge so steeply to the southwest that the strike of the Erwin quartzite here makes two nearly right-angle bends. (See fig. 29.) In the syncline a limestone, which is probably the Shady dolomite, is inclosed above the white quartzite. The limestone is not exposed near the mountain, but a sink hole and red clay residual from limestone seen in a stream bank close to the west slope of Piney Mountain are sufficient evidence of its presence under the covering of wash. Dolomite beds are exposed in Naked Creek south of the Watson mine and also farther out in the valley. The axis of the syncline strikes northeast between the two mountains but lies south of Naked Creek. Along the creek the white quartzite beds, which are north of the synclinal axis, strike N. 70° E. and dip 15°–30° SE. To the east, up the creek the older

Cambrian sandy shale and slate of the Hampton formation and arkosic sandstone and conglomerate of the Unicoi formation crop out beneath the white Erwin quartzite, with similar low southerly dips and nearly east strike. At the base of the Cambrian rocks purple ferruginous sandstone rests on pre-Cambrian greenstone schists.

The ore at the Watson mine consists of concretionary psilomelane and pockets of wad in residual clay of the Shady dolomite. It was mined by means of a shaft and two tunnels and was concentrated in a mill at the mine, but no mining has been done here for several years. Similar ore occurs at the prospect pits along the foot of the mountain for about half a mile southeast of the mine. The mine and prospects are located in a small syncline and are therefore favorably situated for the accumulation of manganese ore, but large, rich deposits are probably not to be expected because of the small size of the syncline. The tract near Naked Creek, however, is larger and more favorably situated for the accumulation of ore, because the syncline from which ore could have been concentrated there is broad and open. Although no ore has been reported from this tract, it is recommended that the tract be thoroughly prospected by drilling or digging pits. It is not advisable to prospect in the stream flats of Naked Creek and its tributary flowing north at the west base of Piney Mountain, for but little, if any, residual clay in which manganese ore would be expected occurs here between the alluvium and the unaltered limestone. Prospecting should be confined to the area between these two creeks.

TRACT 4.

Tract 4 is an irregular lowland area inclosed by low hills, 3 miles northeast of Waynesboro. (See fig. 31.) This region is served by the Shenandoah Valley branch of the Norfolk & Western Railway and the Chesapeake & Ohio Railway, which cross at Basic City.

The boundary between the Blue Ridge and Shenandoah Valley here follows a very irregular but general southwesterly course, which is determined by the irregular structure and distribution of the underlying rocks. Some of the foothills are so low that it is difficult to decide where the boundary between foothills and valley should be drawn. The westernmost foothills of the Blue Ridge are composed of white Cambrian (Erwin) quartzite. Sawmill Ridge and Ramsey Mountain form the main ridge of the white quartzite in this area, and quartzite beds on their west slopes dip 50° W., toward the valley. East of Ramsey Mountain and Sawmill Ridge the white quartzite is underlain by older Cambrian sandy shales and dark arkosic sandstones of the Hampton and Unicoi formations, and east of these are the pre-Cambrian greenstones and schists that compose the larger part of the Blue Ridge. West of the mountain front the

Shenandoah Valley is underlain by Cambrian limestones, dolomites, and shales of the lower part of the Shenandoah group, but these beds are not exposed near the foot of the mountains because of the thick covering of mountain wash consisting of gravel, sand, and clay.

West of Sawmill Ridge there is a low, narrow hill whose anticlinal character is well shown on the road up Sawmill Run, where the anticline plunges south. The narrow valley between this hill and Sawmill Ridge is therefore synclinal and probably contains some Shady dolomite overlying the quartzite. Manganese ore was mined on the Watts property in this syncline many years ago. From the west side of Ramsey Mountain a low ridge that extends 1 mile to the west is made up of several narrow north-south hills with shallow saddles between them. Although no outcrops from which the dip of the rocks could be determined were seen on these hills, they are covered

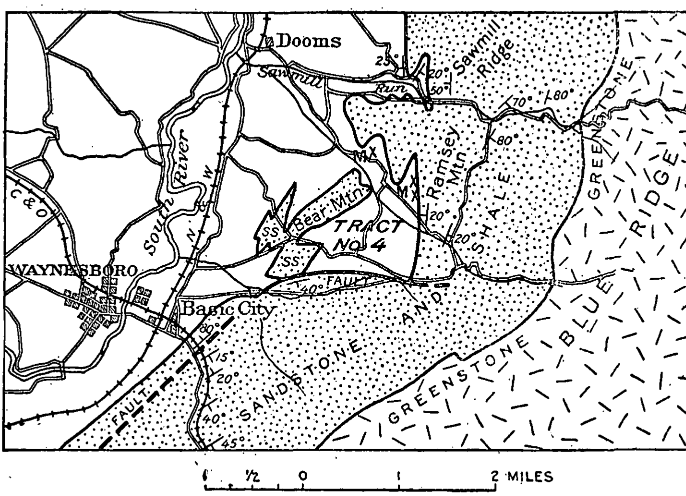

FIGURE 31.—Sketch geologic map of region near Waynesboro, Va., showing location of tract 4.

with angular quartzite fragments nearly in place, and the hills are believed to be small anticlines which plunge steeply to the north, toward Sawmill Run, and less steeply to the south. Between the south ends of these hills are small embayments which are structurally synclinal troughs, and two of them are sufficiently large to inclose the overlying Shady dolomite or its residual clay. In fact, fragments of chert derived from the Shady dolomite were found in the alluvial fill of the valleys. The quartzite in the low hills is seemingly that of the upper beds of the Erwin formation.

West of Ramsey Mountain, across an alluvium-filled valley three-fourths to 1 mile wide, is a group of low hills, including a higher one called Bear Mountain. These are quartzite hills which are covered with angular fragments of quartzite and cemented quartzite breccia, but no rock ledges from which the structure could be determined were seen. The hills are believed to be anticlinal in structure and to be made up of several low anticlines in which the quartzite is barely exposed at the surface. Between the individual hills are several small valleys or hollows, presumably occupying synclinal troughs, which, if not too shallow, may contain Shady dolomite. Those on the north and east sides merge with the embayments on the south side of the quartzite hills to the north, which are known to contain chert residual from the dolomite. These structural troughs, which are large and deep enough to contain a considerable body of the Shady dolomite, or its residual clay, are favorable for the accumulation of manganese ore bodies. A prospect pit northeast of Bear Mountain found considerable manganese ore, and two other prospect pits on the west flank of Ramsey Mountain also show ore. In fact, the whole lowland southwest of Ramsey Mountain and southeast of Bear Mountain is believed to be underlain by residual clay from limestone and therefore to have favorable structural conditions for the accumulation of ore. The surface of much of this area, especially the portions close to the quartzite hills, is strewn with small pieces of flinty iron ore, and the soil is markedly red in places. Both of these features indicate the probable presence of the basal beds of the Shady dolomite, in which some ore has been deposited. The limestone lowland and the white quartzite of Ramsey Mountain are abruptly terminated at the south by the older Cambrian shales and arkosic sandstones, which have been thrust westward about 2 miles along an east-west fault, the trace of which lies close to the main road from the gap south of Ramsey Mountain to Basic City.

Because of the favorable structure just described it is recommended that the triangular valley of about 1 square mile lying north of the fault and extending from Ramsey Mountain to Bear Mountain, with its two northward synclinal prongs, be thoroughly prospected by drilling or test pits to determine the presence of manganese. The small synclinal valleys west and southwest of Bear Mountain are also recommended as possibly containing workable deposits and worthy of examination. The small syncline on Sawmill Run is likewise favorable, but large deposits are not to be expected there.

TRACT 5.

Tract 5 lies 6 miles due south of Luray and just northeast of Marksville. (See fig. 32.) As it is a limestone valley inclosed by quartzite ridges it may prove worthy of careful prospecting. The main quartzite ridge of the mountain front is broken down east of the village of Stony Man (Blosserville), as the white Erwin quartzite is here crushed by faulting. South of Stony Man the ridge appears to be anticlinal, with a fault on its southeast side, and farther southwest, west of Ida, there are two quartzite ridges, the outer one apparently anticlinal, so that the valley between them is a syncline. The fault east of the quartzite cuts out the Hampton shale to the southwest, bringing the Unicoi sandstone and Erwin quartzite together. These are minor structural features, however, and even if the synclines in the white quartzite inclose limestone, as is suggested by exposures of certain residual clays, they are hardly to be regarded as favorable for the accumulation of large manganese deposits.

Northeast of Marksville an outlying quartzite ridge trends northeast, and although large masses of rock cover its surface no rock was observed in place, and the structure could not be determined. It is believed to be an anticline, however, but may be faulted on the west side. The valley between the outlying ridge and the main ridge of the mountain front is deeply covered with sandstone wash, and the bedrock is concealed, but with the quartzite fragments there is much iron-ore float and some ferruginous chert derived from limestone. This valley is therefore believed to be a synclinal limestone valley between two quartzite ridges and thus to be structurally favorable for the accumulation of manganese ore. Manganese ore has not been mined in this area, but in a small synclinal valley on the mountain side 2 miles southwest of Marksville some old workings show fragments of manganese oxide, and preparations are being made to reopen the workings.

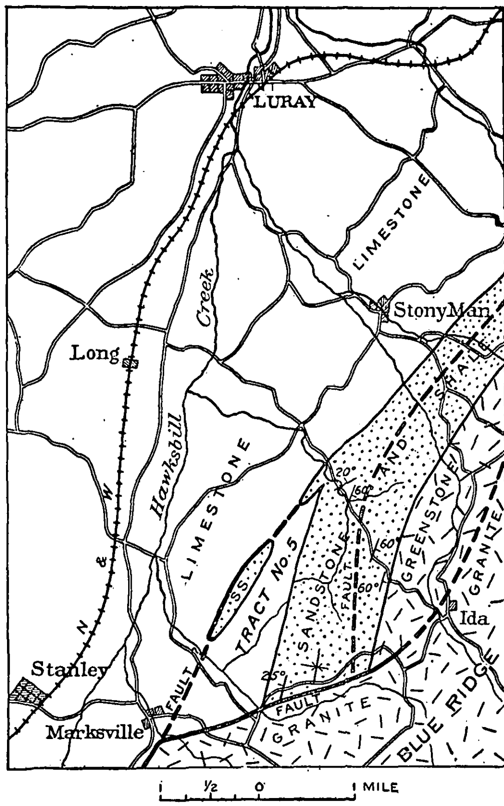

FIGURE 32.—Sketch geologic map of area south of Luray, Va., showing location of tract 5.

The limestone embayment opens into the main valley both at the north and south, but as a fault probably breaks the limestone at these places the bedding is not continuous across these breaks and the syncline is cut off. The synclinal basin therefore forms a wedge-shaped area with the point at the northeast, over 2 miles long and a mile in width at its southwest base. At the southwest it is cut off by pre-Cambrian granite, which is faulted across the end of the basin. The granite has been moved westward along the east-west fracture and now abuts against the ends of first the pre-Cambrian greenstone beds southwest of Ida, then successively the basal Cambrian sandstones and shales (Unicoi and Hampton), the upper white quartzite (Erwin), and finally the limestone of the inclosed valley. The fault thus caused a horizontal displacement of the rocks of at least 3 miles at this place.

This wedge-shaped embayment is regarded as a desirable place to prospect for manganese deposits, as its structure is favorable for the concentration of any manganese that may have been originally present in the surrounding rocks. The portion of the embayment south of the stream and road is a lowland with little coarse wash and has apparently been recently scoured by the stream, so that if ore were originally deposited there it has probably been removed by erosion. The higher part of the area, north of the road, is deeply covered with wash and is more favorable for the occurrence of ore, particularly that portion which lies at or near the saddle in the valley between the outer ridge and the main ridge.

TRACT 6.

Tract 6 is a small area of valley and mountain slope in the vicinity of the Seibel manganese mine, near Happy Creek station on the Southern Railway, 3 miles east of Front Royal. (See fig. 33.) This tract is worthy of careful prospecting for manganese, which can be done most readily with the drill. The rocks of this area are unusually well exposed in the Southern Railway cuts east of the mine. Here the pre-Cambrian greenstone is succeeded on the west by nearly vertical beds of arkosic gray and purple banded sandstone and conglomerate which represent the basal formation (Unicoi sandstone) of the Cambrian. These beds are followed by purple shaly arkosic beds, hackly sandy shales, and soft buff sandstones with low dips and minor folds, and these in turn by nearly vertical, thicker, harder argillaceous sandstone with some thin dark shale partings which represent the Hampton shale. Then follows the main ridge-making upper white quartzite (Erwin), which is nearly vertical but also somewhat folded and much brecciated, the fragments being cemented in part by limonite.

At the foot of the west slope of the mountain is the Seibel manganese mine, described in detail by Hewett.[1] The manganese and manganiferous iron in a new pit at the mine clearly occur in clay that in part retains the original bedding of the limestone from which it was

[1] Hewett, D. F., op. cit., pp. 67–69.

derived and incloses decomposed chert from the limestone. This clay is residual from the Shady dolomite at the base of the Shenandoah group of limestones, for purple shale, residual banded clay, and thin sandstone of the next overlying formation (Watauga shale) crop out near the wagon road west of the mine. In the mine pits the residual clay merges at the top with mottled clay that has moved somewhat down the slope and has been more or less mixed with the sandstone wash from the mountain. The overburden is not more than 10 feet thick at the mine. The ore seems to be mostly deposited in the undisturbed residual clay.

At the west end of the railway cut there is a small detached mass of brecciated white quartzite, which evidently forms a small anticline on the west flank of the main quartzite mass, although it is so highly brecciated that the anticlinal structure can not be determined in the railway cut. The small ridge which this quartzite mass makes on the flank of the main quartzite ridge west of the railway is covered with fragments of the quartzite, but there are no bedrock outcrops on it. It declines toward the southwest and merges into the wash-covered terraced mountain slope on which the Seibel mine is located. In the swale between the main ridge and this small ridge is much iron-ore float and several shallow pits which show considerable manganese oxide. This swale is on the axis of a small syncline that plunges southwestward toward the Seibel mine and incloses the residual clays of the basal limestone beds which rest on the top of the gently dipping white quartzite. Its structure is therefore favorable for the accumulation of manganese ore. The fold, however, is so small that the embayment can not be regarded as likely to furnish a large quantity of manganese and would not be classed as favorable for prospecting if it were not for the good showing of ore at the surface and in the surface pits over a considerable area northeast of the Seibel mine.

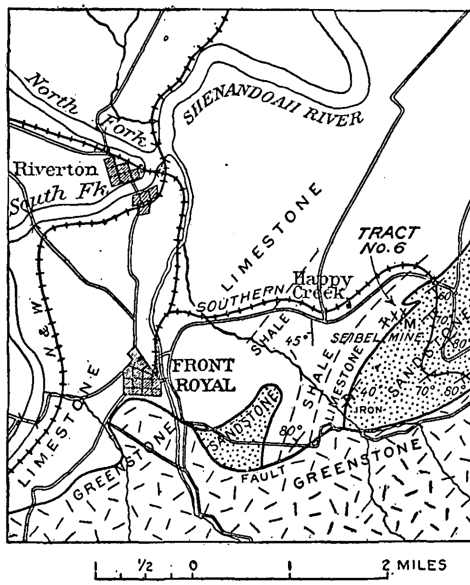

FIGURE 33.—Sketch geologic map of area east of Front Royal, Va., showing location of tract 6.

An iron mine was formerly worked by the Seibel Co. 1 mile southwest of the manganese mine, on the flank of the same ridge. In the mine pit the brecciated white quartzite clearly overlies banded yellow clay residual from the Shady dolomite, which dips 40° SE., so that the beds are overturned. The unaltered Shady dolomite was encountered in a tunnel below the pit. These rocks strike southwestward but are cut off in this direction by the pre-Cambrian greenstone, which is faulted across the ends of the beds. The greenstone has been moved westward along the fault, resting against the ends first of the basal Cambrian beds, then in turn the white quartzite, the residual clay of the Shady dolomite, and lastly purple shales and thin sandstone of the Watauga formation. The horizontal movement of the greenstone was at least 2 miles. To the west the brecciated quartzite makes another low hill 1 mile from Front Royal, which is believed to be a crushed anticline, although the rock outcrops do not fully indicate the structure. The limestone lowland between this sandstone hill and the Seibel iron mine is therefore synclinal. However, on account of the crushing of the quartzite, the marked overturning of the fold at the iron mine, and the probability of minor faulting, this larger syncline is not regarded as particularly favorable for the occurrence of large deposits of manganese ore, although the residual clay is stained in places by manganese oxide.

The most favorable place for prospecting with the drill in this area, therefore, is along the mountain front in the vicinity of the Seibel mine, particularly northeast of the mine, between it and the railway, and search there for commercial deposits is recommended.

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