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DIRECTOR

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Manganese Deposits of the West Foot of the Blue Ridge, Virginia

BY

G. W. STOSE, H. D. MISER, F. J. KATZ,
D. F. HEWETT

PREPARED IN CO-OPERATION WITH THE
UNITED STATES GEOLOGICAL SURVEY

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VIRGINIA GEOLOGICAL SURVEY,

UNIVERSITY OF VIRGINIA,

CHARLOTTESVILLE, May 1, 1919.

Governor Westmoreland Davis, Chairman, and Members of the State Geological Commission:

GENTLEMEN:—I have the honor to transmit to you herewith, and to recommend for publication as Bulletin No. XVII of the Virginia Geological Survey Series of Reports, a manuscript and illustrations of a report entitled "Manganese Deposits Along the West Foot of the Blue Ridge in Virginia," by G. W. Stose, H. D. Miser, F. J. Katz, and D. F. Hewett.

This report, prepared in coöperation with the United States Geological Survey, while being a real contribution to the science of ore deposits, gives a clear exposition of the nature of the manganese deposits of the important Blue Ridge region of Virginia, and should prove of much practical value in future mining developments in that part of the State.

Respectfully submitted,

THOMAS L. WATSON,
Director.

MANGANESE DEPOSITS ALONG THE WEST FOOT OF THE BLUE RIDGE IN VIRGINIA

By G. W. Stose, H. D. Miser, F. J. Katz, and D. F. Hewett.

INTRODUCTION

Manganese deposits occur sporadically along the whole west foot of the Blue Ridge in Virginia, Tennessee, and Alabama. The deposits along the part of the Blue Ridge in Virginia described in this report have yielded most of the output of this State, whose total production, from 1867 to 1917, inclusive, 265,745 tons, exceeds that of any other State. The annual domestic production for a number of years, however, has been small in comparison with the quantity of ore that has been imported. In the past two years, when ships were so greatly needed for service between the United States and our associates in war in Europe, it was necessary that the domestic production be increased as much as possible. Since the world war began the United States Geological Survey and the State Surveys, including the Virginia Geological Survey, have been making a special effort to stimulate interest in manganese mining in this country.

The field and office work for this report has been done jointly by the Virginia Geological Survey and the United States Geological Survey. The field work consisted not only of an examination of the mines and prospects, but also of studies of the physiographic and stratigraphic conditions under which the manganese deposits of the region here described were formed, and of the application of the hypothesis proposed by D. F. Hewett, in a previous publication, for the discovery of new ore bodies. This hypothesis is presented below in the chapter on "ore deposits" (p. 41). A reconnaissance of the central part of the region between Vesuvius, Rockbridge County, and Elkton, Rockingham County, was made in June, 1917, by Dr. T. L. Watson, State Geologist, and Arthur Keith, M. R. Campbell, D. F. Hewett, G. W. Stose, Laurence LaForge, F. J. Katz, and J. B. Umpleby, of the United States Geological Survey, to test the application of the above hypothesis. As a consequence the field work in this part of the Blue Ridge was, in August, 1917, continued and extended to Front Royal, Warren County, by G. W. Stose, F. J. Katz, and H. D. Miser. A less thorough examination of the west foot of the Blue Ridge between Buchanan, Botetourt County, and Roanoke, Roanoke County, and the region between

Ivanhoe, Wythe County, and Quebec, Smyth County, was made in October, 1917, by Katz and Miser, and an examination of Currin Valley and an area southwest of Marion, Smyth County, was made during the same month by Stose. A reconnaissance of the part of the Blue Ridge between Vesuvius and Buchanan had been previously made by Stose in 1912 and 1914. The results of studies of the producing manganese mines in the region by Hewett, and of the earlier reconnaissance of all the prospects in the region by Harder have also been embodied in this report. The areas herein described were selected for examination because of the increased mining activity and prospecting within them, with the view of obtaining information which might not only aid in increasing the output from the mines, but also encourage the opening of new mines in geologically favorable situations.

The method of study in the field was 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 strip of country examined 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 features and the distribution of distinctive débris derived from the several formations.

In addition to the traverses for the purpose of making the accompanying map (Pl. III), and determining the structure of the rocks, manganese and iron mines, prospect pits, and holes of every 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 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 from which it was derived by weathering, so that the structural relations of the ore to these rocks could be determined.

A preliminary report presenting briefly the results of the field work for this study, and describing several undeveloped tracts which, from the structure of the inclosing rocks and the surface relations are regarded as favorable for the occurrence of manganese ore, has been published in Bulletin 660 of the United States Geological Survey.

The map accompanying this report (Pl. III) is based on a detailed reconnaissance mainly by Stose, Katz, and Miser. From Front Royal, Warren County, to the Kennedy mine, Augusta County, the geologic boundaries of the formations along the mountain front, especially the contact of the Erwin quartzite and the Shady dolomite, which is intimately related to the manganese deposits, are accurately located. Those within the mountains are less accurate and are based on more widely separated observations. From the Kennedy mine to Buena Vista, Rockbridge County, the boundaries are all less accurately traced except in the vicinity of mines and prospects visited, and are based on more scattered observations and traverses. From Buena Vista to Buchanan, Botetourt County, where no mines or prospects were visited, the boundaries, except in the James River gorge, are based on a more hasty reconnaissance, and the relations of the faulted masses have not been satisfactorily worked out. From Buchanan to Fullhardt Knob, 9 miles northeast of Roanoke, the boundaries are accurately located, and many mines and prospects were visited. In the Cripple Creek Valley, in Smyth and Wythe counties, the boundaries were largely taken from geologic maps by E. V. d'Invilliers[1] and C. R. Boyd,[2] modified to accord with observations by the present authors in their reconnaissance of the area. They are not accurate for this reason and also because the base map is poor. In Rye Valley, Currin Valley, and the area southwest of Marion, Smyth County, the mapping is as accurate as the base map of the area would permit.

The base maps of certain of the manganese mines (Pls. XIII, XIV, XV, XVIII, XIX, XXI, and XXII) were prepared by the Virginia Geological Survey.

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. Below is given a list of reports treating of the manganeses deposits of the west foot of the Blue Ridge in this State:

[1] McCreath, A. S., and d'Invilliers, E. V., The New River-Cripple Creek mineral region of Virginia, Harrisburg, Pa., 1887.

[2] Boyd, C. R., Wythe County, Virginia, with part of Pulaski County, Philadelphia, Pa., 1888.

Ball, S. M., Manganese deposits of Virginia: Eng. and Min. Jour., vol. 87, p. 1056, 1909.

Boyd, C. R., Resources of southwest Virginia: John Wiley & Sons, New York, 1881.

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

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

Hewett, D. F., Stose, G. W., Katz, F. J., and Miser, H. D., Possibilities for manganese ore on certain undeveloped tracts in Shenandoah Valley, Virginia: U. S. Geol. Survey Bull. 660, pp. 271-296, 1918 (Bull. 660-J).

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McCreath, A. S., The mineral wealth of Virginia tributary to the lines of the Norfolk & Western and Shenandoah Valley railroad companies, Harrisburg, Pa., 1884.

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————, Biennial report on the mineral production of Virginia during the calendar years 1909 and 1910: Virginia Geol. Survey Bull. 6, pp. 23-26, 1911.

————, Biennial report on the mineral production of Virginia during the calendar years 1911 and 1912: Virginia Geol. Survey Bull. 8, pp. 5-6, 1913.

Watson, T. L. and Wherry, E. T., Pyrolusite from Virginia: Jour. Wash. Acad. Sci., vol. 8, No. 16, 1918, pp. 550-560.

GEOGRAPHY

The region herein described lies at the border between two topographic provinces, the Appalachian Valley and the Appalachian Mountains.

APPALACHIAN MOUNTAINS PROVINCE.

This province embraces a mountainous belt to which the name Appalachian Mountains is generally applied, and in Virginia is generally called the Blue Ridge. It is characterized in most places by linear ridges trending southwest, but in places the ridges and mountains are less regularly arranged, and elsewhere it is a broad plateau on which higher ridges stand.

North of Front Royal the Blue Ridge in Virginia is a single straight ridge with few spurs or foothills. South of Front Royal the crest of the main ridge is less regular in direction and is flanked on the west by high and prominent spurs separated by deep rugged valleys. Its height increases from about 2,000 feet at Front Royal to over 3,500 feet southeast of Luray, where Stony Man and other peaks reach altitudes above 4,000 feet. Thence southwestward the foothill ridges on the west side of the main Blue Ridge are of special importance in the present study, for the manganese ores are mostly associated with the rocks composing them. These foothill ridges dwindle to small hills east of Waynesboro where the Blue Ridge locally narrows again to a single ridge, but they rise to even greater prominence south of Waynesboro where the Blue Ridge is a wide belt of high irregular mountains. Southwest of Vesuvius the front ridges are straight and well defined, but some of the hills are small, sharp conical knobs. (See Pls. V and VI.) Beyond Buchanan the ridges and knobs of the foothills are less prominent, and the main Blue Ridge is a single narrow ridge with only a few spurs. This front ridge ends 8 miles northeast of Roanoke, but back ridges continue on southwest and join the main Blue Ridge beyond Roanoke.

Southwest of Roanoke the Blue Ridge is a plateau having a general upland level of 3,000 feet. The eastern edge of the plateau, which is somewhat higher than the plateau level, is generally regarded as the main Blue Ridge. Mountains rise above the plateau here and there, one of the most prominent of which is Poor Mountain, about 4,000 feet in elevation, which makes the mountain front 10 miles southwest of Roanoke. Farther southwest the western edge of the plateau is marked by a low ridge, which south of Wytheville rises to greater prominence and in southwestern Virginia forms Iron Mountain, over 4,000 feet in altitude. Its foothill ridges cover a wide belt in Wythe and Smyth counties, and south of Marion these expand in width so that they unite with an outlying group of ridges called the Brushy Mountain group, inclosing between them and the main Blue Ridge a long southwestern arm of the Appalachian Valley known as Rye Valley. Another group of outlying ridges called Lick Mountains are entirely detached from the Blue Ridge, but are virtually an eastward equivalent of the Brushy Mountain group. Between Lick Mountains and Iron Mountain lies Cripple Creek Valley, which is continuous with Rye Valley. Southwest of Marion, Brushy Mountain and the other foothill ridges end abruptly, and Iron Mountain forms the mountain front to the Tennessee State line. In the portion of the Appalachian Mountains province south and west of Roanoke County the trend of the ridges is more nearly west than it is northeast of Roanoke.

APPALACHIAN VALLEY PROVINCE.

The Appalachian Valley province is a belt of valleys and ridges which lies west of the Appalachian Mountains province. It is divided lengthwise into two distinct parts, an eastern part which is a flat-bottomed valley, practically continuous along the whole length of the province and known as the Great Valley, and a western part made up of long narrow nearly parallel ridges and valleys, and referred to as the Valley Ridges. The eastern division in Virginia is generally referred to as the Valley of Virginia, but its various parts are here given local names. (See fig. 1.) The eastern valley portion of the province only will be described in detail in this paper, which is concerned chiefly with its eastern margin.

The Valley of Virginia extends for over 300 miles from the northern to the southern boundary of the State in a general southwest direction, bending to west-southwest in its southerly portion. Although it is occupied by parts of several large drainage systems—the Shenandóah, James, Roanoke, New, and Holston rivers—and is in places notably dissected by these rivers and their tributaries, and, although the floor of its several parts stands at various elevations between 500 feet and 2,500 feet above sea-level, it is, nevertheless, when examined in a broad way, seen to be a single, generally broad flat-bottomed valley everywhere several hundred feet, and in places 2,000 to 3,000 feet, below the summits of the Blue Ridge on the east and the Valley Ridges on the west. (See Pl. I.) In the following statements references to the valley floor should be understood to apply

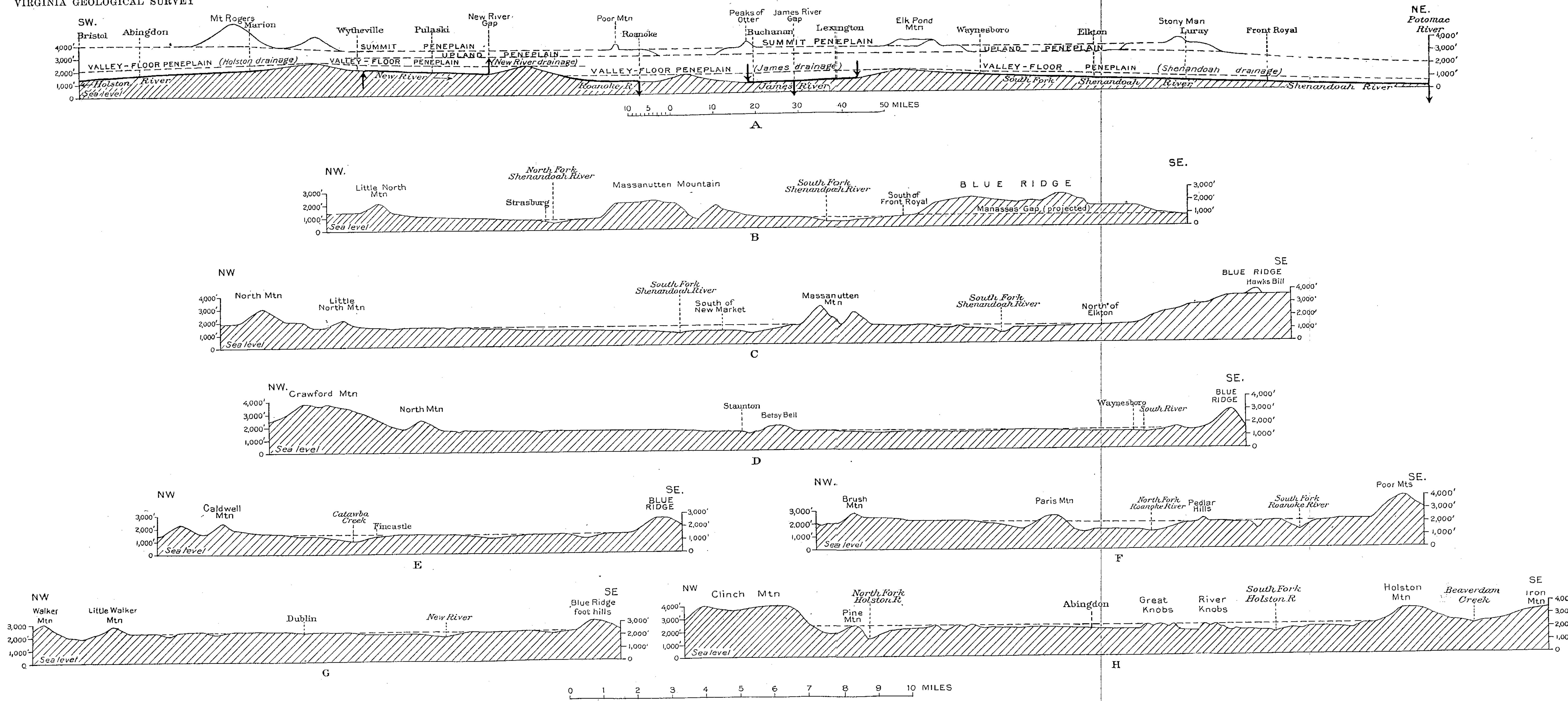
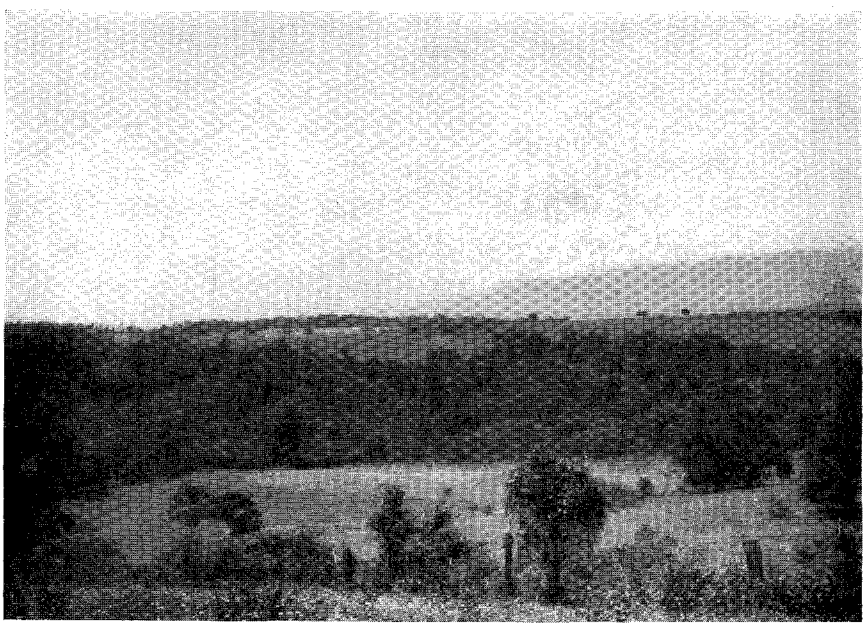


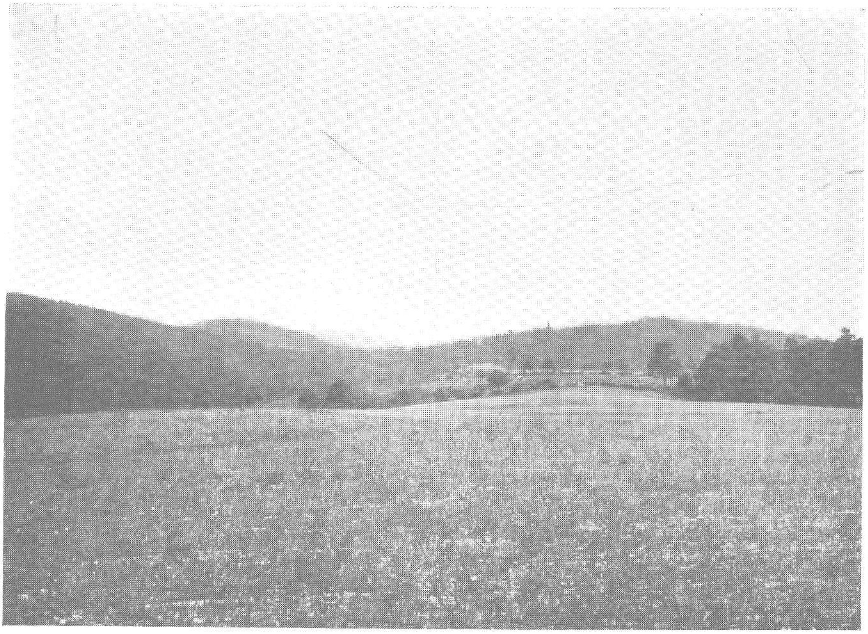
Plate I.—Generalized profile sections of the Valley of Virginia showing peneplain surfaces described in this report.

A. Longitudinal section along the valley from Bristol to Potomac River. The arrows indicate direction of drainage, down meaning southeast and up, northwest.
B. Cross section of the valley south of Strasburg and Front Royal.
C. Cross section of the valley south of Newmarket and north of Elkton.
D. Cross section of the valley near Staunton and Waynesboro.
E. Cross section of the valley near Fincastle.
F. Cross section of the valley southwest of Salem.
G. Cross section of the valley near Dublin.
H. Cross section of the valley through Abingdon.

(A) Looking up gentle slope of valley-floor terrace north of Dry Run toward foothills of Blue Ridge.



(B) Valley floor east of Massanutten Mountain from terrace south of Dry Run. Massanutten Mountain in distance.



(A) Looking up gentle slope of valley-floor terrace north of Dry Run toward foothills of Blue Ridge.

(B) Valley floor east of Massanutten Mountain from terrace south of Dry Run. Massanutten Mountain in distance.

not to the bottoms adjacent to the principal streams and their tributaries, but to the broad lowland level between the streams into which the stream channels are cut. (See Pl. II.) Local irregularities in the width of the valley are due to spurs of the bordering mountains which project into the valley and in places nearly close it off. There are also a few high mountain ridges that lie out in the valley in places and divide it in two lengthwise.

The northern part of the Valley of Virginia is drained by Shenandoah River. It is 20 miles wide at the Maryland State line, where its floor is relatively even and little dissected except near the large streams. Its surface

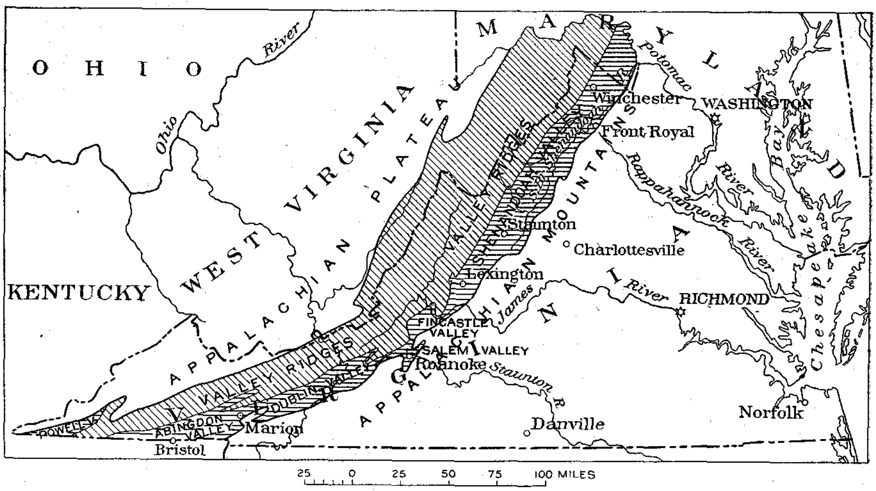


Fig. 1.—Map of Virginia showing subdivisions of the Appalachian Valley province and the adjacent provinces. The Appalachian Valley province is shaded.

stands between 500 and 600 feet in altitude at the Potomac and rises gradually southwestward. It has approximately the same width to the vicinity of Strasburg and Riverton, at the forks of Shenandoah River. Here the valley is divided lengthwise by Massanutten Mountain, a bold high mountain 45 miles long, North Fork draining the part northwest of the mountain and South Fork the part southeast of the mountain. The valley southeast of Massanutten Mountain has an average width of about 5 miles, expanding to 6 or 8 miles in width near Luray and again at Elkton, and is locally constricted to 3 miles in width near Compton and south of Alma. The floor of this eastern part of the valley rises in elevation from about 700 feet at its north end to 1,200 feet at its south end. The valley northwest of Massanutten Mountain has a general width of 6 to 10 miles, and its floor rises from about 800 feet near Strasburg to about 1,500 feet at Harrisonburg. Southwest of Massanutten Mountain the valley is again 20 miles wide, but narrows to about 14 miles near Greenville. This wider part of the valley is drained by North, Middle, and South rivers, which are branches of South Fork of Shenandoah River. Its floor rises from between 1,200 and 1,500 feet on the northeast to 1,800 and 2,000 feet near Lofton and Middlebrook on the Shenandoah-James River divide, the higher level prevailing on the northwest side of the valley.

The valley continues southwestward for 25 miles as an open valley 12 to 15 miles wide, and its floor slopes from between 1,800 and 2,000 feet in elevation on the north to about 1,200 feet in the vicinity of Lexington. This part of the valley is drained by the North Fork of James River and its tributaries, which are in places intrenched as much as 300 feet below the general level of the valley surface. Southwest of Lexington the valley narrows rapidly, and at Buchanan, about 20 miles distant, it is constricted to a width of 1½ miles by Purgatory Mountain, one of the Appalachian Valley ridges which projects into the valley from the northwest. A long narrow outlying ridge, called Short Hills, and a smaller hill called The Knob divide the valley lengthwise just north of Buchanan. The constriction at Buchanan terminates the broad valley to the north, which is one of the main divisions of the Valley of Virginia, and almost breaks the continuity of the Valley of Virginia itself. Although the part of this broad valley between Lofton and Buchanan drains southward through the North Branch of James River, it is topographically continuous with the valley that drains northward through the Shenandoah, and the whole is therefore called Shenandoah Valley. This should not be confused with the Shenandoah drainage basin.

Southwest of Buchanan the Valley of Virginia opens out again to 10 miles in width, but this continues only for a short distance, for in about 15 miles it is narrowed again to a width of 2 miles by Tinker Mountain, another of the Appalachian Valley ridges which projects far into the valley at Cloverdale. This open valley is drained almost entirely by the tributaries of James River, but its extreme southern part is drained southward into the Roanoke by Tinker Creek. Its floor is very level where not cut into by the streams, and stands at about 1,500 feet elevation. This division of the Valley of Virginia is here called the Fincastle Valley, from the town of Fincastle near its center.

Roanoke is situated in another broad part of the Valley of Virginia, which is about 8 miles wide in its widest part and 20 miles in length.

This local valley is here called Salem Valley from the City of Salem. It is drained entirely by Roanoke River which flows diagonally across it from northwest to southeast. The valley is very irregular in shape, a long arm extending northeast from Roanoke between ridges of the Blue Ridge, and a smaller arm extending southwestward. Its floor is only 1,000 feet in elevation. Southwest of Salem the valley narrows to 1½ miles in width and in this narrow part the floor is from 1,400 to 1,600 feet in elevation.

Farther southwestward, at the forks of Roanoke River, the valley is broader but is obstructed by the Pedlar Hills, a tract of country much more rugged than is common within the valley, for the level tops of these hills stand at 2,000 to 2,200 feet altitude, whereas the main streams lie in narrow gorges 700 to 800 feet deep. It is distinctly not a part of the low plain about Roanoke, and although it is drained by branches of Roanoke River it is not regarded as part of Salem Valley. It is part of the next valley to the southwest whose floor has about the level of the tops of the Pedlar Hills.

The Valley of Virginia expands to 12 miles in width in the vicinity of Christiansburg and Blacksburg in Montgomery County, and to 16 miles in Pulaski County. In addition to the narrow arm of the valley, whose floor is dissected into the Pedlar Hills country, another arm extends northeast from Blacksburg back of Paris Mountain. This valley, after narrowing to 2 miles in width, extends 12 or 15 miles between parallel mountain ridges to its junction with the Fincastle Valley east of Tinker Mountain. This attenuated part of the valley, which is drained northeastward by Catawba Creek, is regarded by some as part of the Valley of Virginia, but in this report is excluded from it. The portion of this valley arm which is drained by the North Fork of Roanoke River together with the portion of the wide flat-bottomed valley east of Blacksburg and Christiansburg, which is also deeply dissected and drained by the tributaries of the Roanoke, are regarded as part of the valley here called Dublin Valley, which includes much of Montgomery, Pulaski, and Wythe counties and is drained largely by New River.

Although Dublin Valley is drained chiefly by the tributaries of New River, the river itself flows in the valley but a short distance. Heading in the high plateau country of the Blue Ridge in Tennessee it enters the Dublin Valley through a sharp gap in the flanking foothill ridge, and crosses the valley diagonally northeast to a gap in the flanking Appalachian Valley ridge. The course of this drainage is unique in the Appalachians, for all other streams drain eastward into the Atlantic, whereas New River flows northwestward into the Ohio and thence into the Mississippi. In terms of drainage, therefore, Dublin Valley is farther from the ocean than any other portion of the Appalachian Valley, and its valley floor is correspondingly higher. The floor of Dublin Valley is strikingly even and uniform in altitude over wide areas, especially in the vicinity of Dublin, Christiansburg, and Blacksburg, where it stands at 2,200 feet elevation. The valley floor rises gradually southwestward and large level tracts stand at 2,400 to 2,500 feet elevation near Wytheville, Rural Retreat, and Speedwell. New River and its tributaries have cut their channels into the plain only about 400 feet, and their valleys are broad and have gentle slopes.

Southwest of Dublin the valley is divided lengthwise by two outlying ridges, Draper Mountain and Lick Mountain and still farther southwest by the Brushy Mountain group, which at its western end joins the foothills of the Blue Ridge and shuts in the southern part of the valley as a long arm. The valley south of this chain of medial ridges is drained largely by Cripple Creek, a branch of New River, and is locally called the Cripple Creek Valley. The small western part which is drained westward by the South Fork of Holston River is called Rye Valley. The floor of Cripple Creek Valley is uniformly 2,400 to 2,500 feet in elevation, but terraces in Rye Valley and at the west end of Cripple Creek Valley stand at 3,000 feet or over, and the divide between Cripple Creek and South Fork of the Holston is 2,700 feet.

The part of the valley north of Draper Mountain, which is drained by Peak Creek, is locally constricted to 4 miles in width by a small spur from the mountain on the north. Reed Creek, which drains the valley about Wytheville, turns southeastward between Lick and Draper Mountains and joins New River. The low flat-topped hill called Zion Ridge, which forms the divide between Reed and Cripple creeks, is 2,600 feet in elevation, and the gentle divide between Reed Creek and Middle Fork of Holston River, near Rural Retreat, has the same altitude. As the Valley of Virginia is constricted to a width of 4 miles in this vicinity, this divide is regarded as the boundary between Dublin Valley and the Abingdon Valley, the southwestern division of the Valley of Virginia.

In Smyth and Washington counties the Valley of Virginia again expands and is known as Abingdon Valley, which is drained southwestward by Holston River. At Abingdon the valley is 15 miles wide and its general floor is between 2,100 and 2,200 feet in elevation, but an upper valley floor is well shown at 2,300 to 2,400 feet elevation on the tops of level hills just south of Abingdon and throughout the south side of the valley. The valley is divided lengthwise by Walker Mountain, which begins 7 miles northeast of Abingdon and increases in height and width northeastward. The part of the valley north of Walker Mountain, drained by the North Fork of Holston River and generally called Rich Valley, is about 4 miles wide, and is somewhat hilly because of its deep dissection by numerous streams. The flat hilltops stand at about 2,500 feet elevation, but there is a lower valley floor at about 2,100 feet. The valley ends north of Rural Retreat by the valley ridges closing in. The part of the valley south of Walker Mountain is about 10 miles wide except near Marion, where the Brushy Mountain group narrows it to 5 miles. The floor of the valley is chiefly 2,200 to 2,300 feet in elevation, but the flat-topped low hills along South Fork of Holston River still preserve an upper valley floor at 2,400 to 2,500 feet. This level predominates also on the hilltops around Marion, which rise gradually to 2,600 feet at the low divide at the head of Middle Fork of Holston River, which is the eastern end of the Abingdon Valley.

GEOLOGY

THE ROCKS.

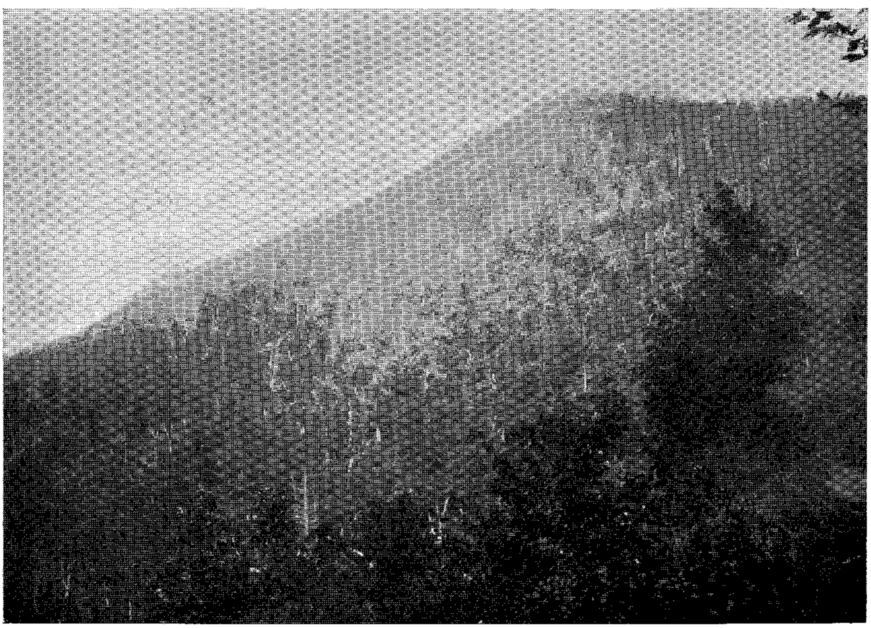
The rocks exposed in the vicinity of the manganese deposits of the Blue Ridge and adjacent part of the Appalachian Valley are sandstones, shales, limestones, and dolomites (called sedimentary rocks because they were deposited as sediment from water), and older crystalline rocks on which they rest. The older rocks formed the floor and shore of the sea in which the sedimentary rocks were laid down, and are among the oldest rocks known.

Pre-Cambrian crystalline rocks.

The oldest crystalline rocks present in the area are granite and granite-like rocks, which were formed by the gradual cooling, solidification, and crystallization of molten material at considerable depth within the earth. The other crystalline rocks present are greenstone and associated greenstone schist and sericite schist, which were originally molten lavas that were poured out on the land surface and hardened into basaltic rocks, which have since been mechanically and chemically altered during the progress of earth movements. Greenstone is so called because of its green color due to the presence of the green minerals, epidote and chlorite, which have been formed since the rock solidified, in the process of its alteration within the earth. Massive greenstone is very resistant to weathering as it is not readily soluble in rain-water nor easily broken up by frost and wind, and therefore it forms the highest summits of the Blue Ridge throughout much of this area. (See Pl. IV.)

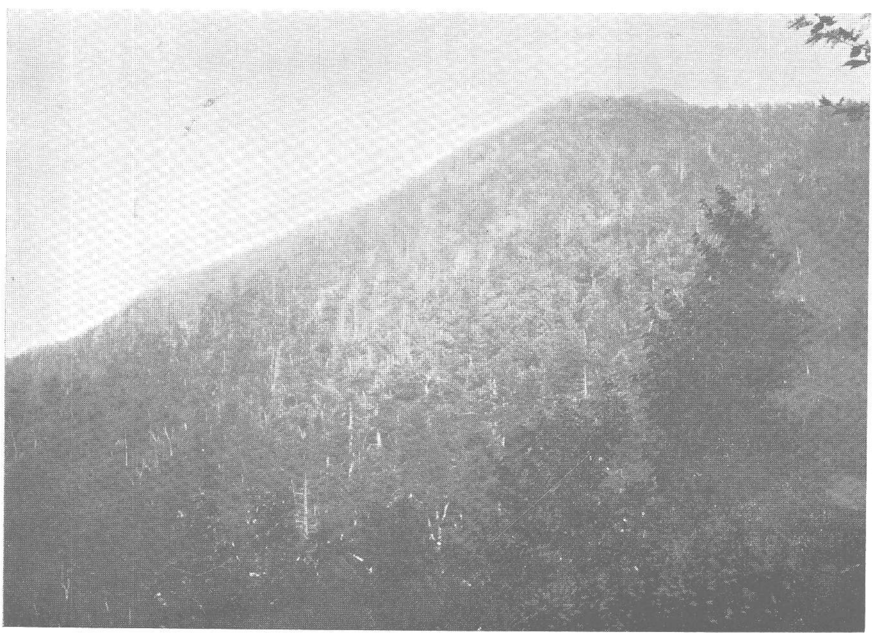
The pre-Cambrian rocks form the main Blue Ridge throughout most of the area here described. (See Pl. III in pocket.) From Front Royal to Vesuvius greenstone generally underlies the Cambrian sedimentary rocks and crops out just east of them except where granitic rocks are faulted against the sediments or directly underlie them. Southeast of Luray the granite is thrust westward along a great fault and cuts out the greenstone over a large area. At one place southwest of Stanley the granite appears west of the greenstone and the sedimentary rocks overlap on it, as they do generally southwest of Vesuvius, where the greenstone is infolded and lies within the granitic rocks in the heart of the mountains.

(A) Pre-Cambrian greenstone ledges in foreground on Stony Man, and old peneplain surface of mountain top, 3,500 feet in elevation, where camp is located.



(B) Stony Man and the bold front of the Blue Ridge composed of pre-Cambrian crystalline rocks, southeast of Luray.

(A) Pre-Cambrian greenstone ledges in foreground on Stony Man, and old peneplain surface of mountain top, 3,500 feet in elevation, where camp is located.



(B) Stony Man and the bold front of the Blue Ridge composed of pre-Cambrian crystalline rocks, southeast of Luray.

The crystalline rocks underlie the sedimentary rocks, and show by their distribution and relation to those rocks that they were compressed, elevated, weathered, and worn down by erosion to a rather even surface before the sediments were deposited on them. The sediments are, therefore, unconformable on the crystalline rocks, and considerable time must have elapsed between the solidification of the igneous rocks and the deposition of the sedimentary rocks. As the oldest sedimentary rocks are Lower Cambrian in age, the crystalline rocks are undoubtedly pre-Cambrian.

Sedimentary rocks.

UNICOI FORMATION.

The Unicoi formation directly overlies the crystalline rocks and includes sandstones, arkoses, conglomerates, and quartzites, which are composed in part of unassorted débris derived from the disintegration of the older crystalline rocks. In the northern part of the area these beds range from soft arkose through harder arkosic sandstone to hard gray sandstone and dark ferruginous quartzite, and associated beds of slaty argillaceous sandstone. 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 highly altered by compression, occurs interbedded with the lowest sedimentary beds at several places. It was observed east of Front Royal and on the Rock Fish Gap road southeast of Waynesboro.

In the part of the Blue Ridge between Buchanan and Troutville the formation is composed of dark shale, thin-bedded gray sandstone, shaly sandstone, and massive, pebbly, white and ferruginous sandstones. The last-named variety of sandstone contains well-rounded quartz pebbles which are so numerous in places that the rock might be termed conglomerate. It is found not only at and near the base of the formation, but also well up in it. Some of the sandstone is highly ferruginous, and in some places beds 5 feet or more thick contain a sufficiently high percentage of iron oxide to be a siliceous iron ore, which is locally called "mountain ore" and "specular ore." Such ore is being mined near Buchanan, Montvale, and Blue Ridge Springs. A ferruginous bed of similar character though much thinner occurs also in the formation north of Vesuvius, and was prospected for iron east of Front Royal.

In southwestern Virginia south of Cripple Creek and Rye valleys the Unicoi formation of Iron Mountain was not studied during the present field work. It, however, probably does not differ greatly from the Unicoi formation in northeastern Tennessee as described by Arthur Keith in the Cranberry folio (No. 90) of the U. S. Geological Survey. As there described it consists of massive white sandstone, feldspathic sandstone, and quartzite with interbedded shales and sandy shales in the upper part, a thin bed of amygdaloid near the middle, and conglomerate, arkose, and graywacke in the lower part. The formation is named from Unicoi County, Tennessee.

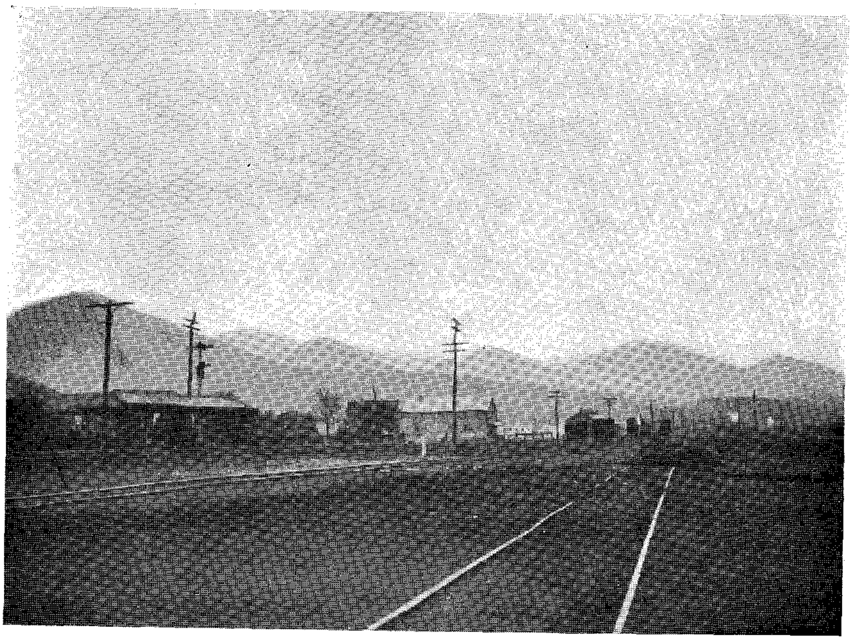
The thickness of the formation in the northern part of the area is estimated to be 1,750 to 2,000 feet. In Iron Mountain in southwestern Virginia it is probably thicker. The formation is finely exposed in the cuts of the Southern Railway, 4 miles east of Front Royal, but the section there is not complete. It is also well exposed on the Simmons Gap road south of Elkton and on other road and stream sections in the belt between the main Blue Ridge and the front foothills.

The Unicoi formation northeast of Vesuvius is nearly everywhere present in the foothills of the Blue Ridge, where it forms an inner row of low knobs or ridges back of the front line of foothills but in front of the main Blue Ridge. This relation is best shown in the belt between Elkton and Waynesboro. Farther southwest the Unicoi formation is more resistant and forms the crest of the Blue Ridge between Buchanan and Troutville and the crest of Iron Mountain, the principal ridge in the western part of the Blue Ridge south of Cripple Creek and Rye valleys.

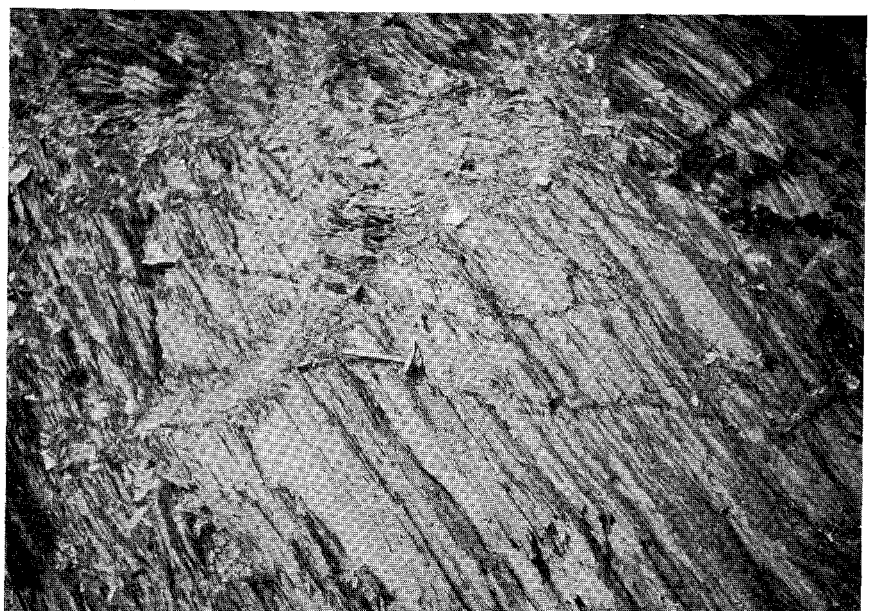
The rocks here called Unicoi formation are the equivalent of the Unicoi formation in northeastern Tennessee and of the Weverton sandstone and Loudoun formation of Maryland and northern Virginia. No fossils have been found in the Unicoi formation, but, as it is overlain conformably by shales and sandstones which in places carry Lower Cambrian fossils, it is regarded as of Lower Cambrian age.

HAMPTON SHALE.

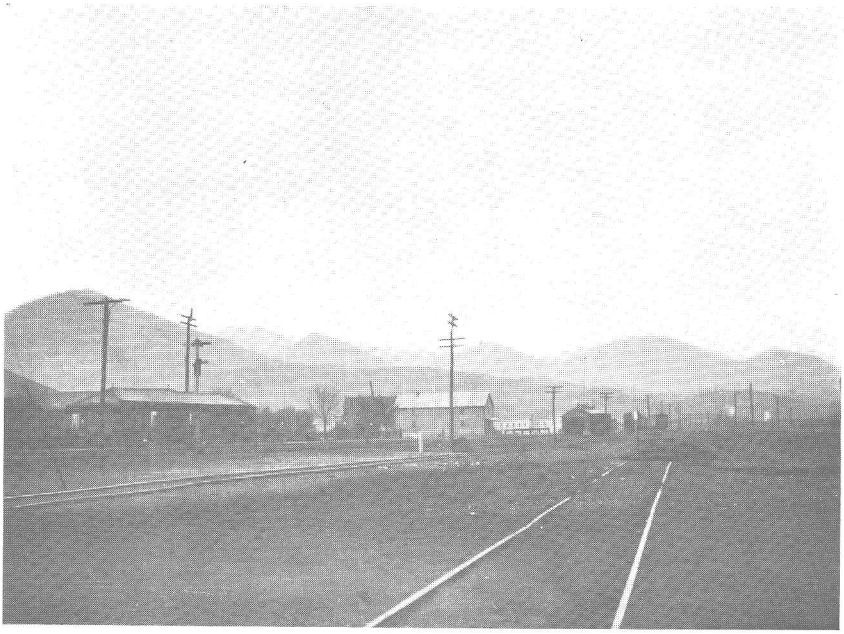
Overlying the Unicoi formation are dark-gray shales, slates, and interbedded thin sandstones, which in northern Tennessee constitute the Hampton shale. The shales and slates are mostly sandy and weather to hackly outcrops, so that in many places their original character and bedding cannot be clearly seen. Some of the fresh dark shale is banded with light streaks, but most of its outcrops are weathered to soft buff shale. (See



(A) Line of front ridges and knobs of Blue Ridge, composed of Erwin quartzite, south of Buena Vista. The knobs are low and conical.



(B) Hampton shale, showing cleavage diagonal to bedding, on Chesapeake & Ohio Railroad southeast of Basic City. Hammer handle is parallel to indistinct nearly horizontal bedding plane, and cleavage dips steeply to the right (southeast).



(A) Line of front ridges and knobs of Blue Ridge, composed of Erwin quartzite, south of Buena Vista. The knobs are low and conical.

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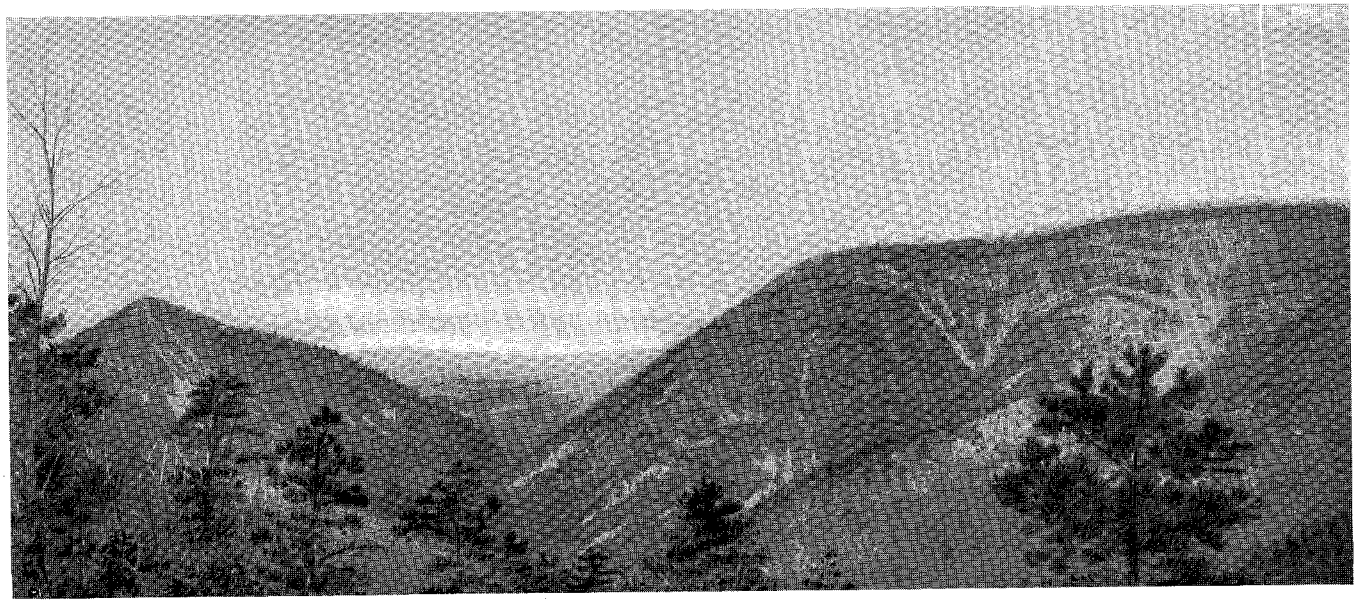
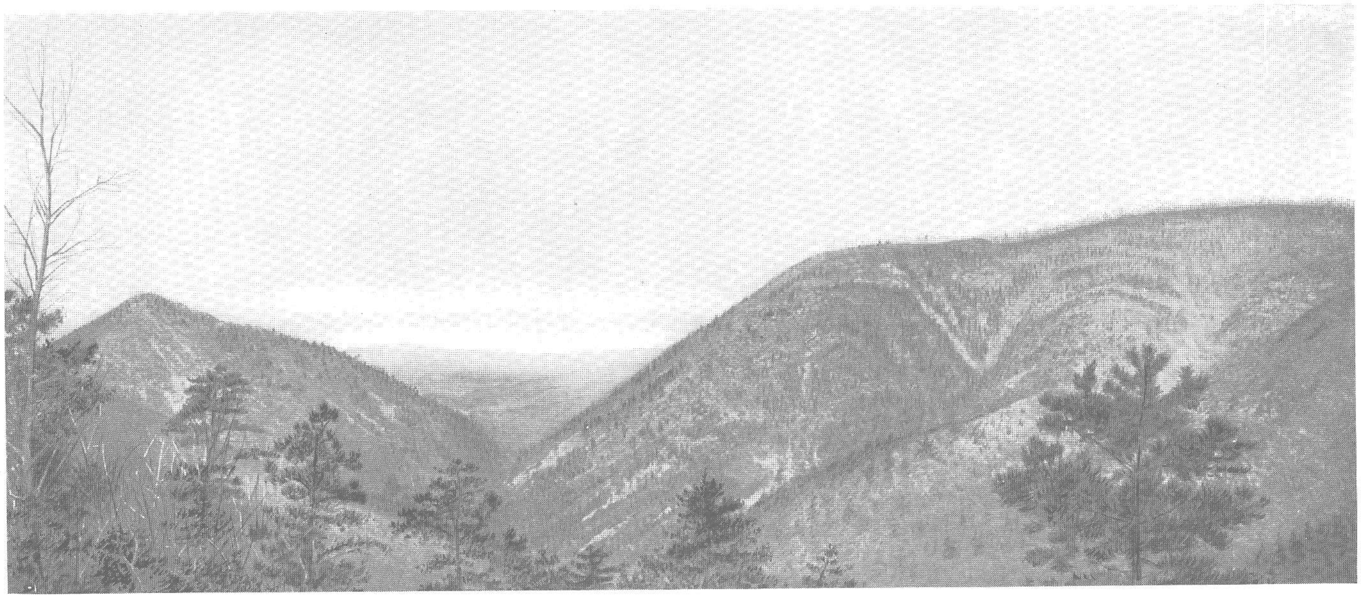


Front ridges of the Blue Ridge composed of steeply dipping white Erwin quartzite, east of Buena Vista.



Front ridges of the Blue Ridge composed of steeply dipping white Erwin quartzite, east of Buena Vista.

Pl. V.) In the southwestern counties black shales with included lenses of ferruginous carbonate are abundant and very characteristic. It is estimated to be at least 400 feet thick in northern Virginia and 600 to 800 feet in southwestern Virginia, but may be much thicker, as it is generally so crumpled that measurement of its thickness is difficult. Although typical rocks of the Hampton and Unicoi formations are easily distinguished, the two formations are not separately mapped because they grade somewhat into each other, and the presence of shaly rocks within the Unicoi and hard sandstones and arkoses in the Hampton make it difficult to separate them in some places in the field.

The rocks of this formation weather more easily than either the underlying arkosic sandstones of the Unicoi formation or the overlying massive white Erwin quartzite, so that it generally forms valleys or depressions between the inner and outer foothill ridges of the mountain front. This is well shown along the front of Iron Mountain south of Teas in Rye Valley, along the west front of the Blue Ridge near Nace and Lithia, and in the area between Elkton and Waynesboro. In the latter region the formation is not only marked by a narrow valley between parallel ridges but in places it forms wide coves back of the front ridges entirely inclosed by high mountains to which there is access only by a narrow rocky gap. These coves are caused by the geologic structure, as explained on pages 27-34, and shown in sections, figure 2 and Plate XI. East and south of Waynesboro the formation occupies a relatively wide belt by reason of its structure and forms the strip of low hills back of the front quartzite ridge.

Although no identifiable fossils have been found in this formation in the areas here described, it is regarded as of Lower Cambrian age. It is called Hampton shale from Hampton, Carter County, Tennessee, and has been correlated with the Harpers shale of northern Virginia and Maryland.

ERWIN QUARTZITE.

The Erwin quartzite, the next higher formation, is a massive white quartzite the outcrops of which make prominent ridges throughout the region. The western foothills of the Blue Ridge in most of the areas here described are composed of this rock (see Pls. V and VI), and it also caps many of the ridges of an inner row where there are several lines of ridges. In Smyth and Wythe counties in the southwestern part of the State the Erwin quartzite forms also two outlying groups of ridges—Brushy Mountains and Lick Mountains—which are detached from the Blue Ridge, Lick Mountain standing several miles out in the valley. In the northern part of the area the formation is generally composed of three massive cliff-making ledges separated by thinner-bedded sandstones. The thickness of the formation in the measured section given below, one of the best-exposed sections in the northern part of the region, is 500 feet. South of Stanley it appears to be much greater, possibly 1,000 feet, and north of Stanley it is apparently thinner.

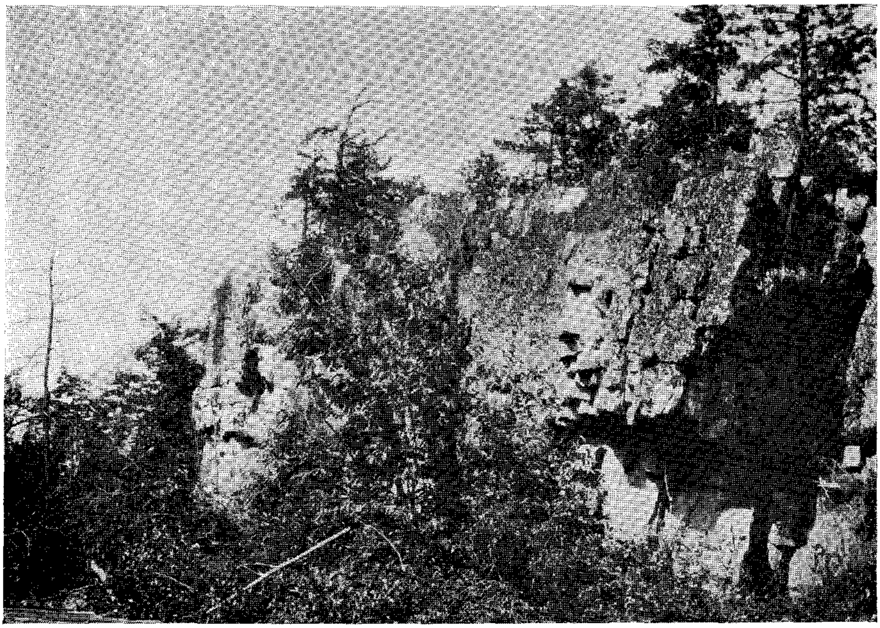
Section of Erwin quartzite in the Blue Ridge near Stanley, Va.

	Feet.
White sandstone full of scolithus; crumbles readily to sand. Rarely exposed in place. Upper layers somewhat 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

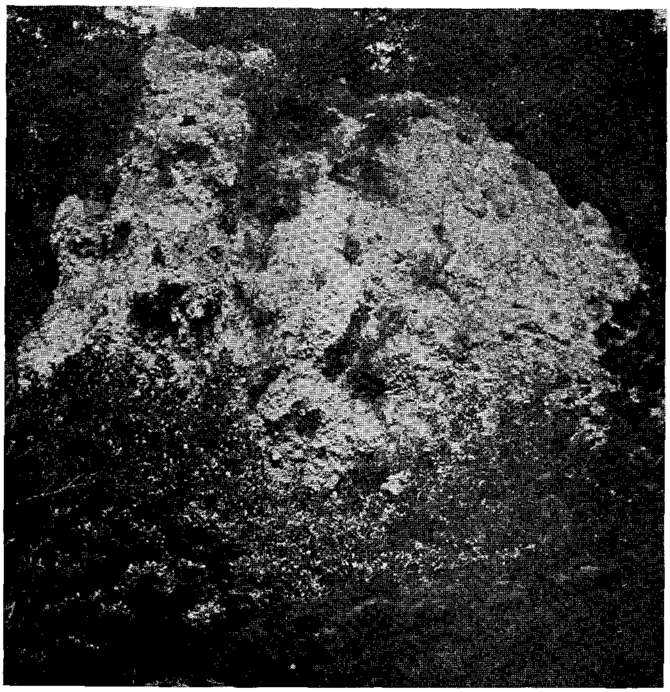
The cliff-making ledges consist largely of massive beds of dense white quartzite, some of which are 15 to 20 feet thick without a visible trace of bedding. (See Pl. VII.) Many of the beds, especially in the northern part of the State, contain casts of worm tubes or scolithus (see Pl. VIII), and as these were vertical when the sediments were first deposited they may be used to determine the bedding of the rocks which is at right angles to them. The uppermost bed at the Crimora mine is peculiarly marked by what appears to be a form of worm tubes (see Pl. VIII, B) which has been noticed at many other places and is a help in identifying the top of the formation.

One of the best exposures of the Erwin quartzite is on Bearwallow Creek, 1½ miles southeast of Buchanan. There the Erwin measures about 1,200 feet thick and is composed chiefly of thin beds of white quartzite and some black shale, and has only one cliff-making ledge, which is within 100 or 200 feet of the base of the formation. Between this locality and Fullhardt Knob, 1 mile south of Troutville, the formation is probably somewhat thinner, and in places contains two cliff-making ledges.

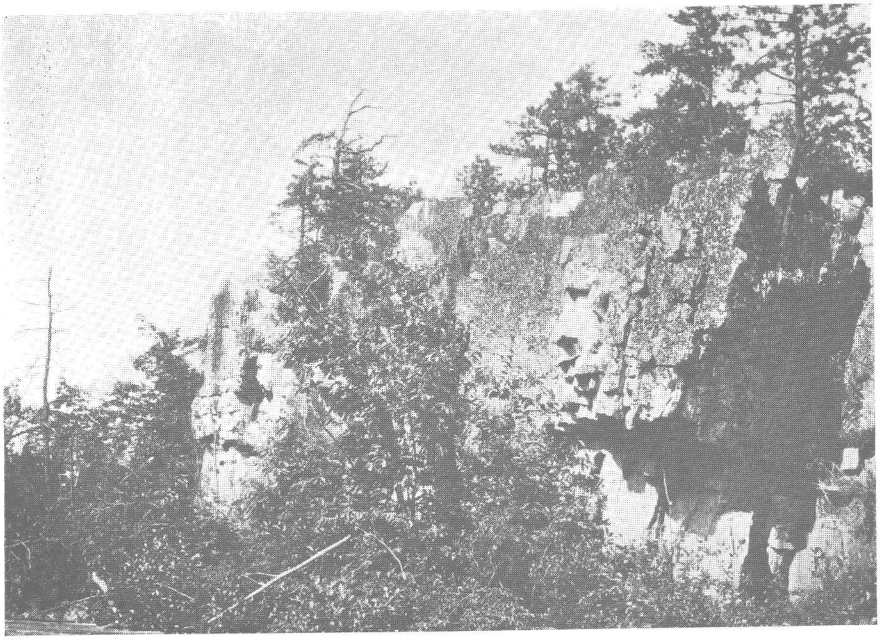
In Smyth and Wythe counties light-brown shaly and flaggy sandstones comprise the larger part of the formation, drab to black shale is less abundant, and white hard massive vitreous quartzite is least abundant. Massive ledges stand out here and there, but they are not nearly so numerous or



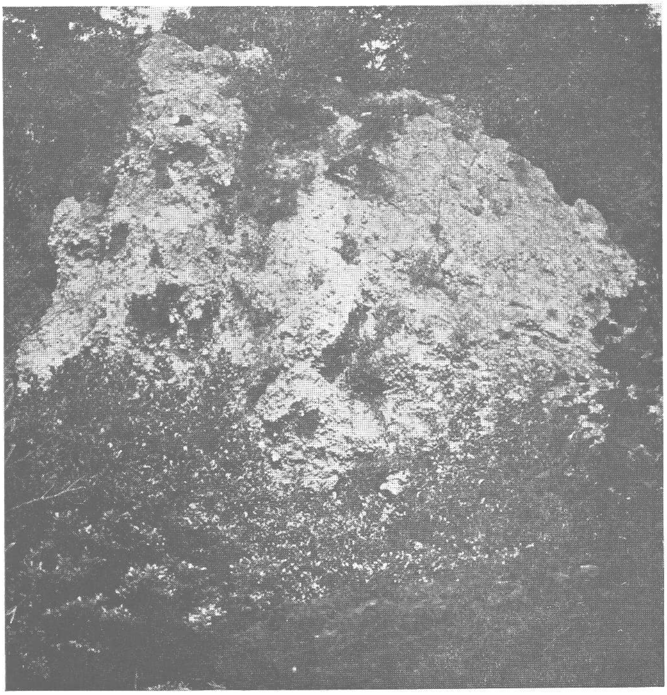
(A) Erwin quartzite ledges on Mills Creek west of Mount Torry mine. The beds of quartzite are nearly horizontal.



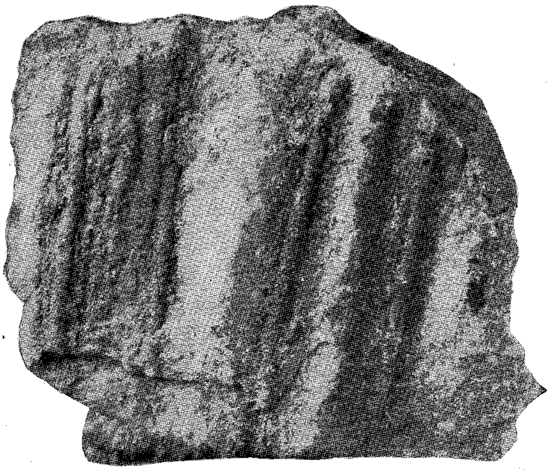
(B) Brecciated Erwin quartzite, near Vaughan.



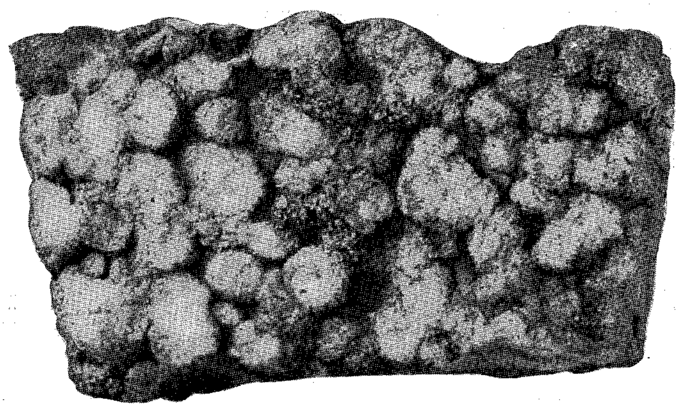
(A) Erwin quartzite ledges on Mills Creek west of Mount Torry mine. The beds of quartzite are nearly horizontal.



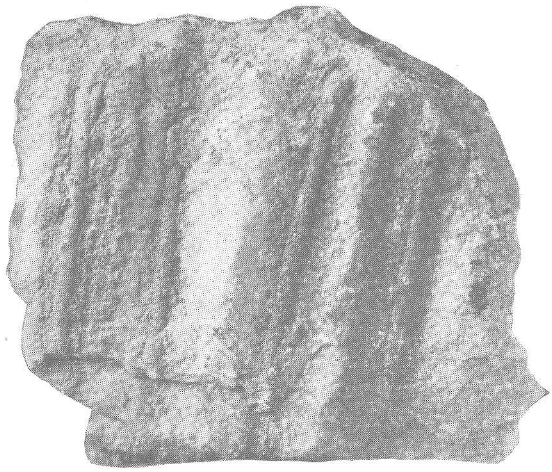
(B) Brecciated Erwin quartzite, near Vaughan.



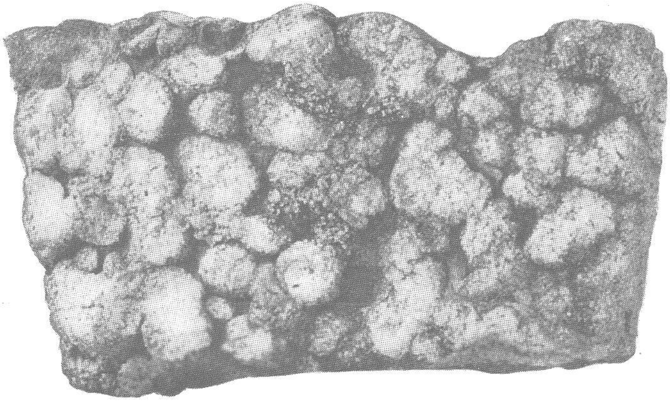
(A) Scolithus tubes, perpendicular to the bedding, generally present in the Erwin quartzite.



(B) Surface marking characteristic of the upper surface of the topmost beds of Erwin quartzite, near Crimora mine. Probably the mouths of worm tubes on an old sea beach.



(A) Scolithus tubes, perpendicular to the bedding, generally present in the Erwin quartzite.



(B) Surface marking characteristic of the upper surface of the topmost beds of Erwin quartzite, near Crimora mine. Probably the mouths of worm tubes on an old sea beach.

prominent as they are along the Blue Ridge between Stanley and Vesuvius. Scolithus tubes were found in but very few places, their scarcity being in striking contrast with their usual abundance between Front Royal and Troutville. Some of the beds contain well-rounded pebbles of white quartz. A bed in which such pebbles are especially numerous was noted at the top of the formation at many places on Brushy Mountains and on the south side of Rye Valley. This bed is a ledge maker and is the most conspicuous part of the formation in that vicinity. It in places has been partly replaced by iron oxide and low-grade manganiferous iron oxide, and on this account has been prospected some for iron and manganese ores. The thickness of the Erwin in Smyth and Wythe counties is probably close to 500 feet, and comprises the following general group of rocks:

	Feet.
Vitreous white sandstone in 1 to 2-foot beds, generally containing scolithus tubes, some beds banded or blotched by iron-oxide replacement, some containing scattered white quartz pebbles, and the bedding planes of some ledges showing wide wave ripples of 3 to 5 feet amplitude	50
Thin-bedded soft, white to buff sandstone, apparently calcareous and weathering to rounded outcrops and buff sand. Some beds are rippled, suncracked, and trail marked. (See Pl. X, A)	200±
Black shale and thin dark argillaceous sandstones	200±
Vitreous, bluish-white quartzite in thick beds and massive ledges	50±

This formation is the same as the Erwin quartzite of northern Tennessee and has been also correlated with the Antietam sandstone of northern Virginia. It contains numerous scolithus tubes, which are the fossil burrows of a low order of worm made in the sand on the shore of the sea in which the sand was deposited. A few fossil shells and fragments of crustaceans have also been found in this formation in Tennessee and Pennsylvania. The crustaceans are trilobites of the genus *Olenellus,* and the shells include the brachiopods *Camarella minor* and the pteropod *Hyolithes communis.* In the cut of the Marion & Rye Valley Railroad on Brushy Mountain, east of Marion, trails of various animals, probably some of them tracks of trilobites, cover the surface of thin slabby sandstone. The fossils are all of Lower Cambrian age.

The Erwin quartzite is one of the most conspicuous formations in the region because it makes such prominent rocky ridges and because of its conspicuous white color. It is also very important in the study of the manganese deposits as they are so closely associated with it, and its distribution will therefore be described in some detail. Its distribution is shown on the geologic map (Pl. III, in the pocket).

East of Front Royal the Erwin quartzite is well exposed in the cuts of the Southern Railroad, and forms a sharp front foothill ridge. The rock is badly crushed and slicken-sided in places, and shows evidence of severe pressure and faulting between the beds. At the south end of the ridge its beds are faulted off, pre-Cambrian greenstone having been thrust across the ends of its layers. With the exception of the low hill 1 mile east of Front Royal, where its crushed and brecciated outcrops are cemented by iron, it is concealed by faulting for 10 miles along this part of the mountain front, the pre-Cambrian greenstone being thrust over on to the limestone of the valley.

East of Bentonville the trace of the fault passes into the mountain and the white quartzite comes in again as a small front ridge which extends to the latitude of Luray. Due to the facts that the rock here is badly crushed and brecciated, and that the quartzite is probably thinner than farther south, it does not make as prominent a ridge as elsewhere. This brecciation is probably due in part to distributed faulting along the bedding. Southeast of Vaughan the quartzite is broken and crushed to such an extent that it does not even make a low hill or rocky outcrop. (See Pl. VII, B.) East of Elgin the quartzite locally makes a high ridge, due to close folding of the rocks, but to the south near Stony Man village (Blosserville) it is again badly brecciated and breaks down so that it fails to make a ridge or outcrop. South of Luray a similar discontinuous front ridge or brecciated white quartzite marks a fault zone along the bedding, but back of this two higher ridges of the white quartzite are apparently exposed in anticlinal folds. East of Marksville these ridges are abruptly terminated by faulting, pre-Cambrian granite having been thrust across the ends of the beds.

South of Stanley the white quartzite ridges are more prominent because the formation is thicker and more resistant. The quartzite measures 500 feet here and comprises three prominent cliff-making ledges, and these characters continue south of Waynesboro. East of Shenandoah it not only forms the front ridge, but caps several of the second ridges where the dips are low. Southeast of Elkton the quartzite is crushed and brecciated to such an extent that locally it fails to make a ridge, but elsewhere it is a prominent feature. South and southwest of Elkton the formation makes a very prominent front ridge and caps several of the back ridges. The gorges here cut in the hard rocky ledges of the Erwin exhibit some of the wildest and most picturesque scenery in this part of the Blue Ridge.

East of Waynesboro the Erwin quartzite ridge is abruptly cut off by a fault, the Hampton shale having been thrust across the ends of the beds. In the adjacent valley several low hills covered with quartzite fragments seem to mark low anticlinal hills of the Erwin barely exposed by the erosion of their limestone cover. South of Waynesboro the front ridge is again weak and small, the rock being largely brecciated, which has resulted from a zone of faulting along the bedding. South of Sherando the fault again cuts out the quartzite, bringing the Hampton shale against the limestone which overlies the quartzite. The fault passes up Back Creek, to the west of which the Erwin quartzite rises in a broad anticlinal uplift and makes bold mountains 3,500 feet in elevation. Deep gorges cut into this hard quartzite present scenery of wonderful beauty and of a type not generally found in the Blue Ridge.

From Vesuvius to the James River gorge the front quartzite ridge is straight and rather simple, but is eroded in places into sharp conical hills. (See Pl. V, A, p. 14.) A line of detached low hills of quartzite (a faulted anticline), extends from Natural Bridge station to Lock Laird where it joins the mountain front. Another small ridge east of Natural Bridge station is also apparently a faulted anticline. The distribution of the quartzite here and its structure are not fully worked out. Two areas of Erwin quartzite are inclosed along the fault on the east side of the main Blue Ridge at and northeast of Rope Ferry. The main body of the quartzite crosses the James at Balcony Falls and caps the main ridge just south of the river. Four miles southwest where it is cut off by the large fault the quartzite is offset to the west and continues southwestward as a narrow low front ridge or as a range of foothills to Troutville. A line of low anticlinal quartzite ridges faulted on the west side lies out in the valley southeast of Buchanan. Southeast of Nace and in places near Troutville the quartzite is much crushed and probably has undergone some faulting, so that its outcrop in such places does not produce ridges as high as usual. Southeast of Troutville the quartzite caps the crest of the main Blue Ridge for a distance of about 2 miles before the quartzite plunges beneath the limestones and shales of Cambrian age in the valley at the southwest base of Fullhardt Knob, causing this part of the Blue Ridge to terminate there. These limestones and shales not only underlie the valley northwest of this part of the Blue Ridge and swing around its southwest end but also underlie the valley areas drained by Glade Creek and the North Fork of Goose Creek, southeast of this part of the Blue Ridge.

Coyners and Mills mountains lying between Fullhardt Knob and Roanoke are composed of post-Cambrian sandstone whose exact age has not been definitely determined, instead of being formed by rocks of Cambrian age and included with the rocks designated as "Potsdam group" on the geologic map of Virginia published in 1916 by the Virginia Geological Survey.

The northwest front of the Blue Ridge between Roanoke and Ivanhoe was not examined during the field work for this report, except near Snowville, where a cursory examination was made during a visit to a manganese prospect near that place. The Erwin quartzite was found at Snowville and it doubtless occurs throughout much of the rest of this part of the Blue Ridge, as indicated on the geologic map of Virginia published by the Virginia Geological Survey. This map shows that an irregular but practically continuous belt of Cambrian siliceous rocks of which the Erwin quartzite is a part, called the "Potsdam group" on the map, extends from near Roanoke to Ivanhoe.

The belts of outcrop of the Erwin were not closely followed and its structure was not worked out in detail in Lick Mountains and the front ridges of Iron Mountain, the principal mountain of the Blue Ridge region between Ivanhoe and Camp. The distribution of the Erwin in these areas as shown in a general way on the map (Pl. III) is in large measure based on the geologic maps by E. V. d'Invilliers[1] and C. R. Boyd,[2] which has been modified to fit the observations by the present authors.

From Ivanhoe to Francis Mill Creek the Erwin not only forms the front ridges and knobs, some of which project out into the Cripple Creek Valley, but forms several of the back ridges, as, for example, on Cove and Francis Mill creeks where the Shady dolomite occupies synclinal basins between the front and back quartzite ridges. Most of the formation is well exposed along Francis Mill Creek in the anticline which forms Hussey Mountain and Frey's Hill, the part exposed consists largely of drab to black shale. From this creek to Dickey Creek near Sugar Grove the Erwin forms a narrow, nearly straight front ridge cut through at numerous places by streams, but near Camp and south of Speedwell it occupies broader areas including back ridges, due to folding. Another of these back quartzite ridges less than a mile long is 3 miles southeast of Sugar Grove. At many places in this stretch of country where the quartzite is vertical or nearly so, a massive vitreous ledge apparently near the base of the formation stands up on the ridge crests like a wall of gigantic masonry. But between Cressy

[1] McCreath, A. S. and d'Invilliers, E. V., The New River-Cripple Creek mineral regi n of Virginia, Harrisburg, Pa., 1887.

[2] Boyd, C. R., [Map of] Wythe County, Va., with part of Pulaski County. Products of soils, ores, rocks, railways, roads, furnaces, etc., Philadelphia, Pa., 1888.

and Dickey creeks the quartzite is badly crushed due to close folding and possibly some faulting, so that rock ledges are not very common and the ridges and hills are much lower than usual.

An anticline that plunges to the northeast at Dickey Knob causes the outcrop of the Erwin to turn northward at Dickey Creek. The contact of the Erwin quartzite with the Shady dolomite is excellently exposed in a cut on the Virginia Southern Railroad just north of where it crosses Dickey Creek, 1 mile southwest of Sugar Grove.

For 2 miles west of Dickey Creek the outcrop of the Erwin is broadly curved and is characterized by knobs, while farther west it is marked by low ridges which inclose a patch of the Shady dolomite in a small synclinal basin. This belt of the Erwin ends just southwest of Comers Creek, where the Hampton and Unicoi formations are thrust northward over the edges of the Erwin. It comes in again in several low quartzite ridges west of Hopkins Creek where the details of the complicated geology have not been satisfactorily worked out. However, several quartzite spurs which here project northeastward into the valley are apparently anticlines faulted off at their northeast ends.

The Erwin quartzite largely forms the Brushy Mountain group south of Marion. Each of the several component ridges of this group of mountains, like the ridges of Lick Mountains to the northeast, are anticlinal, and most of the intervening synclinal valleys inclose Shady dolomite. The structure and composition of these mountains are well shown along the Marion & Rye Valley Railroad and the wagon road to Teas in Rye Valley. The Erwin rocks in the Pond Mountain anticline are finely exposed in the Staley Creek gap at Attoway (see fig. 15, p. 155), and the sandstones at the northeast plunging end of the Rich Mountain fold may also be seen from the railroad. The main Brushy Mountain anticline is cut through by the deep rocky gorge of South Fork of Holston River near Quebec and by Hopkins and Roland creeks to the southwest, but the structure cannot be readily made out along the railroad because of minor folds and faults on its northwest side, these faults cutting off the quartzite ridges to the southwest at Roland Creek. A small outlying ridge south of Quebec and its continuation southwest of Benton Branch apparently represent the well-defined anticlinal quartzite ridge of the Brushy Mountain group northeast of Teas, but faulting on its northwest side has broken the ridge into several parts. White Rock Mountain, one of the ridges of Brushy Mountain northeast of Sugar Grove, takes its name from a prominent cliff of white Erwin quartzite on its crest.

The several narrow ridges comprising the group of mountains to which the name Lick Mountains is generally applied are formed by the Erwin quartzite, and most of them appear to be anticlinal in structure though the quartzite in some is doubtless faulted. The valleys between them are synclinal and are underlain by the Shady dolomite. Rock ledges are not especially abundant on the ridges, but some to which names have been applied are Chimney Rocks, Low Rocks, and High Rocks, 2 miles south of Wytheville.

The Erwin is exposed in what is apparently a low, dome-shaped anticline at the mouth of Fisher Branch, near Eagle siding on the Cripple Creek Branch of the Norfolk & Western Railway. The topmost beds of the formation dipping low to the east and the overlying basal beds of the Shady dolomite with a similar dip are exposed in the bluff at the mouth of this stream. Although there are doubtless many localities in the Blue Ridge region where the contact between these two formations is exposed, this locality is one of the few that have been observed. The Erwin also forms the crest of Gleaves Knob, one of the most prominent topographic features in the Cripple Creek Valley.

SHADY DOLOMITE.

In the Appalachian Valley the Erwin quartzite is overlain by a great thickness of dolomite, limestone, and shale, of which only the lower beds that outcrop at the eastern margin of the valley immediately adjacent to the mountain front need here be considered.

The Shady dolomite, the formation which normally lies above the Erwin quartzite, is composed largely of coarse-grained massive dolomite. In the northern part of the area it is so deeply weathered that outcrops are seldom seen and its fresh condition is hardly known. What has been seen of it in that region, however, is a blue-gray to dark-gray glistening coarse dolomite, bituminous in places. South of Vesuvius outcrops are more numerous and the rock is there a light-gray to bluish-gray dolomite, in part mottled blue and in part very white, but some is dark and bituminous. Abundant nodules of white to black chalcedonic chert are found in the residual clay of the formation. They are especially noticeable in the clay of the manganese mines, near the base of the formation. Large masses of cavernous ferruginous chert breccia, containing quartz druses in some of the cavities, also occur in the ore-bearing zone in places near the base of the Shady. Southwest of Quebec, in Rye Valley, thick layers of white chert and also a zone of round nodular chalcedonic chert occur in the formation, but their respective positions in the section were not determined because of faulting. They are, however, apparently above the ore-bearing zone.

The lower 100 to 200 feet of the formation are generally represented by soft, finely laminated yellow clay and ocher with some red and white layers and scattered chert fragments, which were derived from porous argillaceous or earthy limestone or dolomite by the leaching of the calcareous material. It contains sandy layers, one bed of which, in southwest Virginia, generally shows at the surface as a porous rusty-brown sandstone of rounded quartz grains, which were formerly bound together by calcareous cement but in weathered outcrop are only loosely cemented. It is generally stained by iron oxides set free in weathering and in places is dark from disseminated wad. It lies 95 feet above the top of the Erwin quartzite on the south side of Currin Valley, and shows at several places along the Marion & Rye Valley Railway where it crosses Brushy Mountain and associated ridges. It is probably this bed that is seen in places southeast of Elkton and east of Front Royal and is reported just beneath the manganese-bearing clays in the borings at and west of the Kennedy mine. Farther south, in Shady Valley, Tennessee, the rocks below this sandstone are seen to have several thin beds of porous arkosic sandstone and sandy calcareous shale, variegated red, yellow, green, and white in color. In the cut on the Virginia Southern Railroad just north of Dickey Creek, in Rye Valley, the basal beds are exposed as follows:

Section in cut on Virginia Southern Railroad 1 mile southwest of Sugar Grove.

	Feet.
Shady dolomite:	
Dolomite, fossiliferous, light gray, and fine grained; contains quartz sand and small well-rounded quartz pebbles in thin layers. Manganese oxide in the form of dendrites coats the surface of the ledges in places	7
Erwin quartzite:	
Quartzite, fine-grained, massive, purplish-gray; contains fine quartz pebbles in parts of exposure. The purplish cast appears to be due to iron oxide	9

These beds dip 10° NNE. and the contact between the two formations is even and suggests no unconformity.

Because of the solubility of the dolomite its decay extends to great depth, 200 feet in some places, and as a result the areas occupied by the formation are almost wholly reduced to lowlands and valleys in which sink holes are common. In artificial cuts and stream banks which go below the soil cover, laminated clays are found in many places, particularly in the lower or basal part of the formation. These are most commonly in thin layers of yellow and ocherous colors, but also red, brown, drab, and white, and with them are associated lumps and fragments of more or less disintegrated white chert. These variegated clays are found in nearly all the manganese mines and deeper prospects, and in places are more than 200 feet deep.

Northeast of Roanoke the Shady dolomite occupies a narrow belt of varying width along the west foot of the Blue Ridge slope. As it cannot be generally recognized except by its red and yellow clay soil containing chert fragments its thickness and areal extent cannot be accurately determined. In the vicinity of Natural Bridge, where it is better exposed and where the base of the overlying Watauga shale is well determined, the thickness of the Shady dolomite has been determined to be 1,800 feet, and it is probably about the same elsewhere in this region. Not only is it weathered to clay and soil but its surface is generally deeply covered with sandstone wash from the adjacent mountain slope, so that it has been impossible to map it in most of the region northeast of Buchanan. In the area south and southeast of Marion, including Rye and Cripple Creek valleys, where the base of the Watauga is better shown, these two formations have been mapped separately.

In Cripple Creek and Rye valleys and near Marion the formation is concealed in most places by its residual clays and by sand and quartzite wash from the mountain but it is well exposed on and near many of the streams, so that its upper limit in its several belts of outcrop can be easily followed. Much of the mapping in Wythe County, however, is based on d'Invilliers' geologic map of the New River-Cripple Creek region, which has been modified to accord with observations in 1917 by the present authors. According to McCreath and d'Invilliers[1] the dolomite in the belt shown on the map (Pl. III) as extending in a north of east direction from the north side of Gleaves Knob overlies the Watauga shale, but observations during the examination of the region for this report tend to indicate that this dolomite underlies the Watauga and is thus the Shady dolomite.

Because the residual clays and the wash from the mountains conceal the dolomite in most places the relations of the Shady to the Erwin quartzite are seldom visible. The contact between these two formations was observed in the bluff at the confluence of Fisher Branch and Cripple Creek and on Dickey Creek 1 mile southwest of Sugar Grove.

[1] McCreath, A. S., and d'Invilliers, E. V., The New River-Cripple Creek mineral region of Virginia, p. 10, 1887.

The formation here described was named Sherwood limestone in 1905 by H. D. Campbell[1] in describing the subdivisions of the Shenandoah limestone in the vicinity of Lexington. It is, however, the same as the Shady dolomite of northeastern Tennessee, and as that name has long been in use it will be employed in this report. It is also equivalent to the Tomstown limestone of southern Pennsylvania, Maryland, and northern Virginia, and is the basal formation of the Shenandoah group.

Fossils are rarely found in the Shady dolomite and have heretofore been restricted to the pteropod *Salterella* and fragments of a few trilobites referred to the genera *Kutorginia* and *Olenellus*. Several unusual forms were discovered recently by one of the authors in Rye Valley east of Marion. They are low organisms whose texture was only brought out on the surface of the mass of dolomite by weathering, which suggests that the fossils are probably present but invisible in much of the rock of this type. Two forms were determined by E. O. Ulrich, one composed of concentric laminæ and probably an algal growth of the genus *Cryptozoon*. The other is a more highly organized growth probably of the sponge-like coral family Archæocysthidæ. The species is new and cannot be correlated, but the few other fossils referred to as found in the formation elsewhere determine its age to be Lower Cambrian.

WATAUGA SHALE.

The formation that overlies the Shady dolomite is a shale which is called Watauga in northern Tennessee. In its typical exposures in northeastern Tennessee, and also in southwestern Virginia, it is a purplish sandy shale and sandstone with some limestone beds, but in many places it is less siliceous and more calcareous so that it weathers more readily and loses some of these characteristics. In the northern part of the area it is so deeply weathered that its outcrops are soft buff shale which passes readily into soil and is seldom seen. However, the fresh rock brought up from the bottom of the Niesswaner shaft at the Elkton mines southeast of Elkton is typical purple shale even exhibiting characteristic suncracks. In this northern region also sandstone beds are exceptional in the formation, but laminated ripple-marked sandstones characteristic of the formation were seen east of Front Royal. Some of the beds weather to compact, dry, ocherous clay, banded purple, pink, and buff, as at the ocher mine 10 miles southwest of Luray. Harder thin blue limestones and calcareous shale outcrop in a few places. South of Vesuvius the formation is less weathered

[1] Am. Jour. of Sci., 4th ser., vol. 20, pp. 445-447, 1905.

and preserves its characteristic purple color and has more sandy material in it. In southwest Virginia south of Marion and in Rye and Cripple Creek valleys it is so resistant to weathering that it makes prominent rugged ridges, generally wooded and covered with slabby sandstone and slate fragments. (See Pl. IX.) The formation is so folded that a carefully measured section is difficult to obtain, but a generalized section of the formation south of Marion is as follows:

Generalized section of Watauga shale, south of Marion.

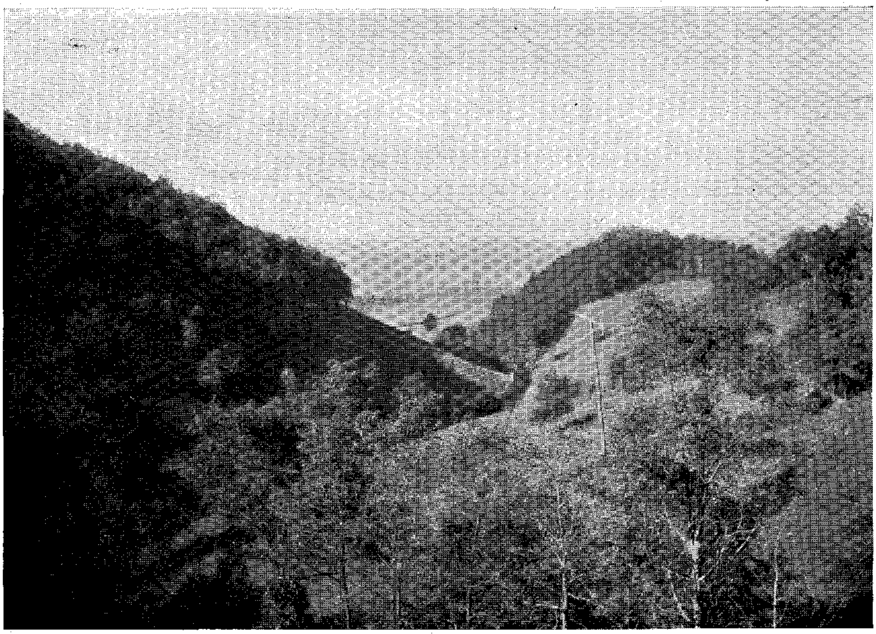
	Feet.
Thin-bedded magnesian limestone and coarse dolomite breccia (overlies the Watauga).	
Red and green, suncracked sandy shale	50±
Softer, probably calcareous shaly beds	150±
Hard, red, rippled, laminated sandstone and sandy shale in thick beds	100
Soft red and green, probably calcareous shales and earthy buff dolomite weathering yellow. Large irregular earthy brecciated cherty masses in shale at base, which weather to large yellow jaspery brecciated chert and white and gray chalcedonic chert nodules	120±
Coarse dark dolomite (Shady dolomite).	
	420±

This is regarded as the minimum estimate of thickness of the formation in the vicinity of Marion and it may be much thicker. In the vicinity of Natural Bridge it has been determined to be about 900 feet thick, but it is probably not so thick farther north where exposures are too poor to determine its exact limits.

In the southwestern part of the State large round ferruginous jaspery cherts with drusy quartz in cavities, preserving evidence of having replaced a conglomerate or breccia, and other large round white and dark chalcedonic flints mark the base of the formation along the front of the mountain south of Marion. They probably represent a basal sediment of reworked dolomite fragments and residual material on an old land surface resubmerged in Watauga time. These cherts strew the surface in many places in this part of the area, and in the eastern part of Currin Valley form a low ridge and spurs on the north slope of Brushy Mountain.

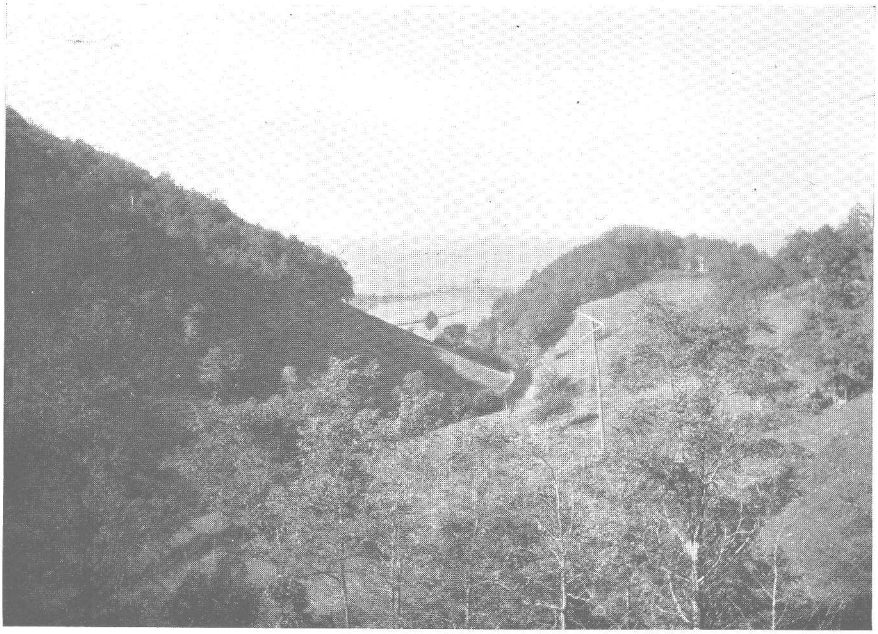
This formation was named Buena Vista shale by H. D. Campbell,[1] but it is the same as the Watauga shale of Tennessee, and as that name has been long in use it will be employed here. It is equivalent, at least in part, to the Waynesboro shale of southern Pennsylvania, Maryland, and northern Virginia.

[1] Loc. cit., pp. 445-447.



(A) Wooded hills composed of Watauga shale, south of Marion. Limestone lowland beyond through the gap.

(B) Cleared hills composed of Watauga shale on south side of Town Creek, south of Marion. Slopes are steep, and soil where cultivated is trenched by rills.



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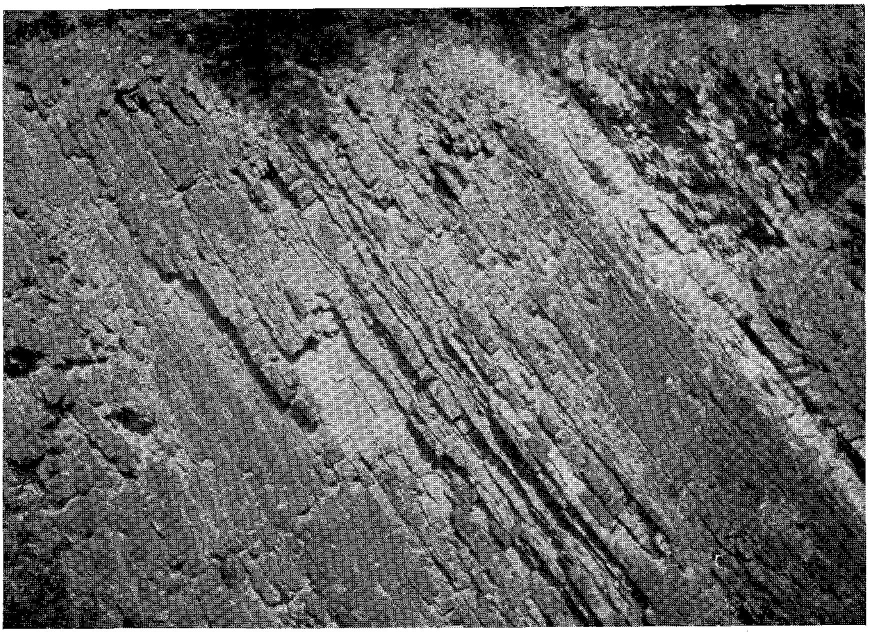
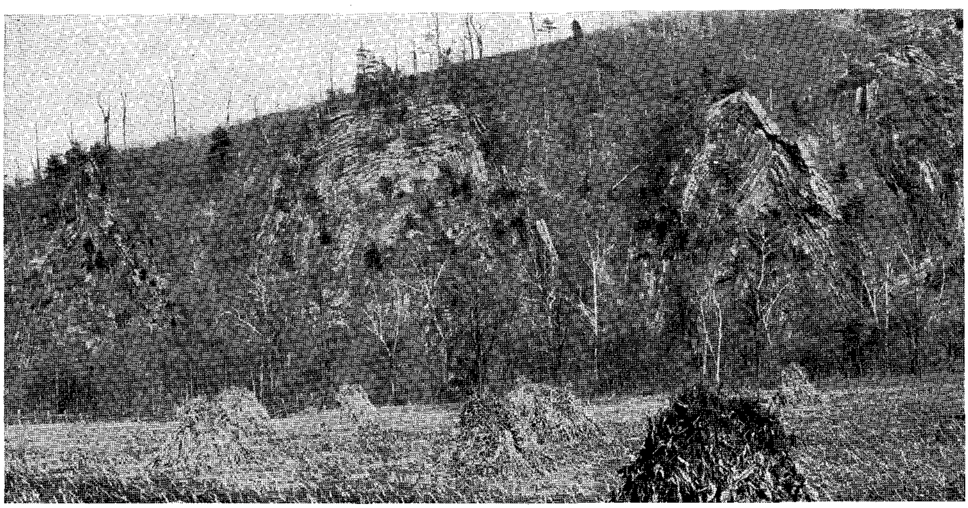
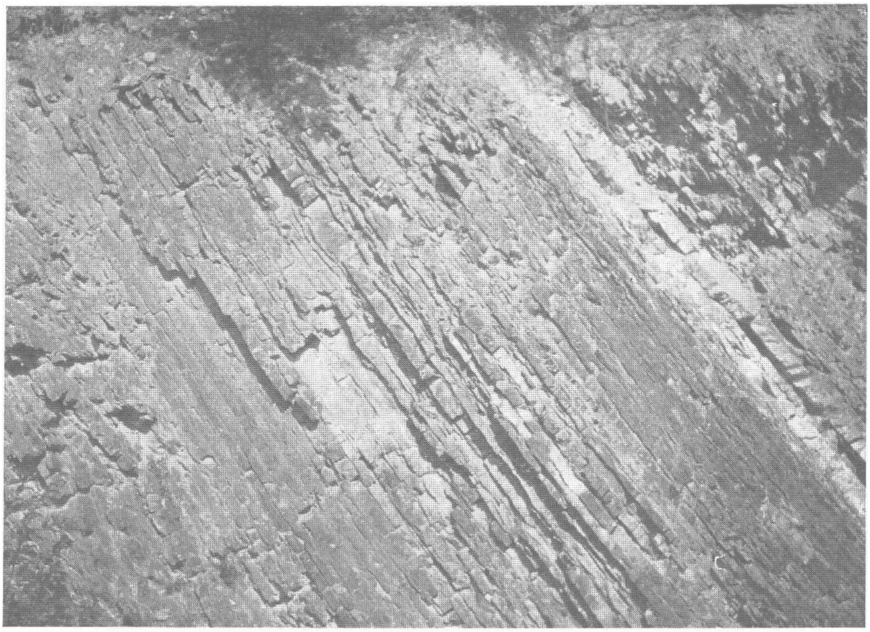


(A) Inclined strata. Thin-bedded sandstone in Erwin quartzite on Marion & Rye Valley Railway near Quebec. Many of the beds are rippled, suncracked, and marked by numerous animal trails.



(B) Folded strata. Hard rocks are inclosed in soft beds that have been eroded from the face of the exposure. Near Great Cacapon, W. Va. The rocks are of Silurian age, similar to those which outcrop northwest of the Valley of Virginia.



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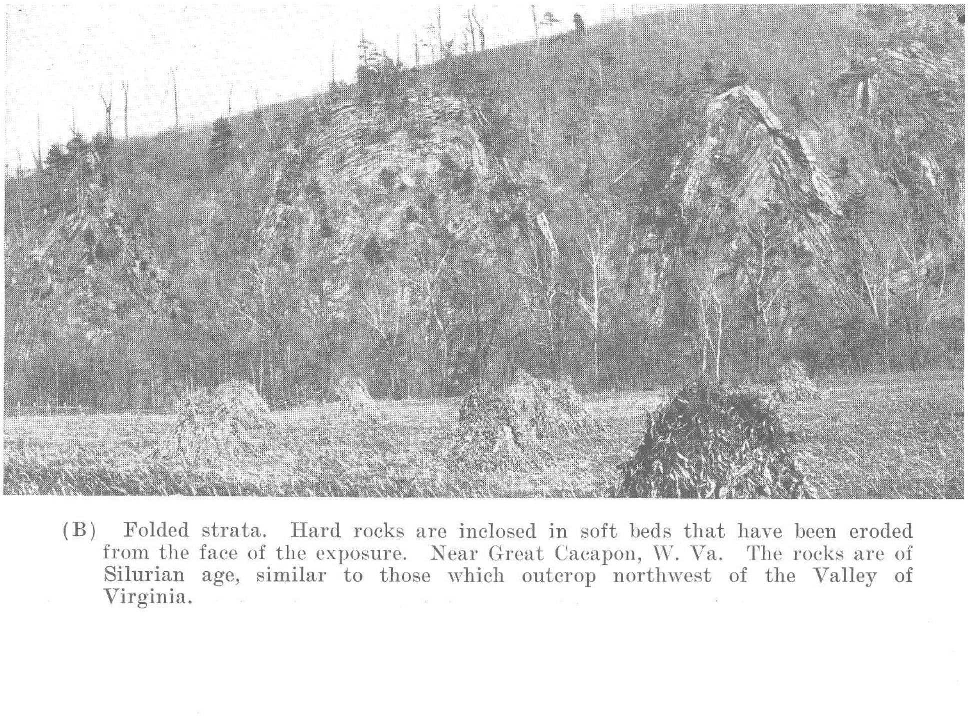


(B) Folded strata. Hard rocks are inclosed in soft beds that have been eroded from the face of the exposure. Near Great Cacapon, W. Va. The rocks are of Silurian age, similar to those which outcrop northwest of the Valley of Virginia.

The Watauga shale is sparingly fossiliferous. Trilobites referred to the genus *Ptychoparia* have been found in the formation in Virginia. On the basis of present knowledge the Watauga is classified by the United States Geological Survey as Lower and Middle Cambrian. In southern Pennsylvania fossil shells referred to the genus *Obolus* and also fragments of trilobites, regarded by E. O. Ulrich as of Middle Cambrian age, have been collected from the Waynesboro formation.

UPPER LIMESTONES OF THE SHENANDOAH GROUP.

Above the Watauga shale are limestones and dolomites which have not been studied in connection with this report as they do not relate to the problem in hand, and as they need not be considered in this connection they will not be described. The dolomite next overlying the Watauga has many characteristics of the Elbrook limestones of Pennsylvania and is regarded as equivalent to that formation.

GEOLOGIC STRUCTURE.

General statement.

The sedimentary rocks were originally nearly horizontal when deposited in the sea. The beds in most places are now steeply inclined (see Pl. X) and folded into long troughs (synclines) and arches (anticlines), whose axes are generally parallel to the northeasterly trend of the mountain ridges. This was brought about by the great horizontal compression of the rocks near the earth's surface during the process of the evolution of the present globe. The compressing force acted from the southeast so that the folds in general trend northeasterly, although in places they locally trend more easterly, and are in general unsymmetrical in cross-section, leaning toward the northwest. The bedding of the rocks is locally obscured by an inclined cleavage (Pl. V, B, p. 14) which is due to the parallel arrangement of the mineral particles that make up the rock. This cleavage has been produced by the movement of the particles under pressure, or flowage, and their partial recrystallization. Cleavage gives to the rocks the property of splitting more readily parallel to the mineral faces. This structure almost invariably dips to the southeast, in the direction from which the force acted. After being folded and wrinkled the rocks were worn down by the processes of atmospheric decay and erosion. The softer and more soluble rocks were removed from the higher regions, and the quartzites, shales, and greenstones underlying the limestones were exposed at the surface in the broad anticlinal areas, and, because of their greater resistance to erosion, they now form the mountains, whereas the limestone underlies the valleys in synclinal areas. 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 2.

The rocks of the Blue Ridge are the oldest in the region and are exposed at the surface by erosion. They form the mountains because they occupy the center of a great upfold or anticlinorium of the earth's exterior. Limestones like those in the Appalachian Valley once covered these older

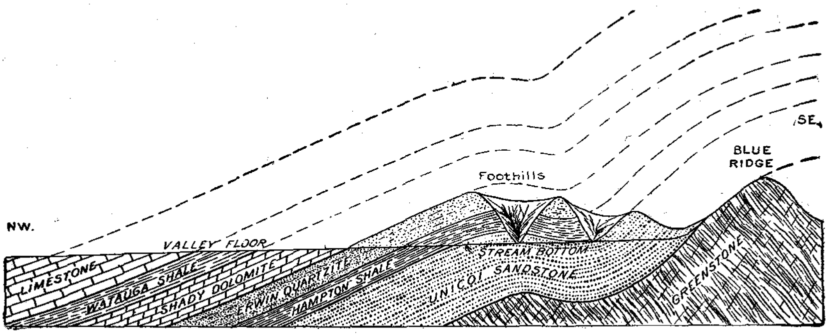


Fig. 2.—Generalized structure section of the west front of the Blue Ridge and the adjacent part of the Shenandoah Valley, showing the general relations of the rocks in this region. The former extent of the rocks before removal by erosion is shown by dashed lines above the present surface.

rocks and have been worn away by the surface solution and weathering and the removal of the residual material by rain, wind, and streams. The layering and other original structures of the older pre-Cambrian rocks have been largely destroyed by the secondary schistosity developed in the rocks, so that although they were intensely mashed, folding or crumpling of the layers is hardly discernible. The sandstones, shales, and quartzites which directly overlie these older rocks lie on the northwest flank of the Blue Ridge upfold or anticlinorium and in general dip toward the northwest at steep angles, but the dip varies from place to place and is even reversed on the sides of minor folds. The folds are also broken in places and the rocks are faulted or dislocated from their normal position, so that outcrops of the beds are duplicated at some places and at others the beds are concealed or removed. A great master fault apparently follows along the Blue Ridge throughout most of the region studied, and lies within but generally close to the west front of the mountains. The rocks are horizontally

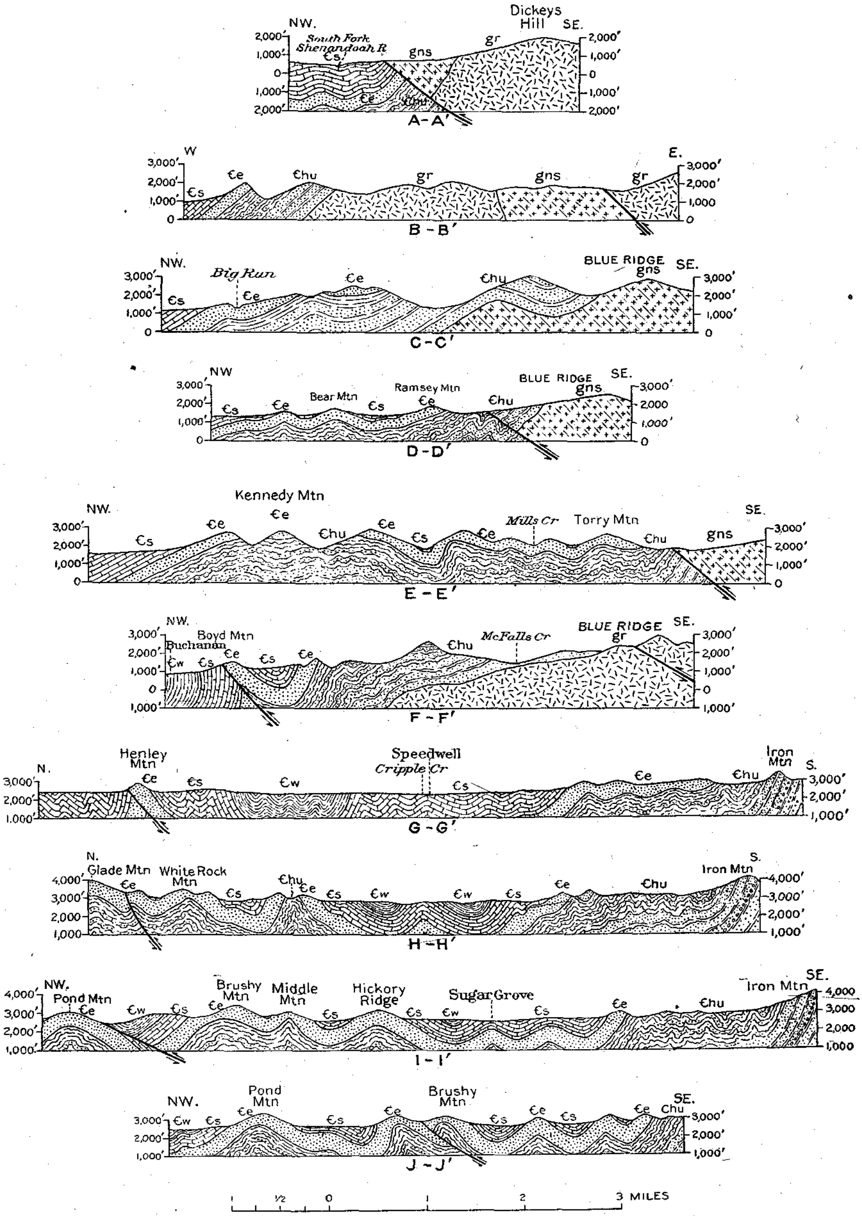


Plate XI.—Geologic cross sections along the lines marked A-A′ to J-J′ on the geologic map, Plate III in pocket.

gr, pre-Cambrian granite; gns, pre-Cambrian greenstone; Chu, Hampton shale and Unicoi formation; Ce, Erwin quartzite; Cs, Shady dolomite; Cw, Watauga shale.

Section A-A′, southwest of Front Royal. B-B′, near Ingham. C-C′, 8 miles southwest of Elkton. D-D′, northeast of Waynesboro. E-E′, south of Stuarts Draft. F-F′, southeast of Buchanan. G-G′, through Speedwell. H-H′, 4 miles east of Sugar Grove. I-I′, through Sugar Grove. J-J′, southeast of Marion.

displaced by this fault a distance of 4 or more miles in places, and the fault is therefore an important element of the structure. The sections in Plate XI show the structure at various points along the mountain front, described in the following pages.

Detailed structure.

Northeast of Front Royal the general structure is monoclinal, i. e., the Erwin quartzite and the older rocks beneath dip in one direction, but accompanied by minor folding, as is well shown in the cuts on the Southern Railway. The Erwin quartzite is nearly vertical in the cuts, but in the pit of the old Seibel iron mine it is seen to be strongly overturned so as to dip toward the southeast. East of Front Royal a great overthrust fault cuts across the beds and the pre-Cambrian greenstone is thrust across the ends of the quartzite, so that along the front of the mountain south of Front Royal the greenstone abuts against the limestone of the valley, the siliceous Cambrian rocks (the Unicoi, Hampton, and Erwin formations) being concealed at the surface. South of Bentonville the great fault cuts across the beds again and passes back into the mountains, so that the Cambrian siliceous rocks are exposed at the surface dipping steeply to the west under the limestones of the valley, or standing vertical and even overturned so as to dip steeply toward the southeast in places. There is apparently some faulting along the bedding of the Erwin quartzite, and possibly also along its base, and folding in the shales and softer beds of the Hampton and Unicoi formations, but the folding shows plainer in the arrangement of the Erwin quartzite hills east of Elgin.

Southeast of Luray the great overthrust fault comes close to the mountain front and brings pre-Cambrian granite against the Erwin quartzite, which is here somewhat folded and in part nearly flat lying. South of Luray the Erwin is repeated by folding and makes three divergent ridges in places, but these are all cut off at their south ends by the great overthrust fault which thrusts the pre-Cambrian granite across the ends of all the siliceous rocks and onto the limestone, a horizontal distance of over 4 miles. There is also faulting along the front quartzite ridge here. South of Stanley a large dome-shaped uplift west of the fault makes a prominent offset of the mountain front in which the Cambrian siliceous rocks dip 40° to 60° north, northwest, and west away from the core of the pre-Cambrian granite and greenstone. East of Shenandoah the dips flatten out on the crest of the fold so that the Erwin also caps hills back of the front ridge.

At Naked Creek a marked inset in the mountain front is caused by a sharp synclinal fold in the Erwin quartzite in which the dips are partly low, 20° to 30°. South of the creek minor folds carry the white quartzite back onto the second line of hills, and the great overthrust fault bringing the greenstone closer to the front nearly cuts out the older siliceous rocks. South of Elkton folding is more evident in the siliceous beds. It produces an outlying ridge of quartzite at Hawksbill Creek and the Erwin also extends back on the inner ridges in gentle synclines. The width of the belt of Cambrian siliceous rocks is increased to 3½ miles by the folding south of Simmons Gap. This minor folding is evident along the mountain front to the vicinity of Waynesboro. Coves within the mountains are developed on the softer Hampton shales brought up on anticlines in several places. At the Crimora mine the Shady dolomite is partly infolded in the quartzite and forms a reëntrant valley and a small offset in the mountain front. Northeast of Waynesboro gentle folding brings up the Erwin quartzite west of the mountain front which forms low hills out in the limestone valley.

East of Waynesboro the great fault cuts abruptly across the bedding of the rocks and comes to the front of the mountain, offsetting the Erwin quartzite about 3 miles horizontally. South of Sherando, where the fault again cuts across the bedding in passing into the mountain, the Erwin is cut off and offset to the east. The geologic map strikingly shows that the mass of rocks intervening between these two offsets has moved westward along the fault, the front quartzite ridges lying out beyond the rest of the mountain front along a distance of 10 miles. Southwestward another large dome-shaped uplift west of the fault makes a group of high mountains composed largely of Erwin quartzite. The Hampton shale is exposed only in some of the deeper valleys that cut into minor anticlines on this broad uplift, which is not a simple dome but has several minor folds, and one or two of the deeper synclines inclose Shady dolomite. Several folds are cut through by the gorge of St. Marys River along the railroad to the Red Mountain and Pulaski mines.

South of Vesuvius the structure is more simple, and the beds in general dip steeply northwestward off the mountain in a normal monocline. Here and there they dip more gently or are slightly folded, and the outcropping belts of the formations widen where the dips are low. The monoclinal structure extends beyond James River to where the formations are cut off by the great overthrust fault which comes to the front of the mountain, and the granite is thrust across the ends of the sedimentary beds. In the gorge of the James the northwestward dipping beds of the monocline are seen to be the west limb of an anticline in which granite forms the center. It is faulted off on the east by Erwin quartzite which is here infolded and the sedimentary series is repeated. In the valley west of Balcony Falls two anticlines, apparently faulted, bring the Erwin quartzite to the surface within the limestone lowland.

The structure of the rocks in Arnold Valley, south of Glenwood, is not understood. It is apparently a syncline inclosing Shady dolomite, for limestone is exposed in a few places in the broad bottomland. A fault along its west side brings the limestone across the ends of the sedimentary beds down to the granite, and this fault apparently passes into the two faulted anticlines in the valley west of Balcony Falls. West of Arnold Valley the Erwin quartzite continues its southwesterly course in a normal northwest-dipping monoclinal structure, but toward Buchanan minor folding is shown by the irregularity of outline and local widening of the belt of quartzite.

Just southeast of Buchanan a small sharp anticline, broken on its northwest side by a thrust fault with the upthrow on the southeast side, brings up the Erwin quartzite in a long narrow outcrop which makes a line of low rocky ridges. The structure of the northwest slope of the Blue Ridge between Buchanan and Troutville is simple as the beds in general dip 40° and 90° to the northwest, but the outcrop of the Erwin quartzite, which is marked by a belt of foothills and ridges, is sharply bent in places by small folds. Furthermore close folding, probably aided by slight faulting, has so crushed the Erwin in places near Troutville and Nace that it does not produce ridges as high as usual and rock ledges are not so common as elsewhere. Just south of Troutville the Erwin dips to the west with some complex minor folding, and passes beneath the limestones and shales in the valley around the end of a southwestward plunging anticline which is cut off on the east side by a thrust fault, thus terminating this part of the Blue Ridge at Fullhardt Knob.

On the southeast side of the Blue Ridge southeast of Lithia there is a great fault by which pre-Cambrian granite and granite gneiss on the lower part of the mountain slope have been brought in contact with the Watauga shale and possibly younger rocks in the adjacent part of the valley of North Fork of Goose Creek, and farther southwest the Unicoi formation is brought in contact with the Shady dolomite and possibly younger formations along the same line. Another great fault on the southeast side of this limestone valley has a much more crooked trace, and the pre-Cambrian granitic rocks of McFalls, Taylors, and Porters mountains are thrust to the northwest upon the Shady dolomite, Watauga shale, and possibly younger rocks in the inclosed valley. The Erwin quartzite is nowhere exposed on the North Fork of Goose Creek northeast of Montvale or on Glade Creek northeast of Roanoke, because it is cut out by these two faults. These faults apparently join or overlap at or near Powell Gap in the Blue Ridge. The area has not been mapped because the structure is not satisfactorily worked out.

As the region between Roanoke and Ivanhoe has not been examined, the structure of the Cripple Creek and Rye Valley region will next be described. The Unicoi, Hampton, and Erwin formations, which are exposed in Iron Mountain and its foothill ridges along the south side of Cripple Creek and Rye valleys, have in general a monoclinal structure by which they dip to the north away from the mass of pre-Cambrian rocks exposed farther south and pass beneath the Shady dolomite and Watauga shale in the valley. But this monoclinal structure is largely obscured by numerous closely compressed anticlines and synclines and by faults. The dip of the beds at most places is 45° to 90°. On the upper parts of Cove and Francis Mill creeks the Shady dolomite occupies synclinal basins which lie between ridges of the Erwin quartzite. Between Ivanhoe and Francis Mill creek several anticlines which bring the Erwin quartzite to the surface in narrow belts marked by ridges project out into the Cripple Creek Valley. One of these anticlines forms Hussey Mountain and Fry's Hill and another Raven Cliff Ridge. The Erwin at the northwest end of the last-named mountain is faulted against the Watauga shale. Gleaves Knob and a small area of quartzite west of Eagle are small anticlinal hills of the Erwin out in the limestone valley. Lick Mountain, a name applied to a group of ridges standing out in the valley south of Wytheville, is a compound anticline (anticlinorium) which brings the Erwin quartzite to the surface out in the valley. Single narrow anticlines, which are represented on the surface by sharp parallel quartzite ridges which trend nearly due east, characterize the southern part of the uplift. Some of the anticlines are probably faulted on the north side. A number of narrow troughlike synclines between the ridges, which plunge away from the center of the uplift, inclose Shady dolomite. At the north the main uplift raises the Erwin quartzite so high that it makes a prominent mountain mass which trends north of east.

From Francis Mill Creek to Dickey Creek near Sugar Grove the front ridges of the mountains which are produced by the Erwin quartzite are monoclinal and nearly in line, but folding carries the outcrop of the Erwin quartzite back of the front ridge, and it is repeated by infolding at one place. An anticline that plunges to the northeast at Dickey Knob causes an offset in the mountain front at Dickey Creek. A small synclinal basin incloses the Shady dolomite entirely surrounded by outcrops of Erwin quartzite 2 miles southwest of Teas. A thrust fault with the upthrow on the south side has cut out the outcrop of the Erwin along the mountain front just southwest of Comers Creek, so that for a distance of almost 3 miles farther southwest the Hampton and Unicoi formations are in contact with the Shady dolomite. South of Quebec the outcrop of the Erwin is repeated in a sharp anticline which is broken on the north side by a thrust fault. The Shady dolomite is exposed in the intervening synclines which to the west also inclose Watauga shale in places.

The Brushy Mountain group of ridges, a compound anticline (anticlinorium) which stands out in the valley like Lick Mountain and is on a southwestward extension of the axis of that uplift, is made up of at least four anticlinal ridges which trend northeastward and plunge at both ends under the limestone of the valley. The main ridge is a large massive anticlinal mountain which is cut through by South Fork of Holston River at Quebec and by Hopkins Creek at the west, at each of which black shale and thick vitreous quartzite are exposed in the center of the fold. The anticline is broken on its northwest side by a thrust fault which cuts it off at the west and terminates the mountain a short distance west of Hopkins Creek. Northeastward the fault cuts diagonally across the strata, cutting off a second anticlinal ridge on the northwest flank of Brushy Mountain and bringing a synclinal belt of Watauga shale in Currin Valley against the Erwin quartzite in the anticline of Pond Mountain. Rich Mountain, at the head of Currin Valley, is a short independent anticline which plunges at both ends. Between these anticlinal ridges are synclinal valleys which plunge away from the center of the uplift and inclose Shady dolomite. Eastward the main Brushy Mountain anticline seems to continue in Glade Mountain and two other anticlines on the south merge with it in the center of the uplift. Shady dolomite extends far up the valleys between these quartzite ridges from both sides, and near the summit of Brushy Mountain on the Slemp Creek road an isolated area of Shady is infolded in the quartzite along one of these synclines. The southernmost of these anticlines is cut through by Slemp Creek and by several other cross streams, exposing the Hampton shale beneath the Erwin.

Cripple Creek and Rye valleys are a compound syncline (synclinorium) trending slightly north of east between the Lick Mountain-Brushy Mountain anticlinal axis on the north and the general monoclinal northward dip of the rocks in Iron Mountain and its foothill ridges on the south. Gentle minor folding and some faulting parallel to the general structure cause the Shady dolomite and Watauga shale to outcrop in a number of narrow belts, the Watauga being infolded in general in three synclinal depressions. A low dome-shaped anticline brings the Erwin quartzite to the surface at the mouth of Fisher Branch, and an anticline broken on its north side by a thrust fault brings the Erwin to the surface in Gleaves Knob, as previously described.

PHYSIOGRAPHIC FORMS.[1]

Viewing the Appalachian Valley province in a broad way it is noticeable that in all of the wider valleys there is a general lowland level which forms the valley floor, into which the streams have cut their narrow channels. This is well shown in the profiles of The Valley in Plate I, page 6. On the mountain summits also there is an upland level to which most mountains rise and above which few stand, but this upland level is not so apparent as is the valley floor. It can best be observed from a mountain summit where the even top of many ridges and mountains can be seen to fall nearly into a plane, but it may be observed also from a study of good topographic maps. On closer study it is found in some areas that the valley floor is made up of two or more benches at levels 100 feet or more apart. It is also to be noted in places that certain of the tops of the ridges in the valley and of the Blue Ridge do not rise to the upper level but to an intermediate level. It is generally believed that the several levels and benches noted in the present land surface represent plains or near-plains that were former land surfaces which resulted from the gradual but more or less complete wearing away of the elevated portions of the land by weathering and stream erosion; that the highest plain was formed first and that the lower plains are successively younger and were cut into the higher plains. These near-plains, or peneplains as they are called, may be referred to for convenience as the valley-floor peneplain, the intermediate peneplain, the upland peneplain, and the summit peneplain, as shown in figure 3.

The process of the formation of these peneplains may be explained as follows: At the time of the formation of the upland plain this region stood somewhat above the sea and the rocks at its surface were attacked by the

[1] Written by G. W. Stose. A fuller treatment of the physiography of the region has been prepared for publication in a bulletin on the Geography of Virginia, West Virginia, and Maryland, by the U. S. Geological Survey.

air, rain, frost, wind, streams, and sea. The processes of weathering, disintegration, and removal of the particles of the rock were of course very slow, the same as they are to-day, and the immediate effect on the land was small, but after a long period of time, probably tens of thousands of years, the total effect was appreciable, and in still longer periods the changes were great. The softer and more soluble rocks were removed more easily and quickly than the harder and less soluble rocks and became lowlands. As the alternating layers of hard and soft rocks composing the earth were intricately folded, this wearing away of the softer beds resulted in valleys between hills of hard rock. As the streams cut their valleys down toward sea-level, their power to cut their channels deeper diminished and they began to widen their valleys. This wearing away of the land continued

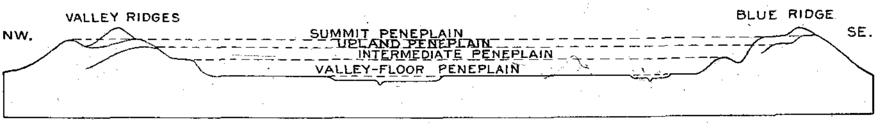


Fig. 3.—Ideal profile section across the Valley of Virginia showing the peneplain surfaces described in this report. The upland peneplain is regarded as Jurassic-Cretaceous in age and the summit peneplain is probably still older. The intermediate peneplain is regarded as Upper Cretaceous in age; the valley-floor peneplain as early Tertiary in age; and a lower valley-floor terrace, where present, as late Tertiary in age.

for a very long period, probably hundreds of thousands of years, for even the hard rocks were largely worn down during this period and most of the land surface was reduced to a rolling plain sloping gently toward the sea, on which there were only low hills where the harder rocks outcropped at the surface. The process was finally interrupted by an earth movement which elevated this part of the continent, raising the planed surface higher above the sea and tilting it toward the sea at its margins. This elevation caused the streams to renew the cutting of their channels and gave renewed activity to the weathering and eroding processes. The parts of the erosion plain that were composed of softer rocks were thus worn away, leaving remnants of the early plain only those parts that were composed of harder rocks. To-day only narrow remnants of this old plain remain on the tops of the highest ridges in the Appalachian Valley, and the evidence of a plain at this level that once extended continuously across the valley is very meager in this area.

After the elevation just referred to the land again remained nearly stationary for another long period, probably hundreds of thousands of years, and another nearly level plain, but not so extensive as the first, was cut upon the land, above which rose the remnants of the former plain. It was during this period of erosion that streams that flowed through depressions in the low ridges composed of harder rocks on the former plain cut their channels into the upturned edges of the layers of these hard rocks. Although weathering, the beating rain, and small rivulets did not perceptibly wear away these hard rocks, large streams carrying sand and gravel and flowing across their upturned edges were able to abrade their channels and cut them down until now they are deep gaps through the narrow ridges of hard rocks. The cutting of the second plain was likewise terminated by an uplift of the land and the process was repeated again.

The even floor of the Valley of Virginia into which the channels of the present streams have been cut represents a plain of erosion at a still later epoch, and as it is formed only on the softer or soluble rocks (shale, thin sandstone, dolomite, and limestone) the epoch of erosion was evidently not so long as in the earlier epochs when the harder rocks were also worn down. Although the floors of the several parts of the valley are not at the same level, they were probably formed during the same general epoch of erosion, for their level would depend on the distance of the area from the sea along the line of drainage which existed at the time the plain was formed. In general terms it may be said that during a certain period of time the land stood at such an elevation above the sea that the erosion of the streams and rivulets cut the softer and more soluble rocks down to a gently sloping plain which is now represented by the higher parts of the floors of Shenandoah Valley and the other wide flat-bottomed valleys on the southeastern side of the Appalachian Valley province, as well as of many of the narrow valleys between the ridges in the northwestern part of the Valley province. These plains extended back to the foot of the bounding ridges where the wash from the mountains built up alluvial aprons and cones to slightly higher levels than the plain.

Since these valley floors were formed the land has been elevated at shorter intervals, so that at each stage of the wearing down of the land the streams have been able only to cut relatively narrow valleys into the floor, and they now appear as benches at successive levels in a belt a mile or two wide along the main streams. The larger stream channels now are in general 200 to 300 feet below the valley floors, although in places they are 800 feet below, and some have cut a wide flood plain at their present level. The winding courses of many of the streams which occupy deep narrow gorges in the valley floor were established when the streams wandered sluggishly back and forth across the valley-floor plain, and these winding courses were preserved when the grades of the streams were increased by the elevation of the land and the streams cut narrow channels into the floors.

The ages of the various partial plains, or peneplains as they are called, in the Appalachian region are not definitely known, but from their relations to sediments on the coastal plain of New Jersey, Maryland, and Virginia, their ages have been approximately determined. The highest peneplain that is recognized in this area ranges in elevation from 3,500 feet above sea-level on the Blue Ridge in the northern part of the State to 4,000 feet in southwestern Virginia. Near the Potomac the Blue Ridge seems to have been entirely eroded below this level and the plain obliterated. Near Luray broad flats and gentle divides on the tops of the Blue Ridge at 3,500 feet elevation probably represent the peneplain. Stony Man and other peaks rise above the plain to about 4,000 feet elevation. Around Elkton the mountain tops are chiefly at 3,000 feet elevation and probably represent a later erosion level. South of Waynesboro the mountain tops again have a uniform level at 3,500 feet elevation, and higher ridges and peaks rise to 4,000 feet and over. The 3,500-foot level is preserved on the mountains on both sides of the James River gorge and as far south as the Peaks of Otter which are about 4,000 feet in elevation and rise above a poorly represented plain at 3,000 to 3,500 feet. In the vicinity of Roanoke River the mountains are reduced below the peneplain level, but to the southwest the Blue Ridge becomes a broad plateau at about 3,000 feet elevation, which is apparently a later lower peneplain developed on slightly softer rocks, for the higher peaks of Poor Mountain rise to nearly 4,000 feet elevation and many of its even-topped ridges are 3,500 feet. In Iron Mountain still farther southwest the even tops of the higher mountains rise to 4,000 feet elevation.

Corresponding even-topped ridges in the valley agree with those of the Blue Ridge, and if the valleys were all filled up to the level of these mountain tops the surface would be a plain sloping gently northeastward, above which a few ridges and peaks would rise to greater height. This is believed to represent the surface of the land in a very early stage of the development of the present features. The correlation of the peneplain with similar peneplains in the northern Appalachians is not yet established, but it seems to be the same as the peneplain at 3,900 feet elevation west of Cumberland, Maryland, and probably is older than the Kittatinny peneplain so well developed on Kittatinny and other mountains in Pennsylvania at 1,600-foot elevation. As that peneplain is believed to be early Cretaceous or late Jurassic in age, this 3,500-4,000-foot peneplain is probably older. It will be referred to in this report as the summit peneplain. (See fig. 3.)

The next lower peneplain is best represented by the Blue Ridge plateau southwest of Roanoke. This plateau is a gently rolling surface slightly trenched by streams, with a general altitude of 3,000 feet, above which rise low rounded hills and bordered in places by mountain ridges which rise to 3,500 and even 4,000 feet. As a whole it stands as a plateau above the lowlands on the northwest and on the southeast, and undoubtedly represents an old erosion surface cut on rocks of different character but of moderate hardness. Although this plain was elevated and subjected to renewed erosion, this part of the old surface was more protected from destruction than other parts and still preserves an even surface with wide shallow valleys, whereas other portions composed of softer rocks have been cut away and now form the adjacent lowlands. This peneplain is not so clearly discernible north of the Roanoke where the 3,500-foot plain predominates, but traces of it may be detected in most place, and northeast of Waynesboro it again forms the broad rounded tops of the Blue Ridge at about 3,000 feet elevation. At Front Royal it apparently descends to 2,500 feet and probably reaches 2,000 or 1,900 feet at the Potomac, which is the elevation of a marked peneplain on the mountain tops in Maryland and southern Pennsylvania that is believed to be the same as the peneplain that is called the Kittatinny peneplain in the northern Appalachians named from Kittatinny Mountain in Pennsylvania and New Jersey, where it has an altitude of 1,600 feet. That plain has been traced more or less continuously to the coastal plain of New Jersey, where it apparently passes beneath the lowest Cretaceous sediments which lie on the even surface of the old sea floor, and it is therefore believed to have been formed just prior to and during their deposition. It is therefore referred to as the Jurassic-Cretaceous peneplain. The peneplain in Virginia will be referred to in this report as the upland peneplain. (See fig. 3.)

A still lower peneplain is poorly represented on some of the tops of foothill ridges, spurs, and knobs, and in some low divides of the Blue Ridge. It is nowhere so well definied as the higher plains, although some broad tracts in the mountains of southern Pennsylvania indicate its wide development there on rocks of a moderate hardness. In Maryland it is called the Weverton peneplain from the town of that name on the Potomac, where the rather even crest of the Blue Ridge at 1,400 feet elevation apparently represents this peneplain. Wind gaps in the Blue Ridge east of Massanutten Mountain at 2,250 feet elevation represent old stream channels probably on this plain which were abandoned when the land was elevated and erosion became more active. The level tract at the head of St. Mary River in the heart of the mountains east of Greenville, 2,250 to 2,300 feet elevation, on which the deposits of the Red Mountain mine are located, may also represent this peneplain. Its age is not readily determinable, but it is supposed to have been formed during Cretaceous time just prior to and during the deposition of the Upper Cretaceous sediments, so it is generally referred to as the Upper Cretaceous peneplain. In this report it will be called the intermediate peneplain. (See fig. 3.)

The next younger peneplain which has been recognized in this region, here called the valley-floor peneplain, has various levels, depending on the drainage system in which the floor was developed and its corresponding distance along its water course from the ocean. In Shenandoah Valley the valley floor ranges from 1,800 or 2,000 feet at its head to 600 feet at the Potomac. Above the forks in Shenandoah River, where the valley is divided lengthwise by Massanutten Mountain, the floors of the two parts of the valley have slightly different elevations and probably represent two separate drainage systems. The southeastern part is the lower and its floor rises to about 1,800 feet elevation at the divide at Lofton. The northwestern part rises to 2,000 feet on the divide at Middlebrook. This peneplain has been called the Shenandoah[1] in Virginia, and is the same as the Harrisburg peneplain in Pennsylvania which is so well developed in the vicinity of Harrisburg, Pennsylvania. It cannot be so readily traced to the Atlantic Coastal Plain as the higher peneplains, but is believed to represent the floor under the earliest Tertiary coastal plain deposits and is therefore regarded as early Tertiary in age.

The peneplain that forms the floor of the Fincastle Valley at 1,500 feet elevation, remnants of which occur also in the Salem Valley at this level; the floor of the Dublin Valley, including Cripple Creek and Rye valleys, 2,200 to 2,700 feet in elevation; and the floor of the Abingdon Valley, 2,300 to 2,600 feet in elevation, are believed to have been formed during the same epoch as that of the Shenandoah Valley—in early Tertiary time—but were developed in different drainage basins and therefore at different distances from the ocean so that their elevations are not the same and they cannot be called the same peneplain. They will be referred to as the valley-floor peneplains of early Tertiary age. The floor of Fincastle Valley and the remnants of that plain in the Salem Valley as well as the

[1] Watson, T. L. and Cline, J. H., Univ. of Va. Phil. Soc. Bull., vol. 1, No. 17, p. 360, 1913.

floors of intermontane valleys north of Salem Valley at 1,500 feet elevation were part of the James River drainage basin at that time, whereas Dublin Valley and its many branch valleys were part of the New River drainage basin.

The later erosion of the softer rocks to a new level, 100 to 500 feet lower than these valley-floor peneplains, is believed to have occurred in late Tertiary time, probably just before and during Pliocene time. This peneplain is well marked along the Atlantic coast by high gravels, formerly called Lafayette, which were deposited upon the plain and have since been elevated. In the Appalachian Valley it is chiefly represented by flat divides in the low parts of the valley floor underlain by soluble or soft rocks, and by broad terraces and benches along the main streams where the rocks are somewhat harder. They cannot be definitely traced far from the trunk streams. The valley floor of Salem Valley, 1,000 feet in elevation, was probably formed at this time, when Roanoke River robbed the James of this large branch.

Narrow lower terraces and benches along the major streams, most of them still covered by stream gravels, were undoubtedly formed in Pleistocene time, but cannot at present be correlated with one another nor with well-defined terraces of similar age along the Atlantic coast which have wide extent and are of uniform character, and mark three to four distinct successive levels of the sea in Pleistocene time.

THE ORE DEPOSITS

MANGANESE MINERALS.

General description.

The deposits that are described in this report include many from which only manganese minerals have been recovered, such as the Midvale, Rockbridge County, and Compton and Eureka, Page County; a number from which both manganese and iron ores have been shipped; a number from which ferruginous manganese ore alone has been shipped, such as the Red Mountain mine, Augusta County; and a number from which only iron ore, here and there slightly manganiferous, has been shipped, such as the Pulaski mine, Augusta County, and Speedwell mine, Wythe County.

The production of the different ores has been due largely to the character of the material in the existing openings, as well as to the variation in demand from time to time. For many years there was a widespread demand for manganese ore with more than 45 per cent manganese and a local demand for iron ore, whereas it was impossible to market material in which almost equal percentages of the two elements were present. If, therefore, a mine yielding largely iron ores, such as the Mount Torry mine years ago, encountered material with 5 to 15 per cent manganese, it was left untouched. Recently, with the growth of a demand for manganiferous pig iron and the use of near-by furnaces for making spiegeleisen, there has been a good market for most classes of material intermediate between manganese and iron ores.

Although locally near-by mines yield rather different products and the character of ore changes with deeper exploration, the manganese deposits predominate in the northeastern part of the belt, especially Page, Rockingham, and Augusta counties, and iron or ferruginous manganese deposits in the southwestern part, Pulaski, Wythe, and Smyth counties. This regional variation is thought to be largely due to differences in the character of the minerals from which the iron and manganese oxides were concentrated, as stated on page 54.

The manganese ores in this region are all oxides, of which only four have been found in the progress of this investigation. They belong to the group of brown to black oxides and hydrous oxides, several of which cannot be positively distinguished without analyses. The identification of minerals and their names is based on the table prepared by Fermor[1] in a report on the manganese deposits of India. In general if the mineral is uncrystallized or amorphous and has the hardness greater than 4, it is classed as psilomelane. If it is crystalline and has a hardness greater than 3, it is classed as manganite, but if the hardness is less than 3 it is regarded as pyrolusite. If it is soft and shows no signs of crystalline structure nor of the compact firm amorphous structure of psilomelane, it is classed as wad.

Psilomelane.—Psilomelane (H_4MnO_5 generally with some potassium and barium) is a bluish or grayish-black dense amorphous mineral, usually having rounded or botryoidal surface forms, concentric structure, and conchoidal fracture. A characteristic botryoidal form is illustrated in Plate XII. The hardness commonly ranges from 5 to 6.5 and therefore some specimens cannot be scratched by a knife. The specific gravity ranges from 3.7 to 4.7. Its composition is complex and apparently not definite. It always contains water, the quantity of which varies from 2.5 to 6 per cent, and it may contain as much as 17 per cent of barium and 5 per cent of potassium. The percentage of manganese varies from 50 to 57. This is the commonest manganese mineral in the Virginia deposits and forms more than 75 per cent of the washed ore.

Manganite.—Manganite ($Mn_2O_3 . H_2O$) commonly occurs as well-defined crystals which have a hardness of 4, and therefore can be scratched with a steel pin but not with a brass pin. The specific gravity ranges from 4.2 to 4.4. It crystallizes in the orthorhombic system and the crystals are generally bladed, wedge-shaped, or needle-like, with brilliant metallic luster. The mineral contains 62.4 per cent of manganese and 10.3 per cent of water. Nodules from many deposits are made up of alternate layers of psilomelane and radiating crystals of manganite. (See fig. 4.) The presence of manganite is locally regarded as an indication of high-grade ore.

Pyrolusite.—Pyrolusite (MnO_2 generally with a little H_2O) is a grayish-black to black mineral with crystalline or granular structure. It is commonly soft, has a hardness of 2 to 2.5 and therefore can be scratched with a brass pin. The specific gravity is about 4.8. It contains 63.2 per cent of manganese. Heretofore it was believed to have been derived from manganite by the loss of water. Although it has not been positively identified in many Virginia deposits, the recent work of Watson and Wherry[2] indicates that it may be widespread but incorrectly determined as manganite.

[1] Fermor, L. L., The manganese ore deposits of India: Geol. Surv., India, Mem., vol. 37, Pt. 1, pp. 117, 228, 229, 1909.

[2] Watson, T. L. and Wherry, E. T., Pyrolusite from Virginia: Jour. Wash. Acad. Sci., vol. VIII, No. 16, pp. 550-560, 1918.

Nodular psilomelane with botryoidal surface, *from* Winn prospect, Wythe County. Characteristic shape of much of the psilomelane which occurs in small and large masses inclosed in clay.

Nodular psilomelane with botryoidal surface, from Winn prospect, Wythe County. Characteristic shape of much of the psilomelane which occurs in small and large masses inclosed in clay.

Wad.—Wad is a dark-brown to black, very soft, earthy mineral which is commonly considered an impure hydrous oxide of manganese. It contains minor accessory elements such as barium, iron, and aluminum. It is generally a loosely coherent powder not sharply distinguished except by color from clay, in which it usually occurs. It contains from 30 to 42 per cent of manganese and 7 to 10 per cent of water.

Limonite.—Limonite ($2Fe_2O_3 . 3H_2O$), hydrous oxide of iron, is commonly a dark-brown dense amorphous material with rounded or botyroidal forms much like psilomelane. Some specimens show a radiate fibrous structure. The hardness ranges from 5 to 5.5 and the specific gravity from 3.6 to 4. The powder as well as streak is yellowish-brown. The pure mineral contains 59.9 per cent iron, but most specimens from this region contain several per cent manganese and some admixed clay.

The ferruginous manganese ores are generally mixtures of poorly defined hydrous oxides of manganese with hydrous oxides of iron in various proportions. The iron oxide is generally limonite. The manganese is generally in the form of psilomelane, though manganite is common in some places. The iron and manganese oxides occur both as a mixture of two minerals readily distinguishable in the hand specimen, or so intimately mixed that it is impossible to tell what proportions of each are present. The amount of manganese in ferruginous ore varies from 10 to 35 or more per cent.

Other minerals.—Other than the common hydrous oxides of iron and manganese, there are few distinct minerals in the manganese deposits. Specimens of pisolitic bauxite, as well as crystalline gibbsite, both hydrous oxides of aluminum, are associated with manganese and iron oxides in the clays of the Houston mines, near Nace, Botetourt County. Wavellite, hydrous phosphate of alumina, which commonly forms clear or white crusts with radiate structure on mineral fragments in the limonite deposits from Alabama to Pennsylvania, was not encountered during this investigation, but, as a small percentage of phosphorous is common in most of the manganese ores, the mineral may be present.

Well formed crystals of pyrite, sulphide of iron, altered to the hydrous oxide, limonite, were found in the center of psilomelane concretions in the Crimora mine, and in fresh gray dolomite from a shallow shaft at the Mount Torry mine, Augusta County.

There are numerous grains of quartz in the ore-bearing clay, especially in the superficial layers, which are residual from the decomposition of quartzose rock, but quartz also occurs in other forms that are evidently secondary and deposited during the decomposition of the rock. A microcrystalline variety occurs as thin veinlets in the clay of the Elkton deposits. Quartz also occurs in some deposits as minute doubly terminated needle-shaped crystals containing rounded nuclei of calcite.

Relations of the minerals.—This investigation, as well as earlier investigations by the authors in the same region, has yielded considerable material that throws light on the manner of formation of the nodules of manganese minerals. It has not been possible, however, to complete the study of the specimens in time to publish conclusive results in this report. The following statement may be regarded as a preliminary summary.

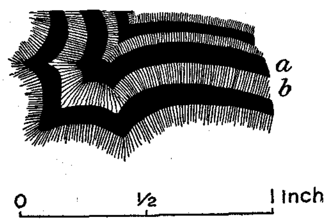


Fig. 4.—Sketch of a polished section of manganese ore from the Blue Ridge region of Virginia showing concentric layers of crystalline manganite and dense psilomelane. *a*, Psilomelane; *b*, manganite.

Very few nodules of manganese oxides are homogeneous throughout, and the external appearance of most nodules gives no clue to their structure and composition. Many nodules are made up of concentric layers of hard and soft psilomelane that range in thickness from the thinnest paper to one-eighth inch. Other nodules are made up of concentric layers of hard or soft psilomelane and manganite (see fig. 4), but the layers of manganite attain a thickness of even an inch or more, and are made up of radiating needle crystals. Although pyrite crystals have been found in the centers of some concentric nodules (Crimora mine), the centers of others are obscure, and some have grown from a veinlet of psilomelane that filled a fracture. Evidently these concentric nodules grew from within outward, layer upon layer.

Radial contraction cracks are common in psilomelane nodules and the structure of some resembles that of septaria in which the cracks are filled with psilomelane of greater hardness. Contraction cracks are commonly small and numerous, and confined to the softer psilomelane, but some flattish nodules are split by a single crack which has been healed by successive layers of psilomelane that are continuous with the external layers. The open cracks of many nodules are covered with crusts of radiate manganite.

These structures suggest that there are several varieties of psilomelane with varying water content and that contraction coincides with loss of water by the more hydrous varieties. The causes for rhythmic concentric deposition of hard and soft psilomelane, as well as of manganite, are obscure. It is possible that they correspond to alternate periods of strong and weak manganese solutions determined by seasonal variations of climate in the region when the nodules were being formed.

Many nodules of psilomelane and manganite occur in masses of wad, but others are brown, yellow, and even found in white clays, from which they are sharply separated. The similar distribution of coarse quartz sand in nodules and in adjacent clay and the ragged areas of clay in hard nodules, as well as other textural features, show conclusively that the nodules of manganese oxides have grown by replacing the clay substance in which they are imbedded. There is, further, no evidence of the crowding back of the inclosing material such as would occur if the nodules had grown in the clay without replacing it. Evidence of the replacement of sandstone and quartzite by psilomelane is common in the deposits in breccia zones in those rocks.

Commercial importance of the Blue Ridge manganese deposits.

The manganese deposits of the Blue Ridge region have yielded by far the larger part of the 270,348 tons of manganese ore that has been mined in Virginia between 1867 and 1917, inclusive. Most of this amount has been produced by the Crimora mine alone. For the period 1838-1917 Virginia produced 45 per cent of the entire production of manganese ore in the United States, almost three times as much as Georgia, the next largest producer.

The output of manganese ore in Virginia and other states, as will be noted by reference to the table on page 47, has been greatly increased since 1914, the year the world war began. This increase in output is the result both of the greater production from old mines and the production from new mines, and is directly due to the stimulus of gradually advancing prices that were offered during the war for manganese ores and alloys (ferromanganese and spiegeleisen), which in turn were caused by the elimination of established sources of ore in Russia and India and of the alloys usually imported from England and Germany. The recent importation from Brazil of most of the manganese ores used in this country did not decrease the prices because of the high shipping rates, the scarcity of vessels, and the increased demand for ores in the manufacture of steel. The prices offered for manganese ores during 1918 were about five times the price which prevailed from 1900 to 1914. They will undoubtedly become lower when normal conditions are established after the conclusion of peace. It therefore must be realized that the great advantage recently given to domestic producers is temporary; but the country, as well as individuals who are directly interested, may permanently profit by this temporary advantage if new deposits capable of producing ore in competition with foreign deposits are thereby developed.

The following table shows the production of manganese ores in Virginia and the other leading manganese-producing states from 1838 to 1917, inclusive:[1]

[1] Compiled from Mineral Resources reports of the United States Geological Survey.

Production of manganese ore in the United States, 1838–1917, in long tons.

Year.	Virginia.	Arkansas.	California.	Georgia.	Montana.	Other States.[a]	Total.
1838–1879		410					410
1866–1879				19,950			19,950
1867–1879	18,000		5,500				23,500
1880	3,661			1,800		300	5,761
1881	3,295	100		1,200		300	4,895
1882	2,982	175		1,000		375	4,532
1883	5,355	400		[b] 400		([b])	6,155
1884	8,980	800		[b] 400		([b])	10,180
1885	18,745	1,483	200	2,580		250	23,258
1886	20,567	3,316	100	6,041		169	30,193
1887	19,835	5,651		9,024		14	34,524
1888	17,646	4,312	1,500	5,568		172	29,198
1889	14,616	2,528	53	5,208		1,792	24,197
1890	12,699	5,339	386	749		114	19,287
1891	16,248	1,650	705	3,575		274	22,452
1892	6,079	6,708		826			13,613
1893	4,092	2,020	400	724		482	7,718
1894	1,797	1,934	278	1,277		1,022	6,308
1895	1,715	2,991	525	3,856		460	9,547
1896	2,018	3,421	284	4,085		280	10,088
1897	3,650	3,240	484	3,332		402	11,108
1898	5,662	2,662	541	6,689		401	15,957
1899	6,228	356	115	3,089		147	9,935
1900	7,881	145	131	3,447	137	30	11,771
1901	4,275	91	610	4,074		2,945	11,995
1902	3,041	82	846	3,500		8	7,477
1903	1,801		16	500		508	2,825
1904	3,054		60			32	3,146
1905	3,947		1	150		20	4,118
1906	6,028	62	1			830	6,921
1907	4,604		100			900	5,604
1908	6,144						6,144
1909	[c] 1,544		([c])			([c])	1,544
1910 [d]	[e] 2,258	([e])					2,258
1911 [d]	[f] 2,457		([f])				2,457
1912 [d]	[g] 1,664		([g])			([g])	1,664
1913 [d]	4,048						4,048
1914 [d]	1,724		501			410	2,635
1915 [d]	1,620	1,343	2,563	3,168		1,015	9,709
1916 [d]	4,388	6,131	6,054	([h])	3,268	[h] 7,156	26,997
1917 [i]	16,000	6,600	11,000	3,500	60,000	25,175	122,275
Total	270,348	63,950	32,954	99,712	63,405	45,985	576,354

[a] Alabama, Arizona, Colorado, Michigan, Missouri, Nevada, New Mexico, North Carolina, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Washington, and West Virginia.
[b] Georgia includes North Carolina.
[c] Virginia includes California and Tennessee.
[d] Marketed production.
[e] Virginia includes Arkansas.
[f] Virginia includes California.
[g] Virginia includes California and South Carolina.
[h] "Other States" include Georgia.
[i] Estimated marketed production by D. F. Hewett, of the U. S. Geological Survey.

Although most of the deposits of the Blue Ridge region of Virginia do not appear to be large, many deposits are known and in the aggregate they are capable of yielding a large quantity of ore. Although small pockets are rapidly worked out and abandoned, new ones are commonly discovered near-by. In the Crimora basin mining has been going on almost continuously for the past thirty or more years, and a large quantity of ore may yet be recovered. Structural conditions, as explained elsewhere in this report, have favored the concentration of the Crimora ore body, and few other deposits of this belt, so far as now known, are comparable to it in size. Single pockets rarely contain more than 25,000 tons, and the majority contain much less. As small or discontinuous ore bodies cannot be worked on a large scale, the manganese mining industry of the Blue Ridge region has not become well established. Though considerable prospecting and exploration has been done and is now being done, it is not at all unlikely that many deposits still remain to be discovered, some of which may prove to be large.

Viewed commercially the manganese deposits are masses of oxides most of which occur in clay. Some masses are rather large and so pure that they may be mined and shipped without preliminary treatment. Most deposits, however, are composed of nodules disseminated through clay in proportions that have a wide range. In places there may be 1 car of ore to 5 of clay, whereas in other places there may be 1 of ore to 15 or 20 of clay. The material from such deposits must be milled to procure ore of high enough grade to warrant shipping. The milling of the ore usually consists in crushing, washing, and screening, after which the remaining rock fragments and clay balls are picked out by hand. The fine material is usually jigged. Frequently the ores are sorted into low-grade and high-grade materials and are sold separately. At some places this sorting is accomplished by hand.

Some of the manganese ore is of high enough grade to be used for chemical purposes. Generally, however, it contains some iron, and can only be used to make ferromanganese. Deposits of manganiferous iron ore, such as occur at the Red Mountain mine near Vesuvius, Mount Torry mine near Sherando, and Bishop and Umbarger mines near Sugar Grove lay idle most of the time until recently. But since 1915 the use of such ores in making spiegeleisen and high-manganese pig iron has greatly increased, so that several of the manganiferous iron ore deposits are now being vigorously exploited. The manganese ores, as well as the manganiferous iron ores at some places contain a large percentage of silica, and some have too much phosphorus to be suitable for steel manufacture. Although, prior to 1914, few shipments with more than 15 per cent silica and less than 40 per cent manganese were accepted for the manufacture of ferromanganese, the recent shortage of manganese ores and the resulting high prices offered for ores and alloys has made materials with as much as 25 per cent silica and as low as 35 per cent manganese acceptable for this purpose, and they are shipped from several mines.

Relations of the deposits to the rock and their structural features.

All but 17 of the 99 deposits described in this report occur in the clays resulting from the decay of the calcareous shale and dolomite in the lower 200 or 300 feet of the Shady dolomite. Of the remainder, 10 occur in breccia zones in the uppermost beds of Erwin quartzite; 3 in the Watauga shale; and 4 in river channel or terrace material overlying the lower part of the Shady dolomite. These relations show the importance of the basal beds of Shady dolomite as a locus for the accumulation of manganese and iron deposits in this region.

Until unweathered sections of the lower 300 feet of Shady dolomite have been explored, it cannot be definitely known whether this zone contains layers that are appreciably richer in manganese than near-by layers, and, if such is the case, what compounds of manganese they contain—oxides, carbonates, or others. Available information only permits speculation concerning this question, but it is thought that it is sufficient to tentatively conclude that the unweathered zone contains one or more layers, each possibly several feet thick in which there are numerous nodules of mixed manganese, iron, and calcium carbonates. Recent studies in a number of regions, especially the Batesville district in Arkansas, show that nodules or concretions of the carbonates of these elements are common in a certain bed of shale as well as in limestone and are fairly uniformly distributed over large areas. The present rather sparsely distributed but locally concentrated masses of oxide minerals in the Blue Ridge region have clearly been deposited where they are now found, in residual clays as well as in bedrock, by the solution and redeposition in more concentrated form of the manganese and iron present in similar carbonate masses in the original sediments.

Studies of a number of deposits that were large enough to have been extensively explored show that at least five structural types may be recognized, and that in many 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.

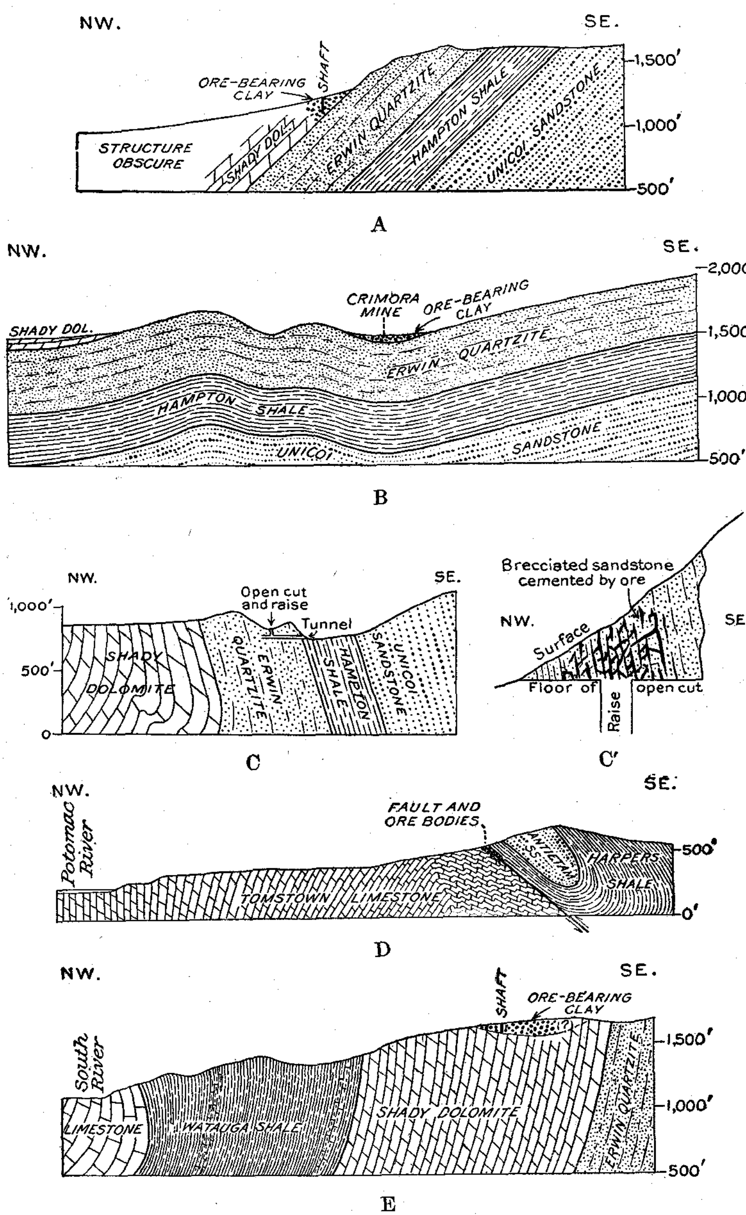


Fig. 5.—Sketch sections showing vertical cross-sections of five manganese mines in the Shenandoah Valley-Blue Ridge region, representing five types of deposits. A, Cross-section through the old Kendall & Flick mine, south of Elkton, Virginia, in which the ore occurs as pockets in clay immediately above the top of

the Erwin quartzite, which has a monoclinal structure; B, cross-section through the Crimora manganese mine, Augusta County, Virginia, in which the ore occurs in residual clay of the Shady dolomite inclosed in a trough in the Erwin quartzite; C, cross-section through the Compton mine in which the ore cements brecciated Erwin quartzite and partly replaces it; C′, is a detailed section of the open cut of the Compton mine; D, cross-section through the mine at Dargan, Maryland, near Harpers Ferry, West Virginia, in which the ore occurs in clay along a fault zone; E, cross-section through the Midvale mine, Rockbridge County, Virginia, in which the ore occurs in gravel in an old stream channel cut on the surface of nearly vertical limestone beds.

The five types of deposits will be briefly described and are illustrated by figure 5, which shows cross-sections of deposits of each type in northern Virginia which have been studied recently.

1. The commonest type of deposit in the region 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. 5, A). These deposits occur in a zone of decomposed calcareous shale and cherty dolomite that lies above, and within 200 feet of, the top of the Erwin quartzite, the beds dipping toward the Shenandoah Valley at angles that range from 30° to 60°. The structure of the rocks in the vicinity of these deposits may be termed monoclinal, as all the beds are similarly inclined, and the upper surface of the Erwin quartzite generally forms the slope of the adjacent conspicuously straight foothill ridge. The ore occurs where the steep slope of the mountain meets the gentle slope at its northwest foot, and float ore is found scattered over the gentle slopes below. The gently sloping bench is underlain by Shady dolomite or its residual clay, and irregular bodies of manganese oxides are found here and there along a narrow belt of the decomposed shaly limestone and dolomite, parallel to and generally close to the outcrop of the Erwin quartzite. The bodies of manganese oxides appear to have no relation to the drainage in transverse ravines which rise in the Blue Ridge and cross the quartzite. Although many mines of this character have been profitably operated on a small scale in this area, none, so far as available records show, have yielded more than 25,000 tons of manganese ore or manganiferous iron ore and many have been abandoned before producing as much as 5,000 tons.

2. Deposits of the second type occur in clays that fill troughs or synclines formed by the upper surface of the Erwin quartzite. The best illustration of this type is the deposit worked at the Crimora mine, Augusta County.[1] (See fig. 5, B.) A detailed description of the Crimora mine will be found on pages 83-95.

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

At the Crimora mine over 161,000 tons of manganese and manganiferous iron ore have been obtained from an area about 20 acres in extent. The deposit lies in beds directly overlying the Erwin quartzite in a syncline which trends N. 40° E. and is therefore slightly inclined to the adjacent foothill ridges which limit it. The syncline plunges southwest under the low plain on the margin of the Shenandoah Valley. Northwest of the syncline is an anticline which also plunges southwest into the low plain. Much ore has been obtained at depths ranging from 100 to 200 feet below the surface, and the ore is known to extend to greater depths toward the southwest end of the deepening trough. Other deposits of manganiferous iron and manganese ores which occupy synclines in beds directly overlying the Erwin quartzite occur at the Mount Torry mine south of Sherando; the Red Mountain mine, 5 miles east of Pkin Siding on the Norfolk & Western Railway, Augusta County; Currin Valley mine, 3 miles southeast of Marion; Bishop mine, 1 mile northwest of Sugar Grove; and the Rock Bank, 2 miles southwest of Teas in Smyth County. Explorations of the deposit at the Crimora mine, which has yielded more manganese than any other mine in the region east of the Alleghany Mountains, and of the other deposits that have similar relations, confirm the conclusion that synclines in which the beds have low dips are the most favorable sites in the Blue Ridge region for the accumulation of ore.

3. In the deposits of the third type manganese oxides occur as fillings and replacements in sandstone along crushed and brecciated zones in the Erwin quartzite. (See fig. 5, C.) One deposit of this type has been actively mined on Dry Run, 9 miles northeast of Luray, by the Compton Manganese Corporation, and others have been prospected in the southeastern part of the Mount Torry tract south of Sherando, Augusta County, on the "Big Survey" on Lick Mountain in Wythe County, and on Glade Mountain in Smyth County. The cracks and crevices of the crushed sandstone are filled with the ore, and the sandstone adjacent to the fractures and bedding planes is gradually replaced until ultimately the whole rock is replaced. Every transition stage from solid ore to sandstone breccia cemented by manganese minerals, may therefore be found. Much of the material that is mined is highly siliceous. As the ore occurs in hard rocks which must be thoroughly crushed and jigged, and the product is usually siliceous, deposits of this type are expensive to exploit. Somewhat similar deposits in brecciated Watauga shale have been mined at the old Glade bank, 3 miles north of Walton Furnace, and at the Horne prospect near Cedar Springs in Wythe County.

4. A fourth type of deposit is that along a fault zone, represented by the exploration near Dargan, Washington County, Maryland. (See fig. 5, D.) This deposit occurs along a fault zone in clay derived in part from the decomposition of limestone (Tomstown, equivalent to Shady) on one side and shale (Harpers, equivalent to Hampton) on the other. Such deposits of manganese appear to be uncommon, and no others of consequence are known in the belt adjacent to the Blue Ridge. They appear to yield only small quantities of ore.

5. The fifth type of deposit of which the structural relations are known is the channel deposit represented by that at Midvale, explored by the Rockbridge Manganese & Iron Co. (see fig. 5, E), and that of the Kennedy property, 3 miles southwest of Sherando, Augusta County. In these deposits manganese oxides replace clay zones in alluvium that fills an ancient stream channel (as at Midvale) or that forms an ancient alluvial fan or gravel terrace (as at Kennedy). The Kennedy deposit is near the outlet of an ancient stream that rose in the high ridges several miles to the south, flowed in a syncline which formerly enclosed limestone, and emerged from the mountains directed toward the place where the deposit now is. Such deposits are flat masses that conform to the depressions in which the alluvium was laid down. Exploration by drilling at the Kennedy mine is reported to show the presence of a large quantity of ore, and it is probable that here, as with deposits in synclines, the size of the deposit may depend upon favorable local geologic structure.

A review of the structural relations of the known deposits as well as of minor occurrences of manganese and iron minerals described in this report shows that 22 rather definitely and probably 7 more, or a total of 29 deposits, belong to the first or monoclinal type. Twenty-eight definitely and probably three more occur near the upper ends of well-defined troughs, and six other areas that show similar favorable structural relations are described. Twelve deposits belong to the third or breccia zone type of deposit, of which 10 are in Erwin quartzite and 2 in Watauga shale. A single iron deposit, the Old Dixie in Augusta County, occurs along a fault and is therefore the only known representative of this type in the Valley. Finally, four deposits belong to the fifth or terrace gravel type. Existing data do not permit a satisfactory classification of the remaining 22 deposits; probably many of them belong to the first or monoclinal type.

It will be noted that the number of deposits in synclines is only slightly larger than that of the monoclinal type. The synclinal group includes the most productive deposits in the valley region, and, since they appear from other reasons to offer the most favorable areas for the accumulation of manganese ore, several undeveloped synclinal areas were recommended for exploration soon after field work was completed, early in 1918.[1]

Relation of deposits to surface features.

Many of the manganese deposits in the region here described are on the gravel-covered bench along the foot of the Blue Ridge, which represents the valley-floor or early Tertiary peneplain, and it is believed that they were accumulated during or soon after the period in which this peneplain was being formed. Other deposits, although not related to this particular peneplain, seem to be associated with some other peneplains, such as the deposit at Red Mountain northeast of Vesuvius, which occurs 400 to 500 feet above the level of the valley-floor peneplain, and the one at the Lyndhurst mine which is nearly 250 feet below it. Therefore, although the conditions during or soon after the early Tertiary peneplanation were apparently particularly favorable to the accumulation of deposits of manganese and iron ores, other deposits were probably formed at earlier and some at later periods of planation. Those which may have been formed at earlier periods have been mostly removed by erosion. The relation of deposits along fault zones and in brecciated zones in quartzite or shale to surface features has not been thoroughly studied and will not be discussed.

Summarizing, it may be stated that apparently the most favorable conditions for the accumulation of manganese ores in the Blue Ridge region are found in structural synclines in which the Erwin quartzite pitches at a low angle under the valley-floor or early Tertiary peneplain, and the parts of the synclines most likely to receive the deposits are those in which the top of the Erwin is not more than 300 feet below the present surface of the ground.

Origin of the deposits.

Direct evidence concerning the source and origin of the manganese in the deposits of this region is lacking, but the hypothesis that most reasonably explains the deposits in residual clay of the Shady dolomite, which includes most of the better known occurrences in the region, is here presented briefly. From the data at hand it appears that the manganese was originally widely disseminated as carbonate, and later became segregated into nodules or concretions in the shale, dolomite, and limestone which

[1] Hewett, D. F., Stose, G. W., Katz, F. J., Miser, H. D., Possibilities for manganese ore on certain undeveloped tracts in Shenandoah Valley, Virginia, U. S. Geol. Survey Bull. 660-J, 1918.

make up the Shady dolomite. Possibly also some manganese in silicates in sedimentary or other near-by rocks was contributed to the deposits by the disintegration of the rocks by weathering. Although manganese carbonate was probably disseminated throughout the sediments, certain layers of the basal part of the limestone series appear to have contained much more than the average. When the rocks weathered, the manganese was dissolved as bicarbonate by circulating underground water, was transported along favorable channels, and was deposited as oxides in the clays produced by the previous decay of impure limestone, dolomite, and sericitic shales. Manganese oxide appears to have been deposited largely by replacing the clay, or, in the case of quartzite breccia, the quartzite or sandstone, although small quantities were probably deposited in open spaces in the clay, limestone, or quartzite breccia.

The oxides were probably deposited where the solutions containing manganese bicarbonate met oxygen-bearing waters. The largest deposits of manganese were formed therefore in places where the maximum amount 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. The process of solution would be most active above the average level of streams and above ground-water level, and therefore more manganese should have been delivered in solution to the belt of country adjacent to the ridges and hills, where the steep slopes meet the plains, than elsewhere.

These solutions would largely follow the surface drainage, and where oxidation was possible manganese ore might have been deposited in the stream channels themselves. It was more likely to have been deposited, however, in the gravel and washed that fill and lay beneath such channels, where the movement of the solutions would be checked in seeping through the gravel, and in the clay that formed the floor of these gravels. The deeper circulation of the surface waters would be controlled by the porous and impervious layers of the bedrock and by their geologic structure. The upper quartzitic layers of the Erwin are more impervious than the overlying Shady dolomite, and the relatively porous layers of shale, sandstone, and impure sandy limestones at the base of the Shady afforded an especially favorable channel for these solutions. Where the Erwin lies in a gently plunging syncline, the solutions flowing in these overlying porous beds would converge toward the axis of the fold and be concentrated there. Manganese ore, therefore, was deposited largely in residual clays directly overlying the Erwin quartzite where those beds dip gently toward the valley and pass under the wash which covers the early Tertiary peneplain, but were concentrated in larger deposits in these same beds where the quartzite lies in gently plunging synclines which pass under the wash on this peneplain.

Surface waters also circulate along faults, and manganese-laden solutions were thus directed into certain channels along fault planes and deposits of manganese ore were thus formed, but their distribution cannot be foretold as the relation of these fault channels to other structures and factors are not known. The brecciated zones of the quartzite likewise afford easy channels for circulating waters and the manganese solutions which passed through them deposited manganese in the crevices and spaces between the broken fragments, cementing them into a breccia, and in some places the ore also largely replaced the sand grains of the quartzite, making a siliceous ore. The distribution of concentrated deposits of these replacement and siliceous-breccia ores cannot be predicted as the factors which control the circulations in these brecciated zones are not fully understood.

MINES, PROSPECTS, AND UNDEVELOPED TRACTS

GENERAL STATEMENT.

Manganese prospects are scattered along the entire front of the Blue Ridge, but are more numerous and show more promise in certain localities than in others. The productive mines, not over a dozen in number, are all limited to very small areas scattered at intervals of 25 or more miles along the front, but more numerous and closer together in vicinity of Waynesboro. The deposits at mines and prospects will be described by counties in the order of occurrence, beginning at the north near Front Royal. Undeveloped tracts where ore may occur between Front Royal and the Kennedy mine are also described, as many of them give promise of containing workable deposits of manganese. Such undeveloped tracts farther southwest are not described because those areas were not studied so closely and the conditions which warrant conclusions as to the prospect of finding ore in such tracts in the northern part of the region are generally not so clearly present in the southern part of the region.

WARREN COUNTY.

HAPPY CREEK OR SEIBEL MINE.

Location.—The Happy Creek or Seibel mine, operated by the Seibel Iron Mines (Inc.), of Philadelphia, Pennsylvania, lies at the west foot of the north end of a low ridge 3 miles east of Front Royal. Although the occurrence of manganese here has been known for a number of years, the present workings, consisting chiefly of two open cuts, have been made since 1907. In 1914 manganese ore was mined by a steam shovel from a 45-foot face of the northern open cut, and carried by narrow-gauge tramway to the mill near Happy Creek station, on the Southern Railway, 2,000 feet distant. In 1917, work was being done on a small scale in both open cuts.

Surface features and geology.—The mine is situated at an altitude of 800 feet at the junction of the steep slope of the ridge and the gentle slope of the valley-floor bench, which is well developed north and northwest of the mine. The channel of Shenandoah River, 2 miles to the north, is cut 350 feet below the valley floor.

Rock outcrops are poor in the vicinity of the mine, except along the crest of the ridge and along the wagon road below the mine. White quartzite of the Erwin crops on the top of the ridge and stands nearly vertical, although it is badly crushed and cemented to a ferruginous quartzite breccia. Along the railroad some of the dips appear to be 30° SE., evidently overturned. At the north end of the cut a small outlying hill of white quartzite, also badly crushed but showing a dip of 60° SE., is evidently a small anticline of quartzite on the west flank of the monocline, for in the intervening small syncline which plunges southwest toward the Happy Creek mine the surface is covered with small rusty granular sandstone fragments typical of the upper layers of the Erwin. Iron and manganese float ore is also plentiful and several prospect pits have revealed very good showings of high-grade lump manganese ore. These pits are evidently on the same lead as the Happy Creek mine but farther northeast along the rising syncline, and it is probable that ore occurs throughout the intervening area. It was reported by residents of the vicinity that most of the prospected property is an undivided estate and there has therefore been difficulty in securing a lease to work it. It was regarded as so favorable an area for the occurrence of manganese ore that it was recommended for prospecting by the present authors in a recent bulletin (660) of the U. S. Geological Survey.

Occurrence of the ore.—The best exposures of ore in 1914 were in the face of the northeast open cut, which was about 300 feet long and about 50 feet deep, and covered slightly more than an acre. Hard slaglike masses of manganese minerals are sporadically distributed in yellowish-brown clay in two nearly vertical lenticular zones which range from 5 to 8 feet in width and trend south. There is little difference between the color of the clay in which the manganese minerals occur and that of the clay immediately adjacent, although elsewhere the manganese-free clay is mottled reddish-brown, light brown, and white. The hard manganese minerals here do not appear to be confined to masses of wad and manganiferous clay, as they are in some other deposits on the west slope of the Blue Ridge. Small irregular patches of wad occur here and there in relations which show clearly that the wad replaces clay, but it forms a small part of the mass. The nodules range in size from very small grains to 8 inches in diameter. Many show an inner zone of concentric bands of radiating crystals of manganite enveloped in botryoidal psilomelane. Limonite nodules are also present, and to get a good grade of manganese ore for shipping these must be eliminated by hand sorting. In mining, only the richest zones are selected, and ordinarily two carloads or about 8 cubic yards of mine dirt yields 1 ton of ore. When the proportion of limonite becomes too great to be profitably eliminated by sorting, a mixed iron and manganese product was shipped. The ratio of washed to crude ore may then rise to 1 ton to 3 cubic yards.

Along a part of the west face of the open cut a poorly defined bed of boulders, coarse gravel, sand, and clay about 15 feet thick is exposed, and, although it contains some wad, it appears to overlie the mass of manganese-bearing clay. The gravel contains well-rounded pebbles of chert, quartzite, and sandstone, the largest 18 inches in diameter. The clay underlying the manganese-bearing zones yields, after the flocculent part is washed away, about 5 per cent of residue that is principally angular quartz sand, with a few grains of psilomelane and many minute quartz crystals containing nuclear grains of calcite and clay substance, such as occur in the clay near ore in the Niesswaner shaft, south of Elkton. The surfaces of the quartz crystals are pitted, but there is no evidence of abrasion and they appear to have formed in the clay. The flocculent part contains traces of sericite. The clay resembles the residual clay in the deposits south of Elkton.

The southwestern open cut, about 250 feet to the southwest and covering over an acre, was being operated in 1917. The deepest part of the working was about 30 feet deep. The upper 8 to 10 feet were of yellow clay mottled with red and white, which is characteristic of residual clay that has been moved a short distance down the slope by creep but not transported by a stream. Scattered in the clay were angular quartzite boulders and pebbles, wash from the Erwin quartzite of the mountain. Beneath this is dense laminated yellow clay with white streaks and containing irregular patches of soft manganese ore and harder nodules. The clay is greatly slickened along planes parallel to the mountain, showing movement by slipping and probably indicating compression but no appreciable faulting. This clay contains no boulders but has masses of white "bone" or decomposed chert and has all the appearance of residual clay derived from impure limestone in place and not having been transported or moved by creep. Although the exposures in the northern pit were less clear in this respect, the sandstone boulders are found only to a depth of 20 feet and it is believed that most of the ore is in undisturbed residual clay beneath the boulder-bearing beds. Iron ore nodules are plentiful in, and apparently restricted to, the upper boulder-bearing beds.

It is believed, therefore, that the manganese ore was deposited in clay which was residual from impure limestone in the lower part of the Shady dolomite by replacing the clay at or near the surface beneath the cover of wash. The iron ore is mostly confined to the superficial layers of mixed clay and wash, and is generally siliceous.

The extent of the manganese deposits southwestward from the Happy Creek mine is not known. At the southwest end of the small quartzite ridge are the larger workings of the old Seibel iron mine, where a large quantity of siliceous iron ore was taken out. The ore is a partial replacement of a brecciated quartzite at the contact with laminated yellow clay derived from the Shady dolomite. There are also large masses of drusy ferruginous chert in the clay adjacent to the quartzite. The section at the Seibel iron mine is given in figure 6.

The beds are greatly overturned, so that the quartzite rests on the clay, dipping 40° SE. overturned.

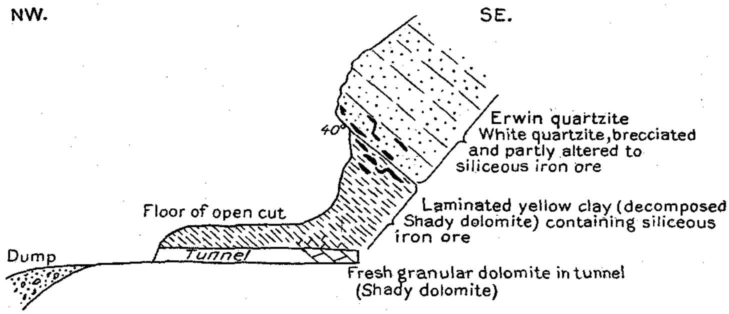


Fig. 6.—Sketch section at the old Seibel iron mine 2 miles east of Front Royal, Warren County, showing Erwin quartzite overturned and dipping 40° SE., and overlying clay residual from Shady dolomite.

Milling.—At the mill crude ore is dumped into the lower end of a double log washer, from which the cleaned coarse material is delivered by a belt to a trommel. This delivers sizes of 1 and 2 inches and an oversize which is crushed in a jaw crusher, elevated, and separated into two sizes in a second trommel. A two-compartment jig treats the material between half an inch and 1 inch and yields shipping ore and tailing. A three-compartment jig treats the fine material and delivers shipping ore and tailing. This plant has produced 300 tons of washed ore a month. Most of the material shipped contains about 20 per cent manganese, 21 per cent iron, and 12 to 15 per cent silica, but some sorted lots contain 38 per cent manganese, 4 per cent iron, and 12 per cent silica. In August, 1917, not much ore was being mined on account of the scarcity of labor and the mill was running only part of the time.

VICINITY OF FRONT ROYAL.

No mines or prospects are known in the near vicinity of Front Royal. Manganese stain and small pockets of wad were seen in the residual clay on the east slope of the small quartzite knob 1½ miles southeast of Front Royal, and it may be that some ore occurs in the clay derived from the limestone in the lowland between the quartzite of the small knob and the old Seibel iron mine 2 miles east of Front Royal. Elsewhere the great fault brings pre-Cambrian greenstone against the limestone, so that the contact of Erwin quartzite and Shady dolomite is covered. This relation prevails southwestward from Front Royal to Bentonville and this tract is therefore not favorable for the accumulation of manganese ore. The small area in the county southwest of Bentonville will be described under the next heading.

PAGE COUNTY.

AREA BETWEEN BENTONVILLE AND VAUGHAN STATION.

From Bentonville to Vaughan geologic conditions that affect the occurrence of manganese ores are very similar. The Erwin quartzite outcrops in a narrow belt, forming a low outer line of foothill ridges along the whole mountain front. The quartzite dips steeply to the northwest under the limestones of the valley, or is overturned so as to dip steeply to the southeast. At the northwest base of the foothill ridges the valley floor is well developed as a gently sloping wash-covered bench about 900 feet in elevation. On these benches float manganese ore has been found and prospected to a small degree, but no deep pits or trenches have been dug to prove its quantity or textent. Several small openings have been made on the first knob south of Bentonville in Warren County by Zach Compton and Dr. Cullers of Bentonville. Associated with the float ore are fragments of drusy ferruginous lamellar chert and white flint, indicating the presence of the residual products of the Shady dolomite beneath the wash. Similar manganese prospects are reported on the Overall property adjacent to Overall Run, which is the boundary between Warren and Page counties.

Very little ore was seen on these terraces, which are, however, deeply covered with wash. Because of the steep dip of the rocks, probably accompanied by faulting for limestones that overlie the Watauga shale occur close to the foot of the mountain in places, little ore is to be expected along this part of the mountain front.

The quartzite of the front ridge is much crushed in places, and has been cemented and partly replaced by iron and manganese oxides. Several prospects have been located in such deposits and one of them, which has been extensively worked, will be described below as the Dry Run or Compton mine.

DRY RUN OR COMPTON MINE.

The Dry Run or Compton mine is on the south side of Dry Run between the two outer foothill ridges of the mountains. It is 1½ miles southeast of Compton and a little over a mile from the railroad, to which the ore is hauled by wagon. The workings include an open cut at the top of a small ridge or spur on the east side of the Erwin quartzite ridge and a tunnel 300 feet long which enters from the floor of the valley between the ridges and intersects the shaft. (See fig. 5, p. 50.)

At the tunnel mouth hard vitreous white quartzite strikes N. 25° E. and dips 75° SE. At the open cut, the rock is much crushed and disintegrated to a soft buff sandstone which crumbles readily. Between the layers of clean sandstone are thin layers or partings of dark sandy shale which has weathered largely to clay. The ore, as seen in the surface cut, is a good grade of psilomelane containing some crystalline manganite in concentric layers, the needle-like crystals of which are transverse to the botryoidal surface of the ore. The ore fills cracks and spaces between the fragments of brecciated sandstone and penetrates along joints and bedding planes in thin sheets which taper to paper thinness at their extremities. In places the sandstone is replaced by the ore and all gradations occur from thin seams of ore along the bedding and joint planes to replacement of nearly a whole block of sandstone between such planes, leaving only a central core of unchanged sandstone. More commonly veins an inch or more in thickness are to be seen in the present workings, but there are some pockets which yield masses of ore weighing over 100 pounds. The zone which contains the ore is said to be 100 feet wide in the tunnel, but in the open cut the zone of workable ore did not seem to be more than 20 feet wide. An incline formerly carried the ore from the open cut to the mill, but since the tunnel has been completed the ore is dumped into the shaft and carried by mine cars out through the tunnel.

The rock in the mine is broken down by blasting and the ore is thus largely loosened from the sandstone. It is further crushed at the mill, washed, concentrated, and hand picked. The product is mostly small particles as the ore is crushed rather fine to remove the included sandstone. Recent shipments contain 43 to 48 per cent manganese, 1 per cent iron, and

8 to 11 per cent silica. The mine has been operated intermittently since 1916 by the Compton Manganese Corporation of Pittsburgh, Pennsylvania. R. F. Watson of Shenandoah is superintendent.

At the gap through the front ridge, where Dry Run passes out into the valley, have been two prospect tunnels, opened by F. S. Heiskell. The ore here cements brecciated quartzite as it does at the Compton mine. Other prospects in the neighborhood are being developed by the Mineral Products Corporation, of which Perry A. Nicklin is secretary.

BAILEY PROSPECT.

The Bailey prospect is on the farm of Jack Bailey, three-fourths of a mile east of Rileyville and one-fourth of a mile north of Narrow Passage Hollow. Nodules of psilomelane have been found in dark-red clayey soil on a terrace or bench about 1,000 feet above sea-level and near the base of the quartzite foothill. At the time of visit no openings had been made except small holes in a potato patch from which manganese lumps had been obtained. Erwin quartzite, much brecciated, is exposed on the mountain slope east of the showing and dolomite is exposed west of the quartzite on Narrow Passage Run. The prospect probably lies on the Shady dolomite but may be separated by a fault from the Erwin quartzite of the foothill. Both rock formations dip steeply to the west.

MINES RUN BANK.

At the contact of the pre-Cambrian greenstone and basal Cambrian sediments, Unicoi formation, at the head of Mines Run, considerable iron ore was mined on the Bailey property years ago and was hauled by wagon to the railroad. A large open cut and an old tunnel and shaft expose highly altered brecciated quartzite and slaty sandstones, largely changed to siliceous iron ore. A little manganese oxide coats cavities and crevices in the ore. The rock is evidently a fault breccia in which the ore was deposited by circulating surface waters. It has no value, however, as a manganese ore.

PROSPECTS NEAR VAUGHAN.

An opening for manganese ore, called the Vaughan prospect, is about 1½ miles north-northeast of Vaughan station, on the crest of a foothills ridge of Erwin quartzite. It is in a zone of faulting and brecciation near the contact of the Erwin quartzite with the Unicoi formation. The white quartzite is crushed into small pieces which are partly cemented together by films and very thin veins of manganese oxide.

The Jarmans Run prospect, comprising several pits one-half to three-fourths mile northeast of Vaughan and north and east of Jarmans Run, is near the base of the foothills which at this point consist of shales, sandstones, and arkoses of the Hampton and Unicoi formations. The rocks in general stand vertical and strike N. 20° E. but they are here considerably faulted and brecciated. The Erwin quartzite is so greatly brecciated that it does not form a ridge and its outcrops are found with difficulty but lie west of the prospects. The material obtained in the pits is quartzite and arkose breccia which has been cemented by manganese and iron oxides. These deposits are too small and too siliceous to be regarded as ore bodies.

PROSPECTS NEAR ELGIN.

Between Vaughan and Elgin station the Shady dolomite lies along the east side of the Shenandoah Valley in a terrace at about 1,100 feet above sea-level, the surface of which is for the most part heavily covered with sand and rock fragments washed from the quartzite foothill immediately to the east. A belt of Watauga shale is exposed in a few places near the railroad one-half a mile west of the mountain. Conditions indicate that the Shady dolomite overlies the Erwin quartzite in normal succession and is succeeded by the Watauga shale and that the structure is a steep monocline dipping toward the valley. At the Fronk prospect, one mile north-northeast of Elgin, there has been some prospecting for ore. Residual clays of the Shady dolomite are exposed in a small ravine which cuts through the mantle of débris at the base of the mountain slope. These clays are typically reddish and ocher colored and contain fragments of chert and small nodules of psilomelane. At one place also manganese oxides fill a few small seams in the clay. On the mountain slope in the same vicinity there are breccia zones in the Erwin quartzite which are cemented with thin veins of manganese oxides. Such material is abundant as "float" in the talus on the mountain slope.

Half a mile east-northeast of Elgin and 1 mile south of the Fronk prospect, similarly situated, several pits have been opened on a belt of weathered Shady dolomite 1,000 to 1,200 feet wide between the Erwin quartzite in the ridge on the east and the belt of Watauga shale on the west. There are also pits in the Erwin and the Watauga. In the pits in the Shady dolomite, which are at elevations ranging from 1,000 to 1,050 feet, earthy ocherous residual clays and small amounts of manganese ore in the form of nodules and thin seam fillings are exposed. In the dumps at these pits are lumps of manganese-cemented quartzite breccia derived from the surface débris.

The physiographic conditions surrounding these prospects are favorable for manganese ore deposition in the residual clay from the dolomite, but the structure is steeply monoclinal and not synclinal, and therefore not so favorable for the localization and concentration of a large ore body. The quartzite breccia deposits have little or no prospective value.

VICINITY OF MARKSVILLE.

Although no prospecting has been done east of Marksville the geologic conditions are such that it is believed that ore may be present, and it was recommended in Bulletin 660 of the U. S. Geological Survey that the area be thoroughly tested. The valley between the low outlying quartzite ridge northeast of Marksville and the main foothill ridges to the east is underlain by Shady dolomite or its residual clay. It is part of the valley floor about 1,000 feet in elevation, and is covered with wash in which are fragments of drusy ferruginous chert and iron-cemented brecciated sandstone. The quartzite in the ridges does not outcrop in ledges so the attitude of its beds cannot be determined, but the character of the rock fragments and the lack of outcrops suggest dip slopes of the upper beds of the Erwin. It is therfore concluded that this valley is a southward plunging syncline, and if there is no faulting within the syncline it should present favorable conditions for the accumulation of ore. Similar synclines between the quartzite ridges to the east are not deep enough to inclose the limestone and are therefore not regarded as favorable for the deposition of ore.

EUREKA MINE.

On the north slope of the mountain mass, almost due south of Stanley and east of Stony Run, locally known as Round Head Mountain, are some old banks formerly known as the Eureka mine. It is well up on the mountain side, on a bench about 1,550 feet in elevation. A large open cut 20 feet deep and a shaft now caved in represent the work done, and considerable ore is said to have been taken out and shipped. Large masses of excellent ore, chiefly pitted psilomelane with manganite in the cavities, occur in the yellow clay on the dump. Fragments of chert in the clay indicate that it was derived from limestone of the Shady dolomite which overlay the quartzite.

The analysis of the ore is as follows:

Analyses of manganese ore from Stanley, Va.[1]

	1	2
Mn	51.46	49.61
Fe	2.94	1.05
P	.23	.31
SiO_2	4.17	.....
H_2O	4.97	.....

The general dip of the quartzite of the mountain is low to the north, about 20°, under the limestone of the valley. In the gorge of Stony Run, just west of the mine, the quartzite is finely exposed in a sharp anticline and an accompanying sharp syncline (see fig. 7). The effect of

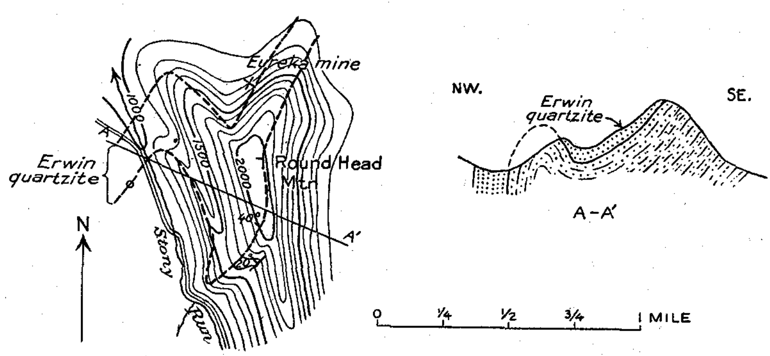


Fig. 7.—Sketch map and section showing geologic relations at Round Head and Eureka mine, Page County, 1 mile southwest of Stanley. A sharp syncline carries the Erwin quartzite up the east side of Stony Run, and the Eureka mine is located on the Shady dolomite inclosed in this northward plunging syncline.

this folding is seen in the front of Roundhead Mountain, the syncline determining the depression in which the Eureka mine is located and the sharp anticline forming a westward projecting spur on the mountain front. The syncline plunges northeastward and incloses clays derived from limestone in the basin where the mine is located and the structure is therefore favorable for the accumulation of ore. The surface of the bench, however, is somewhat above the valley-floor peneplain, but the decomposition of the lime rock to clay is correspondingly deep and the ore may be present to considerable depth. Because of the favorable structure and the good showing of ore still on the surface, it is believed that this deposit is well worth

[1] Watson, T. L., Min. Resources of Virginia, p. 245, 1907.

further prospecting. The property has recently (summer of 1918) been taken over by the Shenandoah Manganese Co., which has opened a large pit on the low terrace below the old mine and is putting up buildings and a plant to treat the ore. A large force of men was at work and the mine should soon be producing if ore has been found in minable quantity at this lower level.

AREA SOUTHWEST OF STANLEY.

The valley-floor bench is well developed along the north foot of the mountain mass which projects into the valley southwest of Stanley. Its general elevation is only 1,100 feet but it is deeply covered with wash from the many mountain streams which emptied on the plain. Many small pits in this wash have exposed some iron and manganese ore but apparently not in sufficient quantity to warrant mining. If, however, the new workings on the low terrace at the Eureka mine prove successful, there is hope that similar workable deposits may be found here.

MINES AND PROSPECTS EAST OF SHENANDOAH.

The general structure of the mountain front near Shenandoah is a gentle monocline, the Erwin quartzite dipping about 35° to 40° west under the limestone. A gravel shelf is well marked along the entire front of the mountain from Ingham south. It represents a great outpouring of alluvium from large mountain streams onto the valley-floor peneplain whose surface is now from 1,300 to 1,400 feet in elevation. The gravels are very thick and no bedrock is exposed close to the mountain except in the deep gorge of Fultz Run, 300 feet below the plain.

INGHAM MINES.

There are two old abandoned iron mines on opposite sides of a run where it comes out of the mountains about a mile northeast of Ingham. The ore as shown in the old pits is in clay that appears to be residual from the Shady dolomite and lies less than one-eighth mile from the Erwin quartzite ledges which dip 60° W. A few very small pieces of manganese oxide and manganiferous iron oxides were seen on the dumps. Another old abandoned iron mine is located on the south side of Watery Branch where it leaves the mountains three-quarters of a mile east of Ingham. The ore deposit at this locality is chiefly brown iron ore with a small quantity of psilomelane. It is in variegated residual clay of the Shady dolomite. These deposits probably have no value for manganese or manganiferous iron ore.

FULTZ RUN PROSPECT.

On the back of a small knob on the east side of Fultz Run, 1½ miles southeast of Ingham, there are several pits about 1,400 feet in elevation which show manganese and iron ore. The knob is covered with quartzite wash, and is connected with the main quartzite ridge by a narrow saddle on which the pits are located. The upper layers of the Erwin quartzite lie about 15 feet below the pits and dip 20° W. toward the valley. The manganese and iron ore are in dark soil mixed with yellow clay, and chert fragments in it indicate that the clay is residual from limestone. The lower prospects closer to the quartzite have less iron ore than the upper ones. The amount of ore is apparently small, although two carloads of manganese ore are said to have been shipped from this locality several years ago by Dent and Rogers. The area of surface outcrop on the knob is necessarily small, so the prospect probably has little value.

KIMBALL MINE.

On the narrow neck between Fultz and Stony runs is located one of the largest iron ore pits in the region, which furnished ore to the old Furnace No. 1 at Shenandoah. Although this neck of land has been sharply undercut by both streams the gravel-covered bench of the valley-floor peneplain is still preserved at an elevation of 1,450 feet, with almost vertical banks to the creek level, 500 feet below. The pit is about 100 feet deep and covers several acres. The Erwin quartzite forms the dip slope of the mountain just east of the pit, dipping 25° W. toward the valley. Large irregular masses of limonite lie below a capping of sandstone wash in yellow clay, mottled with red and streaked with white, in which are large calcedonic flints. These may occur only in the lower clays, which are probably residual from the underlying limestone. Harder[1] states that some of the ore is manganiferous iron and that some good granular manganese oxide occurs in pockets. Ore was mined at two openings and a tramroad carried the ore to the furnace at Shenandoah. The following analyses of ore from this locality show it to be a low manganiferous iron ore:

[1] Harder, E. C., op. cit., p. 56.

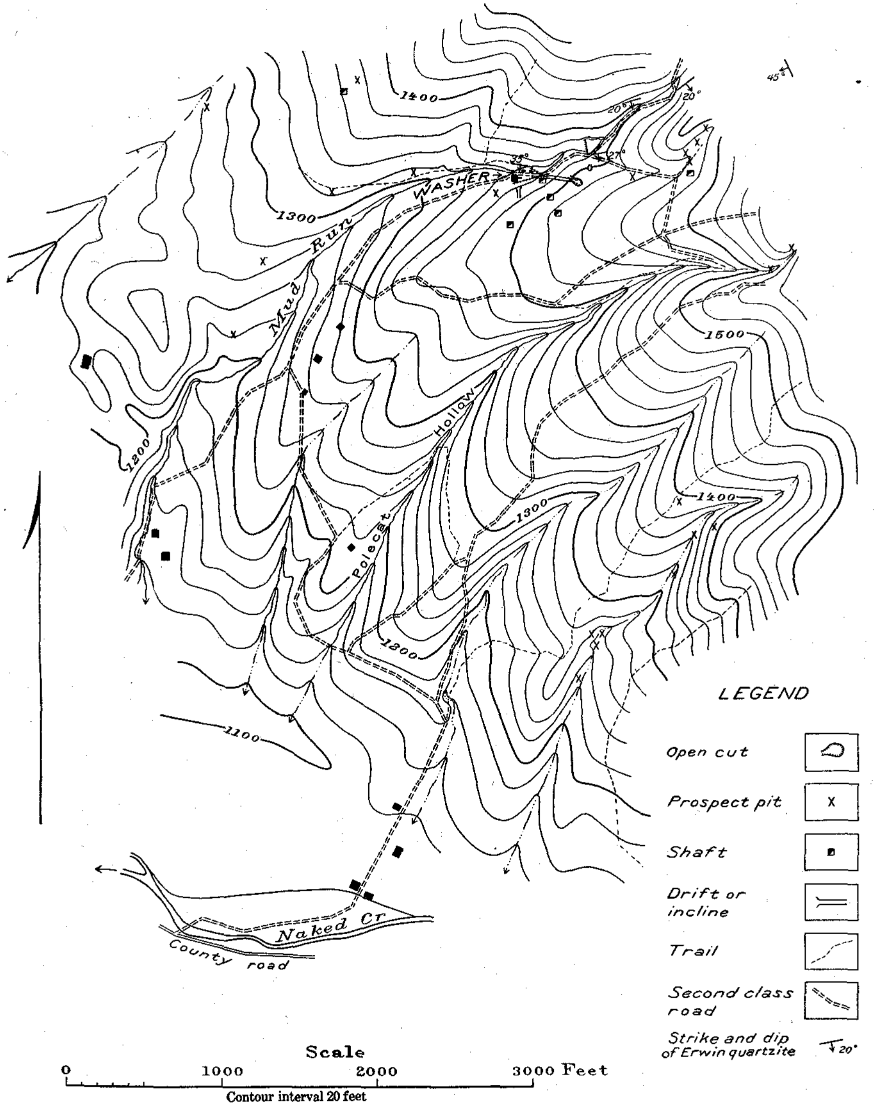


Plate XIII.—Map of Watson mine, Rockingham County, 5 miles northeast of Elkton, showing location of workings and adjacent prospects.

Datum is mean sea level. Contours determined by aneroid barometer based on railroad bench mark at Elkton. Surveyed by T. K. Harnsberger, June, 1915.

Analyses of manganiferous iron ore from Kimball mine.[1]

	1	2
Fe	40.875	.....
Fe_2O_3	......	70.00
Mn	7.349	.....
MnO	......	13.31
SiO_2	15.44	4.73
Al_2O_3	......	.86
P	.084	.....
H_2O	......	11.02

WATSON MINE.

There are several manganese and iron-ore prospects at the west foot of Grindstone Mountain, particularly toward the south end where the gravel cover is deeply cut into by the drainage. The Watson mine is 1 mile northeast of the old Furnace No. 4 on Naked Creek. It was first prospected in 1908. It lies at the west foot of a small quartzite knoll on the slope of Grindstone Mountain at about 1,400 feet elevation, or 300 feet above the old furnace. (See Pl. XIII.) The Erwin quartzite is exposed on the crest and forms most of the west slope of the main ridge, in general striking the mountain N. 10° to 20° W. and dipping 40° to 50° W. but with some minor folding. A small ravine at the mine exposes the top rusty sandstone of the Erwin quartzite and a pebble bed 10 feet below the top, dipping 27° south, indicating a small roll in the structure, i. e., a small anticline and syncline plunging southward, producing a small offset in the mountain front. The mine is in the small plunging syncline ad the clay in the open cut shows the undisturbed bedding of the impure Shady dolomite from which it was derived by weathering. Large rough "bony" masses of decomposed chert and chert conglomerate originally in the Shady are inclosed in the clay. The manganiferous clay is overlain by and partly mixed at the top with quartzite wash from the mountain, which is especially well developed on the wooded benches at about this level along the mountain front, which undoubtedly represent the valley-floor peneplain. The geologic and surface relations are therefore favorable for the occurrence of ore deposits.

The workings at the Watson mine consist of a shaft, two tunnels, and an open cut at an elevation of about 1,400 feet above sea-level. The underground workings could not be entered at the time of visit as the mine had been idle for several years. The ore consists of concretionary psi-

[1] Weeks, J. D., Mineral Resources of the United States for 1885, p. 314.

lomelane and large pockets of wad in the bedded yellow clay. It is free of sand but a little iron oxide is mixed with it, though not enough to class the ore as a manganiferous iron ore. The psilomelane occurs chiefly in small pieces, the largest mass observed weighing only a few pounds. The ore was washed and concentrated in a mill at the mine from which it was hauled in wagons to the Norfolk & Western Railway, a distance of four miles. The mill was equipped with washer and jigs.

WATSON PROSPECTS.

Several prospect pits and cuts occur along the foot of Grindstone Mountain for about half a mile south of the Watson mine, and, although they are in no way connected with the mine, they are here called Watson prospects. Work had been done on some of these recently, and manganese ore similar to that in the Watson mine was seen at most of the openings. The geologic and surface relations seem to be as favorable as at the Watson mine.

GARRISON BANK.

The Garrison bank is an old manganiferous iron-ore mine on the lower west slope of Grindstone Mountain, about 1 mile from the Watson bank, but was not visited by the authors. The manganese is said[1] to occur as blue granular pyrolusite in pockets and seams in residual shaly and sandy clay. Ore of the following composition was reported in the early eighties from this mine.

Analyses of manganese ore from the Garrison tract.[2]

Mn	52.69	53.66
Fe	2.32	1.54
P	.32	.33
SiO_2	27.95	1.95

NAKED CREEK AREA.

Just south of Naked Creek, at the west foot of Piney Mountain, is a triangular tract which apparently has favorable conditions for the accumulation of manganese ore. The near-by surface is a gently sloping plain 1,400 to 1,500 feet in elevation which is covered with mountain wash. It lies in a reëntrant in the mountain front, flanked on the north by Erwin quartzite which dips 30° southward, and on the southeast by the quartzite

[1] Harder, E. C., Bull. 427, U. S. Geol. Survey, 1910, p. 56.
[2] Weeks, J. D., Mineral Resources of the United States for 1885, p. 314.

which dips 65° northwestward. It therefore lies in a syncline which plunges southwest, and the floor of the valley is underlain by Shady dolomite or its residual clay. The conditions, therefore, are favorable for the accumulation of manganese ore, and the area was recommended for prospecting by the present authors in Bulletin 660 of the U. S. Geological Survey. It is shown as Tract 3 in figure 9, page 80.

ROCKINGHAM COUNTY.

FURNACE MINE.

A large old iron bank of the Shenandoah group of mines, which furnished ore for Furnace No. 4 at the old Furnace post-office southwest of Grindstone Mountain, is located on the flat bench 1,250 feet in elevation 2 miles northeast of Elkton. It is south of Naked Creek, some distance from the foot of the mountain, and is apparently associated with higher beds than those in which most of the manganese mines are located, probably Watauga shale. In the large pits, which cover several acres and are full of water, and in long, deep trenches, the iron ore is associated with yellow variegated contorted laminated clay or leached calcareous shale in which are decomposed white chert layers and irregular buff sandy "bony" chert masses. No manganese is reported from this mine.

PINEY MOUNTAIN PROSPECT.

Two small pits or shallow shafts were opened on the small creek at the foot of Piney Mountain. Limonite ore was on the dump at the time of visit but no manganese was observed. It is close to outcrops of Erwin quartzite which is brecciated and cemented by iron oxide. This crushing may be due to faulting near the top of the quartzite, so that the conditions may not be favorable for manganese deposition. No other prospects are known southward to the vicinity of Elkton, although there is a wide bench about 1,250 to 1,300 feet in elevation deeply covered with gravel which reaches from the foot of the mountains to the outskirts of Elkton.

ELKTON MINES.[1]

Location and history.—The Elkton mines, also known as the Kendall & Flick mine and the Mary Campbell mine, comprise three groups of workings on the gravel-covered bench on the north slope of an isolated ridge a

[1] Description chiefly from Hewett, D. F., U. S. Geol. Survey Bull. 640, pp. 61-67; also from Harder, E. C., op. cit., p. 57.

mile south of Elkton. (See Pl. XIV.) The older workings consist of several open cuts, shafts, and tunnels, which lie at the upper edge of the bench in a deep ravine at the west side of the tract, called Number Three Hollow on the accompanying map, and a large open pit and several shafts in Number Two Hollow, 1,500 feet northeast, on the front of the mountain. These were operated intermittently between 1888 and 1909, and a considerable tonnage of iron and manganese ores was shipped. Newer workings, 2,000 feet to the north and somewhat below the bench, consist of several pits and a shaft with extensive underground drifts, which were opened in 1910 and operated almost continuously until January, 1915. The newest workings are in a shallow valley called Number One Hollow at the east end of the tract and comprise two working shafts and extensive underground workings. From 1916 to the present, explorations have been made by the United States Manganese Corporation of New York.

The material taken from the old workings was hauled in wagons and by tram to a mill on the Norfolk & Western Railway, a mile to the north, and washed. This mill burned in 1909 and in 1911 a modern mill was built on the same site.

Surface features and geology.—In the vicinity of Elkton there are numerous flat-topped spurs from the hills east and southeast of the town 1,200 to 1,300 feet in altitude. These flat areas comprise a narrow bench along the foot of the mountain which is a remnant of an old land surface, probably the late Tertiary peneplain. The early Tertiary peneplain was apparently cut away by Shenandoah River in a wide lateral swing in the Elkton area in late Tertiary time, which made the wide flat at this place. Lower benches, about 1,100 feet at the front, represent a still lower valley-floor peneplain. Shenandoah River and its tributaries, such as Elk Run, flow in channels cut 250 feet below the upper bench surface.

The collar of the Niesswaner shaft (1, on the map), at an altitude of 1,075 feet, is on a gently sloping bench that merges with the plain to the north. The collar of the old Kendall & Flick main shaft (5) is about 190 feet higher. Another shaft (6) about 750 feet northeast of this shaft and about 30 feet higher is reported to have struck at a depth of 110 feet, or about 1,185 feet above sea-level, a lens of coarse, well-rounded quartzite boulders apparently lying on shale and sandstone bedrock. The material is clearly waterworn, but it is not certain whether the boulders lie on a terrace or in a channel.

The upper beds of the Erwin quartzite, characterized by a layer with peculiar spotted surface, apparently the ends of short worm tubes (Pl. VIII,

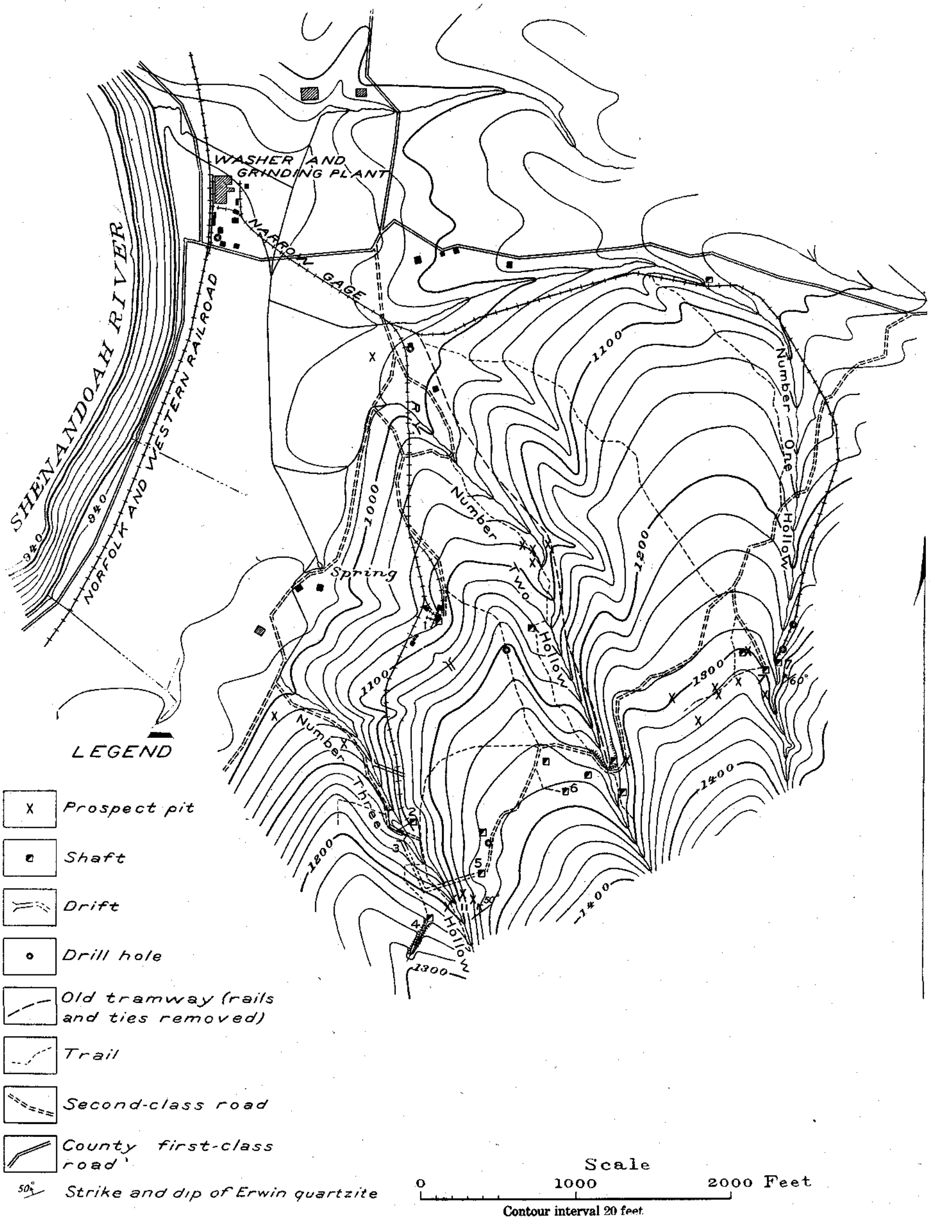


Plate XIV.—Map of group of mines 1 mile south of Elkton, Rockingham County, showing location of operating and recently operated mines, old workings, and prospects.

1, Niesswaner shaft. 2, Bartell shaft. 3, Mule tunnel. 4, Kendall and Flick old shaft and open cut. 5, Kendall and Flick old main shaft. 6, Shaft to bedrock. 7, United States Manganese Co.'s shafts. Datum is mean sea level. Contours determined by aneroid barometer based on railroad bench mark at Elkton. Surveyed by T. K. Harnsberger, June, 1915, with later additions.

p. 17), outcrop 300 feet south and 100 feet above the Kendall & Flick shaft. They strike N. 60° E. and dip 50° NW. and make the dip slope of the mountain here. Similar relations were observed at the new northeast shafts (7), where the quartzite of the mountain about 100 feet south of the shaft strikes N. 45° E. and dips 60° NW. No exposures of bedrock were noted in the area between the mines and the mill. Gray shale and thin-bedded limestone are exposed in the rail road cut 600 feet north of the mill. These beds are locally crumpled, but the strike is east and the dominant dip 60° S. The Niesswaner shaft passed from the clay in which manganese ore was found into soft, decomposed shale and finally, at a depth of 270 feet, into hard, sun-cracked purplish-red shale. These beds dip low to the southeast and the sun cracks show that the shale is not overturned. In the face of the west drift on the 300-foot level similar shale strikes N. 30° E. and dips 10° SE. Decomposed buff shale having a strike of N. 30° E. and dip of 50° E. was also seen in the face of the west drift of the 206-foot level.

The sun-cracked shale of the Niesswaner shaft may be a part of the Watauga shale, in which such material is known, or it may be transitional between the Shady dolomite and the underlying Erwin quartzite. The beds in the railroad cut are believed to be part of the Watauga shale. Since the beds dip toward the mountain, and the rocks of the mountain dip toward the valley, there is a synclinal basin between. The synclinal structure is in harmony with the structure observed southwest of the mine in the gorge of Hawksbill Creek. Here a small outlying ridge of Erwin quartzite is clearly seen to be anticlinal, and the gentle syncline between the ridges plunges northeast toward the Neisswaner shaft. The manganese deposit appears to be inclosed in clay resulting from the decomposition of the red shale in place.

Occurrence of the ore.—With the exception of the open cut (4, Pl. XIV), none of the openings made by Kendall & Flick were accessible in 1913. The old main shaft (5) is reported to have been 246 feet deep when work was abandoned in 1909, but there is no record of the occurrence of the ore. Iron ore only was taken from the open cut (4), but it is reported that some manganiferous ore was obtained from the deep workings and removed through the mule tunnel (3). The walls of the eastern part of the open cut show decomposed sandy shale or clay, here and there impregnated with limonite and containing thin films of manganese oxide. During 1915 a shaft (2) was sunk in the ravine to a depth of 135 feet, but encountered only valley wash of subangular boulders of quartzite.

It is reported that the amount of ore mined above the 140-foot level of the Niesswaner shaft was not great, but the upper work was not accessible in 1913. This shaft reached a depth of 312 feet in May, 1914, but no ore was found below 260 feet, or 105 feet below the level of Shenandoah River, and 220 feet below the original water level. Most of the ore that yielded the output from 1912 to 1914 (1,053 tons) came from the workings between the 140-foot and 206-foot levels of this shaft. As shown by the sections in figure 8, the zone which yielded the ore, and was therefore most thoroughly explored, was roughly U-shaped in cross-section and about 30 feet in maximum thickness on the limbs. The explorations do not appear to have determined the horizontal limits of the ore-bearing zone, except at the face of the southwest heading, where decomposed shale was found. Within this zone hard rounded and slaglike masses of manganese minerals were found, for the most past in dark-brown to black wad, which formed highly irregular bodies in soft variegated clay. Locally, however, the manganese minerals were embedded in pure ocher containing little manganese, but none were observed in white or pale-yellow clay. Although some bodies of wad were small and apparently isolated, many of the larger bodies were connected by irregular pipes and seams of wad, and by following these it was possible to locate new bodies in the zone. As the explorations and stoping tended to follow the ore, the result in places was a veritable maze of drifts and raises.

Although the round ore nodules are generally solid, many of the slaglike masses are cavernous and stalactites of psilomelane hang vertically from their walls. Psilomelane appears to be the commonest mineral, but many nodules show manganite and psilomelane in alternate layers, and in several places manganite crystals fill fractures in psilomelane. It is reported that in systematic sampling, the crude ore yielded washed ore in the ratios of 3 to 2 and 3 to 1; but from the mill records it is doubtful whether a ratio of 3 of crude to 1 of washed ore was maintained over long periods. A few masses of ore weighing as much as 500 pounds have been found, but most of the nodules range from 1 inch to 4 inches in diameter. In addition to ore the washed product contains subangular fragments of microcrystalline quartz that resemble chert and range in size from fine sand to pieces 2 inches in diameter. Pebbles of sedimentary rocks have never been found in the ore body.

The clay adjacent to the ore bodies is commonly yellowish-brown, but here and there is variegated, white, gray, and dark brown. It merges both laterally and below into a zone of pale-brown decomposed shale, in which traces of bedding may be recognized. No hard nodules of manganese occur

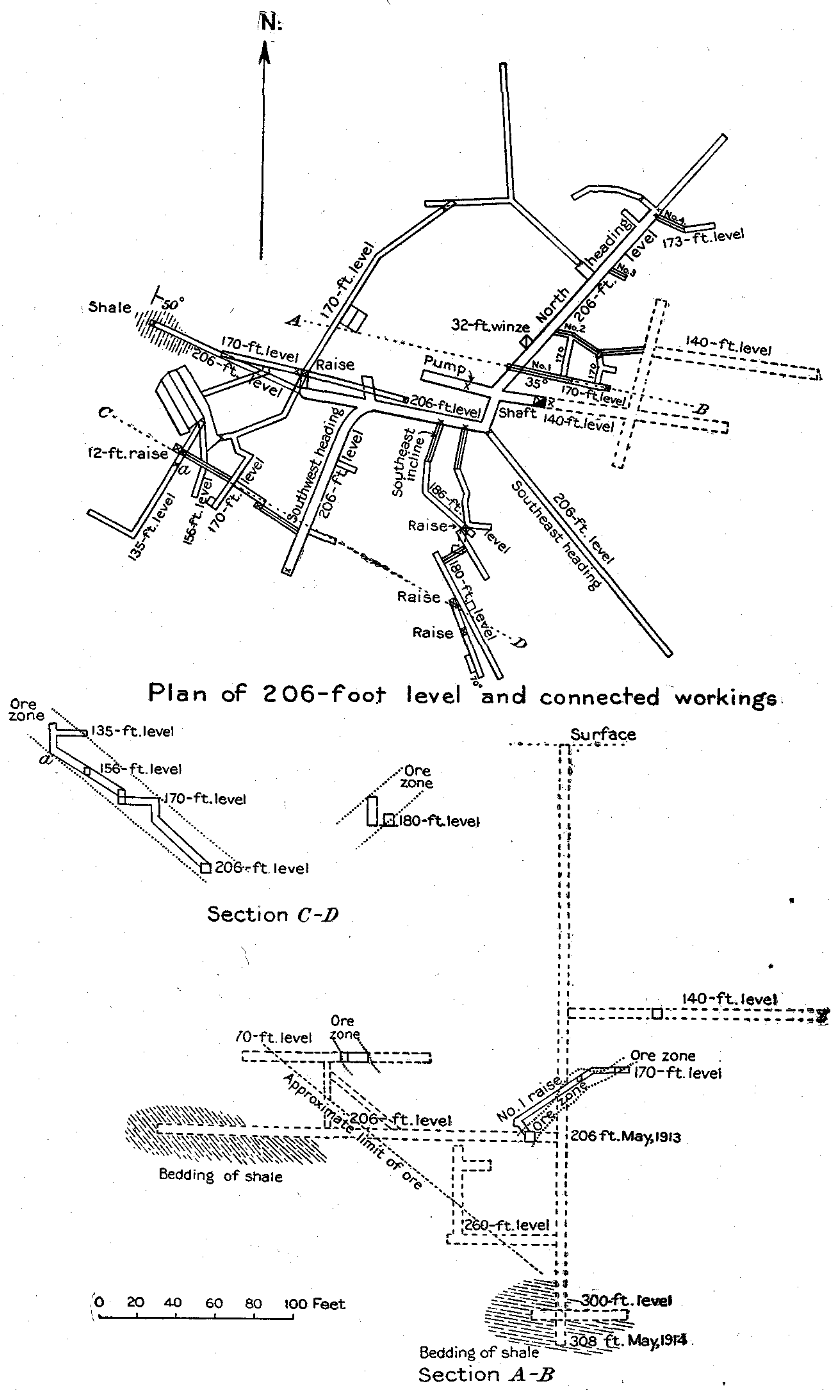


Fig. 8.—Plan and cross-sections of the Niesswaner shaft and workings of the Kendall & Flick mine, 1 mile south of Elkton, Rockingham County. X, marks limit of accessibility in underground workings at time of visit. The relation of workings to other openings on the property are shown in Plate XIV.

in this shale, although there are films of manganese oxide here and there along bedding planes. The thickness of this zone appears to range from a minimum of about 20 feet under the deposit in the shaft to more than 90 feet on the 206-foot level.

Although the important crystalline constituents of the clay have been recognized under the microscope, the exact nature of the changes undergone by the shale in decomposing to clay cannot be determined, because the colloidal materials that make up the bulk of the clay appear similar but may, nevertheless, show a wide range in composition. The unaltered coherent shale contains considerable sericite, ferric oxide, clay, quartz, and possibly minor accessory minerals. The soft shale at the face of the west drift on the 206-foot level also contains sericite, clay, and quartz, but, except for the change to a soft yielding mass, does not appear to differ greatly from the unaltered shale. Some of the clay near wad and nodules of manganese minerals is gray or white and contains considerable sericite and quartz, but most of it is yellowish-brown clay with very little sericite and quartz. Some specimens contain angular platy fragments of microgranular quartz and others, such as that collected at the point marked *a* on the 135-foot level, figure 8, contain numerous minute quartz crystals with many calcite nuclei. Both these forms of quartz appear to be secondary in the clay and to be formed as a result of the decomposition of the shale.

The purpose of the study set forth above was to ascertain whether it is more probable that the masses of manganese ore, which obviously represent more than that contained in a volume of fresh shale equal to that of the clay, represent an enrichment of manganese through loss of shale constituents by solution or whether the volume of the clay has remained essentially constant and manganese has been added. If the clay has approximately the composition of kaolin, the latter assumption appears more reasonable.

The operations of the United States Manganese Corporation during 1916 and 1917 included sinking two shafts (7) and considerable churn drilling farther north and northwest near Number One Hollow. Several thousand tons of ore ranging from 42 to 50 per cent manganese, 2 to 5 per cent iron, and 8 to 10 per cent silica were recovered from material mined from these shafts to a maximum depth of about 210 feet. At this depth in the northeastern of these shafts, 1,060 feet above sea-level and 115 feet above Shenandoah River, it is reported a bed of well-rounded quartzite boulders was struck. These boulders are clearly waterworn and must form a part of a stream channel. All of the ore was found above the bed of boulders. These shafts were abandoned in the summer of 1917 and the associations of the ore could not be determined.

The general relation of the ore to the bedrock at the old works (3 and 4) in the ravine at the west, and in the old Kendall & Flick mine (6) on the slope above the middle shaft, are about the same. It is in chert-bearing clay derived from the decomposition of impure cherty shales near the base of the Shady dolomite. The top of the Erwin quartzite dips 50° to 60° northwest off the mountain and under the deposits so that the structure is monoclinal, and the synclinal structure seen at Hawksbill Creek to the southwest probably does not affect the rocks so high on the slope.

Origin of the ore.—The relations of the hard manganese minerals to wad and clay suggest the following mode of origin: The clay in which the manganese is found was in part a constituent of the original shale and in part has resulted from the decomposition of sericite. Hydrous oxide of manganese, partly an original constituent in the shale but largely brought into the clay mass in solution, first replaced the clay by forming segregated masses of soft wad. Locally masses of fairly pure but incoherent hydrous manganese oxide were formed. The nodules of hard ore have formed from the wad largely by the deposition of successive bands of psilomelane and manganite, largely by the replacement of clay.

Milling.—In the new mill erected in 1911-12 the mined ore is elevated to bins, from which it is fed to a trommel with 1½-inch holes. The oversize, consisting of nodules of ore and masses of mud, is crushed in rolls and joins the screened product, and after preliminary washing with a powerful jet of water, both pass through a double-log washer. The washed ore is sized in a double trommel to three products, the coarsest of which, above 1½ inches, is hand sorted, while the middling, ranging from 1½ inches to one-fourth inch, is sized and jigged in a McLanahan jig. An attempt was made to treat the finest material on a Wilfley table, but as a high-grade product could not be made it was abandoned.

SWIFT RUN PROSPECT.

On Swift Run east of the ridge on which the Elkton mines are located, there is an offset of the mountain front about one-fourth mile to the southeast. The attitude of the quartzites of the mountain indicate an anticline at the front followed by a syncline to the southeast, both of which plunge northeast. Limestone, or clay residual from limestone, probably underlies the lowland enclosed in the angles of the offset, which would furnish favorable conditions for the accumulation of manganese ore. Except in the channel of Swift Run the surface is covered with wash which may conceal manganese ore. The area has not been generally prospected but a small pit on a wooded knoll east of the run showed some good manganese float. Further prospecting with a drill south and southwest of this pit would seem to be worth while.

AREA SOUTHWEST OF ELKTON.

The west front of the mountains southwest of Elkton is in general monoclinal, the Erwin quartzite of the mountain dipping northwestward under the limestone of the valley, and the conditions for manganese deposition are similar to those at the Elkton mines. However, there are several sharp offsets in the general southwest course of the mountain front which are caused by the geologic structure. The Erwin quartzite which composes the western foothills of the Blue Ridge is here folded into anticlines and synclines which trend and plunge southwestward, so that ridges composed of the quartzite descend in that direction and pass below the level of the valley floor. The gravel-covered bench about 1,200 feet in altitude along the west foot of the mountains swings around the ends of these ridges and up the embayments between them and is underlain by clay residual from Shady dolomite, so that the conditions at these embayments are even more favorable for manganese deposition. These embayments are well shown in figure 9, one occurring 1½ miles east of Yancey, another 2 miles southeast of Yancey, and a third 1 mile to the south at Gap Run.

Southeast of Yancey a manganese prospect has been opened north of the small run from the mountain by J. H. Crawford, and another south of the run by W. B. Yancey. The Crawford prospect shaft 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 reëntrant angle between the 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, which is half a mile south of the head of the trough, manganese nodules occur in red clay containing chert fragments. Although the clay was not observed in place the clay and chalcedonic chert are the characteristic residua of the Shady dolomite, and probably the entire embayment is underlain by the Shady dolomite but is completely covered by quartzite wash from the mountains. The shaft is

75 feet deep and its collar is 1,185 feet in altitude. A small quantity of ore was taken out and hauled to Elkton where it was washed.

The 1,200-foot bench on which the mountain wash lies is evidently part of a peneplain surface that was formed during a stage of erosion later than that of the early Tertiary peneplain, as it is somewhat lower in altitude, and probably represents the lower valley-floor or later Tertiary peneplain. 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 inclosed basin having a peneplained surface covered 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 conclusion that this triangular area possesses favorable conditions for the deposition of manganese ore, and it was recommended for thorough prospecting by the present authors in Bulletin 660, U. S. Geological Survey. The area recommended for prospecting is marked Tract No. 1 in figure 9.

The conditions in the embayment in the mountain front 1 mile to the south were not so well determined. The structure of the quartzite hills 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. The workings at the Yancey prospect, which is 1¾ miles southeast of Yancey, consist of two shafts, one near the bottom of a ravine and the other on the slope a short distance to the north. The lower shaft is 36 feet deep and is said to have reached good manganese ore in the bottom, but the upper one, which is 60 feet deep, yielded no ore. It may not have been sunk deep enough to have passed through the cover of clay and reached the ore body beneath. Both the shafts are in yellow clay in which no chert was found and the clay may thus be residual from higher beds than those at the base of the Shady which usually contains chert fragments, but the Shady dolomite or its residual red clay is probably present beneath the wash throughout the embayment. The area, therefore, has favorable conditions for the accumulation of manganese ore and further prospecting is recommended. It is shown on figure 9, just south of the embayment marked Tract No. 1.

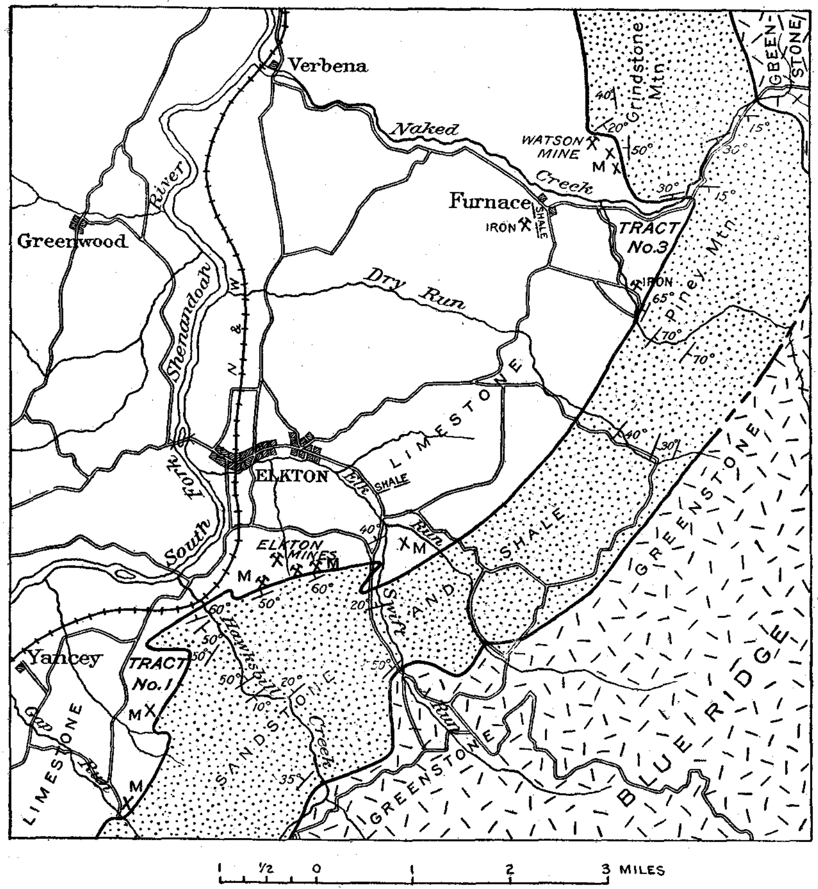


Fig. 9.—Sketch geologic map of region near Elkton, Rockingham County, showing location of undeveloped tracts (Nos. 1 and 3) recommended for prospecting and the Elkton mines and Watson mine.

AREA BETWEEN YANCEY AND GROTTOES.

Between Gap Run and Big Run the mountain front is practically straight and trends nearly due southwest. The quartzite dips steeply west 70° to 80° under the limestone at most places along the front but flattens to low dips of 20° to 30° back from the mountain front where it caps high spurs and some back ridges. The structure along the mountain front is therefore monoclinal. At Big Run, however, the mountain front is offset by a projection into the valley of a quarter of a mile, and the strike of the

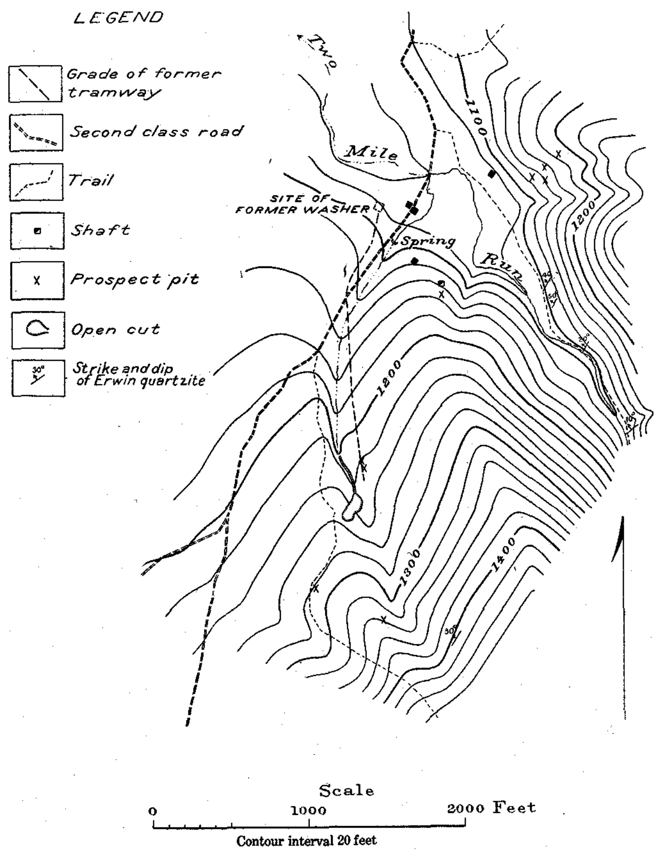


Plate XV.—Map of old Seller mine, Rockingham County, 6 miles southwest of Elkton, showing location of old ore bank and prospects.

Datum is mean sea level. Contours determined by aneroid barometer based on railroad bench mark. Surveyed by T. K. Harnsberger and W. J. Cox, June, 1915.

quartzite is seen to bend parallel with the front, with low dips of 10° to 30° into the valley. There is here, therefore, a gentle anticline that plunges northeast, and a flat syncline behind it, giving rise to favorable conditions for the deposition of manganese in the lowland embayment. The gravel-covered bench is well developed along the foot of the mountain from Yancey to the vicinity of Grottoes, and slopes gently toward the valley from about 1,400-feet elevation near the mountain. This bench probably represents the early Tertiary peneplain. It is deeply covered with wash which conceals the underlying formations, but is trenched by the streams from the mountains which flow across it.

Manganese seems to occur generally along this belt but has been prospected only where its float has been found in the wash, usually where small streams have cut into the surface covering. Three mines which are described below have been operated on a small scale in this area.

SELLER MINE.

The Seller mine is about 3 miles south of Yancey, on the south side of Two-Mile Run, near the west base of a spur of the Blue Ridge. (See Pl. XV.) The workings consist of an open cut about 200 feet across and 20 to 30 feet deep, one-fourth mile south of the run. It was worked several years ago by Kendall & Flick but the tramroad once leading from the railroad to the mine has since been removed. The bank has slumped badly but the ore was seen to lie in red residual clay containing a small quantity of chert, which is residual from the Shady dolomite. The ore is bluish psilomelane in both concretionary and cellular masses embedded in the clay. The concretionary ore is good solid botryoidal masses that range in size from very small particles up to those 8 or 10 inches in diameter, some resembling large bunches of grapes. The cellular ore occurs in large masses which include some clay in pockets. There are also pockets of wad in the clay. Considerable good ore is still on the dump and scattered over the ground and it is believed that the deposit is not worked out and further prospecting with the drill is recommended.

Near Mile Run, about three-fourths mile southwest of the Seller mine, there is a small pit exposing a huge mass of siliceous brown iron ore with a little ferruginous manganese coating. It is apparently of no commercial value but is mentioned here because the ore is in the belt of outcrop of the Shady dolomite. It, however, is farther from the quartzite than most of the manganese deposits occur.

BIG RUN MINE.

The Big Run mine, also called the Lower Sipe mine, is on the west slope of a foothill ridge or spur of the Blue Ridge, 5 miles east of Lynnwood. It is about one-half mile northeast of the mouth of the rocky canyon of Big Run where it passes out of the mountains. The workings consist of two or more open cuts which reveal manganese and iron ores in the top layers of the Erwin quartzite and in residual clay of the lower part of the Shady dolomite. They lie on the side of the small syncline that plunges steeply to the north. The openings examined by the writers were evidently those called the Lower Sipe iron-ore mine for they contain chiefly brown iron ore and but little manganese ore. The old manganese mine, indicated on a plat of the property as lying northwest down the slope from the iron mine, was not visited by the writers. Harder[1] describes the ore at this opening as follows:

"Cellular psilomelane is found in large masses, some of them 4 or 5 feet in extent, embedded in dark-brown and black clay. The black clay occurs in specks and irregular masses through the brown clay. Several deposits of brown iron ore are found near the manganese-ore deposits."

SHAVER BANK.

The Shaver bank, described by Harder as half a mile south of the Big Run mine, also was not seen by the present writers but must be close to the small shaft referred to below. It is described by Harder as containing both iron and manganese ore, the latter in the form of cellular psilomelane.

Just west of the mouth of the Big Run gorge prospecting has been recently done by a shaft, which was full of water at the time of visit but the timbers indicated recent working. Much good iron ore was on the dump but no manganese ore was seen at this opening. The iron ore is associated with white and yellow clay. The shaft is within 100 feet of outcrops of quartzite which dips 50° northwest toward the shaft, and the ore therefore lies only a short distance above the quartzite, similar to the location of most of the manganese deposits.

Other iron-ore diggings occur farther southwest along the bench at the foot of the mountain. One of these, described by Watson[2] as the Fox Mountain mine, is said to have once yielded 100 tons of iron ore a day. All

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

[2] Watson, T. L., Mineral Resources of Virginia, p. 434, 1907.

the iron mines were worked years ago and were connected by a well-constructed nearly level road with the Mt. Vernon Furnace, located on Madison Run 3 miles east of Grottoes, where the ore was smelted.

AUGUSTA COUNTY.

AREA FROM GROTTOES TO THE CRIMORA MINE.

No mines or prospects were seen along the foot of the mountain for 8 miles south of the latitude of Grottoes. The structure of the quartzite of the mountain front is monoclinal throughout, the quartzite dipping from 20° to 40° northwest under the limestone of the valley. The wash-covered bench follows the foot of the mountain, and is about 1,500 feet in altitude near the mountain and slopes gently away toward the valley. Manganese and iron ores may occur in this tract and be covered by so thick a deposit of wash that they have not been discovered. At the south end of the tract, 1 mile north of Crimora mine, an offset in the mountain front is caused by folding and presumably also faulting as the quartzites south of the embayment seem to dip away from the lowland and to be cut off across the bedding. If, however, after more careful study the reëntrant valley proves to be due to a syncline in the quartzite, it will have faborable conditions for manganese deposition. It may therefore be worth while to search for manganese ore in this embayment, which is close to the Crimora mine and may have somewhat similar conditions.

CRIMORA MINE.[1]

INTRODUCTION.

The Crimora mine has long attracted unusual interest because it has the distinction of having yielded more manganese ore than any other mine in the United States. It was discovered before the need for manganese alloys in modern steel-making practice was fully realized, and for several years it contributed a large part of the ore required by the domestic steel industry. Since about 1895, however, the domestic needs have been supplied largely from rich deposits in Russia, India, and Brazil, and, like many other domestic deposits whose product had to be concentrated to yield a marketable material, it has been unable to successfully compete for the market at prevailing prices and has been operated intermittently only. As the war brought a period of high prices for manganese ore, an attempt was recently made to reopen the mine on a larger scale than ever before.

[1] Description by D. F. Hewett.

The mine openings, shafts, and open cuts lie about 2½ miles east of the little settlement of Crimora, Augusta County, where a spur railroad to the mine connects with the Shenandoah Valley branch of the Norfolk & Western Railway. The area within which more or less ore has been found is nearly 16 acres, the largest open cut alone covering 8 acres. The dumps of waste and barren overburden, and the settling ponds in which the waste waters have been collected, cover a large area west of the open cut and measure the past activity of the mine.

The examination on which this report is based covered about ten days in April and May, 1917, and was planned in the hope that it might yield conclusions that would aid in the exploitation of other deposits in the Valley of Virginia. Although none of the old underground workings were accessible and the association of the richest ore bodies can only be inferred, the examination was aided by records of recent drilling to determine the extent of the remaining ore.

HISTORY.

The exploitation of the Crimora deposit may be separated into four periods. The first period extends from 1867 to about 1882, during which the deposit was attacked by open pits and shallow shafts. From 1867 to 1869 it was operated in a small way at a loss by a stock company. From May, 1869, to April, 1882, the mines were alternately either idle or worked by Samuel W. Donald in the interest of the stock company.[1] During this period the ore was shipped to England and Belgium.

The second period of exploitation is that of maximum production and extends from April, 1882, to 1892, when, first under lease to J. A. White & Co., of Pittsburgh, and later to the American Manganese Co., Ltd., a subsidiary of the Carnegie Steel Co., of Pittsburgh, 130,000 tons of ore were shipped from extensive underground workings from shafts.

The third period extends from 1892 when the property reverted to the owners, the Virginia Manganese Co., to May, 1915, when the present Crimora Manganese Corporation took possession. The production during this period is not definitely known. The mine was worked in a small way during most of the years of this period, but operations generally were confined to searching for ore remaining in the old workings. Beginning about 1895, an ambitious attempt to mine the remaining ore by hydraulic methods was made. This involved driving (from 1902 to 1905) a tunnel 6,000 feet

[1] Day, D. T., U. S. Geol. Survey Mineral Resources, 1883-84, p. 551.

long from the west under the deposit, but it was never carried to successful operation, partly because the available water supply was inadequate.

The fourth period into which the mine recently entered began in May, 1915, with the installation of new equipment, including modern excavating machinery and mills, in the hope that a large part of the remaining ore-bearing clay could be cheaply mined and treated. Although the rate of production has not yet greatly increased, it is too early to estimate the prospect of success.

Unfortunately, there is little record of the underground work prior to 1905. Except the brief statements by Penrose [1] and Hall,[2] there are no printed descriptions of the extent of underground work and the mode of occurrence of the ore.

[1] Penrose, R. A. F., Jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 402-405, 1891.

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

Production of the Crimora mine.

	Tons High-grade.	Representative analyses.			Tons Low-grade.
		Mn	Fe	SiO_2	
Prior to 1869	5,684				
May 1869 to Feb. 1876	280				
Feb. 1876 to Dec. 1878	2,326				
Dec. 1878 to Dec. 1879	1,602				
1880	2,963				
1881	2,495				
1882	1,652				
1883	5,185				
1884	8,804				
1885	18,212				
1886	19,382				
1887	19,100	48–50	2–4	10.2	
1888	16,100	44.5	3.2	14.0	
1889	12,974				
1890	11,332				
1891	13,645				
1892	4,389				
1893	2,597				
1894	0				
1895	0				
1896	0				
1897–1899, incl.	([a])				
1900	[b] 934				
1901	([a])				
1902–1905, incl.	([a])				
1906	1,450				
1907	373				
1908	792				274
1909	1,314				305
1910	988	47			301
1911	815	46	5		82
1912	601	46	5		117
1913	323				0
1914	575				93
1915	201				241
1916	1,517	45.6	3.7		0
1917	1,280	42–53	2.5–5	5–10	0
Total recorded	159,685				1,410

[a] No record.
[b] Partial record.

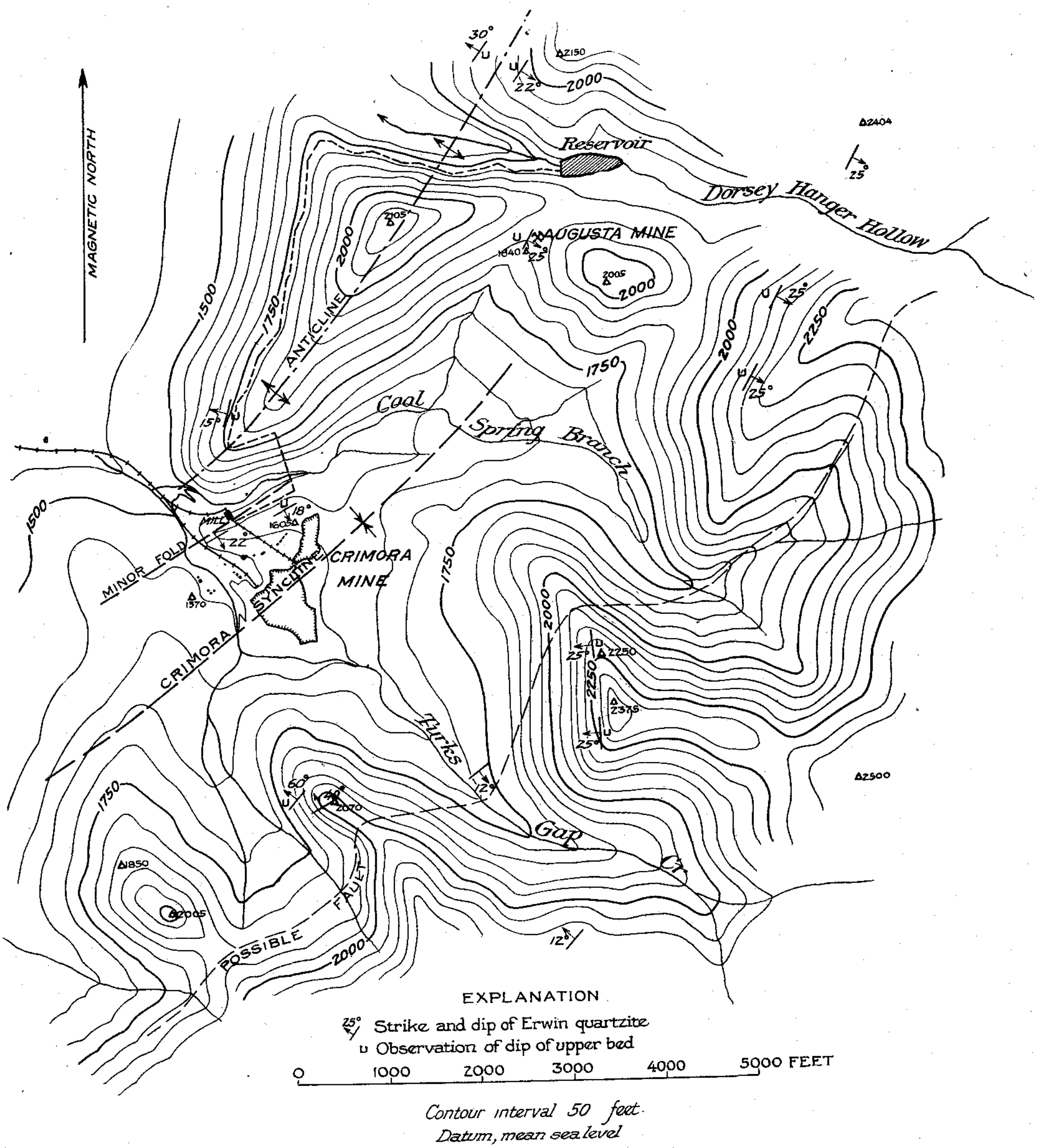


Plate XVI.—Map of Crimora and Old Dominion mines, Augusta County. Altitudes determined by telescopic alidade; intermediate contours sketched. Surveyed by D. F. Hewett, April, 1917.

SURFACE FEATURES.

In the vicinity of the Crimora mine, the broad valley plain rises gradually from the central part of the valley at an elevation of 1,300 feet to about 1,540 feet, where it meets the steep slope of the conspicuous foothills that lie between it and the main Blue Ridge. Most of the foothills rise abruptly to 2,000 or 2,300 feet and are connected by ridges that ascend to the broad flat summit of the Blue Ridge at an elevation of 3,000 feet. The local features of the foothills belt are largely determined by the structure of the Erwin quartzite, but the rather uniform elevation of 2,000 to 2,300 feet that many hills with diverse structural relations attain, suggests that they represent the position of the intermediate peneplain (p. 35).

The Crimora mine (Pl. XVI) lies on the western border of a flat area almost enclosed by the ridges that merge with the Blue Ridge on the east and a sharp straight longitudinal ridge that separates the area from the valley plain on the west. The flat area almost coincides with an alluvial fan, now trenched by Turks Gap Creek, which merges with the valley plain southwest of the mine. The northern part of the flat area drained by Cool Spring branch is not covered by the alluvial fan.

Turks Gap Creek formerly flowed over the middle of the Crimora ore deposit, but was diverted to its present position so as not to interfere with mining operations. West of the mine it flows through a narrow rock gorge to its channel cut into the plain. Cool Spring branch similarly cut a channel through hard quartzite above its junction with Turks Gap Creek. The watershed of the two streams is approximately four square miles and at an early period the waters of both drained to the area within which the ore deposit lies.

GEOLOGY.

Bedded rocks.—Although this examination included rapid traverses over an area of about four square miles and nearly to the summit of the Blue Ridge, and therefore covered rocks that range from the top of the Erwin quartzite down to the pre-Cambrian greenstone schists, it was not possible at the time to make a detailed geologic map of the area represented on Plate XVI. Conclusions with regard to the structure of the rocks near the mine are based largely on the attitude of the top of the uppermost bed of the Erwin quartzite and the records of recent drill holes.

With the exception of a small area in the southeast corner in which lower rocks are exposed, the region covered by Plate XVI is underlain by beds of the Erwin quartzite and the products of decay of the overlying

Shady dolomite and associated shale. The formations below the Erwin occupy the upper slope and crest of the Blue Ridge, east of the area represented on the map.

Although there are good exposures of the upper part of the Erwin quartzite, beds of the lower part outcrop sporadically and a complete section of the formation cannot be examined. Thick beds of bluish-gray dense vitreous quartzite resembling porcelain, which outcrop in the upper valley of Turks Gap Creek, probably represent the middle part of the formation. The upper 100 feet or more of the Erwin quartzite is well exposed on the slopes of ridges east and southeast of the Crimora open cut. The uppermost bed of quartzite forms the west slope of the conspicuous hill east of the mine, and beds near the top form the surface of the narrow ridge northwest of the mine from Turks Gap Creek to Dorsey Hanger Hollow. The upper part of the formation is largely dense white to pale-gray vitreous quartzite in beds that range from 2 to 6 feet thick. Scolithus tubes are rare in these beds. The higher beds include 10 to 30 feet of white quartzite in beds that range from 6 inches to 1 foot thick, in which the granular texture is conspicuous and scolithus tubes are rather common. The beds that show the peculiar markings reproduced in Plate VIII (B) are exposed 200 feet northwest of the Jim Crow pit.

Although there are no outcrops of Shady dolomite near the Crimora mine, dense gray limestone was struck in a drill hole 40 feet below the surface at the northwest edge of the main open cut. The extent to which limestone or dolomite made up the several hundred feet of beds over the uppermost Erwin quartzite bed before they were weathered and the soluble parts dissolved, can only be conjectured. Good exposures of 30 to 40 feet of material directly over the quartzite are found in the Jim Crow pit and in the tunnel of the Augusta mine, a mile northeast of the Crimora mine. In the tunnel, thick-bedded sandstones are succeeded abruptly by a zone of alternating soft shaley sandstone and soft reddish shale, which merge upward into variegated laminated clay that is clearly rotten shale.

In the Jim Crow pit, the quartzite is overlain successively by three zones (1) 25 feet of very tough pale-brown clay, entirely free of manganese nodules; (2) 8 to 10 feet of soft variegated brownish clay with sporadic manganese nodules, and small lenses of chert; (3) 6 feet or more of soft brownish, sandy clay, with no manganese nodules but here and there persistent sandy layers, and small lenticular masses of brownish chert. There can be no doubt that an ore-bearing zone persists over an area 100 feet square, that it is parallel to the underlying quartzite, and that it has not

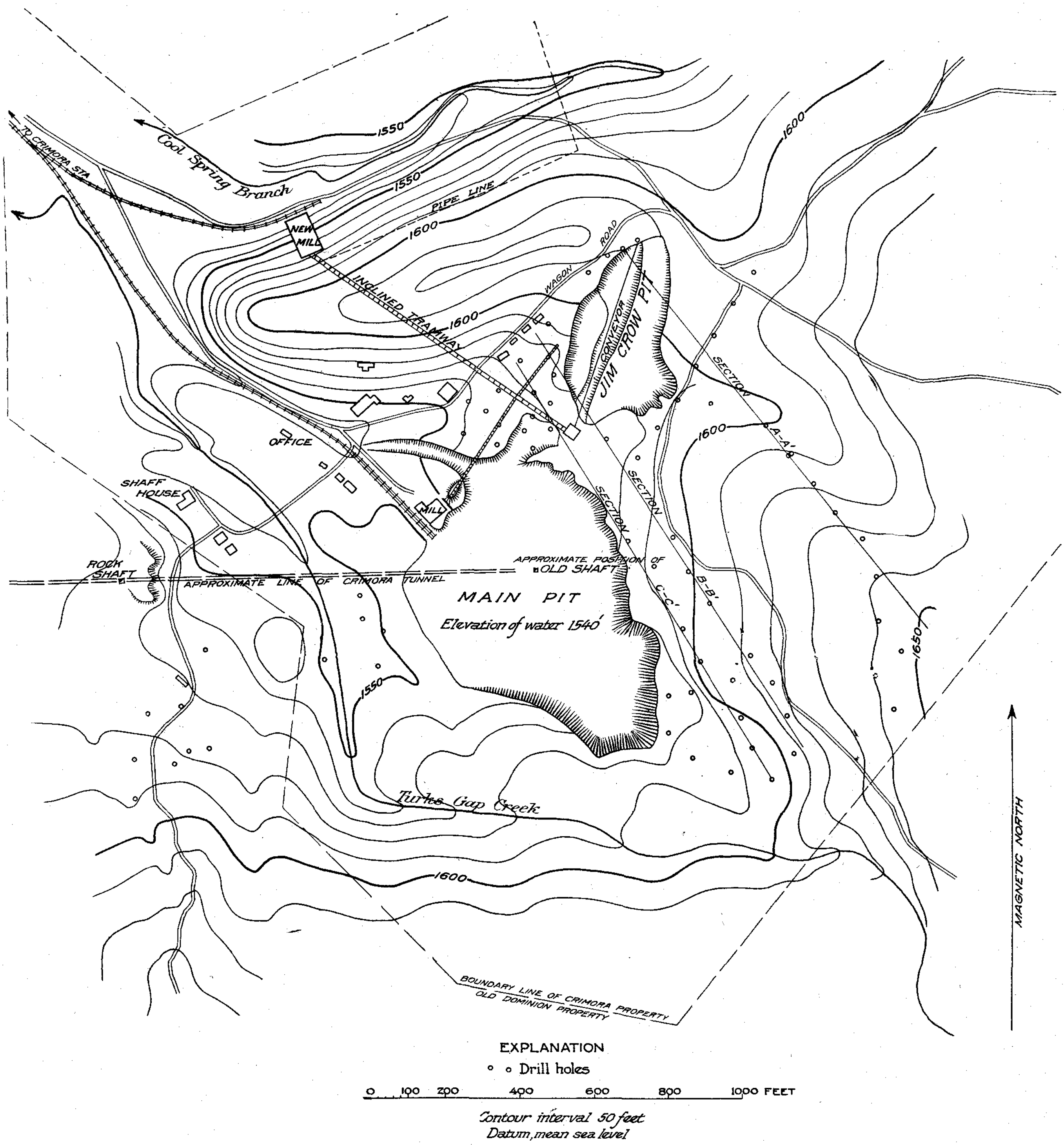


Plate XVII.—Detailed map of Crimora and Old Dominion mines, Augusta County. Survey with plane table by D. F. Hewett, April, 1917.

been disturbed by the shrinkage in volume of the intermediate material. The sandy layers in the uppermost zone are also parallel to the bedding of the quartzite. If it be assumed that the chert lenses indicate the previous existence of calcareous or dolomitic rocks, the uppermost zone was originally largely shaley limestone or dolomite. The exposure suggests that the manganese nodules occur in a fairly defined zone of rotten shale that may have contained some carbonate material but that it was not largely carbonate rock. The lowest zone of tough clay appears to be the weathered product of a homogeneous shale. Probably before weathering the rocks successively overlying the quartzite were (1) slightly calcareous shale, probably with interbedded thin beds of limestone or dolomite; (2) sandy calcareous shale in which manganese ore is now found; and (3) shaley limestone or dolomite, with thin layers of sandstone.

Specimens of clay from each zone have been disintegrated and washed with the view to comparing them with similar clays elsewhere in the Valley of Virginia associated with manganese ores. There are few important differences among the clays. Although the ore-bearing clay contains platey fragments of chalcedonic silica, no minute quartz crystals with calcite nuclei which are common in clays residual from limestone were found. Material from each zone, however, contains many minute crystals of limonite pseudomorphs of pyrite, thereby showing that the unweathered sediments contained an appreciable quantity of the latter mineral.

A large part of the area underlain by the Crimora manganese deposit was originally covered by gravel overburden, which was removed from several acres when surface mining succeeded underground mining. This overburden consists of rudely bedded sand, coarse gravel, and boulders of the rock types exposed along the west slope of the Blue Ridge. It attains a maximum thickness of 35 feet in the easternmost drill holes and becomes thinner westward until it disappears near the western border of the manganese deposit. It rests on a gently sloping surface which cuts across the bedding of the residual clay and approximately coincides with the position of the valley-floor peneplain.

Although a few pebbles in the overburden are stained black by manganese, no nodules of psilomelane were found in it and for this reason it appears to have been laid down after the ore was formed in the underlying clay. Near the western border of the Jim Crow pit, the barren overburden is locally overlain by a 20 to 30-foot bed of dark-brown clay, angular fragments of chert, quartzite, and manganese ore. This material appears to have been washed from the northeastern end of the ore-bearing clay and spread upon the older overburden.

STRUCTURE.

The interpretation of the general structure of the rocks in the Crimora region is based on surface observations and the structure of the area near the mine, on records of drilling in the exploration of the property in 1916. Although this examination yielded sufficient information to confirm the earlier interpretation by Hall[1] that the ore body lies in a structural trough, it did not afford enough data from the region east of the mine to present a satisfactory explanation of structural relations there.

The conspicuous ridge that separates the flat ground near the mine from the main valley coincides with the crest of an anticlinal fold that disappears under the valley several thousand feet southwest of Turks Gap Creek. A cross-section of the fold is well shown in Dorsey Hanger Hollow. The short ridge, 500 feet northwest of the main pit, is part of a minor fold on the southeast limb of the main anticline, and although it also plunges southwest under the valley, the crest coincides with the low hill southwest of the mine. This double fold forms the northwestern limb of the trough in which the Crimora deposit occurs.

The Crimora syncline or trough is well defined by drill holes and the cross-sections in figure 10 have been constructed from the data that they yield. Some caution is necessary in interpreting the data, as the holes were driven until the drillings became too sandy or the rock too hard to hold out the hope of encountering deeper ore. The outlines of the trough coincide therefore approximately with the points at which hard rock was struck but they may deviate as much as 10 feet from the form of a definite bed of quartzite. The sections show a trough which is unusually constricted toward the northeast, and widens toward the southwest as far as drill-hole data are available. This widening probably continues southwestward beyond the limit of explorations and the trough gradually disappears under the main valley.

Available information from drill holes as well as surface observations suggests that the main Crimora trough widens slightly northeastward beyond section line A-A′ on Plate XVII and extends to the vicinity of the Augusta mine.

The structure of the region east and northeast of the mine is complex. Observations on the uppermost bed of Erwin quartzite south of the mine appear to show that it forms the southeast limb of the Crimora trough. Good outcrops on three ridges that rise to the crest of the Blue Ridge

[1] Hall, C. E., op. cit., p. 46.

indicate the presence of an extensive fault more or less parallel to the mountain crest, which probably dips southeast at a low angle.

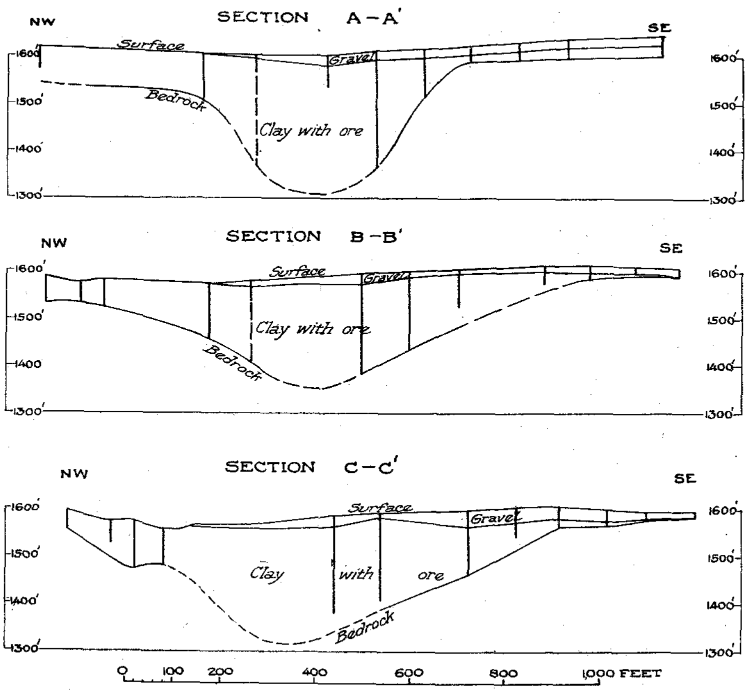


Fig. 10.—Cross-section through the Crimora trough along the lines indicated on Plate VII, constructed from data yielded by drill holes. Crimora mine, Augusta County.

THE MANGANESE DEPOSIT.

The minerals that have been encountered in the Crimora deposit include psilomelane, manganite, pyrolusite, wad, and limonite, the latter both as concretions and as pseudomorphs of pyrite. Rounded nodules of psilomelane probably formed more than nine-tenths of the output of the mine.

Although some analyses, such as that quoted by Watson,[1] show as much as 57 per cent manganese and only .37 per cent iron and 2.13 per cent silica, the average of many carloads is nearly 46 per cent manganese, 2 per cent iron, and 8 per cent silica. Inasmuch as little uncombined silica can

[1] Watson, T. L., Mineral Resources of Virginia, p. 248: Jamestown Exposition Commission, 1907.

be detected by the eye in some recent carloads, it appears that the average psilomelane here present contains more combined silica than commonly.

Manganite is associated with psilomelane nodules, and crystals of pyrolusite commonly cover the walls of cavities. Limonite pseudomorphs of pyrite are found both in the clays that fill the trough and in the centers of psilomelane nodules.

As the old explorations which yielded most of the ore are no longer accessible, the associations of the manganese minerals can only be observed in the Jim Crow pit or can be inferred from the drill-hole data. In the northern part of the pit, nodules of psilomelane that range from one to ten inches in diameter are distributed sporadically throughout the 10-foot zone so as to make up about five per cent of the weight. They are imbedded in light-brown clay rather than in wad as is the case in many places elsewhere in Virginia. Most of the nodules are free from impurities such as quartzite, chert, sand, or clay, and show characteristic concentric hard and soft layers. A few, however, have ragged inclusions of clay and show relations which indicate that in their growth the nodules have replaced the clay. Penrose[1] records that masses of ore as large as 30 feet long and 5 feet thick were found and old records at the mine state that 215 tons of ore was mined from a single lump. During recent years very few nodules more than 10 inches in diameter have been encountered.

From old maps and the records of recent drilling, it is concluded that the area north of the southern Crimora boundary, within which ore has been recovered or is known to exist, is approximately 16 acres. As some ore is known to have been recovered from the adjoining Old Dominion property, the total ore-bearing part of the Crimora trough may be 20 acres and even more.

Hall[2] emphasizes the association of nodules with the clay rather than sandy zones and this is confirmed in recent workings. The clay which yields ore in contrast with the barren clay underlying it is variegated rather than homogeneous in color, and more highly plastic and sticky. It appears to absorb water and go into suspension in it more readily than the barren clay.

The records of the drill holes show that ore-bearing clay ranges from 4 to 135 feet thick and that the yield of the different parts of the ore-bearing zone shows a wide range. There is even the widest range in thickness of ore-bearing clay and in the yield of ore from holes no more than 100 feet apart. Existing records do not permit an accurate estimate of the probable average yield of ore from the productive zone.

[1] Penrose, R. A. F., Jr., op. cit., p. 404.
[2] Hall, C. E., op. cit., p. 48.

There is fair basis for the following conclusions concerning the associations of the ores: (1) as noted in the Jim Crow pit, the ore-bearing zone is roughly parallel to the bedding and to the underlying quartzite; (2) the valley, or northwestern, side of the trough has probably yielded ten times as much ore from an area five times as large as the mountainward, or southeastern, side; (3) beginning on the northeast the more southwestern sections of the trough show thicker zones of ore-bearing clay until the base of the zone attains an approximate depth below the present surface of about 200 feet. It is not possible to state with any assurance how much farther southwest of present explorations manganese ore may exist in the Crimora trough, although there is undoubtedly a limit which is controlled largely by the depth of rock decay.

GENESIS.

As there is more information available concerning the distribution and associations of ore in the Crimora mine than in any other large mine in Virginia, it may serve a purpose to summarize the bearing of this information on the genesis of such deposits.

The Crimora mine does not yield any satisfactory evidence concerning the source and original condition of the manganese that now makes up the masses of oxides. There is some slight basis for the belief that small particles or nodules of manganiferous carbonate were sporadically distributed through a zone of shale and shaley limestone, possibly from 20 to 100 feet thick near the base of the Shady dolomite, and that the present oxide ore bodies represent accumulations gathered by surface waters from such disseminated carbonates. Until explorations shall have been made in unweathered parts of this zone, the suggestion cannot be verified.

In order to consider the bearing of the circulation of ground water on the accumulation of the manganese oxides, the probable influence of the local rock structure on the circulation will be briefly stated. If a region, underlain by thick layers of hard and impervious rock alternating with soft or soluble or more pervious rock forming a group of broad folds, is elevated and subjected to erosion, the hardness and texture of the rocks will soon begin to control the movement of both surface and underground waters. Although long-continued erosion will wear away the hardest rocks, at any earlier stage only the soft and soluble rocks will be eroded and they will determine valleys or drainage lines, while the hard rocks will form hills. The movement of that part of the surface water which filters into the soil and rocks is largely determined by the form of impervious beds. Near the

Crimora mine the hardest and most impervious rocks are the beds of Erwin quartzite and they therefore make up the near-by hills and ridges. The overlying dolomite, limestone, and shale have been dissolved and eroded and only the clays representing their insoluble residues underlie the valleys. During the period of erosion that produced the present surface forms having an elevation of between about 2,200 feet and about 1,600 feet above sea-level near the mine, the surface waters from about four square miles were directed to the area now underlain by the manganese deposit, and the underground waters of an area of nearly one and one-half square miles flowed into Crimora trough.

In general, the deposition of the common manganese oxides—wad, psilomelane, manganite, and pyrolusite—appears to take place where solutions containing manganese meet other solutions with excess oxygen. Such solutions with excess oxygen are largely confined to shallow surface zones. The northwest or valley limb of the Crimora trough is an area where waters that have flowed down the southeast, or mountainward, slope and the northeast lip of the trough would, on rising, meet a more stagnant zone of oxygen-bearing water that had entered the northwestern outcrop of the manganiferous beds. During the early stages of erosion of the surface forms below 2,200 feet elevation, little manganese in solution would have been carried to the bottom of the trough, but as the valley-floor level was approached, conditions would have highly favored movement of solutions from the east to the bottom of the trough and the entrance of oxygen-bearing water from the northwest.

At a later period the barren overburden was laid down and the beds of angular ore, chert, and quartzite derived by the local erosion of the ore-bearing zone was laid on the older overburden.

MINING AND TREATMENT OF ORES.

As stated above, the exploitation of the Crimora deposit may be divided into four stages, during the first two of which underground workings yielded most of the output, whereas several methods of surface operation have been used during the last two. The only available records of the early operations are found in the articles by Penrose,[1] Hall,[2] Judd,[3] and Watson.[4] Descriptions of the new mill erected in 1916 have recently been published.[5]

[1] Penrose, R. A. F., Jr., op. cit.
[2] Hall, C. E., op. cit.
[3] Judd, E. K., The Crimora Manganese Mine, Eng. & Min. Jour., p. 478, 1907.
[4] Watson, T. L., op. cit.
[5] Anonymous, Mining of Manganese Ore in Virginia: Iron Age, vol. 97, p. 776, 1916.

During 1916 and 1917, that part of the deposit exposed in the Jim Crow pit was excavated by dragline excavator, from which material was loaded to cars and trammed to the mill. In 1918 steam shovels were installed.

Treatment in the new mill includes the use of grizzlies, double-log washers, screens, picking belts, and jigs.

THE OLD DOMINION TRACT.[1]

The tract that adjoins the Crimora property on the southwest has been the scene of explorations for manganese from time to time. According to Watson[2] explorations were in progress in 1906, through a drift from the rock shaft 176 feet below the surface. The seven drill holes indicated on Plate XVII were sunk in 1916 and the records have been available in the preparation of this report. Several old shafts and pits nearby are completely caved.

The surface near the drill holes is almost flat but rises gently to the southeast and is clearly part of an extensive alluvial fan that can be traced into the ravine south of Turks Gap Creek. The alluvial fan appears to have merged northeastward with that which covered the site of the Crimora opencut and like it lies at the level of the valley plain. The low hill 500 feet northwest of the rock shaft and 1,000 feet northwest of the drill holes shows a few outcrops of quartzite and appears to coincide with the position of the minor fold mentioned in the description of the Crimora mine. The records of the recent drill holes show that the layer of sand and gravel that make up the alluvial fan ranges from 15 to 30 feet thick. During April, 1917, water level in the drill holes ranged from 9 to 15 feet below the surface.

Four of the seven holes were sunk to bedrock and when its position is compared with that determined by similar holes on the Crimora tract, it is found that the seven holes lie along the northwest limb of the Crimora trough, about 300 feet northwest of the axis. They show that the limb continues straight and unbroken for 1,500 feet southwest of the explored area near the Jim Crow pit, and indicate that the axis trends north 52° east.

The drill records show that the nodules of manganese oxides were encountered in each of seven holes in a zone that ranged from 60 to 140 feet thick and attained a maximum depth below the surface of 230 feet,

[1] Description by D. F. Hewett.

[2] Watson, T. L., Mineral Resources of Virginia, Jamestown Exposition Commission, p. 249, 1907.

or about 32 feet below the deepest ore recorded in the Crimora mine. It is noteworthy that the zone of manganese oxide nodules is much thicker than that recorded in any holes on the Crimora tract. Although the seven holes were drilled in an area scarcely 300 feet in diameter, no definite zone of nodules can be identified with assurance throughout the area.

There are no drill holes along the southeast limb of the trough, and it is not known whether manganese nodules persist farther southeast. The records of these holes are in accord with the conclusion previously expressed under the "Crimora Mine," that although the zone of manganese nodules in residual clay is roughly parallel to the underlying bed of quartzite, it is progressively deeper, thicker, and richer in a southwesterly direction parallel to the axis of the trough, at least as far as the area explored by the seven drill holes on the Old Dominion tract. That portion of the tract which lies southwest of the drill holes offers a favorable area for further exploration.

AREA BETWEEN CRIMORA MINE AND BASIC CITY.

Although the mountain front in this area is fairly straight and continuous, the structure is complicated by minor folding, especially in the portion west of the front. South of the Crimora mine the mountain front trends southwest to a small offset opposite Turk Mountain, beyond which the trend is due south to the latitude of Basic City except for a small reëntrant valley along Saw Mill Run, which makes a local break in the continuous front. The westernmost foothills of the Blue Ridge are composed of the white Erwin quartzite. Saw Mill Ridge and Ramsey Mountain form the main ridge of this white quartzite, and outcrops of the rock on their west slopes dip 50° W. toward the valley, under the Shady dolomite and other limestone and shales which underlie the Shenandoah Valley. These calcareous beds are not exposed near the foot of the mountains because of the thick covering of quartzite wash and gravel, sand, and clay from the mountain slope.

West of Saw Mill Ridge there is a low, narrow hill whose anticlinal character is well shown on the road up Saw Mill Run from Doom, where the dips of the uppermost quartzite beds of the Erwin show that the anticline plunges south. The narrow valley between this hill and Saw Mill Ridge is therefore synclinal and incloses Shady dolomite above the quartzite. Manganese ore was mined on the Watt property in this syncline many years ago. The workings consisted of several shafts, mostly south of the run. The mine was operated in 1886 or 1887, and has since been abandoned although some drilling has recently been done on the property. The ore was not seen in place, but on the dump are found chiefly psilomelane with some manganite in concentric layers. Yellow sandy clay is associated with the ore and is inclosed in some pockets in the ore.

A low bench that extends westward 1 mile from the west side of Ramsey Mountain 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 with angular quartzite fragments approximately in place, and the hills are believed to be small anticlines in which only the uppermost layers of the Erwin quartzite are exposed and 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 deep to inclose the overlying Shady dolomite or its residual clay, as fragments of chert derived from the dolomite were found in the alluvial fill of the valleys.

Southwest 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 also quartzite hills, and although they are covered with angular fragments of quartzite and cemented quartzite breccia, no rock ledges from which the structure could be determined were seen. These hills also are believed to be anticlinal in structure and to be made up of several low anticlines in which only the uppermost quartzite beds of the Erwin are exposed at the surface. Between the individual hills are several small valleys or hollows, presumably occupying synclines, some of which 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 places for the accumulation of manganese ore bodies. A prospect pit northeast of Bear Mountain, which may be called the Bear Mountain prospect, found some manganese nodules, and two other prospect pits on the west flank of Ramsey Mountain, which are here called the Ramsey Mountain prospects, also show some nodules. 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 siliceous 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 ben deposited, and accompany many of the deposits of manganese. 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.

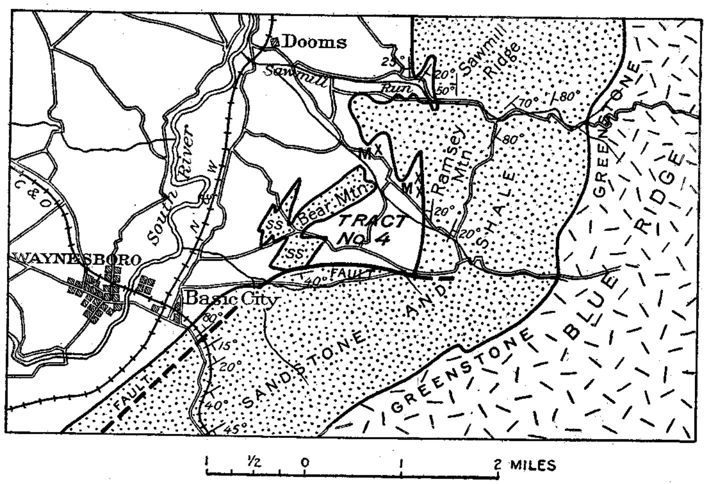


Fig. 11.—Sketch geologic map of region near Waynesboro, Augusta County, showing location of undeveloped tract (No. 4) recommended for prospecting.

Because of the structure and conditions just described it is believed that the triangular valley of about 1 square mile lying north of the fault and extending from Ramsey Mountain to Bear Mountain (shown in fig. 11 as Tract No. 4) with its two northward synclinal prongs, the small synclinal valleys northwest and southwest of Bear Mountain, and the small syncline on Sawmill Run are areas which are favorable for the accumulation of manganese deposits, and in Bulletin 660, U. S. Geological Survey, were recommended for thorough prospecting by drilling or test pits to determine the presence of manganese.

AREA BETWEEN BASIC CITY AND SHERANDO.

The mountain front in this area is rather uniform, comprising a single line of low hills of the white Erwin quartzite which trend almost due southwest most of the distance. Northeast of Sherando two small offsets in the mountain front are due to minor folding, but the quartzite is so badly crushed and cemented by iron that the nature of the structure is not clear. In fact the quartzite along the whole length of this strip is badly crushed, as is excellently shown in the ganister quarry east of Waynesboro, and is the locus of the great overthrust fault apparently distributed between the beds. The area is not regarded as structurally favorable for the deposition of manganese ore, but some manganese coats the fracture planes in the quartzite in places and replacement of the breccia by manganese minerals may occur locally. No manganese deposits were seen in this belt but the reported finding of manganese in some of the gaps in the ridge south of Waynesboro indicates that some replacement deposits do occur.

LYNDHURST MINE.[1]

The Lyndhurst mine lies on the west bank of Back Creek, about 2 miles south of Lyndhurst station on the Norfolk & Western Railway. It is in the stream bottom about a mile from the mountains and in this respect differs from all the other manganese mines in the region. It was first opened in 1859[2] and in 1885 and 1886 there was considerable development by the Virginia Manganese Mining Co., which obtained ore from a shaft 65 feet deep. The mine has since been worked by the Metallic Alloys Co., of Elkton and by Kendall & Flick, but was abandoned in 1908. None of the underground workings were accessible in 1914 nor since.

The workings consist of several shafts with drifts at 4 or 5 levels. The collars of the shafts are on a terrace 15 feet above the bed of the creek. This terrace is 150 to 200 feet below the level of the early Tertiary peneplain and may represent the later Tertiary peneplain. Although some ore occurs near the surface, a 20-foot zone at a depth of 65 feet was richer in ore than the higher ground and was mined over a horizontal distance of 300 feet. It is from this zone that high-grade chemical ore was obtained by careful hand picking.

As described by Harder, the ore consists of small nodules of psilomelane scattered through yellow and variegated clay, and in irregular large bodies of psilomelane in black manganiferous clay which occurs as lenses and layers interbedded with the variegated clay. The nodules range from one-fourth inch to several inches in diameter but are characteristically

[1] Description largely from Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, p. 62, 1910, and Fontain, W. M., Notes on deposits at certain localities on the west part of the Blue Ridge: The Virginias, p. 55, 1883.

[2] Weeks, J. D., U. S. Geol. Survey Min. Res. for 1885, p. 317, 1886.

small and of irregular shape. In places they are packed close together, while elsewhere they may be scattered 6 inches apart. The ore in the manganiferous clay is both hard and soft and occurs in irregular seams and masses, a foot or less in diameter. The interstices are filled with clay. The ore is scattered and much dirt has to be washed to obtain a small quantity of ore.

The material on the dump contains numerous well-rounded pebbles and boulders of quartzite which are cemented by siliceous manganese oxide containing grains of quartz. Many of the lumps of psilomelane also contain both well-rounded and angular quartz sand and gravel. These ores, rejected because they were too siliceous, are believed to have come from the upper part of the workings. Chert fragments with the yellow clay on the dump are believed to come from the lower richer workings, and to represent residual material from the underlying Shady dolomite or Watauga shale in place. It is believed, therefore, but cannot be demonstrated without access to the shaft and workings, that the deeper richer deposits are in residual clay distinctly below layers of rounded gravel at the surface. The solutions carrying the manganese probably flowed through the gravel along the floor of decomposed limestone and shale and deposited manganese oxide in the spaces between the boulders and pebbles cementing them into a conglomerate and inclosing much quartz sand. It also penetrated the clay of the floor beneath the gravel, replacing it along joint planes and in pockets along irregular solution crevices or channels, and the associated yellow clay contains the chert fragments which are residual from the limestone.

There are no unaltered rock outcrops in the vicinity of the mine, but hard yellow ocherous laminated and contorted clay, residual from calcareous shales probably of the Watauga, crop out in the stream bed adjacent to the shaft. The structural relations near the mine cannot be determined.

MOUNT TORRY MINE.

The Mount Torry property lies in a small valley between front ridges of white quartzite west of Back Creek, about 6 miles south-southwest of Lyndhurst station. (See fig. 12 and Pl. XVIII.) It is in the valley of a west branch of Back Creek which heads between the two ridges and opens out to the northeast into the Shenandoah Valley.

Torry Mountain, southeast of the mine, is a high ridge of white Erwin quartzite which is exposed in cliffs above the road along Back Creek, where it strikes N. 30° to 40° E. and dips 30° to 50° SE. Several spurs on the west slope of the mountain are composed of the quartzite, which suggests

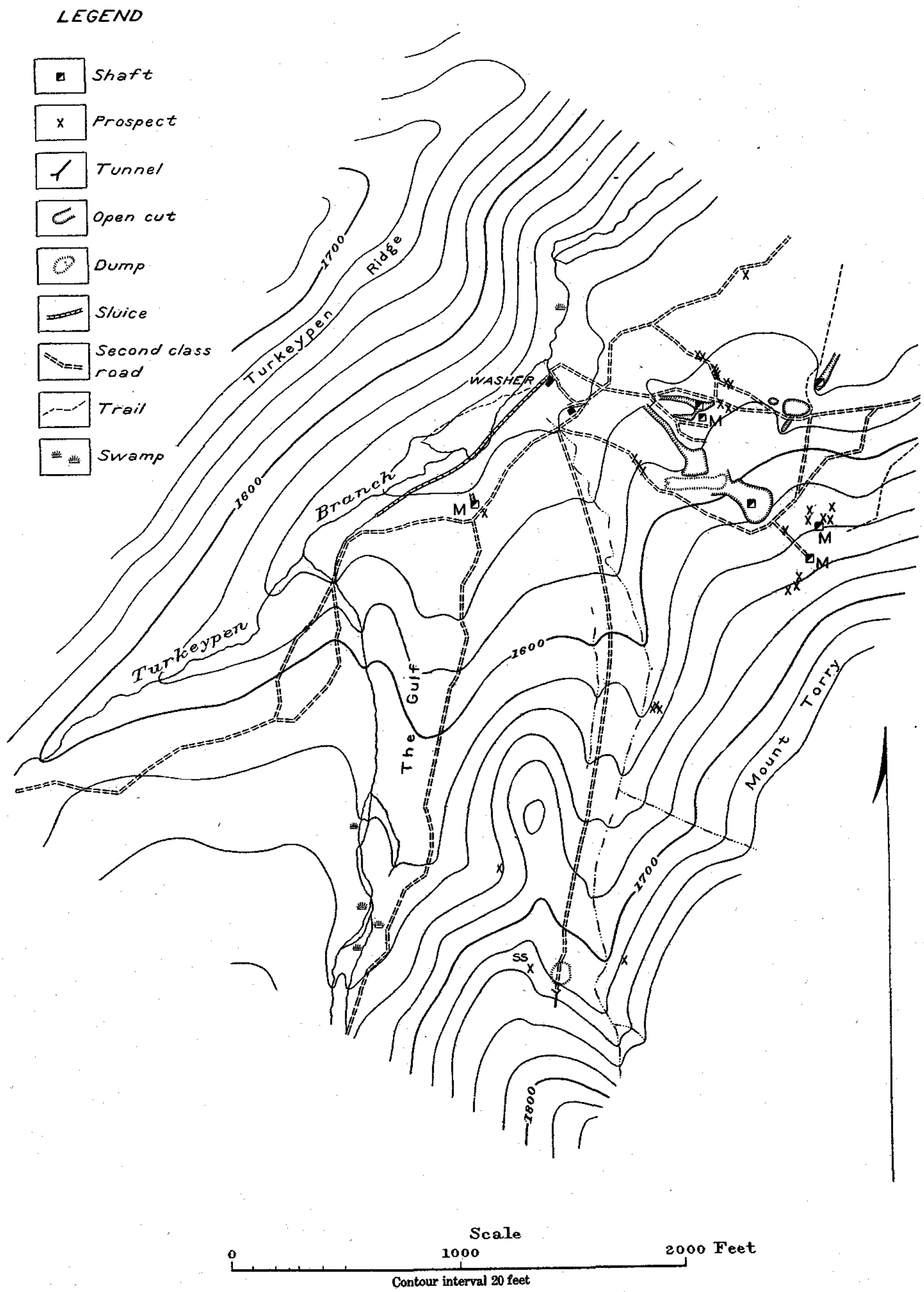


Plate XVIII.—Map of Mount Torry mine, Augusta County, 6 miles southwest of Lyndhurst, showing operating mine, old workings, and prospects.

All open cuts on map were for iron; most of the prospects were for manganese; the shafts where manganese was mined are marked M. SS, pit exposing brecciated sandstone replaced by ore. The most recent workings for manganese (since 1915) are not shown. Contours determined by aneroid barometer based on railroad bench mark. Datum is mean sea level. Surveyed by W. J. Cox, July, 1915.

minor folds that plunge steeply northeast under the limestone of the valley. Turkey Pen Ridge, northwest of the mine, is a low ridge of quartzite with poor exposures on its south side. At the west, where it is cut through by Mills Creek, it is seen to be an anticline which evidently plunges northeast at its outer end under the limestone of the valley. The valley in which the mine is located is therefore a syncline which plunges gently northeast and is deeply filled with wash to the level of a marked bench, 1,550 feet in elevation. A higher bench probably represents an outpouring of wash on the early Tertiary peneplain and stands somewhat above its general level. The limestone is nowhere exposed in this valley, but a shaft near the center of the basin struck at an unknown depth fresh dense gray dolomite, undoubtedly Shady dolomite, which inclosed small crystals of pyrite.

The older workings consist of a number of pits scattered over an area about one-fourth mile square and a shaft from which iron ore was first taken out and smelted in the company's furnace on Back Creek. The ore contained too much manganese to be satisfactory for iron manufacture at that time and was abandoned, but later it was extensively prospected and worked to a small extent for manganese ore. In the manganiferous iron ore, according to Harder,[1] the iron and manganese are intimately intergrown, and psilomelane penetrates the limonite in small veins. The principal manganese mineral is psilomelane which occurs in botryoidal nodules and in solid irregular coral-like masses 6 inches thick and a foot or more in length in yellow clay. In an open cut in altered buff sandstone on the side of Torry Mountain, at an elevation of about 1,740, nodular ore occurs in clay and as an impregnation of the adjacent sandstone. The manganese oxide penetrated along joints and bedding planes and replaced sandstone blocks to various degrees, some having only a small core of unchanged sandstone. The ore was carried by an old tram to the stream below where it was washed and hauled to the railroad.

At present the Mount Torry Mining Co., a Minneapolis corporation, is operating the mine as a manganese and manganiferous iron mine. At the time of visit in 1917 they were opening a deep trench by horse-drawn scoops but were to install a cable and drag scoop to be operated by machinery. The trench extends southeastward into the hill from the lower part of the slope where ore is encountered. The exposed ore lies in yellow clay streaked with white, beneath 5 to 15 feet of wash. A log washer was being installed at the stream below the trench, from which a road leads to the lumber railroad, a mile distant.

[1] Harder, E. C., op. cit., p. 63.

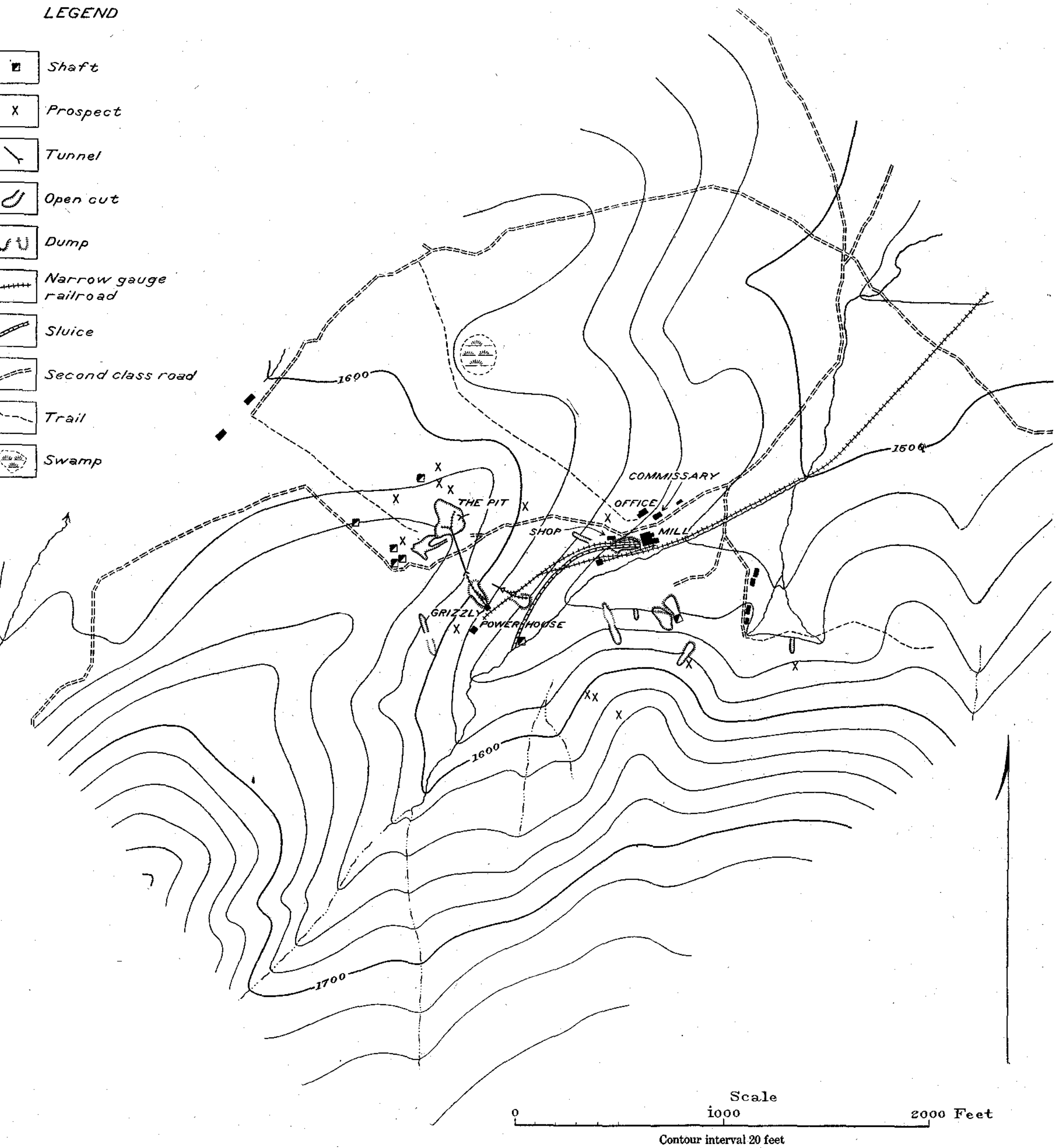
The conditions at the Mount Torry mine appear favorable for the deposition of manganese ore. The Erwin forms a syncline with minor wrinkles on its surface that plunges northeast beneath a wash-covered basin which is floored by the Shady dolomite and its residual clay. The manganese ore exposed in several of the pits is of good grade, but the fact that certain boring tests that have been made by one of the prospecting parties failed to show a large body of high-grade ore is somewhat discouraging. It is not known, however, how thoroughly or systematically this boring was done nor the results.

MILLS CREEK AREA.

The Mills Creek area lies between two spurs of the Blue Ridge about 6 miles south-southwest of Lyndhurst, and just northwest of the Mount Torry mine, and is drained by Mills Creek. (See fig. 12.) A lumber railroad over which ore from the adjacent 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.

The mountain spurs on both sides of the tract are composed of white Erwin quartzite. Turkey Pen Ridge on the southeast is a sharp anticline, as described above. The spur on the northwest is also anticlinal. These two folds merge into each other to the southwest, where the spurs join to form a high mountain. Both anticlines plunge northeastward at their ends where the quartzite descends below the Shady dolomite of the Shenandoah Valley. The area between the spurs is therefore a northeastward-plunging syncline, probably underlain throughout by limestone and some shale, and closely resembles the adjacent synclinal embayment on the southeast, in which the Mount Torry mine is situated. (See fig. 12, Tract No. 2.) No outcrops are to be seen in the embayment as the surface is deeply covered with quartzite wash from the mountains to the general terrace level at about 1,550 feet. The anticlinal spurs on both sides of the plunging syncline 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 lowland of the Shenandoah Valley.

The structural and surface conditions in the Mills Creek area are closely similar to those at the Mount Torry mine, and are favorable for the deposition of manganese ore in commercial quantities. Although no manga-



e XIX.—Map of Kennedy mine, Augusta County, 4 miles southeast of Stuarts Draft, showing present workings and prospects.

The active workings are the large open cuts marked "The Pit," the tunnel leading from these to the Grizzly, and the tunnel east and below the Grizzly. The latter is driven to pass 30 feet beneath the upper end of the Pit. The upper pit is 15 to 20 feet deep, and the lower pit is 35 to 40 feet deep, and they are connected by a chute 30 feet long by 2 feet wide. Contours determined by aneroid barometer based on railroad bench mark. Datum is mean sea level. Surveyed by W. J. Cox, 1915.

nese ore has been found in this tract so far as known, it is believed that ore may occur in the undisturbed clay residual from the limestone beneath the thick cover of drift which has effectually hidden it thus far. For this reason, thorough prospecting of this tract by drilling was recommended by the present authors in Bulletin 660 of the U. S. Geological Survey.

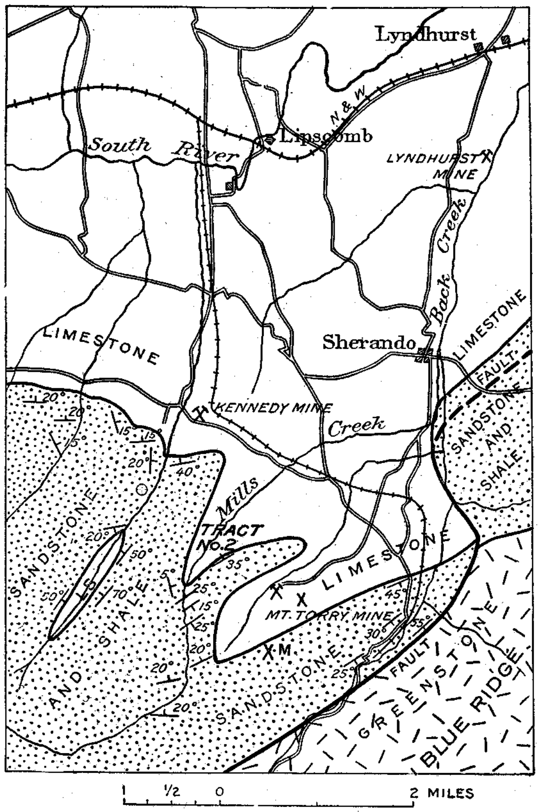


Fig. 12.—Sketch geologic map of area south of Lyndhurst, Augusta County, showing location of an undeveloped tract (No. 2) recommended for prospecting, and its relation to the adjacent Kennedy and Mt. Torry mines.

KENNEDY MINE.

The Kennedy mine is located on the bench at the front of one of the long high spurs of the Blue Ridge 6 miles southwest of Lyndhurst. (See Pl. XIX.) The mountain here is composed of long narrow straight ridges, which trend northeast and are spurs of a high northwest trending ridge which in turn is a spur from the Blue Ridge. These long straight ridges are separated by deep narrow rocky valleys. The Kennedy mine lies east of Kelley Creek which heads in the mountains between Kelley Mountain on the northwest and a parallel lower ridge on the southeast. Kelley Mountain is a high ridge to its north end where it terminates abruptly. Kelley Creek occupies the valley next west of Mills Creek valley.

The ridges are composed of Erwin quartzite whose white ledges and débris cover their crests and slopes. Kelley Mountain is a monocline, the white quartzite dipping southeast 30° to 50°, and its bedding surfaces making the southeast slope of the mountain. The edges of the quartzite beds make cliffs on the northwest side of the ridge and the underlying Hampton shale and Unicoi formation come to the surface below in the valley of Kennedy Creek. The ridge east of the valley of Kelley Creek is anticlinal and the bedding surfaces of the quartzite dip 50° to 70° NW. down the northwest slope of the mountain. The valley of Kelley Creek is therefore a narrow sharp syncline which trends NE. and incloses, or formerly inclosed, the overlying Shady dolomite. If any dolomite or its residual products are still present in the wider part of the valley, they are covered by the blanket of coarse quartzite débris from the surrounding mountain slopes.

Farther down Kelley Creek toward the front of the mountain the strikes of the rocks converge, the quartzite ridges come together and close in the valley, and the stream cuts a gorge in the upper layers of the Erwin. At the front the quartzite dips toward Shenandoah Valley 15° to 40°, but a depression or small syncline coincides with the mouth of the gorge of Kelley Creek. The general structure of this whole mountain mass southwest of the Mount Torry mine is therefore a domelike uplift west of the main Blue Ridge which has brought the top of the Erwin quartzite to over 3,500 feet elevation over most of the area and which plunges steeply northwest and northeast along the mountain front toward Shenandoah Valley. Minor folds on the surface of this dome strike northeast in this part of the uplift and make sharp infolds of limestone in the synclines, as in the valley where the Mount Torry mine is located, Mills Creek, and Kelley Creek, and bring the older rocks to the surface in some of the anticlines, as at the head of Mills Creek and on Kennedy Creek.

The Kennedy mine is on a gravel-covered terrace 1,750 feet in elevation about one-half mile from the foot of the steep slope of the mountain. It is located in front of the small plunging syncline in the quartzite at the mouth of the gorge of Kelley Creek. The drainage from this gorge and the limestone valley which formerly existed within the mountain probably flowed across the bench where the mine is located when this was the general surface of the valley in early Tertiary time. The stream probably carried solutions of manganese carbonate dissolved from the limestone in this intermontane valley and manganese oxide was precipitated in the gravels and wash on this plain and in the clay floor beneath the gravel. The large deposits which seem to be present at this place are thus explained as concentrations from a large synclinal valley which formerly inclosed limestone within the mountain.

The workings at the Kennedy mine comprise an old open cut and short tunnel and a new deep wide trench, about 250 feet long and 30 feet wide, which crosses the trend of the deposit. (See Pl. XIX.) At its deepest part, about 45 feet depth, the section shows at the top about 15 feet of gravel, sand, red mottled clay, and wash which contain red nodular iron ore and a little manganese; then about 15 feet of yellow to red clay containing scattered rounded rotted quartzite boulders and pebbles, decomposed white chert, and masses of manganese ore; below this is brown clay apparently free from boulders containing richer pockets and masses of manganese ore and wad. The deposit is said to have been thoroughly tested by bore holes which show this lower clay to be about 15 to 30 feet thick beneath which a layer of coarse porous sandstone is struck, then more clay, and finally the top hard layer of the Erwin quartzite. This porous sandstone composed of large round grains loosely held together has been observed at many places, especially farther south where it lies about 50 feet above the top quartzite beds of the Erwin and in the interval between are soft purple, red, yellow, and white sandy clays and thin sandstones containing a little glauconite, and in some places chert-bearing yellow clay evidently derived from limestone. These transition beds are regarded as the basal beds of the Shady dolomite. The test holes are reported to have determined an ore body which runs northeasterly, suggesting that the stream which deposited it had this course. In an old open cut adjacent to the new trench laminated yellow clay containing chert fragments, unquestionably derived from the decomposition of limestone in place, is exposed, overlain by red and white mottled clay, evidently transported only a short distance by creep on the mountain slope, and this overlain by gravel and wash. The basal part of the gravel is jointed and manganese is deposited on the joint planes and in crevices. The few boulders in it are rotted and the chert fragments are soft and porous, indicating that at least the lower part of the gravel deposit is old. A generalized cross-section of the deposit as it appears from the data obtained by the bore holes and open cut is shown in figure 13.

This shows the ore to be a deposit in a channel filling and in the clay floor beneath the channel on an old peneplain surface covered with old gravel probably of the same date, the concentration of ore solutions being determined by the geologic structure of the valley in the mountain from which issued the stream that occupied the channel.

The open trench is excavated by a drag scoop operated by a power cable at its upper end. The ore and dirt are delivered through a bin to tram cars on an incline which descends a small gully to the mill beside a small stream

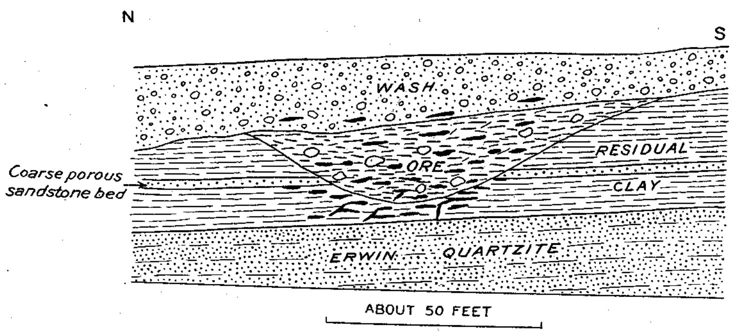


Fig. 13.—Sketch section of the geologic conditions believed to occur at Kennedy mine, Augusta County. The ore apparently replaces sand and clay in an old stream channel and in the floor of the old stream bed, the bedded residual clay lying on the Erwin quartzite.

east of the mine. Water is carried by flume and ditch from Kelley Creek to the mill. Here the ore is washed in a double-log washer, crushed and jigged, and the larger product hand picked from a belt. The washed ore is hauled by wagon to a broad-gauge lumber railroad, one-half mile distant.

The ore is chiefly psilomelane. It occurs in large and small irregular masses and nodules in the clay, usually associated with wad or dark manganiferous clay. Some of the masses are branching and cavernous an inclose clay. A little crystalline manganite lines cavities in the psilomelane. Some of the nodules of limonite from the upper layers contain cores of psilomelane. The following is an analysis of ore from this mine:

Analysis of manganese ore from Kennedy tract.[1]

Mn	43.30
Fe	3.88
S	.083
P	.052
Ba	6.93
SiO_2, H_2O, etc.	17 69

PROSPECTS WEST OF KENNEDY MINE.

West of the Kennedy mine the mountain mass is a group of long north-south spurs or ridges which end abruptly on the north, where the Erwin quartzite composing them dips 15° to 20° toward the valley and passes under an extensive wash-covered bench about 1,750 feet in elevation. This bench extends around on the west side of the last ridge also, where the quartzite dips northwest under the valley floor. No rock outcrops occur on this bench and even where cut into by the streams which cross it only yellow clay containing decomposed chert is seen. Near John Run a small prospect trench called the John Run prospect, exposes such residual clay beneath 8 feet of wash. Manganese oxide here had partly replaced a boulder of quartzite in the wash and some banded cherty layers in the underlying laminated clay which dipped about 30° toward the valley. Bore holes put down by the Kennedy Mining Co. were said to have struck the quartzite at about 60 feet depth and to have passed through a considerable thickness of overlying manganiferous clay along this part of the mountain front.

Farther southwest a shaft, called the Black shaft, was sunk by the Kennedy Mining Co. on this bench between Stony and John runs. At a depth of 20 feet, chiefly in wash, a drift was run into laminated clay with cavernous cherty breccia which dipped about 10° SE. Cavities in the chert were lined with secondary drusy quartz and the breccia was impregnated with manganese oxide. Quartzite was reported to have been struck in bore holes about 20 to 30 feet below the brecciated chert. The dip of the beds indicates an anticlinal axis northwest of the shaft which does not seem to bring the quartzite quite to the surface but which makes a structural basin of the area between the shaft and the mountain. Bore hole records are said to bear this out. If this proves to be a fact, a narrow area parallel to the mountain front and close to the foot of the steep slope should have favorable structure for the accumulation of ore. A short distance southeast of the shaft, up a small stream from the mountain, an open cut exposes wavy

[1] Weeks, J. D., Mineral Resources of U. S. for 1885, p. 318.

banded residual clay and chert which are impregnated with manganese. The bedding dips 5° to 10° NE., indicating that the exposure is near the bottom of the syncline. The quartzite of the mountain dips 15° NW., representing the dip on the other side of the syncline.

On the west slope of Bare Mountain, plainly visible from the main road up the Shenandoah Valley, large iron-ore banks were operated for the Cotopaxi furnace, under the name of Bare Bank mine, and another just southwest on the mountain front called the Crozier mine. No manganese ore is reported from these banks and they were not visited by the writers.

RED MOUNTAIN MINE.

In the heart of the mountain mass southeast of Greenville there is a relatively open valley at the head of St. Mary River, 3 miles from the nearest mountain front, in which the Red Mountain mine is located. (See Pl. XX.) It lies southwest of the Kennedy and Mount Torry mines over the main high spur of the Blue Ridge and is about 6 miles northeast of Vesuvius, up St. Mary River. The lower part of the St. Mary River valley is a picturesque rocky gorge cut in the Erwin quartzite. At the mountain front the quartzite is very steep and even overturned, as locally it dips 65° SE. Back from the mountain front the rocks become nearly horizontal, and the stream flows between walls of quartzite cliffs. Near the head of the stream the quartzite dips gently northeastward and forms a shallow basin in which clay residual from the overlying Shady dolomite is inclosed. The quartzite on the northwest side dips gently southeast under the basin, but on the southeast side it apparently also dips southeast and is either overturned or, more probably, faulted.

The floor of the basin at the Red Mountain mine is at about 2,200 feet elevation, far above the valley-floor peneplain. The floor of this basin, however, is nearly flat and the limestone is deeply weathered, rock decay having clearly been going on for a long time and has extended to a great depth. It is not clear whether the valley floor is simply a local level of planation due to the quartzite dam across the stream or whether the position of this dam was determined at a stage of planation earlier than the early Tertiary peneplain and has persisted ever since at nearly this level. The fact that the basin floor is about 100 feet higher than the present quartzite lip favors the latter view. At any rate the conditions for deposition of manganese ore are very favorable, for the basin is synclinal in structure and its limestone floor is deeply weathered and nearly level.

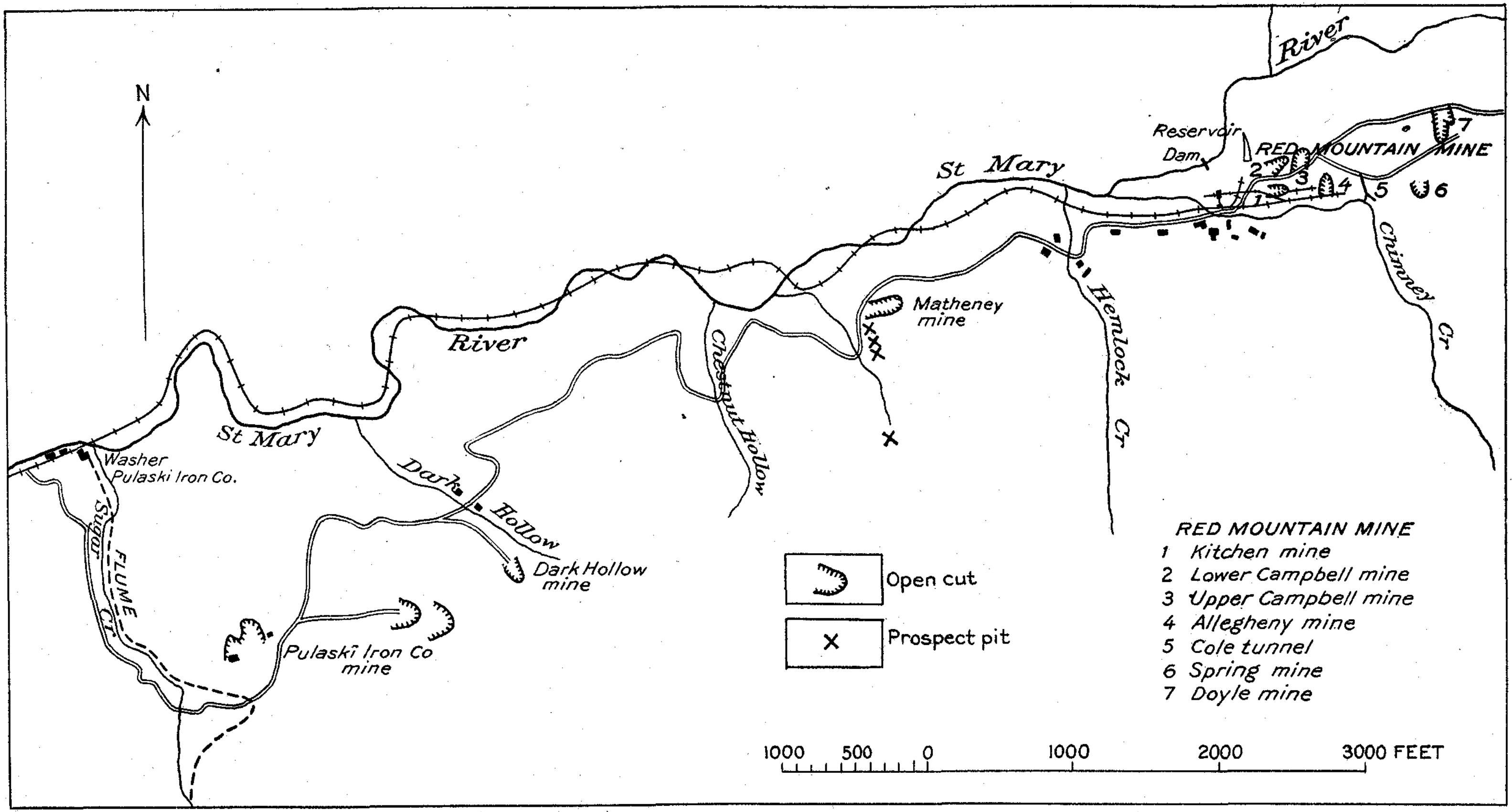


Plate XX.—Map of St. Mary River basin, showing location of Red Mountain and Pulaski mines. Drawn from mine plats by the Union Manganese Corporation.

The workings at the Red Mountain mine consist of several open cuts and deep trenches. (See Pl. XX.) They are located at the southwest end of a low hill in the bottom of the basin composed of the residual clay from the limestone and capped by wash from the adjacent mountains. When visited in 1917 two open cuts at the southwest end of the hill were being operated by steam shovel. A third large open cut had been worked from the stream level at the southeast and another large trench had been opened on the top of the hill to the northeast. The intervening ground was reported to have been fairly well prospected by drill holes and trenches, and ore was reported at shallow depth over most of the hilltop. The open cuts are 30 feet deep and expose wavy laminated yellow clay showing the bedding of the limestone to have been about horizontal in the bottom of the syncline. The clay is covered by a thin layer of quartzite wash. Large masses of crumbly white sandstone are mixed with the upper layers of the clay and a few seem to occur deeper in the clay, possibly in solution channels. The clay contains pockets and seams of wad in which there is considerable psilomelane and iron ore. The ore, however, seems to be restricted to the upper 10 to 15 feet of the clay, the deeper parts of the trenches seeming to be barren of ore. The two deep open cuts have therefore been abandoned and shallower workings at the top of the hill are being extended.

The ore and dirt are loaded by steam shovel into wagons and tram cars. The waste is dumped from a high trestle into the lowland, and the ore is carried to the double-log washer below, where water under pressure comes in and helps to break up the clay lumps. The mill below the washer is well equipped with crushers, screens, and jigs. Large elevated receiving bins deliver the washed ore to the cars on the narrow-gauge railroad which carry the ore down the St. Mary River gorge to the Norfolk & Western siding at Pkin station. The product is a manganiferous iron ore as the iron and manganese ores are not readily separable.

PULASKI MINE.

The Pulaski mine is located in a side valley which meets the St. Mary River midway between the Red Mountain mine and the mouth of the rocky gorge. (See Pl. XX.) The quartzite is about horizontal at this point in the gorge, and in the side valley to the south it is bent up gently in a low anticline which forms a ridge parallel to the gorge. It descends again toward the south into a gentle syncline which is occupied by a shallow valley south of the ridge. The top layers of the quartzite form the dip slope of the adjacent ridges and the residual clay of the overlying Shady dolomite forms the valley floor in places. The workings of the Pulaski mine consist of a few open pits located at the top of the quartzite on the north side of the syncline. The pits expose yellow clay which contains iron ore and a little manganese oxide, overlain by a bed of coarse rusty sandstone which is capped by a hard crust of iron ore. The near-by rocks lie nearly horizontal, dipping gently into the shallow syncline. The sandstone bed associated with the iron crust is probably the coarse bed near the base of the Shady, and the clay in which the mine is located is probably the residuum of calcareous beds beneath the sandstone bed at the base of the Shady. A section is given in figure 14.

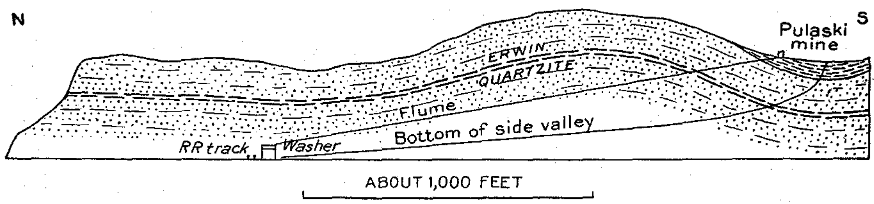


Fig. 14.—Sketch geologic section in the vicinity of the Pulaski mine, Augusta County. Shows gentle folding of the massive Erwin quartzite and shallow syncline at the Pulaski mine inclosing residual clay of the Shady dolomite.

There is very little manganese in the ore that is being mined but more manganese is reported in prospect pits east of the mine where higher beds apparently are inclosed. The Pulaski mine is operated by a subsidiary of the Pulaski Iron Co., and the ore is shipped to Pulaski, Va. The product is all iron ore with the content of manganese not over 5 per cent. The ore is carried from the mine by a flume 2,200 feet long to the log washer at the narrow-gauge railroad on St. Mary River. From here to the main railroad the road bed belongs to the Pulaski Iron Co. They have an extensive tipple and bins on a siding from the main Norfolk & Western Railway.

VESUVIUS MINE.

The Vesuvius mine is on the north side of Dogwood Hollow, at the mouth of its gorge through the quartzite ridges of the mountain, 2 miles northeast of Vesuvius. (See Pl. XXI.) It is on a narrow bench along the mountain front 1,600 to 1,700 feet above sea-level. At the mouth of Dogwood Hollow the white quartzite strikes N. 65° E. and dips about 70° NW. The mine is on the flank of this monocline. The front quartzite ridge which trends almost due southwest at St. Mary River makes an offset

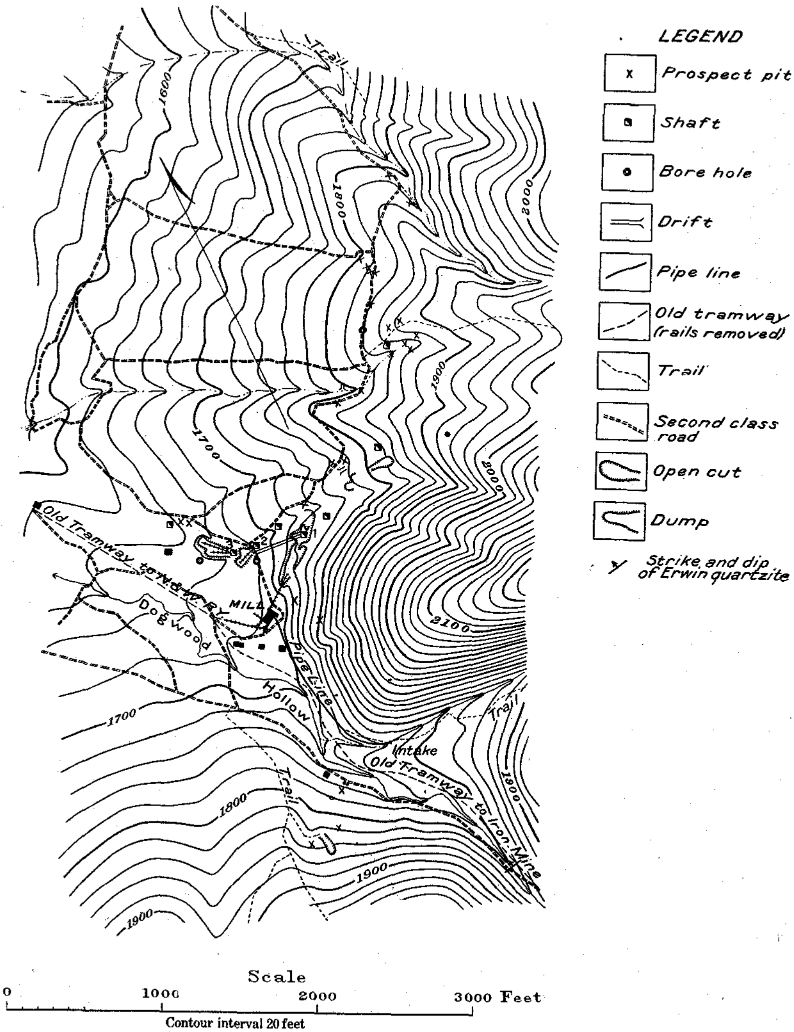


Plate XXI.—Map of Vesuvius mine, Augusta County, 3 miles east of Vesuvius, showing recent workings, old pits, and prospects in the vicinity.

1, Upper shaft, 80 feet deep. 2, Middle shaft, 50 feet deep. 3, Lower shaft, 160 feet deep. Datum is mean sea level. Contours determined by aneroid barometer based on railroad bench mark. Surveyed by T. K. Harnsberger and W. J. Cox, June, 1915.

to the east just north of the Vesuvius mine. This is apparently due to a southwestward plunging anticline and syncline which probably affect the structure at the Vesuvius mine. Although no near-by outcrops confirm this, the mine is probably located in an extension of the syncline.

The workings consist of several old pits and a shaft with drifts, formerly operated under the name of the Fauber mine, and two more recent shafts, operated by the Manganese Corporation of Virginia. (See Pl. XXI.) The old shaft (1) is higher on the slope, 1,750 feet in elevation, and is reported to be 80 feet deep. The newer shafts are 1,690 (2) and 1,660 (3) feet in elevation and are reported to be 50 feet and 160 feet deep respectively. A drift is said to run from the bottom of the deeper shaft (3) 300 feet toward the mountain. There are yellow clay and fresh chert fragments on the dump of the lower shaft and the associated ore was chiefly manganiferous iron. From the upper shaft good nodular manganese ore was obtained, a considerable quantity of which was still at the mill below. It is mostly stalactitic and kidney psilomelane, 2 to 3 inches in diameter, with some crystalline manganite in cavities. Psilomelane also coats and cements white chert and fine sandstone fragments into a breccia and to some extent replaces them. This material apparently came from the upper layers in the open cut and represents deposition in the surficial wash. Soft wad occurs in streaks and patches in the clay and follows the original bedding of the clay which is the residual product of decomposed Shady dolomite.

The mine and mill were closed when visited in 1917, but the mill was in good repair. It is reported that Mr. Wilcox, of New York, is to reopen the mine under the name of the Vesuvius Manganese Corporation.

BLUE BANK.

The Blue Bank, at the west end of Cellar Mountain just north of the mouth of St. Mary River gorge, has been abandoned for a number of years and was not visited by the present writers. It has been described by Harder[1] as follows:

"The workings consist of a series of open cuts and tunnels some distance apart. The iron mined was a dark-brown to blue, highly manganiferous iron ore. In the principal type of ore the manganese and iron oxides occur thoroughly intermixed, and psilomelane and pyrolusite [manganite] are found separately lining cavities in it. The ore apparently occurs in large masses."

[1] Harder, E. C., op. cit., p. 64.

OLD DIXIE MINE.

Large iron-ore banks in the mountains up Dogwood Hollow from the Vesuvius mine, were mined for many years under the name Dixie mine by the Alleghany Ore and Iron Co. The ore is a high-grade compact limonite, somewhat siliceous, and contains no manganese. It is reported by Watson[1] to be a fault deposit, and to have been mined for 1,200 feet along the fault plane and 175 feet in depth. The ore body is said to be 4 to 25 feet wide.

ROCKBRIDGE COUNTY.

KELLY BANK.

The Kelly bank, about 1 mile southwest of the Vesuvius mine and 1 mile northeast of Vesuvius, was mined years ago chiefly for iron, but some manganese ore is reported to be associated with it. It was not visited by the present writers.

MARY CREEK MINE.

The Mary Creek mine is located on the bench 1,800 feet in elevation on the northwest front of the quartzite knob 2 miles south of Vesuvius, adjacent to Mary Creek. The white Erwin quartzite composes the knob and stands about vertical or somewhat overturned to the east. The mine is 1,000 or more feet west of the quartzite outcrop. The top of the bench where the upper tunnel enters is covered with quartzite wash. It is reached by a steep cable tramroad from the creek bottom to the south, 400 feet below. Two other tunnels are on the mid slope, where the engine for the hoist was located. In the cut for the steep tramway argillaceous limestones are exposed and at its foot are other earthy thin-bedded limestones and purple shales, of the Watauga formation, which dip 45° SE., probably overturned. A washer was at the foot of the incline, and the ore was hauled in wagons to the railroad about a mile distant. The tunnels could not be examined but the ore on the dump and in small open cuts when visited in 1914 was blue psilomelane and soft ore in yellow clay, probably residual from the calcareous shale, and limonite crusts and cemented masses of sand rock probably from the cover of wash. The mine has since been abandoned. It was worked for iron for a charcoal furnace in earlier days.

[1] Watson, Thos. L., Mineral Resources of Virginia, Jamestown Exp. Com., p. 437, 1907.

MIDVALE MINE.[1]

Location and history.—The Midvale mine is about 4,000 feet due east of Midvale, Rockbridge County, Virginia, on the Norfolk & Western Railway. (See Pl. XXII.) The surface workings are at an altitude of 1,560 feet on the top of a broad flat-topped spur that extends northwestward from the main Blue Ridge. A new tunnel extends northeastward under the old workings from a ravine, 120 feet lower, and from the mouth of the tunnel an aerial bucket tramway leads to the mill near the railway, 1,020 feet in altitude. The mill is equipped with a log washer, crusher, several Harz jigs, a Wilfley table, bucket elevators, and a picking belt, the latter having been recently discarded. The ore over 1½ inches is hand picked. That under this size is crushed and jigged and the finer material is passed over tables.

The property was opened in the early eighties and was subsequently worked by Cohalan, Irwin & Co., the Midvale Manganese Co., and Frank Schultz. The present lessee and operator is the Rockbridge Manganese & Iron Co., of which George Horton, St. Johns, New Brunswick, Canada, is president. The production from 1909 to 1914, inclusive, was 914 tons, but there is no record of earlier shipments other than 250 tons produced in 1887.

Surface features and geology.—In the vicinity of Midvale, South River, a tributary of the James, flows southwest in a narrow, flat-bottomed valley 1,000 feet in altitude. Short spurs from the long, high, main Blue Ridge that abut against the valley on the southeast are characteristically flat-topped, attaining altitudes that range from 1,500 to 1,600 feet. Numerous remnants of a flat upland at similar altitudes are also to be seen northwest of the river. There is warrant for believing that these flat areas, which are cut on highly inclined rocks of diverse character, represent portions of the early Tertiary erosion surface.

The rocks that underlie the area near the mines are exposed along the ravine southwest of the mine and the clearing adjacent to the tramway. The following section was measured:

Section near Midvale mine.

	Feet.
Red shales and impure sandstones	100+
Gray and olive-colored shales, weathering brown, with a few thin beds of dense gray limestone near the base. The lowermost shales contain large nodules of chalcedonic white chert	1,720±
Dense-colored gray and cream, dolomite in beds 1 to 3 feet thick	500+

[1] Description chiefly from Hewett, D. F., Some manganese mines in Virginia and Maryland: U. S. Geol. Survey Bull. 640, pp. 54-60, 1916; also from Harder, E. C., op. cit., p. 65.

The dolomite at the base of the section is Shady, and the shaly beds above are Watauga shale. Farther east, beyond the limits of the area shown in Plate XXII, the front ridge of the Blue Ridge is composed of nearly vertical beds of Erwin quartzite, but no rock outcrops were found between the mine and the ridge. The mine workings are stratigraphically below the dolomite beds of the Shady that are well exposed in the ravine 500 feet to the southwest and which outcrop northwest of and higher on the slope than the mouth of the new tunnel. All the outcropping beds dip from 80° to 85° NW. except the uppermost shale beds near South River, which dip southeast. There is little doubt that the normal succession of rocks is present in this belt and that there are no faults of great magnitude in the vicinity of the mine.

Workings and occurrence of the ore.—None of the explorations made prior to 1912, except the incline, are now accessible. The following explorations are reported and shown on Plate XXII. The Schultz shaft (1) with drifts at several levels; the Schultz incline (2) with connected drifts; the new shaft (3) with levels at 50, 70, and 105 feet, of which the 50-foot level was in 1914 extended through to connect with the Schultz incline. The accessible explorations in 1914 include the new tunnel (4) with connected drifts, and the 50-foot level. The production since 1909 has come from the Schultz shaft, Schultz incline, and new shaft. In 1917 the tunnel had been extended to the new shaft and a large glory hole 150 feet across and 50 feet deep had been opened about the shaft, the ore and dirt from which had been taken out through the tunnel. At present the ore from the new workings on the surface is dropped to the bottom of the hole and down the shaft to the cars in the tunnel. The overburden of wash and clay is also dropped into the hole and removed through the tunnel. At the tunnel mouth the waste is dumped from a trestle into the ravine. The ore is dumped into a chute which feeds automatically the bucket aerial tram.

The drifts on the 50-foot level struck manganese ore at a number of places, and most of the material mined during exploration has been washed. Only films of manganese oxide occur here and there on the tunnel level and no nodules of ore have been found there. On the 50-foot level the clay is generally sandy and contains here and there rounded pebbles of quartzite and quartz schist as large as 4 inches in diameter, as well as lenses of relatively clean reddish sand. Ordinarily the sand merges with the clay, but in a few places there is a sharp line of separation. Well-defined stratification is lacking. The clay is commonly mottled brown, but there are also

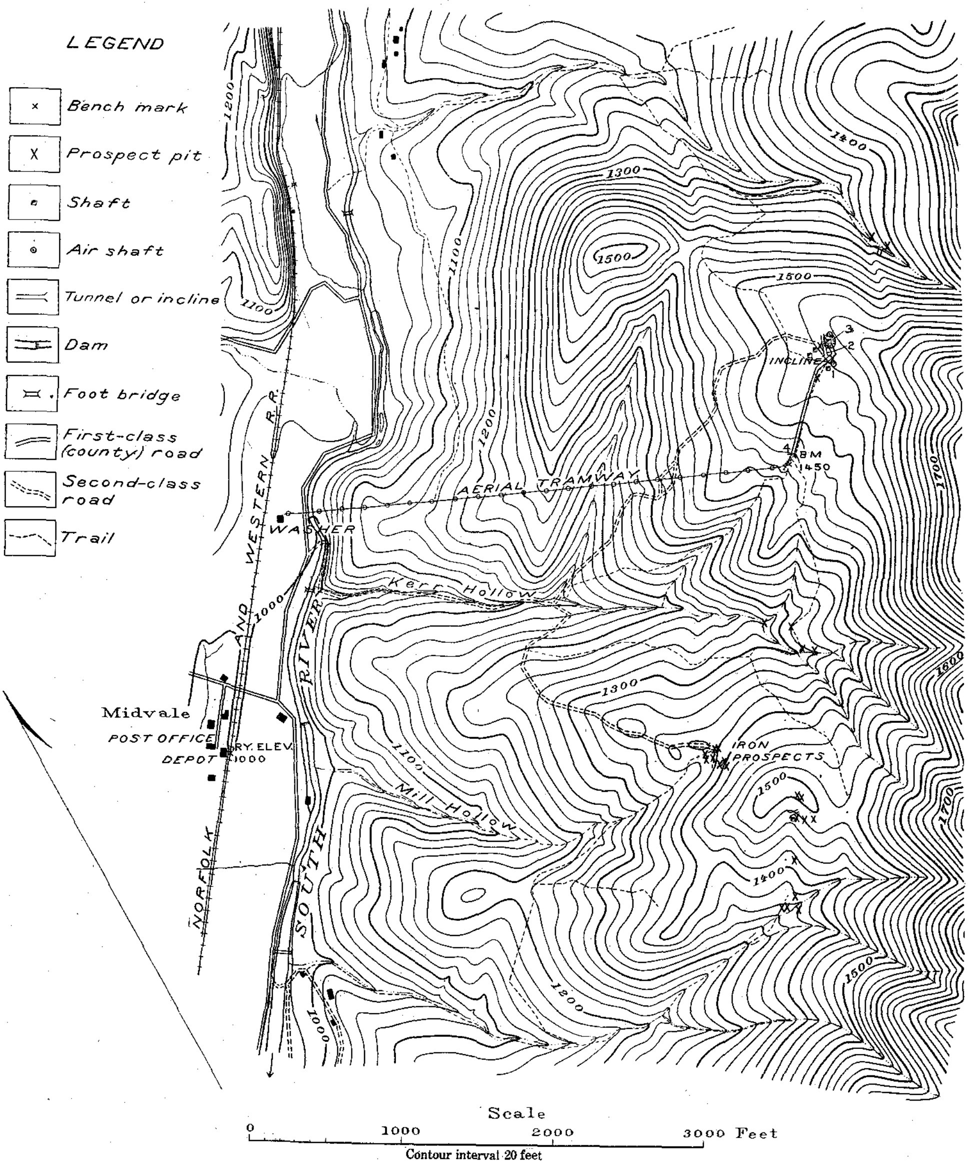


Plate XXII.—Map of Midvale mine, Rockbridge County, near Midvale, showing present workings and prospects in the vicinity.

1, Schultz shaft; 2, Schultz incline; 3, new shaft and glory hole; 4, new tunnel connecting with new shaft and glory hole. Contours determined by aneroid barometer based on railroad bench mark at Midvale. Surveyed by T. K. Harnsberger and W. J. Cox, July, 1915, with later additions.

patches of pure white, dark reddish-brown, and pale rose-pink, the last a variety that resembles montmorillonite. The masses that are homogeneous in color are small. Pisolitic structure such as bauxitic clays commonly show is lacking, and although some varieties appear to contain considerable limonite, none harden on exposure, as most lateritic clays do.

There can be little doubt that the sands are stream worn and not formed by residual decay or brecciation. Although most of the grains are single grains of quartz, many are, like the larger pebbles found in the clay, fragments of quartzite and quartz schist closely resembling the Erwin quartzite that underlies the Shady dolomite and forms the adjacent mountain slope. Some grains are angular and the faces of some present a mammillary appearance. These are composed of microgranular quartz and appear to be fragments of minute veinlets of secondary origin.

The pebbles found on the 50-foot level range in size from coarse sand grains to pebbles 4 inches in diameter and in shape range from subangular to well rounded. They do not occur in defined lenses but are scattered here and there in both the sand and the sandy clay. In many of them the cementing material is decomposed and the pebbles crumble under slight pressure. On the new tunnel level sand predominates over clay and there are more pebbles that tend to occur in lenses. On the tunnel level, 630 feet from the entrance, a rounded boulder of quartzite 36 inches long was embedded in sandy clay and a few feet farther north decomposed siliceous dolomite was struck on the floor of the drift. A raise near the former face of the tunnel cuts a zone of gravel-bearing sand. The relations of the materials on this level strongly suggest that the tunnel has been run close to the bottom and near the west edge of a filled stream channel. Although the channel appears to trend northeast, the east limit and shape have not been determined.

The entire mass of clay and sand is wet, but there are few water courses and little water flows from the mine workings. The clay is sufficiently plastic in places to flow slowly through small open spaces between the lagging in the drifts.

The hard manganese ore appears to be confined to highly irregular masses of dark-brown wad and manganiferous clay embedded in variegated clay. This clay may be residual from decomposed limestone in place. No ore or wad has been found in the zones of sand. The masses of wad have a great range in size and shape and the limit of the larger bodies have not been determined. Some are rudely lenticular and are disposed in various positions. Locally the limits are sharply defined, but generally wad merges with reddish-brown clay.

Psilomelane is the commonest manganese mineral in the washed product. It forms both rounded botryoidal nodules and slag-like stalactitic masses. Some nodules show considerable manganite, much of which forms terminated crystals lining cavities. Some large masses of psilomelane with manganite lining cavities have recently been taken out. A polished section of one specimen shows nuclear masses of fine crystals of manganite enveloped by numerous alternating fine layers of psilomelane and manganite. These two minerals appear to have been deposited alternately in succession, but at one place in the specimen manganite may have been formed by the hydration of psilomelane. Limonite nodules have been found sporadically on the 50-foot level.

The following analysis of the ore was furnished by Mr. H. L. Whitney, manager of the mine:

Analysis of washed ore from Midvale mine.

MnO_2	79.20
MnO	2.79
Fe_2O_3	3.07
Al_2O_3	3.56
CaO	.33
MgO	.34
BaO	2.99
Cu	.06
Zn	Tr.
Co	0.79
Ni	.26
SiO_2	2.11
P	.113
S	.045
	95.658
Mn	52.23

The yield of washed ore has not been accurately determined, except on a small scale on material from the manganiferous clay. Samples of this ran from 25 to 50 per cent concentrates of all sizes down to fine sand. The ordinary log washer does not, however, recover lumps smaller than half an inch, so that under milling conditions the yield would probably be lower than this figure.

In addition to the deposit that has been the scene of recent operation, old explorations indicate the existence of a similar deposit on another spur from the Blue Ridge, 3,000 feet to the southwest. Well-rounded quartzite pebbles were noted both in the clay exposed in the tunnel walls in one of these openings and on the dump. Ore was taken from these workings and hauled to South River valley for washing. According to aneroid-barometer measurements the lowest explorations in gravel-bearing clay on this hill coincide closely in altitude with the new tunnel on the northern deposit. No rock outcrops were observed near the southern deposit.

The "Glory hole" recently opened at the shaft above the new tunnel end gave a better view of conditions in 1917 and although it was somewhat slumped may throw some further light on the deposit. There is at the top about 5 to 20 feet of wash containing round quartzite gravel and boulders, and red and white mottled clay in which there are some manganese nodules. Many of the boulders are coated with manganese oxide, others are cemented into conglomerate by the oxide. It is probably from this zone that the rounded quartzite gravel at the mill comes from. It varies in thickness and appears to descend in steep-sided channels or in old sink-holes. Below this wash is a zone of dark manganiferous clay and wad in which are scattered harder lumps and nodules of psilomelane containing some manganite crystals. This is claimed to run 15 to 20 per cent washed ore. This ore zone extended to the bottom of the open hole and is reported to be about 70 feet thick. Beneath it in the shaft and tunnel are reported 25 feet of barren clay. There were no quartzite boulders seen in the dark manganiferous clay and it is probable that this represents deposition in and replacement of residual clays from limestone in place. The boulders and sand reported in workings at lower levels may be in channels or in sink-holes which reached a lower level in those places than they did in the ground now in the open workings.

Origin of the ore.—The coarse gravel and boulders, as well as the sand contained in the clay of the deposit at the mine, are such as are characteristic of stream sediments rather than of residual or fault-zone clays. The coarse sediments resemble the quartzite of which the high ridge 1,500 feet east of the deposit is composed and are entirely different from the dolomite that underlies it, shown by exposures underground and in adjacent ravines. The angular grains of quartz washed from one specimen of clay are probably parts of veinlets deposited from the solutions with which the clay is saturated. It is believed that part of this manganese deposit occurs in remnants of channel sediments laid down by a stream that flowed on the surface of the early Tertiary peneplain. The amount of manganese in the channel filling is clearly greater than is present in ordinary sediment, and the manganese has probably been brought into the channel from outside sources by circulating solutions. As the deposits occur on flat spurs which were once part of the early Tertiary plain but have been separated by later dissection, since which they have received little surface drainage or underground water, it is clear that the deposition of the manganese must have taken place largely in early Tertiary time before the plain was dissected.

AREA BETWEEN MIDVALE AND BUCHANAN.

Although many large old iron-ore banks have been worked at Buena Vista and elsewhere along this part of the mountain front and some manganese prospects have been reported, the area was not examined for manganese deposits by the writers. Conditions are locally favorable for such deposits.

BOTETOURT COUNTY.[1]

BEARWALLOW CREEK TRACT.

An undeveloped tract containing manganese ore lies just southwest of Bearwallow Creek, 1 mile southeast of Buchanan. It lies between Boyd Mountain and a spur of the Blue Ridge about half a mile to the southeast, and is a part of a northeastward-trending trough-like syncline over 3 miles long which widens and deepens toward the southwest. It is underlain by the Shady dolomite, exposures of which occur in and near Bearwallow Creek. In most other places in this basin the Shady dolomite is overlain by variegated residual clays containing a small quantity of light and dark colored chert but in places the Shady or its residual clay is concealed by stream wash consisting mainly of quartzite boulders. In places these surface materials probably exceed 100 feet in thickness. A well on the farm of J. C. Burkholder penetrated 84 feet of clay below 8 to 10 feet of gravel. The Erwin quartzite forms the ridges on either side of the syncline. The structure of Boyd Mountain and of Jones Mountain in line with it to the southwest is that of an anticline broken on the west side by a thrust fault. The quartzite in these ridges has a dip at different places of 40° to 50° SE. The structure of the ridges formed by the Erwin quartzite to the east of the tract is monoclinal, the Erwin there dipping 75° to 90° NW.

Manganese ore occurs for a distance of 700 to 800 feet along the wagon road one-fourth mile south of C. G. Layman's house, and it is said to have been found a number of years ago in yellow-ocher pits at the east base of Boyd Mountain.

The ore by the roadside consists of nodules of hard compact steel-blue psilomelane up to 1 pound in size in red clay. The presence of sand and a

[1] The descriptions of the mines and prospects in Botetourt and Wythe counties and most of those in Smyth County are by H. D. Miser and F. J. Katz.

few chert and quartzite fragments in the clay indicate that the materials of the deposit, although they are probably residual from near-by rocks, have been transported and laid down as wash. Quartz sand is present in some of the psilomelane and a few fragments of chert and sandstone are partly replaced by manganese oxide.

Although this tract is synclinal in structure like certain tracts in the Shenandoah Valley, the rocks on either side dip so steeply and the syncline is so broad that manganese ore is not apt to be found in all parts of it. Prospecting by drilling and making test pits in the vicinity of the above-described occurrences of manganese ore seems to be advisable.

GOWANS BANK.

The Gowans bank is 2 miles south of Lithia Station and 3 miles east of Nace station (formerly called Houston) on the Shenandoah Valley Branch of the Norfolk & Western Railway. A roadway nearly a mile long in a southeast direction and the bed of an old tramway, both of which closely follow a small stream, East Hollow, connect the mine with a point on the railroad 3 miles northeast of Nace, at which point is the site of an old furnace.

The bank was worked for iron ore during the Civil War and it has been prospected for manganese by lessees who are reported to have sorted out and shipped some manganese ore. Harder[1] mentions the production of manganese at this mine, but no further historical data are available.

The mine is situated at the west base of the Blue Ridge Mountains, on East Hollow and on a small ridge immediately northeast of that stream. Elevations near the mine range from about 1,500 feet on the stream to 1,650 feet on the ridge. Directly southeast of the mine the western front ridge of the mountains, 1,800 to 2,200 feet in height, trends northeast. Three-fourths of a mile farther southeast is the main Blue Ridge crest, here 2,300 feet to 2,700 feet in elevation.

The mine openings include a shaft and a number of small adits and hill side cuts, all of which were badly caved at the time of visit, October, 1917. They extend northeast from the stream bottom 1,600 feet to the crest of the small ridge. The only rocks outcropping at the workings are a vertical bed about 5 feet thick of coarse ferruginous grit and brown sandy chert which is cavernous and drusy. The pits which are west of

[1] Harder, E. C., The production of manganese ore in 1907: U. S. Geol. Survey Min. Res. for 1907, pt. 1, p. 94, 1908. Also Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, p. 65, 1910.

(above) this bed expose red and ocherous residual clays containing a few chert nodules and abundant lumps of more or less siliceous limonite. Near the base of the southeast slope of the small ridge on which the workings are situated an adit exposes thin-bedded sandstones with low dips both northwest and southwest and evidently slightly faulted. Five hundred feet up East Hollow are good exposures of Erwin quartzite which strike N. 50° E. and dip 50° NW.

The rock underlying the mine openings is evidently the basal part of the Shady dolomite, which in this region is generally flinty and contains one or more beds of coarse calcareous and ferruginous grit or fine conglomerate.

The character of the Gowans bank ore can only be inferred from material found on old dumps. These appear to be both pure iron ore which was not observed to be manganiferous, obtained from the coarse grit bed, and brown iron ores which are siliceous and slightly manganiferous, associated with residual clays and flints. The latter contain small spots and streaks of soft granular manganese oxide (pyrolusite) and there are also present in the dumps small nodules, less than one-fourth of a pound each, of hard and apparently rich psilomelane. The manganese content of the ore may in places be higher than indicated by visible material, inasmuch as the dumps appear to have been sorted and picked over by the prospectors. The disturbed conditions of the workings prevented the measurement of the deposit.

WHITE BANK.

The White bank is on land of the Pulaski Iron Co., on the northwest slope of a low northeastward-trending ridge, about 3½ miles east of Nace. Although it was worked 15 to 20 years ago as an iron mine, manganese ore was found in some of the workings, but so far as could be learned none of it was shipped. The workings consist of a number of cuts and pits through a distance of fully one-fourth mile parallel with the trend of the ridge. They occur at different elevations on the ridge, the highest being 1,600 feet above sea-level. They reveal variegated clays and large masses of yellow to brown porous chert which are typical weathered products of the basal beds of the Shady dolomite. Brown iron ore is present in large quantity at several openings. Psilomelane in concretionary masses up to 1 or 2 pounds in weight is found at some openings, but none is found where the iron is most abundant.

DEAL BANK.

The Deal bank is on land of the Pulaski Iron Co., 1 mile south-southeast of Nace at the northwest base of the Blue Ridge. This property was worked for several years as an iron mine, but a small amount of manganese ore that was found in places was also shipped. The last work done here was 15 or 20 years ago. Many pits and open cuts occur over an area of several acres, but the principal opening is a bank about 1,570 feet above sea-level. The openings are in variegated residual clays of the lower part of the Shady dolomite. The dip of the Shady was not determined, as there are no exposures of it in this vicinity, but its dip is probably the same as that of the Erwin quartzite in the Blue Ridge just to the south, which is vertical and strikes N. 70° E. Massive brown chert in which are angular cavities occurs in some of the openings. Most of the ore at this locality is brown iron ore, although there is also some psilomelane and granular manganite, both of which are intermixed in the same specimen.

HOUSTON MINES.

The Houston mines comprise two large banks, between one-fourth and one-half mile apart on the northwest slope of the Blue Ridge about 1½ miles south-southwest of the village of Nace. This property was first worked as a source of manganiferous iron ore but purer manganese ores were encountered in the lower part and attention was then turned to them.[1] Some of the manganese was used for chemical purposes, but most of it was used in the manufacture of steel. Bauxite was discovered in the west bank and eight cars of it are reported to have been mined and shipped in 1915. This is said by T. L. Watson, Director of the Virginia Geological Survey, to be the only known bauxite deposit in Virginia. A railroad once connected the mines with the Norfolk & Western Railway at Nace, but the track was removed several years ago.

The banks reveal white, red, yellow, and brown residual clays of the lower part of the Shady dolomite. No ledges of the dolomite are exposed in the banks although the clays have been worked to a depth of 100 feet—from 1,750 down to 1,650 feet above sea-level—and none are exposed in the vicinity. The structure of the Shady was therefore not determined but the Erwin quartzite beneath it is exposed in the Blue Ridge just to the south where it dips 60° to nearly 90° northwest toward the valley.

[1] Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, p. 65, 1910.

Besides manganese and iron ores and bauxite, the clays contain small fragments of white altered chert and massive ledges of brown fine-grained siliceous rock that is probably chert, and at the surface they contain fragments of this chert and weathered quartzite. Although the brown clays occur also in the upper parts of the banks, they prevail in the lower parts where they are associated with masses of dark manganiferous clays. Brown iron ore and small masses of manganese ore occur in the red and yellow clays, but most of the manganese ore is found as concretions in the brown and manganiferous clays and as veins and replacements in the ledges of massive brown chert.

Most of the manganese ore observed at the time of visit consisted of steel-blue psilomelane; the rest was manganite occurring in small crystals mixed with the psilomelane. Harder,[1] who visited the mines in 1909 describes the ore as follows: "The principal portion of the manganese ore . . . is in the form of rather soft and friable blue granular pyrolusite. With it are associated small amounts of crystalline pyrolusite in the form of coarse needles. The granular ore appears to be largely a replacement, and the needles to be a cavity filling. Some of the ore is in irregular masses and some in definite layers. A good deal of partly replaced material is generally associated with it and grades into it."

The following are analyses of ore from the Houston mines:[2]

Analyses of manganese and manganiferous iron ore from the Houston mines.

	1	2	3	4
Mn	44.312	7.277	59.870	39.00
Fe	12.325	47.15	.50	12.00
P	.101	.061	.049	.....
SiO_2	5.470	8.03	2.30	.....

1. Manganese ore.
2. Manganiferous iron ore.
3. Selected sample of manganese ore.
4. Average of monthly shipment, 1884-1885.

The bauxite in the west bank is pisolitic and although some of it is cream-colored, most of it is red from the presence of considerable iron oxide. Many of the larger pisolites have been removed through solution leaving spherical cavities partly or entirely filled with clay. Here and there fine crystals of gibbsite coat cavities in the bauxite. The exact relations of the bauxite to the iron and manganese ores were not determinable

[1] Harder, E. C., op. cit., pp. 65-66.
[2] Weeks, J. D., Mineral Resources of the U. S. for 1885, p. 320.

owing to the slumping of the bank since work was discontinued. At only one place was the bauxite observed in place; it there occurred as fragments up to 40 pounds in weight in red clay a few feet below the surface.

BRUSHY RUN PROSPECTS.

Several openings have been made on Brushy Run 1½ miles southwest of Nace at the base of the Blue Ridge. Brown iron ore that is probably a bog ore of recent origin was being prospected near the bed of the run at the time of visit. A cut made many years ago on the west side of the run shows manganiferous iron ore and a very little nodular psilomelane in red residual clay of the lower part of the Shady dolomite. Steeply dipping massive ledges of a fine-grained brown siliceous rock that is probably chert occur on the south side of the cut. This rock is near the base of the Shady dolomite.

STONER MINE.

The Stoner mine is 1 mile east of Troutville Station on the Shenandoah Valley Branch of the Norfolk & Western Railway. It lies on the northwest side of the lower course of Stoney Battle Run and on a short low ridge between 1,500 and 1,600 feet in elevation, which adjoins and parallels the lower steep slopes of the Blue Ridge. The mine was briefly noted by Harder,[1] who quotes from Weeks[2] an analysis of ore from the vicinity:

Analysis of manganese ore from the Chapman property.[3]

Mn	45.80
Fe	3.06
P	.164

The workings in October, 1917, consisted of an old shaft and several prospect pits, the condition of which did not permit examination. Several new prospect pits and a short adit were made in the fall of 1917. On the ridge top these show a surface covering of coarse quartzite débris and sand derived from the mountains on the south, the débris mantle being thicker, about 5 to 7 feet, in the eastern and nearly absent in the western holes. Beneath the surface débris in the creek bank is a clay, mottled and streaked in various tawny shades and red, and containing abundant small fragments of white and dark chert. This is the clay residuum from the Shady dolo-

[1] Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, p. 65, 1910.

[2] Weeks, J. D., Mineral Resources of the United States for 1885, pp. 303-356.

[3] Ibid., p. 321.

mite and it contains abundant small nodules of hard black psilomelane minutely botryoidal in form. Some of the chert fragments are partly replaced by manganese oxide. The psilomelane nodules in the adit and newer prospect pits are seemingly abundant enough in the clay to make a workable ore, probably present in the minimum ratio of 1 of psilomelane to 10 of clay.

The extent of the manganiferous ground was not established by the workings which cover a belt 1,200 feet long, east to west, by about 150 feet wide along Stoney Battle Run. The depth of the manganiferous residual clay is also not disclosed. The maximum exposure visible was 12 feet but the bottom was apparently not reached in the old shaft, the depth of which is unknown however. All of the prospects are from 10 feet to a maximum of about 100 feet above creek level and it is probable that the limestone in this tract is all decomposed to or below creek level.

The Stoner mine is seemingly on an old and deeply decomposed erosion surface 1,550 to 1,570 feet in elevation, probably the marginal part of the old valley floor of Fincastle valley, which is here the divide between the Roanoke and James drainage.

Detailed rock structure was not determinable in exposures at the Stoner mine. In general the strike of the beds is nearly east and they dip steeply north, but there is a small quartzite hill west of Stoney Battle Run, southwest of the mine, which appears to be an anticlinal nose plunging steeply west. The manganese showing is near the base of the Shady dolomite, northeast of the summit of this hill. Banding of the clay in the adit suggests a local strike N. 70° W. and dip 50° SW., which however could not be positively identified as bedding.

GRUBB OR LYNCHBURG MINE.

The Virginia Iron, Coal & Coke Co. is operating the Grubb or Lynchburg mine[1] 2 miles northwest of Blue Ridge Springs and other mines in that vicinity. These are iron mines, the ores of which in places contain very meager quantities of manganese oxide associated with the brown iron ore. The principal deposit at this locality is in variegated residual clay of the Shady dolomite and is just south of a fault by which the Unicoi formation is brought adjacent to the Shady dolomite.

[1] Holden, R. J. in Watson, T. L., Mineral Resources of Virginia, 1907, pp. 443-4.

PULASKI COUNTY.

STIGLEMAN PROSPECT.

Mr. W. T. Stigleman, of Snowville, has prospected for iron and manganese ores on a tract 3 miles south of Snowville, Pulaski County. The tract lies west of Little River and north of Laurel Creek on the east end of and in the hollow east and south of an east-west mountain ridge. This mountain is an eastward-plunging anticline of Erwin quartzite and the next ridge or mountain south appears to be the same. Beds of Shady dolomite surround these ridges and extend up the intervening hollow in a synclinal trough. This area is not shown on the map, Plate III.

The prospect openings include a shaft in a ravine on the east end of the northern quartzite mountain and several small cuts in the hollow and the flat to the south and east of the shaft. At the shaft and in its vicinity near the base of the quartzite slopes there is lean brown iron ore abundantly developed in the cherts and cavernous sandy flints and the red ocherous and white clays of the basal parts of the Shady dolomite. In the hollow and the flats east of the end of the mountain there are banded and mottled residual clays replaced in small spots by iron ores, and farther east small nodules of psilomelane are scattered sparsely through the clay. In a cut in a roadside bank about one-fourth mile east of the shaft, stiff ocherous clay containing a little white chert overlies argillaceous limestone (Shady dolomite) dipping northwest. Small nodules of psilomelane replace the clay but some contain so much clay that they are soft and too impure to make a good ore. The material at the top of the cut contains much iron ore, but the manganese replacements in the lower part are free of iron. Farther down the road a considerable number of hard, pure, but small lumps of psilomelane were found which had been washed out of the clay and concentrated by rain. The geologic conditions are favorable for the occurrence of a manganese ore body and the tract should be more systematically prospected.

WYTHE COUNTY.

WALTON FURNACE BANKS.

Walton furnace lies 4 miles northeast of Ivanhoe on a belt of limestone (Shady dolomite) one-half mile wide between ridges of Watauga shale. On this belt of limestone for some distance west and east of Walton furnace there are many iron banks which have yielded a large tonnage of iron ore.

Some iron ores from the vicinity of Walton furnace, and particularly some from the Blair property just west of the furnace site are manganiferous. The extent and quality of manganiferous deposits here have not been determined, but probably at best the general run of ore will be only slightly manganiferous.

GLADE BANKS.

At the head of the south prong of Glade Creek on the farms of George Hudson and Grover Hudson 5¼ miles north-northeast of Ivanhoe, on the Cripple Creek branch of the Norfolk & Western Railway, and 3 miles north of Walton furnace are manganese prospects. Ore was drawn from openings on the George Hudson farm about 1880-1885 and the Grover Hudson farm was prospected about 1908 and a few tons hauled out. McCreath[1] supplies the following description:

"Three miles north of Walton furnace is the Glade Manganiferous ore bank, worked by shaft and tunnel. The character of the ore seems to vary somewhat, being sometimes a rich brown hematite, often fibrous and quite free from manganese; while on the other hand, portions of it are highly charged with manganese, this element not unfrequently predominating. The ore is simply screened, there being no water for washing purposes in the vicinity of the mine. About one-twelfth of the burden of the Walton furnace at present consists of this ore."

A sample comprising one hundred and forty-three pieces selected from a small ore pile at the furnace yielded the following analysis, according to McCreath:

Metallic iron	50.450
Metallic manganese	4.971
Phosphorus	.444
Siliceous matter	5.440

At the time of the visit (October, 1917) nothing could be seen of the old workings and the recent prospect cuts were badly obscured by slumping. The deposits lie on a slightly hilly, rolling surface, which has an average elevation of about 2,400 to 2,500 feet, and which is a part of an old valley-floor erosion surface of Cripple Creek Valley. The ore materials occur in a greatly shattered, fissured, and brecciated portion of the Watauga shale and are replacements of the shale by limonite, hematite, and manganese oxides and also small thin vein fillings of the same minerals in both the shales and replacement ores.

[1] McCreath, A. S., Mineral wealth of Virginia, p. 87, 1884.

AYER PROSPECT.

At the Ayer prospect, which was not visited by the Survey party in 1917, Mr. John Ayer is reported to have found manganese in clays on his farm. The Ayer farm is situated in a small cove underlain by Shady dolomite between quartzite spurs of Mays Mountain, just southwest of Lots Gap, and is about five miles southeast of Wytheville. It apparently lies in a syncline which pitches east and therefore has favorable geologic structure.

FISHER PROSPECT.

The prospect on J. W. Fisher's farm is 4½ miles north-northwest of Ivanhoe near the head of Mill Creek. The prospect lies just northeast of the end of a quartzite ridge which is either a simple anticline or an anticline faulted on its north limb and thrust over Shady dolomite. There was a single shallow pit at the time of the visit (October, 1917). This was opened in residual clay of the Shady dolomite a short distance below quartzite exposures on the ridge at an elevation of about 2,550 feet.

This pit shows abundant small concretionary nodules of psilomelane, 5 and 6 inches in diameter, replacing banded clay and sandy flint. Some of these are thorough replacements but most of them are only partial and contain clayey and sandy residues which preserve the banding and lamination of the original rock.

Manganese nodules are found also in the clay soil on the Fisher farm at a place about one-half mile south of this prospect pit.

DUNFORD PROSPECT.

On the Wayne Dunford farm 500 feet east of the Fisher prospect another pit 6 feet by 2 feet and 4 feet deep was dug in a gravelly flat about 2,500 feet above sea-level east of the end of the quartzite ridge. This pit discloses 10 or 12 inches of loosened soil and below that sandy and bouldery detritus, which is notably rotted by weathering. The upper 2½ feet of this material, particularly 6 to 18 inches at the top, is mottled by impregnations of manganese oxides which also largely replace some small spots. This Dunford prospect is in old detritus or gravel covering the old valley-floor peneplained surface.

DUNGEON BANK.

The Dungeon bank is on the south side of Dungeon Hollow and at an elevation of about 2,700 feet on the southeast spur of Lick Mountain, which lies just north of Swecker Mountain. It is 4¼ miles south-southeast of

Wytheville, on the Norfolk & Western Railway, and 5 miles northwest of Ivanhoe, on the Cripple Creek branch of that railroad. It is on a tract locally known as "The Big Survey" and is said to have been worked by Rodney Ludlow, of Pittsburgh, about 1904 when several carloads of iron ore were hauled to Catron siding. It had, however, been opened at an earlier date as shown by McCreath and d'Invilliers' description.[1] At the time of visit (October, 1917) there was one large open cut 40 feet deep at the face and 10 to 25 feet wide, and several small holes extend the workings 300 feet further south up the ridge. The pits were in such condition that inspection of bedrock was impossible. The ridge south of the workings is quartzite and seemingly anticlinal. Dungeon Hollow is a synclinal trough occupied in the lower part by limestone (Shady dolomite). An outcrop of the Erwin quartzite 100 feet west of the mine dips southeast. Thus it appears that the bank is near the axis of a syncline in the top beds of the Erwin quartzite. The ore is göthite and siliceous limonites associated with beds of shaly sandstone and rusty cavernous flint. Some thin veinlets of psilomelane cut the iron-ore lumps and there are also very small botryoidal nodules of psilomelane. The following analysis of a sample representing a general average of the entire deposit is quoted from McCreath and d'Invilliers.[2]

Metallic iron	51.450
Metallic manganese	1.642
Phosphorus	.637
Silicious matter	9.330
Phosphorus in 100 parts iron	1.238

PAINT BANK AND SINK-HOLE OPENINGS.

The Paint bank and Sink-hole openings which lie about 1½ miles and 1¾ miles, respectively, west of the Dungeon bank have long been idle and it was reported that the pits were in such condition that examination was impossible in October, 1917. They were, therefore, not visited. The following is based on a general examination of the Lick Mountain area and abstracted from McCreath and d'Invilliers.[3] These mines are in the long narrow synclinal valley of Paint Branch between Swecker Mountain and a southeast spur of Lick Mountain. Both ridges are anticlinal quartzite mountains and the valley between is a syncline which probably contains Shady dolomite as indicated by the sink-hole and the residual clays.

[1] McCreath, A. S. and d'Invilliers, E. V., The New River-Cripple Creek mineral region, p. 137, 1887.
[2] Op cit., p. 137.
[3] Op. cit., pp. 137-139.

"The Paint bank shows a somewhat circular pit, low down on the mountain flank and about 100 yards north of the creek. When visited, the open cut was somewhat fallen in, and the ore-faces gave only an indication of the presence of manganese, in the form of a black earthy wad mixed with a somewhat tough yellow clay, in which sometimes a thin streak of hard black oxide of manganese is exposed. It is claimed that a carload or more of commercial ore was shipped from this opening to the Cambria Iron Company at Johnstown, Pennsylvania, in 1885; but certainly no merchantable ore is visible now. Some few excellent lumps still lay in the dirt bank, and these are said to represent the character of the ore shipped; but there was not a sufficient amount of this on the dump to warrant sampling.

"The Sink-hole opening, also a manganese bank, lies still a half mile further up the branch, and close to the center of the valley. It is fairly a duplication of the Paint bank opening in its general characteristics, showing however a little more hard ore, which seemed to be somewhat ferruginous. The opening is close to the synclinal basin, the approximate dips being north and northeast about 15°. The Paint branch sinks at this point and disappears for nearly a quarter of a mile along the ravine; and the presence of limestone in the basin this far west is made still more probable by its occurrence in small pieces in the bank accompanying the manganiferous iron ore. The thickness of the bed exposed here may measure 10 or 12 feet, and it is shown for about the same width along the face. The ore is more or less disintegrated, although a good deal of solid ore occurs in places. Occasionally pieces of quartz spoil the appearance of the lump ore; but this is not a conspicuous feature. The product from this opening also formed a portion of the shipment to the Cambria Iron Company; and, from a small pile of ore still left, it may be assumed that only the best portion of the deposit was shipped."

An analysis of a general sample of the ore in place and the loose lumps near-by is quoted from McCreath and d'Invilliers as follows:

Metallic iron	39.712
Metallic manganese	11.519
Phosphorus	.047
Siliceous matter	12.840

BIG LICK DEPOSIT.

The manganese deposit, for convenience here designated the Big Lick deposit, is in a high saddle on Lick Mountain at about 3,050 to 3,100 feet above sea-level. It is 3½ miles south of Wytheville, 6½ miles northwest of Ivanhoe, and one-half mile west of the mountain road from Wytheville to Ivanhoe. The deposit is about 250 yards east of the "Big Lick" in the pass between the heads of Vaughan Branch (Dean Creek) and Venrick Run and is included in the tract locally known as the "Big Survey."

The deposit has been mined and some ore was shipped about 10 or 15 years ago, and three large cuts, all within an area 200 feet square, were made. These had caved considerably and were largely covered with surface débris at the time of the visit (October, 1917). The bedrock is sandstone (Erwin quartzite) which is much brecciated. The manganese oxide ores are replacements of the sandstone and cavity and fissure fillings very much like the Glade Mountain, Smyth County, deposit (page —) except that the Big Lick deposit carries very little, or is almost free from, iron oxides.

The sandstone is in places almost wholly replaced by psilomelane, yielding small lumps of rich ore up to 4 inches thick. For the most part, however, the sandstone replacement is not complete and ore of that kind is full of fragments and of sandstone and individual grains of sand. The best ore occurs as filling of spaces between the breccia fragments and in fissures. Ore of this type is hard steel-blue to black psilomelane of lamellar concentric structure and botryoidal surface. These fillings range in size from very thin veins to layers 2 inches thick and in some parts of the deposit are so closely spaced that they form large lumps of fairly clean ore, some of which weigh about 100 pounds. At least 100 tons of selected ore is piled at the cuts and about 15 tons on the haulway to the road.

OTHER PROSPECTS ON LICK MOUNTAINS.

An old prospect cut on the north side of the Lick Mountains lies 3 miles southeast of Wytheville on the east of the mountain road from Wytheville to Ivanhoe and near the highest point on the road. It is opened on a crushed zone in the Erwin quartzite, about 7 feet wide, in which sandstones and sandy shales are brecciated and have been cemented, seamed, and partly replaced by brown iron oxides. Some stalactitic limonite was noted and also a few thin seams of manganese oxide. There is no indication of a workable ore body at this place.

There is said to be a manganese deposit, from which several carloads of ore were shipped, on the north side of the Lick Mountains near Chimney Rock (High Rocks) about 3 miles south of Wytheville. Little could be learned about this prospect in October, 1917, and its location was not definitely ascertained. It is probably situated in the small cove on the southwest side of the northernmost ridge of the Lick Mountains. This appears to be a small synclinal basin enclosing Shady dolomite.

DAVIS PLACE.

Manganese ore in small quantity was observed in gullies by the roadside on the Wiley Davis farm at the east end of Davis Mountain. It is hard steel-blue psilomelane and occurs as fragments up to 1 pound in weight in the red residual clay of the Shady dolomite on the south slope of Davis Mountain, an Erwin quartzite ridge. Some iron ore is associated with the manganese ore.

GROSCLOSE PROSPECT.

About 20 pits have been made in search for manganese ore on the J. E. Grosclose place at the south base of Davis Mountain, 2½ miles northwest of Eagle siding on the Cripple Creek branch of the Norfolk & Western Railway. Mr. Grosclose says that the greatest quantity of ore found at any one place does not exceed a bushel and that the largest piece that was found weighed 5 or 6 pounds. Pieces of iron oxide and several pieces of steel-blue psilomelane in which there is a minute quantity of manganite were seen on the surface near the road. McCreath and d'Invilliers describe as follows the deposit at this place:[1]

"Near the base of the hill, back of Grosclose's house, some slight showing of manganese ore occurs, both on the Aaron Cordell tract (24 acres) and on the J. H. Grosclose tract (100 acres), largely associated with boulder clay and mountain wash; and also showing some lean iron ore mixed with drift. About 250 feet up the mountain slope from the house, a trench has been made in a lean mountain ore, filled with siliceous matter and commercially worthless; and 100 feet above this, a small pit has been sunk through a dark, blue-black manganiferous clay, carrying some few pieces of lean, siliceous ore. No exposure of rock occurs here, but the dip is probably a steep southeast one.

"A large number of pits have been sunk along the terrace north and east of Grosclose's house. Almost every one of them was more or less productive of ore-material; and indeed in some of them the showing was quite abundant. But to one familiar with the characteristics of the New River-Cripple Creek ore deposits, an inspection of these pits would at once disclose the fact that the ores developed here are not deposits in place. The terrace is formed of the lowest limestone rocks [Shady dolomite], or those occurring between the Potsdam sandstone [Erwin quartzite] and the Knox red slates [Watauga shale]. These rocks are concealed by a heavy

[1] McCreath, A. S. and d'Invilliers, E. V., The New River-Cripple Creek mineral region of Virginia, pp. 134-135, Harrisburg, Pa., 1887.

mountain sand wash; but their presence beneath this wash is confirmed by numerous sink-holes and outcropping limestone ledges to the east and west. Even in the pits themselves, a large amount of foreign material is mixed with the ore, much of it rolled and water-worn, while the ore itself partakes largely of a rather lean and, in some places, manganiferous mountain ore, which no doubt has been derived from precisely similar measures outcropping in place further up the hillside. Under these circumstances, in the absence of railroad facilities, and on account of the extreme irregularity of these secondary deposits, it is doubtful whether the amount of work done so far has demonstrated the presence of a commercial body of ore. A single exception might be made to this general statement, viz.: the occurrence, in a very shallow pit, of a considerable quantity of bomb-shell ore—a variety not hitherto specially noticed in other parts of the field, but which may probably be identified as in place in these lower limestones. The bombs are largely filled with clay, though in themselves they show an ore of good quality. In any event, any commercial ore body to be found along this terrace in the future will have to be sought for under this stripping of secondary wash-deposits."

WILLIAMS PROSPECT.

Prospecting for manganese was done many years ago by Major Gleaves on land now owned by S. C. Williams on the south slope of Davis Mountain, 1½ miles northeast of Henley precinct. Several of the openings were visited, but no manganese ore was observed. A very small quantity of iron oxide is present in places in the yellow clay which is residual from the lower part of the Shady dolomite. The Erwin quartzite is exposed on Davis Mountain above the openings and the structure is probably monoclinal.

DICKSON PLACE.

Manganese is said to occur near the top of a hill on land belonging to R. Dickson about 3 miles southeast of Crocketts, on the Norfolk & Western Railway, but none was seen at the time of visit (October, 1917). So far as known no prospecting has been done here. Dark-red clay and large boulders of porous yellow chert, both of which are residual products of the Shady dolomite, occur at this locality apparently on the south border of a syncline which lies between east trending ridges of the Erwin quartzite. A small quantity of brown iron oxide is scattered about over the surface.

HOUSMAN PROSPECT.

The Housman prospect is on the south slope of a low ridge on land belonging to E. B. Housman about 3 miles southeast of Crocketts on the Norfolk & Western Railway. The workings, which consist of a number of pits, reveal a small quantity of very sandy manganiferous iron ore in yellow residual clay from the Shady dolomite. The Erwin quartzite forms the crest of the ridge and the Shady occupies the synclinal valley south of the ridge.

HAGEE PROSPECT.

The Hagee prospect is on the south slope of Sand Mountain on land belonging to Hiram Hagee, about 3 miles southeast of Crocketts on the Norfolk & Western Railways. It is one-half mile northeast of the Housman prospect. A number of shallow pits have been made at different times and a carload of manganese ore said to have been picked up from the surface of land formerly owned by Mr. Kenser but now owned by Hiram Hagee and John Jones was shipped about 25 years ago by A. B. Harris.

The pits on the Hagee place are in a narrow shallow synclinal trough which plunges to the east. The Shady dolomite which once occupied the trough at this locality has been carried away in solution leaving its residual clay and a massive yellow cavernous chert. The Erwin quartzite is exposed on the mountain both north and south of the belt underlain by the residual clay and could doubtless be found only a few feet below the surface at many places in the clay belt. The quartzite on the hill south of the clay belt also occurs as a narrow tongue whose structure appears to be that of an anticline plunging to the east.

The manganese ore consists of hard steel-blue slightly porous psilomelane which is found lying on the surface or embedded in the clay. Since the shipment of ore 25 years ago pieces of ore up to 50 pounds in weight have been picked up in the field and piled in fence corners, so that at the time of visit (October, 1917) several tons of ore had been accumulated. Red and brown oxides of iron are found in very small pieces but the fragments of psilomelane are free of such oxides. One or two shallow pits made recently contained ore, but a few of the pits farthest west contain no ore. If further prospecting is done here it should be done wherever the psilomelane occurs on the surface and farther east where the clay is thicker and may contain ore below the surface. If hard sandstone is found in prospect pits or drill holes it will be useless to go deeper in search for ore, because the ore can as a rule be expected only in the clay overlying the sandstone.

JONES PROSPECT.

The Jones prospect is lower on the south slope of Sand Mountain than the Hagee prospect and is on adjoining land belonging to John Jones. No pits were observed on this place at the time of visit (October, 1917), but a low mound of yellow clay at one locality indicates that prospecting was done here many years ago. As stated above a part of a carload of manganese ore shipped 25 years ago from this vicinity was picked up from the surface of the land now owned by Mr. Jones. The Erwin quartzite dipping 40° S. is exposed in a gully at the south base of Sand Mountain and the residual clay of the Shady crops just to the south but is covered almost everywhere by surface wash. A few pieces of hard slightly porous psilomelane weighing several pounds each were found widely scattered on the surface. They are said to occur here and there over an area of several acres.

DUNTFORD PROSPECT.

A deposit of manganiferous iron ore occurs on the G. W. Duntford place near the tops of the hills on the divide between Painter and Cripple creeks, 1 mile southeast of Catron, the first station west of Ivanhoe on the Cripple Creek Branch of the Norfolk & Western Railway. These hills attain the general level of the Cripple Creek Valley floor which is about 2,400 feet above sea-level in this vicinity.

The deposit was worked 15 or 16 years ago by W. A. Wood & Son, and some ore was shipped after it was hauled in wagons to Ivanhoe. The openings consist of a number of shallow pits, all within about an acre. They are in red residual clays of the Shady dolomite. Many exposures of the Shady are near-by but they are not always lower on the slope than the pits. This seems to indicate that the upper surface of the unweathered dolomite is irregular, as shown at the zinc mine at Ivanhoe and the Little Wythe iron mine near Cripple Creek station. The dolomite just south of the pits is nearly flat-lying but the dips at the other outcrops were not determined. There, however, appears to be an anticline in this vicinity bringing to the surface the lower beds of the Shady dolomite. The reason for this opinion is the occurrence on the surface of many massive boulders of porous yellow chert similar to that found near the base of the Shady.

The ore occurs in nodules and irregular masses up to several pounds in weight and consists of both red and brown iron oxide and psilomelane which may occur separately but are usually intimately mixed, even in the same masses. The ore appears to be in sufficient quantity to work as a manganiferous iron ore provided the manganese content is found to be high enough, but the following analyses of ore collected from this vicinity—from either this or the Sam Crozer farm described below—by McCreath and d'Invilliers[1] show that some of the ore contains a fair amount of manganese but is high in silica.

Analyses of manganese ore from near Catron, Va.

	a	*b*
Mn	37.314	35.835
Fe	6.700	5.075
P	.102	.103
SiO_2	15.070	16.610

a, Lump ore.
b, Wash ore.

CROZER PROSPECT.

Many shallow pits that have been made in prospecting for iron ore are on the Sam Crozer place, now owned by the Virginia Iron, Coal & Coke Co., 3 miles west of Ivanhoe on the divide between Painter and Cripple creeks, just east of the Duntford place described above. The hills in this vicinity as on the Duntford place attain the general level of the Cripple Creek valley floor, about 2,400 feet above sea-level. The pits are in the residual clay of the Shady dolomite, several exposures of which are found near the prospected area. The structure of the Shady was not determine from the dips of the exposed ledges but the occurrence on the surface of boulders of porous massive chert, a variety commonly found in the lower part of the Shady, suggests that there is an anticline bringing this part of the Shady to the surface. The nearly eastward alignment of the chert boulders indicates that the supposed anticline which is the same as the one on the Duntford place trends in this direction. The prospected area is just north of the belt of chert boulders and thus north of the supposed anticline.

Brown and red oxides of iron, mainly the former, are the most abundant minerals but associated with them at places on the surface and in the pits there are manganese and manganiferous iron ores. The manganese ore comprises psilomelane, manganite, wad, and possibly pyrolusite, the first being most abundant. It occurs in pieces varying in size from minute grains up to 25 pounds. Although some manganese oxide is free from iron most of it is intimately mixed with iron oxide even in a hand specimen. The analyses of manganese ore from this vicinity are given in above table. A

[1] McCreath, A. S. and d'Invilliers, E. V., The New River-Cripple Creek mineral region of Virginia, p. 91, Harrisburg, Pa., 1887.

soft manganese oxide occurs in sufficient quantity in one spot several feet across to make the soil black in striking contrast to the red color found elsewhere.

Manganese and manganiferous iron ores were seen on this and the adjoining Duntford place through an east-west distance of about three-fourths of a mile.

EAGLE CLIFF MINE.

The Eagle Cliff mine is just northeast of the confluence of Fisher Branch and Cripple Creek and near Eagle siding on the Cripple Creek Branch of the Norfolk & Western Railway. It was worked as a manganese mine 20 or more years ago by the Eagle Mining Co., and 500 tons of ore are reported to have been mined and hauled in wagons to Ivanhoe where it was shipped.

The workings consist of two badly caved pits 200 feet above Cripple Creek and about 2,250 feet above sea-level, standing a little below the level of a broad dissected terrace. The Shady dolomite with a dip of only a few degrees to the east forms high bluffs both on Cripple Creek and Fisher Branch but several feet of the top of the Erwin quartzite with a dip of 10° N. 80° E. are exposed at the base of the bluff at the confluence of these streams. The dolomite ledges outcrop on the slopes above the bluffs to an elevation of 130 feet above these streams, and for 70 feet above them to the top of the terrace there are variegated residual clays of the Shady overlain by a few stream cobbles. The manganese ore occurs in these clays and consists mainly of hard steel-blue psilomelane in both small and large masses up to over 100 pounds in weight. Some of the masses are nodular, others are tabular, and still others are irregular and porous. A minute quantity of manganite is associated with the psilomelane. So far as the ore can be judged from that in and near the pits, it is free from iron oxide and quartz sand.

McCreath and d'Invilliers, who visited the mine about 30 years ago, describe the ore as follows:[1]

"The manganese ore occurs as black oxide, generally in small lumps; and while the developments are very meager, yet as far as could be seen both pits showed a considerable proportion of wash-ore. Inasmuch as the quality of the ore as shown by the analysis below is really quite good, and so little of this desirable ore has as yet been found throughout the region,

[1] McCreath, A. S. and d'Invilliers, E. V., op. cit., pp. 93-94.

the circumstances should warrant further systematic development of this territory; for abundant facilities exist near at hand for washing the ore material."

Samples of the ore from this locality gave the following analysis:[1]

Analysis of manganese ore from the Eagle Cliff mine.

Mn	46.215
Fe	2.550
P	.118
Silicious matter	3.010

GLEAVES KNOB PROSPECT.

Manganese ore is reported to occur on the south side of Gleaves Knob. In an attempt to find it three very small pits on the south side of the east end of the knob were visited. They are in soft sandstone, platy sandstone, and yellow clay, all of which appear to be near the top of the Erwin quartzite which forms the crest of the knob. Platy brown iron oxide was taken out of one of the pits and stains of manganese oxide were found on some of the sandstone fragments.

LITTLE WYTHE MINE.

The Little Wythe mine, which is operated as an iron mine by the Virginia Iron, Coal & Coke Co., is in a synclinal basin containing the Shady dolomite on Francis Mill Creek, 2 miles south of the village of Cripple Creek. The syncline lies between the quartzite ridge of Hussey Mountain and the front ridges of Iron Mountain. The ore is brown iron ore occurring in the residual clay of the Shady dolomite and is mined down to the irregular pinnacled surface of the hard limestone. Psilomelane as thin coatings was observed on a quartzite boulder at the mine, but Thomas Painter, the superintendent, says manganese ore is not found in commercial quantity at this or other mines in the vicinity.

PORTER BANK.

The Porter bank on the north base of Hussey Mountain, 1½ miles southwest of Cripple Creek station on the Cripple Breek Branch of the Norfolk & Western Railway, is being operated as an iron mine by the Pulaski Iron Co. R. K. Vaughn, the superintendent, says that a large pocket of soft manganese ore was found in the mine and that it had to be

[1] Idem.

avoided as much as possible to keep the manganese content of the iron ore down to the usual percentage of 2 per cent or less for this mine. The iron ore is brown iron oxide and is largely what is termed "shot-ore." It occurs in the residual clay of the Shady dolomite on the north limb of the anticline exposing Erwin quartzite in Hussey Mountain.

MINES NEAR SPEEDWELL.

In the vicinity of Speedwell are a number of iron banks or mines which have been worked at various times during a long period. They have been described by McCreath and d'Invilliers.[1] These mines, which include those formerly worked by the Cave Hill Co. and the Wythe and Speedwell Mining & Iron Manufacturing Co. and which were recently worked by the Virginia Iron, Coal & Coke Co., lie south of Speedwell both east and west of Dry Run. They are included in a tract of country underlain by Shady dolomite about 1 mile wide between quartzite mountains on the south, in which the Erwin quartzite dips north, and a ridge of Watauga shale in a synclinal axis on the north. In this tract, which lies on the general upland surface at about 2,700 feet above sea-level, the limestones are deeply decayed and are covered by a thick mantle of reddish residual clays. The ores are limonites, for the most part in nodular concretions and replacements in the residual clay. The iron ores in this tract seem generally to carry only a very small amount of manganese but in some banks the mining companies have at times encountered more richly manganiferous ore, particularly in the Cave Hill ore bank, which is about 1¼ miles southwest of Speedwell village. McCreath and d'Invilliers[2] state that "quite a conspicuous outcrop of ore is visible, sometimes showing a rather rich-looking dark-brown ore, but again a highly manganiferous variety, while occasionally almost pure pieces of the black oxide of manganese show through the deposit. Owing to these variations in the character of the ore, and the concealment of a large portion of the ore in place, it was deemed inadvisable to take any sample for analysis, as no correct idea could be formed of the relative proportions of the different ore masses which the bank might yield in regular mining operations. The bank was abandoned long prior to the stoppage of the furnace in 1884, largely owing to the excess of manganese found in the deposit, which caused the production of a white, brittle iron showing at times a cleavage quite similar to that of Spiegel.

[1] McCreath, A. S. and d'Invilliers, E. V., The New River-Cripple Creek mineral region, pp. 124-134.

[2] Op. cit., pp. 127-8.

"A sample of this metal was analysed with the following results:

Silicon	.140
Manganese	3.524
Phosphorus	.459

"This amount of manganese in the metal will give but little idea of the percentage in the ore, for it is quite likely that, with the low heat obtained in a cold-blast charcoal furnace, much of the manganese has gone into the slag."

The following analyses of manganiferous iron ores are quoted from the same authors[1] to show the character of ore from the Percival bank (A), 1 mile east of the Cave Hill mine, and the Andis bank (B), 1 mile west of the Cave Hill bank:

A

Metallic iron	51.175
Metallic manganese	.929
Sulphur	.005
Phosphorus	.197
Phosphorus in 100 parts iron	.384

B

Metallic iron	43.775
Metallic manganese	4.570
Phosphorus	.368
Silicious matter	17.320
Phosphorus in 100 parts iron	.840

According to the superintendent at the mines in October, 1917, manganiferous ores occur in these banks only in small and sporadic bodies.

HORNE PROSPECT.

On the property of R. M. Horne's heirs, which is 4½ miles south-southeast of Rural Retreat on the Norfolk & Western Railway, a showing of manganese ore has been prospected recently by the Bluestone Metal Mining Co., of Bluefield, West Virginia.

The prospect is one-half to three-fourths mile east of Grays Branch and one-fourth mile south of the Dry Road and on the crest of a narrow flat-topped ridge of Watauga shale at an elevation of about 2,500 feet. This ridge is one of a number of similar flat-topped shale ridges of like elevation in the Cripple Creek Valley, which are remnants of the old valley-floor surface. The prospect is opened by a line of pits and trenches through a distance of 120 feet and to a maximum depth of 12 feet. In these it is

[1] Op. cit., pp. 129-30.

seen that the shale is greatly decomposed and very soft but the characteristic vari-colored and thin-bedded features of the formation are preserved. The beds strike N. 85° E. and dip 85°-90° S. The ore zone is 2 to 4 feet wide trending east parallel to the ridge top and is greatly fractured. The shale in it is shattered by seams in various directions and divided into small blocks measuring at most a few inches. The fracture zone as a whole and the principal set of fractures dip 65° to 70° S.

The mineralization is by black manganese oxides, in part hard steel-blue psilomelane, and in part black soft granular ore, which occur as crevice fillings and as replacement of the shale along these crevices and penetrating inward from them. Iron minerals and iron stain are conspicuously absent. The fillings range in thickness from a mere film to 3 inches and the penetration and replacement of the shale shows the same range. Certain thin white (bleached ?) beds are free of ore, and dark-purple beds, notably one 15 to 20 inches wide, contain the richest replacements. Of these latter, some pieces are solid psilomelane and others are a network of thin psilomelane stringers, plates, and concretions inclosing residual clay or empty cavities.

The fracture zone as a whole is a rich manganese ore but it is too small to yield a large tonnage and could probably not be worked at a profit.

WINN PROSPECT.

The prospect on the Winn estate is 1 mile north-northwest of Cedar Springs and 3½ miles south-southwest of Rural Retreat on the Norfolk & Western Railway. The property was being prospected at the time of visit (October, 1917) but had also been previously opened.

The workings are at the low east end of a quartzite ridge which is a spur of Glade Mountain several miles long. Aligned with this ridge is another quartzite ridge about one-fourth mile to the east, which is low and not over one-half mile long. The prospect is in the western part of the saddle between these ridges, on an area of Shady dolomite.

The pits and cuts lie between 2,600 and 2,700 feet above sea-level on the east end slopes of the ridge. Seven prospect pits follow a line trending N. 60° W. and two others are 500 and 900 feet north-northeast of this line. Of these the three highest passed through clayey soils and stopped in coarse friable sand which is the weathered topmost bed of the Erwin quartzite. Several old shallow pits still higher up show only quartzite, and the crest of the ridge is covered with heavy coarse débris from the Erwin formation. All other openings show, below 2 to 3 feet of reddish clayey soils containing quartzite débris, residual clays of the Shady dolomite containing ore and fragments of decomposed chert. It is apparent that the sandstone or quartzite dips easterly at a greater angle than the slope of the end of the ridge, so that lower down the slope the greater is the depth to the quartzite. The Erwin quartzite ridge trends S. 70° to 80° W. Its structure is probably (though not definitely because no outcrops afford strike and dip) anticlinal, plunging eastward on a pitch of 20° or more. The prospect is on the east nose or end of the anticline.

The ore materials are manganese oxides—psilomelane, soft granular earthy black wad or pyrolusite, and manganite—and a very small quantity of iron oxide found at a few of the openings. Psilomelane is by far the most abundant ore. The soft ore, wad or pyrolusite and manganite, were noted only at one pit, a narrow circular shaft 25 feet deep. The soft ore seems to be in small masses well distributed through clay, and with it is associated some cavernous lumps of crystalline manganite ore. The ore constitutes about one-seventh to one-fifth of all the material removed from this shaft. The psilomelane is in irregular nodular and tabular masses which have mammillary or botryoidal surfaces. It is hard, compact, and usually steel-blue and contains in places a few sand grains. Many pieces are visibly concentrically lamellar, parallel to the botryoidal surfaces and a few are marked by fine parallel straight laminations which are traces of the laminations of the clays by the replacement of which the manganese nodules were formed. The largest opening on the property, a cut 60 feet long and 12 feet deep at its face, gave opportunity for studying the ores in place. In this cut, beneath an overburden 2 to 3 feet thick of dark-reddish clay soil containing some ore nodules and quartzite débris, there are undisturbed brick-red and umber clays, residual from the Shady dolomite, containing very abundant large and small botryoidal nodules and tabular masses of psilomelane, many of these weighing 40 to 50 pounds and a few as much as 75 pounds. In one part of the opening are fragment and blocks from 3 inches to 2 feet in size of flint with drusy cavities and also a little soft black manganese oxide. The ore masses are of various shapes but most commonly flattish and are irregularly distributed, but many of the ore nodules are aggregated into tabular or sheet-like bodies embedded in the clay. The most prominent of these dip 30° NE., perhaps parallel to the bedding of the limestone, and others lie in steeply-dipping planes which may mark joints. Some of the psilomelane nodules are traversed by minute seams of secondary psilomelane, like septarian concretions, and fracture surfaces and cavities are lined with films of brownish-black soft manganese oxide of velvety appearance.

The manganese content of the ground is, as indicated by the openings, high enough for profitable working provided the deposit has sufficient area and depth. Except for distance from ample water supply, the situation is favorable for mining.

SMYTH COUNTY.

PROSPECTS NEAR CAMP.

Several deposits of manganese minerals, some of which are noted below, occur near Camp post-office on the east border of Smyth County.

Pieces of psilomelane weighing less than 1 pound and a small quantity of red and brown iron oxides were observed in red clay on a slope just back of C. L. Jennings' house. The clay at this locality is residual from the lower part of the Shady dolomite. No prospecting has been done here.

A deposit of massive brown iron ore, from which ore was hauled many years ago to the White Rock Furnace 3 miles north-northwest, is between one-eighth and one-fourth mile south of Camp. No manganese minerals were observed at this locality.

A small quantity of shaly manganiferous iron ore was removed a number of years ago from a shallow pit about one-fourth mile southeast of Camp.

Manganese oxide has been found in shallow openings on the east end of a ridge on the Haywood place one-half mile southwest of Camp. It is present in small quantity and is associated with brown iron oxide. These oxides cement together fragments of the Erwin quartzite which has been much crushed at this locality.

Manganese ore is said to occur on the north side of the ridge between Camp and the Roberts place described below. None of them were visited as but little if any prospecting had been done on them.

ROBERTS PROSPECT.

Recent prospecting has been done on the W. B. Roberts farm on the headwaters of Cripple Creek 4 miles east of Sugar Grove on the Marion & Rye Valley Railway. Iron and manganese oxides were found in several of the pits that were visited and at one place in a near-by field. The manganese oxides comprise wad, manganite, and psilomelane, mainly the last, and in places appear to be present in minable quantity. The psilomelane is hard, free of iron oxide, and somewhat porous, and occurs in small pieces up to several pounds in weight. The manganite is present as small crystals scattered through the psilomelane.

The ores are in red residual clay of the Shady dolomite on the north side of the quartzite ridges of the mountain front.

UMBARGER MINE.

The Umbarger mine is on what is known as the Umbarger land on the north slope of a nearly straight ridge 2 miles S. 75° E. of Sugar Grove on the Marion & Rye Valley Railway. The mine is at present operated by H. H. Green for the Manganese Products Co., of Philadelphia, Pennsylvania, and up to the time of visit (October, 1917) had yielded a total production of about 100 carloads of manganiferous iron ore.

The ore occurs in both small and large masses in variegated clays which are residual from the Shady dolomite and which at this locality are, as shown by a drill hole, 200 feet thick. Exposures of unweathered Shady dolomite are found on Cressy Creek between the mine and Sugar Grove and at numerous other places in Rye Valley. The Erwin quartzite forms the ridge south of the mine and was struck at a depth of 220 feet beneath the residual clay of the Shady in a drill hole at the mine. Its structure in this vicinity is not known as débris and residual clay conceal the rock strata at most places. On the ridge crest to the southwest the Erwin quartzite strikes N. 80° E. and appears to dip 70° SE. and on the crest to the southeast it dips 70° N. 30° W. It yields an abundant débris of sand and boulders up to several feet in longest dimension which in places near the mine cover the clays to a depth of 20 feet or over.

A few hills and spurs at and near the mine are between 3,000 and 3,100 feet in elevation above sea-level and taken together form a high dissected bench on the north face of the ridge. This bench is probably everywhere underlain by residual clay of the Shady dolomite but is capped by sand and large quartzite boulders. It is presumably the remnant of an old peneplain surface higher than the valley-floor plain. The mine workings, consisting of a cut 200 feet long, 100 feet wide at the widest place, and 100 feet high at the face, and of a number of smaller pits and trenches, are on or near the surface of this bench. The floor of the large cut from which the ore was being mined at the time of visit was about 3,000 feet above sea-level.

In the southwestern part of the large cut a thin layer of nearly horizontal black carbonaceous sticky clay overlies the manganese-bearing clay. It is 2 feet thick and merges upward into clayey white sand, 1 to 2 feet thick, which is covered by sand and quartzite wash to a depth of 16 feet. The carbonaceous black clay contains abundant macerated remains of plant stems and leaves and fragments of wood and pine cones. It also contains a number of concretions of earthy siderite up to 1 inch in diameter. It evidently represents a deposit in quiet ponded waters on an old peneplained surface in which wood and leaves from the adjacent slopes were deposited with the fine mud, and all was later covered by the coarse wash from the mountain brought down by the stream in the near-by ravine. Mr. F. H. Knowlton, of the U. S. Geological Survey, in reporting on the organic remains collected, states:

"The cone belongs to *Pinus strobus* Linné, the well-known white pine that was so widely distributed over eastern North America. It ranges from Newfoundland to southern Pennsylvania, and along the mountain belt to northern Georgia. South of Pennsylvania it is smaller, which probably accounts for the small size of this cone, 4 inches long. *Pinus strobus* has previously been reported from the Pleistocene of the Don Valley, Toronto, Canada, and from the Talbot formation at Bodkin Point, Maryland. I see no reason, except that the material is not compressed or distorted, why the specimen from Sugar Grove might not be referred to the Pleistocene and I am strongly inclined to do so. The wood appears to be coniferous and probably pine wood."

The residual clays are white, yellow, red, brown, and black in color and are stiff and laminated, but here and there they contain small lenses of white and yellow sand and in the northeast part of the large cut there is a large mass of friable yellow sandstone containing small quartz pebbles. The sand in this mass and the lenses is believed to have been carried by streams into channels or sink-holes in the dolomite before it decomposed.

Most of the ore consists of a porous mixture of psilomelane and brown iron ore. A small quantity of wad is associated with some of the psilomelane and a little red iron ore occurs near the surface. The percentage of manganese, as is indicated by the character of the ore in the cut and by chemical analyses, increases with depth. The average manganese content of the ore shipped in 1917 is about 24 per cent, whereas it was less in previous years when the ore was obtained at less depth. The iron content of the ore averages close to 30 per cent; the silica content ranges from 6 to 8 per cent; and the amount of phosphorus ranges from 0.151 to 0.227 per cent, the average being 0.19 per cent.

These ores occur in large pockets and masses and as small fragments and concretionary nodules in the variegated clays. The pockets and masses comprise most of the ore; those visible in the large cut are several feet across, but it is reported that one mass penetrated by a drill hole is 26 feet thick vertically and another 15 feet thick.

The sandstone mass in the northeast part of the cut contains thin veins of manganese and iron oxides and is partly replaced by these oxides.

The two drill holes referred to above are near the south edge of the large cut and are 45 feet apart. The top of the one to the northwest is about 3,015 feet above sea-level. Its log is as follows:

Log of drill hole at Umbarger mine.

		Depth in feet.
1.	Quartzite fragments and sand	0–20
2.	Low-grade iron ore	20–22
3.	Manganiferous iron ore	22–48
4.	Light-colored clay	48–75
5.	Good grade manganese ore containing over 40 per cent manganese	75–90
6.	Clay	90–220
7.	Hard sandstone containing scattered gravel	220–226

Layer No. 1 is probably all surface wash. No. 7 is the top of the Erwin quartzite. The intervening part of the log is ore-bearing clay that is residual from the basal beds of the Shady dolomite.

The top of the other drill hole is 3,025 feet above sea-level. Its log is said to be exactly like that above except that it is 202 feet deep and did not reach the Erwin quartzite.

The manganese deposits as shown by the number of openings are scattered over an area of several acres. The ore is mined with two steam shovels and conveyed on a narrow-gauge tramroad about a mile to the mill near Cressy Creek. The mill was being remodeled at the time of visit so that when completed it will have a daily capacity of 300 tons and will be equipped with a log washer containing 4 30-foot logs, 8 four-compartment Harz jigs, and storage bins of a capacity of 750 tons. The larger pieces of ore are hand picked. After the ore is milled it is hauled on a narrow-gauge tramroad from the mill to Sugar Grove about a mile away where it is transferred to freight cars for shipment. Water is brought to the mill by a flume from Cressy Creek.

UMBARGER PROSPECT.

The Umbarger prospect is on the headwaters of Cripple Creek on the east end of the Umbarger land about 1½ miles east of the Umbarger mine. Some work was done here a number of years ago and new work was being done at the time of visit (October, 1917). The openings which consist of pits and cuts over an area of a few acres penetrate yellow and dark residual clays of the lower part of the Shady dolomite. There are no exposures of unweathered Shady in the vicinity but the Erwin quartzite is exposed in the ridges to the south and in the small stream that flows just east of the prospect. There the Erwin has a low dip to the north.

The ore consists of hard psilomelane in small concretionary masses and in larger masses the size and shape of which could not be determined on account of the lack of exposures. The largest piece of psilomelane that was observed weighed close to 50 pounds. The ore is free from iron oxide but much of it contains some quartz sand. Most of it is compact; only a little is porous. The quality and quantity of the ore seems to warrant further prospecting. The stream that is near-by would probably afford sufficient water for washing the ore during all seasons except those of light rainfall.

HORN PROSPECT.

Three very small old pits are in a field underlain by Shady dolomite on the Horn place half a mile south of Sugar Grove. Red and brown iron ores were seen on the dumps. The only manganese observed at this locality was a 2-pound piece of psilomelane that was found on the surface near one of the pits.

CATRON PLACE.

Manganese ore in small pieces is reported to occur at a number of places near the home of Charles Catron, 1 mile south of Sugar Grove, but none was observed at the time of visit to this locality. Small pieces of manganese and iron oxides were seen at some very old shallow pits in a chestnut and maple grove about one-fourth mile east-northeast of Mr. Catron's house. The area in which the manganese was observed and reported to have been found is underlain by the Shady dolomite, but the dolomite is overlain by its residual clay and the clay is in turn overlain by surface wash consisting of sand and quartzite fragments. The Shady here lies in a northeastward-plunging syncline which is skirted on the south and southwest by Quarter Ridge and on the northwest by a rocky wooded hill, both of which are formed by the Erwin quartzite.

NELSON PROSPECTS.

The Nelson prospects comprise 3 small openings on Quarter Ridge 1¼ miles south of Sugar Grove. The ore consists chiefly of brown iron oxide occurring as narrow veins and partial replacements in a pebbly bed a few feet thick at the top of the Erwin quartzite. Only a very small amount of soft manganese oxide was observed at the time of visit. The Erwin at and near this locality forms a northeastward-plunging syncline. Near the two openings farthest southeast the strike is about N. 80° E. and near the one farthest northwest it is N. 10° W. The dip was not determined at any place in the vicinity.

ROCK BANK.

The Rock bank is just south of the crest of a ridge over 3,000 feet above sea-level, 2 miles southwest of Teas on the Marion & Rye Valley Railway. It was worked as an iron mine a number of years ago but a year or two ago a small amount of work was done and one carload of manganiferous iron ore was shipped. The ore was shipped as it came from the mine without being washed to free it entirely from the clay in which it is embedded. The workings which consist of a number of cuts and pits, all within an area of several acres, penetrate the residual clay of the base of the Shady dolomite. The usual color of the clay is yellow but at the surface it is bright red and in the lower part of the workings much of it is dark colored. Boulders of pebbly ferruginous quartzite from a bed that occurs at the top of the Erwin quartzite cover the crest of the ridge north of the openings and mark the approximate location of the crest of an anticline which here trends S. 80° E. parallel with the ridge. As is represented on Plate III the Rock bank is on the north edge of a synclinal basin surrounded by Erwin quartzite.

The manganese and iron ores occur in the form of veinlets, small nodules, and irregular masses up to several inches in their longest dimension scattered through the residual clay, from the surface down to the bottoms of the workings which are only a few feet deep.

Only brown iron ore is in the openings farthest west, whereas both iron and manganese ores either in the same or separate masses are in the other openings which are lower on the ridge. The manganese ore consists entirely of steel-blue psilomelane most of which occurs in nodular masses with irregular botryoidal surfaces but some of which occurs in stalactitic forms. A small quantity of chert at this locality is partly replaced by manganese and iron oxides. Although this deposit is not extensively explored it appears to be promising enough to warrant further prospecting on the south slope of the ridge and possibly at other places in this synclinal basin. The ore would require washing to free it of the clay. An abundant supply of water for such purpose is furnished by Comers Creek about 1 mile west of the mine and by South Fork about 1½ miles to the north. Hand picking would doubtless yield some manganese ore of a grade good enough for the manufacture of ferromanganese.

WHITE ROCK FURNACE BANKS.

The valley that is west of White Rock Furnace lying between White Rock Mountain and the ridge about three-fourths of a mile to the south contains deposits of manganese and iron ores. It is synclinal and is underlain by the Shady dolomite, whereas the ridges on the north and south are anticlinal and are formed by the Erwin quartzite.

Two old iron-ore banks about one-fourth mile apart are on the north side of the valley about 2 miles west of White Rock Furnace. The banks are in cherty residual clay of the Shady dolomite and contain both red and brown iron ores and a very small quantity of psilomelane which occurs both in masses by itself and in masses mixed with iron oxide.

Hard manganese oxide in pieces weighing less than a pound were observed in the trail leading west up the valley, about 3 miles west of White Rock Furnace.

GLADE MOUNTAIN MINE.

The Glade Mountain mine on the property of the Glade Mountain Lumber Co. is about 3 miles west-northwest of White Rock Furnace and 4½ miles southwest of Rural Retreat on the Norfolk & Western Railway. The deposit was opened up and some ore hauled to Rural Retreat for shipment several years ago.

The mine is situated at about 3,000 feet above sea-level near the summit of a ridge of Erwin quartzite, which there consists of interbedded layers of coarse pebbly grit, sandstones, and fine shaly sandstones. This ridge extends eastward 4 miles and ends at the Winn prospect described on page 140. Immediately north is the higher, more massive quartzite ridge called Glade Mountain, and to the south is a long, narrow synclinal valley whose lower part is occupied by Shady dolomite.

At the mine there is a narrow shelf or terrace formed by the erosion of brecciated quartzite. The brecciated zone is about 100 feet wide and trends easterly. On this zone there are a number of prospect pits but only the large mine opening and a few pits above it, all included in 2 or 3 acres, show any notable iron and manganese mineralization. The large opening is an irregular hillside cut 100 feet wide, about 50 feet into the hill, and about 30 feet high at the face. The entire surface exposed by the cut is in manganiferous material, most of which is ore. This consists of brecciated fine and coarse sandstones and shaly sandstones which have been impregnated with manganese oxides and limonite. The central part for 10 to 15 feet along the side of the pit is chiefly solid hard ore. A capping, which conforms to the slope and is in places about 15 feet thick and in others about 5 feet thick, is loose and softer material. The ore materials are in the main replacements of the rock by manganese oxides and by brown iron ores. The coarser sandstones are replaced chiefly, if not solely, by manganese oxide, blue-black psilomelane for the most part. This replacement is in nodular concentric concretionary form and in some parts is complete; in other places pieces of sandstone and much granular silica remain within the psilomelane masses. The finer-grained sandstones and softer shaly material have been replaced by both iron and manganese oxides, chiefly limonite and soft granular pyrolusite or earthy wad. There are abundant patches or layers of soft reddish clay which contain small particles of manganese ore. All of the ores, but principally the hard replaced sandstones, are traversed by veins and contain cavities in which there are fillings of hard blue steely psilomelane in lamellar and mammillary or botryoidal form. The masses of psilomelane of this type are of various thicknesses up to 4 or 5 inches. Cavities in the ore generally have a limonite coating, and limonite veins from 1 to 3 inches wide are common in all types of ore. In a few places the workings have cut through ore into soft clay, suggesting that the deposit as a whole may be a thin surficial cap. As the area of the deposit also seems to be small, there is little probability that it will yield more than a small quantity of ore fairly rich in manganese but rather siliceous.

PIERCE PROSPECTS.

Prospects on the farm of J. C. Pierce are on the west side of Slemp Creek about 1¼ miles northeast of Sugar Grove, south of Hickory Ridge. West of Pierce's Branch and at the base of the ridge some shallow pits in residual clay of the Shady dolomite show psilomelane nodules and iron ores. Directly north of these are ledges of brown drusy flint, ferruginous in places, such as are commonly seen near the base of the Shady dolomite. On Pierce's Branch several prospect pits have been opened in ferruginous breccia zones within the quartzite of Hickory Ridge, from one of which 4 carloads of brown iron ore have been shipped. No manganese was seen in the material from the openings.

Another prospect on the west side of Slemp Creek near its forks discloses coarse sandstones or grits cemented by iron oxides and fine sandstones and shales largely replaced by iron oxides. The materials have much the same appearance as those at the Barton bank (p. 153), except that no manganese ores are visible.

One mile above the mouth of Slemp Creek and a mile east of the creek at the end of a quartzite ridge some slightly manganiferous brown iron ore lumps have been thrown out of a shallow prospect pit.

BISHOP MINE.

The Bishop mine, operated by H. H. Green for J. E. Baum, of Philadelphia, is in Hickory Hollow, 1 mile north-northwest of Sugar Grove and 1 mile by fair wagon road from Sugar Grove Station on the Marion & Rye Valley Railway. The property is owned by Sam Forney, of Pulaski, and M. M. Caldwell, of Roanoke, and had been prospected by pits during preceding years but active development began in 1917.

The property is in an open basin about 1½ miles long and one-half mile wide at the mine. The basin slopes to the west and has a general elevation of 2,600 to 2,700 feet. It lies between Middle Mountain on the north, a part of Brushy Mountain 3,000 feet high, and Hickory Ridge on the south, 2,850 to 2,900 feet high. These ridges merge to the east and close the basin.

The western end of Hickory Ridge, also called Sheep Ridge, narrows and declines gradually westward terminating northeast of Teas, near which town the Hickory Hollow basin joins Rye Valley—the headwaters basin of South Fork of Holston River. The floor of Hickory Hollow is a gently rolling surface underlain by residual clays of the Shady dolomite, and around the margins is strewn with boulders of quartzite. Brushy and Middle mountains and Hickory Ridge enclose the hollow with steep rocky walls on the north and south and more moderate but débris-covered slope on the east. These slopes are of Erwin quartzite which dips toward the basin under the limestone-derived clays. Middle Mountain and Hickory Ridge are diverging anticlines and the hollow between is a syncline, both plunging slightly to the west, at 150 feet to the mile or about 3° to 5°. The mine is situated where the stream in Hickory Hollow turns south through a gap in Hickory Ridge, and is at an elevation of about 2,550 feet.

The workings in October, 1917, consisted of an irregular pit about 100 feet long by 50 feet wide and 40 feet deep. A small hole 50 feet deep 600 feet farther upstream showed ore at the bottom but was not being worked. The material in the upper portion of the north and west walls of the main pit, to a depth of 1 to 2 feet and locally 6 to 9 feet, consisted of clay, sand intermingled with quarzite boulders, and lumps of ore. The lower portion of the walls and the floor of the pit were residual clay of the Shady dolomite mottled and banded with red, brown, yellow, and white, containing a few small fragments of chert and some sand lenses and ore nodules.

The upper part of the opening shows bouldery material disturbed by creep and mixed with surface wash. The underlying material is clearly in place. Both iron and manganese ore are present as nodules in so-called pockets of all sizes from minute particles to large irregular cavernous masses several feet across. The ores seem to constitute upwards of a fifth of the material in the cut below the zone of surface wash, but there are probably wide differences in yield of the ground, some of it being lean whereas locally ore masses are very abundant.

The iron ore consists of red and brown oxides which usually occur in lumps or masses distinct from the manganese nodules or concretions. Some pieces of iron ore, however, are cut by veinlets of psilomelane. The iron ore appears to be more common in the upper part of the pit while manganese ore has been found in greater abundance in the lower part. The foreman reported that large masses of ore in the floor of the pit (October, 1917) were free from iron ores.

The manganese ore occurs in small nodular concretions and large irregular cavernous masses, some of which are 2 to 4 feet across. By far the larger part is steel-blue psilomelane; the rest is wad and crystalline, granular manganite. Some good specimens of manganite druses have been obtained from the mine. For the most part the manganese nodules and lumps are free from iron minerals, but some contain druses lined with thin coatings of iron oxides.

Up to the time of visit 60 carloads of ore had been shipped. Most of this was manganiferous iron ore but a part was manganese ore obtained by hand sorting. A carload of manganese ore shipped is reported by H. H. Green to have given the following analysis:

Analysis of carload lot of manganese ore from the Bishop mine.

Mn	47.89
Fe	5.14
P	.156
SiO_2	4.12

The fact that the mine is located in a gently plunging syncline floored with residual clay from Shady dolomite lends hope that the ore deposit may be large, as the structure is favorable for the accumulation of ore. It has, however, not been thoroughly tested by boring.

In the fall of 1917 the pit was being dug with pick and shovel. All material handled was hauled by cable in small wooden cars up a short incline to a dumping platform and grizzly above a small double-log washer.

From this the washed ore passed through a perforated iron trommel. Oversize was hand sorted into manganese ore, iron ore, and waste. Undersize was stocked as manganiferous iron ore. Water for washing the ore was obtained through a flume from a creek. A new mill was being built and was to be equipped with larger log washer, trommels, and Harz jigs.

WRIGHT OR TATE BANK.

The Wright bank, or old Tate property, is between Brushy and Middle mountains, at an elevation of about 3,000 feet on the divide between the west prong of Slemp Creek and Georges Branch, 2 miles north of Sugar Grove. It was worked during the Civil War as an iron mine, but about 15 years ago attention was directed toward the manganese ores, of which some 15 or 20 carloads were shipped. The bank is known as the old Tate mine. It is in cherty residual clay of the Shady dolomite lying in a trough-like syncline between Brushy and Middle mountains, which are anticlines of Erwin quartzite. The ore, as shown in the old pits and cuts, is brown iron ore and porous hard steel-blue psilomelane, both of which occur in masses at least several feet in diameter. Some of the openings contain iron ore free from manganese and some contain manganese ore free from iron, but in places the two are mixed. Some of the iron ore is cut by veinlets of psilomelane, showing that the psilomelane in such places was deposited later than the iron. A small quantity of the psilomelane occurs in small irregular masses over which are numerous nodular projections.

The property, comprising 1,600 acres, has recently been further prospected, and the showings of manganese ore were regarded so attractive that in the summer of 1918 a company of Tazewell and Bluefield business men bought the property intending to operate it as a stock company. At the time of visit (October, 1917) the showing in the pits did not appear favorable, and, although reports of recent developments show that encouraging samples of good ore were struck, there does not seem warrant for the anticipation of an unusually rich deposit.

WARD PROSPECT.

The Ward prospect is 2 miles north-northwest of Sugar Grove at an elevation of about 3,200 feet on the south slope near the summit of Brushy Mountain. This prospect is on a small tract between the Wright property on the east and the Barton property on the west. The showing is in the Erwin quartzite which in that vicinity has a general southerly dip. The quartzite beds exposed appear to belong to the upper part of the formation. Two openings were seen at the time of visit, October, 1917. The walls of both had caved in so that local features were badly obscured. The prospect seems to be along a zone of faulting, which trends about S. 70° W., in which the rocks are much crushed and brecciated. The lower, eastern cut was 4 feet wide by 40 feet long and about 4 feet deep, and seemingly exposed the full width of the crushed zone. The ore material on the dump is red and brown iron oxides cementing and replacing brecciated, fine-grained flaggy sandstone. Ore sorted out in a pile on the dump consisted of sandstone which had been minutely shattered and which had been cemented and largely replaced by iron oxides. Some of the more completely replaced lumps are traversed by small seams of psilomelane and contain druses lined with that mineral. At best the ore is slightly manganiferous iron ore and the quantity available is probably small.

BARTON BANK.

The Barton bank is 1¾ miles northwest of Sugar Grove and 1¾ miles north-northeast of Teas. It is on a western tributary of Georges Branch at an elevation of about 2,900 feet. Many years ago ore was hauled from the bank to an old forge in Rye Valley. The mine is in a hollow on the south slope below a high knob of Brushy Mountain. This hollow is part of the synclinal trough extending westward from the Wright bank to a point about 2,000 feet west of the Barton bank. The surrounding area is all underlain by Erwin quartzite, seemingly the upper beds of that formation. It is not improbable that some remnants of the basal part of the Shady dolomite are preserved also in this part of the syncline, but none was seen in outcrop and débris had slumped into the mine pits so that at the time of visit, October, 1917, bedrock could not be seen. Examination of the dumps disclosed brown iron ores in lumps up to 18 inches and 24 inches in diameter. Most of this is siliceous and clayey, the ore having the appearance of ferruginous chert, and replaced fine-grained sandstones and shales. Very probably better grades of ore had been entirely removed, leaving only lean stuff on the dumps. A large pile, seemingly sorted out or rejected manganiferous material, contains lumps of massive brown ore and abundant fragments of sandstone and grit or fine-grained conglomerate in which grains or pebbles reach one-fourth inch in diameter. In most of these the matrix, or cement between grains and pebbles, is entirely or very largely manganese oxides; others are cemented by iron ores. Both the brown ores and the manganiferous and ferruginous sandstones are much fractured or brecciated and the fractures are more or less completely healed by veins of hard black psilomelane. Some of these veins have drusy cavities and show botryoidal surfaces on the psilomelane filling.

PUGH AND HULL BANKS.

On the Pugh and Hull tract which covers a large area northwest of Sugar Grove and north of Teas are a number of old pits and banks which supplied iron ore to an old forge on Holston River below Sugar Grove. The banks are all in the westward prolongation of Hickory Hollow syncline and appear to have been opened in residual clays derived from the Shady dolomite. Some of the ores are reported to be manganiferous, particularly that from a bank near the end of Sheep or Hickory Ridge. Only the Red bank was visited in October, 1917. Here are a number of old openings at the edge of the valley and just below the lower slopes of Brushy Mountains, at elevations of 2,650 to 2,700 feet and eight-tenths of a mile north of Teas. This bank was worked for iron ore. Under an overburden of 2 to 3 feet of gravelly and sandy clay containing quartzite boulders and a little ore, the residual clay is in place. This is for the most part dark red but in part ocherous and white. In it are embedded nodules of brown iron ore which, so far as could be determined by inspection, contain no manganese seams or replacements. No nodules of clean manganese ore were found.

CALHOUN PROSPECTS.

On G. T. Calhoun's farm one-half mile north of Teas on the Pugh Road two groups of small prospect pits have been made to test showings of manganese ore discovered in cultivated fields.

The prospects are in the Rye Valley area of the Shady dolomite about one-fourth of a mile south of the base of Brushy Mountain and in the prolongation of the Hickory Hollow basin. They are about 2,500 feet in elevation. A pit near the road in a small swale and 25 feet above the bed of an intrenched stream shows 1 to 3 feet of sandy overburden (slope wash) and 5 feet of residual clay in place. The soils and overburden are deep red and contain a few small iron and manganese lumps. The red residual clay is crowded with lumps and nodules of manganiferous brown iron ore. These ore lumps contain veins of psilomelane and drusy cavities lined with manganite crystals. There are also present in the clays small patches of soft granular manganese oxides. Probably about 40 per cent of the material is ore but of this the manganese content probably is less than 10 per cent.

A group of pits 100 yards northeast at the bottom of a ravine bank show under a heavier overburden of stream gravels residual clay with ores like those above noted and also some small nodules of clean psilomelane. The tract is worthy of very careful and systematic investigation.

MINES AND PROSPECTS IN CURRIN VALLEY.[1]

Currin Valley is an intermontane valley which lies south of Pond Mountain, the front ridge of the mountains southeast of Marion. The valley

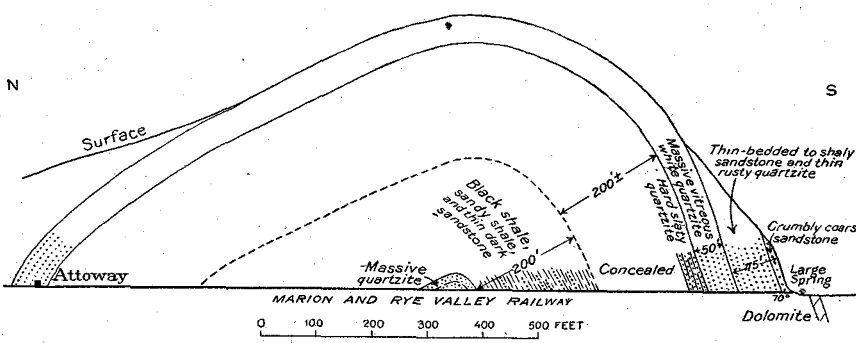


Fig. 15.—Sketch geologic section of Pond Mountain along the Marion and Rye Valley Railway southeast of Attoway, Smyth County, exposing Erwin quartzite in an anticline.

is about 5 miles long in a northeasterly direction, and averages 1 mile wide. Its floor is rather level and flat bottomed, and stands at about 1,600 feet above sea-level. The valley is drained by Staley Creek northwest through a rocky gap in the front ridge, which opens about midway of the length of the valley. Staley Creek joins the Middle Fork of the Holston at Marion. The Marion & Rye Valley Railway follows up this creek from Marion into Currin Valley, and around the head of the west branch of Staley Creek to an elevation of 3,000 feet on a low divide on Brushy Mountain and thence into Rye Valley south of Brushy Mountain, on the headwaters of the South Fork of Holston River.

In the gorge through the front ridge, Pond Mountain is seen to be an anticline exposing the white Erwin quartzite on its flanks, a thin dark shale beneath, probably within the Erwin, and a massive thick-bedded dark quartzite, which is probably the lower part of the Erwin, barely exposed at the center of the arch. (See fig. 15.)

[1] Description of deposits in Currin Valley and southwest of Marion are by G. W. Stose.

Brushy Mountain south of Currin Valley is composed of a group of several sharp folds, some of which are faulted. At least one of the faults is a thrust fault of large horizontal displacement and cuts diagonally across Currin Valley near the middle, so that the structure east of the gap differs from that west of the gap. Currin Valley is a syncline and is underlain by limestone and shale or their clay residuum. The syncline rises toward the west so that south of Marion the Erwin quartzite is exposed at the divide between Pond and Rich mountains at an elevation of 3,160 feet. Rich Mountain is also an anticline and the quartzite on its eastward-plunging end may be seen on the Rye Valley Railway where it rounds the head of Currin Valley.

At Currin station, just east of the Currin Valley manganese mine, a quartzite spur from Brushy Mountain descends to the valley bottom and its end is cut through by the creek which reveals an anticline of Erwin quartzite, the section of which is shown in figure 16. Eastward this anti-

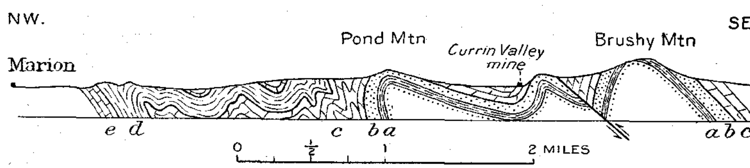


Fig. 16.—Section across Currin Valley at the Currin Valley mine, Smyth County. a, Shale and quartzite in lower part of the Erwin; b, massive white quartzite at top of the Erwin; c, Shady dolomite; d, Watauga shale; c, younger limestone.

cline is cut off by the diagonal fault which cuts across the synclinal valley to the Pond Mountain anticline at the upper end of the gap in the mountain. Currin Valley southwest of this anticline is therefore a closed syncline inclosing Shady dolomite which is exposed on the floor of the valley, and the structure is therefore favorable for the deposition of manganese ore.

CURRIN VALLEY MINE.

The Currin Valley mine lies just west of Currin station on the Marion & Rye Valley Railway and about 3 miles southeast of Marion. It is being operated by the Staley Creek Manganese & Iron Co., of which J. C. Buchanan, of Marion, is manager. Its workings lie chiefly on the south side of the valley close to the foot of the quartzite ridge and consist of several adjacent open cuts into the hill from the floor of the valley which together cover a length of about 200 feet. The two larger openings are each about 30 feet wide, 50 feet long into the hill, and 60 feet deep at the face. The mountain slope is covered by 5 or 6 feet of quartzite wash at the base of which there are large crusts of siliceous iron ore that make a thick hard ledge at the entrance of the cuts. The quartzite wash above the capping is partly cemented by iron and manganese oxides. The face of the cut is made up largely of red and yellow plastic clay with scattered manganese nodules, but it was so badly slumped in a month after work had been stopped that the original relations could not be determined. At one place a 2-foot bed of dense yellow ocher was underlain by 1 foot of black wad and this by a yellow clay in which were breccia-like masses of laminated gray clay streaked with manganese oxide. No large masses of ore were seen and apparently much clay must be handled to get the ore. It was reported, however, that about 4 carloads of ore a month were shipped when the mine was in active operation and that plenty of ore was still in the ground. The open cuts were operated by steam shovel. The mill is just below them, and the ore is hauled by wagon and dumped into the bin which feeds the log washer by gravity. The washed ore is delivered to tram cars on the company's tracks which connect the several openings.

Besides the two large cuts there are several small pits and trenches in the neighborhood. One exposes a large amount of siliceous iron ore in coarse sandstone wash; another, finely laminated yellow clay with manganese stains on the bedding planes which dipped 45° to 50° NW., and this overlay soft crumbly sandstone, apparently the top of the Erwin quartzite. The pits are all within 50 feet of the top of the Erwin. About one-half mile southwest along the foot of the same ridge a new open cut has been started by the same company. A layer of manganese and iron cemented wash had been struck near the surface and the steam shovel was cutting into the red and yellow clay beneath. Several prospects above the working exposed wad and hard psilomelane nodules in yellow clay. Chert fragments here extend to an elevation of 100 feet above the valley floor, beyond which the quartzite forms the steeper slope.

In the valley bottom, opposite the new open cut, there is a flat-topped hill 40 feet above the stream bottom which represents a higher level of the valley floor. The face of this was formerly mined for iron and manganese and exposed at the bottom fresh coarse gray dolomite, typical of the Shady. There are numerous fresh prospect pits on the top and sides of this hill out of which have been thrown large masses of good psilomelane and much iron ore. This is regarded by the company as one of their best showings.

East of this hill, where another part of the higher wash-covered terrace is preserved in the valley bottom many small pieces of manganese and iron ore occur with the gravel on the surface and some large masses of hard siliceous psilomelane, evidently cemented and partly replaced sand and gravel. Dolomite outcrops on the lower slope adjacent to the stream. This ground does not look so promising as the hill to the west, but it has not been tested by pits.

AMBURG MINE.

On the north side of the valley are many small prospect pits, and at one place near the station of Amburg, on the Marion & Rye Valley Railway, considerable ore has been mined by A. T. Short, of Marion, from ramifying trenches 25 feet deep in massive yellow clay. It will be referred to as the Amburg mine. A small washer was installed here and at the time of visit considerable washed ore was on the loading platform. It was largely red-coated nodular black manganiferous iron ore mixed with some manganese ore and the grade is therefore low. At other places on the north side ore has been taken out and several carloads shipped but it also is a mixture of red-coated nodular iron ore and psilomelane, and is of low grade. All the prospects on the north side lie on the lower slopes, as the upper slopes are deeply covered with quartzite wash and have not been prospected so far as known.

ATKINS MINE.

On the north slope of Brushy Mountain 1 mile southeast of Attoway on the Marion & Rye Valley Railway are some old pits from which considerable ore was formerly taken and which are now being further prospected by G. M. Atkins, of Attoway. It is under lease by parties from Bluefield, West Virginia, who recently dug numerous pits over the property and were preparing to wash a test carload of ore.

The pits are on a bench about 2,800 feet in elevation, just east of the Pugh road to Sugar Grove. The top bed of the Erwin quartzite crops at the foot of the steeper mountain slope with strike N. 65° E. and dip 75° NW. One hundred feet below on the slope the coarse round-grained porous sandstone bed in the lower part of the Shady dolomite outcrops, which is here dark with manganese impregnation but is not an ore. Ninety-five feet farther down the slope is the first prospect pit in red and yellow sticky clay with white seams, the laminations dipping 80° NW. Small lenses and seams of manganese ore follow the bedding planes. Below on the slope and out on the top of the bench are many shallow pits in yellow clay in which some manganese nodules occur and considerable red-coated manganiferous iron nodules mixed with quartzite wash in the upper layers. The surface of the bench and slope is covered with quartzite wash with which is mixed a large amount of float red-coated, black manganiferous iron ore, some of which is highly siliceous. An old pit near the top of the bench is reported to have yielded years ago a large mass of high-grade manganese ore. The newer prospects did not show much manganese ore at the time of visit, but more recent prospecting is reported to have struck other good pockets. The property, however, may be profitably worked only if the whole surface layer containing the nodular ore can be handled in an economical way, and the absence of abundant water in the near vicinity is a serious handicap for such low-grade ore.

The manganiferous iron ore and dark manganiferous soil at this horizon are exposed at several places in the fields along the mountain front and have been prospected a little on the Pugh road over Brushy Mountain southwest of the Atkins mine. At the summit of the mountain beside the Pugh road is a small opening showing good slickened red hematite and quartzite breccia cemented by manganese oxide. The ore is evidently along a small fault within the quartzite series but the high-grade iron ore is of very limited extent.

MARCHANT PROSPECT.

On the north slope of Brushy Mountain, 1½ miles east of Attoway, a prospect has been opened on the property of J. E. Marchant. The opening is at an elevation of 2,940 feet in a small valley back of a knob covered with large flints and cherts, probably near the base of the Shady dolomite. The Erwin quartzite crops a short distance southeast on the mountain slope. In the pit is deep-red soil at the surface and dry chocolate-brown clay below, highly jointed and slickened and containing red-coated manganiferous iron nodules, a little psilomelane in nodules, and some larger masses of brown iron ore. The showing of manganese was very poor. On the slope below, quartzite and chert fragments have films and thin coatings of manganese oxide.

PROSPECTS SOUTH AND SOUTHWEST OF MARION.

The area south of Marion adjacent to the South Fork of the Holston is made up of short parallel ridges which successively overlap in the valley to the west. The geology is intricate and consists of sharply plunging folds, most of the ridges being anticlines of Erwin quartzite the ends of which plunge under the Shady dolomite in the valley. The end of some anticlines are apparently faulted off. The sharp-plunging synclines between these anticlinal ridges inclose limestone or its residual clay and therefore have favorable structure for the accumulation of ore. It is not surprising that several prospects have been opened in this area, and when the region is more densely settled and more of the land on the lower slopes is cleared, other deposits may be found.

DEAN BRANCH PROSPECT.

Southwest of the head of Currin Valley the syncline between Pond and Rich mountains plunges gently southwest and the valley widens and is drained by Dean Branch of South Fork. The south side of the syncline apparently has several minor folds. At an elevation of about 2,750 feet, in an area in which large drusy cherts of the Shady dolomite strew the surface, a small pit has been opened in clay showing considerable good psilomelane. The Erwin quartzite crops on the mountain slope to the south. An old iron-ore pit near-by was opened years ago and the ore hauled to a local furnace. J. D. Perkins and A. T. Short, of Marion, are developing this property, but the prospecting has not progressed sufficiently to determine whether it can be economically worked.

ROLAND CREEK PROSPECT.

On the Peck property on the east side of Roland Creek, 3 miles south of Adwolf, some prospecting has been done by Thomas Bros., of Marion, who own the mineral rights. The prospect lies on the south side of a small knob of Erwin quartzite which is the southwest end of a quartzite ridge. The ridge is probably an anticline plunging southwest and faulted on its northwest side, although the bedding of the quartzite was not observed. Massive ledges of coarse dolomite below the prospect strike N. 65° E. and dip 65° NW. toward the quartzite, so there may be faulting or local folding here. There are several small pits on a bench at about 2,700 feet elevation between the dolomite and the quartzite outcrops. A tunnel that extends into the hill 20 feet exposes sticky clay with thin seams of manganese ore and red-coated nodules of black manganiferous iron ore and psilomelane. Similar ore is shown in the pits on the surface, but the quantity is small. The fact that a branch lumber road from the Marion & Rye Valley Railway has recently been extended near this property has increased the interest in it.

JERRYS CREEK PROSPECT.

Near the head of Jerrys Creek, 4 miles south of Adwolf, there is considerable prospecting on the Widner and Denton properties. The openings are on the south side of a small ridge composed of Erwin quartzite which strikes northeast, and is practically a continuation of the ridge at the Roland Creek prospect, although the break between suggests that the quartzite is faulted out. Several old pits 100 feet above the stream represent the mining of many years ago. Recent prospect pits in the vicinity made by parties from Marion have found a small amount of psilomelane in dark manganiferous soil and a few larger masses of ore but no large quantity. On the lower slope of the ridge there are large masses of brown jasper and quartzite breccia cemented by iron ore. The largest opening is a stripping of the slope near the stream level where a thick irregular layer of iron ore overlies clay, steeply dipping southeast toward the creek. The strike is N. 60° E. parallel to the ridge and the dip 50° SE. This is probably the bedding and the clay overlies the quartzite which forms the crest of the ridge. The rocks are slickened and brecciated and probably there was considerable movement along the bedding but no extensive faulting. The iron ore seems to have replaced the clay in part, changing it to a banded brown jaspery iron ore. With it are iron oxide with brilliant iridescent surfaces and bright red jasper specks. The lumber railroad is extended up Jerrys Creek past the property, so that transportation facilities are convenient should development prove worth while. The showings of manganese, however, give little hope for an extensive deposit.

HOPKINS CREEK PROSPECT.

Near the head of Hopkins Creek, 4 miles southeast of Adwolf, manganese and iron ore float are strewn on the north slope of a low quartzite hill, which is on the north side of the west branch of the creek. The soil is the characteristic dark manganiferous clay which accompanies ore at the base of the Shady. It has not been prospected so far as known. Nodular dolomite crops in the stream at the foot of the slope.

HUTTON PROSPECTS.

Six miles south of Marion and 1 mile southwest of Quebec, a lumber town near the Marion & Rye Valley Railway, considerable prospecting has been done in an intermontane valley. The main ridge of Brushy Mountain is cut through by South Fork at Quebec, where it is seen to be an anticline with Erwin quartzite on its flanks and black shale, presumably Hampton, in the center. Rye Valley which lies south of this ridge terminates 1½ miles southwest of Quebec. On the gentle divide on the valley floor between Hopkins Creek on the west and Barton Branch on the east, there is a bench at an altitude of 2,700 feet, 50 feet above the valley, along the foot of the ridge. The quartzite on the ridge dips 50° SE. and at the foot of the terrace coarse massive dolomite inclosing great masses of chert dips 70° SE. The prospects are on the bench where residual clays from the dolomite have been preserved. Scattered over the surface is much float iron and manganese ores. Mr. H. H. Green, manager of the Umbarger mine at Sugar Grove, has sunk a number of deep circular holes, 20 to 30 feet deep, over the terrace in which are exposed yellow and dark clays inclosing chert fragments, red ferruginous sand balls, iron ore, and considerable psilomelane. Iron ore was mined here years ago for a local furnace. The lumber railroad at the foot of the terrace will be convenient if mining is undertaken, but the prospects for a large amount of ore are not encouraging.

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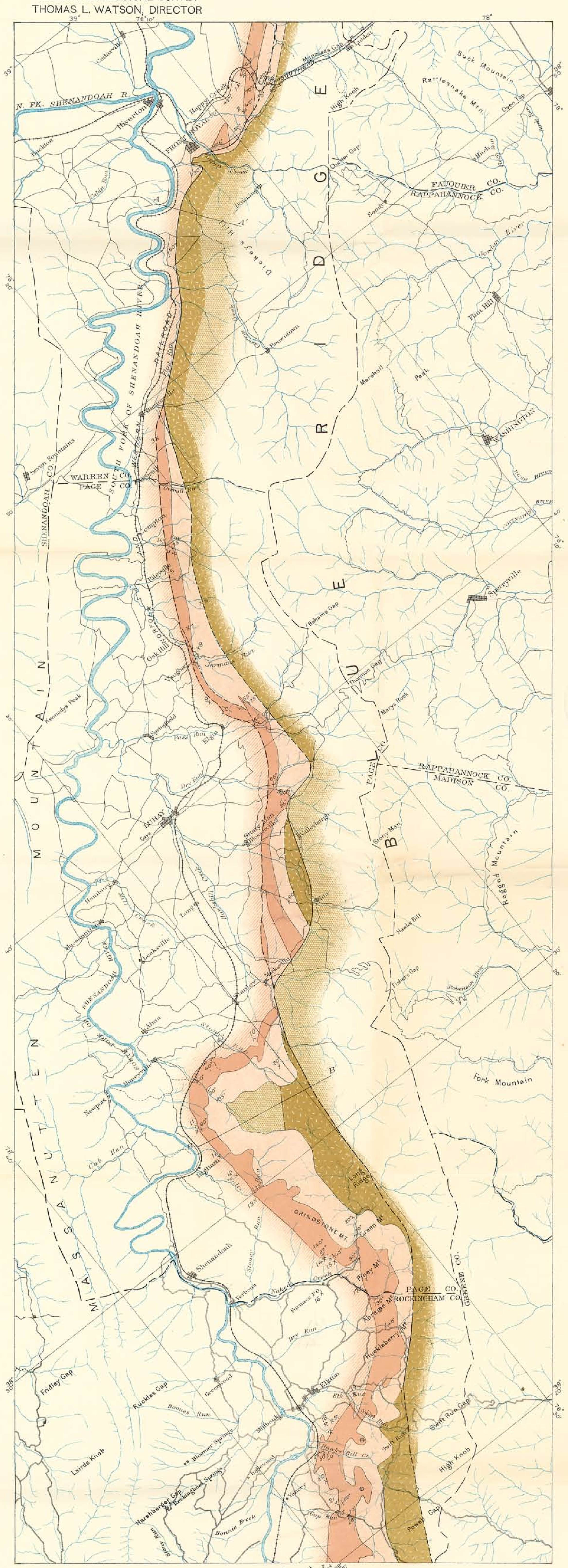

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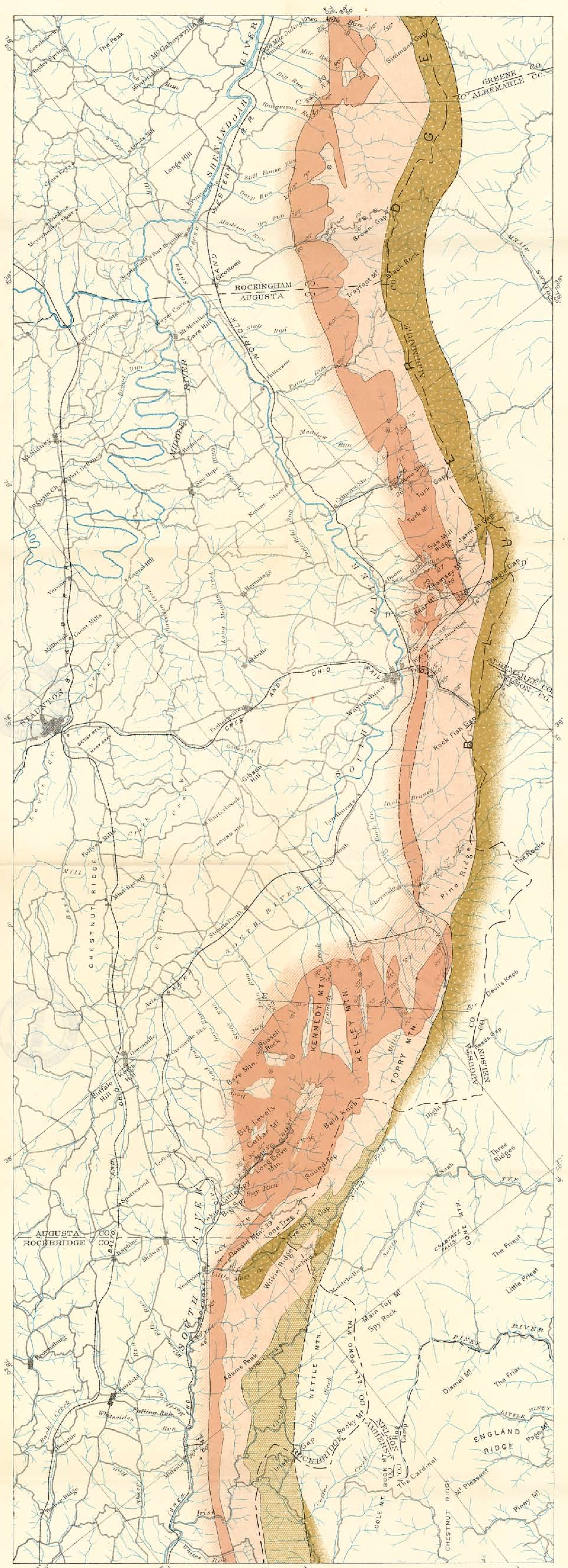

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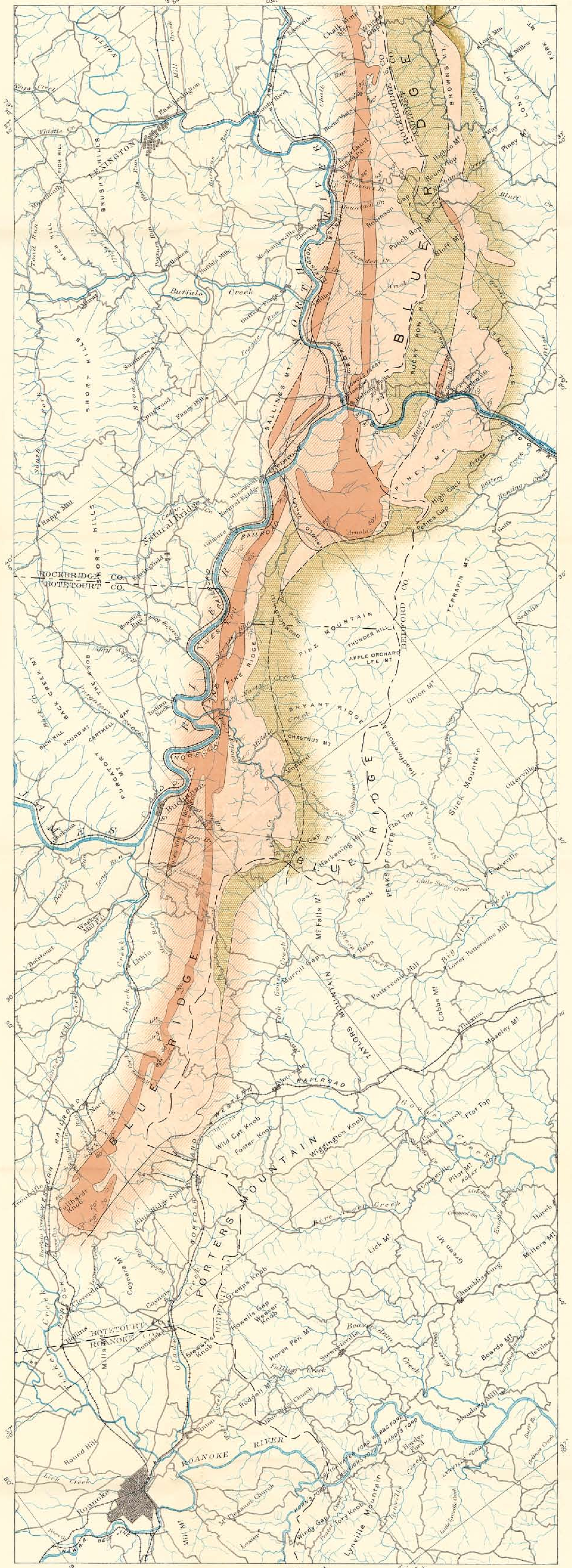

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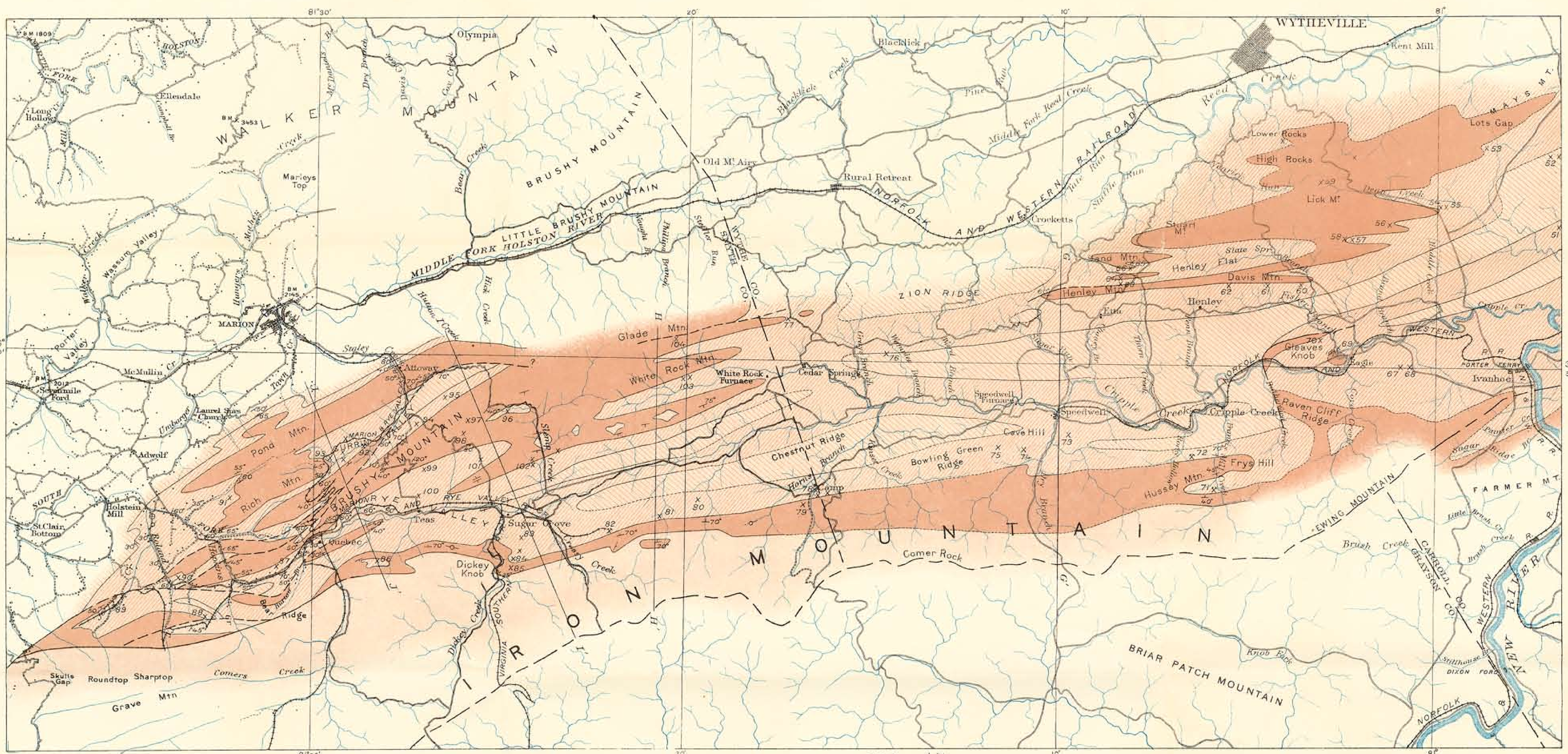


D

LEGEND

CAMBRIAN

Limestone, dolomite, and shale
(chiefly Shady dolomite and overlying Watauga shale; Watauga separated and represented by lighter color on map D)

Erwin quartzite
(chiefly hard white vitreous quartzite containing Scolithus tubes)

Hampton shale and Unicoi formation
(chiefly dark sandy shale above and arkosic sandstone and conglomerate below)

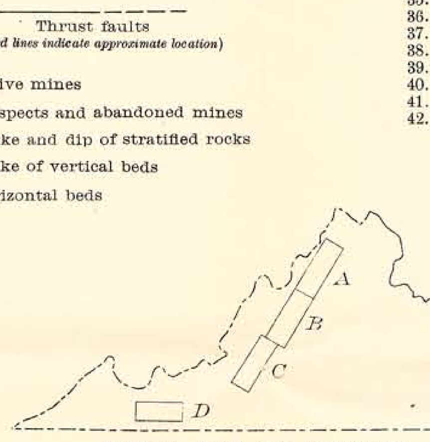
PRE-CAMBRIAN

Greenstone
(altered basaltic lava, in part a schist)

Granitic rocks
(chiefly coarse granular granodiorite)

Thrust faults
(dashed lines indicate approximate location)

Active mines
Prospects and abandoned mines
Strike and dip of stratified rocks
Strike of vertical beds
Horizontal beds



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A. HOEN & CO. BALTIMORE, MD.

GEOLOGIC MAP OF A PORTION OF THE WEST FOOT OF THE BLUE RIDGE, VIRGINIA

Maps A, B, C from vicinity of Front Royal to Troutville
Map D from vicinity of Marion to Ivanhoe
Geology chiefly by G. W. Stose, F. J. Katz, and H. D. Miser

Scale 1/125000
1 0 1 2 3 4 5 Miles

Surveyed in cooperation with
the U. S. Geological Survey
George Otis Smith, Director