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VIRGINIA CONSERVATION COMMISSION
VIRGINIA GEOLOGICAL SURVEY
ARTHUR BEVAN, *State Geologist*

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Geology and Manganese Deposits of the Glade Mountain District, Virginia

By

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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., March 6, 1944.

To the Virginia Conservation Commission:

GENTLEMEN:

I have the honor to transmit for publication as Bulletin 61 of the Virginia Geological Survey, the text, geologic map, and illustrations of a report on the *Geology and Manganese Deposits of the Glade Mountain District, Virginia,* by Dr. Ralph L. Miller of the United States Geological Survey.

The field work was done and the report was prepared by the Federal Geological Survey as a project in the series of strategic minerals investigations in Virginia and other states. The Glade Mountain district is in Smyth and Wythe counties, southeast of the Lee Highway (U. S. No. 11). The character of the manganese deposits in this district and their geologic relations are discussed in sufficient detail to be a guide to further exploration and mining, not only in this district but in similar areas. Some fifty mines and prospects are described in detail.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
Virginia Conservation Commission,
Richmond, Virginia, March 8, 1944.
R. A. GILLIAM, *Executive Secretary and Treasurer.*

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Geology and Manganese Deposits of the Glade Mountain District, Virginia

By Ralph L. Miller*

ABSTRACT

The Glade Mountain manganese district includes an area 20 miles long and 6 miles wide, in southern Smyth and western Wythe counties in southwest Virginia. It is on the southeast side of the Appalachian Valley, bordering the Blue Ridge province.

The district consists of a series of ridges and intermontane valleys, which form a compact mountainous group rising 500 to 1,500 feet above the surrounding lowland. The ridge crests are composed of the Lower Cambrian Erwin quartzite and the intermontane valleys of the Shady dolomite, also Lower Cambrian. A series of parallel, high-angle reverse faults repeat the Erwin-Shady sequence many times across the district.

Nearly all the important manganese deposits are in residual clays of the Shady dolomite. The manganese was originally disseminated through the dolomite, probably in the form of manganodolomite, and was especially abundant in the lower part of the formation. It was removed in solution by circulating meteoric waters and concentrated in the residual clays in the form of manganese oxides. Clays closely overlying the dolomitic sandstone at the base of the Shady dolomite were particularly favorable for manganese concentration, because the weathered sandstone is extremely porous and furnished an excellent aquifer to promote circulation of manganese-bearing waters.

A hard amorphous manganese oxide, identifiable by X-ray methods as cryptomelane, is the most abundant ore mineral, but pyrolusite is locally common and psilomelane is known. The manganese oxides occur as hard nodules in clay; hard, ledgelike masses in clay; partial or complete replacements of silicified dolomite or sandstone; and pockets of pure black powder.

Early production from the mines of the Glade Mountain district was of iron and manganiferous iron to supply local charcoal-burning furnaces. The production of high-grade manganese concentrates was small until shortly before World War I. Many former mines and

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some new mines produced manganese during that war, but all production of both manganese and manganiferous iron ceased with the fall in prices at the end of the war. No manganese was mined from 1919 to 1937. The Glade Mountain mine was opened in 1937, and production from the district has been more or less continuous since then, reaching in 1942 a maximum of 1,817 long tons of concentrates containing more than 35 percent of manganese. Five mines contributed to this production, of which the Glade Mountain mine was by far the largest. Several other mines and prospects have been worked recently on a small scale but no shipments have resulted. Altogether, 55 manganese mines and prospects are known in the Glade Mountain district. They are described in detail in this report.

Prospecting at most mines in the district has been superficial and sporadic. Estimates of ore reserves are necessarily based largely on surface showings and past mining history. The proved or measured reserves of ore are about 1,000 tons of concentrates averaging more than 35 percent of manganese, but an additional 2,000 tons of concentrates can probably be produced at the present price level, and possibly as much as 10,000 tons are available.

The important iron deposits of the district are of nodular or ledge-type limonite in residual clay of the Shady dolomite. Much of the iron ore is manganiferous. None of the mines have been operated since World War I, unless they were also producers of manganese. Iron mining was discontinued in the district because of loss of local markets rather than because of exhaustion of the deposits. The total production of iron and manganiferous iron from all mines in the district is estimated to have been not less than 150,000 tons of concentrates.

Barite, lead, and zinc have also been mined in the district on a small scale. Sand, gravel, road metal, and agricultural limestone quarries are still active.

INTRODUCTION

Location of the Area

The Glade Mountain manganese district is in southern Smyth and western Wythe counties in southwest Virginia (Fig. 1.) The main part of the district is a belt 5 to 8 miles wide and 20 miles long, extending in an east-northeast direction. The northwest border is formed approximately by the Lee Highway (U. S. 11) and the southeast border by the edge of the Iron Mountain range. The belt covers parts of the Marion, Rural Retreat, Mt. Rogers and Mouth of Wilson topographic quadrangles of the Federal Geological Survey.

A small area in the southwest corner of Smyth County, which includes the Savage prospect, is also covered by this report. This area, about 1½ miles square, is located 2½ miles southwest of the main belt (Fig. 1).

Previous Geologic Work

Numerous writers have discussed the geology and economic deposits of southwest Virginia, but few have dealt specifically with the manganese deposits. The earliest important contribution to the geology of the manganese deposits was a detailed topographic and geologic map of Smyth County made in 1899 by C. R. Boyd and J. D. Barns.[1]* The geology was generalized but was nevertheless remarkably accurate. The map showed the location of all known iron and manganese occurrences. Watson's[54] report on the mineral resources of Virginia and Harder's[26]

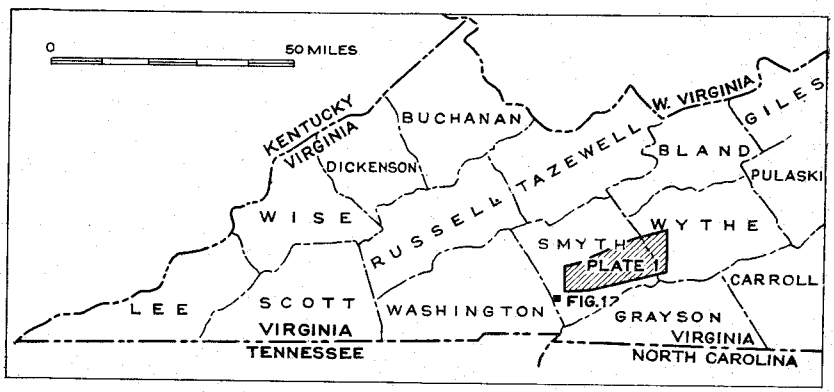


Figure 1.—Index map of southwestern Virginia, showing the location of the Glade Mountain district.

*Numbers refer to "References" on pages 144-146.

bulletin on the manganese deposits of the United States both discuss briefly the manganese deposits of the Glade Mountain district. The most comprehensive treatment of the district is by Stose, Miser, Katz, and Hewett.[38] Their generalized geologic map, on the scale of 1/125,000, includes the Glade Mountain district, and they list and describe many of the mines and prospects discussed in this report.

Recent detailed studies of areas near the Glade Mountain district have been made by Currier[16], Cooper[11], and Stead and Stose[33]. Cooper mapped an area adjoining the Glade Mountain district on the northwest, including the town of Marion. Most of his studies were confined to formations younger than those discussed in this report, but included structural features of importance in understanding the geology of the Glade Mountain district. Currier mapped and described part of the Glade Mountain district in connection with studies of lead and zinc deposits. His detailed mapping of Rye Valley and Cripple Creek Valley on the scale of 1/62,500 complements the geology shown on Plate 1 of this report. His mapping of the mountain areas of the Glade Mountain district was generalized, however, and did not show the geologic and structural relations of the manganese deposits. Stead and Stose have recently mapped and described the Lick Mountain manganese district, lying 5 miles northeast of the Glade Mountain district.

FIELD WORK AND ACKNOWLEGMENTS

Field work for the present report was done during the months from May to December, 1942. Ralph H. Wilpolt of the Federal Geological Survey served as field assistant from August to December. E. O. Sexton served as rodman from August to November.

The main part of the manganese-producing area was mapped geologically, and all known manganese mines and prospects in the district were visited and studied. The writer mapped the central and western parts of the area and the mountains in the eastern part, and made the geologic studies at the mines. Wilpolt mapped the Shady dolomite and Rome formation in the eastern part of the area and made planetable or pace-and-compass maps of the more important mines and prospects.

Fossil identifications were made by Josiah Bridge of the Federal Geological Survey and C. E. Resser of the United States National Museum. The manganese minerals were identified by J. M. Axelrod, Charles Milton, and C. S. Ross of the Federal Survey. The pen drawings of scenes were made by Ansel M. Miller. Conferences in the field with P. B. King and Arthur Bevan were helpful. The field and office

work on this project was done under the direction of H. D. Miser of the Federal Geological Survey.

Numerous manganese operators were helpful in supplying information on present and past workings. Special thanks are due N. T. Dixon, A. E. Morse, E. O. Sayers, Arthur Short, L. L. Savage, George Murray, J. Carson Adkerson, and A. H. Fisher.

GEOGRAPHY AND PHYSIOGRAPHY

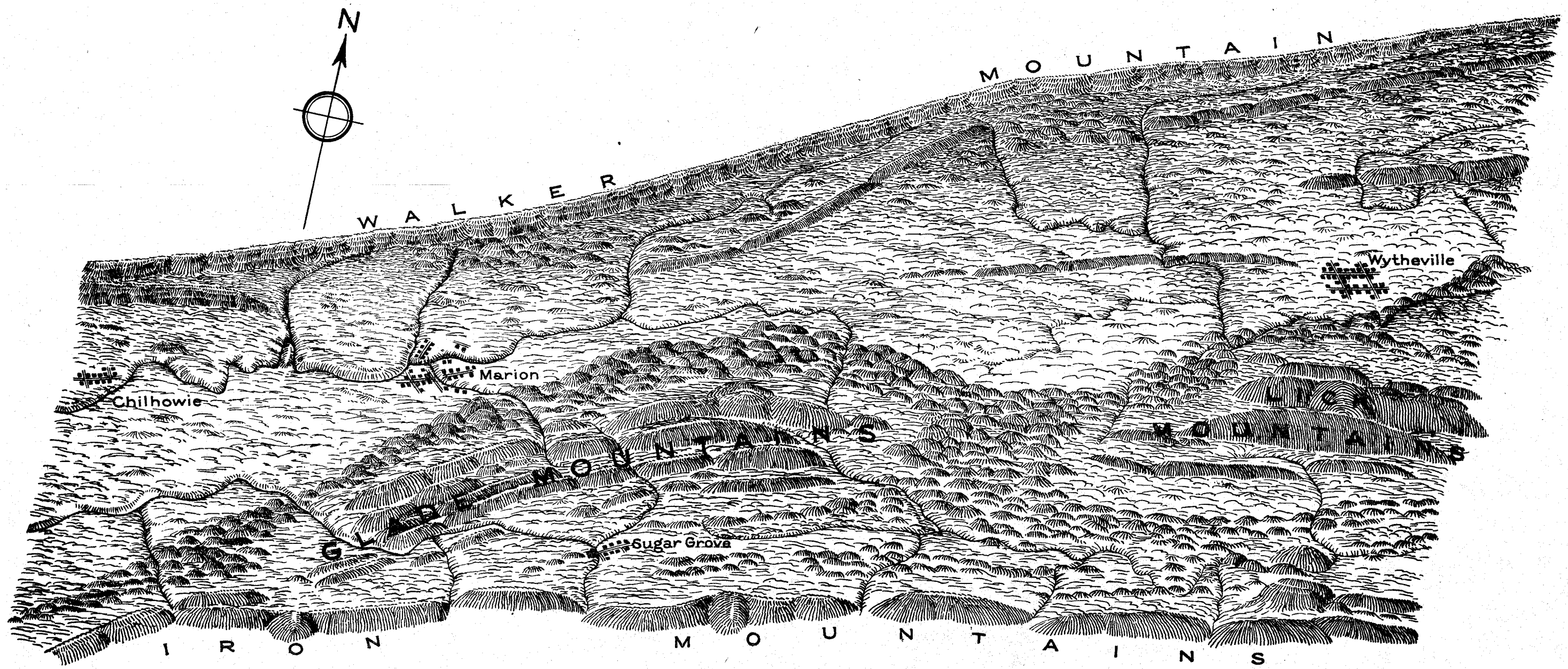
The Glade Mountain district is in the Appalachian Valley and Ridge province. In southwest Virginia the Appalachian Valley consists of a broad valley on the southeast, sometimes called the "Great Valley" or the Valley of Virginia, and a series of ridges and valleys on the northwest. The "Great Valley" in Smyth and Wythe counties is about 11 miles wide. The Iron Mountains form the front of the Blue Ridge province on the southeast side of the Valley. Walker Mountain is the first ridge of the Valley and Ridge section on the northwest side (Pl. 2).

Two isolated groups of mountains rise from the floor of the "Great Valley" in Smyth and Wythe counties. The eastern group, known as the Lick Mountains, is in Wythe County, and the Glade Mountains are in adjoining Smyth County. The Glade Mountains, which consist of a series of parallel ridges and valleys, together with the adjacent lowlands, form the area covered by this report. The geology and manganese deposits of the Lick Mountains are treated in a companion publication.[34]

The valley lowland around the Glade Mountains is at an altitude of 2,000 to 2,600 feet. The divide between New River and Tennessee River drainage crosses the area, and the lowland slopes eastward and westward from the divide.

Dolomite and limestone underlie most of the lowland near the mountains. These rocks form a gentle, rolling topography. The major streams have eroded shallow, gentle-sided valleys in crossing this lowland. More resistant shales of the Rome formation surround Glade Mountains and Lick Mountains and form prominent belts of knobby hills (Pl. 3,A) rising from 50 to 500 feet above the surface developed on the dolomite and limestone.

The Glade Mountains consist of a series of parallel, sharp-crested ridges formed of the Erwin quartzite, separated by narrow intermontane valleys on the Shady dolomite. Glade Mountain, the highest of the ridges, reaches an altitude of 4,083 feet. It lies in the northeast part of the area, somewhat north of the main group of ridges. South and west of Glade Mountain three ridges, whose crest altitudes range from 3,000 to 3,500 feet, extend nearly the full length of the area. Different names are applied to parts of the same ridge, which are separated from each other by water gaps; for example the next ridge south of Glade Mountain is known from east to west as Locust Mountain, Chestnut Mountain and Pond Mountain; and the southernmost ridge is named Buchanan Mountain, Hickory Ridge, and Sheep Ridge. Besides the main long ridges, several shorter ridges, such as Rich Mountain and



Physiographic diagram of the Great Valley in Smyth and Wythe counties, Virginia. The front ridge of the Iron Mountains and the ridges of Glade and Lick mountains are composed mainly of Erwin quartzite. The lowlands around Glade and Lick mountains are underlain by Shady dolomite. The belts of knobby hills in the southern and central parts of the area are of Rome shale and sandstone. The length of the area is 35 miles. The greatest width of the Valley is 17 miles.

the unnamed ridge west-southwest of Teas, rise from the valley bottoms.

Most of the intermontane valleys are narrow, steep-sided and more or less choked with talus from the quartzite ridges. Currin Valley, in the middle of the mountain group, and White Rock Valley, near the east end of the mountains, are broader and are relatively flat-floored. Staley, Slemp, and Nick creeks which head in the mountains and flow along intermontane limestone belts for some distance, each turn to cut across hard quartzite ridges in deep transverse gorges. The perfect alignment of the transverse courses of Slemp and Nick creeks is striking. No line of structural weakness controlling the transverse courses is apparent in the bedrock geology. The streams may have inherited their courses from an ancient stream which was superposed across the quartzite ridges and has since been diverted. The South Fork of Holston River also crosses one of the quartzite ridges in a watergap, instead of continuing westward down an open limestone valley into the broad lowland beyond.

A lowland, 1 to 2 miles wide, separates the Glade Mountain group of ridges from the front of the Iron Mountains. The western half of this lowland, which is drained by the South Fork of Holston River is named Rye Valley, and the eastern half, which is drained by the headwaters of Cripple Creek, will be referred to as Cripple Creek Valley.

The Iron Mountains, which border the Glade Mountain area on the south, rise steeply from the Rye Valley-Cripple Creek lowland to form a series of ridges and knobs whose crests are at altitudes of about 3,000 feet (Fig. 2). The backbone of the Iron Mountain range lies a mile or two farther south and is more than 4,000 feet in altitude.

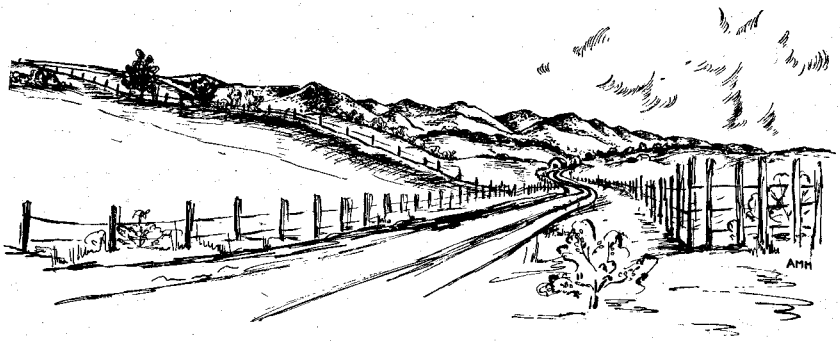


FIGURE 2.—Sketch of Rye Valley and the Iron Mountains, looking west from a point near Sugar Grove. By Ansel M. Miller.

Several peneplains, or partial peneplains, have been recognized in southwest Virginia, including a summit peneplain, various intermediate peneplains, and a valley-floor peneplain. Within the Glade Mountain district evidence permitting correlation of local levels with regional peneplains is, however, singularly lacking. The crest altitudes of the Glade Mountain ridges are not accordant, as may be seen by examining the profiles on Plate 1. They would appear even less accordant if the usual practice of exaggerating the vertical scale had been followed. Walker Mountain and Iron Mountains, on opposite sides of the valley, have more regular and accordant summits, suggesting the presence of a peneplain at about 4,000 feet altitude. If the summit peneplain in southwest Virginia is approximately at this altitude, it lies above the crest level of all the ridges of the Glade Mountain district except the highest part of Glade Mountain itself.

The writer finds no evidence within this district for any sub-summit peneplain. Instead, great heterogeneity of crest altitudes prevails with no well-defined levels or benches. The valley-floor peneplain is well developed east and west of the Glade Mountain district, where it stands at altitudes of about 2,200 feet. Within the area mapped in this report this peneplain is practically unrecognizable. This is partly because the area includes a major drainage divide, near which the peneplain was poorly developed, and partly because the area is underlain by narrow belts of rocks of greatly differing resistance.

Recent uplift and erosion have resulted in entrenchment of the major streams, and dissection of the floors of the broader valleys. The lowland levels of the Glade Mountain district thus show as little accordance as do the upland levels.

FIGURE 3.—Sketch of the Glade Mountians, looking west from the crest of White Rock Mountain. The distant ridge on the left is Buchanan Mountain, the central ridge is Brushy Mountain, and the ridge on the extreme right is Locust Mountain. By Ansel M. Miller.

The dolomite and limestone lowlands surrounding the Glade Mountain ridges are almost everywhere cultivated. The hills of Rome shale and sandstone on the north side of the mountains are timbered or in pasture, but some of them are cultivated in the Rye Valley-Cripple Creek lowland. The remainder of the region, including the ridges and intermontane valleys of the Glade Mountains and also the Iron Mountains, is largely timbered. Most of the mountainous part of the district is in the Jefferson National Forest. The vegetation is thick, with much underbrush along the stream courses. When the leaves are on the trees, there are few points of good visibility in the mountains and few distinctive landmarks. Figure 3 shows a typical view in the Glade Mountains.

The Middle and South Forks of Holston River drain the western part of the Glade Mountain district southwestward into Tennessee River, and the headwaters of Cripple Creek drain the eastern part of the area eastward into New River. The divide between these drainage systems is low and inconspicuous.

The main routes of travel are east and west along the broad lowlands and around the Glade Mountains. The Lee Highway (U. S. 11) and the Norfolk and Western railroad are parallel along the north side of the area. Travel across the Glade Mountain ridges is difficult. Three roads cross the mountains, each making use of transverse stream gorges to cross most of the ridges, but having to ascend one steep ridge. The Marion and Rye Valley Railroad, which was abandoned in 1937, crossed the mountains by following Staley Creek and Currin Valley, then crossed a high divide and descended to Rye Valley through a series of watergaps, with sharp curves and switchbacks. Roads along the intermontane valleys are few and poor. A Forest Service road connects Atkins and Cedar Springs in the valley between Glade Mountain and Locust Mountain. Another road, which is passable in dry weather, extends several miles up White Rock Valley. Other poor roads traverse most of Currin Valley. Numerous logging roads and trails wind through the mountains, but most of them have fallen into disrepair and are impassable for automobile travel.

STRATIGRAPHY

GENERALIZED GEOLOGIC SECTION

The sedimentary rocks described in this report belong in the Lower and Middle Cambrian series. Six formations are mapped, totaling about 12,000 feet in thickness. Only the Erwin quartzite and the Shady dolomite underlie extensive areas. The Unicoi formation is the oldest Paleozoic formation in southwest Virginia. It rests on a crystalline complex of pre-Cambrian age, which crops out in the Blue Ridge province a few miles south of the Glade Mountain district.

A generalized section of the rocks of the area is shown in Table 1.

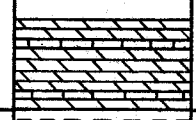
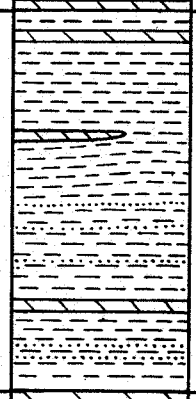
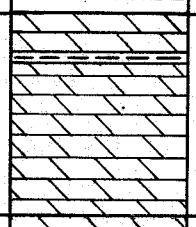
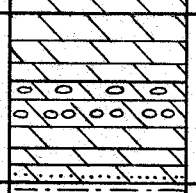
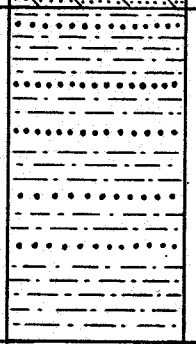
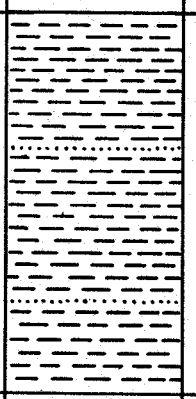
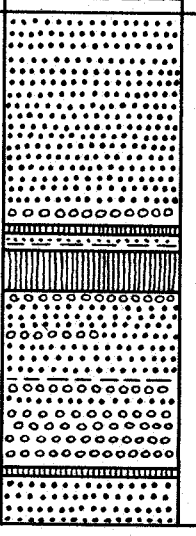
UNICOI FORMATION

The Unicoi formation was named[9] from exposures in Unicoi County in northeastern Tennessee. The Unicoi is not present in the area mapped in detail on Plate 1, but it forms the crest and south slopes of the Iron Mountains, which border the Glade Mountain area on the south. It is also present along the north slopes of the Iron Mountains near the Savage prospect (Figs. 2 and 17), where a major overthrust has brought it in contact with the Shady dolomite.

The Unicoi formation consists of interbedded conglomerate, arkose, sandstone, quartzite, shale and amygdular lava flows. The coarser conglomerate and arkose are mainly in the lower part of the formation, and the finer grained sandstone and quartzite are more prevalent in the upper part of the formation. Many of the sandstone beds are red or salmon-pink due to their feldspar content, and some of the shale is also red. At least one amygdular lava flow is present in most sections. A section measured by Butts[2] in southeastern Smyth County near Konnarock contains three flows. One of these flows, near the middle of the formation, is 200 feet thick. It is described as a "dark greenish rock with bands containing pink, spherical inclusions, probably of pink feldspar, some half an inch in diameter." A similar lava flow, 45 feet thick, lies a short distance higher in the section, and a 20-foot lava flow is interbedded near the base of the formation.

The Unicoi formation is exposed in several road cuts along U. S. Highway 58 over Iron Mountain south of Sugar Grove. At

TABLE 1.—*Generalized geologic section of the bedrock formations of the Glade Mountain district, Virginia*[a]

SERIES	FORMATION AND MEMBER		COLUMNAR SECTION	THICKNESS (FEET)	CHARACTER OF ROCKS
UPPER CAMBRIAN	Elbrook formation			1400-2000	Light-gray, platy and shaly dolomite containing interbedded limestone; only lower part of formation exposed in Glade Mountain district.
MIDDLE CAMBRIAN	Rome formation			2000±	Red, gray, and green shale and red sandstone with interbedded dolomite units up to 160 feet thick.
	Shady dolomite	"Saccharoidal member"		1068±	Gray and white, fine- and medium-grained crystalline dolomite in even, massive beds; local dark-colored shale units in upper part.
		Patterson member		860±	Gray dolomite; thin dolomitic sandstone at base; massive-bedded dolomite with blebs of white recrystallized dolomite in middle; even-bedded dolomite with indistinct ribbon banding in upper part.
LOWER CAMBRIAN	Erwin quartzite			1500-2000	Resistant beds of quartzite and quartzitic sandstone, 20 to 50 feet thick, separated by thick, nonresistant zones of platy and shaly sandstone.
	Hampton shale			2000±	Dark-colored, shaly sandstone and shale; local zones of more resistant sandstone; red shale locally present but rare.
	Unicoi formation			2600±	Conglomerate, arkosic sandstone, quartzose sandstone, shale and amygdaloidal lava flows.

[a] The Unicoi section was measured by Butts near Konnarock, Smyth County. The other sections are generalized from the Glade Mountain district.

the crest of the mountain a 20-foot layer of white glassy quartzite near the top of the formation is interbedded with yellow sandstone and pebbly conglomerate. An amygdular lava flow crops out in a cut about a third of the way down the south slope of the mountain. It is a dense, greenish-black rock with scattered small pinkish amygdules and also vesicles. The lava flow is overlain by coarse-grained arkosic sandstone. The base of the flow is concealed, but the exposed 35 feet probably is nearly the full thickness. No other lava flow crops out along this road, but others could be present in the long, covered intervals. Conglomerate becomes increasingly abundant and coarser in the road cuts near the south base of the mountain. The contact of the Unicoi and the pre-Cambrian formations apparently is not exposed in this section, but the lithologic distinction between the two is not clearly evident here. The base of the Unicoi can be determined only after careful regional studies along the south flank of the Iron Mountains.

The Unicoi is 2,604+ feet thick in the Konnarock section measured by Butts. It is probably of this order of thickness in the Iron Mountains south of the Glade Mountain district.

No fossils have been reported from the Unicoi. It has been generally accepted as Lower Cambrian because it overlies igneous and metamorphic rocks whose pre-Cambrian age is generally accepted, and because it seems to belong in the same sedimentary series with the Hampton shale and Erwin quartzite, the last named of which contains Lower Cambrian fossils. The Unicoi has been correlated with the Loudoun formation and Weverton sandstone of central and northern Virginia.

HAMPTON SHALE

The Hampton shale was named from exposures near the town of Hampton in Carter County, northeast Tennessee[10]. The Hampton is present in four separate areas in the district mapped on Plate 1. The largest of these is on the north side of Buchanan Mountain; the other three are on Glade Mountain. Exposures are extremely poor in all four areas. The Hampton is better exposed along the north slope of Iron Mountain about a mile south of the Glade Mountain area. It is also well exposed along St. Clair Creek east of the Savage prospect (Fig. 17).

The Hampton shale consists mainly of thin-bedded sandstones and dark-colored sandy shale and slate. Red shale is included in

some places on Glade Mountain and thin quartzite layers are interbedded in the shaly sandstone on St. Clair Creek. The Hampton is quite variable within short distances, but in Smyth County it is distinct lithologically from the underlying arkosic sandstone of the Unicoi and from the overlying more platy sandstone and thick quartzite layers of the Erwin. The Hampton is so incompetent that it is almost everywhere intricately folded or faulted. Slaty cleavage is well developed in the more shaly parts of the formation, locally obliterating the bedding.

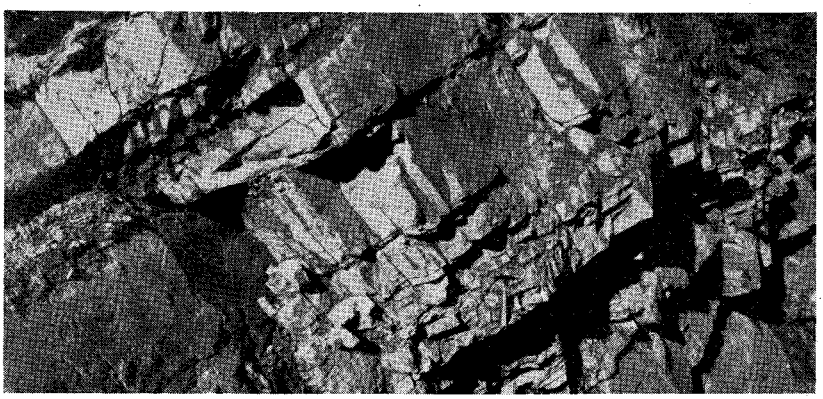
In the Glade Mountain district the Hampton forms gentle to moderate slopes, which are capped by resistant beds in the overlying Erwin quartzite. As a result, the Hampton crops out in few places on the mountain slopes; moreover, none of the transverse stream gorges across the Glade Mountains intersect any of the Hampton shale areas. Fragments of shale and shaly sandstone in the soil, combined with an absence of resistant quartzite or sandstone ledges, are the chief evidence for mapping the Hampton. The lower part of the formation is not exposed anywhere in the Glade Mountain area proper.

The Hampton is well exposed in road cuts on the Troutdale road south of Sugar Grove. Here it forms a fairly continuous depression between the frontal ridge of the Iron Mountains, which is composed of Erwin quartzite, and the crest ridge, composed of quartzite near the top of the Unicoi formation. The Hampton shale in this area is dominantly fine-grained, sandy shale and shaly sandstone. Slaty cleavage is locally well developed and some of the least sandy beds approximate true slates. An exposure near the crest of the mountain shows a typical outcrop of the shaly sandstone, and also shows some peculiar curved joints, each of which is shaped like the bowl of a shallow spoon with the top of the spoon paralleling the bedding (Pl. 3,B).

Good exposures of the Hampton are also found along St. Clair Creek northeast of the Savage prospect. Here, as elsewhere, the beds are so folded and faulted that a continuous section across the formation is not obtainable. The rock is mainly dark-colored, shaly sandstone and shale, which weather brown. A zone of uniform black slate is several hundred feet thick. One quartzite bed, 7 feet thick, forms a prominent ledge in the creek bank. This is the only quartzite seen in the Hampton in the Glade Mountain district. It is possible that similar quartzite or resistant sandstone beds,

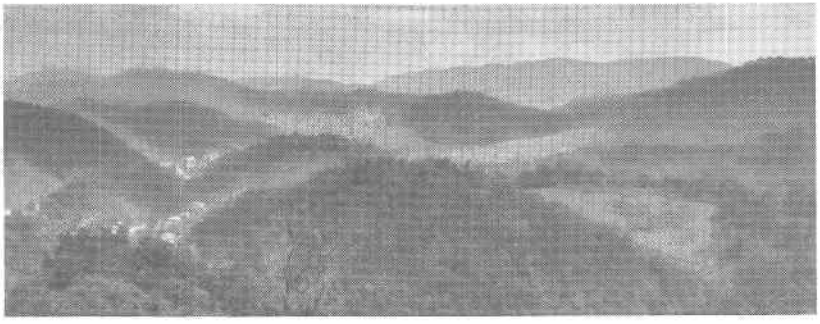
A.

B.



C.

A, Foreground hills of Rome shale and sandstone, and skyline ridges of Erwin quartzite. View looking southeast from Staley knob, near Marion. B. Hampton shale near the crest of the Iron Mountains, on the Sugar Grove and Troutdale road. C, Quartzite zone near the top of the Erwin, on the road along the west fork of Nick Creek at the north base of Brushy Mountain.



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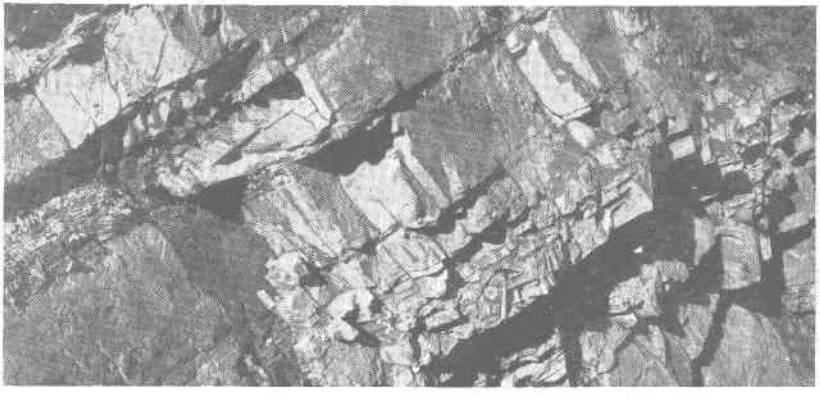
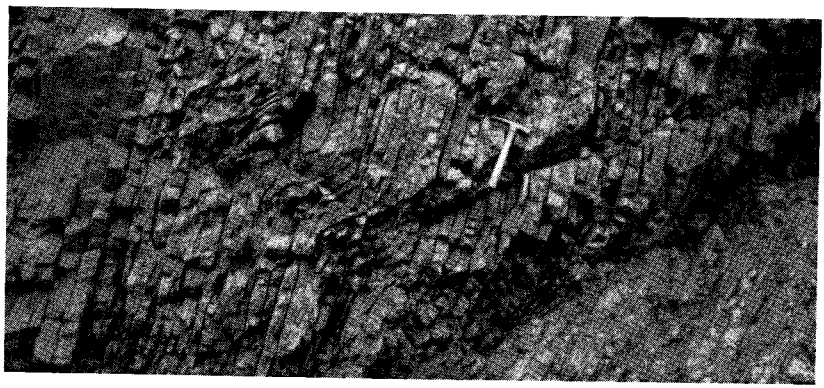


C.

A, Foreground hills of Rome shale and sandstone, and skyline ridges of Erwin quartzite. View looking southeast from Staley knob, near Marion. B, Hampton shale near the crest of the Iron Mountains, on the Sugar Grove and Troutdale road. C, Quartzite zone near the top of the Erwin, on the road along the west fork of Nick Creek at the north base of Brushy Mountain.

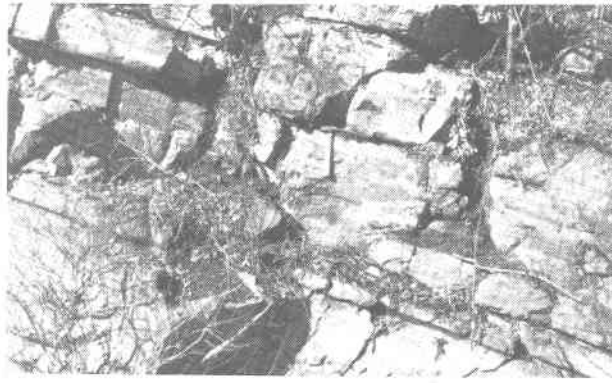
A.



B.

C.

A, Contact of Erwin quartzite and Shady dolomite along Dickey Creek. Hammer is at contact. B, Platy sandstone in the middle of the Erwin; in Slemp Creek gorge between Buchanan Mountain and Hickory Ridge. C, Patterson member of the Shady dolomite in a quarry near Asbury School. (See Pl. 5,A.)



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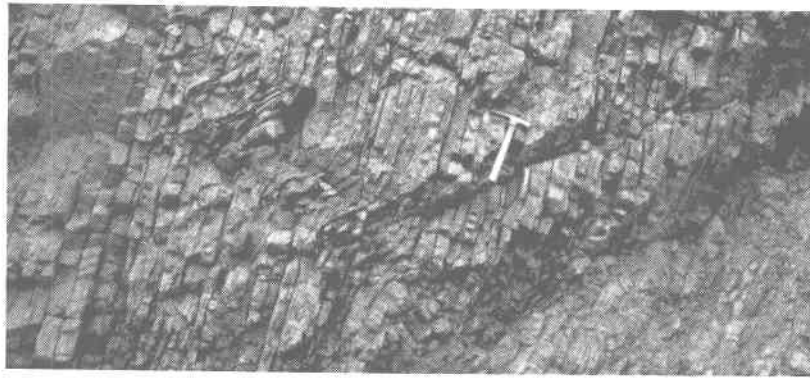


B.

C.

A, Contact of Erwin quartzite and Shady dolomite along Dickey Creek. Hammer is at contact. B, Platy sandstone in the middle of the Erwin; in Slemp Creek gorge between Buchanan Mountain and Hickory Ridge. C, Patterson member of the Shady dolomite in a quarry near Asbury School. (See Pl. 5,A.)

which belong in the upper part of the Hampton, were mapped as part of the Erwin because exposures were inadequate to establish their correct stratigraphic position.

The thickness of the Hampton is not known because of the ubiquitous folding and faulting which make section measurements unreliable. Butts[3] estimates that the formation is probably 2,000 feet thick in southwest Virginia.

The Hampton shale is unfossiliferous. It underlies the Erwin quartzite which contains Lower Cambrian fossils, and overlies the Unicoi formation which is believed from stratigraphic and structural evidence also to be Lower Cambrian. If the Unicoi is correctly dated the Hampton must likewise be Lower Cambrian.

ERWIN QUARTZITE

The Erwin quartzite was named by Keith[28] from exposures near Erwin, Unicoi County, northeast Tennessee. It was described as consisting of 500 to 700 feet of white sandstone and quartzite. In the Glade Mountain district the Erwin quartzite is areally extensive and topographically prominent. It forms the crest and upper slopes of nearly all the mountain ridges. It also forms the front of the Iron Mountains bordering the Glade Mountain district on the south. Parallel faults have duplicated the Erwin quartzite many times at the surface.

The Erwin quartzite is composed mainly of platy and shaly fine-grained sandstone which accounts for about nine-tenths of the total thickness of the formation. Quartzite and quartzitic sandstone are interbedded with the weaker sandstone and are much more prominent in outcrop. Thus the practice of designating the formation the Erwin quartzite is justified.

The quartzite is white and yellow, fine- to medium-grained and is mostly in beds from 1 to 10 feet thick. In a few places, such as on the pinnacle of White Rock Mountain, massive ledges of quartzite 30 to 40 feet thick have no visible bedding. Most of the quartzite members in the Erwin are 20 to 50 feet thick. A quartzite only 20 feet thick is ordinarily so much more resistant than the enclosing sandstones that it causes a marked change in slope on the mountain side and may even form the crest ledge of one of the mountains. Two typical quartzite members crop out along the road up the east fork of Nick Creek and another is well exposed along the west fork. (Pl. 3,C).

Besides the quartzite members, zones of quartzitic sandstone and of medium-grained sandstone are numerous. These are more resistant than the enclosing shaly and platy sandstone and also form prominent mappable units. They are about the same order of thickness as the quartzite beds. The quartzite members tend to be more abundant in the upper part of the formation and the quartzitic sandstone and sandstone beds in the lower part. Many sandstone zones, however, contain some beds of glassy quartzite, and other zones predominantly of quartzite may contain some sandstone beds. The quartzite members are thickest and best developed in the northeastern part of the district and especially on and near Glade Mountain. The mappable resistant units in the western half of the area are mainly sandstone and quartzitic sandstone. Traced along the strike one of the mapped resistant units may change from quartzite through quartzitic sandstone to sandstone and then thin out or grade into weak sandstone which no longer forms a mappable unit. Ripple marks are preserved locally in the quartzite and sandstone but are not abundant.

The number and spacing of the quartzite and resistant sandstone members vary from area to area, and especially from fault block to fault block. The thicker quartzite members are traceable for several miles, but many of the thinner ones may be prominent at one place and inconspicuous nearby. A typical section of the Erwin contains two or three mappable quartzite members in the upper half of the formation and three or four mappable sandstone members in the lower half.

The beds that enclose the resistant quartzite and sandstone members constitute the bulk of the formation, but outcrops of them are rare except along a few deep gorges across the mountains. They consist of platy sandstone, shaly sandstone, and shale. These are mainly yellow, brown, and gray, but in a few places, as near the northeast tip of Glade Mountain, some of the shale is red. The platy sandstone is prominent in quarries and road cuts along the road up the east fork of Nick Creek. The shaly sandstone and shale are well exposed along the gorge of Slemp Creek north of Sugar Grove (Pl. 4,B). Despite their weaker character, these sandstone and shale units are normally not strongly folded but dip uniformly with the quartzite.

The contact of the Erwin quartzite and Hampton shale has not been seen in the Glade Mountain district. No striking differ-

ence exists between the platy and shaly sandstone which constitutes most of the Erwin formation and the shale and shaly sandstone of the Hampton. In the areas of poor exposures on the mountain slopes, the base of the Erwin was drawn below the lowest mappable member of resistant sandstone or quartzite. This procedure could result in considerable error, if sandstone or quartzite were locally interbedded in the Hampton, but no interbedding of these rocks was noted along Dickey Creek and other gorges through Iron Mountain, in which the Hampton is much better exposed than it is at any place in the Glade Mountain district.

The contact of the Erwin quartzite with the Shady dolomite is plainly marked almost everywhere. In some places a thick quartzite lies near the top of the Erwin; elsewhere the topmost beds are of sandstone or shaly sandstone which are in many places glauconitic. In the coarser-grained sandstone the glauconite is present as visible light-green grains scattered through the rock. In some of the finer grained sandstone and shaly sandstone the presence of glauconite is inferred from the greenish tinge in beds which are otherwise light-gray to white. A conglomerate with pebbles the size of peas is found at a number of places in the upper 50 feet, and is prominent because it is much coarser than any other bed in the Erwin or Hampton. The contact of the Erwin quartzite with the Shady dolomite is conformable. The exact contact is obscure because the change from a dense, fine- or medium-grained sandstone to a dolomitic sandstone is gradational through an interval of about 5 feet. The contact has been drawn at the base of the lowest bed which can be recognized as containing dolomite. This contact is well exposed along Dickey Creek south of Sugar Grove (Pl. 4,A) and is less well exposed on the Atkins-Sugar Grove road at the north base of Brushy Mountain and also along the highway in the gorge between Barton and Short mountains.

No well-exposed section across the entire Erwin is known in the Glade Mountain district but thicknesses, calculated from the top of the Hampton shale to the base of the Shady dolomite in areas of uniform dip, where no known faults intervene, are between 1,500 and 2,000 feet.

The Erwin quartzite is sparingly fossiliferous. *Scolithus* is common in the resistant quartzite and sandstone, especially in the upper part of the formation. A small fragment of an unidentifiable trilobite was found near the top of the formation in the small gap crossing the unnamed ridge a mile west-southwest of Teas. The Erwin is known

to be Lower Cambrian because it has yielded species of *Olenellus* in other regions.

Two measured sections of the Erwin which show the nature of the formation are given below. The first of these is of the upper 769 feet of the formation along Slemp Creek; the second a section across the Erwin-Shady contact along Dickey Creek.

Geologic section of the Erwin quartzite along State Highway 88, 1-1/2 miles north of Sugar Grove, Virginia

	Thickness Feet
Shady dolomite	
Erwin quartzite (769+ feet)	
11. Not exposed; float of white quartzitic sandstone and brown and white pebbly sandstone on surface	100±
10. Quartzite, white and pink; forms prominent ledge	15
9. Sandstone and shaly sandstone, fine grained and medium grained, yellow and light-brown	105
8. Shale, sandy, poorly exposed	135
7. Quartzite, pink and light-yellow, fine grained	9
6. Not exposed	75
5. Quartzite, white, dense, medium grained; forms crest of small ridge	50+
4. Shale, poorly exposed	80
3. Sandstone, fine grained, and shale interbedded; sandstone in beds 2 to 3 feet thick weathers into rounded blocks between joints	50
2. Sandstone, gray to black, fine grained, massive bedded; lower part more shaly with well-developed fracture cleavage	105
1. Sandstone, shaly, black	45

Geologic section of the upper part of the Erwin quartzite and lower part of the Shady dolomite along Dickey Creek 1 mile south of Sugar Grove, Virginia

	Thickness Ft.	In.
Shady dolomite (73½+ feet)		
24. Dolomite, gray, fine grained, massive with gnarled, undulatory bedding; drusy cavities lined with quartz abundant near top	19	0

	Thickness Ft.	In.
23. Dolomite, light-gray to white, fine grained, massive; thin, undulatory sandy partings give hackled appearance	9	7
22. Dolomite, greenish-white and brownish-white, medium crystalline, thin bedded	8	3
21. Dolomite, brownish-white and grayish-white, finely crystalline, in thin and thick beds	13	6
20. Dolomite, interbedded brownish-white, medium crystalline and greenish-white finely crystalline, siliceous; in massive ledges with prominent undulatory bedding	10	5
19. Dolomite, brownish-white, crystalline, even bedded, sugary textured, with small drusy cavities	4	3
18. Not exposed	3	0
17. Dolomite, brown and gray, crystalline, with lenses of light-green, cryptocrystalline, siliceous dolomite; scattered grains of glauconite	2	3
16. Dolomite, gray, crystalline; streaked and mottled with brown impurities; small drusy cavities lined with crystals	2	2
15. Dolomite, gray and brown, crystalline, sandy; rounded sand grains abundant; small pebbles up to a half inch; contact with underlying bed tight and conformable; erosion at contact slight	1	2
Erwin quartzite (58+ feet)		
14. Quartzite; greenish-white, fine-grained beds interlayered with dark, medium-grained sandy, glauconitic beds; dense and glassy	2	4
13. Sandstone, gray, fine grained, quartzitic, and greenish-gray; slightly coarser, glauconitic beds from 6 to 18 inches thick	5	0
12. Sandstone, gray, fine grained, glauconitic	5	6
11. Sandstone, gray, fine grained with a slightly coarser, friable sandstone near top containing scattered grains of glauconite	4	7
10. Sandstone, gray and greenish-gray, very fine grained, quartzitic; forms a massive ledge but with distinct parallel bedding	6	2

		Thickness Ft.	In.
9.	Sandstone, greenish-gray, fine grained, quartzitic; forms one massive unit with indistinct bedding planes at 3- to 6-inch intervals	2	9
8.	Shale, green, siliceous; sandstone, fine grained, earthy; and sandstone, medium grained, friable	3	3
7.	Shale, green, thin bedded, siliceous; sandstone, medium grained, well-rounded grains poorly cemented	2	4
6.	Not exposed; probably same as bed 7	10	2
5.	Sandstone, gray and brownish-gray, fine grained, quartzitic, with scattered flecks of clay	4	1
4.	Sandstone, gray and reddish-brown, very fine grained, quartzitic; a few thin sandy lenses; weathers into well-laminated beds 1 to 4 inches thick	6	1
3.	Quartzite, reddish-brown, fine grained; a few thin, sandy, lenses in which well-rounded, glassy quartz grains show; in even beds 2 to 5 inches thick	1	1
2.	Sandstone, gray and brown, fine grained, quartzitic; flecks of clay and scattered, glassy, green glauconite grains; forms small ledges in creek	3	0
1.	Sandstone, fine grained, impure; well-rounded quartz grains scattered through finer grained groundmass; small flecks of clay; forms prominent riffle in Dickey Creek	1	10

SHADY DOLOMITE

The Shady dolomite was named by Keith[29] from exposures in Shady Valley, Johnson County, in northeast Tennessee. In southeastern Wythe County the Shady dolomite has been divided into three members, known in ascending order as the Patterson member, the Austinville member, and the Ivanhoe member. The Ivanhoe member is missing in the Glade Mountain district, and doubt exists whether the upper part of the Shady in Smyth County and parts of Wythe County is the same as the Austinville member at Austinville.[37] The upper member of the Shady in Smyth County will, therefore, be referred to by its old name, "saccharoidal member," and the lower part will be called the Patterson member. The two may be distinguished wher-

ever the bedrock is exposed, but outcrops of the dolomite are so few in the mountainous areas, with which this report is principally concerned, that tracing of the contact between the two members was found impracticable. These two members were, therefore, mapped as a unit (Pl. 1).

The Shady dolomite is widely distributed in the Glade Mountain district. It forms a series of long, narrow, parallel belts. In most of these belts the Shady dolomite normally overlies the Erwin quartzite on one side and is cut off by a fault on the other. Along the south side of the district, parallel belts of Shady dolomite and Rome shale and sandstone combine to form the Rye Valley-Cripple Creek lowland. In the mountains, belts of Shady dolomite underlie all the long, narrow valleys that separate the quartzite ridges. Some of these are so narrow and steep-sided that the dolomite beneath them is largely masked by talus and slope wash from the quartzite on the mountain slopes, but careful search will almost always reveal indirect evidence of the presence of dolomite in a valley even though outcrops are lacking. Other narrow belts of Shady dolomite form slight depressions or benches on the mountain slopes. Still another belt of Shady dolomite lies between the quartzite ridges and the hills of the Rome formation on the north side of the area. This belt of dolomite is topographically less prominent than most of the others because it lies on the long, gentle, timbered lower slopes of the mountains.

The Shady dolomite consists typically of light-gray, fine- to medium-crystalline dolomite in massive beds. The basal unit is a dolomitic sandstone which grades upward into a sandy dolomite and then into the pure dolomite of the main part of the Shady. The lowest beds in this unit are hardly distinguishable in fresh exposure from the underlying sandstone and quartzite of the upper part of the Erwin. The interstitial dolomite dissolves away readily on weathering, leaving a porous, friable sandstone which may be stained or entirely recemented by iron and manganese oxides. This basal unit crops out in a few places only, but the float from it is conspicuous and is an invaluable aid in mapping the Erwin-Shady contact. The unit is shown separately on the geologic map (Pl. 1). It ranges in thickness from 1 foot to 30 feet. Currier[17] referred to this basal unit as the "transition beds." This term has been used in nearby Tennessee, however, to describe a sandstone and shale member at the top of the Erwin quartzite. In view of this difference in

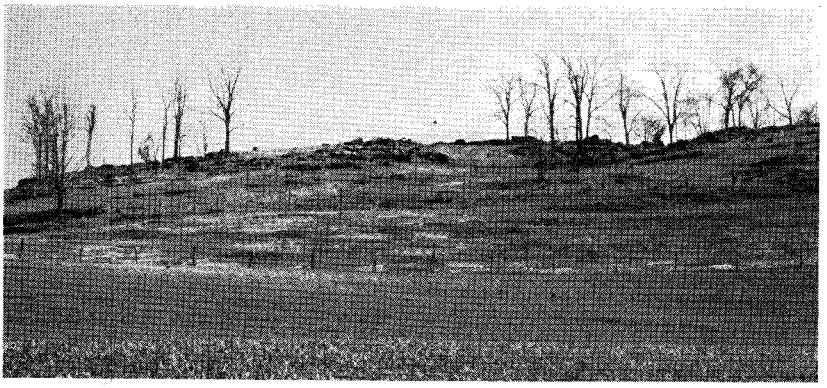
usage, the term "transition beds" is not continued here, but the thinner sandy unit at the base of the Shady dolomite will be referred to as the basal Shady sandstone.

About 50 feet of fine- to medium-crystalline dolomite in thin, even beds overlies the basal sandstone and is overlain by more massive beds of light-gray dolomite which constitute the main part of the Patterson member. Blebs and patches of white, recrystallized dolomite are abundant in many of these beds, especially in the lower part of the Patterson member. The massive blebs are ¼ to 1 inch in size, and tend to be ovoid and to be strung out along the bedding. They give the rock a very characteristic, mottled appearance which has been described as knotty or warty (Pls. 4,C and 5,A). Ledges along the main highway in the town of Sugar Grove display this feature especially well. Other oval patches are partly hollow and are lined with crystals of dolomite or quartz. In places, silica has intergrown with or replaced the dolomite crystals. The resulting crystals are called dolocastic quartz. The presence in residual clay of well-shaped quartz crystals or of dolocastic quartz crystals is one of the best indirect evidences that the clay was derived from the Shady dolomite. Ribbon banding is developed in some of the massive dolomite beds of the Patterson member, but it is not a conspicuous feature in the Glade Mountain district as it is in other areas. The upper part of the Patterson member is composed mainly of gray, fine- and medium-crystalline dolomite in less massive beds. Ribbon banding and blebs of recrystallized dolomite are present in some beds, but the blebs are not as abundant as in the lower part of the member.

The total thickness of the Patterson member is approximately 860 feet in the Asbury School area, and it appears to be of this order of thickness in the Sugar Grove area.

The "saccharoidal member" consists of white, pink, and gray dolomite. The name refers to the sugary texture of many of the more coarsely crystalline beds. The dolomite is predominantly lighter colored than in the Patterson member and tends also to be more regularly bedded. The blebs of white recrystallized dolomite and the ribbon banding, which are the most conspicuous features of the Patterson member, are absent in the "saccharoidal member." Shaly partings separate some of the dolomite beds. In places, one or more shale units from 1 to 3 feet thick are interbedded with the dolomite near the top of the member. Ripple marks are present in

A.



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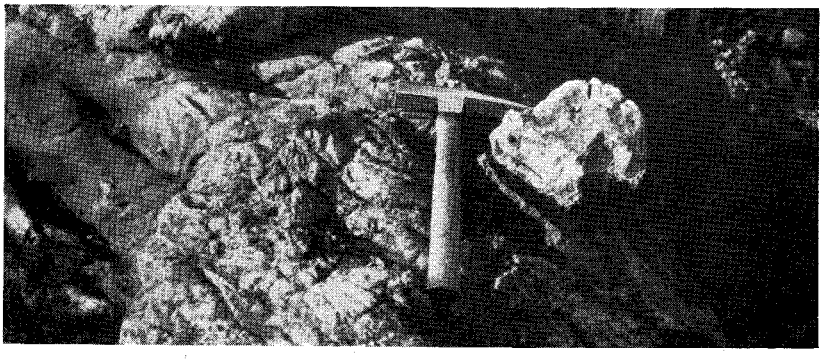
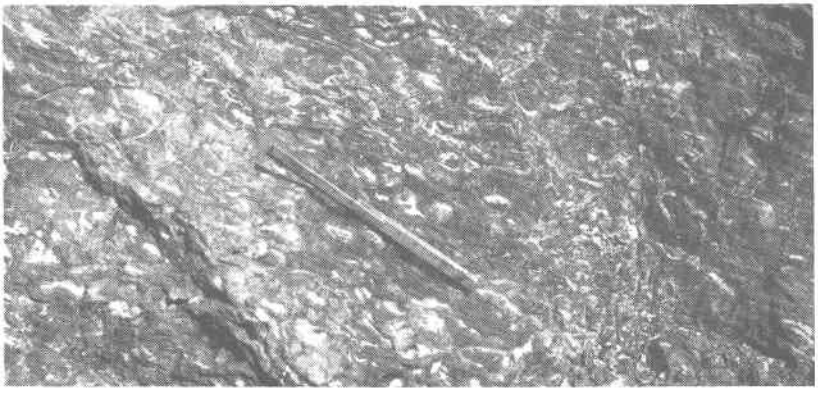


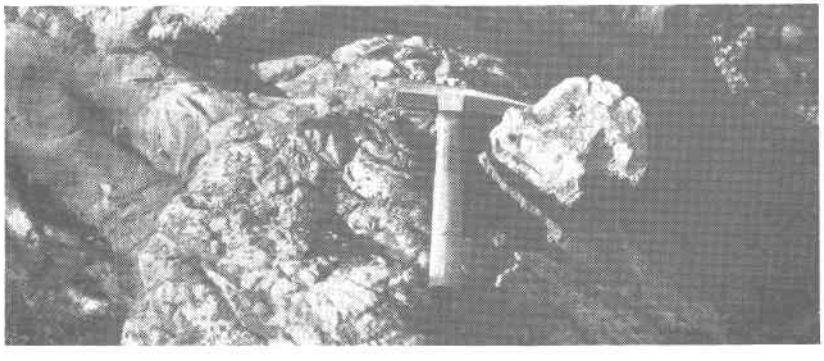
C.

A, Near view of Pl. 4,C. Blebs and veinlets of secondary dolomite in the Patterson member of the Shady dolomite. B, Outcrops of Shady dolomite in Rye Valley one mile west of Teas. C, Nodule of chert in Shady dolomite; common in the residual clays of the Shady but rarely seen in the bedrock.



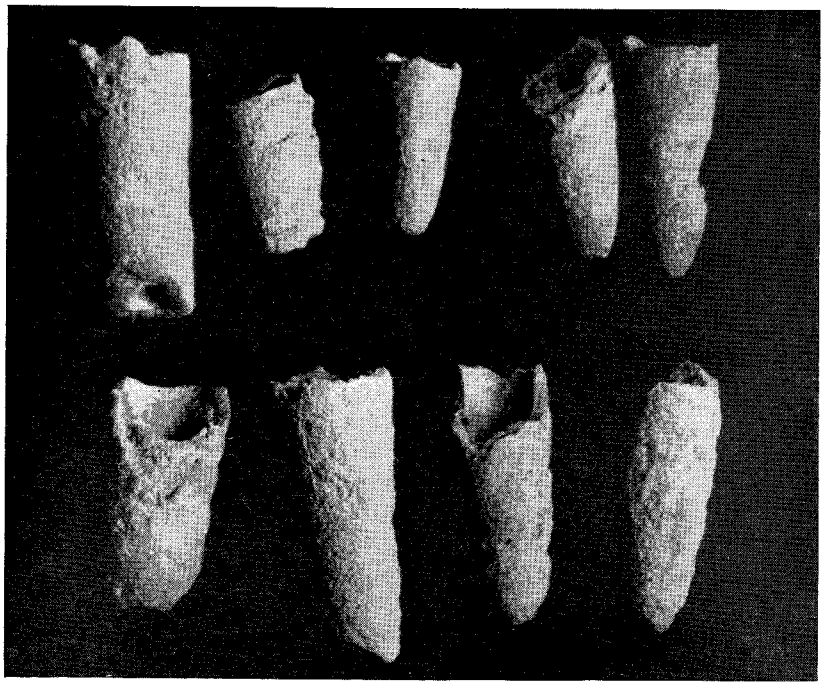
A.

B.



C.

A, Near view of Pl. 4,C. Blebs and veinlets of secondary dolomite in the Patterson member of the Shady dolomite. B, Outcrops of Shady dolomite in Rye Valley one mile west of Teas. C, Nodule of chert in Shady dolomite; common in the residual clays of the Shady but rarely seen in the bedrock.



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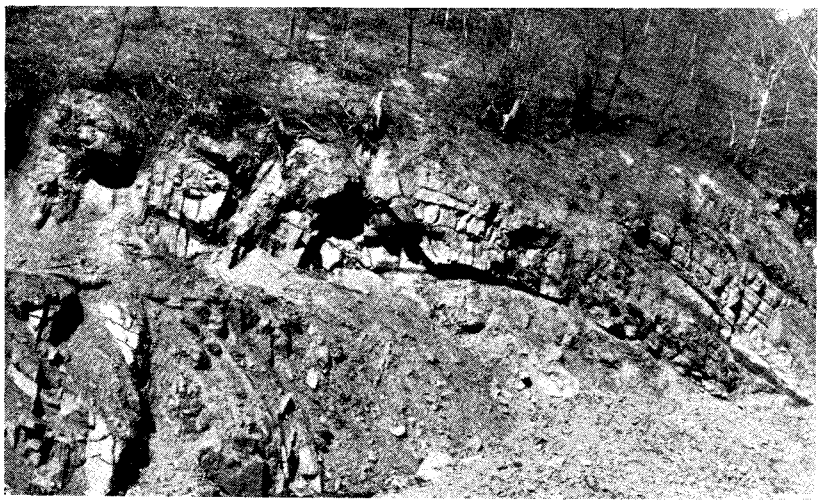
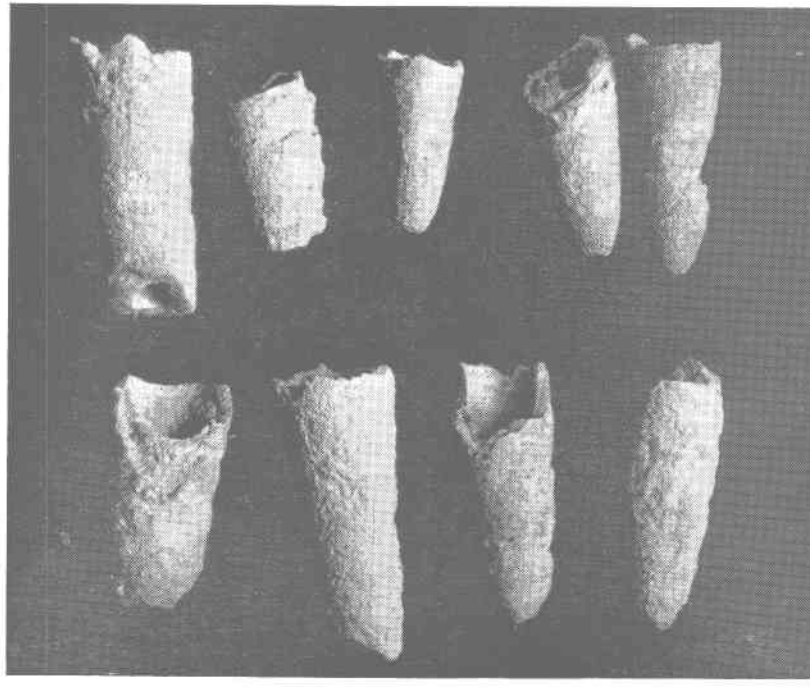


B.

A, Silicified specimens of *Salterella acervulosa* from the lower part of the Shady dolomite; in residual clay at the Umbarger mine. B, Rome shale and sandstone in an anticline overturned to the northwest, along the highway at Furnace Hill southeast of Marion.



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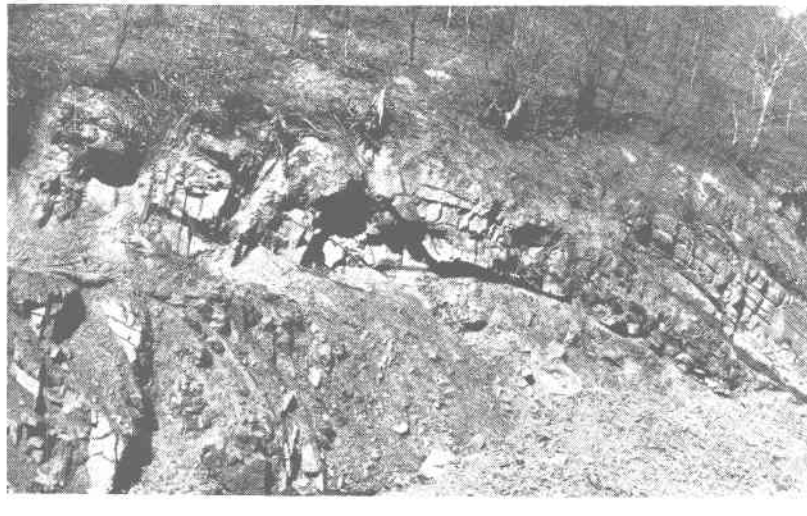


B.

A, Silicified specimens of *Salterella acervulosa* from the lower part of the Shady dolomite; in residual clay at the Umbarger mine. B, Rome shale and sandstone in an anticline overturned to the northwest, along the highway at Furnace Hill southeast of Marion.

a few places, especially in the thinner bedded dolomite. The top of the Shady dolomite is drawn at the base of the lowest shale of Rome type, although dolomite like that in the "saccharoidal member" is locally interbedded with the shale and sandstone of the Rome formation. In most places the contact is sharp and distinct.

The "saccharoidal member" is approximately 1,068 feet thick in the Asbury School area. It appears everywhere in the district to be thicker than the Patterson member, but its outcrop is much less extensive because it is partly or entirely faulted out in most of the belts of Shady dolomite.

The total thickness of the Shady dolomite in the Asbury School area is 1,928 feet. A poorly exposed but complete section east of the Winn mine is 2,088 feet thick. The Shady dolomite thus appears to be about 2,000 feet thick in the Glade Mountain district.

The Shady dolomite weathers readily to a sticky yellow clay, which blankets the bedrock except where recent erosion has been most active. In places the clay is stained red and brown by iron, or black by manganese, and the surface layers are commonly a dark-red or reddish-brown. The residual clay mantle is known to be 220 feet thick at the Umbarger mine where a drill hole penetrated to the underlying Erwin quartzite and encountered no undecomposed dolomite. It is probably scores of feet thick almost everywhere in the mountain areas except near the streams. Only in the Rye Valley-Cripple Creek lowland does the dolomite lie near the surface over extensive areas (Pl. 5,B). Yellow clay has been derived also from weathering of shale in the Rome formation, and of shaly beds in the Erwin quartzite, but this clay is normally less plastic and more gritty than that derived from the Shady. Furthermore, the residual clay of the Shady dolomite in most places contains at least a few nodules of silica and may also contain crystals and dolocasts of quartz.

Little silicification is visible in the dolomite of the Shady. Chert lenses and nodules, such as the one shown in Plate 5,C have been seen at a few places, but they are not common. On the other hand, nodules, and irregular masses of various forms of silica are common in the clay derived from the Shady dolomite, and are locally abundant. Their presence on the surface is one of the most useful clues in determining the proximity of the Shady formation in areas of poor exposures. The silica ranges from glass-clear and snow-white, through various shades of yellow and brown, to gray

and jet-black. There is also a considerable variation in texture. The colorless and smoky varieties are chalcedonic and are called chert, whereas the black counterpart is called flint. The tan, yellow, and brown varieties are mainly cryptocrystalline or finely crystalline and may also show a fibrous or cavernous structure. These varieties are called jasperoid. The term ferruginous chert has been applied to similar material by other writers and is equally descriptive. Still another variety is light-colored or snowy-white and is composed of fine- to medium-sized crystals. The term silicified dolomite has been used to distinguish this variety because the crystallinity is believed to be due to replacement of the original crystals of the dolomite by silica. Much of the silicified dolomite is sugary in texture and is friable. Large masses or lenses of this silicified dolomite have disintegrated into a white to light-yellow sand, which has in places been mistaken for sand derived from the Erwin quartzite, and has in the past caused extensive areas of Shady dolomite to be mapped as Erwin quartzite.

The residual clay of the Shady creeps and slumps readily, and in oversteepened mine faces it is subject to landsliding in the wetter seasons of the year. The clay is laminated in many places, apparently preserving some of the bedding of the original dolomite. Movement downslope has generally occurred, however, so that the laminae are not regular over areas larger than a few score feet, and in many places they are much contorted. Blocks of sandstone derived from the Erwin may be found in residual clay of the Shady dolomite as the result of this creeping and mixing process.

The Shady dolomite is sparingly fossiliferous in southwest Virginia. Fossils have been found in the Austinville area in some abundance, but the only fossils reported from the Glade Mountain district are *Archaeocyathus,* a reef-forming sponge, and an algal growth possibly belonging to the genus *Cryptozoon.* Specimens of these forms were collected by Stose from the "saccharoidal member" at a locality 1 mile west of Teas[39]. The writer found abundant, well-preserved specimens of a small pteropod (Pl. 6,A) in residual clay at the Umbarger mine south of Sugar Grove. The geologic evidence at the Umbarger mine indicates that the Shady dolomite normally overlies the Erwin quartzite which is present 600 feet to the south, so that these fossils are almost surely derived from the Patterson member of the Shady dolomite, and probably from its

lower part. The form was identified by Bridge as *Salterella acervulosa* Resser, possibly equivalent to *S. pulchella* Billings.

In the Austinville area, 18 miles east of the Glade Mountain district, trilobites, gastropods, and brachiopods have been identified from the Shady, including a species of *Olenellus* which is universally recognized as a Lower Cambrian genus. The early Cambrian age of the Shady dolomite is thus well established. The Shady dolomite of southwest Virginia is correlated with the Tomstown dolomite of northern Virginia and Pennsylvania.

A section of the Shady dolomite beginning in the ravine 0.4 mile northwest of Asbury School near the east edge of the Glade Mountain district and ending near the bridge across Crigger Creek 0.6 mile southwest of Asbury School, is as follows:

Geologic section of the Shady dolomite in the eastern part of the Glade Mountain district

	Thickness Feet
Rome formation (157+ feet)	
44. Shale, red and green, and shaly limestone, in bed of Crigger Creek	21.1
43. Not exposed	136.7
Shady dolomite (1,928 feet)	
"Saccharoidal member" (852± feet)	
42. Not exposed	47.6
41. Dolomite, fine grained, massive bedded, showing laminations on weathered surface; crops out underneath bridge	18.7
40. Dolomite, gray, fine grained, platy to shaly, weathering buff	22.9
39. Dolomite, buff, medium grained, in beds 2-3 feet thick	11.4
38. Inaccessible beds crop out beneath water level; probably similar to 37	65.6
37. Dolomite, light-gray to buff, fine grained, massive bedded, showing closely spaced laminations on weathered surfaces	42.1
36. Clay, yellow residual, with a few beds of light-gray, fine-grained dolomite cropping out in lower 100 feet	164.0

	Thickness Feet
35. Dolomite, greenish-white, finely crystalline, in beds 3 inches to 2 feet thick	36.0
34. Dolomite, light-gray to greenish-white, fine grained, in beds 1 to 5 feet thick; lower part has blebs of white, secondary dolomite similar to those in middle of Patterson member; upper part has mottled light- and medium-gray dolomite complexly intergrown	41.3
33. Dolomite, medium-gray, light-gray and grayish-white, fine grained, in even beds 3 inches to 2 feet thick; several beds have thin laminations; small amount of secondary dolomite along laminae	52.4
32. Dolomite, medium-gray, fine to medium grained, massive bedded; closely spaced laminations show on weathered surfaces; small veinlets and patches of secondary dolomite in upper part	32.0
31. Dolomite, light-gray to medium-gray, fine grained, in even beds 6 inches to 3 feet thick; several beds show fine laminations	27.7
30. Dolomite, greenish-white and buff, fine grained, very massive bedded; strongly developed joints in upper part; a small shear zone at top, but displacement appears to be minor	81.9
29. Dolomite, grayish-white to pinkish-white, very fine grained, in beds 4 to 10 feet thick	39.4
28. Dolomite, grayish-white to pinkish-white, very fine grained, in one massive unit	20.8
27. Dolomite, light-gray, fine grained, in massive beds; crops out behind spring house	49.7
26. Dolomite, light-gray and medium-gray, medium grained in massive beds; beds contain ramifying veinlets of secondary dolomite	80.5
25. Dolomite, light-gray, fine grained, in massive beds with a poorly developed ribbon bedding	17.6
Patterson member (1,076± feet)	
24. Not exposed; contact between Patterson member and "saccharoidal member" is in this interval	433.0

	Thickness Feet
23. Limestone, light-gray and medium-gray, in alternate layers forming a striking ribbon limestone; pinch-and-swell structure along some bands; a few bands broken so that small areas resemble an intraformational conglomerate	51.6
22. Limestone, light- and medium-gray, in alternate layers forming a ribbon limestone, especially prominent on weathered surfaces; pinch-and-swell structure developed along some bands where calcareous limestone flowed around more dolomitic limestone	17.5
21. Dolomite, light-gray, fine grained, with prominent ribbon banding; a little secondary dolomite	7.5
20. Dolomite, gray, fine grained, in prominent beds 1 to 4 inches thick; abundant dolomite veinlets along joints, and a few blebs of secondary dolomite; even bedding distinguishes this from all underlying units; shaly partings along some bedding planes	7.0
19. Not exposed	25.6
18. Dolomite, medium grained, sugary textured, with small patches of colorless to pink calcite	2.0
17. Not exposed	141.7
16. Dolomite, light-gray, fine grained, in very massive beds with dolomite veinlets	82.2
15. Dolomite, gray, fine grained, massive bedded, with a few secondary dolomite blebs and abundant dolomite veinlets; deeply weathered surfaces reveal partings not visible in fresh rock	42.9
14. Dolomite, gray, massive bedded, with secondary dolomite blebs; secondary mineralization has worked inward from joint surfaces as replacement of primary dolomite	39.0
13. Dolomite, light-gray to dark-gray, fine grained, in massive beds 1 to 5 feet thick; abundant blebs of white secondary dolomite rimmed with brown-stained dolomite containing pyrite; blebs average 1 inch in length and tend to par-	

		Thickness Feet
	allel bedding; appearance suggests solution of dolomite to form clay-rimmed cavity later filled with secondary dolomite	11.0
12.	Dolomite, light-gray, fine and medium grained, with blebs of tan and pink dolomite; weathered surfaces have hackled appearance due to etching out of joints invisible in fresh rock	21.0
11.	Dolomite, light-gray, medium grained, in massive beds about 4 feet thick; a few lenses of tan-colored dolomite; contains vugs a half inch to 2 inches in size lined with dolomite crystals; joint surfaces covered with dendrites; tiny pyrite and pyrrhotite crystals abundant in some beds	17.5
10.	Dolomite, white and gray, medium grained, in even beds 1 to 2 feet thick, with thin lenses and blebs of tan dolomite probably stained by iron	5.3
9.	Dolomite, light-gray, sandy, containing grains of glauconite and pyrite; upper part covered	10.6
8.	Dolomite, greenish-gray, slightly sandy, in one massive bed; weathering reveals undulatory, shaly bedding	4.8
7.	Not exposed	8.0
6.	Dolomite, light- to dark-gray, medium grained, slightly sandy	12.2
5.	Dolomite, white to dark-gray, fine and medium grained, sandy; known from float only	53.0
4.	Dolomite, light-gray and purplish-gray, fine and medium grained, sandy; scattered specks of glauconite; tiny specks of clay visible in weathered rock; known from float only	40.8
3.	Dolomite, dark-gray, fine and medium grained, sandy; known from float only	12.2
2.	Sandstone, coarse grained, friable, with small glauconite grains; sandstone, fine grained; and sandstone, dolomitic; known from float only	29.7

	Thickness Feet
Erwin quartzite	
1. Sandstone, fine grained, hard; known from float only	14.3
	2,100±

Fault with float of Rome shale below

ROME FORMATION

The Rome formation was named by Hayes[27] from exposures at Rome, Georgia. The name Watauga has been applied to equivalent rocks in Tennessee, but Rome has priority and is now used in Tennessee and Virginia.

The Rome forms a belt from ½ to 1½ miles wide, which almost surrounds the area of Shady-Erwin-Hampton rocks in the Glade Mountain district. The most prominent belt of Rome lies along the north side of the Glade Mountain district, between the Glade Mountains and U. S. Highway 11. Broad areas of Rome are also present at both ends of the mountains. Two parallel belts of Rome lie along the central and eastern part of the Rye Valley-Cripple Creek lowland. As no important manganese deposits are known in formations above the Shady dolomite in this district, the Rome was not completely mapped and detailed studies were not made.

The Rome formation is one of the most distinctive in the Appalachian Valley. It consists of red, gray, and green shale and fine-grained sandstone, and locally contains interbedded dolomite and limestone. The most important dolomite unit seen in the Glade Mountain district was 160 feet thick. Plate 6, B illustrates a typical exposure of Rome shale and Plate 7,A shows one of the interbedded dolomite units. Ripple marks and mud cracks are common in the shale and sandstone. The Rome formation forms knobby, steep-sided hills which stand well above the main valley level but are less prominent than the Erwin quartzite ridges. Along the Rye Valley-Cripple Creek lowland, the Rome topography is somewhat subdued, but it is especially well developed in the belt of Rome north of the Glade Mountains (Pl. 3,A).

The beds in the Rome formation are almost everywhere steeply dipping, and in many places are strongly folded and crumpled. At the road junction 0.8 mile south of St. Matthews Church near Atkins, the beds are almost completely overturned, so that the Shady dolomite overlies the Rome (Pl. 10,B). No accurate measurements of the thickness of the formation have been made because of the structural complexities. Butts[4] estimates that the formation reaches a maximum thickness of at least 2,000 feet in southwest Virginia. The width of the belt of Rome suggests that the formation has about this thickness in the Glade Mountain district.

No fossils were found in the Rome in the Glade Mountain district, but a few have been found elsewhere in Virginia. They seem to indicate that the Rome is in part Lower Cambrian and in part Middle Cambrian[5].

The following section of the upper part of the Rome and the lower part of the Elbrook is typical of the two formations in the Glade Mountain district. The section was measured on Church Street three quarters of a mile south of Main Street in the town of Marion. The beds are overturned, and dip 60° SE.

Geologic section of the upper part of the Rome formation and the lower part of the Elbrook formation in Marion, Virginia

	Thickness Feet
Elbrook formation (218+ feet)	
11. Dolomite, light- to dark-gray, crystalline, in massive beds; weathers white and with hackled surface	12
10. Dolomite, light-colored sandy and dark-colored non-sandy zones interbedded in even beds	6
9. Dolomite, light- and dark-gray, shaly, gnarled; possible small fault	10
8. Dolomite, light-gray, crystalline, in massive beds; ribbon banding apparent on weathered surfaces	18
7. Dolomite, thin-bedded, finely laminated, light- and dark-gray, fine grained; also massive bedded, crystalline, siliceous	16
6. Dolomite, light-gray, massive bedded, hackled on weathered surfaces; also even bedded, fine grained gnarled; contains ripple marks; possible small fault at base	60

	Thickness Feet
5. Dolomite, light-gray, hackled, strongly jointed	5
4. Dolomite, light- to medium-gray, crystalline, massive bedded and gnarled; also thin bedded	22
3. Covered	50
2. Dolomite, white, gnarled, massive bedded and thin bedded; contains ripple marks	10
1. Dolomite, light- and dark-gray, massive bedded, fine and coarse grained, siliceous	9
Rome formation (235+ feet)	
8. Shale, red, gnarled, containing lenses of dense, fine-grained dolomite 1 to 3 feet long and less than 1 foot thick	15
7. Shale, red	18
6. Dolomite, sandy, thin bedded to shaly	12
5. Dolomite, light- and dark-gray, laminated, crystalline; some beds oolitic	10±
4. Shale, red, with a little green shale; contains one bed of dolomite 3 feet thick	50
3. Shale, red, yellow and green; poorly exposed	50
2. Shale, red and green interbedded with even-bedded to shaly dolomite in nearly equal amounts	65
1. Shale, red, with a little green shale; contains one bed of dolomite 1 foot thick	15
	453

ELBROOK FORMATION

Dolomite belonging to the Elbrook formation overlies the Rome along the north edge of the Glade Mountain district. In parts of Smyth and Wythe counties, the Elbrook equivalent has been divided into a lower unit, the Honaker dolomite and an upper unit, the Nolichucky shale, but elsewhere in these counties the Nolichucky is not recognizable and the name Elbrook is used for the dolomite. The writer's observations included only the lower beds, so the presence or absence of the Nolichucky shale is not known. For this reason the more general formation name, Elbrook, is used for these post-Rome dolomites, rather than the name Honaker.

The Elbrook formation was named by Stose[36] from exposures in south-central Pennsylvania. In the Glade Mountain district the El-

brook forms a belt parallel to and north of the Rome on the north side of the district. Only three small patches of this belt were mapped, one south of Rural Retreat, one south of Atkins, and one near Adwolf. The best exposures of the lower part of the formation are in the Rural Retreat area, where the beds consist of light-gray, platy dolomite and limestone. The dolomite is much more thinly bedded than the Shady dolomite, and in places is even shaly. Flint and chert nodules are common in the clay derived from the Elbrook. They are distinct from those in the residual clay of the Shady, in that they are much fractured and veined.

The Elbrook dolomite is reported to be 1,400 to 2,000 feet thick in southwest Virginia[6]. The lower part of the Elbrook is Middle Cambrian, but the formation may include beds at the top which belong in the Upper Cambrian.

QUATERNARY DEPOSITS

Recent gravel and alluvium are present along many of the larger streams in the Glade Mountain district. Older high-level gravel is prominent on many benches and slightly dissected slopes. These gravels are not shown on Plate 1, but they are important because they locally obscure the bedrock and because they afford evidence as to the erosional history of the region. The gravel is especially abundant along the north slopes of Glade and Pond mountains and along the south slope of Buchanan Mountain. The cobbles and pebbles of which the gravel is composed are derived from the mountain away from which the gravel covered surface slopes. The deposits thus seem to have most of the characters of pediment gravels.

The gravel is well exposed on the spur just south of the Winn mine and also at the northeast tip of Glade Mountain, where it obscures the relations between the Erwin, Shady, and Rome formations. A large pit near the town of Currin Valley is excavated in a thick deposit of gravel on the tip of a spur.

Recent talus and slope wash mantle many of the mountain slopes, and in places they are so thick and extensive as to obscure the geology of the bedrocks over considerable areas. The Erwin quartzite is the principal contributing formation.

STRUCTURE

GENERAL FEATURES

The Glade Mountain district is part of a structurally complex region whose major outlines have been delineated by Keith, Campbell, Butts, Jonas, Stose, and others. The pre-Cambrian metamorphic and igneous rocks of the Blue Ridge province lie about 5 miles south of the district. North of these are the Lower Cambrian clastic formations which form the Iron Mountains, the prominent barrier along the south edge of the Glade Mountain district. The front of the Iron Mountains in Tennessee and at Damascus, Va., near the State line, is marked by a major overthrust (Pl. 9). This fault, or an equivalent one, is present just south of the Savage prospect at the southwest corner of the Glade Mountain district. It appears, however, to be absent to the northeast or else it has lost its position at the front of the Iron Mountains and lies farther south in the pre-Cambrian complex.

The Appalachian Valley, which includes the Glade Mountain group of ridges, is underlain by a series of folded and faulted sedimentary rocks ranging in age from Cambrian to Mississippian. The Silurian formations, which form Walker Mountain, Clinch Mountain, and other mountains to the north, are absent in the Great Valley. One of the major thrust faults of the southern Appalachians lies in the Valley three miles north of the Glade Mountain area. This is the Pulaski thrust which has been identified from a point near Marion for a distance of 160 miles to the northeast. Butts[7] considers the Seven Springs fault, which begins at a point near Marion and is traceable for 150 miles to the southwest, to be a continuation of the Pulaski thrust. The offset of the fault in the Marion area may be due to the presence in the overridden block of a prominent structural dome, called by Cooper[12] the Marion dome. At Pulaski, 50 miles east of Marion, the provable horizontal displacement along this fault is 10 miles (Pl. 9), but Butts estimates the horizontal displacement to be at least 20 miles. If it has only a third of that displacement in the Marion area, the fault plane must extend southward completely beneath the Glade Mountain district.

Walker Mountain, whose crest is formed by the Clinch sandstone, borders the Great Valley on the north. The Saltville fault in Rich Valley north of Walker Mountain is another major dislocation. It has a stratigraphic displacement of 14,000 feet in Washington County, which adjoins Smyth County on the southwest. Beyond Rich Valley, major

folds and faults persist for another 15 miles westward to the edge of the Appalachian plateaus.

The Glade Mountain district thus lies in the midst of a strongly deformed belt. Folding is combined with abundant faulting, including a major overthrust, the plane of which probably passes beneath the Glade Mountain district.

The Glade Mountain district is an area of Lower Cambrian rocks, whose resistant units form a series of closely spaced parallel ridges in the southern part of the Appalachian Valley. The Lick Mountains, which lie 10 miles to the northeast, are topographically and geologically quite similar to the Glade Mountains. Resistant quartzite of the Erwin formation forms the ridges of the Glade Mountain district, which are separated by long narrow valleys of the Shady dolomite. The Hampton shale, underlying the Erwin quartzite, is exposed on the slopes of some of the ridges. The whole mountainous area is almost entirely surrounded by belts of the Rome formation, except for a seven-mile gap on the southwest edge of the district. The area thus has the superficial appearance of a large dome 19 miles long and 4½ miles wide. The internal structure of the mountain group is, however, not dome-like, but is exceedingly complex.

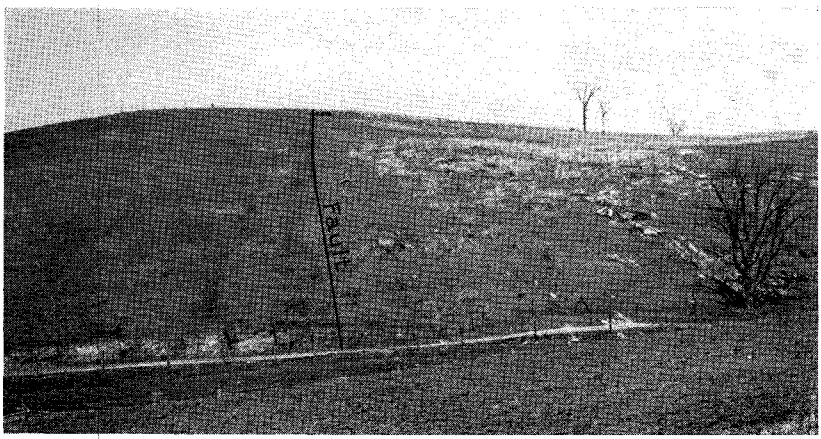
The major structural pattern of the district is formed by a series of parallel, steeply dipping, reverse faults along which older beds on the southeast have moved upward against younger beds on the northwest. These faults break the rocks of the district into a series of slices, by which the Erwin and Shady formations are repeated many times. The wider belts of Erwin quartzite form the major mountain ridges and the wider belts of Shady dolomite form the major valleys. Folds, normal faults, and overthrust faults complicate, but do not greatly alter, the main pattern.

Stose[40] suggested that the ridges were anticlines of quartzite separated by synclinal valleys of Shady dolomite, the whole constituting a large anticlinorium. Currier[18] included most of the Glade Mountain district in his geologic map of the lead-and-zinc region of southwestern Virginia, and interpreted the Glade Mountains as a klippe of Erwin quartzite from a block that was thrust northward over a folded and faulted area of the Shady dolomite and Rome shale.

STRUCTURE OF A TYPICAL RIDGE AND VALLEY

The higher parts of the mountain ridges are formed by the Erwin quartzite. Quartzite beds crop out in numerous places and dip con-

A.



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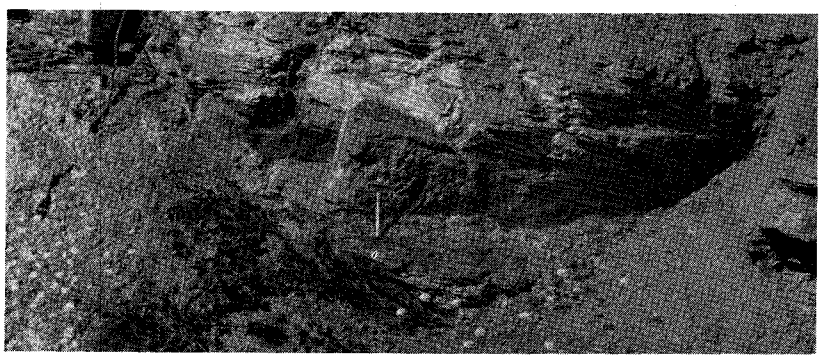

C.

A, Dolomite interbedded with red shale in the Rome formation. B, Sugar Grove fault, 0.1 mile south of Roberts Mill; Patterson member of the Shady dolomite on the right (south) in contact with vertical beds of red Rome shale. C, Overturned Shady dolomite (above) and Rome shale near Atkins.

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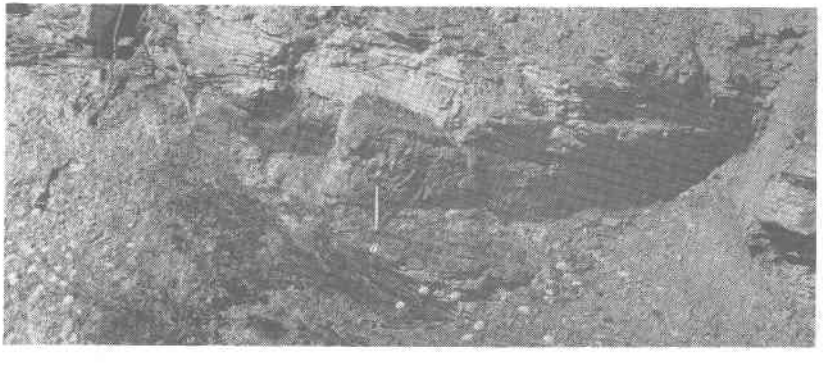
B.



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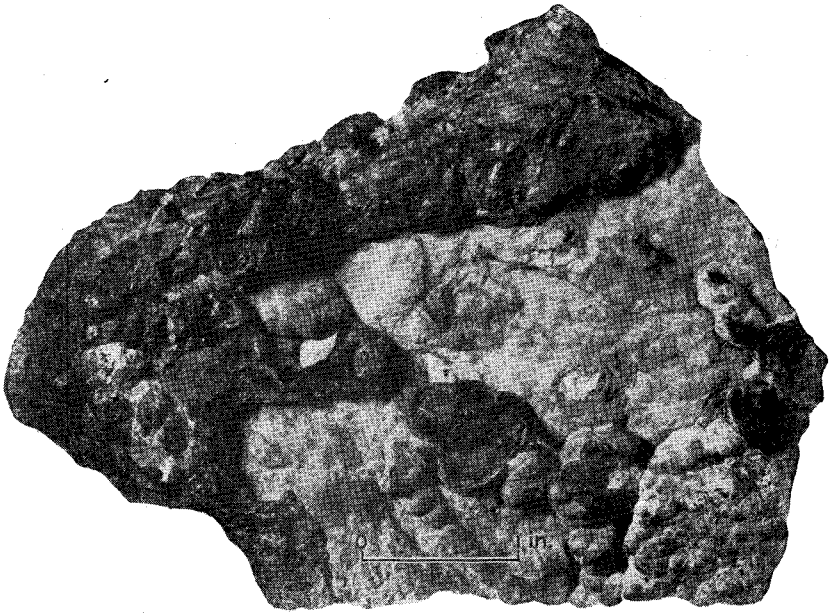

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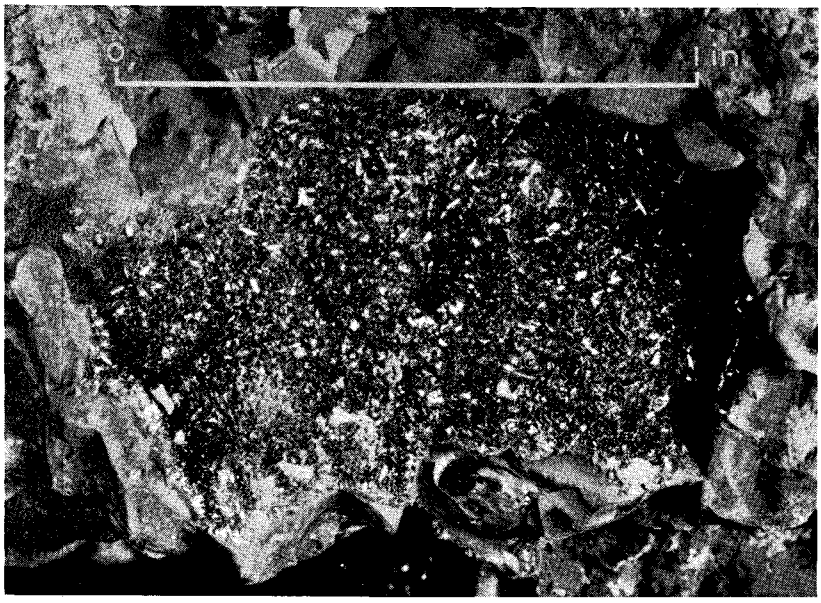
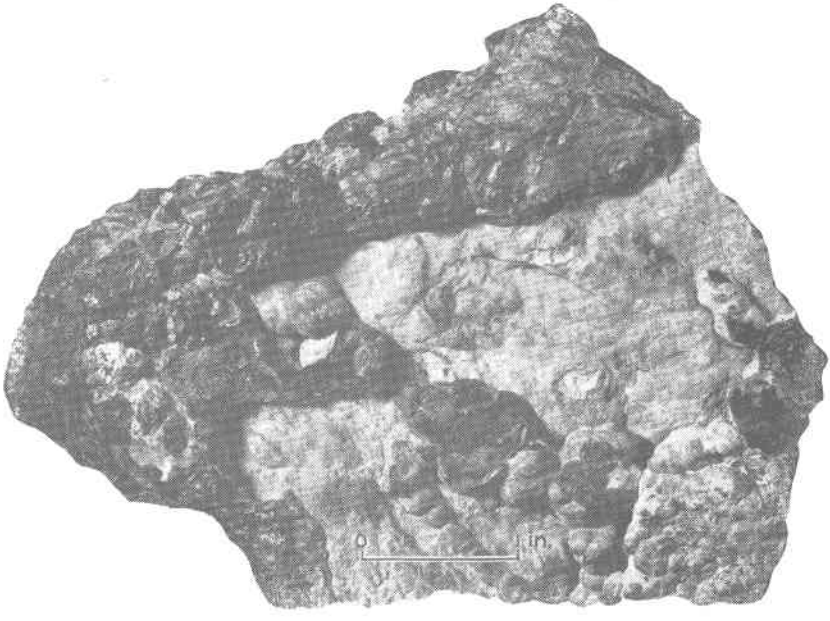
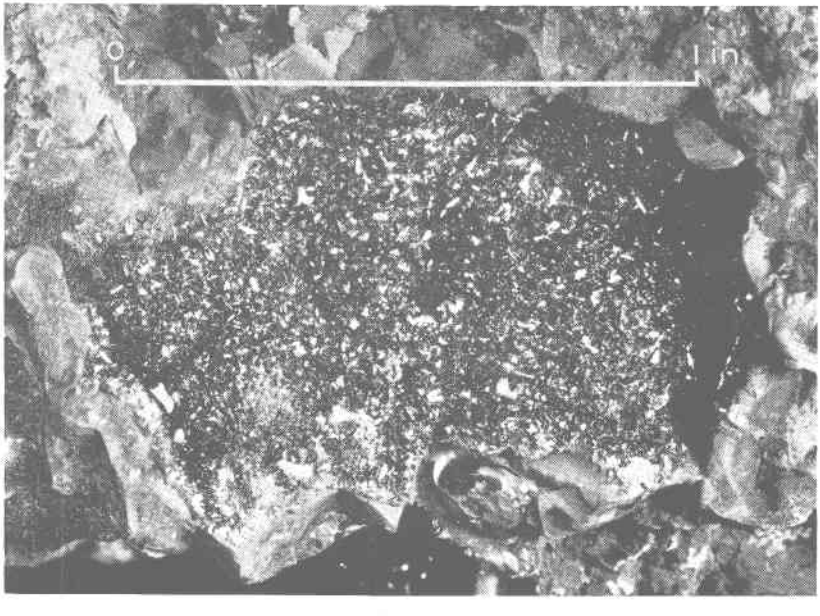


B.

A, Black cryptomelane intergrown with and coating the main part of a nodule of limonite. B, Pyrolusite crystals lining a cavity in a nodule of limonite. Both from Currin Valley mine No. 1.



A.



B.

A, Black cryptomelane intergrown with and coating the main part of a nodule of limonite. B, Pyrolusite crystals lining a cavity in a nodule of limonite. Both from Currin Valley mine No. 1.

sistently 20°-90° SE. On some ridges, five or six resistant quartzite or quartzitic sandstone units are present, separated by greater thicknesses of less resistant sandstone. One of the quartzite units normally crops out along or near the ridge crest, but a quartzite unit that has formed the crest ledge for a considerable distance may pass diagonally downslope and be succeeded at the crest by another quartzite unit. At the west end of Glade Mountain, for example, each of three different quartzite units in turn forms the crest for a short distance. On other ridges the crest may follow one quartzite unit for some distance, then offset across a swale to another unit.

Exposures on each typical ridge reveal a progressive sequence from the lower part of the Erwin quartzite or the underlying Hampton shale on the northwest side to the Shady dolomite on the southeast side. This normal sequence, combined with the consistent southeast dips, precludes the possibility that the ridges are anticlinal.

The major longitudinal intermontane valleys, and some poorly defined minor longitudinal depressions are underlain by Shady dolomite. Contacts between the Erwin and Shady on the southeast sides of the belts of Erwin are almost everywhere normal, as shown by the uniform southeast dips which cause the uppermost Erwin beds to pass beneath the lowermost Shady. Few outcrops of Shady dolomite are present in the intermontane valleys, but those that have been seen show the same southeast dips that are typical of the quartzite on the ridges. The available evidence therefore indicates that most of the dolomite valleys are homoclinal, as are the quartzite ridges.

At variable distances down the northwest slopes of most of the ridges a major reverse fault is encountered, by which the mountain rocks on the southeast are brought in contact with the Shady dolomite on the northwest. Where the Hampton shale is present at the surface, the stratigraphic displacement along one of these faults is between 2,500 and 5,000 feet. More commonly, the middle or lower Erwin quartzite is faulted against the Shady dolomite and the displacement is between 1,000 and 2,500 feet. The traces of these faults are remarkably straight and they cross ravines and spurs with practically no deflection.

None of the fault planes between the Erwin or Hampton formations and the Shady dolomite are exposed in cross-section, but outcrops of similar faults have been observed, in which older Erwin beds on the southeast have been faulted against younger Erwin beds on the northwest. In all of these faults, the fault plane must dip steeply to pass between the exposed beds on opposite sides of the fault. The Sugar Grove fault, one of the major reverse faults of the area, is exposed at a point

1½ miles southwest of Sugar Grove where it is almost vertical (Pl. 7,B). At this place, the lower Shady is in contact with the Rome formation. This evidence, coupled with the remarkable parallelism of all faults in the system, and the fact that the major regional compression is known to have been from the southeast, leads to the conclusion that the major faults, which repeat the Erwin quartzite and other formations at the surface, are high-angle reverse faults dipping steeply to the southeast.

From the fault contacts on the northwest slopes of the ridges to the valley floor, residual clay from the Shady dolomite may be exposed in places and search will generally reveal pieces of chert or silicified dolomite. As a rule, most of the surface is normally mantled by slope wash from the Erwin or Hampton above.

Many of the ridges and valleys of the district, such as Buchanan Mountain, White Rock Valley, White Rock Mountain and most of Brushy Mountain conform to this general pattern. Some of the mountains are, however, structurally compound in that the pattern of parallel Erwin and Shady belts is repeated several times on one mountain. The best example of this structural pattern is Glade Mountain, where a section from Killinger Creek through the Glade Mountain mine to the Rome shale north of the mountain shows six belts of Shady dolomite and five belts of Erwin quartzite (Pl. 1, Section CC′). Glade Mountain is further complicated by a series of small overthrust faults along its north edge.

Other structural features in the district are folds, normal faults and thrust faults. The structural features are described below in more detail.

STRUCTURE OF THE LOWLANDS AROUND THE GLADE MOUNTAINS

The Rye Valley-Cripple Creek lowland south of the Glade Mountains is in part structurally different from the mountains. Along the north side of this lowland the mountain type of structure persists, and steep southeast dips predominate in the Shady dolomite and Rome formations. A major reverse fault forms the south edge of the northern belt for 12 miles along the lowland. South of this fault, however, the structure changes and the southern part of the Cripple Creek lowland is essentially a broad syncline. Rome shale and sandstone are flanked by the Shady dolomite which dips gently inward beneath the Rome from both sides. The belt of Rome along the trough of the syncline is interrupted for half a mile along the course of Dry Creek by a transverse upwarp

which brings the Shady dolomite to the surface. To the west, the syncline dies out in the vicinity of Sugar Grove in an area of Shady dolomite, but eastward the syncline has been traced to the town of Speedwell 6 miles east of the Glade Mountain district. Currier[19] has applied the name Sugar Grove basin to the part of the syncline west of Dry Creek and the name Speedwell basin to the part east of Dry Creek.

The lowland north of the Glade Mountains is underlain by belts of the Shady, Rome and Elbrook formations. The Shady dolomite has been thrust against the Rome in the western half of the district, but the Shady-Rome contact appears to be normal in the eastern half, although the beds are in places overturned, so the Shady appears to overlie the Rome, as shown in Plate 7,C. The incompetent shale and thin-bedded sandstone of the Rome are closely folded in this belt and in many places the beds are overturned (Pl. 6,B). South and southwest of Marion, the Rome almost everywhere overlies the Elbrook due to strong overturning.

The Seven Springs overthrust, one of the major faults of the Appalachian Valley, is ¼ to 1 mile north of the area mapped on Plate 1. Its trace is in the vicinity of U. S. Highway 11.

TYPES OF STRUCTURAL FEATURES

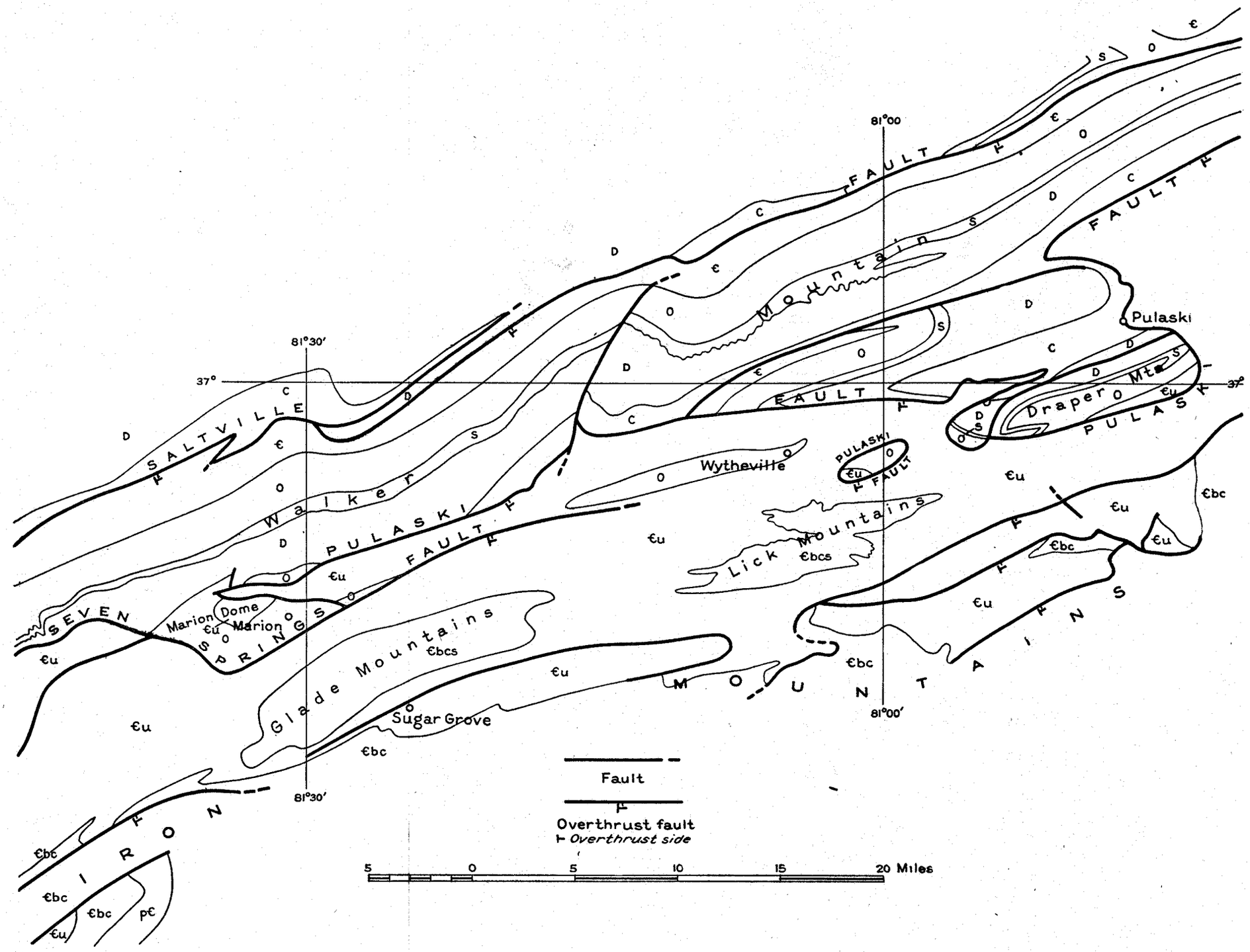
Reverse faults.—Reverse faults are the dominant structural features of the area. Altogether there are twelve major reverse faults and numerous minor ones, all approximately parallel. They strike about N. 75° E. in the eastern part of the area, and N. 60° E. in the western part. Most of the major faults are several miles long. Two of them, the Buchanan Mountain fault and the Barton Mountain fault, extend for 15 miles from the eastern to the western ends of the Glade Mountain district. They may persist even farther but were not traceable in the areas of poorly exposed Shady dolomite east and west of the mountains. The major faults are spaced less than a mile apart throughout the area and in places are less than a quarter of a mile apart.

The faults have no topographic expression, where they are within one formation, but where the Shady dolomite is faulted against the Erwin quartzite a change in slope marks the contact. The Hampton shale is only slightly more resistant to erosion than the Shady dolomite, so that a change of slope is vague or nonexistent at fault contacts between these two formations. Fault breccias are rare. They were produced only in the brittle quartzite and quartzitic sandstone of the Erwin

formation, and these units compose only a small part of the formation. Silicification tends to be more prominent near the faults, especially where the Shady dolomite is one of the formations involved.

The reverse faults are not confined to the mountain belts. One of the major reverse faults of the area is in the central part of Rye Valley and passes just north of Sugar Grove. In two places it brings the top of the Erwin quartzite against shale of the Rome formation and elsewhere the Patterson member of the Shady dolomite is in contact with the Rome. The fault extends from a point near Teas for 13 miles to the east edge of the district, and Currier has traced it for an additional 7 miles eastward. In the Glade Mountain district, this fault has all the characteristics of the mountain faults and seems to belong to the same system. At several localities the fault plane may be seen to dip steeply; it is nearly vertical in an excellent exposure on a hillside south of Roberts Mill (Pl. 7,B). Stose[35] has recently mapped a similar series of reverse faults in the Lick Mountain district 10 miles east of the Glade Mountains.

Overthrust faults.—Overthrust faults are present in the Glade Mountain district only on the north sides of Glade Mountain and Pond Mountain and near the east end of Rich Mountain. The Rich Mountain fault is small, but the Glade Mountain and Pond Mountain faults are more important, although their displacements are measurable in thousands of feet rather than in miles. One of the faults begins at the northeastern tip of Glade Mountain and is traceable about 3 miles westward. Beds in the middle of the Erwin quartzite are thrust over Shady dolomite. At the east end of the mountain, the Erwin quartzite may lie on Rome shale beneath a thick cover of gravel. The stratigraphic displacement is about 3,000 feet and the horizontal displacement is probably not less than a mile. North of this fault, four small "islands" of quartzite surrounded by Shady dolomite, appear to be klippen, indicating that the fault plane dips at a very low angle. The largest of these klippen is 1,500 feet long, the smallest 800 feet. The easternmost one is on a spur so heavily mantled with gravel, that its outlines are poorly shown, and some doubt exists whether quartzite is present at all beneath the gravel. The other three klippen are better shown by outcrops and float. These quartzite areas are interpreted as klippen because of their round or oval shapes, which bear no relation to the regional trend of the rocks; their positions on the crests of spurs; and the absence of the conspicuous basal Shady sandstone around the mar-



Map showing the major faults in the vicinity of the Glade Mountains. p€, pre-Cambrian igneous, sedimentary and metamorphic rocks; €bc, Cambrian basal clastics (Unicoi, Hampton and Erwin formations); €bcs, Cambrian basal clastics and Shady dolomite; €u, Cambrian undifferentiated (post-Erwin formations); O, Ordovician; S, Silurian; D, Devonian; C, Carboniferous. Modified from geologic map of the Appalachian Valley of Virginia by Butts and maps by B. N. Cooper. Compare with Pl. 2 and Fig. 4.

gins of the quartzite areas, which indicates that the quartzite is in fault contact with the Shady dolomite on all sides.

The second overthrust fault north of Glade Mountain is 1,000 feet north of the first one, overlaps it for nearly 2 miles, and then extends another 2½ miles to the west. This fault has a more sinuous trace than the first but is similar in other respects. One isolated area of quartzite 800 feet in diameter and 500 feet north of the fault is interpreted as a klippe.

A third fault, which is probably an overthrust, is present north of the second one and is traceable for nearly 2 miles. No klippen are associated with it.

Along the north side of Pond Mountain a large fault that has brought the lower part of the Shady dolomite against the Rome formation may be an overthrust. Three patches of the Erwin quartzite are found along the contact, so that the stratigraphic displacement at these places is in excess of 2,000 feet, the thickness of the Shady dolomite. The fault trace is somewhat more sinuous than that of many of the typical reverse faults, but it is not sufficiently affected by the topography to be a low-angle overthrust. The fault has, therefore, been indicated (Pl. 1, Sections EE′ and FF′) as a reverse fault, intermediate in dip between the high-angle reverse faults of the mountains to the south and the low-angle overthrusts north of Glade Mountain.

The existence of an overthrust fault on the southeast side of Rich Mountain is not certain. Several discrepancies were noted in tracing the quartzite beds at the east end of Rich Mountain, and one sinuous fault was drawn to explain the situation. This fault, as shown on Plate 1, is an overthrust fault with a horizontal displacement of about 500 feet. A series of shorter, unrelated faults could as readily be drawn, but an overthrust seems to be the simplest explanation for the observed facts.

A fault between the Shady dolomite and the Rome formation along the south side of Buchanan Mountain, which has been mapped as a normal fault, somewhat resembles an overthrust. The geologic relations are obscured by gravel and slope wash from the mountain. If it is an overthrust, the two small lenticular areas of the Rome formation surrounded by the Shady dolomite would be windows, and the small isolated area of Rome north of the fault would be a klippe.

Gravity faults.—Most of the gravity faults in the area have small displacements. They are parallel to the reverse faults. The largest normal fault extends about 4 miles along the north side of Spring Creek Valley south of Buchanan Mountain (Pl. 1). Shale of the Rome formation is dropped on the southeast against the Shady dolomite. This relation appears to be normal, and the dolomite dips southeast as though to pass beneath the Rome, but a fault must be present because the belt of the Shady dolomite is too narrow to contain the full thickness of the formation. Along the middle part of this fault, the trace swings northward toward the mountain, bringing shale of the Rome formation against the Erwin quartzite for a short distance. The displacement at this place is more than 2,000 feet.

Other normal faults are smaller. Most of those mapped are along the Erwin-Shady contact, and cut out the basal Shady sandstone for various distances. Such faults are located along the south sides of White Rock and Locust mountains. Other small normal faults probably exist within the formations but have not been recognized because they do not displace distinctive rock units.

Cross faults.—Three cross faults are present in the district. One of these is in a complex area near the eastern tip of Buchanan Mountain. It is almost at right angles to the regional strike and displaces the rocks and the strike faults that it crosses, showing that it was formed after the other major structural features. The nature of the movement on the cross fault is not clear but the result has been to bring Shady dolomite on the east side against the Erwin quartzite on the west along most of the fault. This effect could have been produced by a vertical movement downward on the east side.

The other two cross faults are found at the northwest tip of Locust Mountain. They also cross the regional strike at nearly right angles and offset prominent quartzite beds about 500 feet horizontally.

Folds.—All but three of the folds in the district are plunging anticlines at the ends of belts of quartzite. The anticlines are cut off on their northwest sides by reverse faults; some near the axes so that very little of the folds remains, others on the northwest flank so that the folds are nearly complete. The axes of the folds trend at small angles to the adjacent reverse faults.

The largest and best developed anticline is in Brushy Mountain south of Currin Valley. This fold is traceable for nearly 3 miles (Pl. 1). The belt of Erwin quartzite involved in the anticline extends eastward for 8 miles to form the main mass of Brushy and White Rock mountains. The axis of the anticline is a short distance north of the crest of Brushy Mountain. At its west end, the crest of the fold extends down a spur of the ridge and the quartzites plunge beneath the Shady dolomite, which forms the floor of Currin Valley. Changes in dip across the crest of this fold are revealed in outcrops of the upper part of the Erwin quartzite along the road over Brushy Mountain from Currin Valley to Teas. Where the quartzite in this anticline starts its westward descent toward Currin Valley, the Brushy Mountain ridge crest is offset across a narrow belt of the Shady dolomite; thence it continues westward along the next quartzite belt to the south. The place where the belt of the Shady dolomite crosses the ridge crest is marked by a prominent sag, utilized by a power line and an abandoned road.

Another large, plunging anticline is at the west end of Pond Mountain. There the basal Shady sandstone can be followed around the end of the anticline and shows by its pattern that the crest of the anticline is sharp. This anticline dies out against the Pond Mountain fault less than a mile from the point where the quartzite plunges westward beneath the dolomite.

Most of the anticlines are only partly preserved because the reverse faults on their northwest sides lie along the axes or even slightly southeast of the axes. The only evidence for these remnants of anticlines is at the ends of the quartzite belts, where the beds in the upper part of the Erwin quartzite curve northward and are cut off by the adjacent fault. This relation is well shown along the Currin and Rye Valley Railroad right-of-way at the east tip of Rich Mountain and along Roland Creek at the west tip of Short Mountain. Remnants of similar anticlines are present along most of the spurs at the east end of Glade Mountain, where the basal Shady sandstone is deflected slightly northward at the end of each quartzite belt, to die out against the reverse fault which it parallels farther west.

Only three synclines are known in the district. One of these is on the lower north slopes of Glade Mountain. Here the upper part of the Erwin swings around the west end of a belt of Shady dolomite and disappears beneath a thrust fault along the south side

of the dolomite belt. The poorly exposed syncline of Shady dolomite thus delimited, is of small size. The second syncline is at the east end of Buchanan Mountain where a belt of Shady dolomite, 1,000 feet wide, is bounded on both sides by beds at the top of the Erwin quartzite. The dip on the south limb is 83° S., so that the syncline must be somewhat overturned. The dip on the north limb is unknown. The third syncline is the large basin-like fold in the Rye Valley-Cripple Creek lowland which was described above.

The Erwin quartzite and Shady dolomite have not been affected by minor folding and crumpling; on the other hand, the shales of the Rome and the Hampton formations are in places strongly deformed, and many folds may be seen in some good exposures (Pl. 6,B). Folds are upright and overturned; open and isoclinal. One of the overturned folds is partly exposed in a cut at the three-road intersection 0.7 mile southeast of St. Matthews Church. Here the upper Shady dolomite, dipping 15° S., overlies the Rome shale which forms the hilly belt north of the contact (Pl. 7,C).

Complex areas.—Several parts of the Glade Mountain district are unusually complex. The largest of these areas embraces the lower north slopes of Glade Mountain. Here the regional pattern of steep southeast dips and parallel reverse faults is absent; instead, the beds in some places dip northwest, elsewhere are nearly flat, and in still other places dip southeast. The strike of the beds is, with few exceptions, northeast. Near the west end of the mountain the mappable quartzite and sandstone beds in the Erwin swing northwestward and are cut off by a thrust fault at the north edge of the quartzite area.

Structural features are most complex in the area at the northeast corner of Glade Mountain a quarter of a mile southwest of the two small klippen. Outcrops of the Erwin quartzite are intermingled with red shale, which is practically unknown in the rest of the Glade Mountain district except in the Rome formation. This shale, however, probably belongs in the lower part of the Erwin or the upper part of the Hampton. This small area appears to be broken by numerous faults, but only two were sufficiently clear to be mapped.

The complex structure of the areas described above, and their lack of conformity with the general pattern are apparently due to the overthrust faults, which lie at the north base of Glade Mountain.

Under their influence, the bedrock has been tilted in various directions, even trending in places at right angles to the regional strike, and it has also been shattered by more closely spaced faults than elsewhere in the district.

The isolated, unnamed ridge just south of the South Fork of Holston River is another area of unusual complexity. Its structural pattern is similar to that throughout most of the mountain area, but the reverse faults are more closely spaced. A section through this ridge (Pl. 1, Section FF′) midway between the two ends shows three repetitions of the Erwin-Shady contact in a distance of 1,200 feet.

ORIGIN OF THE MAJOR STRUCTURAL FEATURES

Reverse faults are the dominant structural features of the district. The folds that are present in the mountains consist only of the noses of plunging anticlines, cut off on their northwest sides by reverse faults. The anticlines seem to have been formed where the stress deforming the quartzites was small; hence, they lie at or near the ends of the major faults. Faults have not been mapped in the areas of the Shady dolomite east and west of the mountain group because of inadequate exposures, but those that do not have anticlines at the ends of the quartzite belts they bound, probably continue into areas of the Shady dolomite and perhaps into those of the Rome formation beyond. The Rome formation is complexly folded in most places, indicating that the stresses, which caused major faulting in the brittle quartzites, were largely spent by crumpling of the shales in the Rome.

Several peculiarities of the Glade Mountain area supply clues to explain the origin of the major structures. The parallelism of the reverse faults to one another and to the regional strike of the rocks is significant. It shows most perfectly along the belts of the Shady dolomite. Many of these belts are only 1,000 to 2,000 feet wide, but they persist for miles with only minor changes in width, although each is bounded on one side by a large reverse fault and on the other by a normal contact. Another significant feature is the persistent dip of the rocks to the southeast. Exceptions to this regional southeast dip are found in areas where overthrust faults are the dominant structures, as north of Glade Mountain, or where folds are present, as at the ends of some of the quartzite belts. Thus the reverse faults and the southeast dips seem to be related.

Where these faults cease to be dominant structural features, the beds may dip in other directions or lie horizontally. Overturned beds are practically unknown in the Glade Mountains or in the Rye Valley-Cripple Creek lowland. They are common along the north edge of the district, and in places the beds are so inverted that the Shady dolomite lies on top of the Rome formation and the Rome on top of the Elbrook formation.

The parallelism of faults and normal contacts, the persistent southeast dips and the close association of reverse faults and southeast dips are believed to be due to the reverse faulting itself, which acted on rocks that originally were only gently folded or perhaps nearly flat-lying. Each rock slice appears to have been broken by a reverse fault on its northwest side and rotated to a steeply dipping attitude by movement along the fault. The resulting southeast dip is thus due to the faulting, and hence the strikes of the rocks and also the formational contacts closely parallel the faults. The normal faults are minor features developed as the result of slipping within slices during reverse faulting, or of subsidence after the relief of the compressional forces. The anticlinal noses at the ends of the reverse faults are folds formed during the first application of compressional stress. These folds were almost entirely obliterated by movement along the faults, which developed later with the increase of compressional stress. The folds are now preserved only near the ends of the faults, where the fault movement was small.

The controlling factor that produced the uniform, closely spaced reverse faults was probably the Pulaski overthrust, one of the major faults of the southern Appalachians, whose trace is only a short distance north of the Glade Mountain district (Pl. 9). This overthrust has two branches which overlap north of Chestnut and Glade mountains. The southern branch, named by Cooper[13] the Seven Springs overthrust, is between 1 and 2 miles north of the northernmost quartzite ridge of the Glade Mountain district. It passes north of Seven Mile Ford, south of Marion, through Atkins, and through points a short distance north of Groseclose and Rural Retreat[8,14]. The northern branch, locally called the Hungry Mother Creek overthrust, is a direct continuation of the Pulaski overthrust, which has been identified for 160 miles northeastward from the Marion area. It is about 2 miles north of the Seven Springs overthrust. Butts believes that the horizontal displacement on the Pulaski overthrust, or on the two faults which he considers branches

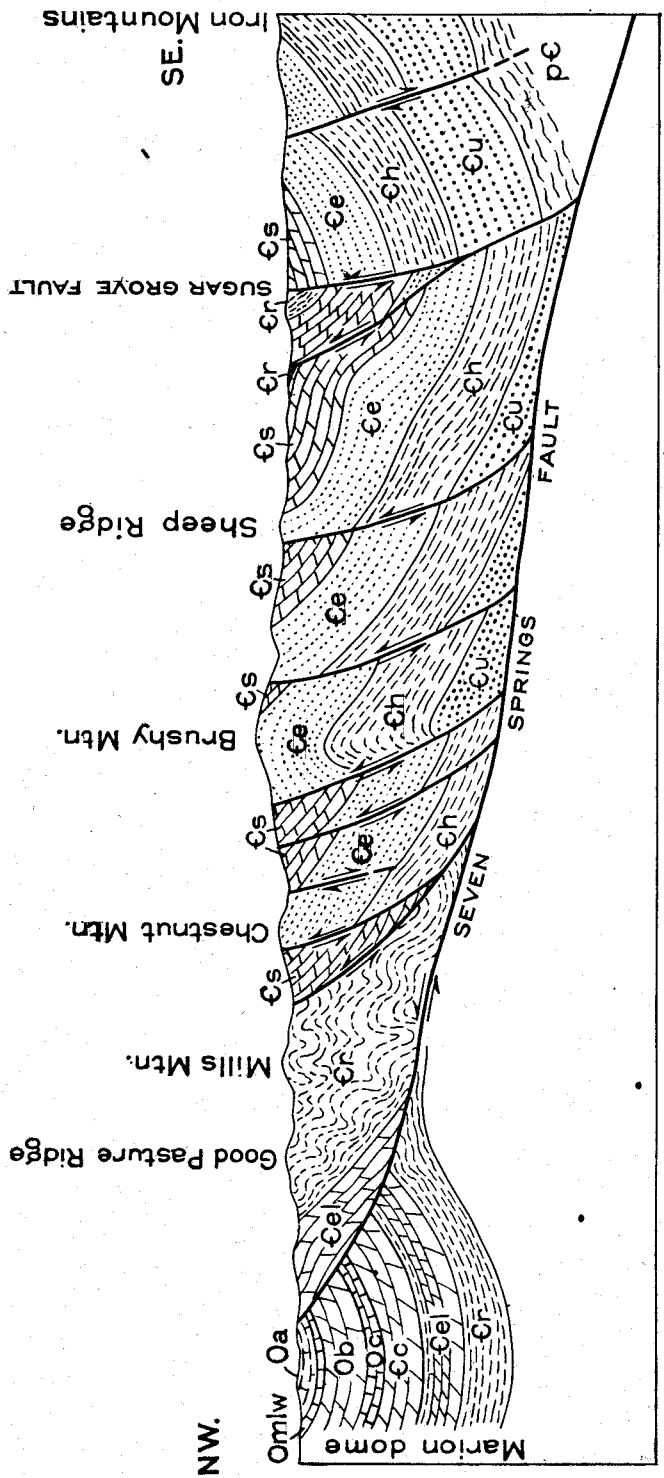


FIGURE 4.—Geologic section showing the origin of the major structural features of the Glade Mountain district. Length of section 8 miles. pꞒ, pre-Cambrian rocks; Ꞓu, Unicoi formation; Ꞓh, Hampton shale; Ꞓe, Erwin quartzite; Ꞓs, Shady dolomite; Ꞓr, Rome formation; Ꞓel, Elbrook formation; ꞒC, Conococheague formation; Oc, Chepultepec formation; Ob, Beekmantown formation; Omlw, Mosheim, Lenoir and Whitesburg formations; Oa, Athens shale.

of this overthrust in the Marion area, is not less than 20 miles. Cooper states that the Seven Springs overthrust and Hungry Mother overthrust are "high-angle thrusts." In cross section, however, he shows them dipping at angles from 20° to 40° and he also refers to the blocks between these major faults as shingle blocks. This reference implies that the fault planes overlap each other as seen in vertical section and are, therefore, at moderately low angles. Cooper now interprets these faults as high-angle faults. The writer believes that the Pulaski and Seven Springs faults pass beneath the Glade Mountain area at fairly low angles. The upper fault of the two, the Seven Springs overthrust, would then lie at a shallow depth beneath the northern part of the Glade Mountain district. The reverse faults of the Glade Mountain area are logically explained as branches of one or both of the underlying major thrust faults, relieving some of the compressional strain upward as the main fault block pushed northwestward at a low angle. The overturning of the Rome and Elbrook beds along the north edge of the district is also explained by the proximity of this major thrust fault. The interpretation described above is illustrated in Figure 4, which should be compared with the structural map (Pl. 9). The brittle quartzite beds probably broke and slipped upward where the thrust plane lay close beneath them. Farther south the fault plane was at greater depth beneath the Erwin quartzite, and hence the quartzites of the Iron Mountains do not show the same reverse fault pattern. To the east, west and north of the Glade Mountain district the upward stress was probably dissipated in crumpling the Rome shale, Athens shale, and other weak formations, so that the reverse fault system does not seem to offset rocks younger than the Shady. All the faulting of the region took place under a thick cover of younger Paleozoic formations; hence it is probable that the reverse faults, which displaced the Erwin in the Glade Mountain district, did not break through to the surface of that time.

The small overthrust faults on the north side of Glade Mountain are minor faults associated with the major underlying overthrusts. They probably helped produce the stresses that found relief upward in the form of reverse faults. They are not in themselves large enough to have been the controlling forces in producing the reverse faulting, inasmuch as the total displacement on one of these faults is no greater than that in one of the major faults in the reverse fault system.

The interpretation described above seems to offer a logical and satisfactory explanation of the structures of the Glade Mountain district. It should, however, be tested further by studies of the surrounding region, especially in areas east and north of Glade Mountain.

AGE OF THE DEFORMATION

All the folding and faulting of the Glade Mountain district took place during the Appalachian revolution at the close of the Paleozoic era, approximately 200 million years ago. At that time the major structural features in the broad belt between the crystalline rocks of the Blue Ridge province to the southeast and the flat-lying rocks of the Appalachian Plateau to the northwest, were produced. Numerous uplifts, probably accompanied by some warping and tilting, have since occurred, but there has been no material alteration of the structural pattern. Erosion, working on the structural system formed at the time of the Appalachian revolution, has produced the present ridges and valleys.

ECONOMIC GEOLOGY

MANGANESE

ORE MINERALS

Cryptomelane is the commonest of the hard, compact, very finely crystalline "manganese oxide" minerals. The mineral species of this general description were formerly grouped together under the name psilomelane. Richmond and Fleischer[32] have recently restricted the name psilomelane to the mineral which is essentially a hydrous barium-manganese manganate. This is distinct from cryptomelane, which contains appreciable amounts of potassium and very little barium. Small amounts of zinc, cobalt, and copper are also commonly present in cryptomelane. The only reliable method for distinguishing cryptomelane from psilomelane is X-ray analysis. Throughout this report cryptocrystalline, hard "manganese oxide" minerals, which have been identified by X-ray, are referred to by their appropriate mineral names. Specimens that have not been thus identified are referred to as of the "psilomelane type," following the suggestion of Fleischer and Richmond[24]. Eleven of the twelve specimens that were X-rayed proved to be cryptomelane and only one to be psilomelane, so that cryptomelane appears to be much more common in manganese ores of the district.

Cryptomelane is steel-gray to dull-black, with a metallic luster and a dark brownish-black streak. Impure specimens may be dull and earthy and quite soft, but the pure mineral is dense, hard, and breaks with a conchoidal fracture. The measured hardness is 6 to 6½. Most cryptomelane is structureless, but it also forms botryoidal, radiating, and fibrous masses. The botryoidal or well-rounded nodules may show shadowy growth bands roughly concentric to the center, or centers, of growth of the nodules (Pl. 11,C). The brownish tinge of the streak and a flame test for potassium help to distinguish cryptomelane from other minerals of the "psilomelane type," but as noted above the only certain test is by X-ray.

In the manganese ores of the Glade Mountain district cryptomelane is commonly associated with limonite, and may be intimately intergrown with it (Pl. 8,A). Chemical analyses of specimens that appear visually to be pure cryptomelane commonly show a small amount of iron oxide.

Psilomelane is a bluish- or grayish-black, crypto-crystalline mineral. It is a hydrous barium manganese manganate. Pure psilomelane contains about 50 percent of metallic manganese. Its luster is submetallic to metallic. The hardness of the pure mineral is from 5 to 6,

harder than a knife blade. The specific gravity ranges from 3.7 to 4.7. Most psilomelane has botryoidal or rounded surfaces, and many specimens show laminations parallel to the surface. Some specimens show radiating fibrous structures internally and others are dense, structureless masses. Iron, as a rule in the form of limonite, is commonly intergrown with it. Much of the material that has been called psilomelane is now known to be cryptomelane.

Pyrolusite is a crystalline black mineral compound of MnO_2, commonly with a little nonessential H_2O. It has a hardness of 2 to 2.5 and is therefore much softer than most other manganese ore minerals and will soil the fingers readily. The specific gravity is 4.7 to 4.9. Some pyrolusite forms terminated crystals, and is thereby distinguishable from crypto-crystalline cryptomelane and psilomelane. In the massive form in which pyrolusite usually occurs, the crystals are small and nearly equidimensional. In some places larger, well-formed crystals of pyrolusite line cavities or form encrusting layers on psilomelane. Commonly these crystals resemble a series of intergrown discs standing on edge (Pl. 8,B). More finely crystalline forms of pyrolusite are illustrated on Plate 12,A and B. Pyrolusite is the mineral of the "crystallized ore" referred to by miners. It is highly regarded by them because it is much less likely to be mixed or intergrown with iron or silica, and therefore normally contains a high percentage of metallic manganese. Pure pyrolusite contains 63.2 percent manganese.

Manganite has been described from the Glade Mountain area but was not found by the writer. It is a crystalline black mineral harder than pyrolusite but softer than a knife blade. It is rare in the district, and therefore unimportant as an ore mineral.

MINERALS ASSOCIATED WITH THE ORES

Wad is a dark-brown to black soft mixture of manganese oxides with a low apparent specific gravity. It may contain barium, iron, and aluminum. It forms a powdery or clayey mass, which is said to contain 30 to 42 percent of metallic manganese, but is generally so inextricably mixed with clay that for practical purposes the manganese content is much lower. Wad is so soft and finely divided that it is carried off in suspension when put through the usual log washer. Granules and nodules of recoverable hard manganese oxides may be embedded in wad, and areas of wad in many places border or overlie ore zones. Hence wad is useful in suggesting the presence of manganese ore nearby.

Lithiophorite is a hydrous lithium aluminum manganate containing variable proportions of cobalt and nickel. Lithiophorite was identified by X-ray analysis in one specimen of ore from the Glade Mountain mine. It was present in small quantities associated with cryptomelane. It is not abundant in the Glade Mountain district and is unimportant as an ore of manganese.

Lithiophorite is described[25] as a dull-black mineral commonly with a distinct bluish tinge, probably due to its cobalt content. It has a black streak, a hardness of about 3, and a specific gravity of 3.1.

Limonite, the commonest iron mineral in the manganese deposits of the district, is yellow, brown and black, with a yellowish-brown streak. In many places it encrusts manganese nodules or forms the cores of nodules whose outer part is of manganese oxide. It is also intergrown in variable amounts with manganese oxides, especially cryptomelane and psilomelane. The pure mineral has a hardness of 5 to 5.5 and a specific gravity of 3.6 to 4, but most of it is impure, soft and ocherous. Limonite was the important ore mineral of the old iron and manganiferous iron mines of the region.

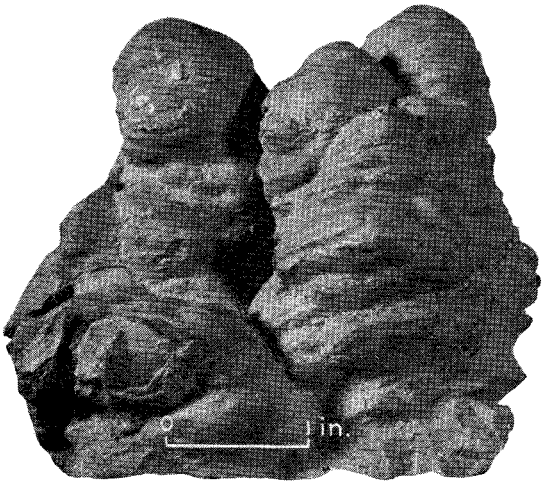
Hematite is red or black, and in this area is commonly soft, earthy and noncrystalline. It is less abundant than limonite with which it is commonly associated. It has a hardness of 5.5 to 6 and a specific gravity of 4.9 to 5.3.

Goethite is a red or brown mineral which in this district is present as feathery or velvety crusts on cryptomelane. It has a hardness of 5 to 5.5 and a specific gravity of 4.4. It is not abundant.

TYPES OF ORES

The manganese ores of the Glade Mountain district are highly variable in the size and shape of the individual pieces of recoverable manganese oxide, and in their relation to the surrounding gangue. Eight different types, which are described below, are distinguishable, although there are gradations between types. Many mines have more than one type of ore. These types are independent of the mineral composition of the oxides. Pyrolusite seems to be the only manganese mineral found in the powder type of ore, but any or all of the three common ore minerals, cryptomelane, psilomelane and pyrolusite may occur in any of the other seven types.

Granular ore.—In granular ore, the manganese oxide forms rounded and subrounded particles less than one inch in size, disseminated through clay, wad, sand and disintegrated silicified dolomite. The term



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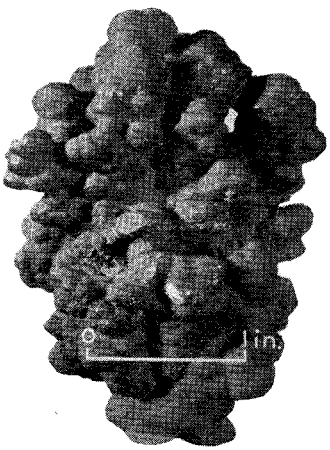

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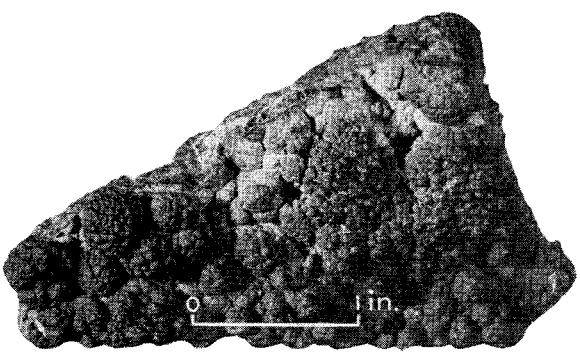
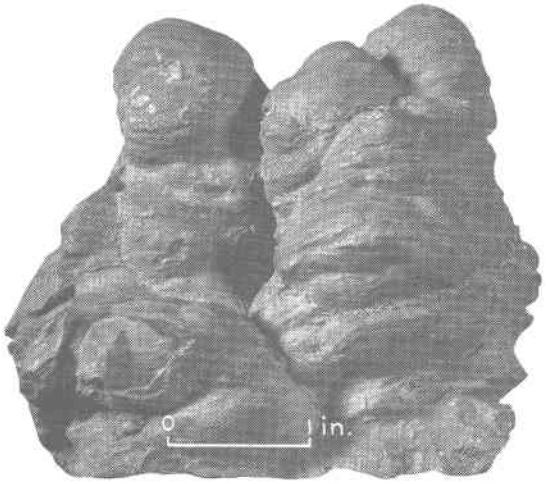


C.

A, Nodule of manganese oxide from the Winn mine. B, Grape-cluster type of manganese oxide nodule from the Winn mine. C, Mammillary type of manganese oxide nodule from Deans Branch prospect.



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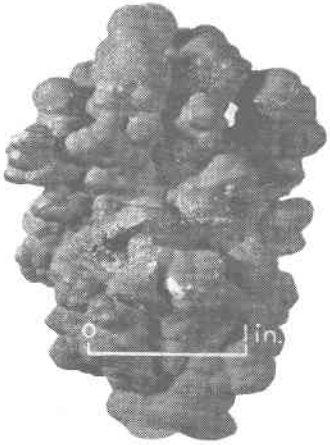

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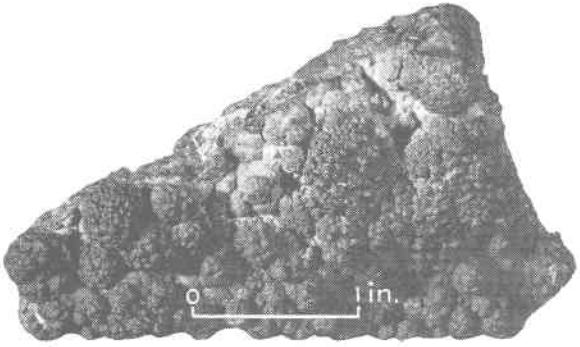

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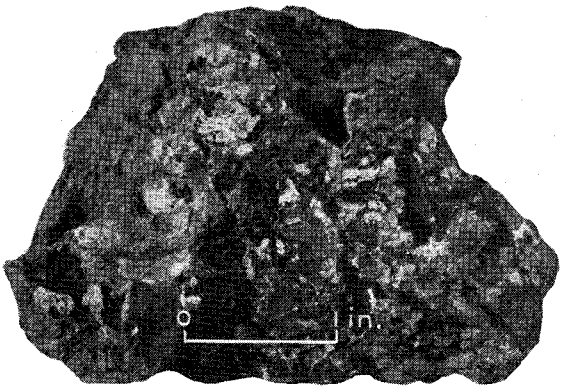

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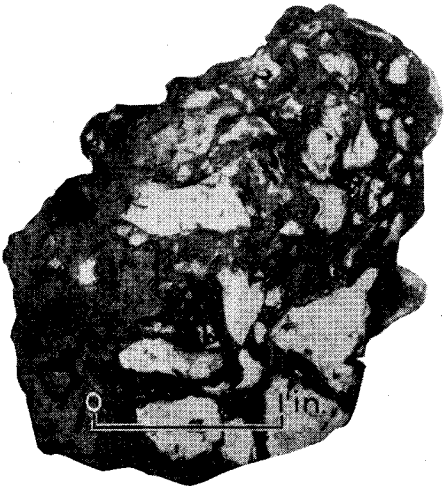

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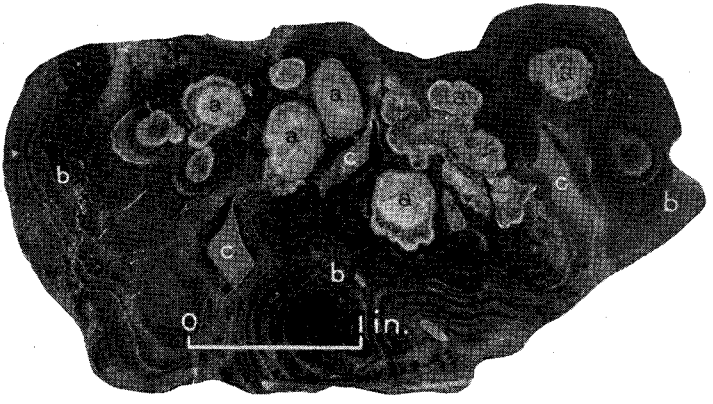
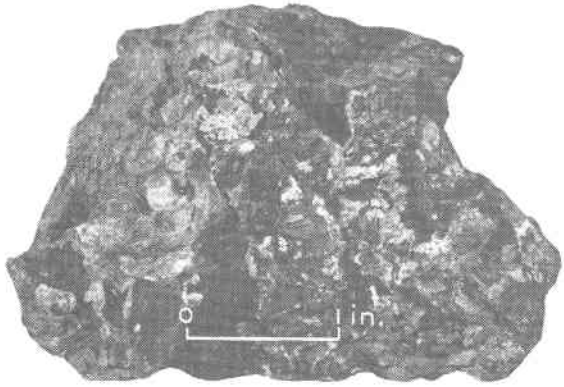


C.

A, Ledge-type manganese oxide ore from the Glade Mountain mine. B, Modified breccia-type of manganese ore from Currin Valley mine No. 2. C, Polished surface of a cryptomelane nodule from the Savage prospect, showing concentric growth lines.



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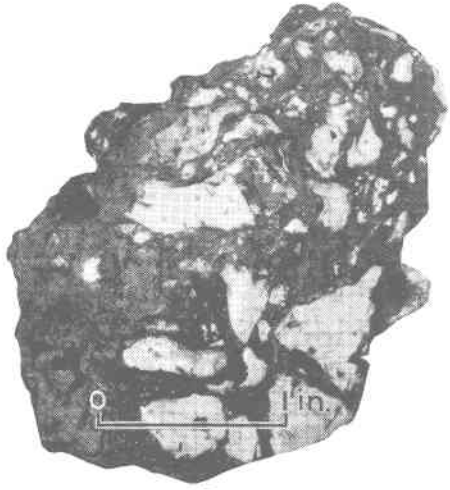

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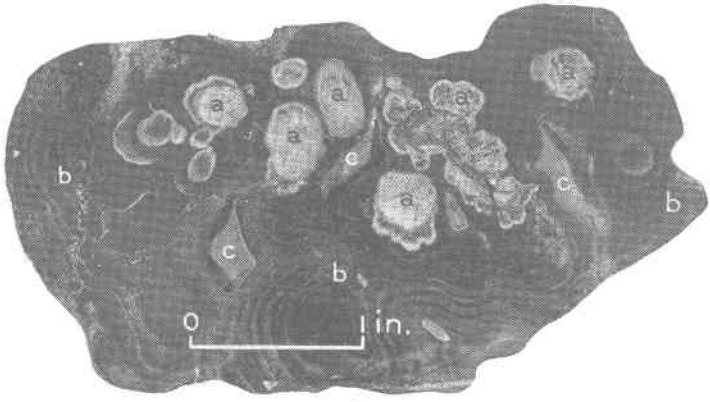


C.

A, Ledge-type manganese oxide ore from the Glade Mountain mine. B, Modified breccia-type of manganese ore from Currin Valley mine No. 2. C, Polished surface of a cryptomelane nodule from the Savage prospect, showing concentric growth lines.

"wash ore" is frequently applied to this type, although technically "wash ore" means any ore from which a profitable quantity of concentrates can be recovered by washing. The ore at the Rich Mountain mine is a good example of the granular type, but most of the mines have at least small amounts of granular ore.

Nodular ore.—The recoverable manganese in nodular ore forms subrounded to rounded masses larger than one inch in size (Pl. 10,A). Many of these nodules have an internal lamination concentric to the outer surfaces, showing that they have grown layer on layer. The rounded nodules may grow as a series of knobs, resembling bunches of grapes, which are called botryoidal nodules (Pl. 10,B). Smaller rounded growths on an otherwise smooth surface form the mammillary type of nodular ore (Pl. 12,C), and elongate rodlike clusters form the radial or stalactitic type. Laminations of the enclosing clay may cause the nodule to have edges or flanges, and in some nodules the straight laminae of the original clay are preserved in the internal structure of the nodule. Nodules are commonly stained yellow or brown on the outer surfaces but are dark-gray to black inside. The best specimens of well-developed nodular ore come from the Winn mine and the Savage prospect.

Angular ore.—Angular ore consists of hard pieces of manganese oxide of irregular and angular shape, which may be flattened or roughly equidimensional. Most specimens are less than two inches in size but large angular chunks of dense, hard, amorphous manganese oxide, weighing several hundred pounds, have been found. The angular type of ore results from haphazard growth of hard manganese oxide in clay, sand, or disintegrated silicified dolomite, or even in cavities. Good examples of this type are present at the Kyva mine and small amounts of angular ore are present at many of the other mines.

Ledge ore.—Tabular solid masses of manganese oxides a few inches to 10 feet thick are termed "ledge ore." Pockets of clay, wad, or powdery manganese oxides may be scattered through the mass, but ledge ore is essentially rocklike in its solidity and continuity. The ledges tend to lie parallel to the laminations of the enclosing clay, showing the control exerted, during growth, by the structure of the clay. The only good examples of ledge ore in the area are at the Glade Mountain mine. A specimen of ledge ore is shown in Plate 11,A.

Bedded ore.—Solid layers of manganese oxide which have been formed by partial or complete replacement of beds of sandstone or

quartzite constitute bedded ore. The thickest bed in the district is 8 inches. This bed and several other thinner beds were temporarily well exposed at the Deans Branch prospect, which contained the only specimens of this type of ore found in the district. Iron oxides more commonly replace the Erwin quartzite or sandstone than do manganese oxides, and several deposits of limonite of the bedded type are known in the Erwin.

Breccia ore.—Fracture filling and partial replacement of shattered bedrock by manganese oxides produce breccia ore. The best breccia type of ore is formed where brittle beds in the Erwin quartzite have been fractured and later cemented by precipitated manganese derived from the overlying Shady dolomite. No manganese deposits of this type are known in the Glade Mountain district, but the small iron prospect along the Brushy Mountain fault ½ mile southeast of Currin Valley mine No. 1 is of the breccia type. Brittle quartzitic sandstone in massive beds has here been extensively shattered and recemented by limonite. A modified breccia type of manganese ore is formed by fracturing of masses or lenses of silicified Shady dolomite, followed by filling of the fractures by manganese oxides and partial or complete replacement of the wall rock bordering the fractures. Most of the brittle silicified dolomite is probably shattered as the result of creep or slumping of the enclosing clay, but some may have been shattered by deformation of the bedrock before weathering took place. This modified type of breccia ore is common in the Glade Mountain district, especially in the Currin Valley area. Currin Valley mine No. 2 contains good specimens (Pl. 11,B).

Vein ore.—Vein ore consists of tabular masses of hard or earthy manganese oxides cutting across enclosing decomposed and disintegrated mantle rock or solid bedrock. Many of the veins branch off from larger masses of ore. Some of the manganese in the veins is hard and therefore recoverable, but much of it is earthy or powdery and would be lost in passing through a washer. This condition, combined with the thinness of most of the veins, makes this type of ore of little commercial importance in the Glade Mountain district. Vein type ore was temporarily well exposed in 1942 in small cuts at the Thomas prospect, the Kyva mine, and the Deans Branch prospect.

Powder ore.—Powder ore consists of loose, uncontaminated particles of manganese oxides, probably pyrolusite, which either form separate pockets in the clay or adjoin masses of hard ore. Pockets several

feet in diameter have been found. This type of ore would be lost if put through a log washer, but sizable pockets may be mined by hand and put aside for shipment without further treatment. The normal powder ore is exceptionally pure and high-grade, and hence may be sold for chemical ore at higher prices than the common metallurgical grade of ore. Powder ore is common at many mines but is rarely present in large quantities. It has been separately mined, however, at the Glade Mountain mine and at the Deans Branch prospect.

Manganiferous clay (wad) is not included as a type of ore, for it has no commercial importance in the Glade Mountain district, except as it may contain hard ore of the other types. Iron minerals may be associated with the manganese in all types of ore except the powder ore. Where the iron and manganese are solidly intergrown the iron can not be economically separated and a lower grade of concentrates results. Even pieces of ore that appear to be completely pure manganese oxide commonly contain small percentages of iron oxide, as shown by analysis. Iron and manganese, though formed in a similar manner, in the residual deposits, tend to be deposited separately, so that the manganese-rich materials can for the most part be selectively mined, leaving the iron-rich parts behind.

STRUCTURAL TYPES OF MANGANESE DEPOSITS

Most of the described deposits of the Glade Mountain district belong to the homoclinal ("monoclinal") type. No representatives of the synclinal type or of the terrace-gravel type are known. Deposits in which the circulation of manganese-bearing solutions has been controlled by faults are not definitely known. The Wright bank and one or two others may have been formed in this manner, but they may equally well be homoclinal deposits.

The homoclinal type of deposit is one in which the bedrock of the region dips uniformly in one direction and has partly controlled the circulation of the mineralizing ground waters. In the Glade Mountain district the regional dip, and consequently the attitude of bedrock at almost all the manganese deposits except those along the Iron Mountain front, is 20° to 70° SE. Two subdivisions of the homoclinal type of deposit are distinguishable: the residual homoclinal type, and the bedrock homoclinal type.

Residual homoclinal type.—In the residual homoclinal type the manganese deposit is in the weathered mantle overlying bedrock. In

the Glade Mountain district this mantle consists of residual clay derived by deep decomposition of the Shady dolomite. The clay is almost everywhere extensive and deep except along the Rye Valley-Cripple Creek lowland. The major rivers that drain it have removed the residual clay almost as fast as it was formed and dolomite crops out abundantly (Pl. 5,B). Elsewhere, recent erosion has not entirely removed the clay blanket, even on the valley floors. The clay is especially well preserved on the benches and gentle slopes on the valley walls. The depth to which the clay extends is known to be 220 feet at the Umbarger mine. The fact that only two manganese mines in residual clay of the Shady dolomite (Currin Valley mine No. 5 and Porter Bank) encountered bedrock in the workings indicates that the clay is almost everywhere at least 30 to 40 feet thick and it may average much thicker. The manganese deposits consist of pockets and ledges of ore scattered through the clays. Several mines have worked ore 60 feet below the original surface and drilling at the Umbarger mine encountered ore at depths between 75 and 90 feet below the surface. Unless there has been extensive slumping, the lamination of the clay roughly parallels the dip of the dolomite from which the clay was derived. Much of the clay, however, shows no visible structure. At most mines the ore pockets are scattered at random through the clay except that in laminated clay they tend to be elongate parallel to the laminations. Ore nodules from partly eroded ore pockets may be scattered over the surface but deeper ore bodies have little or no surface manifestation. Black, brown, or red clays surround and overlie many pockets of hard ore. The black and brown colors are due to wad, and the red and reddish-brown colors to iron oxides which are in many places closely associated with the manganese oxides. On the other hand many fine showings of iron-stained or waddy clays have no accompanying hard ore, and in some ore bodies, such as those at the Winn mine, the nodules are embedded in yellow clay. This lack of uniformity in manganese deposits makes it extremely difficult to estimate the size of a manganese ore body from surface showings, or to prove up tonnage except by extensive prospecting.

Bedrock homoclinal type.—The bedrock homoclinal type of deposit has only one representative in the area, the Deans Branch prospect, where manganese oxide has replaced beds in uniformly dipping solid sandstone near the top of the Erwin quartzite. The largest bed is 8 inches thick, but several others are more than 2 inches thick. The circulation of the mineralizing solutions has apparently been controlled

either by a prominent open bedding plane or by a particularly porous bed. Veins and veinlets of manganese branch upward from the main bed at several places.

RELATION OF MANGANESE DEPOSITS TO GEOLOGIC AND TOPOGRAPHIC FEATURES

In the Glade Mountain district 49 of the 55 described manganese deposits are in residual clay derived from the Shady dolomite. Two prospects in shale of the Rome formation and two in the Erwin quartzite are dominantly iron prospects and are of minor importance. The Deans Branch prospect, where the manganese replaces sandstone at the top of the Erwin quartzite, and the Horne prospect in the Rome formation are the only deposits of importance outside the Shady dolomite.

Shady dolomite and its residual clay underlie the valleys and lower mountain slopes of most of the area, and the Erwin quartzite underlies the steep upper slopes and the crests of the ridges. The contact between these two formations is normally about a third of the way up the ridge, and is in most places marked approximately by a change of slope, which is rarely definite. A typical belt of Shady dolomite is bounded on one side by a normal contact with the Erwin, which dips beneath the Shady at an angle of 20° to 70°, and on the other by a reverse fault, which brings the Erwin again to the surface. Most of the manganese deposits lie in the residual clays of the Shady dolomite near the normal contact on the northwest side of the belt. Where the belts of Shady dolomite are narrow, the deposits may be centrally located in the belt as at the Glade Mountain mine, or nearer the fault contact as at the Wright bank, but all deposits seem to be in the lower part of the dolomite, and most are within 500 feet horizontally of the Erwin-Shady contact. This places them within 200 to 300 feet stratigraphically of the base of the dolomite.

Talus and slope wash from the higher mountain slopes of Erwin quartzite choke the valleys of tributary streams flowing from the mountains, so that the dolomite or residual clay of the dolomite is rarely exposed in the ravines or valleys. Along the narrow sharp-crested spurs which form the interstream divides the clay is more likely to be exposed. Many of the manganese deposits lie on or near the crests of spurs, not because the deposits were formed with

FIGURE 5.—Sketch of Glade Mountain from a point near Cedar Springs. The main ridge of Glade Mountain is in the center and right background. The crests of Glade Mountain and the lower ridge paralleling it are formed by Erwin quartzite, separated from each other by a belt of Shady dolomite. Shady dolomite also underlies the foreground. The two knobs on the extreme left are parts of White Rock Mountain. By Ansel M. Miller.

regard to the present mountain drainage, but because deposits so located are better exposed and so more likely to be discovered, and also because a greater thickness of the clay mantle on the spur crests has been preserved from erosion.

Several of the manganese deposits are in belts of dolomite that form benches or shallow depressions between a major ridge of Erwin quartzite and a parallel Erwin belt part way down the mountain side. The Glade Mountain mine (Fig. 5), the Phillipi Branch prospect, and the Marchand prospect are among the deposits so situated. The lower Erwin belt may form a prominent though lower, dissected ridge, as at the Glade Mountain mine, or it may be topographically inconspicuous because no ridge-making quartzite is present.

The lowest body of residual clay from the Shady dolomite is at an altitude of 2,200 feet along the South Fork of Holston River at the west side of the district. The highest bodies of residual clay are at altitudes of 3,550 feet. One of these is on the Killinger Creek-Nicks Creek divide and the other is in the saddle between Little Round Mountain and Glade Mountain. The mines and prospects have a smaller range of altitude. All the 53 significant deposits lie at altitudes between 2,300 and 3,340 feet (Fig. 6) and all but nine lie between altitudes of 2,620 and 3,090 feet. The geologic environment below the altitude of 2,620 feet is not favorable to the formation of manganese deposits, for reasons which are discussed in the section on their origin, but no geologic reasons are known why manganese deposits should not be formed equally as well at the higher as at

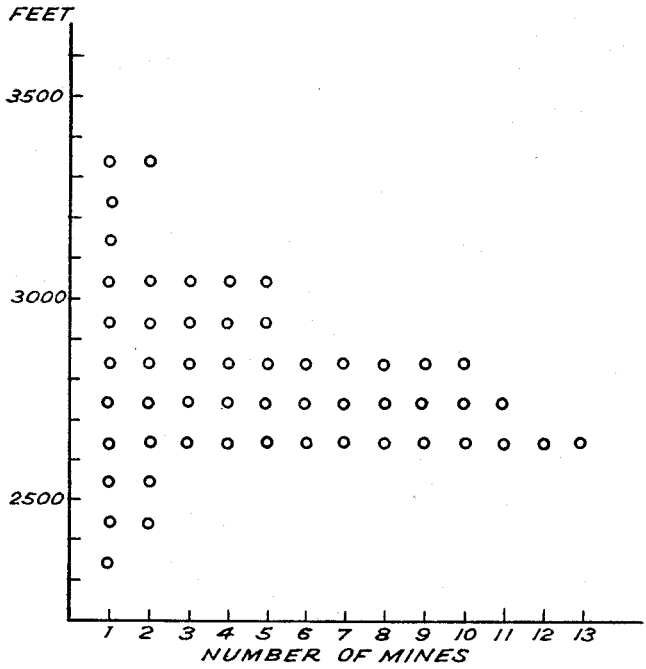


FIGURE 6.—Chart showing altitude above sea level of 53 manganese mines and prospects in the Glade Mountain district. Each circle represents one mine or prospect.

the intermediate altitudes. Probably few deposits are known above the altitude of 3,090 feet, because (1) the area of Shady dolomite becomes increasingly smaller at the higher altitudes; (2) the higher timbered mountain slopes have been less thoroughly explored by local lumbermen, farmers and prospectors; and (3) such ore showings as have been noted have not been prospected owing to their long distance from roads and from water.

ORIGIN OF THE MANGANESE DEPOSITS

Source of the manganese.—The origin of residual manganese deposits is only partly understood. Deposits of this type in the southern Appalachians are abundant, are found in different formations and in different types of rocks, and have not all been formed in the same manner. Within a given district, however, the deposits are likely to have a uniformity in character and in mode of origin. This is especially true of the deposits in the Glade Mountain district, all

but six of which exhibit such a close kinship as to lead to the conclusion that they were formed in the same general manner. Local details of stratigraphy, structure, and topography affect the resulting details of the deposit but apparently not the general process of formation.

The manganese is believed to have been originally disseminated through the lower part of the Shady dolomite, and concentrated especially in beds within 300 feet of the base of the formation. The reasons supporting this conclusion are:

Almost all the manganese deposits of the district are concentrated in clay derived from the lower part of the dolomite. If the manganese came from sources outside this lower part, and migrated to its present location, then clay derived from the upper part of the Shady dolomite, from shale and interbedded dolomite in the Rome formation, and from higher limestone and dolomite formations, or from underlying shale in the Erwin and Hampton might be expected also to be mineralized. Furthermore, of the six deposits that are not located in clays derived from the lower Shady dolomite, one (Deans Branch prospect) is a replacement deposit in Erwin sandstone only a few feet below the Shady and four of the remaining five are chiefly iron deposits and contain little manganese.

Primary manganese-bearing minerals have not been identified in any of the unaltered bedrock of the region. Thus the manganese must be present in minute amounts disseminated through a considerable mass of rock or else come from sources now concealed. The only formation that has been extensively or deeply leached of its soluble mineral constituents is the Shady dolomite. The Erwin below the Shady and the Rome above it normally exhibit fresh rock within a few feet or a few inches of the surface. On the other hand the blanket of insoluble residues from weathered Shady dolomite is known to be 220 feet thick at the Umbarger mine, and is probably scores of feet thick everywhere, except near rapidly degrading streams. The concentration in one place of manganese and iron disseminated through dolomites of this order of thickness could readily account for the observed deposits, even though the original concentration in the bedrock was very slight.

King[31] has supplied the following analyses of Shady dolomite from Shady Valley in Johnson County, northeast Tennessee. All analyses show appreciable quantities of manganese in the carbonate

form with the greatest concentration of manganese 150 feet above the base of the formation.

TABLE 2.—*Chemical analyses of Shady dolomite*

SAMPLE	$MnCO_3$ Percent	Calculated Mn Percent
150 ft. (?) above base of formation	2.59	1.24
30 ft. above base of formation	1.82	.87
15 ft. above base of formation	1.29	.62
1 ft. above base of formation	.82	.39

Almost all of the deposits are on benches or slopes that incline toward the major valleys and are underlain by bedrock that dips toward the major valleys. The normal direction of circulation of meteoric water would therefore be from the surface downward through the mantle to bedrock and then along the beds toward the valley bottoms. The structure does not favor circulation that might bring ground waters upward or laterally into the residual clay of the Shady dolomite. Faults, which are somewhat abundant in the district, might afford channels for upward circulation of ground water, but most of the deposits are not located above or near any known fault.

The deposits are predominantly at altitudes above 2,600 feet despite the fact that there is abundant residual clay from the Shady dolomite and from other formations below this altitude. If ground waters circulating upward along fault planes had formed the ore bodies they would be expected to deposit some of their mineral content in near-surface clay regardless of the altitude of the clay.

A hydrothermal origin has been suggested for some Appalachian manganese deposits.[30] In the Glade Mountain district a pegmatitic dike 3½ miles northwest of Pond Mountain cuts the Elbrook formation and indicates some igneous activity in post-Cambrian time[15]; also, a barite deposit on the north side of the Glade Mountain district is believed by Edmundson[23] to be of hydrothermal origin.

No hydrothermal minerals have been recognized as associated with the manganese ore in the Glade Mountain district. Furthermore, the failure to find concentrations of manganese minerals along joints or faults; the failure to find manganese deposits in clay derived from other dolomites, such as the Elbrook, Conococheague,

and Beekmantown; the sensitivity of the deposits to topographic control; and the presence of manganese and iron stains in the basal sandstone of the Shady wherever it is exposed and weathered, all combine to make apparently impossible a hydrothermal origin for the manganese deposits of the Glade Mountain district.

Concentration of manganese in residual clay.—The manganese in the ore bodies seems originally to have been disseminated through the lower part of the Shady dolomite in the form of a manganiferous carbonate. Compared with other compounds of manganese, the carbonate is relatively soluble in waters charged with carbon dioxide. It was thus easily removed in solution as manganese bicarbonate when the dolomite was subjected to weathering. Low relief and a warm humid climate favor deep weathering and therefore favor the removal of manganese from a large amount of bedrock. The relief at the time of the formation of the deposits was lower than today, and the climate was probably more humid.

Deep weathering of the Shady dolomite occurred in late Tertiary and perhaps also in Pleistocene time in places where the resulting clay was protected from erosion. Those places would have been on the gently sloping sides of the main valleys and on the divides between tributary streams draining the ridges. It has been suggested that the profound decomposition of the dolomite and the formation of the manganese deposits took place during a cycle of peneplanation in the Tertiary. The altitudes above sea level of the known mines and prospects in the Glade Mountain area were plotted to see whether they were concentrated at any level or levels which might be related to former peneplains. The results shown in Fig. 6 indicate that few deposits of manganese are found below the 2,600 foot level. The greatest concentration of deposits is between 2,600 and 2,900 feet above sea level, but there is no marked concentration at any particular level in this interval. Few deposits have been found above 2,900 feet, presumably because the amount of Shady dolomite above this altitude is small and also because the higher areas have been less prospected, rather than because deposits were not formed at higher levels. The evidence in the Marion area thus does not indicate any definite levels at which the formation of manganese deposits was most favored. The benches or gentle slopes on which most of the deposits lie do not appear to be remnants of any recognizable peneplain or series of erosion levels. Downcutting during the mineralization must have

been less rapid than it is today, for apparently neither manganese deposits nor deep clay deposits are now being formed. The present regime is rather one of erosion and removal of previously formed deposits.

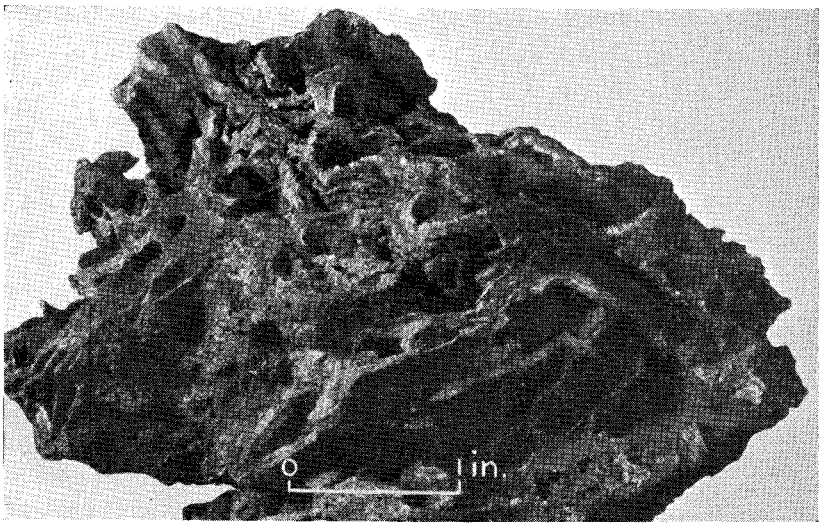
Removal of the carbonates of calcium, magnesium, and manganese in solution from the Shady dolomite took place as the result of meteoric waters coming in contact with bedrock. These mineralized waters were drawn off along such channels of circulation as then existed. Faults, breccia zones, caverns, joints, open bedding planes, and porous beds may have served as conduits. The migration of ground water from a large area toward one of these conduits would result in the bringing of large quantities of manganese-bearing waters into a small area. The most extensive and effective conduit in the Glade Mountain district is believed to have been the dolomitic sandstone at the base of the Shady dolomite. Although fresh beds of this sandstone are as dense and impervious as the underlying Erwin quartzite, the interstitial dolomite is readily dissolved in the zone of weathering, leaving a coarse, very porous sand. During the period of profound weathering when the manganese deposits were formed, decomposition of this dolomitic sandstone in favorable places probably extended to depths of several hundred feet. This sand, therefore, made an ideal aquifer, lying as it did between relatively impervious Erwin quartzite and residual clay or undissolved dolomite of the Shady. The aquifer drained off the slow seepage of meteoric waters and all pervious parts of the clay near the aquifer were bathed in abundant mineralized waters. The most heavily mineralized water would be that which had migrated a considerable distance laterally at or near the dolomite bedrock surface before reaching the aquifer. The iron and manganese stains, which are everywhere abundant around the sand grains of the basal sandstone, wherever the interstitial dolomite has been dissolved, indicate the passage of mineralized waters through this sand. The direction of circulation after the waters entered the porous sand depended on local conditions of surface and bedrock topography and of rock structure, but did not greatly affect the mineral deposition, most of which took place in the overlying clay before the waters entered the aquifer. Locally, however, the sand grains of the aquifer have been recemented or partly replaced by manganese and iron oxides. At the Deans Branch prospect, replacement of a pervious sandstone has been complete. This sand-

stone is not at the base of the Shady dolomite but is about 20 feet lower, in the upper part of the Erwin quartzite.

The agency that caused the downward-seeping waters to stop dissolving and to begin precipitating their mineral load is unknown. Stose[41] has suggested that waters containing manganese bicarbonate in solution mingled with oxygen-bearing waters. Inasmuch as residual deposits of both manganese and iron seem to be near-surface phenomena, solution was probably most active in the zone of vadose water. Precipitation may have taken place when the saturated waters reached the water table and carbon dioxide slowly escaped under the more stagnant conditions. Both manganese and iron were precipitated in the oxide and hydrated oxide forms. The problem is unsettled, however, and more data are needed, especially as to the composition, behavior, and flow of the ground waters of the region.

A few manganese deposits in other regions have been attributed to the flow of mineralized surface and vadose waters into sink holes and the deposition of their mineral load in the surrounding clays. A sink hole or a cavern could readily be a conduit toward which mineralized waters would migrate. No manganese deposits of the Glade Mountain district have definitely been traced to this agency, but the presence of masses and lenses of sand in clay derived from the Shady dolomite, which is normally not sandy, might be due to the washing or slumping of surface material into a sink hole or to the collapse of a cavern roof.

The manganese oxides were deposited in a disseminated form through the clay as wad, or they grew layer on layer, replacing the clay to form solid pieces. Regular outward growth from a nucleus formed rounded and subrounded bodies in which the growth lines may show as shadowy bands in the nodule (Pl. 11,C). If the nucleus was elongate, the stalactitic type of nodule resulted. If the nuclei were more regular the botryoidal or mammillary types were formed. Growth around many small nuclei was probably the result of seepage of the mineralized waters throughout the clay and caused the formation of ore consisting of many small granules. On the other hand, the growth of large nodules was probably brought about by the concentration of mineralized waters along fewer better developed channels in their passage through the clay. Many pieces of hard manganese oxide are flat, angular, or without regular shape. Some pieces are flat probably because certain layers of the lam-



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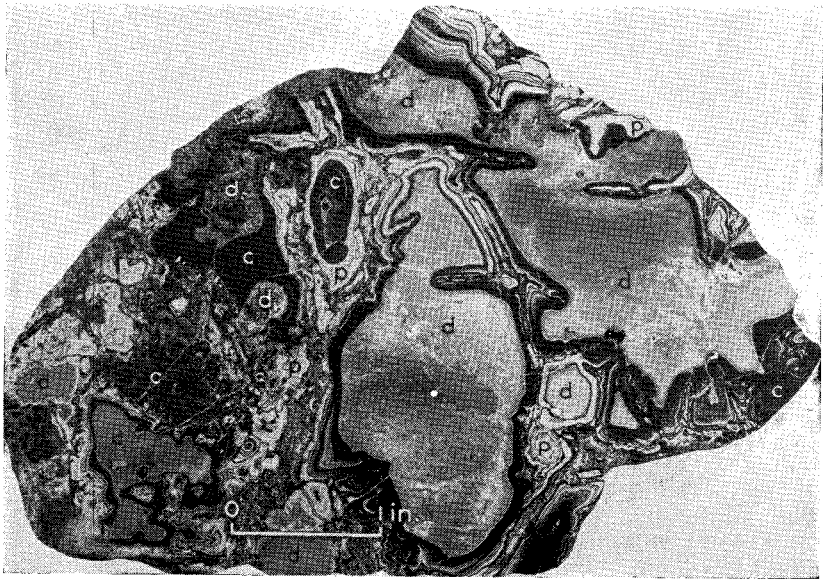
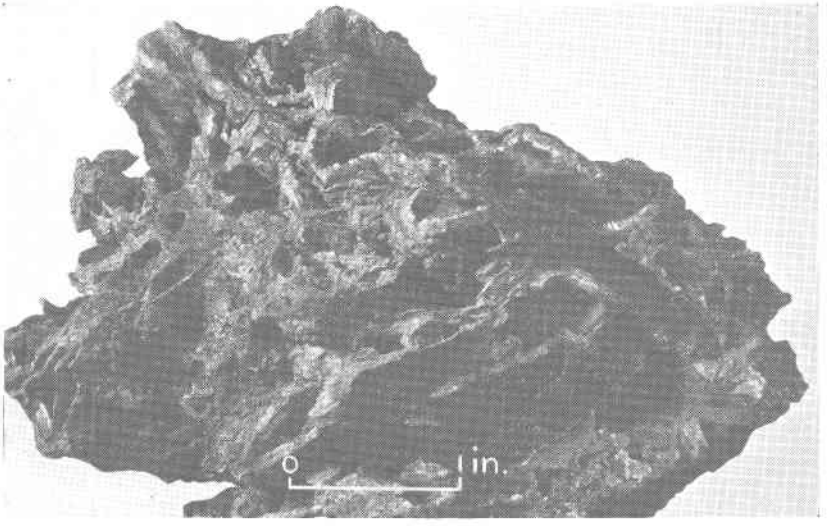


B.

A, Fretted type of manganese ore (pyrolusite) from a very cavernous but solid ledge of ore at the Glade Mountain mine. B, Replacement of silicified dolomite by manganese oxide at the Glade Mountain mine. (c) cryptomelane; (d) unreplaced silicified dolomite; (p) pyrolusite.



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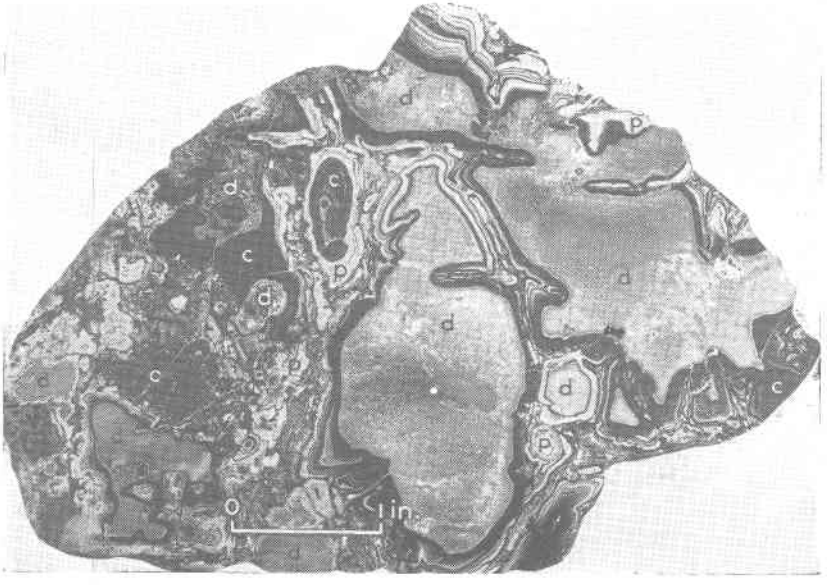

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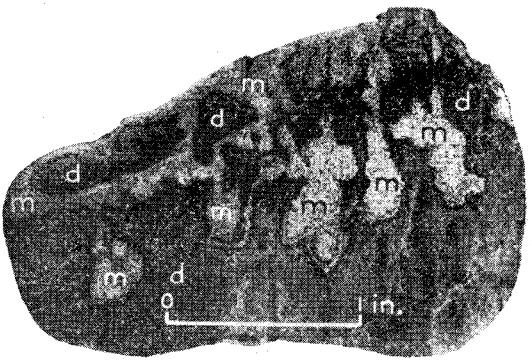

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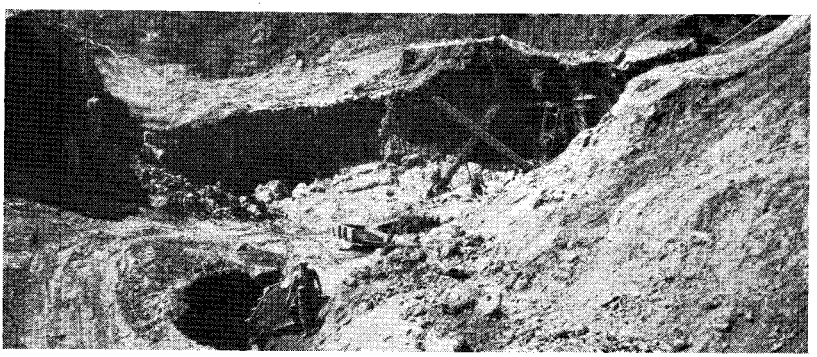
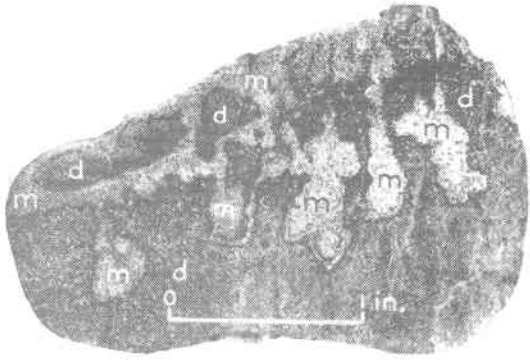


B.

C.

A, Incipient replacement of silicified dolomite (d) by manganese oxide (m). B, Hand mining of manganese ore at the Glade Mountain mine. C, Washing plant at the Umbarger mine.



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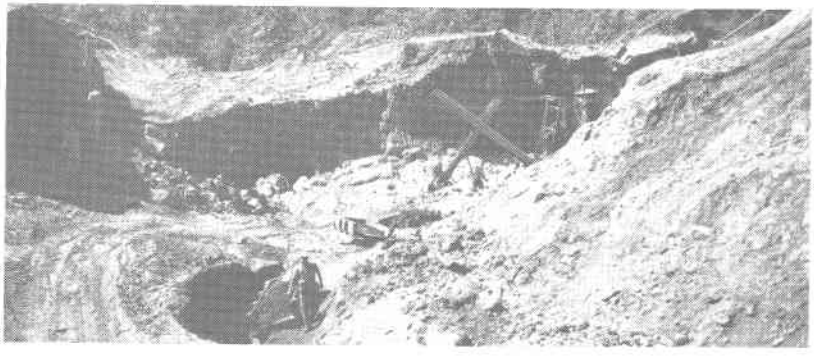

B.

C.

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inated original clay were more readily replaced than others. The shapeless particles grew in haphazard fashion, probably in homogeneous clay which had no structure to affect the seepage of water or the replacement process. Most of the large masses, some of which weigh several hundred pounds, are irregularly shaped. Well-formed pyrolusite crystals line some cavities, but the more finely crystalline varieties of pyrolusite are probably due to replacement.

The large, well-rounded nodules tended to grow near the centers of mineral deposition and the smaller flat or irregularly shaped particles developed around the margins, where the concentration of manganese in solution or the supply of manganese-bearing waters was less. This zoning is demonstrated especially well at the Winn mine. Solid ledges of manganese oxides, such as those at the Glade Mountain mine, formed where well-developed channels, as a rule along the laminae of the clay, conducted manganese-rich waters along the same course for long periods of time. The common occurrence of powdery manganese oxide and wad around the margins of these ledges suggests that the replacement process worked outward in waves. A zone, in which partial replacement occurred, was formed during the first wave. During a later one replacement was completed and loose oxide grains were cemented together into a solid rocklike mass. Specimens in which replacement took place along intersecting channels of circulation, leaving intervening cores of unreplaced clay, formed a very striking fretted type of ore (Pl. 12,A).

In places the manganese oxides also replaced sandstone or sand, silicified dolomite, chert, and jasperoid. The Deans Branch prospect illustrates the replacement of sandstone. The Currin Valley mine No. 2 and the Glade Mountain mine have many fine examples of replacement of silicified dolomite (Pls. 12,B and 13,A). Where various forms of silica were replaced by manganese oxide and the process was not completed, unreplaced sand grains or patches of unreplaced sandstone or silica are scattered through the ore so intimately that the two can only be separated by fine grinding and jigging, tabling, or flotation.

Iron oxide in the form of limonite, goethite and hematite is commonly associated with the manganese deposits. Most of the older manganese mines and prospects of the area were originally iron mines, and every iron mine must be considered as a possible producer of manganese. The iron deposits in the residual clay of

the Shady dolomite have been formed in essentially the same manner as the manganese deposits. Minerals of the two elements tend to be segregated in the clay, but all degrees of intermixture have been noted. Nodules that started to grow as manganese nodules may later have become coated by iron oxide; the reverse of this process also occurred (Pl. 8,A). Apparently also, either oxide replaced the other under favorable conditions. Iron is therefore a common adulterant of the manganese ore and is the most difficult to remove in milling.

Six manganese deposits, as noted previously, are not in residual clay of the Shady dolomite: three are in the Rome formation and three in the Erwin quartzite. Only one of those in the Rome appears to contain manganese in promising quantity. This is the Horne prospect, where cryptomelane replaces partly weathered shale of the Rome formation. The other two deposits in the Rome formation lie north of Pond Mountain. Both were dominantly iron mines and now have little manganese ore showing at the surface. One consists of iron nodules in deep clay residual from the Rome. The other appears to have been a nearly solid limonite ledge in shale. Manganese and iron deposits are also known in the Rome formation in northeast Tennessee. The manganese and iron are believed to have been originally disseminated through the shales, and to have been dissolved by meteoric waters. They were later concentrated at lower levels in zones adjacent to favorable channels of circulation in a manner similar to that in which deposits in residual clay of the Shady dolomite were formed. Although dolomite is interbedded in the Rome formation, no evidence was found to relate any of the three deposits to one of these zones or to clay derived from it.

Two of the three deposits in the Erwin quartzite contain little manganese. They consist of ledges of nearly solid limonite replacing sandstone in the Erwin. One is described under "Deposits north of Chestnut Mountain," the other under "Deposits north of Pond Mountain." The source of the iron for these deposits is not known. The third deposit in the Erwin quartzite is the Deans Branch prospect, where sandstones within 50 feet of the top of the formation have been replaced by manganese oxides. The source of the manganese was the Shady dolomite which formerly overlay the Erwin quartzite but has now been largely removed by erosion. The meteoric waters are believed to have percolated downward through the lower beds of the Shady, dissolving disseminated manganese carbonate, and to have deposited it at a lower level by replacement of a pervious sandstone bed near the top of the Erwin.

PROSPECTING

In the Glade Mountain district most of the appreciable showings of manganese ore on the surface have been prospected. This prospecting was mainly by digging test pits, by sinking shafts, driving drifts, and by churn drilling. Most of the test pits were no deeper than the depth at which a man could shovel clay out of the hole and many were even shallower. Shafts from 10 to 30 feet deep have been sunk, and drifts 10 to 50 feet long have been driven into hillsides at several places, especially where there were previous mining operations. These gave a much better test because they were more likely to penetrate below the superficial mantle of soil, talus or slope wash. Very little prospecting has gone deeper than 30 feet below the surface because any ore body buried beneath more than 30 feet of barren overburden would be expensive to work. Churn drilling for prospecting purposes has been used at the Umbarger mine and more recently at Currin Valley mine No. 1.

In almost all old prospecting and much recent prospecting, no effort was made to measure the quantity of ore available or the amount of waste material that would have to be handled to obtain the concentrates. If good ore was encountered in one or two test diggings an attempt was made to work it or to interest others in working it without prospecting farther in an effort to establish the available tonnage. Thus many mines in the district have been operated for only a few weeks or months before the ore gave out. Where the capital investment in equipment and in development of the ore body was small, no great loss resulted, but the reverse has been true at several mines.

Digging of prospect cuts with a bulldozer has come into favor with manganese operators in recent years and is now the chief prospecting tool employed in the Glade Mountain district. A cut 12 feet wide, 100 feet long, and 10 feet deep can be dug in a day in unconsolidated material with a bulldozer and a perfect cross section gained. If ore or wad is encountered it shows immediately as a dark color on the floor of the cut after the blade has scraped across it, and it may also show in vertical section in the cut walls. Thus even a small ore pocket can scarcely be overlooked by the man operating the bulldozer, though it may not be visible to one examining the completed cut later. Prospecting by bulldozer in the past has not been entirely satisfactory, because the cuts have rarely been dug deep enough to furnish conclusive tests. An orebody 20 or 30 feet beneath the surface can be worked profitably if sufficiently rich, and very little bulldozer prospecting has been carried to these depths. Furthermore, there is scant possibility of estimating ac-

curately the amount of ore that has been moved in a bulldozer cut because ore, clay, and soil are pushed into a heap at the end of the cut where the last material covers that removed earlier.

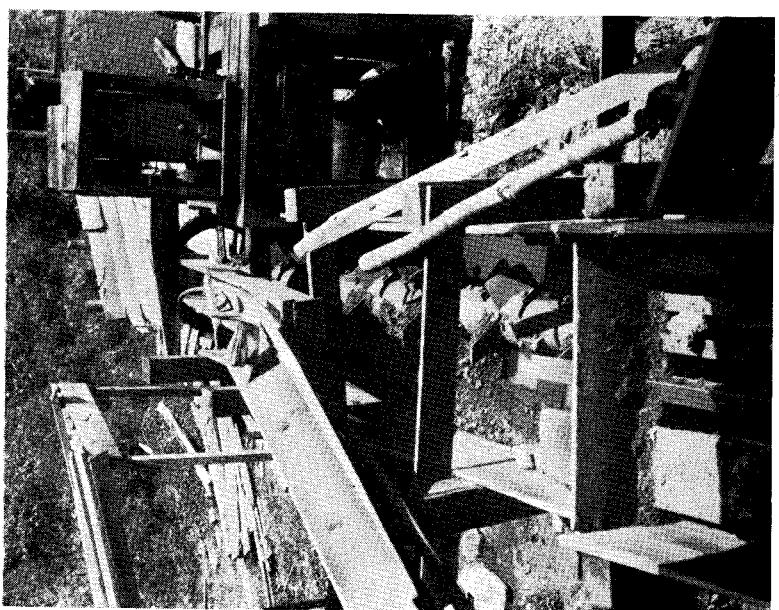
The quantity of available ore, the distance the ore must be hauled to a source of water adequate to operate a washer, the price per ton of the concentrates f. o. b. at the shipping point, the rental on the mineral lease, the distance concentrates must be hauled to the nearest railroad, the cost of mining equipment and of labor, and similar factors should be considered in determining whether an ore body can be worked profitably. Although some of these factors are difficult to estimate in advance, consideration of them by the prospector results in a much clearer picture on which to base a course of action.

MINING AND MILLING METHODS

Mining methods in the Glade Mountain district differ in details depending on the size, depth and type of the manganese deposit, but there is a generalized technique which is followed by most operators. Overburden is removed by a bulldozer (or angledozer), essentially a caterpillar tractor equipped with a scraper blade which operates in snowplow fashion. The average caterpillar tractor in use in the district weighs from 12 to 20 tons, and is equipped with a blade from 10 to 12 feet wide weighing about two tons. Soil, sand, and moist clay are quickly scraped up and pushed out of the way. Some dry clay is so tough that it must first be drilled and blasted. The clay is drilled with a 1¼-inch drill-bit attached to a long 1-inch pipe, which is pounded up and down by two or three men. If rock ledges are encountered, air compressors and pneumatic drills are used, but most mines do not contain solid rock.

After ore pockets or ledges are uncovered by the bulldozer, mining is done by power shovel or by hand labor. The power shovel handles more ore in a shorter time but is not as selective as hand mining. The ore is loaded into trucks or sleds for hauling to the washer, and waste material is pushed out of the way by the bulldozer (Pls. 13,B, and 14,B). The miners refer to the overburden and the barren material around the ore pockets as "deads."

When a deep cut is dug following an ore lead, the clay walls are hand-drilled and blasted into the cut to be removed by a bulldozer. In dry weather steep or vertical clay banks will stand, but in wet weather and especially during the freezes and thaws of the winter months the saturated, slippery clay slumps readily. Much barren clay must there-



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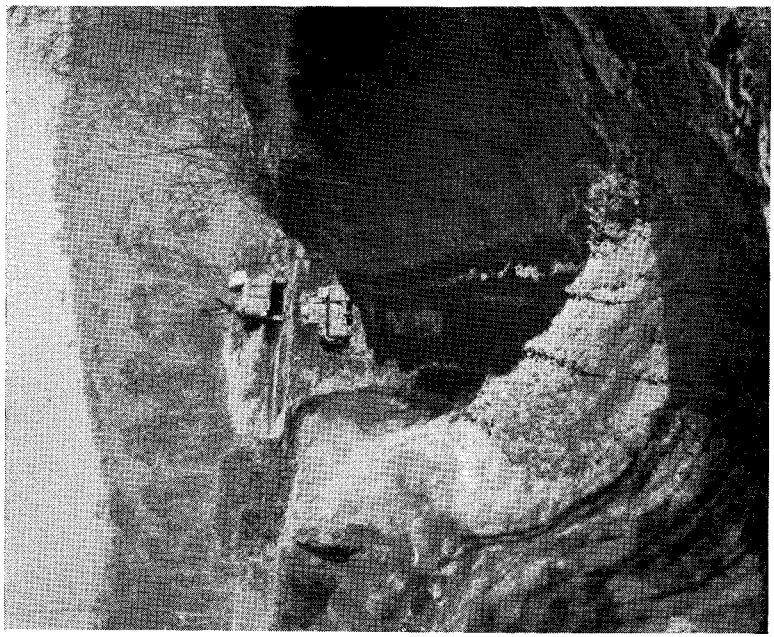
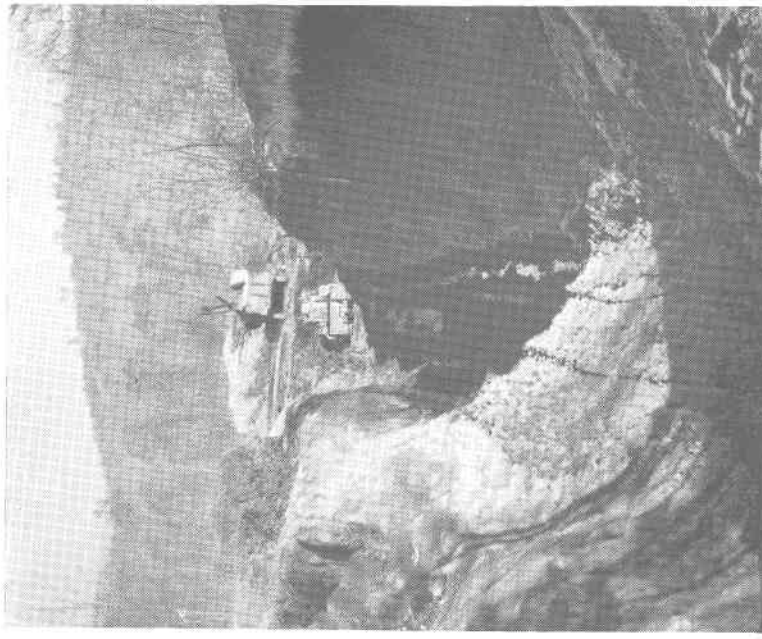


B.

A, Single-log manganese washer at Currin Valley mine No. 1. B, Active cut at the Umbarger mine, from which most of the recent manganese production has come. (See Pl. 16,A.)



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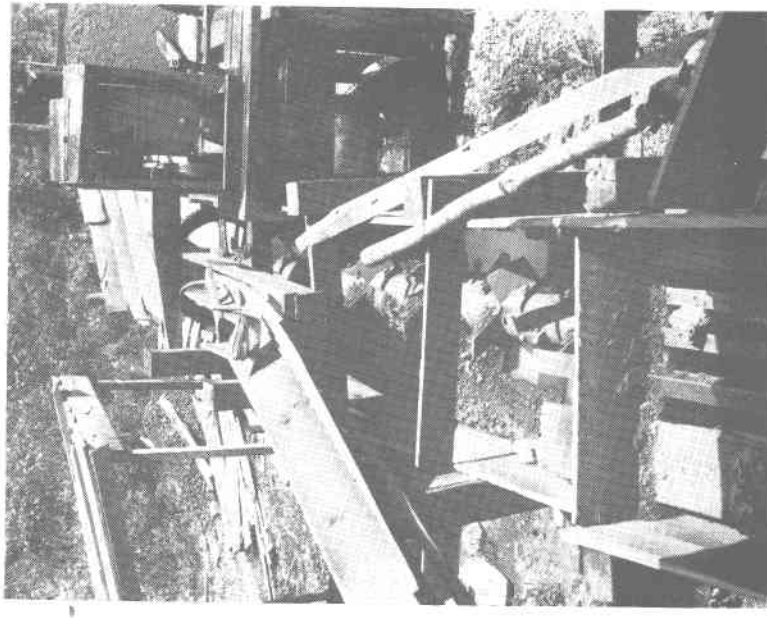

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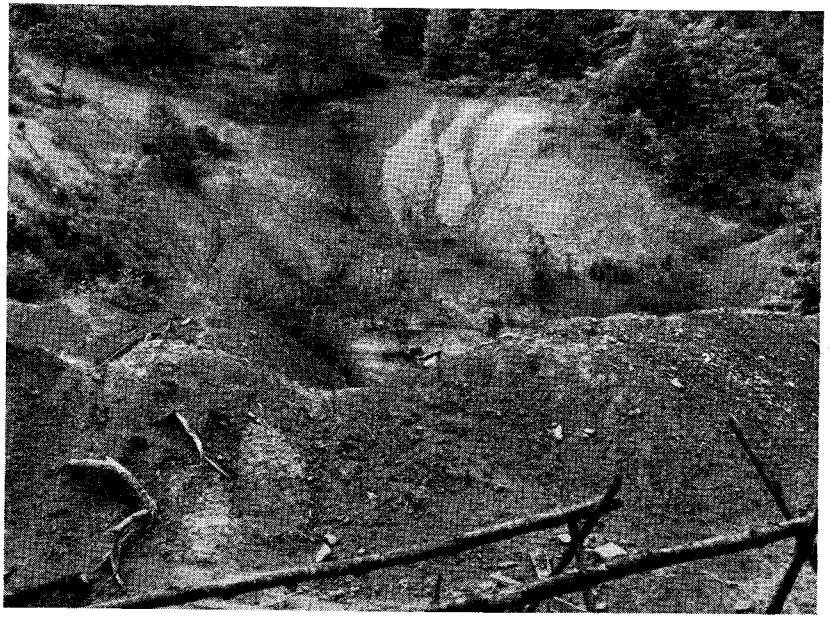
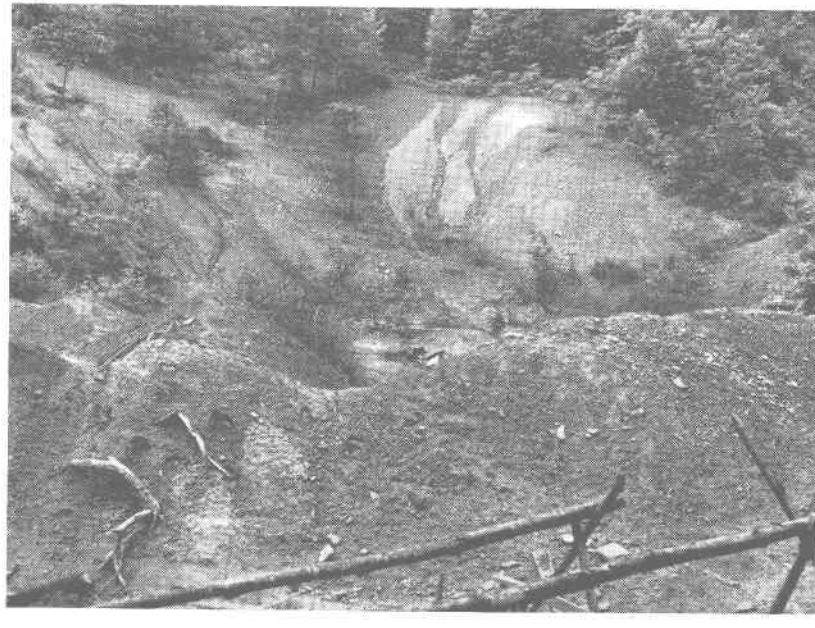


A.

B.

A, Main pit at the Umbarger mine. Most of the manganiferous iron and manganese produced at this mine before and during World War I came from this pit. B, Main pit at the Glade Mountain mine. Most of the ore mined prior to 1942 came from this part of the mine.



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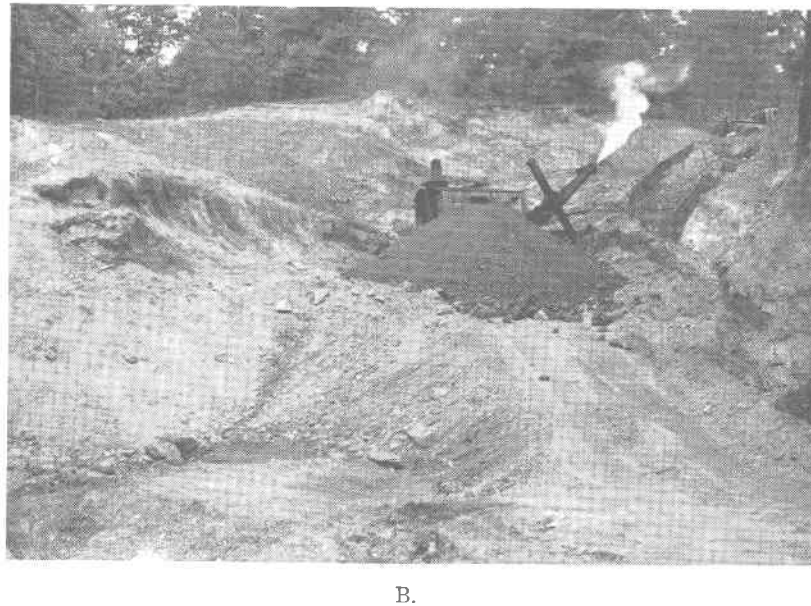

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fore be moved to prevent slides into the working cuts or else removed after slides have occurred. In a few places, shafts and drifts have been driven to mine ore bodies underground and thus avoid the expense of stripping. This type of mining is done with pick and shovel and hand hoist or wheelbarrow. Deep shafts and all drifts must be timbered if they are to be safe.

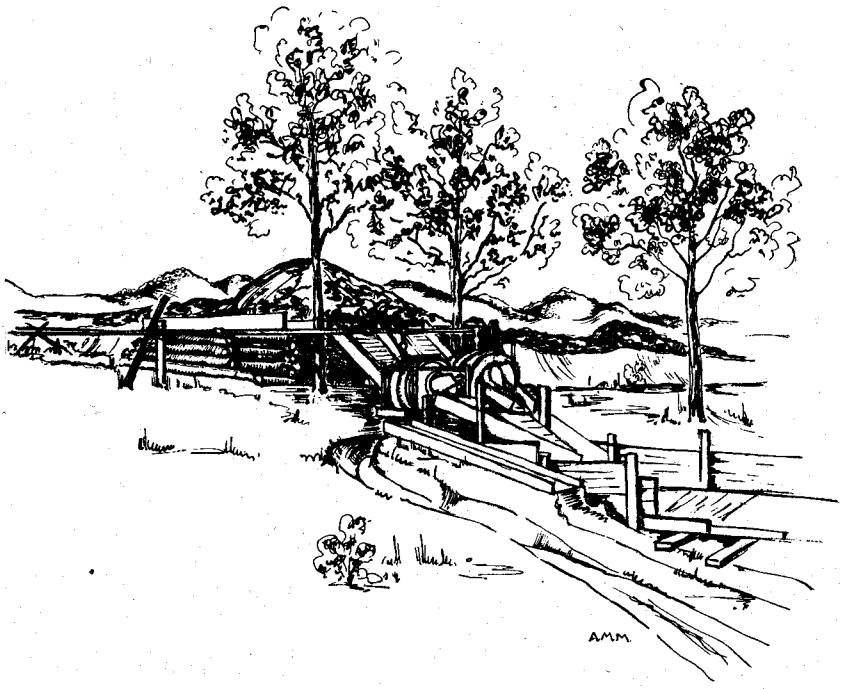


FIGURE 7.—Cement mixer used to wash ore at the Savage prospect. A pile of ore has been pushed up ready for washing. By Ansel M. Miller.

Beneficiation of manganese ore in the Glade Mountain district consists of washing clay and soil from the pieces of hard ore, picking out worthless rock and iron oxide, and sizing the final product. This is achieved by very simple means for small mines. Hand-washing of the ore in troughs or tubs has been used, and cement mixers do a satisfactory washing job where the amount of ore is not large (Fig. 7). The larger mines have been equipped with the more elaborate log washer (Pls. 13,C and 14,A and Fig. 8).

HISTORY OF MANGANESE MINING AND PRODUCTION FIGURES

The early history of manganese mining in Smyth County is intimately related to iron mining and before World War I was greatly overshadowed by it. Much of the iron ore was manganiferous, but it was mined and sold without regard to its manganese content. For many years this ore went entirely to local charcoal-burning furnaces. The oldest forge in the region, located a short distance west of Sugar Grove, dates back to pre-Revolutionary days. Other forges were built in the early part of the nineteenth century. Two of these in Rye Valley were known as Barton's and Nichols' forges; the latter located in the gorge near the mouth of Comer Creek. A large forge on Staley Creek south of Marion was destroyed by Major Harrison during Stoneman's raid in the War between the States. These and other early forges used only local ore. Among the mines that supplied ore for these early operations are the Wright bank, the Barton bank, and the Porter bank, described in this report. Most of the iron mines worked nodular limonite ore in residual clay of the Shady, which also contained some nodules of high-grade manganese and others of manganiferous iron. A better grade of iron was no doubt produced at the forges owing to the presence of manganese in much of this ore.

One of the most important charcoal furnaces of the early days was located near the mouth of White Rock Creek, where its ruins are still visible. It was built in 1873 and was operated for many years by the Lobdell Car Wheel Co. The ore came from several mines in this area, the most important of which were in White Rock Valley. Two of these old workings have been recently prospected and show the presence of some manganese ore. The quality of the railroad car wheels produced by the Lobdell Company at that time has been attributed to the manganese content of the White Rock ore used in the local furnace. The iron ores were concentrated in washers near the mines and the more recent, larger iron mines were equipped with log washers and jigs similar to those in use today to treat manganese ores.

Iron and manganiferous iron mining was on a small scale and none of the concentrates were shipped outside the county until the building of the Marion and Rye Valley Railroad. The first six miles from Marion to Currin Valley were completed in 1893. In 1896 the railroad was extended to Sugar Grove in Rye Valley, where it connected with the Virginia and Southern Railroad, which crossed Iron Mountain to Troutdale. The passage through the mountains from Currin Valley to Rye Valley was achieved by a series of hairpin curves and switchbacks which

must have made this a train trip of extreme interest and scenic beauty. The first link of this railroad was built to tap the iron and manganese deposits of Currin Valley, and its later extension to Rye Valley stimulated the exploration and development of the deposits of that area. Shipments of iron and manganese were made over this railroad until the end of World War I, when mining ceased with the fall in prices. The railroad was abandoned and the tracks torn up in 1937.

About the time of the first railroad shipments of Currin Valley ore, the manganese content of many of the local iron ores began to attract attention, and efforts were made to separate the higher grade manganese ore from the iron ore and ship the two separately. Until World War I brought an acute shortage of manganese and resulted in a tremendous increase in its value, the larger part of the production from Smyth County, both in quantity and in value, was of ore high in iron and low in mangenese.

Between 1896 and 1918 production of iron ore and of some manganese ore was more or less continuous. Most of the accurate records on the amount and grade of this production have been lost, but the Currin Valley mines are said to have shipped about 100,000 tons of iron concentrates and about 1,000 tons of manganese concentrates; the Wright bank at least 10,000 tons of iron and manganiferous iron concentrates; the Umbarger mine about 10,000 tons of manganiferous iron concentrates and nearly 1,000 tons above 40 percent manganese; and the Kyva mine about 300 to 400 tons of manganese concentrates. Log washers were built at the Umbarger mine, at the Kyva mine, at the Bishop mine, on Slemp Creek near the Wright bank, and in White Rock Valley. At least two log washers were located in Currin Valley to serve the mines there. Short tram lines were built to haul ore from the mine to the washer at the Umbarger mine and at Wright bank, and a long tram line was built from the washer at the Kyva mine to haul the concentrates to the highway. The most elaborate mill was at the Umbarger mine where a four-log washer and eight 4-cell Harz jigs were installed in 1917.

The great increase in the domestic price of manganese which began in 1914 and eventually brought the price to four to five times its pre-war level, was partly responsible for the sudden increase in manganese production. In addition, the local market for iron ore had disappeared with the closing down of the last of the forges in the early 1900's, and large domestic and foreign mines

were producing iron for shipment to the steel mills at a price which the local operators were finding difficult to meet. This combined stimulus resulted in an intensive search for manganese. The effectiveness of this search may be judged by the fact that all but three of the mines and prospects described in this report were known and had been prospected prior to 1918. Many mines and prospects, besides those previously mentioned, produced small amounts of manganese ore during these war years, but the main production came from the large mines that had previously been worked for iron. The only new mine that is known to have been opened as the result of the war boom and that produced an appreciable amount of manganese was the Kyva mine.

When manganese prices returned to their pre-war levels in 1919, and because importation of foreign ores was resumed, local production of both manganese ore and manganiferous iron ore stopped. There is no record of further production or prospecting until 1937, when a company was formed to work the Glade Mountain mine. Every year since then, some manganese concentrates have been produced from that mine. The total production has been 3,550 tons of concentrates, of which nearly half was in 1942 when a new two-log washer and other mining equipment were installed. The Umbarger mine was worked for a few months in 1941 and two carloads of concentrates were produced. In 1942 a new company was formed to operate the Umbarger properties, a single log washer was built on the foundations of the old 1917 mill and one carload of concentrates had been produced by the end of the year. In 1941 and 1942 from half a car to one car of concentrates was mined from each of the following mines or prospects: West Nicks Creek prospect, Kyva mine, Deans Branch prospect, Currin Valley mine No. 2, Currin Valley mine No. 4, and Atkins mine. Two carloads of concentrates were produced at the Rich Mountain mine in 1942. A moderate amount of prospecting was done at the Savage prospect, the White Rock mines, the Kyva mine and the Winn mine but little production resulted. A small amount of prospecting was done at Barton bank, Walker-Forney prospect, Thomas prospect, Roland creek prospect, and the Morris prospect, but without production. In April 1943 the active mines of the district were the Glade Mountain, the Umbarger, the Atkins, and the Rich Mountain.

The new activity in manganese mining is largely the result of the domestic shortage brought about by World War II.

TABLE 3.—*Manganese and manganiferous iron concentrates (long tons) produced in the Glade Mountain district, Virginia*

Mine or Prospect	1750–1892		1893–1915		1916–1918		1919–1936		1937		1938		1939		1940		1941		1942		Total 1750–1942	
	Below 35% Mn	35–60% Mn	Below 35% Mn	35–60% Mn	Below 35% Mn	35–60% Mn	Below 35% Mn	35–60% Mn	Below 35% Mn	35–60% Mn	Below 35% Mn	35–60% Mn	Below 35% Mn	35–60% Mn	Below 35% Mn	35–60% Mn	Below 35% Mn	35–60% Mn	Below 35% Mn	35–60% Mn	Below 35% Mn	35–60% Mn
Atkins mine	...	...	300?	...	150	50?	...	...	...	...	...	...	...	...	...	...	...	...	...	30	450	80
Barton bank	5,000?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5,000	...
Crigger bank	...	...	25,000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	25,000	...
Currin Valley mines Nos. 1-6	...	...	50,000	500?	10,000	500?	...	...	...	...	...	...	...	...	...	...	...	...	45	45	60,045	1,045
Deans Branch prospect	...	...	50?	50?	...	...	...	...	...	...	...	...	...	...	...	...	...	45	...	...	50	95
Glade Mountain mine	...	...	...	...	...	...	...	...	217	358	476	50	...	47	...	28	76	563	...	1,622	769	2,668
Kyva mine	...	...	...	...	...	400	...	...	...	...	...	...	...	...	...	...	...	25	...	...	...	425
Porter bank	...	...	35,000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	35,000	...
Rich Mountain mine	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	90	...	90
Umbarger mine	...	...	600	45	7,198	1,092	...	...	...	...	...	...	...	...	...	...	...	130	41	30	7,839	1,297
West Nick Creek prospect	...	...	500?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	25	...	...	500	25
White Rock mines	5,000?	...	5,000?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20	...	10,020	...
Winn mine	...	...	...	...	...	100?	...	...	...	...	...	...	...	...	...	20	...	...	...	...	...	120
Wright bank	5,000?	...	3,500?	500?	9,000?	100?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	17,500	600
Other mines	10,000?	...	50,000?	...	20,000?	200?	...	...	...	...	...	...	...	...	...	...	...	20	...	...	80,000	220
Total	25,000±	...	169,950±	1,095±	46,348±	2,442±	...	...	217	358	476	50	...	47	...	48	76	808	106	1,817	242,173	6,665

Although production began in 1937, it was limited to one or two operators, and production was less than 1,000 tons of concentrates annually until the war shortage brought a sharp rise in the price of manganese in 1942. Then there was an immediate wave of renewed prospecting and log washers were built to treat the Currin Valley ores, the Umbarger ores, and the Atkins mine ores. At the time of writing a log washer is also proposed for the Rich Mountain mine and possibly for the Savage prospect.

In Table 3 are shown the production of manganese, manganiferous iron, and iron from the Glade Mountain district by years and also by mines. Figures for 1918 and earlier years are based largely on verbal reports and are subject to considerable error. Most of the ore below 35 percent manganese was mined and sold for iron ore, but a considerable part of it probably contained more than 10 percent manganese. For example, all but 1,035 of the 7,198 tons of the 1916-1918 output at the Umbarger mine is known to have been above 10 percent manganese and much of the output from the Wright bank, Currin Valley mines and White Rock mines was probably also above 10 percent manganese. On the other hand, most of the ore produced at the mines listed as "other mines" was probably below 10 percent in manganese content.

STATUS OF MANGANESE MINING AND RECOMMENDATIONS

The stimulus to manganese mining owing to the curtailment of imports and the 1942 increase in prices has resulted in reopening several old mines and enlarging operations at another, the Glade Mountain mine. Other old mines have been prospected recently. The 1942 production of 1,840 tons of concentrates above 35 percent manganese is more than double the 1941 production and 40 times the 1940 production. The Savage prospect is, however, the only entirely new mining operation. Other new mining sites have not been discovered because practically every showing of float manganese or iron in the district was prospected, at least superficially, before or during World War I. In earlier years extensive lumbering was carried on in the mountains and the lumbermen, as well as the farmers, seem to have recognized the appearance and value of manganese ore.

New ore bodies of importance have been discovered recently only at the Glade Mountain mine. This is because all other recent prospecting, except at the Winn mine and Savage prospect, has

been limited to areas previously worked and because most of the prospecting has been more superficial than the earlier mining and prospecting. Thus some of the previously worked ore bodies have been uncovered again, but few new areas have been tested and deeper zones have not been penetrated by the prospecting.

New ore bodies of importance may not exist in the district, but, if they do, more extensive, intensive and deeper prospecting will be necessary to find them.

Recommendations which may assist prospecting and mining in the Glade Mountain district are as follows:

1. All but two of the important manganese mines or prospects are in residual clays of the Shady dolomite and both of the exceptions (Deans Branch and Horne prospects) are small deposits. Hence the favorable areas for prospecting are the belts of Shady dolomite shown on the geologic map (Pl. 1).

2. The most favorable locations for manganese deposits in the belts of Shady dolomite are within 500 feet horizontally of the normal contacts between the Erwin and Shady formations.

3. The most favorable locations for deposits are on the benches, on the gentle slopes, or on spur crests on the mountain sides. No prospects of importance are known below an altitude of 2,600 feet or on the floors of the major valleys.

4. The clay mantle should be deep and extensive to favor formation and preservation of manganese deposits. Areas of abundant dolomite outcrops, as in the lower parts of Rye Valley and Cripple Creek Valley, are therefore unfavorable.

5. Float of coarse-grained, strongly manganese-stained or iron-stained sandstone at the base of the Shady dolomite indicates that some solution and redeposition of iron and manganese have gone on in the area. The clay overlying the source bed of this float would be especially favorable for prospecting.

6. Prospecting, by whatever method used, should extend to a depth of at least 30 feet and preferably deeper unless bedrock is found, because rich ore bodies could be mined underground at these depths, even if open-cut methods were too expensive.

RESERVES

Any estimate of the reserves of manganese in the Glade Mountain district must take into consideration the economic conditions under which the manganese is to be produced. These include all

the diverse factors affecting cost of production, such as prevailing wage scale, cost of shipping and many other cost items, but outweighing all other factors is the price per ton received by the producer. The manganese that can or will be produced at the peacetime prices which have prevailed in the past is extremely small. Reserves calculated on the basis of the price scale prevailing in the latter part of 1942 are considerably larger. Nevertheless, many mines and prospects that are potential producers of small amounts of ore containing above 35 percent manganese, are not being reopened and will not be reopened because the major share of their production would be of manganiferous iron, which can not be produced in the district at a profit. Four mines in the district were producing manganese at the close of 1942, but several other prospects may become small-scale producers.

The following table shows the estimates of ore reserves for the Glade Mountain area. The low estimates for ore at peacetime prices, and for ore below 35 percent manganese at present prices are based on the belief that most mines can not produce profitably at the price levels cited and their ore bodies are therefore not calculable as reserves.

TABLE 4.—*Reserves of manganese ore in the Glade Mountain district in terms of long tons of concentrates*

	PEACETIME PRICES		1942-43 PRICES	
	20–35% Mn	35–60% Mn	20–35% Mn	35–60% Mn
Measured	0	0	0	1,000
Indicated	0	0	0	3,000
Inferred	0	1,000	1,000	10,000

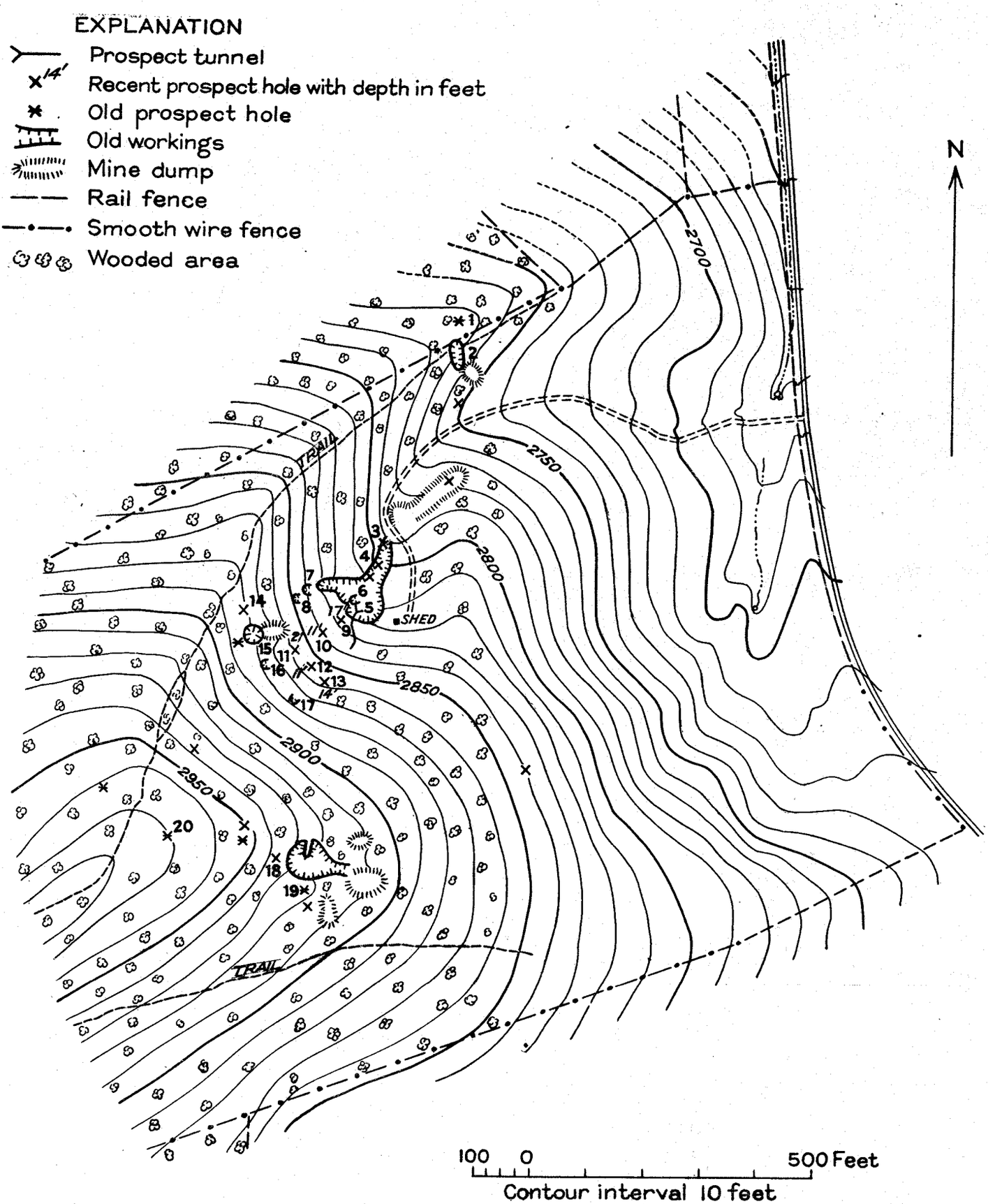
The ore estimates would be greatly increased and production would be expanded if the mining of ore containing from 20 to 35 percent of manganese were made profitable. Some additional output of ore containing above 35 percent manganese would result from the reopening of mines where the main output would be of lower grade. Many prospects would also be worked on a small scale if the price for both high- and low-grade manganese ore were to rise still more, but the total production of the district would probably not be greatly increased by the coming into production of numerous

mines and prospects whose ore reserves are small or are not completely known.

DESCRIPTION OF MANGANESE MINES AND PROSPECTS

Horne prospect.—The Horne prospect is unique in that it is the only one in the Glade Mountain district showing appreciable quantities of manganese in the Rome formation. It is on the farm of J. J. Horne, 2 miles east-northeast of Cedar Springs and 1.4 miles north of Asbury School, at an altitude of 2,680 feet. It is on the sharp crest of a sparsely wooded ridge, which rises about 100 feet above the cultivated valley to the north. Shady dolomite, dipping 25°-39°S., crops out in the valley near the farmhouse of Mr. Horne. Abundant fragments of chert, silicified dolomite, and shaly dolomite are present in the fields up to the base of the prospect ridge, but float of red shale appears on the lower slopes of the ridge. The contact between the Shady dolomite and the Rome formation is thus at the north base of the ridge. Outcrops farther west indicate that the dolomite dips southward beneath the Rome shale. A few pieces of sandy dolomite mixed with red shale float on the south side of the ridge suggest the presence of at least one interbedded dolomite in the Rome. The ridge crest trends N. 81° W., apparently following the strike of the shale beds.

The Horne prospect was worked briefly during World War I. Two trenches were dug on the backbone of the ridge about 1,500 feet east of the highest point. The trenches are elongate along the crest, are about 35 feet long, and from 5 to 15 feet wide. Both have caved in completely so that no exposures of the ore body remain. They were dug in a yellow clay which is residual from decomposition of the shale, and is probably only a few feet deep. The deposit may have extended into underlying shale, for shale chips are present on the crest nearby, though none were seen in the trenches. The ore, which was removed from the trenches, consists of chunks of dense, hard, metallic, amorphous manganese oxide, most of which is uncontaminated by any visible impurities or by adhering clay. A few chunks are very porous and somewhat earthy, but the bulk of the visible ore on the dumps is of good grade. Many of the pieces have two flat, parallel faces, suggesting strongly that the ore occurs as veins from 1 to 8 inches thick, and that the veins were probably formed in the underlying shale, rather than in the clay mantle. The ore is said to have been quite soft when it was



Topographic map of the Winn mine. Numbers refer to descriptions of the prospect pits in the text. By Ralph H. Wilpolt.

mined and to have hardened materially during its 25 years of exposure on the dumps.

About 12 tons of nearly clean, good-grade ore were piled alongside the trenches during World War I, the western trench being the more productive of the two. The operators are reported to have lacked sufficient money and the prospect was abandoned without any ore being washed or shipped. In 1941 N. T. Dixon of Marion shipped about 10 tons of the ore mined during the earlier operation, but did no digging. The writer visited the prospect in the spring of 1943, when Mr. Dixon was considering opening up the old cuts to determine the extent of the ore body. No ore shows at the surface beyond the limits of the two trenches, which span a distance of about 100 feet along the crest.

The ore piled on the sides of the trenches is rather clean but would be improved by washing. The nearest source of water is one of the small creeks lying ¼ to ½ mile east of the prospect. No road or lane passes near the prospect, but in dry weather a truck could probably be driven across the fields and up the hill to the prospect.

Winn mine.—The Winn mine is 1.2 miles north of Cedar Springs at the western tip of Glade Mountain in Wythe County, just east of the Smyth County line, on land owned by T. E. Simmerman of Max Meadows. The workings are in the woods on the nose of a spur extending eastward from the end of the main Glade Mountain ridge. An isolated knob formed by the most eastern exposure of the Erwin quartzite lies east of the mine, across a prominent swale. The crest of the spur, at the tip of which the Winn Mine lies, is formed by sandstones, in the upper Erwin quartzite, which strike slightly north of east and dip to the southeast beneath the Shady dolomite. Just west of the mine, these beds swing sharply to the north and the contact extends diagonally down the northeast slope of the spur. It is cut off by a fault near the crossroad 1,500 feet north of the mine. The basal sandstone of the Shady was found in the deeper prospect pits at the mine. The contact between disintegrated sand and the overlying clay dips 20° E.

The Winn mine was opened before World War I and was prospected again during that war. It was worked briefly by N. T. Dixon in 1939 and was prospected in 1941 by A. W. Newberry, and again in 1942 by Richard Talmage. Except for about a quarter of a carload of concentrates shipped by Mr. Dixon there has been no

production at the Winn mine since World War I. Mr. Dixon's ore was mixed with ore from the Glade Mountain mine, and the resulting carload averaged 45 percent manganese.

Ore has been mined from two sizable excavations, and numerous prospect pits, shafts, and trenches have been dug in the area (Pl. 16). The upper open pit has not received much attention in recent years and the exposures are not good. It is about 120 feet long, 45 feet wide and 15 feet deep. Reddish-brown clay forms the walls of this pit and is prominent on the dumps. Good nodules of hard amorphous manganese oxide are abundant on some of the weathered banks but absent on others. A few chunks of medium-textured pyrolusite were also found. More prospecting would be necessary to determine whether the ore-bearing clay is sufficiently extensive near this pit to warrant mining, but the surface showings are rather encouraging, and the quality of the nodules appears good.

The lower pit has been the scene of more intensive prospecting and the exposures are much better. It is irregularly shaped, about 150 feet in longest dimension and from 10 to 20 feet deep. Yellow clay is present in the lower part of the pit, but the soil and clay near the surface are reddish-brown. The overburden of clay soil mixed with sandstone and quartzite fragments ranges from 1 to 10 feet in thickness. Concretions and angular blocks of jasperoid as much as 4 feet in diameter are scattered over the floor of the pit. The best ore showings are in the southwest face where large nodules of solid, good-grade, hard ore weighing as much as 50 pounds are embedded in yellow clay beneath a zone of chert concretions.

The showings in the principal prospect pits, as exposed in 1942, are listed below, the numbers referring to the prospect numbers shown on Plate 16.

1. Caved pit, 10 feet by 8 feet and 4 feet deep. Reddish-brown clay soil with no ore visible.

2. Caved pit 50 feet by 10 feet and 10 feet deep. Yellow and brown clay soil with a few small pebbles of hard manganese oxide.

3. Test hole in yellow clay. Numerous small flattened pieces of fair-grade hard manganese oxide, and some nodules of good-grade hard manganese oxide.

4. Test hole, 7 feet deep. Soil has manganese nodules but underlying clay is barren.

5. Adit, 55 feet long, driven in a direction S. 10° W. Passed through some ore-bearing clay but mostly barren clay. Ore consists mainly of irregularly shaped masses of amorphous manganese oxide from 1 inch to 1 foot across. Ore showing fair.

6. Small fresh cut in wall of open pit. Yellow clay contains shaly pieces of fair-grade cryptomelane mixed with goethite.

7. Small pit, 10 feet square and 10 feet deep. Ferruginous chert ledge exposed and also small pieces of siliceous manganese.

8. Tiny barren pit.

9. Shaft, 17 feet deep. Five feet of overburden, then 12 feet of nearly barren, yellow clay containing chert, silicified dolomite, a few pieces of shaly, fair-grade, hard manganese oxide and a few nodules of good-grade, hard, amorphous manganese oxide. Basal Shady sandstone in bottom of pit.

10. Test hole, 11 feet deep. Five feet of red clay, underlain by 6 feet of nearly barren yellow clay.

11. Shaft, 21 feet deep. Five feet of reddish wash at top underlain by 13½ feet of yellow clay containing irregularly shaped pieces of hard, amorphous manganese oxide of fair to poor grade, and also pieces of chert; 2½ feet of disintegrated basal Shady sandstone in bottom.

12. Shaft, 15 feet deep. Soil and barren clay 9 feet thick, underlain by 6 feet of clay containing abundant nodules of good-grade, hard, amorphous manganese oxide.

13. Shaft, 14 feet deep. All yellow clay with abundant nodules of hard, amorphous manganese oxide in lower part.

14. Small test pit and trench. Red soil containing no visible ore.

15. Caved cut, 25 feet square and 15 feet deep. Large blocks of silicified dolomite and irregularly shaped shaly pieces of

fair- to good-grade, hard, amorphous manganese oxide on the dump.

16. Filled-in cut which encountered friable basal Shady sandstone. Apparently no ore.

17. Filled-in cut in clay. Apparently no ore.

18. Pit 4 feet deep, in red clay. Fair number of nodules of poor-grade, amorphous manganese oxide.

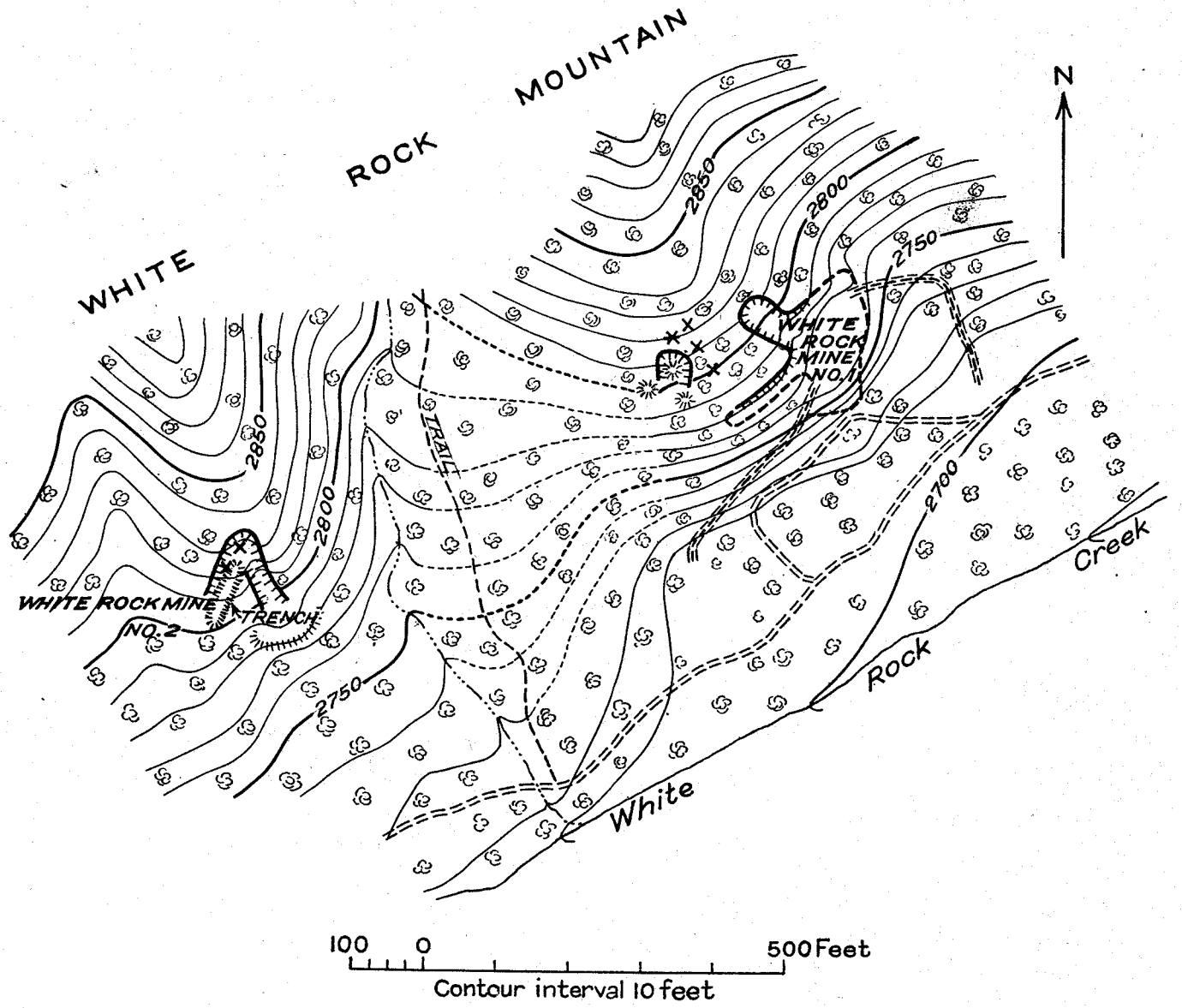
19. Hole 7 feet deep. Upper 4 feet of barren soil; lower 3 feet of yellow clay with numerous masses of low-grade, siliceous, hard manganese oxide.

20. Caved pit, 10 feet in diameter and 5 feet deep. Coarse-grained sandstone partly replaced by limonite in bottom of pit.

The nodules at the Winn mine are well developed in mammilary, botryoidal and stalactitic shapes (Pl. 10, A and B). They are discolored yellow and brown on the surface, but inside they are of dense, hard, dark-gray and black metallic, amorphous manganese oxide. Most, if not all, of it is cryptomelane. Many of the nodules show clearly concentric laminations parallel to the outer surfaces.

The zone of residual clay of the Shady dolomite lies southeast of a vague line approximately following the trail down the crest of the spur. The clay that contains good-grade nodular ore appears to lie southeast of a line roughly from prospect hole 4 to prospect hole 17. In the belt between these two lines the sandstone floor beneath the clay is close to the surface, and the manganese particles are in the form of shaly, low-grade pieces of cryptomelane. Insufficient prospecting has been done in the nodule-bearing belt to estimate accurately how much ore is present, but the showings are good enough to encourage further prospecting. No adequate source of water for washing ore exists near the mine. Several small creeks, which probably have adequate flow, lie about a mile to the northeast. Abundant water is found in Fisher Creek at Cedar Springs, 1.5 miles by road to the south.

White Rock mines.—The White Rock mines consist of a series of old workings on the floor and on the north slope of White Rock Valley, 2.6 miles east of Cedar Springs. These were worked for iron and



Plane-table map of White Rock mines 1 and 2. By Ralph H. Wilpolt.

manganiferous iron in the last century by the Lobdell Car Wheel Co. of Wilmington, Delaware. This company still owns the land and the mineral rights. The ore was hauled to an iron furnace about 2 miles east of the mines. The manganese content of most of this iron ore was said to result in a superior grade of cast iron, which made it especially desirable for car wheels. Several sizable workings and numerous prospect pits were dug in White Rock Valley at the time of these operations but only four of the mines now afford good exposures.

White Rock Valley is the broadest and most open intermontane valley of the Glade Mountain district. The flat valley floor and the gentle lower slopes of Brushy and Buchanan mountains are underlain by Shady dolomite which forms a belt averaging 2,000 feet wide. Only two outcrops of dolomite were found in this section of the valley, both of which showed steep dips to the south. All four of the mine workings are a considerable distance from the nearest Erwin quartzite and are on or only slightly above the valley floor. In both these respects they differ from the majority of the manganese mines and prospects of the Glade Mountain district. The valley has probably been lowered very slowly in recent geologic time, and thus deep weathering of the dolomite and concentration of iron and manganese oxides in the residual clays could proceed without disturbance for a long period. In the steep-walled, narrow valleys of the district, the active streams erode the residual clays nearly as fast as they are formed on the valley floors.

Two of the workings lie close together on the north side of the valley (Pl. 18). The larger one is in the woods about 500 feet northwest of White Rock Creek and 1,000 feet west of the ford where the woods-road crosses the creek. This was prospected in 1942 by H. T. Whistman of Sugar Grove and O. E. Sayers of Marion. Prospect pits were first sunk in the bottom of the old excavation, but later the pit was opened up with a bulldozer. Several truck loads of ore were hauled to the Umbarger mine south of Sugar Grove and washed. A representative sample of the concentrates analyzed manganese 34.04 percent, iron 14.30 percent, silica 9.08 percent, and phosphorus 0.146 percent. The soil at the mine is red but the underlying clay is yellow. The manganese occurs as hard, amorphous, manganese oxide in the form of nodules, irregularly shaped flattened particles and large irregularly shaped masses. Limonite nodules are present, but they tend to be separately zoned and do not seriously contaminate the manganese-bearing clays. Many of the manganese nodules contain numerous grains of quartz and some iron; thus the grade of ore is only fair. The

abundant nodules found in some of the first prospect pits proved to be very local, and the clay in much of the enlarged prospect was nearly or entirely barren. This, combined with the disappointing analysis of the washed ore, caused Messrs. Sayers and Whistman to abandon the property.

The smaller western pit was not as thoroughly prospected. Several new prospect holes were dug in the bottom of the old workings. The nodules were not as large or abundant as at the eastern prospect, but as the manganese oxides contained little silica and iron, the ore was of better quality. The principal ore mineral is cryptomelane. Additional test pitting would be necessary to determine whether the ore-bearing clays are sufficiently extensive to encourage mining.

The third mine consists of a series of old trenches in yellow clay on the floor of the valley ½ mile west of the No. 2 mine and a few hundred feet north of the old lumber road. Limonite, jasper, and silicified dolomite fragments are abundant on the banks but no manganese oxide was seen. The fourth mine is 1.5 miles east of No. 1 mine on the south-facing slopes near the tip of Brushy Mountain. The workings consist of many small pits and cuts in yellow clay, on the banks of which silicified dolomite, chert, and iron nodules are scattered. Manganese oxide discolors some of the masses.

Glade Mountain prospect.—The Glade Mountain prospect (Pl. 17) is on the south slope of Glade Mountain near the east end of the ridge at an altitude of 3,010 feet. It is 1,800 feet east of the Glade Mountain mine and 1,200 feet north of the Glade Mountain road. An old lumber road, which leads by easy grades to an abandoned sawmill, passes within a few feet of the prospect. This road has fallen into disrepair, but a small amount of work would restore it for trucking. The land is a part of the Jefferson National Forest, but the mineral rights are owned by the Belmont Corporation of Philadelphia, and are now leased by the Glade Mountain Corporation.

The belt of residual clay of the Shady dolomite, in which the Glade Mountain mine is located, extends eastward to include the Glade Mountain prospect. Bedrock is not exposed in the immediate vicinity of the prospect, but a uniform southward dip between 30° and 45° seems to exist elsewhere in this fault block. Assuming the same attitude here, the beds of Shady dolomite underlying the Glade Mountain prospect would be about 300 feet above the base of the formation.

Residual clays of the Shady are exposed, in several places along both forks of the creek above the prospect, and on the crest of the spur

between the forks of the creek. Thick quartzite and sandstone talus covers the hill slopes, so that the Shady in most of this area is considerably obscured. The clay belt is cut off abruptly 150 feet south of the prospect by a reverse fault, which brings up sandstone and quartzite of the upper part of the Erwin. The Erwin does not crop out here, but a thick body of quartzite float 250 feet south of the prospect marks the location of the prominent quartzite unit, which also forms the high knob 700 feet to the west and the crest of Locust Mountain still farther west.

A small test pit at the Glade Mountain prospect probably dates back to World War I. The Glade Mountain Corporation dug two intersecting bulldozer cuts at this location in the summer of 1942. One of these extends for 50 feet along the base of the hill slope a few feet above creek level. The other lies at right angles to the first, and reaches from the base of the hill for 100 feet up the slope. This cut has a maximum depth of about 6 feet but does not penetrate the mantle of talus and soil which has crept downslope from the Erwin quartzite hill. The exposed material consists of quartzite and sandstone fragments and loose sand. No manganese was observed. Three feet of yellow clay was exposed beneath a similar talus mantle in the lower cut at the time of the visit. No manganese was visible in the walls of the cut, but a small pile of manganese nodules had been picked out of the clay that had been pushed aside by the bulldozer. These nodules consisted of hard but cavernous, good-grade, amorphous manganese oxide without visible iron or silica. The nodules ranged in weight from a few ounces up to about 35 pounds. Several were subrounded or stalactitic; others were angular and irregularly shaped. Although the quality of manganese nodules was good, the quantity obtained for the amount of clay moved was not large.

Prospecting at this site has not been sufficiently extensive to indicate the depth or extent of the ore-bearing clay. The location, only a few feet above the level of a small actively degrading stream, suggests, however, that the depth of the deposit is not great.

Glade Mountain mine.—The Glade Mountain mine is the largest producer of manganese in the district. It is on the lower slopes of Glade Mountain at an altitude of 3,150 feet, 3.0 miles west-northwest of Cedar Springs and 5.4 miles southwest of Rural Retreat. The mine is in the Jefferson National Forest, but the mineral rights are owned by the Belmont Corporation of Philadelphia. A Forest Service road passes within 800 feet of the mine.

The mine is in a long shallow depression which parallels the mountain crest and which lies between a series of knobs to the south and the main mass of the mountain to the north. The depression is not so apparent at the mine because south-flowing tributaries of Killinger Creek have eroded below it and destroyed its symmetry, but it is very striking when viewed from a distance (Fig. 5). The depression is formed by a belt of Shady dolomite which is in fault contact with Erwin quartzite on its south side (Pl. 17). A resistant quartzite unit in the Erwin forms the knobs south and southeast of the mine. The quartzite dips southward at high angles and in places is nearly vertical. It is well exposed in a road cut at the junction of the mine road with the Forest Service road. This quartzite belt crosses Killinger Creek south of the mine and forms the crest of Locust Mountain farther west.

North of the mine the Erwin quartzite dips normally beneath the Shady dolomite. Although there are no outcrops on the slope above the mine, the contact between these two formations can be mapped with considerable accuracy by noting the increasing abundance and then the sudden disappearance upslope of float of the distinctive, iron-stained, coarse-grained, porous sandstone which lies at the base of the Shady. Large blocks of coarse, brecciated sandstone near the water tank on the north edge of the mine suggest the possibility of another fault not shown on Plate 17, repeating the base of the Shady at that point. The problem of this possible fault has considerable practical importance, for the residual clay at the mine would be very shallow if a fault brought up the basal Shady sandstone almost at the edge of the workings. The brecciated sandstone has no continuity along the strike east and west of the water tank, however, and residual clay of the Shady is exposed both to the north and to the south of the water tank. Furthermore, sandy lenses, which are visible in the mine openings, are interbedded in residual clay and do not represent the upper Erwin or basal Shady sandstone. The blocks of brecciated sandstone are therefore interpreted as large blocks that have crept downslope from the outcrop of basal Shady sandstone above, and their brecciation is attributed to minor bedrock movement, or to shattering during creep rather than to faulting. The geologic map and section (Pl. 17) have therefore been drawn without showing a fault.

The Shady dolomite does not crop out in the area. Laminated clay in the mine dips in most places 30°-40° S. Dips of this approximate amount and direction are persistent elsewhere in this fault block along the mountain front. If this dip persists in the bedrock at the mine and no faults intervene, the depth to the basal Shady sandstone in the

middle of the mine pit would be about 150 feet. At the Umbarger mine decomposition of the dolomite to form clay has gone to a depth of 220 feet; thus it is possible at the Glade Mountain mine that all of the dolomite has decomposed to form residual clay down to the basal sandstone.

Lenses of angular, white sand, which results from the weathering of partly silicified dolomite, are interbedded in the clay at several places in the mine. Elsewhere yellow sand lenses, which are probably of similar origin, are interbedded in the clay, but these may have been formed by weathering of dolomite which was originally sandy. Sandy dolomite is not common in the Shady, but sandy beds are present at least 40 feet above the base of the formation along Dickey Creek south of Sugar Grove and they may locally be present still higher.

The Glade Mountain mine was opened before World War I and some ore was hauled to Rural Retreat for shipment. The ore is said to have been siliceous. There was no activity at the mine during World War I and the mine was not reopened until 1937. Since that time there has been intermittent mining, with some ore shipments each year. Four different operators have worked the mine, the present company known as the Glade Mountain Corporation, having taken possession early in 1942. In 1937 and 1938 the ore was washed in a concrete mixer at the mine. The ore worked at that time in the central part of the pit was intermixed with iron ore. Many of the shipments had almost as much iron as manganese, as shown in Table 5. In 1939 and 1940 the ore from the mine was hauled to a concrete mixer along the main road ½ mile southeast of the mine. One of the 1939 shipments came from an uncommonly high-grade ore pocket, for the car load analyzed 54.81 percent manganese. In 1941 a log washer was installed at a site on the slope overlooking the main road, considerably nearer Killinger Creek than the present washer site. The ore had to be hauled farther from the mine to the washer but the pumping expense to lift water from the creek to the washer was less.

Early in 1942 the present milling equipment was erected and additional mining equipment was obtained to handle ore on a larger scale.

The Glade Mountain mine as it appeared in the fall of 1942 is shown on Plates 13,B, 15,B and 17. Ore has been mined in five different places, which in order from west to east, are as follows:

1. On the gentle slopes 300 feet northwest of the washer, excavations have been made to a depth of about 10 feet in a cut 200 feet long. About a dozen pockets of ore were found and mined out. These

pockets consisted of brown to black nodule-bearing clay surrounded by barren, structureless yellow clay. They were roughly equidimensional, and from 3 to 10 feet in diameter. The manganese occurred in the form of granules and small nodules of hard, amorphous manganese oxide, most of which was of good quality. One ledge of solid oxide about a foot thick and 50 square feet in area was also found. About two car loads of concentrates were produced from this section of the mine in 1942. More pockets of this type probably exist, but the amount of clay which must be moved to find and uncover them is large, so that this part of the mine has been operated only when development work prevented mining of the richer ore bodies in other parts of the mine.

2. A large ore body was formerly mined in the central part of the pit about 200 feet due north of the washer. This is the ore body worked by all operators before the Glade Mountain Corporation began mining. About 1,800 tons of concentrates had been produced from it to the end of 1941. This ore body was not exposed in 1942 and has not been seen by the writer. It is described as consisting of nodular, wash ore of hard amorphous manganese oxide embedded in clay and sandy clay. Some of the 1937-38 shipments of this ore were very high in iron and silica, probably due to the lack of adequate washing, picking and screening equipment. After the installation of a log washer many shipments of the ore contained more than 45 percent of manganese and one phenomenal carload, which came from a pocket of fine-grained, clean, granular ore, analyzed 54.81 percent. The ore body in this part of the mine has not been worked out, for ore is known to be present beneath the incline leading to the northeast part of the mine at a point 320 feet north-northeast of the washer.

3. The ore ledge, which has produced most of the ore mined in 1942, is in the northeast part of the mine, 450 feet from the washer. It consists of a ledge of nearly solid, hard ore which has ranged from 1 to 6 feet in thickness. The ledge is overlain by a few inches to a few feet of wad and then by barren yellow clay. The ledge contains small pockets of wad and of yellow clay but is mainly rocklike and consists of cryptomelane and psilomelane intergrown with zones of pyrolusite. Lithiophorite (a lithium cobalt manganese aluminate) was found to be present in small quantities in one of the ore specimens and an analysis of a typical specimen from this ledge showed 0.63 percent cobalt. The ledge trends northeast and dips from about 25° at its southwest end to nearly vertical at its northeast end. It has been worked over its full length of approximately 75 feet. It is thickest at the southwest end

and thins gradually to the northeast. The ore has been worked from near the surface to a depth of about 30 feet and the ledge continues but thins downward. The deeper the cut becomes, the more barren clay has to be moved from the walls of the cut to prevent slides, and the higher the costs per ton of ore mined. About 1,200 tons of concentrates were produced from this ledge in 1942. Most of this went through the washer, but some was clean as mined and was hauled directly to the shipping bins.

A solid ledge of cherty iron oxide capped the slope to the northwest and dipped beneath the manganese ore ledge at an angle of 30°. This ledge has been largely quarried away and a few small pockets of solid manganese ore and also of wash ore were found directly beneath it.

4. A solid ledge of hard amorphous manganese oxide was uncovered late in 1942, about 50 feet north of the big ore ledge on the northwest side of the cut. Only a few tons of ore had been mined from it when winter weather curtailed activities, and mud slides covered it again. The ledge appeared to be nearly flat, was at least 2 feet thick, and at least 5 feet long. It may prove to be much larger.

5. The highest level of mining operations is on the divide 600 feet east-northeast of the washer. A bulldozer cut has been dug to a depth of 30 feet below the original surface. Early in 1943 this cut was being connected with the deep cut at the No. 3 and No. 4 ore bodies. Pockets of ore have been found at various levels in this cut, but all have been small, and they seem to be getting scarcer with depth. Most of the pockets consist of nodular and granular ore in brown or black clay, but a few have contained small masses of hard ore. One steeply dipping solid vein of manganese oxide was about a foot wide, 15 feet long and 10 feet deep. Pockets nearer the surface also contained powdery black manganese oxide, probably pyrolusite, uncontaminated with clay or silica. Enough of this was present in several pockets to warrant special efforts to mine it separately for sale as chemical ore. About four carloads of concentrates have come from this upper level of the mine, but the amount of barren clay moved has been large.

The present practice is to mine the ore pockets and ledges by pick and shovel, and hand load the ore into sleds (Pl. 13,B) which are pulled to the washer by a small caterpillar tractor. Very clean high-grade ore is separated by hand in the mine and is taken directly to the shipping bins. The use of sleds for hauling ore to the washer has allowed mining to go on when the pit was too mucky from rains or thaws for trucks to be used. Bulldozers are used to uncover the ore bodies and to move barren material out of the working cuts. A steam

shovel has been used from time to time for special excavation jobs. The washing plant is equipped with a double-log washer, screens, and a picking belt (Fig. 8). Water to operate the plant is pumped from Killinger Creek 135 feet below and 1,000 feet to the south. From the shipping bins the concentrates are hauled by truck 8 miles to the Norfolk and Western Railroad at Rural Retreat. Most of the shipments have been made to Lynchburg.

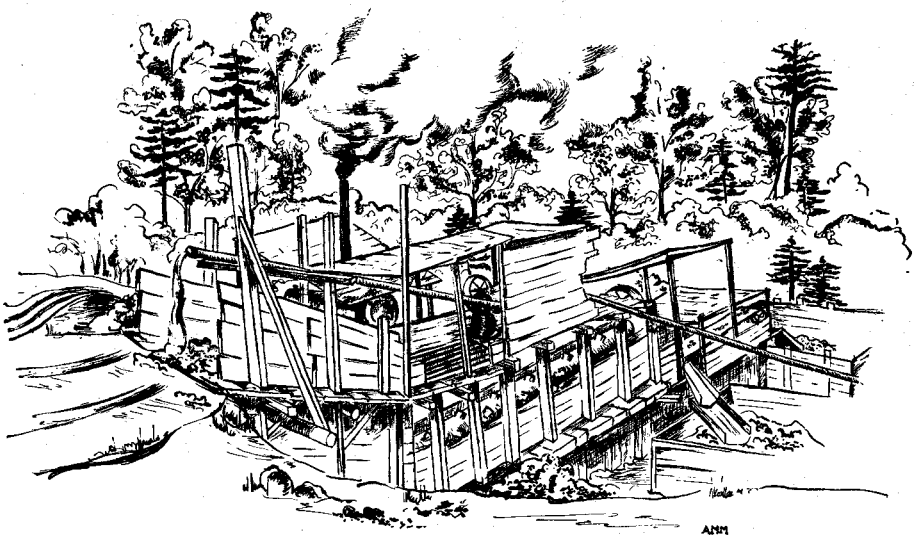


FIGURE 8.—Sketch of washer at the Glade Mountain mine. From left to right: chute into which the ore from the mine is dumped; steam engine which powers the washer; grizzly of steel rails, through which the ore drops into the log washer; a small rock crusher beside the grizzly; one log of the double log washer; chute from which washed ore finer than half-inch sizes passes into the near bin; picking belt from which rock and low-grade ore are removed by hand, while the high-grade concentrates pass into the bins at the lower end of the washer. By Ansel M. Miller.

Prospecting in the vicinity of the mine has been only superficial. Shallow bulldozer cuts and a few shallow pits have been dug west, northwest and north of the mine. Several pits about 100 feet west of the water tank found small quantities of ore, but other recent ones have been almost barren. All three of the main ore bodies have been relatively deep beneath the surface; hence shallow prospecting has not been adequate to prove the presence or absence of other similar ore bodies. The most favorable area for prospecting in the immediate vicinity of the mine seems to be the gentle slopes to the north.

Data have not been kept on the amount of overburden moved and the amount of clay washed per ton of concentrates. The writer has made rough calculations from measurements of the recent cuts and the known recent production of ore. From these it appears that in 1942 about 12.5 cubic yards of barren material were handled for each ton of concentrates. Of this amount approximately eighty percent was overburden which was pushed aside, and 20 percent was clay, sand, wad, iron, chert and silicified dolomite, which were removed in the washing plant.

Production figures for the Glade Mountain mine are given in Table 5 below.

TABLE 5.—*Manganese produced at the Glade Mountain mine in terms of the weight and analysis of each carload shipped*

DATE	Long tons Dry	Manganese	Iron	Silica	Phosphorus
1937					
April 14.....	42.6429	35.22	19.10	4.72	.298
May 6.....	48.2143	19.20	30.20	12.40	.474
20.....	42.2321	31.97	23.30	9.40	.388
June 2.....	48.6161	18.65	34.80	6.28	.553
28.....	37.1429	47.80	7.50	2.12	.188
Aug. 2.....	45.9375	43.66	10.30	4.44	.215
Sept. 2.....	44.7321	45.58	7.20	4.46	.137
20.....	45.2232	45.97	6.70	4.52	.116
27.....	48.5268	46.60	3.20	3.41	.149
Oct. 2.....	32.5000	32.50	19.80	4.64	.279
7.....	42.1429	43.63	9.70	3.84	.167
19.....	51.7857	37.97	24.80	8.08	.350
Nov. 1.....	45.4911	34.28	18.00	5.64	.268
1938					
May 2.....	49.6875	19.82	27.45	14.52	.418
10.....	45.3571	19.52	29.40	14.08	.470
21.....	49.1071	17.73	34.90	6.80	.544
June 7.....	48.0804	24.42	25.60	10.16	.409
20.....	48.7500	23.39	28.00	9.68	.436
July 5.....	47.6786	20.57	27.40	13.64	.418
19.....	46.3393	33.08	19.80	6.04	.191
30.....	47.5000	.....	.....	.....	.....
Aug. 17.....	44.1071	19.97	30.50	10.58	.263
27.....	50.0893	37.50	15.23	5.96	.171
Sept. 3.....	49.6429	32.33	18.20	10.46	.189
1939					
July 19.....	25.0000(?)	54.81	3.30	2.74	.....
Oct.	32.3000(?)	49.32	4.50	4.04	.....

TABLE 5.—*Manganese produced at the Glade Mountain mine in terms of the weight and analysis of each carload shipped—Continued*

DATE	Long tons Dry	Manganese	Iron	Silica	Phosphorus
1940					
Nov.	27.6200(?)	44.85	8.40	6.96	.....
1941					
Jan. 6.....	31.0898	46.64	5.82	6.92	.107
Feb. 22.....	34.0854	46.12	6.33	6.80	.124
April 18.....	40.0143	42.09	9.87	6.58	.152
May 25.....	36.2178	39.77	10.80	5.40	.218
June 17.....	42.6000	23.00	27.60	8.06	.238
27.....	34.9684	44.27	8.02	7.84	.138
Aug. 15.....	34.0000	32.04	21.10	9.00	.....
Sept. 5.....	36.3880	49.58	.....	.....	.....
17.....	46.7810	49.76	4.94	4.68	.192
Oct. 6.....	52.1015	48.92	5.27	4.10	.186
21.....	52.4313	45.29	6.08	10.96	.182
Nov. 4.....	49.5543	49.64	4.25	5.72	.150
17.....	45.9147	44.85	9.12	4.78	.202
Dec. 5.....	51.4851	47.90	4.66	7.02	.154
17.....	51.5062	46.01	4.56	10.76	.157
1942					
April.....	49.9473	47.35	4.50	9.34	.189
do.	45.5953	48.54	5.70	7.72	.185
May.....	39.4525	43.55	5.67	12.82	.160
do.	46.6026	39.34	13.68	6.14	.291
do.	50.1534	39.05	12.66	9.26	.275
June.....	45.4074	43.83	7.39	9.44	.210
do.	39.2951	46.30	6.18	6.62	.129
do.	48.5606	43.11	8.91	9.02	.206
do.	49.2976	43.83	9.22	8.02	.218
July.....	45.6696	43.40	10.33	6.18	.232
do.	47.6200	42.96	12.91	4.40	.237
do.	47.8386	43.51	11.00	4.12	.264
do.	52.7934	41.44	12.20	4.82	.267
do.	48.8422	38.18	15.10	5.72	.297
August.....	49.0085	41.88	12.60	4.08	.234
do.	50.4601	40.85	10.70	8.30	.210
do.	50.6719	42.18	10.70	5.34	.221
do.	46.5248	45.14	9.00	5.42	.184
do.	45.3288	43.81	8.30	6.52	.198
do.	50.6129	44.56	8.26	5.98	.168
do.	45.8328	45.87	7.91	6.08	.197
Sept.....	44.8046	45.87	9.72	2.98	.209
do.	47.6048	38.46	15.27	7.28	.206
do.	45.5850	43.55	10.35	5.28	.198
do.	42.1943	36.58	14.87	9.22	.156
do.	45.5617	44.12	8.32	6.84	.176
do.	46.3022	47.75	5.71	5.64	.173
do.	44.9033	51.09	4.24	2.70	.170
Oct.....	46.2196	49.35	5.09	4.02	.205
do.	44.9855	47.60	5.14	7.76	.168

TABLE 5.—*Manganese produced at the Glade Mountain mine in terms of the weight and analysis of each carload shipped—Continued*

DATE	Long tons Dry	Manganese	Iron	Silica	Phosphorus
Oct.....	46.7067	48.91	4.86	6.28	.170
do.	46.0446	46.73	6.50	6.06	.174
Nov.....	48.7942	45.87	6.73	6.44	.186
do.	40.3219	42.09	9.04	8.96	.208
Dec.....	36.2953	41.51	9.66	8.30	.230
Total....	3,447.4238	.....	.....	.....	.....
Average.	.....	40.45	12.45	6.95	.218

Dutton prospect.—This prospect is on the farm of W. H. Dutton, 1.9 miles south-southeast of Groseclose. The farm is in a broad belt of Shady dolomite on the north slope of Glade Mountain.

The prospect consists of surface showings of iron and manganese on the west side of a small ravine 500 feet southeast of the farm house. Dolomite is exposed in two small quarries east of the house, but south of these a mantle of residual clay of unknown depth covers the slopes. Limonite nodules are abundant at several places. A few manganiferous iron and manganese particles were found. Most manganese particles are smaller than one inch and are of a dull, jet-black oxide. They were most abundant at a point just east of Mr. Dutton's property line on land owned by T. L. Pippin. Although the surface showings are not impressive, enough manganese is visible at one or two places to warrant a prospect digging. The iron nodules on the surface may possibly overlie zones in which manganese is more abundant.

Phillipi Branch mine.—The Phillipi Branch mine is near the east fork of Phillipi Branch 2.1 miles south of Groseclose, at an altitude of 3,000 feet. It is in the woods on the east slope of a spur which overlooks the creek. The mine is in a narrow belt of Shady dolomite. Quartzite beds near the top of the Erwin crop out along Phillipi Branch below the mine, where they strike due east and dip gently southward beneath the Shady dolomite. Both the Shady and Erwin are part of an overthrust fault block, which is recognizable for ½ mile to the east of the mine and 1 mile to the west. The Shady is cut off 400 feet south of the mine by another over-

thrust fault which brings the upper part of the Erwin against the lower part of the Shady. These small overthrust faults near the mine are associated with the larger overthrust which is ¼ mile farther south (Pl. 1, Section CC′).

The Phillipi Branch mine was worked for manganiferous iron ore during World War I. A washer was located on the creek below the mine, but all the machinery and other salvageable equipment have since been removed. The workings consist of a large and a small open pit and two trenches. The larger pit is about 100 feet in diameter. The working face at the back of the pit is 25 feet high. The clay is red near the surface but yellow in the deeper parts of the pit. Exposures on the walls of the pit are now very poor but on the dumps below the mine are many small pieces of limonite, manganiferous iron oxide, white chert and iron-stained chert. Larger cobbles of silicified dolomite are also prominent. Nodules in which manganese oxide is more abundant than any other constituent, are extremely rare. A trench, which is 75 feet long and appears to have been about 10 feet deep, lies 50 yards southwest of the big pit. The nodules in the clay are mainly of impure limonite. A few nodules of high-grade manganese oxide were seen but more showed intergrowths of manganese with limonite or silica. A second trench a little farther to the south and up the spur is also about 75 feet long. The only nodules seen here were of shaly limonite and iron-stained chert. A pit 15 feet in diameter and 3 feet deep lies to the southwest on the flat crest of the spur. A few limonite nodules but none of manganese oxide were seen here.

Most of the ore from this mine was probably manganiferous iron. Some fair-grade manganese seems to have been mined, for the writer found several nodules of siliceous manganese oxide and one large mass of high-grade manganese ore along the lane below the mine, which may have been dropped from wagons hauling the concentrates. The mine does not at present look favorable for the production of manganese, though manganiferous iron might still be produced.

East Nick Creek prospect.—The East Nick Creek prospect is on the east branch of Nick Creek 1.8 miles south-southeast of Atkins, at an altitude of 2,700 feet. It lies in the forest near the west end of Glade Mountain about 400 feet north of the Glade Mountain road and 300 feet east of the north-south road across the west end of

Glade Mountain. The prospect is in a belt of Shady dolomite which ends against a fault 1,500 feet to the east. This fault forms the south edge of the belt of Shady 700 feet south of the prospect. The top of the Erwin quartzite lies 300 feet to the northeast, dipping normally beneath the Shady. Some unexplained complications on the slopes above the prospect make it probable that other small unmapped faults exist in this area.

The prospect consists of a very old open pit, 75 feet long, 50 feet wide and about 15 feet deep, which extends up the hillside in a northeast direction. Iron ore or manganiferous iron ore was produced. The walls of the pit are composed of light-yellow, earthy, clayey soil which contains abundant white and pink chert fragments. Small limonite nodules and a few earthy manganese oxide nodules are present, and also a few large cobbles of white, finely crystalline, silicified dolomite. The manganese oxide particles now visible are not sufficiently abundant or high-grade to encourage prospecting at this site.

Chestnut Mountain prospects.—Three minor prospects are along the north slope of Chestnut Mountain. The easternmost of these is on the north side of a small, east-draining ravine 800 feet south-southwest of the junction of the Glade Mountain road with the Atkins and Sugar Grove road. The prospect is in residual clay of the Shady dolomite about 100 feet north of the large fault at the base of Chestnut Mountain. It is a very small cut exposing yellow clay which contains small nodules of red hematite, some of which have a core of manganese oxide. No manganese or iron float was found on the slopes nearby, so the ore pocket is probably very small.

A trench and pit are on the gentle slopes at the base of Chestnut Mountain 1,700 feet southwest of the junction of the Glade Mountain road with the Atkins and Sugar Grove road at an altitude of 2,780 feet. These are in the same belt of Shady dolomite as the prospect described above and are about 300 feet north of the fault contact with the Erwin. The trench is 60 feet long and 15 feet wide. The pit is 15 feet in diameter. Both were apparently quite deep but have now largely caved. They show reddish-brown, clayey soil containing small red and black hematite and limonite particles, white chert, and a few large blocks of brecciated silicified dolomite cemented by manganese oxide.

The third prospect is high on the north slope of Chestnut Mountain 1.1 miles west of the Atkins and Sugar Grove road and 1.2 miles southeast of the road junction near Centenary School, at an altitude of 3,140 feet. It consists of a very small quarry exposing an 18-inch bed of solid limonite, part of which is siliceous. The limonite bed directly overlies a massive ledge of resistant quartzite. The limonite is a replacement of sandstone which was probably originally more pervious than the underlying quartzite and thus served as a channel for the circulation of the iron-rich ground waters. The limonite and quartzite beds strike N. 45° E. and dip 67° NW. This dip is uncommon in the Erwin formation of this district, and is here probably due to drag on the large reverse fault which lies a short distance downhill to the north. The limonite prospect does not seem to contain manganese. It is of especial interest, however, because it shows iron oxide replacing solid rock. This type of deposit is not uncommon in the Erwin sandstones and several such deposits seem to have been worked in the Glade Mountain district. Most of these iron mines in the Erwin were small and they have been so long abandoned that the ore bodies are not as well exposed as the one in the Chestnut Mountain prospect. None of the three Chestnut Mountain prospects seem to be of much importance as possible producers of manganese.

West Nick Creek prospect.—The West Nick Creek prospect is on the west fork of Nick Creek 3.2 miles south of Atkins. It lies in the forest on the north slope of Brushy Mountain about 100 feet above the base of the mountain and 60 feet above and 400 feet west of the Atkins and Sugar Grove road.

This prospect is in a long belt of Shady dolomite which separates the quartzites of Brushy and Locust mountains, and which continues westward to become a part of the Currin Valley belt of dolomite. Quartzite at the top of the Erwin crops out prominently along the highway below and east of the prospect, and dips southward beneath the residual clay of the Shady formation. A small reverse fault brings a narrow belt of the uppermost Erwin quartzite to the surface in the middle of the main belt of the Shady dolomite. The prospect is in the clay of the basal Shady a few feet south of this narrow belt of the Erwin quartzite and about 300 feet north of the Brushy Mountain fault (Fig. 9).

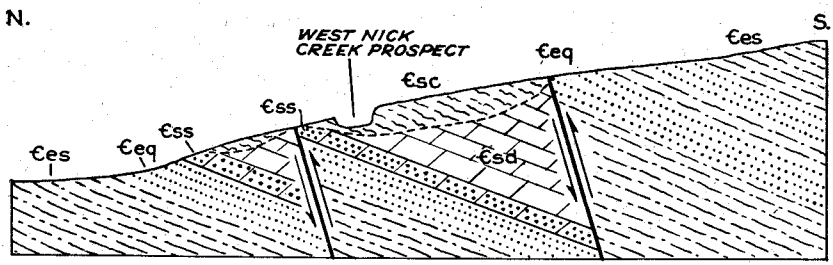


FIGURE 9.—Geologic section through the West Nick Creek prospect. Length of section 2,000 feet. Ꞓes, sandstone and shaly sandstone beds in the Erwin quartzite; Ꞓeq, quartzite zones in the Erwin; Ꞓss, dolomitic sandstone at the base of the Shady; Ꞓsd, Shady dolomite; Ꞓsc, residual clay from weathering of the Shady dolomite. The depth of residual clay is unknown.

The prospect was worked many years ago for iron. In 1942 N. T. Dixon of Marion took out half a carload of ore, which analyzed 19 percent manganese and 35 percent iron. The main pit is about 40 feet in diameter, and 20 feet deep at the uphill face. The walls are largely covered with brown, clayey soil, but in places red and yellow mottled clay is revealed. Large and medium sized masses of jasperoid, limonite, and hematite lie in the bottom of the pit. A bright red, argillaceous hematite is the most conspicuous mineral present. Small nodules of fair-grade manganese oxide are scattered through the clay but are not abundant.

Two trenches and several small pits, a few feet down the slope to the east, are in yellow clay, which contains nodules of silica and iron oxide. Several of the nodules are limonite with iridescent surfaces. No manganese oxides were seen in the pits. Another long shallow trench is on the crest of the spur above the main pit, but it has almost completely slumped and now shows neither iron nor manganese ore. Pieces of coarse-grained, iron-stained sandstone from the base of the Shady dolomite lie on the surface about 100 feet south of the prospect.

Another prospect in this area was explored in 1942 by Mr. Dixon. It is 600 feet north of the prospect just described, in the west bank of Nick Creek. It consists of a cut extending a few feet into the bank, exposing a solid ledge of sandstone at the base of the Shady, which has been largely replaced by iron and manganese oxides. The iron content is greater than the manganese and in no part of the ledge was any high-grade manganese ore seen. Although the exploration has been very limited, the low grade of the ore exposed and the position of the prospect at the bottom of a narrow

steep-walled valley seem to preclude the existence of a significant manganese ore body at this site.

Slemp Creek prospect.—The Slemp Creek prospect is 2 miles north of Sugar Grove on a hillside overlooking Slemp Creek and State Highway 16. An old washer, located just above the highway and below the mine openings, was first used to wash ore from the Slemp Creek prospect. A tramroad was built later from this washer to the Wright bank 1 mile to the west. Apparently most of the ore washed at this site came from the Wright bank, and not from the Slemp Creek prospect. The history of the Slemp Creek prospect is not known, but it probably produced manganiferous iron ore to supply one of the early iron furnaces in Rye Valley. There is no record of any ore having been produced from this prospect after the construction of the Currin and Rye Valley Railroad in 1896.

The prospect is in clay derived from the basal part of the Shady dolomite. The belt of Shady dolomite is here only 200 feet wide. It is bounded on the north by a normal contact with the Erwin quartzite, which forms the small knob north of the prospect and which dips beneath the basal Shady sandstone. On the south side the belt of Shady is cut off by a reverse fault, which brings up the lower part of the Erwin quartzite.

The workings consist of three cuts, the smallest of which is directly above the washer site along the main highway. This cut was narrow and the clay walls have slumped badly. Limonite nodules are abundant on the weathered banks, but none of manganese were seen. The other two workings are about 500 feet to the west at slightly higher altitudes. One of these is 50 feet in diameter and has a working face 25 feet high against the hillside. The other is about 100 feet long, 40 feet wide, and is now about 20 feet deep. Ledges of iron-stained sandstone at the base of the Shady dolomite stand nearly vertical on the north side of the opening. The mining was in clay directly overlying the basal Shady beds. The mine banks and dumps are covered with pieces of silicified dolomite and chert and iron nodules, some of which are discolored with manganese oxide. No manganese oxide of good quality was seen. The workings here are so old that exposures are extremely poor, but the almost complete absence of manganese oxide particles on the banks and dumps makes it probable that iron was the only material of any importance, and that little, if any, manganese was found.

Wright bank.—The Wright bank (also called Tate bank, Peery property, and Peery mine) is 2½ miles north-northwest of Sugar Grove in a shallow valley near the crest of Brushy Mountain, at an altitude of 3,220 feet. Where State Highway 16 between Marion and Sugar Grove crosses the crest of Brushy Mountain, a passable lane leads west through the forest 0.3 mile to the mine.

The mine is near the south edge of a belt of Shady dolomite 700 feet wide. The crest of Brushy Mountain, which rises 180 feet above the mine to the north, is formed by the topmost beds of the Erwin quartzite. Outcrops are lacking, but elsewhere along the crest of Brushy Mountain the upper part of the Erwin quartzite dips southward beneath the Shady dolomite at moderate angles, and it probably does likewise here. A reverse fault brings the Shady dolomite in contact with sandstone of the lower part of the Erwin quartzite about 150 feet south of the mine. A fault wedge of Erwin splits the belt of Shady into two parts about 1,000 feet east of the mine. The projection of this fault line westward would pass very close to the Wright bank. Whether the fault continues as far as the mine is not known, but it is probable. If so, the circulation of manganese- and iron-bearing solutions through the residual clays would undoubtedly have been facilitated by fracturing of the underlying dolomite beds along this fault.

The Wright bank was worked for iron during the War between the States. In the early 1900's the manganese ores were first mined and some 15 to 20 carloads of manganese concentrates are reported to have been shipped. Activity was renewed in 1917 and 1918, when the Holston Mineral Co. mined and shipped ferruginous manganese ore. The ore was hauled by tramline to a washer located about a mile to the east on Slemp Creek. With the collapse of manganese prices at the end of World War I, operations ceased.

The property was prospected in the winter of 1940-41 by N. T. Dixon. Several test pits were sunk and two of the old drifts were reopened. The results of this prospecting were not encouraging, and there was no production. A sample of typical ore collected from a test pit by Mr. Dixon analyzed as follows: manganese 19.90 percent, phosphorus 0.36 percent, silica 7.62 percent, iron 33.60 percent. The mineral rights are now owned by the J. D. Perry estate of North Tazewell.

The open pit at the mine (Fig. 10) is 150 feet long, 75 feet wide and 30 feet deep at its deepest point. The walls have slumped so that the original outlines are considerably modified and fresh clay banks are nowhere visible. Four vertical shafts in the bottom of the pit, and

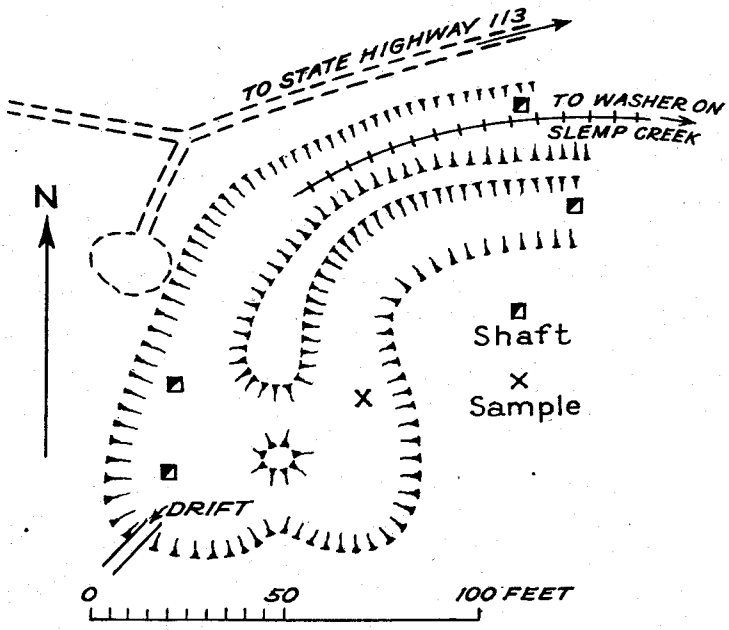


FIGURE 10.—Sketch map of Wright bank.

several horizontal drifts into the hillside have also caved and the drifts are partly or entirely obliterated.

Yellow clay is dominant in the open pit, but streaks and patches of red and brown clay are present. Limonite nodules are abundant on the weathered slopes. In some, manganese oxide is intergrown with iron oxide, and a few small particles of pure, hard, amorphous manganese oxide were found. A solid ledge of manganiferous iron is still exposed in Shaft 1 (Fig. 10). Some of the underground workings are said to have penetrated iron-free manganese ores, but there is no indication of these at the surface. The history of the property and present showings lead to the conclusion that the amount of high-grade manganese ore is small and that manganese could not be produced in any appreciable quantity without recourse to roasting and magnetic separation of the iron from the manganese. The tonnage of ferruginous manganese ore still present is probably considerable and may be large. The nearest available source of abundant water is Slemp Creek one mile away.

Marchand prospect.—The Marchand prospect is on the north slope of Brushy Mountain 1.1 miles east of Attoway and 0.4 mile south of

State Highway 16, at an altitude of 2,950 feet. The prospect is in the Jefferson National Forest. It is in a belt of Shady dolomite 400 feet wide, which is in normal contact with a short narrow belt of the Erwin quartzite 100 feet to the north, and in fault contact with the main mass of Erwin quartzite, which forms Brushy Mountain to the south.

The prospect was worked for iron ore many years ago but has not been active in recent times. It consists of a long trench and several small pits. The trench extends from the base nearly to the crest of a low spur of Brushy Mountain. Brown and yellow residual clay of the Shady dolomite is exposed. Manganese nodules and particles are scattered over the dumps at the lower end of the trench. A few of these have rounded, botryoidal surfaces and consist of dense, hard, high-grade amorphous, manganese oxide. Some are subangular, and consist of a black, less metallic-appearing manganese oxide coated with iron oxide. Masses of red and black hematite, from two inches to one foot in length, have been piled along the margins of the trench. The separation of the hematite masses from the manganese nodules would not be difficult, for practically all of the manganese nodules are smaller than the smallest masses of iron oxide.

Very little manganese or iron ore is now visible in the trench and pits so that it is impossible to estimate the amount of the excavated clay that was ore-bearing. Although this prospect does not appear particularly promising, nevertheless enough good manganese ore is visible on the dumps to justify some prospecting to determine whether the ore is present in small, rich, workable pockets, or is scattered through all the clays.

Barton bank.—The Barton bank is 2 miles northwest of Sugar Grove and 2 miles north-northeast of Teas on the south slope of Brushy Mountain, at an altitude of 3,050 feet. The nearest passable road is about ½ mile to the south but an abandoned forest road passes near the mine.

The Barton bank lies in a belt of Shady dolomite about 600 feet wide. The basal beds of the Shady dolomite normally overlie the southward-dipping Erwin quartzite 200 feet north of the mine, but a reversal of dip and the reappearance of the upper part of the Erwin quartzite and the lower part of the Shady dolomite at the mine indicate that a minor fault is probably present nearby. The belt of the Shady dolomite is cut off on the south by a reverse fault with a displacement of about 1,200 feet, which brings the lower part of the formation into contact with the middle part of the Erwin quartzite.

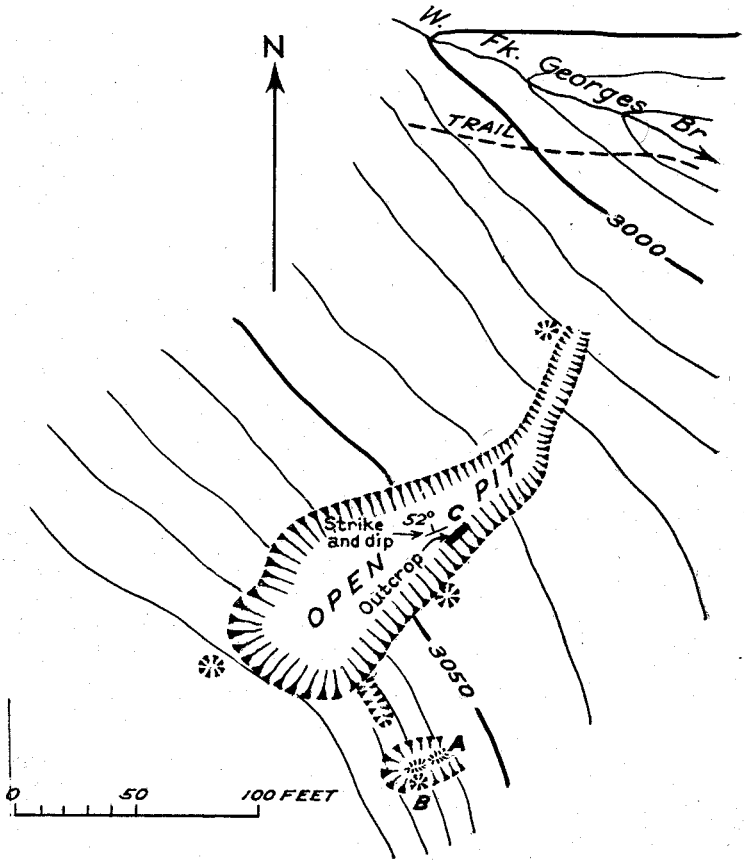


FIGURE 11.—Sketch map of Barton bank.

The major operations at the Barton bank date back to the middle of the last century, when iron ore was mined and hauled to a forge in Rye Valley. Sporadic prospecting has gone on since then, but no record of any other production was found. A test pit and a trench were dug in the summer of 1942 by R. M. Richardson of Marion.

The old mine consists of two open pits of unequal size (Fig. 11). The larger is 140 feet long, 60 feet wide, and is now 20 feet deep at the deepest point but was probably considerably deeper at first. The smaller open pit is about 25 feet by 15 feet. A trench (A, Fig. 11) 4 feet deep in the bottom of the smaller open pit passed through talus into a disintegrated sandstone at the bottom. A prospect pit (B, Fig. 11) a few feet to the southwest passed through the talus into yellow clay.

Subrounded masses of iron oxides, consisting of mixed limonite and hematite, were found in both the pit and the trench. A few of these masses contain cores of dull, black, low-grade manganese oxide. A sample of the best specimens is said to have analyzed between 31 and 33 percent manganese. The clay and sand in the bottom of these diggings are probably not in place but have become intermingled in the process of creeping down the slope.

No recent prospecting has been done in the large open pit. Large blocks of coarse-grained to pebbly sandstone are numerous on the floor of the pit, and a ledge of pebbly sandstone crops out on the south side (C, Fig. 11). This ledge strikes N. 68° E. and dips 52° NW., but beds on the hill slope southwest of the mine seem to lie nearly flat. Some of the sandstone is partly replaced by chert and iron oxide and in a few places also by manganese oxide. The ore sent to the furnace probably consisted of ledges and loose blocks of sandstone, in which the replacement by limonite had been almost complete.

The sandstone, sand, and clay at the Barton bank appear to come from the top part of the Erwin quartzite and from the lowest part of the Shady dolomite, but exposures are not sufficient to work out the relations of these formations and the detailed structure. The iron and manganese mineralization appears to be largely in sandstone and sandy dolomites, but a small amount of yellow clay derived from non-sandy dolomite is present and iron and manganiferous iron nodules in this clay may have accounted for some of the ore. No manganese ore of good grade was seen, and most of the iron ore now exposed is also low grade.

Walker-Forney prospect.—The Walker-Forney prospect is 1.9 miles north of Teas and 0.7 mile south of Attoway near the crest of Brushy Mountain, at an altitude of 3,340 feet. It is 0.4 mile from the nearest road and nearly as far from an abundant source of water. The prospect is in forest 800 feet N. 25° W. of the highest point on the Appalachian power-line crossing of Brushy Mountain. It is believed to lie within the National Forest on property formerly known as the Bob Williams tract. Some doubt has existed whether the prospect may not actually lie south of the boundary and thus on the land of George Atkins. The mineral rights of the Bob Williams tract are now owned by the heirs of the Walker-Forney estate.

This prospect is in the same belt of Shady dolomite and clay as the Barton bank to the east, but the belt has here narrowed to 300 feet. The Shady crosses Brushy Mountain at a low angle at this point caus-

ing an offset in the crest and a gap which the Appalachian power-line and the Pugh road utilize in crossing the mountain. The Pugh road has long been abandoned and is now impassable to automobiles.

Prominent ledges of pebbly, quartzitic sandstone crop out 250 feet north of the prospect, striking N. 73° E., and dipping 48° SE. These beds are at the top of the Erwin quartzite, and they dip normally below the Shady dolomite. Deep weathering of the dolomite in the lower part of the Shady has produced the clay visible at the prospect. The prospect is on the gentle slopes between the offset parts of the ridge crest and has therefore been protected from removal by erosion. The belt of Shady dolomite is cut off on the south by a reverse fault with a displacement of approximately 1,500 feet, which brings the dolomite into contact with sandstone in the lower part of the Erwin formation.

A small prospect pit at this site is many years old. In 1942 N. T. Dixon took a bulldozer up the north slope of the mountain to the prospect. He dug one prospect trench 170 feet long, which trends N. 56° E., and three shorter ones. Two of the shorter cuts intersect the long cut at low angles and the third lies parallel to and a few yards north of the long cut. The greatest depth reached in any of these cuts was 10 feet. The mantle rock, composed of sandstone and quartzite blocks derived from the ridge crest to the south, averages 5 feet thick. A yellow clay, mixed with wad in a few places, underlies this mantle. A few nodules of light-weight powdery pyrolusite show in the walls of the cut, but the main showing of ore consists of masses of dense, hard amorphous manganese oxide up to 20 pounds in weight which have been piled on the edge of the cut. In some of these the manganese is combined with iron and silica but in others it is uncontaminated. No ore nodules were seen in place in the cuts but most of those collected were said to have come from the deepest part of the long cut.

The prospecting at the Barton bank has not been sufficiently extensive to determine whether any appreciable quantity of ore is present. The showing of nodular ore collected is not large, considering the amount of clay moved. The long difficult haul to the nearest source of water adequate for washing is also a deterrent to mining operations at this site.

Atkins mine.—The Atkins mine is 1 mile south-southeast of Attoway and 0.6 mile southeast of the town of Currin Valley. It is located high on the northwest slope of Brushy Mountain, at an altitude of 2,870 feet. The abandoned Pugh road over Brushy Mountain passes

about 50 yards southwest of the main workings, which are on the crest and southwest slopes of an untimbered gentle spur.

The mine workings are in residual clay of the Shady dolomite. Those farthest south are only a few yards from the basal sandstone of the Shady. The Erwin quartzite beneath this sandstone is part of a plunging anticline which rises eastward to form the crest of Brushy Mountain but westward plunges beneath the dolomite of Currin Valley. The outcrop nearest the Atkins mine shows the quartzite on the north flank of this anticline dipping 61° NW. beneath the Shady dolomite. No bedrock is exposed at the mine, but residual clay derived from the dolomite is present in and around the mine workings.

The Atkins mine many years ago produced manganiferous iron ore. It was prospected in World War I, at which time a small amount of ore was produced. It was prospected again in 1942 by N. T. Dixon and later by Clay Sayers. The latter started operations on a small scale, and nearly a carload of ore had been washed to the end of 1942. This ore was hauled about 2 miles to a converted gravel washer on Staley Creek near Currin School. A sample of the washed ore analyzed 36 percent manganese, 17 percent silica and 10 percent iron.

The mine consists of cuts, trenches and prospect pits scattered over several acres of land owned by George Atkins of Attoway. The excavations farthest to the west consist of several prospect pits alongside the Pugh road. A few of these dug in 1942 showed fresh exposures of yellow clay nearly barren of ore. One small pocket of wad contained a little granular manganese oxide and a few pieces of limonite. One mass of hard manganese oxide, and a little powdery manganese oxide were also seen.

Long abandoned trenches, pits, and cuts in yellow clay lie northeast of these prospect pits. Particles of limonite are abundant on the banks and dumps and in places particles of hard, amorphous manganese oxide and of sandstone cemented by manganese oxide are present. Iron oxide was clearly the dominant mineral. A long-abandoned 40-foot shaft, which is said to have exposed manganese ore, is somewhere in this area but was not found.

Only one of the old workings has recently been extensively prospected. This is an open pit 50 feet by 30 feet and 10 feet deep near the crest of the spur east of the other workings. Prospecting by Dixon and Sayers at the northeast (uphill) end of this pit exposed a zone of patchy red, yellow, brown and black clay 10 feet wide, striking N. 31° E. and dipping 58° SE. This clay contains granular ore consisting of hard pellets of amorphous manganese oxide, many of which

include visible grains of silica. This ore zone has been worked in the old excavation, and has also supplied the carload of ore recently mined. Bulldozer cuts above this working exposed only barren clay, soil, and slope wash. The history and present ore showings of the Atkins mine indicate that deposits of iron and manganese ore are scattered over a considerable area but all the deposits seem to be both small and low-grade. The long haul to the nearest adequate source of water for washing the ore is also a handicap to mining operations at this locality.

CURRIN VALLEY MINES

Although the Currin Valley deposits were worked on a small scale in the middle of the last century, the building of the Marion and Rye Valley Railroad in 1896 tapped the valley and furnished an outlet for the ores in larger quantities. About 100,000 tons of iron ore and 1,000 tons of manganese ore are said to have been shipped from the Currin Valley mines before they were abandoned near the end of World War I. Most of this production was by the Staley Creek Manganese & Iron Co. All the important mines and prospects in Currin Valley except the Atkins mine, are now under one mineral lease of 4,460 acres, owned by Clay Sayers of Marion. This lease also includes the Deans Branch and Rich Mountain mines, which lie outside Currin Valley. The mines were being worked in 1942 by the N. T. Dixon Co. A single-log washer, powered by a gasoline engine, was installed on the site of the Staley Creek Company's washer at the No. 1 mine, and ore from the No. 1, No. 2, and No. 4 mines, and also the Rich Mountain mine, was trucked here for washing. Early in 1943 the Rich Mountain mine was furnishing the only high-grade ore, so that plans were under way to abandon the Currin Valley mines, and to install a new washer at a site nearer the Rich Mountain mine. Descriptions of the six important Currin Valley mines that are included in the Sayers lease follow. The Rich Mountain mine and the Deans Branch prospect are described separately.

Currin Valley mine No. 1.—Mine No. 1 is the largest of the group of six numbered mines in Currin Valley. It was the focus of operations by the Staley Creek Manganese & Iron Co. before World War I, and more recently by the N. T. Dixon Co. The main washer, which handled the ore-bearing clay for the active mines in the valley, was located near mine No. 1 by both operators (Pl. 14,A). The workings form a series of prominent scars on the north-facing slope of a

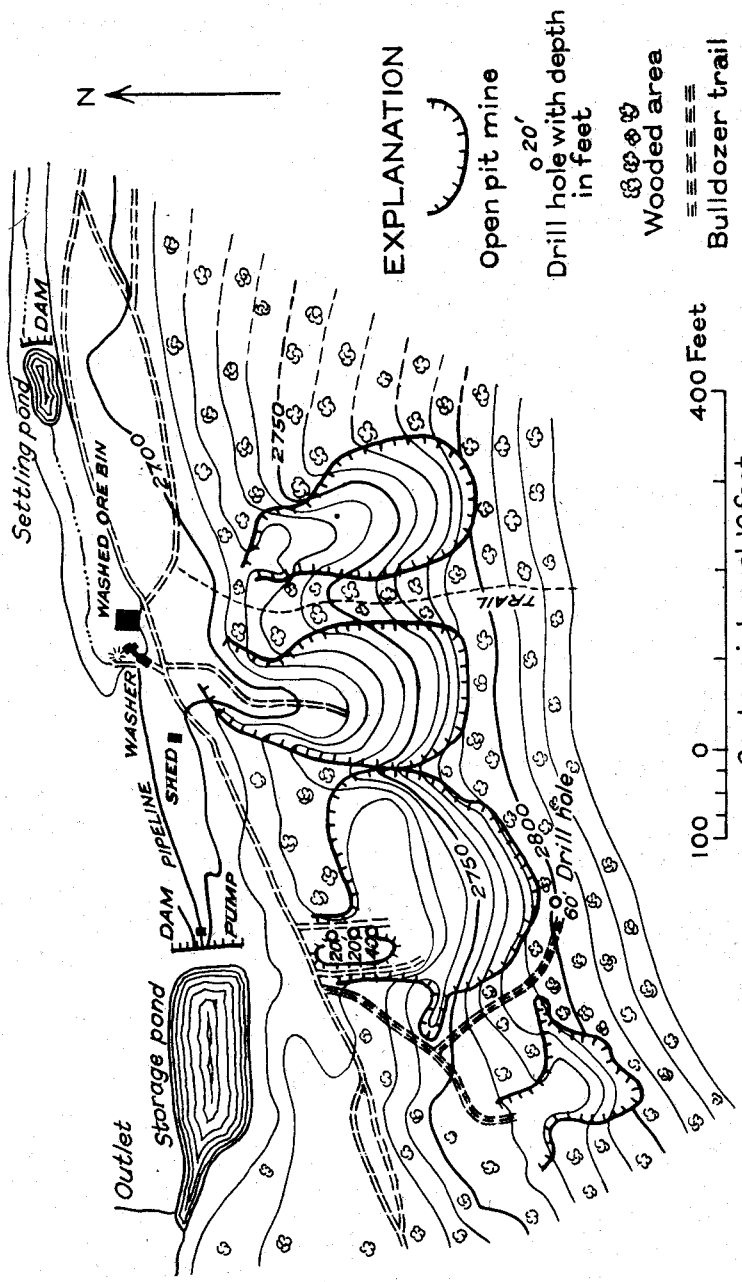


FIGURE 12.—Pace and compass map of Currin Valley mine No. 1. By Ralph H. Wilpolt.

low ridge, which farther west is called Dunford Ridge. There are three large open pits, and one small one, all closely grouped (Fig. 12). The flat-bottomed valley in front of the mine is floored with alluvium from Staley Creek and near the mine it is more deeply buried under the silts which have accumulated in a large settling pond as the result of extensive ore-washing in the earlier operations. The lower slopes of the mine ridge are covered with residual clay derived from the Shady dolomite. The Shady dolomite is in fault contact with sandstone of the Erwin formation about two-thirds of the way up the ridge, and the crest is formed by a resistant quartzite in the Erwin. The dip of the dolomite and of the quartzite is not known for bedrock does not crop out in the vicinity of the mine. Both dolomite and quartzite crop out across the valley north and northeast of the mine.

Mine No. 1 is said to have produced four carloads of concentrates a month for a considerable time after the completion of the Marion & Rye Valley Railroad in 1896. The shipments were largely, if not entirely, iron and manganiferous iron. The mine was abandoned in 1917 and lay idle until 1942, when it was reopened by N. T. Dixon.

The four open pits of the mine expose yellow clay, which in several places contains lenses of sand and disintegrated silicified dolomite. Mr. Dixon uncovered a solid ledge of limonite and ferruginous manganese ore, containing a few zones of high-grade manganese. Abundant rains in the spring of 1942, however, saturated the clays and caused a slide which buried the ore ledge deeply, and it has not been dug out since. The writer did not see this ore ledge, and in the summer of 1942 there were no other important ore showings in any of the pits. Specimens mined from the ledge consisted of dense, black, amorphous manganese oxide and dense, brown iron oxide in angular blocks and in nodules. In some pieces the two minerals were so intergrown that their mechanical separation by the customary methods would be impossible. Many other pieces, however, consisted largely of one mineral or the other. A few specimens contained small cavities lined with pyrolusite crystals (Pl. 8,B). By careful picking, manganese ore above 35 percent manganese could be obtained from this ledge, but the iron content would probably be high. No ore from this mine was shipped in 1942. Four churn drill holes were made at locations shown in Fig. 12, in an effort to determine whether the solid ore ledge is extensive enough to warrant underground mining. None of the holes encountered the ledge, although all passed below the level at which it was expected. Even if a modest-sized body of manganese or manganiferous iron ore still remains in the pits of this mine, it is doubtful whether

it could be mined successfully under present conditions, for the walls of the pits are so steep that continuation of surface mining would be hampered by repeated slides.

Currin Valley mine No. 2.—Mine No. 2 is on the north side of Currin Valley 0.3 mile northwest of the No. 1 mine. The right of way of the abandoned Marion & Rye Valley Railroad passes about 100 yards south of the mine. No. 2 mine was worked during World War I, but the excavations were not extensive and production could not have been large. The old workings consisted of several small pits and at least one drift. The mine was reopened in the summer of 1942 by N. T. Dixon, and one carload of concentrates was produced. The ore was hauled to the Currin Valley washer at the No. 1 mine.

The mine is on the gentle slope at the southern tip of a spur extending southwest from a prominent hill 200 feet high. Dolomite crops out on the north slope of the hill and in the railroad cuts on the south slope. The strike of the dolomite is northeast and the dips range from 17° to 38° SE., with the lower dips nearer the mine. The beds are dominantly of light-gray, finely crystalline dolomite, belonging to the upper part of the Shady dolomite. Lenses of milky-white chert are interbedded in the dolomite along the railroad cut, and large blocks of silicified dolomite lie loose along the right of way. The silicified dolomite is medium crystalline, snowy-white, and composed of loosely adhering grains. Elsewhere on the hill residual clay covers the surface.

The mine workings, as they appeared in the latter part of 1942, are shown in Fig. 13. A series of cuts and trenches are closely grouped on the west side of the low spur. The barren clay in the cuts was pushed downslope by a bulldozer onto the flats. Where zones of wad and ore-bearing clay were found, pick and shovel pits were dug along the leads. Most of these consisted of steeply dipping zones of wad and brown clay. The masses of hard manganese oxide are of several different types. Some of them are irregularly shaped pieces of hard black cryptomelane from one to four inches in size. Others are similarly shaped but contain rounded grains of quartz scattered throughout the matrix. These were formed by the partial replacement of silicified dolomite by cryptomelane. Nodules of cryptomelane of the botryoidal and of the stalactitic type are present but not abundant. Most of the rounded nodules are mixtures of limonite and cryptomelane. Some were found in which the limonite forms a rim around a central core of cryptomelane, others in which the cryptomelane had been deposited on the outer surfaces of limonite nodules, and still others in

which the two minerals are intimately intergrown. A few large lumps of cryptomelane contained cavities lined with pyrolusite crystals. Although some high-grade ore was found in the pits, much of the ore was high in silica and iron. The analysis of the carload of concentrates shipped in the summer of 1942 is as follows:

	Percent
Manganese	39.96
Iron	7.60
Silica	11.24
Alumina	4.27
Barium oxide	2.37
Phosphorus	0.064

The quality and abundance of the ore at this mine did not seem to warrant extensive removal of barren clay to establish good drainage of the workings. The narrow deep pits and trenches were frequently flooded by rainstorms and were abandoned after about one carload of concentrates had been produced.

Subsequently, old workings on the east side of the spur were explored . Ore of the same general type was found here and was worked for several weeks, but much of it was high in silica. Some ore consisted of brecciated silicified dolomite in which the matrix between angular fragments was replaced by manganese oxide, making a very striking black and white rock.

Currin Valley mine No. 3.—Mine No. 3 is on the south side of Currin Valley ½ mile west-southwest of the Currin Valley No. 1 mine, and about 0.1 mile southwest of the farmhouse of Mr. Smith. It consists of two cuts; one a narrow, recent bulldozer cut; the other a larger and older steam shovel excavation. The two are in alignment about 100 yards apart. Both lie on very gentle slopes in the forest south of a small clearing.

The smaller cut was dug by N. T. Dixon in 1942, reopening a small trench which dates back to the early operations in Currin Valley. It is 75 feet long and 5 feet deep. Two small pits dug in the bottom of the cut reached a depth of 15 feet below the surface. The cut and the pits reveal yellow clay which is barren except for a few large lumps of brown limonite and siliceous limonite. So far as known, this cut has not produced either iron or manganese ore.

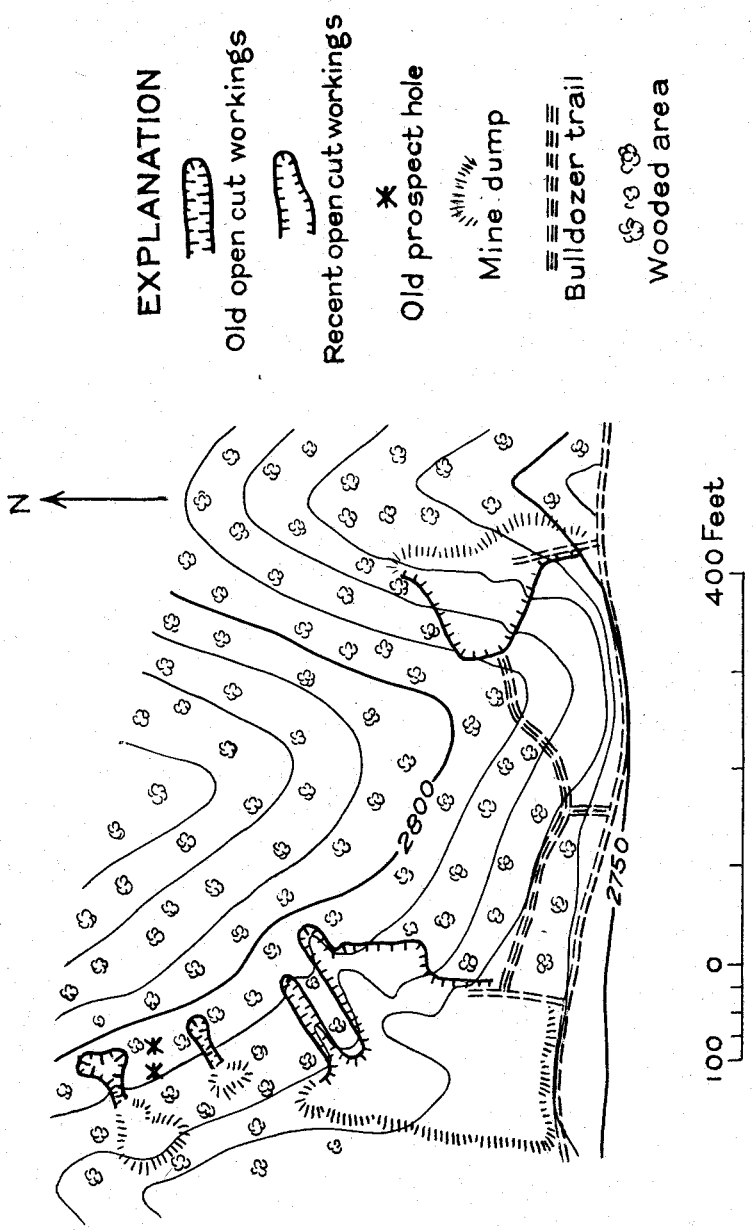


FIGURE 13.—Pace and compass map of Currin Valley mine No. 2. By Ralph H. Wilpolt.

The larger cut lies a short distance to the south, farther in the forest (Fig. 14). It was worked during World War I and the ore was hauled to a washer at the No. 1 mine. The cut is 150 feet long, 50 feet wide and 20 feet deep. In 1917 a layer of sandy and pebbly wash, partly cemented by manganese and iron was found at the surface, and this was underlain by red and yellow clay. The wash is not now exposed and the banks of clay have slumped badly so that the original appearance of the cut is much altered. Three new prospect pits and two bulldozer trenches have been dug recently by Mr. Dixon in the southern part of the cut, and these afford fresh exposures (Fig. 14). The two bulldozer trenches are in the east wall. They reveal barren yellow clay mainly, but a zone of red clay and black wad, 15 feet thick, was exposed. The wad contained almost no hard ore, either as nodules or granules,

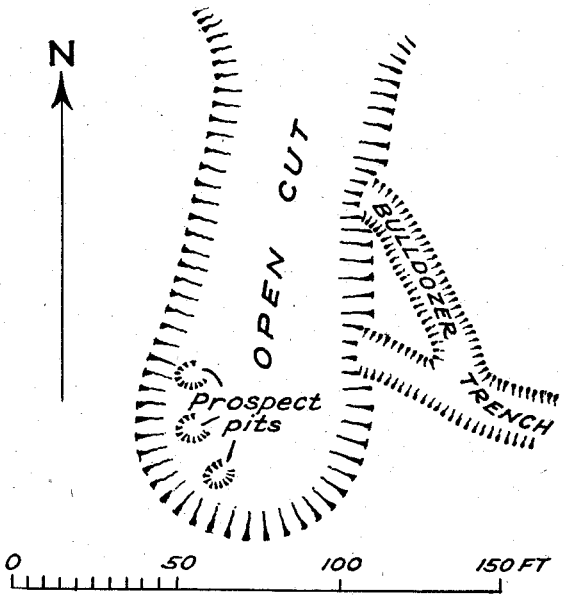


FIGURE 14.—Sketch map of Currin Valley mine No. 3.

but it might lead into ore-bearing clays at greater depth. Considerable amounts of manganese ore were found in two of the three small test pits near the southwest corner of the cut. In one pit the ore is in the form of botryoidal nodules averaging from 7 to 10 inches in diameter; in the other the nodules are flatter and more

angular. The manganese occurs as a dense, hard, high-grade amorphous manganese oxide. The quantity of hard ore obtained was considerable for such small prospect pits. Ore of this quality and in this abundance was probably not found in much of the mine, for almost no nodules can be found on the surface in the northern half of the cut. It is possible, however, that the good ore zone may extend beyond the cut to the south and west. The showings, though small, are sufficiently promising to warrant more prospecting in and near this end of the cut.

Currin Valley mine No. 4.—The No. 4 mine lies on the south side of Currin Valley 0.6 mile west-southwest of the No. 1 mine and 0.2 mile west-southwest of the No. 3 mine. It is in the forest on very gentle slopes at the base of Dunford Ridge and 0.1 mile east of the tip of Rich Mountain. This mine is one of the series worked by the Staley Creek Manganese & Iron Co. before and during World War I. The amount and quality of ore produced here are not known.

Residual clay of the Shady dolomite is exposed at numerous places in the area but bedrock does not crop out. The basal sandy dolomite of the Shady is exposed in cuts where the railroad right-of-way goes around the end of Rich Mountain. The beds dip east at the tip of the ridge and southeast on the south flank, and thus appear to pass normally beneath the dolomite which produces the residual clay around the mine. The belt of Shady dolomite is continuous for 1,000 feet up the slopes south of the mine to a fault, which brings up the Erwin quartzite.

The open pit resulting from the operation of the Staley Creek Co. is oval, about 100 feet long and 50 feet wide. The highest working face is 25 feet high at the southeast end of the pit. Yellow clay forms the walls in most parts of the pit, but slumping has covered almost all traces of the ore zones that were being worked. The only fresh exposure is on the east side of the pit where N. T. Dixon mined about a carload of ore in 1942. The soil and gravel overburden ranges from one to six feet thick, above a yellow and brown clay with red streaks and patches. No lamination that might indicate the original bedding, is recognizable in the clay. Pellets of dense, hard manganese oxide from pea size to walnut size are imbedded in some of the brown and red clay. The ore pocket, being worked in 1942, was flattened and nearly horizontal. It was about 10 feet thick and about 25 feet in diameter. Pellets in the

central part of this pocket were dominantly of manganese oxide, but around the margin iron pellets and nodules were abundant and also pieces of iron-stained silicified dolomite. The ore taken from this open pit years ago probably came from similar pockets. By careful selective, hand-mining, a fair grade of manganese concentrates can be obtained from material of this type, but steam-shovel operation would result in a washer product high in both iron and silica.

The carload of ore shipped from this mine in the summer of 1942 analyzed as follows: Manganese 34.93 percent, iron 8.0 percent, silica 15.66 percent, alumina 5.63 percent, barium oxide 2.32 percent and phosphorus 0.06 percent.

Currin Valley mine No. 5.—The No. 5 mine is in the southeast face of a flat-topped hill, which rises abruptly from the floor of Currin Valley. It is on the north side of the creek 0.5 mile due west of Currin Valley mine No. 1. In 1917 the Staley Creek Manganese & Iron Co. operated it concurrently with their other properties on the south side of Currin Valley, but it has not been exploited since the end of World War I. Stose[42] states that the company then considered it to be one of their best properties, and notes that large masses of good manganese oxide and much iron ore were being taken from the workings at the time of his visit in 1917.

The steep southeast slope of the hill has been opened up for a distance of 400 feet. The working face reaches from the valley floor to the hill top, a vertical height of 50 feet, and the depth of excavation into the hillside is 100 feet. Thus a large amount of clay was removed. On the floor of the pit, two pinnacles of bedrock are exposed. The rock is finely crystalline, white- and buff-colored dolomite, which is so massive bedded and so strongly jointed that the bedding can not be recognized. The clay which forms the high banks of the pit is yellow and light-brown, with a few streaks of wad. On the dumps at the base of the pit, and to a lesser extent on the pit walls, small limonite pebbles are abundant, and small impure manganese oxide particles are present but uncommon. One of the local residents states that ore was left in the lower part of the pit when mining ceased, but no ore of any consequence is now visible. In spite of the fact that the mine has been long inactive and the banks are slumped badly, it is surprising that so large an excavation should have such meager showings of ore. Possibly, this is because large blocks of iron and manganese, which are

said to have constituted the bulk of the ore, do not readily work out to the surface of weathered banks, and because little valuable ore would have been left behind on the dumps in working material of this type.

Currin Valley mine No. 6 (Amburg mine).—Mine No. 6 was named the Amburg mine by Stose[43] from the nearby station of Amburg on the now abandoned Marion & Rye Valley Railroad. It lies on the north side of Currin Valley 0.7 mile west of the No. 1 Currin Valley mine. Some excavations in a railroad cut through a low spur mark the site of the most recent prospecting, but the older excavations lie in the forest on both sides of the railroad cut.

The mine was worked by A. T. Short of Marion in 1917, and the ore was washed in a small plant on the spot. Stose described the washed ore as red-coated, nodular, black manganiferous iron ore mixed with some manganese ore of low grade. Several carloads of this type of ore were shipped. At present the older workings, which consist of about a dozen closely grouped cuts and open pits, do not afford good exposures. They were dug in a sandy, yellow clay. No nodules are visible on the walls or around the edges of some of these excavations, but iron nodules, some of which contain small percentages of manganese, are abundant at others. A few highly siliceous manganese nodules were found, in which manganese oxides have partly replaced silicified dolomite.

In 1942 N. T. Dixon prospected on the north side of the railroad cut. Yellow clay was exposed, containing some flat nodules from half an inch to two inches in size. Many of these consisted of a rim of limonite surrounding a core of manganese oxide in approximately equal amounts. The past history and the recent prospecting at this mine both support the conclusion that only low-grade manganese ore could ever be mined here.

Prospects north of Pond Mountain.—Five minor prospects, in which limonite is the principal mineral now visible, are on the north slopes of Pond Mountain. The westernmost one is 2 miles southeast of Marion on the west side of a saddle which separates two knobs of Rome shale. The excavations consist of a series of long-abandoned trenches and pits between the crest of the saddle and creek level, a distance of several hundred feet. The excavations and dumps show mainly a yellow clay containing numerous chips of red and yellow shale, and also brown and black limonite nod-

ules. No manganese was seen. The alignment of the workings along a narrow belt makes it probable that a zone of limonite, replacing beds of shale or residual clay in the Rome, was worked.

Another old iron mine is 1 mile due south of Staley Knob at the south tip of an oval hill of Rome shale. This is an open pit about 40 feet by 50 feet and filled with water to an unknown depth. The banks and dumps consist of yellow clay probably derived from weathering of the red shale, although it is possible that dolomite interbedded in the Rome contributed to the production of the clay. Small limonite particles are scattered over the banks, but no manganese was seen. This mine probably dates back to the middle of the last century. It probably supplied ore to the iron furnace at Furnace Hill southeast of Marion.

A prospect in the belt of Shady dolomite on the north side of Pond Mountain is 1.3 miles nearly due south of Staley Knob, at an altitude of 2,640 feet. The prospect lies about 100 feet south of a narrow belt of Erwin quartzite, which dips south beneath the Shady dolomite. This prospect is in the basal beds of the Shady dolomite, a characteristic location for the manganese and iron deposits of the district. The excavations consist of one pit 25 feet by 15 feet and 10 feet deep, two much smaller pits, and two trenches. These show typical residual clay of the Shady dolomite, which contains large irregularly shaped blocks of limonite and jasperoid. No manganese was seen and the visible iron is not abundant.

Another prospect is in the same belt of Shady dolomite 1.5 miles south-southwest of Staley Knob. It is on a sharp-crested spur at an altitude of 2,620 feet. This small, long-abandoned trench now shows red soil and some cobbles of sandstone cemented by limonite, but no ore of any consequence.

The fifth prospect is 0.3 mile farther up the same spur at an altitude of 3,000 feet, within the belt of Erwin quartzite. A very small trench excavated here apparently tapped a solid ledge of limonite replacing sandstone beds in the Erwin. The ledge is not now exposed but blocks of brown and black limonite are piled around the margins of the trench.

Rich Mountain mine.—The Rich Mountain mine is at an altitude of 2,870 feet on the south slope of Rich Mountain 2.8 miles west of Thomas Bridge and 0.5 mile southeast of the Quebec firetower, which is on the highest point of Rich Mountain. It is reached by following the Marion and Rye Valley Railroad right-of-way around

the east end of Rich Mountain and across the divide separating Currin Valley drainage from South Holston drainage. From this point a poor road extends along the south side of Rich Mountain to the mine.

The mine is in residual clay of the Shady dolomite 200 feet south of the contact with the Erwin quartzite. Exposures on the mountain slope are so poor that the structure in this area is not known with certainty. Evidence based largely on float seems to indicate that the dolomite has been thrust a short distance northward over the quartzite.

The Rich Mountain mine was operated for the first time in 1942 by Clay Sayers but was later taken over by N. T. Dixon. The ore was trucked 3 miles from the mine to a washer located at the No. 1 Currin Valley mine, but plans were considered early in 1943 to install a new washer nearer the mine. Two carloads of ore were produced in 1942, the analyses of which are as follows:

	Percent	Percent
Manganese	49.73	47.24
Iron	2.70	1.07
Silica	5.12	6.99
Alumina	1.39	9.0
Barium oxide	1.76	——
Phosphorus	.094	.06

The workings consist of a deep narrow cut driven in a northeast direction into a gently sloping hillside. A small creek, whose course has been diverted, now flows past the mouth of the cut. The working face at the time of the visit was 27 feet high and 15 feet wide. Mining was by hand methods, although a bulldozer had been used to make a prospect trench at right angles to the main cut. The overburden, consisting of sandstone and silicified dolomite masses in yellow clay, varies from 3 to 10 feet thick. Beneath this, laminated yellow and brown clay dips 39° SE. The ore zones are streaks and lenses of black wad from a few inches to 2 feet thick, but with some pockets nearly 4 feet in diameter. The hard manganese oxide is present in the wad as granules of black cryptomelane about the size of peas. Some granules are scattered through the surrounding yellow clay, but the waddy clay contains more hard ore. Almost no silica or iron is present, either in the

cryptomelane pellets or as separate nodules, so that high-grade concentrates were obtained by washing the ore.

Prospecting by bulldozer on either side of the main cut did not uncover other ore-bearing clay zones, but the zone being worked continues an unknown distance to the northeast, and also continues below the floor of the cut. The deposit does not appear to be large, but at least a few more carloads of high-grade ore can be produced. Underground mining will probably be necessary if the ore is to be followed downward much below the present level of the cut.

Deans Branch prospect.—The Deans Branch prospect is at an altitude of 2,900 feet between Pond and Rich mountains on Deans Branch creek 1.8 miles east-northeast of Thomas Bridge. It is reached by a poor road which fords the South Fork of the Holston 0.3 mile southeast of Thomas Bridge and follows up Deans Branch to the prospect. Another road, now impassable to trucks, leads westward from Currin Valley, over the divide between the Deans Branch and Staley Creek drainages.

The Deans Branch prospect is one of the few manganese mines or prospects in the Glade Mountain district, which does not lie in residual clay of the Shady dolomite. Instead, the manganese occurs here as a replacement in sandstone beds near the top of the Erwin quartzite. The sandstone crops out at the mine, showing gentle folds but with general south or southeast dips ranging between 5° and 25°. About 100 feet south of the prospect a major reverse fault brings up beds in the middle part of the Erwin quartzite. A belt of residual clay derived from the lowest part of the Shady dolomite is probably present between the prospect and

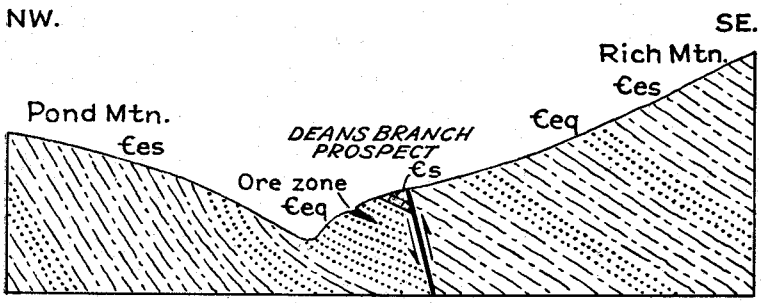


FIGURE 15.—Geologic section through Deans Branch prospect. Length of section 2,000 feet. Ꞓes, sandstone and shaly sandstone in the Erwin quartzite; Ꞓeq, quartzite zones in the Erwin; Ꞓs, Shady dolomite.

the fault but is concealed beneath a mantle of talus and wash from the Erwin. If present, it can not be more than a few tens of feet wide. This clay belt broadens both up and down the valley, and the clay is exposed at a number of places along the valley bottom and on the north slope of Rich Mountain. The writer's interpretation of the probable stratigraphic and structural relations at the prospect is illustrated in Figure 15.

The Deans Branch prospect was first explored many years ago. Stose[44] reports a small amount of development work by J. D. Perkins and A. T. Short in 1917. N. T. Dixon operated intermittently at Deans Branch in 1941 and 1942. He mined and shipped 34 tons of ore which analyzed 49 percent manganese and less than 3 percent of silica and iron. The rock was drilled and blasted and the ore hand-picked and washed in a concrete mixer. A bulldozer was later used to cut a prospect trench through soil and talus above the prospect.

The excavation at the prospect is at the top of a steep slope overlooking Deans Branch. It is a shallow cut, about 150 feet long, paralleling the hillside and 6 to 12 feet high at the working face. The bedrock is mostly weathered, fine-grained sandstone, but several beds of coarse-grained sandstone are included. The ore is of the bedded type, formed by replacement of favorable sandstone beds by dense, black cryptomelane. Some of the ore zones persist for 30 feet across the cut before disappearing below the level of mining. Some of the cryptomelane has rounded mammillated surfaces, but more is in flat-sided lumps, roughly showing the bedded structure of the replaced sandstone. Haloysite, a porcelain-white clay mineral, surrounds and adheres to some of the more irregularly shaped pieces of cryptomelane. The thickest ore zone consists of 8 inches of solid cryptomelane underlain by 2 inches of a powdery manganese oxide of high purity. This bed was exposed in a small pit in the deepest part of the cut but had been mined away over a considerable area in the central part of the cut. Several ore beds 2 to 4 inches thick were exposed in the higher levels of the working face. One of these had veinlets of manganese oxide ramifying upward and cutting across the enclosing sandstone.

A narrow trench had been dug from the mine down the steep slope to the trail along Deans Branch, exposing continuously the sandstone and quartzite which underlie the beds at the prospect. No veins of manganese oxide or other signs of mineralization were

noted. Another prospect trench was dug by a bulldozer in talus and disintegrated sandstone immediately above the main cut. No signs of ore were exposed here. The sandstone beds which contain veins of cryptomelane seem to be about 12 feet thick. The veins dip into the hillside so that underground mining would have to be adopted if they were to be followed much farther. An eight-inch vein of solid cryptomelane would have to be completely mined over an area 35 feet square to produce 100 tons, or approximately two car loads, of concentrates. Much of the ore requires no washing.

Holston River prospect.—The Holston River prospect is 0.9 mile southeast of Thomas Bridge and 0.1 mile from the South Fork of the Holston River. The bedrock is Shady dolomite, which has decomposed to yellow clay in the vicinity of the prospect. The sandstone at the base of the Shady dolomite is present 250 feet north of the prospect. It dips about 30° S. The prospect is almost exactly in line with the fault, that cuts across the west end of Rich Mountain. Whether the mineralization at the prospect is the result of normal percolation of ground waters through the residual clay in the lower part of the Shady, or is due to circulation of mineralized waters along an underlying fault zone is not known.

The prospect consists of two cuts on the southwest side of the road. The larger is 15 feet high, 10 feet wide, and has been dug about 10 feet back into the bank. It exposes yellow and brown clay containing streaks and patches of black wad. These are irregularly shaped, and some are in ramifying veins. The widest zone of wad exposed is 2 inches and the longest about 2 feet. Several of the patches of wad contain small granules of hard, amorphous manganese oxide from the size of wheat grains to pea size.

The smaller cut is about 50 feet to the northwest. It exposes mainly surficial gravel but in the bottom there is a little yellow clay which contains patches of wad. No hard ore was noted in this wad. The amount of recoverable manganese exposed in the two cuts is small, but the prospecting has been too slight to supply much information on the deposit.

Kyva mine.—The Kyva mine (also called Jerrys Creek prospect) is on the west side of Jerrys Creek 2.3 miles south-southwest of Thomas Bridge. An old lumber road follows along the east side of the creek past the mine, which is in the forest on the south-

east slope of a spur extending northeastward from High Point. On the basis of limited exposures in the vicinity of the mine, the crest of the spur seems to be formed by beds of Erwin quartzite, which strike N. 65° E. and dip 71° NW. The Shady dolomite crops out at the mine and in the valley of Jerrys Creek but its relation to the Erwin quartzite is not known.

This mine was worked for about six months shortly before World War I by a group of men from Kentucky and Virginia (hence the name Kyva). A pump was installed on Jerrys Creek and water was pumped under high pressure up to the workings (Fig. 16). A powerful stream of water was directed against the clay banks, and clay and ore were washed into a sluice and down to the washer at creek level. Reports on the amount of manganese concentrates produced range from 7 to 32 carloads, but the smaller amount is probably more nearly correct. The quality of the ore is not known. In 1941, N. T. Dixon shipped half a carload of concentrates from this mine, which averaged 38 percent manganese. The concentrates consisted of large and medium sized nodules, that were picked up in the main pit and on the dumps.

The mine was prospected again in 1942 by G. W. Pawel, representing the Fleischman-Burd & Co. of New York. About a dozen new prospect holes were dug, some in the old pit and some in the surrounding forest. The ore showings did not encourage this company, and there has been no activity since that time.

The size and shape of the workings and prospect holes are shown on Figure 16. The diggings penetrated tough yellow clay, some of which is laminated. Local residents, who worked in the mine, report that there was good ore in the bottom of the pit when operations ceased, but the new prospect holes dug here failed to find it. One cut, part way up the mine wall, showed veinlets of powdery manganese oxide ramifying through the clay. The best ore showings were in three holes near the top of the main pit, where large nodules of dense, black, high-grade amorphous manganese oxide were embedded in the clay. The largest of these weighed about 100 pounds. The prospect holes around the main excavation exposed yellow and brown clay which was largely or entirely barren, but one hole on the crest of the spur (Fig. 16, hole marked sandstone) encountered bedrock sandstone at a depth of 5 feet. The smaller excavations near the creek are poorly exposed now, except for the most northern one, in which a ledge of solid

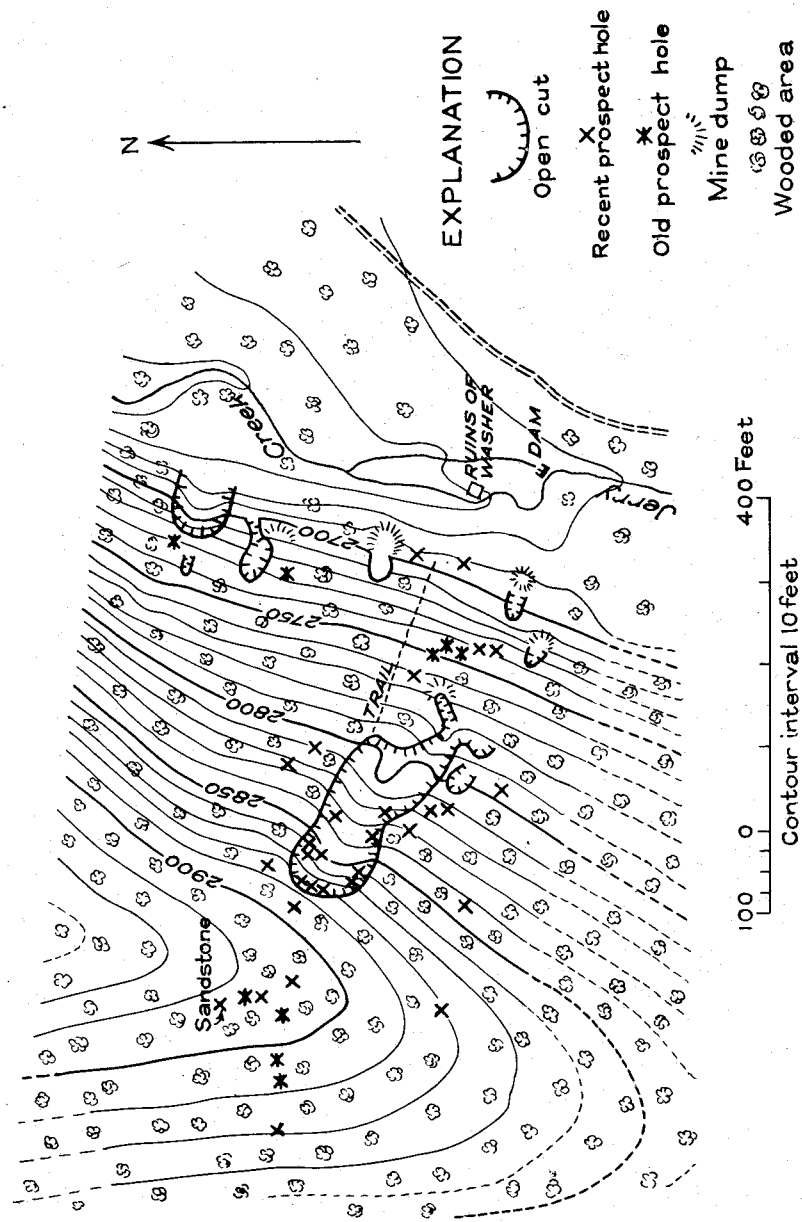


FIGURE 16.—Pace and compass map of the Kyva mine. By Ralph H. Wilpolt.

limonite crops out. Although ore showings in a few parts of this mine are good, so many prospect pits were entirely barren that there seems little likelihood of any large quantity of manganese remaining near the surface. Two samples collected from this mine in 1919 were analyzed. These were picked samples and probably did not represent the average grade of concentrates shipped. The first sample analyzed as follows:

	Percent
Mn	50.20
S	.03
P	.25
Fe	2.00

The analysis of the second sample was as follows:

	Percent
SiO_2	2.20
Fe_2O_3	13.39
(Fe)	(10.77)
Al_2O_3	2.94
MnO	61.04
(Mn)	(47.29)
CaO	.82
P_2O_5	.95
(P)	(.416)
SO_3	.041
(S)	(.016)
MgO	3.89
Loss on ignition	13.60

Savage prospect.—The Savage prospect is in the southwest corner of Smyth County, 6.3 miles south-southeast of Chilhowie and 3.7 miles southeast of Loves Mill. It lies southwest of the area included in Plate 1. It is in a gentle sag at an altitude of 2,750 feet, on the crest of a spur extending northwest from the Iron Mountain front (Pl. 19). The spur terminates in a knob, 1,300 feet northwest of the prospect.

The geology of this region has not been worked out in detail, but certain features have been established which are depicted in the partial geologic map (Fig. 17). The Unicoi formation crops out on the lower

slopes of Iron Mountain ½ mile southeast of the mine. As the nearest exposures below this outcrop reveal residual clay of the Shady dolomite, a major fault is indicated. This is probably the Iron Mountain overthrust, which has been traced for many miles to the southwest in Washington County, Virginia, and into northeastern Tennessee. Another large fault, nearly at right angles to the one above, lies northeast of the mine spur. The trace of this fault parallels St. Clair Creek and probably lies only a few rods northwest of it. This fault brings the Shady dolomite, which forms the slopes of the prospect spur, into contact

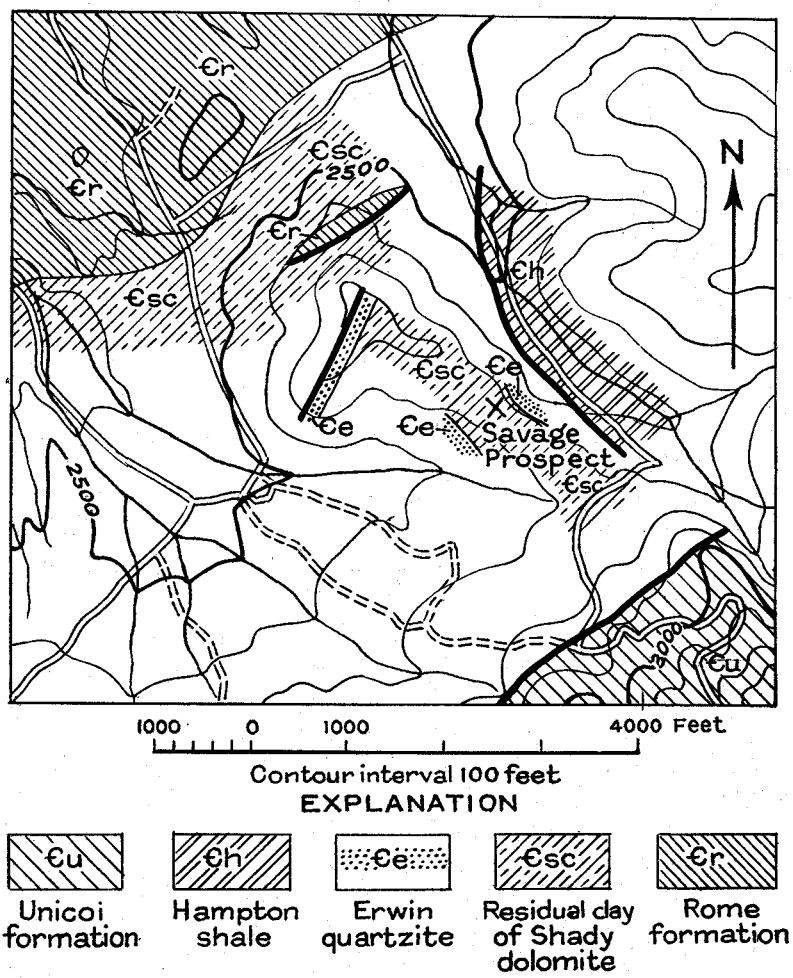


FIGURE 17.—Partial geologic map of the vicinity of the Savage prospect.

with folded, steeply dipping shales and slates of the Hampton formation, which crop out in the bluffs just east of the creek, and which strike southwest toward the prospect spur. Still another fault of much smaller displacement lies on the northwest side of the knob at the end of the prospect spur, and brings the Erwin quartzite against the Shady dolomite. A small area of shale belonging to the Rome formation probably owes its position on the slopes northwest of this knob to a fault.

The geologic structure of the prospect spur is confused, and probably more complex than first appears. The crest of the spur from its junction with Iron Mountain to the Erwin quartzite knob at its tip is capped with residual clay of the Shady dolomite (Fig. 17), except where a superficial cover of gravel lies on the clay. This clay mantle is very thin at the prospect, for a test hole on the crest encountered, at a depth of 17 feet, coarse glauconitic sandstone at the base of the Shady. Similar sandstone was also temporarily exposed in two prospect cuts on the slope 200 feet northeast of the spur crest, and a concentration of float of the same type appears on the slope about 350 feet southwest of the crest, indicating the presence of the glauconitic sandstone near the surface. Not enough is known about the structure of the surrounding area to give a logical explanation of this peculiar geologic situation, but it seems probable that faulting is involved. No attempt has been made, therefore, to give a coordinated interpretation of the geology in Fig. 17, and only those faults and geologic boundaries are shown, about which there is a considerable degree of assurance.

L. L. Savage of Passaic, N. J., began development work at this prospect in the spring of 1942. A pump was installed on St. Clair Creek and pipe was laid to the washer located just southeast of the spur crest. A concrete mixer was used for washing the ore (Fig. 7), but no concentrates had been shipped to the end of the year.

The ore on the Savage prospect consists of nodules of dense, dark-gray and black, manganese oxide in yellow structureless clay. Many of the nodules are rounded, and show concentric laminations which clearly represent outward growth from a nucleus (Pl. 11,C). The absence of bedding and the growth of the nodules in all directions indicate that they formed in structureless clay which was saturated with manganese-bearing ground water. Most of the nodules at the Savage prospect are between 3 and 12 inches in diameter. Little visible iron or silica is combined with the manganese. Test pitting proved the presence of nodules in considerable abundance in clay, at least 6 feet thick, over an area about 200 feet in diameter. Some nodules were found in pits

on the southwest slopes of the spur and along the crest, but most of the test holes in these places were barren. The deposit thus appears to be small, but the ore is of good quality and easily mined. An analysis of a grab sample taken from one of the prospect pits in May, 1942, follows: manganese 46.77 percent, iron 7.10 percent, silica 2.70 percent, phosphorus 0.295 percent.

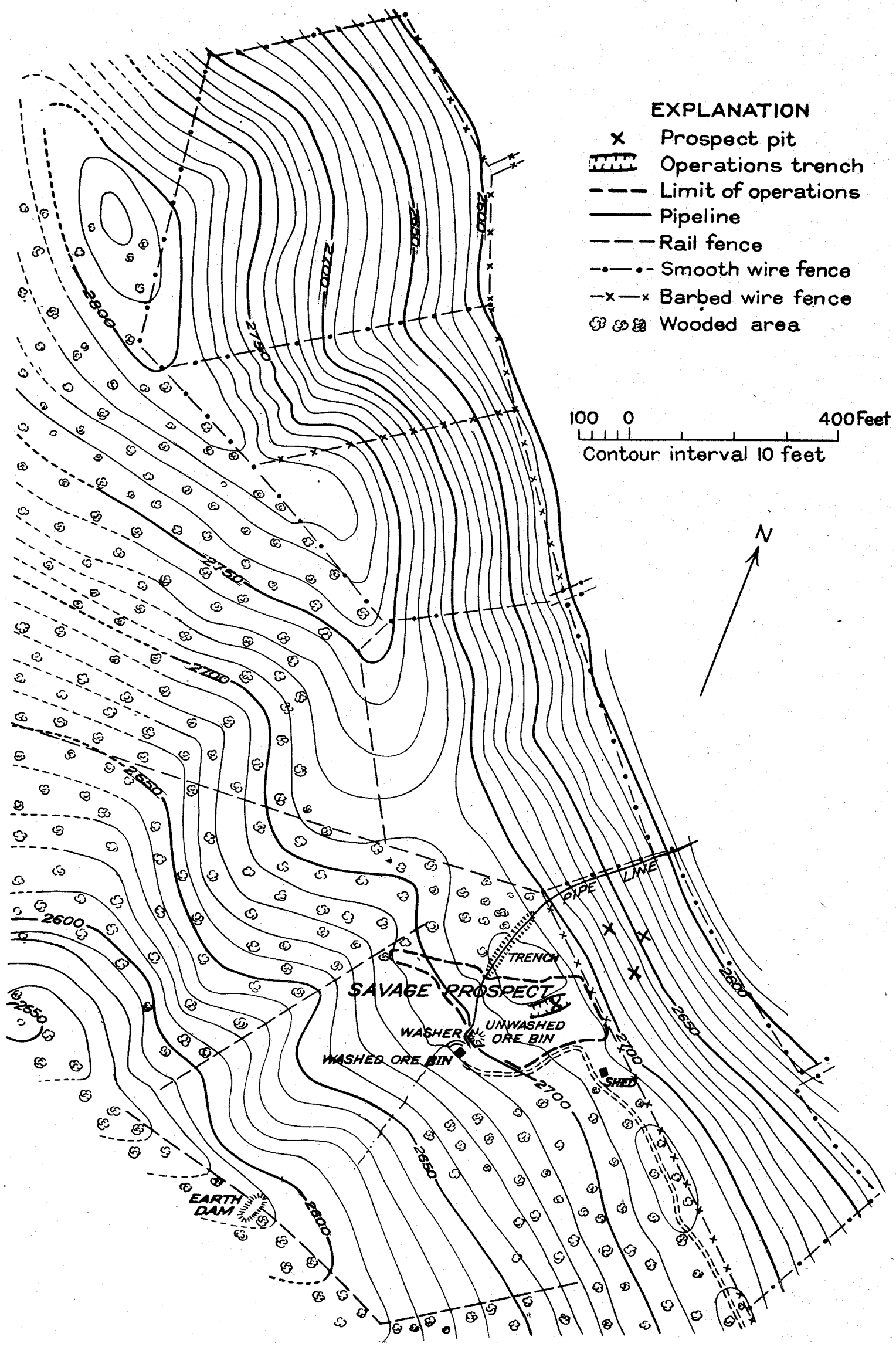
Thomas prospect.—The Thomas prospect is at the bottom of a narrow valley tributary to Roland Creek, 1.5 miles south of Thomas Bridge and 0.6 mile northwest of Stony Creek Church. It consists of two small excavations in the forest on the west bank of the creek. The creek flows into a sink hole about 50 yards below the prospect. A fence line separating the land of W. H. Rosenbaum and J. F. Richardson runs between the two excavations. The bedrock is the Shady dolomite, which extends for a considerable distance in all directions. The structure and attitude of the beds in this area are not known.

This prospect was worked during World War I by Mr. Rosenbaum who mined less than one carload of ore. In 1942 Charles Thomas of Marion opened up both pits, but no production resulted.

The prospect pit on the creek bank east of the fence is on the land of Mr. Richardson. It is 8 feet deep and about 6 feet in diameter. The upper 5 feet is excavated in sandy clay containing ramifying veinlets, ¼ to ½ inch thick, of powdery manganese oxide. Two nearly flat-lying, solid ledges of intimately intergrown iron and manganese oxides were exposed in the lower part of the pit—the upper one 6 inches thick and the lower one of unknown thickness. The manganese oxide is the more abundant, but in no place is it sufficiently pure to constitute a high-grade ore. The second excavation, 50 yards downstream and a few feet west of the fence, is a short tunnel dug in sandy yellow clay which included a small amount of black wad, but no other manganese of any significance.

Roland Creek prospect.—The Roland Creek prospect is at the southwest tip of Short Mountain, 1.6 miles south of Thomas Bridge and 0.2 mile north-northeast of Stony Creek Church. Short Mountain ends in a sharp knob which rises 350 feet above Roland Creek on its west side. The excavations are 400 feet south of, and 100 feet below, the crest of this knob, at an altitude of 2,660 feet.

Shady dolomite, which underlies the prospect, is not exposed in the immediate area, but crops out prominently along the bluff overlooking Roland Creek. The beds consist of finely crystalline gray dolomite of the lower, or Patterson, member of the formation, strik-



Topographic map of the Savage prospect. By Ralph H. Wilpolt.

ing N. 67° E. and dipping 46° SE. Solution openings are prominent along bedding planes and joints. The crest of the knob north of the prospect is formed by sandstone at the base of the Shady dolomite, and the north slope of the knob is underlain by sandstone in the upper part of the Erwin quartzite. These beds are also well exposed along the Roland Creek bluff to the west. Nearly continuous exposures are present along this bluff from the top of the Erwin through the Patterson member of the Shady dolomite to the upper or "saccharoidal member" of the Shady.

The prospect was first worked in 1862 by Abijah Thomas, who took two wagonloads of iron ore from a pit on the crest of the spur. In 1917 Charles Thomas drove a drift into the hillside on the slope east of, and below, the original excavation. A small amount of ore was found but none was mined. In the summer of 1942 Mr. Thomas reopened the old prospect pits and dug several new ones. Two small pits about one-third the distance down the west slope of the spur were dug in a reddish clay which was barren of manganese. A small cut on the crest of the spur revealed a reddish mantle of soil which contained a few small nodules of manganese oxide. Beneath this soil was barren yellow clay. Another cut and a tunnel were dug about half way down the east slope of the spur. The cut revealed yellow clay containing one small pocket of granular manganese oxide and a few veinlets of manganese oxide along cracks in the clay. The tunnel penetrated horizontally into the hillside for about 50 feet, including the cut leading to the portal. In the walls of the cut, veinlets of manganese and iron oxide are interlaced in yellow clay, but they are soft and crumbly so that most of the oxide would be lost in washing. A zone of nodules several feet thick, exposed in the tunnel, consists of black, somewhat earthy and ferruginous fair-grade manganese oxide embedded in yellow clay. A zone of black wad, said to contain manganese nodules, was visible at the rear of the tunnel but was not examined, because that part of the tunnel was unsafe at the time of the visit. Analyses of two specimens collected by Mr. Thomas on the surface near the mouth of the tunnel are as follows:

Analyses of samples of manganese ore from the Roland Creek prospect

	Percent	Percent
Manganese	28.56	25.05
Iron	15.90	14.34
Silica	11.02	15.72
Phosphorus	0.09	——

Some of the nodules seen in the tunnel appeared to be somewhat higher in manganese than the samples analyzed above, but no high-grade ore was seen either in the tunnel or in the other excavations at this prospect. The amount of ore-bearing clay visible at the time of the visit was very small. Several World War I prospect pits on slopes east of the tunnel are said to have found ore at shallow depths. These pits have since been filled and obliterated by cultivation.

Morris prospects.—The Morris prospect is near the house of Robert Morris, 700 feet northeast of Highway 656, 1.5 miles south-southeast of Thomas Bridge and 0.5 mile east-northeast of Stony Creek Church. The visible ore consists of small nodules of steely, blue-black, hard manganese oxide of good quality in yellow residual clay of the Shady dolomite. These nodules were found in a prospect hole only 5 feet long and 2 feet deep. A well at the house was dug to a depth of 30 feet entirely in clay, so that the clay has considerable thickness in this area. The quality of the ore and the amount obtained from such a small pit warrant further exploration.

Another prospect lies 2,000 feet to the northeast on the farm of Mack Tillson. This is between Short Mountain and Long Ridge 50 yards east of the divide separating the Roland Creek drainage from the Holston River drainage. Nodules of manganese oxide, less than a half inch in size, are scattered over a bank of red clay. Much of the manganese oxide is siliceous or earthy. The depth of the clay at this point is probably not great, for dolomite crops out prominently only 50 feet away on both sides of the prospect.

Hutton prospect.—The Hutton prospect is 5.8 miles due south of Marion and 1.0 mile southwest of the former railroad station of Quebec on the abandoned Marion and Rye Valley Railroad. It is on the divide between Mile Branch and Holston River drainage, 300 feet north of U. S. Highway 58 and 1,000 feet east of Valley View School. The prospect lies in a belt of Shady dolomite, 1,100 feet southeast of its contact with the Erwin quartzite on the south slope of Barton Mountain. The Shady crops out along the highway, where it consists mainly of dense, fine-grained, gray dolomite. The strike of the beds is persistently to the northeast but the dip is variable in amount and direction.

Iron ore was mined many years ago at the Hutton prospect. The site was explored for manganese before World War I by H. H. Green, then principal owner of the Umbarger manganese mine and the Rye Valley lead mine. Mr. Green is reported to have sunk a number of prospect pits 20 to 30 feet deep, which exposed yellow and dark-

colored clay inclosing chert fragments, red, ferruginous sand balls, iron ore and considerable "psilomelane."[45] These excavations have been filled and cultivated. At the present time the ore showings consist of numerous pieces of hard manganese and iron oxide, scattered over cultivated fields on the spur north of the house on the north side of the road. Most of the nodules are about the size of walnuts, but several masses 6 inches in diameter have been picked up in the fields and thrown into a ditch on the crest of the spur. The manganese oxide is black, slightly earthy and somewhat pitted, but the cavities are not clay-filled, so that clean washing of the ore would not be difficult. The quality of the manganese oxide ranges from fair-grade to good-grade. Most of the nodules are not contaminated with limonite—the iron and manganese oxides apparently having been deposited separately in the clay. The clay may not be thick, for dolomite crops out abundantly a few hundred feet down the slope from the prospect, but it does exceed 30 feet, the known depth of the prospect pits dug by Mr. Green.

Rock bank.—The Rock bank is at the crest of a prominent hill 2.0 miles southwest of Teas. The hill is 3,090 feet above sea level and 550 feet above the adjacent valleys of Comer Creek, Slabtown Branch and Slabtown Hollow. The crest of the hill and the northeast spur are underlain by coarse-grained, iron-stained sandstone at the base of the Shady dolomite. The beds dip southeast beneath non-sandy dolomite, which forms the southeast slopes of the hill. The mine excavations, which have been dug in clay derived from weathering of the dolomite, are located from 1 to 100 feet southeast of the contact of the sandstone and dolomite. A prominent quartzite near the top of the Erwin crops out a short distance down the northwest slope of the spur, and furnishes abundant float which covers most of the lower hillside. The lower slopes are underlain by the Shady dolomite which is in fault contact with the Erwin quartzite above. The Erwin forms a narrow tapering belt which is 200 feet wide at the Rock bank and which dies out against the fault 1,500 feet to the northeast. Conditions appear to be similar to those found in many places to the north and east, where reverse faults, upthrown on the southeast side, have caused the stratigraphic displacement. Figure 18 illustrates the interpretation of the structure of the Rock bank locality.

More than 30 years ago the Rock bank was worked for iron ore. It then lay idle for a few years but was reopened about 1916 when one carload of manganiferous iron ore was shipped. The ore was probably considerably contaminated, for it was shipped without washing to free

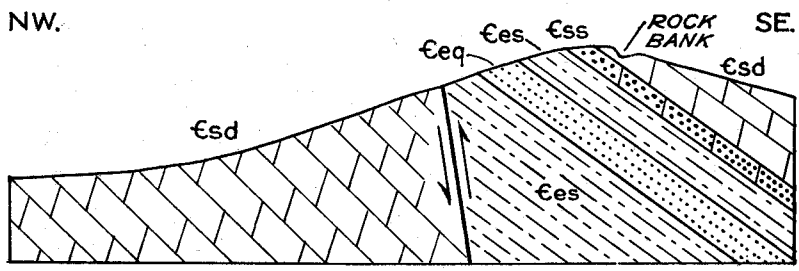


FIGURE 18.—Geologic section through Rock bank. Ꞓes, sandstone and shaly sandstone in the Erwin quartzite; Ꞓeq, quartzite zones in the Erwin; Ꞓss, dolomitic sandstone at the base of the Shady dolomite; Ꞓsd, Shady dolomite. Length of section 2,900 feet. Horizontal and vertical scales the same.

the iron and manganese nodules from the adhering clay. The mine has not been active since 1916. The workings consist of nine small cuts and open pits which are on the gentle southeast slopes adjacent to the spur crest. They are roughly aligned parallel with the crest and are distributed along it for a distance of 600 feet. All are in the forest but the three eastern pits are on the edge of a large cleared area which reaches to the crest of the hill.

The most eastern pit, about 60 feet long, 40 feet wide and 25 feet deep, was excavated in yellow clay derived from weathering of the lowest beds of the Shady dolomite. Nodules, 1 to 3 inches in size, are common on the slumped walls and spoils bank. Some are nearly pure, steely, black manganese oxide, but more consist of intergrowths of iron and manganese oxides, or shells of iron oxide surrounding an inner core of manganese oxide. The next excavation, 60 feet long, 30 feet wide and 12 feet deep, is 100 feet to the west on the crest of the spur. The clay is brown and contains abundant iron and manganese nodules. Most of these are smaller than one inch and are irregular and subangular. More are of iron than of manganese, but the manganese nodules are numerous. The third excavation, a cut 60 feet long, 20 feet wide and 15 feet deep at the back face, is 200 feet farther west and is slightly south of the spur crest. It was dug in yellow clay which contains small nodules of limonite and mixed limonite and hematite. Little manganese was seen and the iron nodules are much less abundant than in the two pits previously described. Five closely-spaced small pits lie a short distance west of the cut. All are smaller than 30 feet in diameter and were so badly caved that the exposures at the time of the visit were poor. Small limonite and manganiferous iron nodules are common but not abundant on the piles of clay around the pits. None

of the pits seem to have pentrated zones containing high-grade manganese nodules. The high point of the hill is 200 feet farther southwest. The basal sandstone of the Shady crops out here, striking N. 35° E. and dipping 32° SE. This sandstone is coarse-grained to pebbly, iron-stained, gnarled, and massively bedded. A short trench, which parallels this ledge, was dug in non-sandy clays directly overlying the sandstone. Small limonite particles were found here, but none of manganese.

The two most eastern pits, which seem to have supplied most of the ore mined, are the largest. The nodules on the spoils banks are most abundant, and the ratio of manganese to iron nodules is highest. If renewed prospecting were undertaken on this property, it would be well to explore along the crest of the spur northeast of these excavations. Transportation of the ore from the Rock bank to an adequate source of water for washing, such as Comer Creek, will always be a problem because of the height and steepness of the hill.

Calhoun prospect.—The Calhoun prospect lies 0.3 mile north of Teas at an altitude of 2,520 feet. The prospect formerly consisted of several excavations, which were on the south and southeast slopes of a low cultivated hill 500 feet due north of the junction of the Brushy Mountain road with the Georges Branch road. This is in the middle of a broad belt of Shady dolomite and clay. Because the bedrock is poorly exposed in the vicinity of the prospect, the structure is unknown, nor is it known whether the dolomite which produced the clay visible at the surface is in the lower or upper part of the Shady formation.

During World War I several pits and trenches were dug on the Calhoun farm. Most of these have been filled and obliterated by cultivation. No manganese or iron nodules were seen. In 1917 the exposures were better and some ore was visible. Excerpts from Stose's[46] description of the prospect at that time are as follows:

> "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 percent of the material is ore but of this the manganese content probably is less than 10 percent.

"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."

The Calhoun property was unsuccessfully prospected for lead ore by the Virginia Lead and Zinc Company[20] in 1904.

Red bank.—The Red bank, also called Pugh bank, is at an altitude of 2,760 feet on the lower forested slopes of Brushy Mountain 0.9 mile north of Teas and 1.7 miles northwest of Sugar Grove. The land around the mine is owned by Edward Pugh of Teas. The mine lies in the middle of a belt of Shady dolomite about 2,000 feet wide. The Shady extends up the gentle south slope of Brushy Mountain to a point about 1,000 feet north of the mine. The Erwin quartzite forms the higher part of the mountain, and dips southward beneath the Shady at angles averaging about 50°. The belt of Shady dolomite is separated from the dolomite farther south in Rye Valley by the Hickory Ridge-Sheep Ridge fault, which brings up Erwin quartzite about 1,000 feet south of Red bank. The hill formed by this narrow belt of Erwin is only slightly more prominent than the surrounding dolomite hills, so that no topographic barrier here separates Brushy Mountain from Rye Valley.

Many years ago the Red bank was worked for iron ore, being one of a number of small mines which supplied ore to a forge on Holston River. The mine has not been active since the forge shut down. The workings consist of a series of long narrow cuts, both above and below a prominent trail which here parallels the mountainside. The longest of the cuts is 100 feet long, 20 feet wide, and is now about 10 feet deep but was probably considerably deeper before the walls slumped. Red clay is poorly exposed in the cuts beneath a thin overburden of clay, sand, gravel, and boulders. Botryoidal nodules and angular particles and masses of limonite are abundant in the clay. A few of the particles consist of intergrowths of limonite and hard, amorphous manganese oxide but none of pure manganese oxide were found. The abundance and high quality of the iron nodules indicate that this was a rich though small iron mine. Manganese particles are so rare and so

low grade that apparently no manganese ore of importance was found in the iron mining operations.

Hull bank.—The Hull bank is near the southwest tip of Sheep Ridge 0.8 mile north-northeast of Teas and 2.0 miles northwest of Sugar Grove. It is in the forest on the south slope of the ridge about half way between the base and the crest, at an altitude of 2,670 feet. Sheep Ridge is a westward-plunging anticline of the upper part of the Erwin quartzite, which has been faulted on the north side. The Erwin is overlain by the Shady dolomite which rises high on both slopes of the ridge and is locally present to the crest. The Hull bank is excavated in residual clay derived by weathering of the southward-dipping dolomite beds near the base of the formation. The contact of the Shady with the Erwin is about 150 feet up the slope north of the prospect.

The Hull bank was worked about 1910 by a Mr. Horn, who mined and piled up a small amount of iron ore. It is reported that none was ever hauled away. Yellow clay only is exposed in the cut, which is 40 feet long, 15 feet wide and 20 feet deep at the back face. The iron ore is said to have come from a solid ledge, now covered. Some lumps piled at the edge of the cut, which probably represent the type of ore mined, consist of dense, hard limonite and ferruginous chert. No manganese was seen either in the iron ore specimens or in the clay walls of the cut.

Nodules of manganese are said to have been found on cultivated north-facing slopes about 550 feet south-southeast of the Hull bank, but a search failed to reveal any. A few manganese nodules were found at the base of Sheep Ridge east of the Hull bank, but the showing was sparse.

Bishop mine.—The Bishop mine is in a small valley lying between Hickory Ridge and an outlier of Brushy Mountain, 1.5 miles northwest of Sugar Grove and 1.7 miles northeast of Teas. This valley is drained southward by Bishop Branch through a water gap which separates Hickory Ridge from its westward extension, Sheep Ridge. The valley narrows eastward due to the junction of Hickory Ridge with the Brushy Mountain outlier, but it opens out westward to merge with Rye Valley. The land around the mine is a part of the Jefferson National Forest.

The Bishop mine lies in the middle of a belt of Shady dolomite and clay 2,000 feet wide. The Erwin quartzite, which forms the outlier of Brushy Mountain, dips beneath the Shady dolomite on the south slope of the mountain, 1,100 feet north of the mine. Hickory Ridge on the

south side of the valley consists of an anticline of Erwin quartzite which is faulted on its north limb. Residual clay derived from the Shady dolomite is exposed at numerous places in the valley, but the dolomite does not crop out, so that the attitude and structure of the valley rocks are not known.

Mining is said to have been done at this site for 40 or 50 years, but there has been no activity since World War I. The large open cut (Fig. 19) is partly filled with water, and no fresh cuts or other good exposures of the ore-bearing zones remain. Stose[47] described the mine when it was at the height of its activity, as follows:

> "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 quartzite boulders, and lumps of ore. The lower

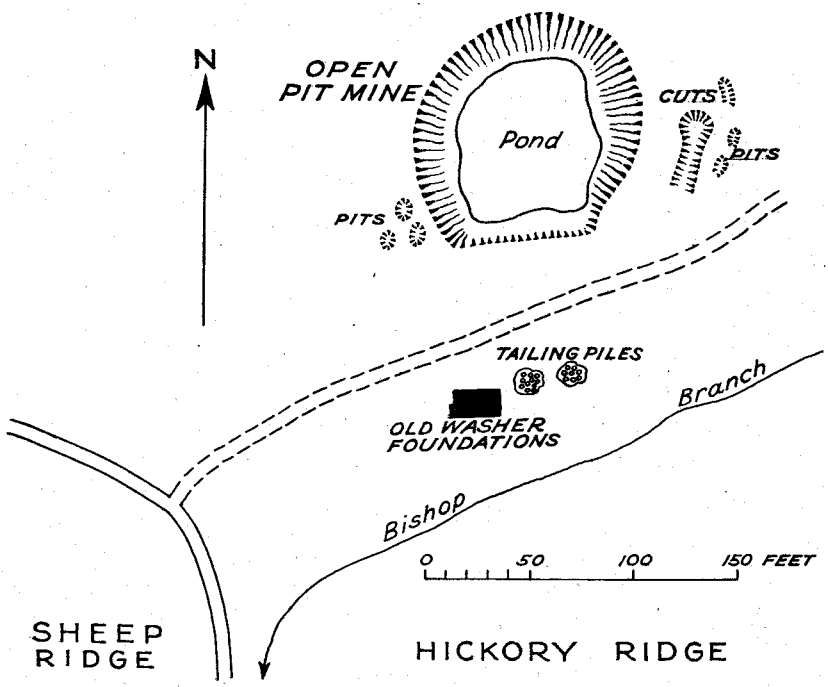


FIGURE 19.—Sketch map of the Bishop mine.

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

"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 a larger log washer, trommels and Harz jigs".

At the present time small particles and nodules of limonite and mixed limonite and hematite are abundant on some of the weathered slopes of the main pit. Particles of hard, amorphous manganese oxide are less common. They vary from low-grade, earthy oxides to dense, steely, high-grade oxides. A few, medium-size particles of beautifully crystallized pyrolusite were found. The ratio of manganese oxides to iron oxides was estimated to be about 1 to 20. The smaller pits and trenches on both sides of the main open pit (Fig. 19) are now almost completely overgrown and show no good exposures. Only the concrete foundations and several piles of fine tailings remain to mark the site of the washer. The tailings are higher in iron than in manganese.

The history and present aspect of the Bishop mine indicate that the ore produced was dominantly manganiferous iron, and that the amount of high-grade manganese was small. The extent of the ore body is not known, but it is reported that ore pockets were becoming scarcer and smaller when mining ceased.

Iron and manganese nodules were picked up on the lower north slope of Sheep Ridge, 1,500 feet west-southwest of the Bishop mine, and 600 feet south of and 40 feet above the road along the north side of Sheep Ridge. The iron nodules are abundant; the manganese nodules are scarce but of good-grade. No prospecting has been done at this place.

Hickory Ridge prospect.—An old iron mine is on the south slope of Hickory Ridge 1.5 miles due north of Sugar Grove and 0.3 mile west of Slemp Creek. It is at an altitude of 3,370 feet, a few feet southwest of a well-marked trail which continues northward up a spur of the ridge from a prominent saddle. The mine is in a narrow belt of Shady dolomite 250 feet south of its contact with the Erwin

quartzite. The openings consist of half a dozen closely grouped trenches and several small pits dug in yellow residual clay from the Shady dolomite. The solid material piled on the sides of the trenches consists mainly of blocks of silicified dolomite with some limonite nodules. Slight traces of manganese were seen in a few of the limonite nodules, but nothing of much significance is now visible. The site has not been prospected for many years and the exposures are very poor.

Pierce prospect.—The Pierce prospect is on a spur at the base of Brushy Mountain 1.5 miles north of Sugar Grove and 0.7 mile northwest of the Sugar Grove and Marion highway, at an altitude of 2,850 feet. The land is owned by the heirs of the Walker-Forney estate. The spur is underlain by Shady dolomite which does not crop out, but exposures ¼ mile away in different directions show dips ranging between 44° and 80° to the south-southeast. The Erwin quartzite lies 1,000 feet to the northwest on a spur of Hickory Ridge, and the shale of the Rome formation is 1,000 feet to the southeast.

The prospect consists of a dozen circular pits, each about 10 feet in diameter and from 5 to 20 feet deep, which penetrated yellow clay after passing through a thin mantle of soil and humus. All but two of the holes were largely or entirely barren of either manganese or iron ore. A pit near the south end of the prospected area had numerous manganese nodules, from the size of walnuts up to that of eggs, piled around its rim. The nodules were estimated to contain about 40 percent manganese. A few iron nodules were present. A small quantity of iron nodules was found in the southernmost pit, and also a few manganese nodules of low grade. This prospect does not appear promising because so much of the explored area failed to show any ore.

Iron and manganese nodules are abundant in an open field on the adjoining spur about 1,000 feet due east of the Pierce prospect. Most of the nodules are of iron and manganiferous iron but several of good-quality manganese oxide were found. So far as known, there has been no exploratory digging on this spur.

Horn prospect, Catron place, Nelson prospect and Cox prospect.—The Horn prospect, Catron place, Nelson prospect, and Cox prospect, are south and southwest of Sugar Grove between Cressy and Dickey creeks. The Horn prospect is ½ mile south of the town and

the Catron place 1 mile south, both in rolling farm country. The Nelson prospect is 1½ miles south of Sugar Grove on the slopes of the Iron Mountains, facing Rye Valley, at an altitude of 3,100 feet. The Cox prospect is on the farm of Walter Cox 0.7 mile south-southwest of Sugar Grove near State Highway 88.

Stose[48] reported a small amount of red and brown iron ore, and one two-pound piece of psilomelane from three small pits on the Horn place. He also reported small pieces of manganese and iron oxides from shallow pits on the Catron place. The exact locations of these two old prospects were not established and the locations shown on Plate 1 may thus be somewhat in error.

The Nelson prospect consists of a series of small pits in the forest, two of which were visited. The ore is limonite, combined in places with a small amount of manganese. These pits lie very near the contact of the Erwin quartzite and the Shady dolomite. Above the prospect the Erwin quartzite forms the crest of the ridge (sometimes called Quarter Ridge), and the Shady dolomite forms the lower slopes of the ridge and underlies a large part of Rye Valley. The customary friable, iron-stained sandstone that marks the Erwin-Shady contact was not noted at the two pits visited, but Stose remarks on its presence in this area, so that the contact between the two formations is probably normal here. The prospects appear to be in the lowest part of the Shady formation.

The Cox prospect consists of meager showings of iron nodules and fragments at several different places on the Cox farm. The ore showings are in cultivated fields east of the highway. One small prospect pit contained a few earthy manganese oxide pellets in red clay.

Umbarger mine.—The Umbarger mine is in Rye Valley on the lower slopes of Little Pine Mountain, one of the frontal ridges of the Iron Mountains, 2 miles southeast of Sugar Grove. A woods road, which turns east from the Cressy Creek road 1.3 miles southeast of Sugar Grove, leads directly to the mine. It is at an altitude of 3,000 feet on a gently sloping bench which is considerably dissected by the headwaters of the South Fork of the Holston.

The geology of the area around the Umbarger mine was not completely mapped by the writer (Pl. 1). Currier[21] indicates that the quartzites of Iron Mountain are thrust northward over the Shady dolomites. He points out, however, that the existence of this Iron Mountain fault is in doubt in this district. The writer's

examination of sections in the vicinity reveals no stratigraphic reason for postulating a fault. Furthermore, a deep drill hole at the mine passed through residual clay of the Shady dolomite and at a depth of 220 feet, entered pebbly sandstone, which resembles sandstone at the base of the Shady dolomite. This suggests that the Erwin quartzite dips northward normally and passes beneath the Shady dolomite at the mine. The contact between the Shady and the Erwin is approximately 600 feet up the slope south of the mine. Dolomite has not been seen in this area, but the residual clay derived from it is exposed in many places, especially in the mine and prospect pits.

The Umbarger mine is reported to have been worked by a Mr. Fox as early as the 1890's. In 1907 Arthur Short of Sugar Grove mined about 500 tons of manganiferous iron and 50 tons of 41 percent manganese concentrates at the Umbarger mine. The Southern Manganese & Iron Co. worked the property in 1916, and the Manganese Products Co. mined there in 1917 and 1918. Production figures covering this period are shown in Table 5. The shipments were largely of ferruginous manganese but included some manganese. In 1917 elaborate milling equipment was erected, consisting of a four-log washer and eight four-cell Harz jigs. The ore was brought by a narrow gauge tramroad 0.9 mile from the mine to the washer near Cressy Creek. The mine was inactive for many years after World War I and the washer and tramroad were dismantled. In 1941 N. T. Dixon operated the Umbarger mine for a short time and shipped two car loads of ore. In 1942 the Sugar Grove Mining Co. was formed, and the mine was reopened with O. E. Sayers as manager. A single log washer was built on the concrete foundations of the World War I washer and 1,000 feet of pipe were laid to bring water from Cressy Creek. A bulldozer and gasoline shovel were brought in, and prospecting was done in the main mine, in the Umbarger prospect, and in two cuts west of the main mine. The ore was disappointing in quality and quantity but one carload was shipped in 1942 and mining was being continued in the cut 200 feet east of the big pit.

The main workings at the Umbarger mine are shown in Fig. 20. Most of the ore of earlier operations came from the large open pit (Pl. 15,A) which is about 300 feet in diameter and has a working slope nearly 100 feet high. The walls of this pit have slumped badly since the large-scale mining of the Manganese Products Corpora-

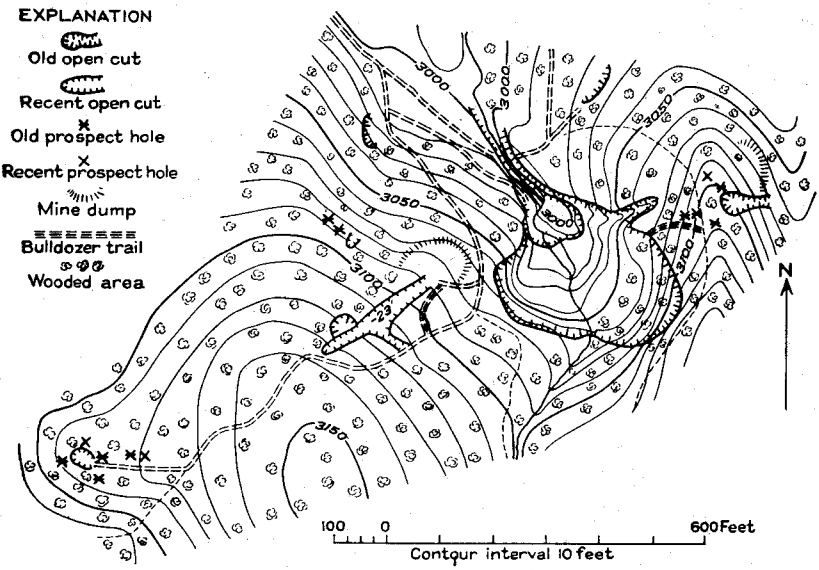


FIGURE 20.—Pace and compass map of the Umbarger mine. By Ralph H. Wilpolt.

tion ceased in 1918. A small stream and many seeps keep the clay moist and a series of landslips has taken place, especially on the southeast and south sides of the excavation; hence the ore zones which were formerly worked in most of the pit are now deeply buried. Little iron or manganese is now visible on the weathered clay banks, except on the southeast and east slopes, where small flattened fragments of fair-grade cryptomelane are present and are in places quite abundant. On the upper east wall, black wad was exposed in the bottom of a recent bulldozer cut and also in another fairly fresh prospect cut, but the wad contained practically no hard oxide. Mr. Sayers excavated the narrow cut leading into the bottom of the main pit with a gasoline shovel in the summer of 1942. The fresh walls showed layers of yellow, red, brown and black clay dipping 50°-60° N. Some of the brown and black waddy zones contained small pellets of cryptomelane, but most of the wad contained no hard ore. A considerable quantity of the dark-colored clay was hauled to the washer. The yield of concentrates was low, and they were high in silica and iron. In addition, the clay was kept wet by rains and by seepage so that operations were hampered by slides and by the constant threat of slides. The main pit was therefore abandoned. The prospect holes and trenches around the

main pit are old and afford no good exposures. Two drill holes, 45 feet apart, were put down many years ago, apparently on the floor of the main pit near the south edge. One of them was 202 feet, the other 226 feet deep. The logs of the two holes are said to be identical except that the deeper hole entered the Erwin quartzite. The log of the deeper hole, as given by Stose,[49] is as follows:

Log of drill hole at the 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 more than 40 percent manganese	75- 90
6.	Clay	90-220
7.	Hard sandstone containing scattered pebbles	220-226

This hole is of special value because it records an ore zone at a depth of 75 feet, and because it shows that the dolomite was completely weathered to a depth of 220 feet.

A small pit, 900 feet southwest of the main mine (Fig. 20) was enlarged by gasoline shovel in 1942 and dug to a depth of 5 feet. Yellow clay formed the walls, containing in one place a pocket of wad 3 feet in diameter. Granules of manganese oxide and a few larger masses of earthy manganese oxide were included in the pocket, but it was too small to be of commercial importance and no additional pockets were found.

Manganese ore was found more abundantly in the cut 300 feet southwest of the big pit (Fig. 20 and Pl. 14,B). This cut had been deepened to 25 feet at the time of the writer's last visit, and operations were continuing. The laminations in the clay trend N. 50° E. and dip 46° NW. The ore zone consists of brown, black and yellow clay layers. The brown and black zones contain manganese nodules, veinlike masses of chunky amorphous manganese oxide and a few pieces of crystalline pyrolusite. The total thickness of the ore-bearing clay is 25 feet, of which the upper 15 feet consists of clay, weathered silicified dolomite and manganese oxide. All the hard ore in this upper zone is highly siliceous, and it is not being mined. The lower 10 feet contains higher grade ore but the first two cars shipped analyzed less than 40 percent

manganese. This ore zone continues in a southwest direction for an unknown distance and may also go much deeper. The expense of moving so much barren clay in the walls of the cut in order to prevent slides will probably prevent following the ore very deep by open-cut methods. The cut is being worked by drilling and shooting the side walls, loading the ore-bearing clay into trucks with the gasoline shovel, and removing the barren clay in the cut and the overburden on the surface with a bulldozer.

The Umbarger mine has supplied the only fossils of importance in the Glade Mountain district. A collection of macerated leaves, fragments of wood, and pine cones was made many years ago from surface clays in the main pit[50]. Knowlton identified the pine cone as *Pinus strobus* Linne and referred it to the Pleistocene. The writer has collected abundant fossils from the deeper clays, derived from the Shady dolomite, at three different places in the Umbarger mine. The fossils are all of one species, a tiny tubular form about ½ inch long when unbroken (Pl. 6,A). They were identified by Bridge of the Federal Geological Survey, who reports as follows:

> "The fossils submitted by Ralph Miller from Umbarger mine, Sugar Grove, Virginia, can be identified as *Salterella acervulosa* Resser, possibly equivalent to *S. pulchella* Billings. This is a very common lower Cambrian form and has been found in the Shady at several localities. It is, however, very rare to find it weathered out so free."

The fossils were first found in the bottom of the big pit, embedded by the thousands in black waddy clay. This exposure has since been covered. Subsequently the fossils were found to be equally abundant in brown clay high on the east wall of the main pit and in brown clay on the northwest wall of the active cut west of the main pit. These occurrences probably represent three exposures of the same deeply weathered bed. The discoloration of the fossil-bearing clay by iron and manganese oxides at all three localities, whereas most of the clay in the mine is the normal yellow color, suggests that deposition of the oxides does not take place fortuitously in whatever clay the mineral-bearing waters pass through, but is at least in part controlled by the physical or chemical composition of the clay that is being infiltrated.

Shipments of ore from the Umbarger mine since 1916 are listed in Table 6 below. Iron was high in all the ore in which manganese was low. Silica ranged from 5 to 15 percent, averaging about 10 percent.

Phosphorus was below 0.3 percent in all the ore and below 0.2 percent in most of it.

TABLE 6.—*Manganese produced at the Umbarger mine (long tons)*

YEAR	Below 20 percent of manganese	20-30 percent of manganese	30-40 percent of manganese	Above 40 percent of manganese
1916	1,895	159	0	20
1917	393	1,782	182	147
1918	553	1,341	1,272	546
1941	.....	.....	.....	90
1942	.....	.....	41	.....

Umbarger prospect.—The Umbarger prospect is on the lower slopes of the Iron Mountains 2.4 miles east-southeast of Sugar Grove and 0.6 mile east-northeast of the Umbarger mine, at an altitude of 3,140 feet. The woods road, which leads east from Cressy Creek to the Umbarger mine, continues for about another mile to the prospect.

The Umbarger prospect was explored many years ago, and was examined again in 1917 at the time of operations at the Umbarger mine. When the mine was reopened in 1942 by E. O. Sayers of Marion, the principal cut at the Umbarger prospect was again explored in the hope that ore from it might supplement ore from the Umbarger mine. Several days' work with a bulldozer failed to uncover sufficient ore to warrant further development.

Pits and cuts are reported over an area of a few acres as the result of the 1917 operations[51]. The main exposure in 1942 consisted of a bulldozer cut, 250 feet long, 15 feet wide and 12 feet deep, excavated in yellow and red residual clay of the Shady dolomite (Fig. 21). Streaks and zones of wad from 2 to 6 feet thick occur in the upper five feet, but they seem to contain no hard ore. The clay in the lower part of the cut was almost entirely barren except for one large block of solid, nearly pure, amorphous manganese oxide which was estimated to weigh 150 pounds. Except for this one unusual find, no other ore of any consequence was encountered, and the prospect was abandoned in favor of concentrated activity at the Umbarger mine.

Porter bank.—The Porter bank is in Rye Valley 2 miles east-northeast of Sugar Grove, at an altitude of 2,830 feet. It is in a belt of Shady dolomite midway between two belts of the Rome formation. The dolomite dips 40°-60° S. and passes normally beneath the shale

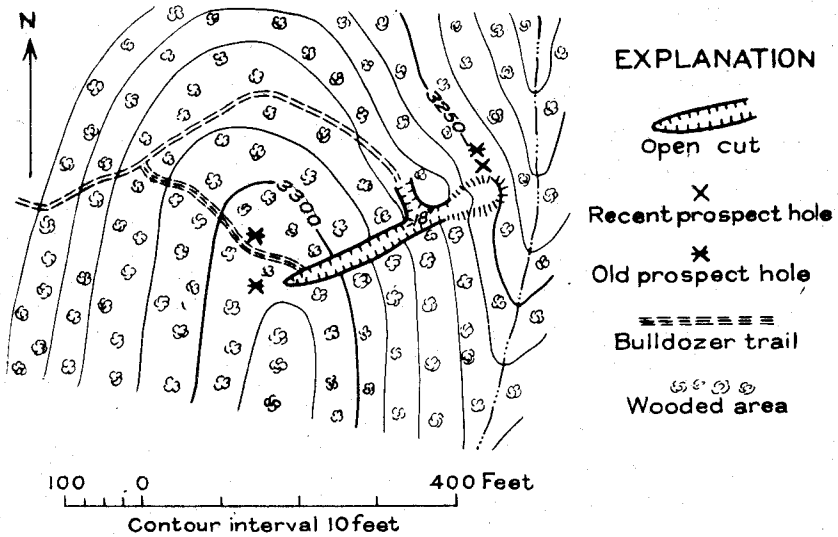


FIGURE 21.—Pace and compass map of the Umbarger prospect. By Ralph H. Wilpolt.

of the Rome formation to the south, but it is in fault contact with the belt of Rome to the north. Within the belt of Shady dolomite, no complications of folding or faulting are apparent. The mine is in residual clay derived by weathering of the dolomite, and appears to be in the lower part of the upper or "saccharoidal member" of the Shady dolomite. In this respect it differs from most manganese and iron deposits of the Glade Mountain district, the majority of which are near the base of the lower or Patterson member of the Shady. Partly decomposed bedrock crops out in two places in the mine and elsewhere nearby. The clay mantle is thus shown to be locally thin, and is probably not over 100 feet thick anywhere in the area.

The Porter bank is one of the iron mines which supplied ore in the 1880's and 1890's to the White Rock furnace near Cedar Springs. According to Holden[27a] it produced 35,000 tons of "limonite" ore which was high in manganese and carried some lead. The land is owned by the Lobdell Car Wheel Co. of Wilmington, Del., the last firm to operate the White Rock furnace.

The workings are in a small woods on a gentle south slope. They consist of a series of closely grouped open pits and cuts covering about an acre. The largest pit is 180 feet long, 100 feet wide and 40 feet deep. A timbered shaft in the bottom of this pit indicates that some underground mining was done.

All the pits were excavated in yellow and reddish-brown clay. The iron ore now visible is in the form of nodules and irregularly shaped pieces on the slumped and weathered banks of the pits. These are mainly of limonite of high purity, with small amounts of hematite. Similar nodules may also be found scattered over the nearby fields. Some nodules are manganiferous, but good-grade manganese nodules are rare. A few were found, however, near the middle of the long cut southwest of the big open pit. These were composed of hard, metallic manganese oxide of "psilomelane type" in masses one to four inches in size.

No fresh exposures are available in the workings, by which the extent and quality of the ore body may be observed directly, but the paucity of manganese nodules on the banks makes it unlikely that any appreciable quantity of manganese is present. Local residents also report that little manganese was found when the pits were being actively worked for iron 50 years ago.

Roberts prospect.—The Roberts prospect is 4 miles east of Sugar Grove and 3 miles west of Camp at the headwaters of the east fork of Ashland Hollow Creek. The farm on which the prospect lies was formerly occupied by W. B. Roberts, but the land was then and is now owned by Enoch Horne. It is in a belt of Shady dolomite between Erwin quartzite in the Iron Mountains front to the south and a belt of the Rome formation to the north. The dolomite crops out 100 yards southeast of the Roberts farmhouse, striking N. 86° E. and dipping 77° SE. Residual clay and gravel cover most of the lowland near the farmhouse and also the wooded slopes to the south.

The Roberts prospect was described by Stose[52] in 1917 as follows:

> "Recent prospecting has been done on the W. B. Roberts farm . . . . 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."

All the prospect pits seem to have been filled and the location of most of them has been lost. No ore shows on the surface near the only one which could be definitely located. Two small pits, which are probably not connected with the manganese prospecting mentioned by Stose, lie near the edge of the woods just south of Ashland Hollow Creek and Dry Creek divide. These showed a few limonite nodules but no manganese. Search through the woods and over the fields failed to discover any pieces of manganese on the surface. The promising ore showings, which were visible in 1917, are no longer exposed or else they were overlooked.

Prospects near Camp.—Stose[53] describes several minor prospects near Camp in southeastern Smyth County. These were not visited by the writer. Stose's findings are briefly summarized as follows:

Iron oxides are present on the slope back of the C. L. Jennings' house. A deposit of iron ore, which formerly helped supply the White Rock furnace, lies one-eighth to one-quarter mile south of Camp. Shaly manganiferous iron ore was quarried from a pit a quarter of a mile southeast of Camp. Manganese and iron oxides cement fragments of brecciated Erwin quartzite exposed in shallow pits on the Haywood place a half mile southwest of Camp. Manganese ore is reported on the north slope of the ridge between Camp and the Roberts prospect to the east, but without any prospecting of the occurrences.

None of these prospects were especially significant in 1917, and they seem to have aroused no interest since that time.

IRON

Iron ore was mined for many years in the Glade Mountain district, beginning in the early part of the last century, and continuing at intervals through World War I. The total production of iron concentrates from the district is known to be not less than 150,000 tons, and it may have been considerably larger. Most of this ore went to local iron furnaces, but some was shipped outside the district after the building of the Marion and Rye Valley Railroad in 1896. The small iron furnaces and the small iron mines of this district found it difficult to compete with large producers of iron and steel, however, and the last iron furnace ceased operations early in this century. Iron ore continued to be produced at mines where manganese was also available until the close of World War I, but there has been no production of iron in the district since then.

The large iron mines of the district were open pit operations, working ore bodies in residual clay of the Shady dolomite. The chief ore mineral is limonite, but some hematite and goethite are present at many of the mines. The iron oxides are in the form of nodules or granules in the residual clay, and also as hard, ledgelike masses in the clay. The nodules are yellow, brown and black. Most of them range in size from a half inch to two feet in diameter. The grade of this nodular iron ore is uniformly good. Some nodules contain minor amounts of visible impurities, of which the most common is an earthy, black manganese oxide. The ledge ore is less high-grade. It forms as a replacement of silicified dolomite ledges by iron oxide. The replacement has not always gone to completion, so that quartz grains and patches of silica may be scattered through the iron ore.

The iron ore in residual clay of the Shady dolomite has probably formed in almost the identical manner as the manganese deposits. The iron was originally disseminated through the Shady dolomite. It has been dissolved by meteoric waters and later precipitated at favorable places in the residual clay. The most favorable site for the concentration of the iron was the clay near the base of the Shady, because the weathered basal sandstone of the Shady formed an excellent aquifer for conducting the iron-bearing waters. The iron concentrations are not confined to this basal zone as strictly as are the manganese deposits, however, but may be found in clay derived from dolomite high up in the Shady formation. Much of the iron was precipitated around small nuclei, which grew outward layer by layer to form granules or nodules. Some of the iron, however, replaced masses or ledges of silica, formed previously by silicification of patches or zones of the dolomite.

Besides the iron deposits in residual clay of the Shady, several small iron mines have worked bedded limonite ore in the Erwin quartzite and in the Rome formation. In these deposits the iron oxide has replaced beds of sandstone or shale in the bedrock. None of the iron in these deposits is appreciably manganiferous, in contrast with the deposits in the Shady where manganese and iron minerals are commonly associated. Although the limonite ore in these mines in the Erwin and Rome was of good quality, the tonnage of available ore seems to have been small. A good example of an iron mine in the Erwin is described in this report under the heading "Chestnut Mountain prospects," and one of the iron mines in the Rome is described under the heading "Prospects north of Pond Mountain."

The important iron-producing mines of the district were the Porter bank, Crigger bank, White Rock mines, Bishop mine, Wright bank, Currin Valley mines Nos. 1, 3, 4, 5 and 6, and the Umbarger mine. All of these, except the Crigger bank, are described in the section headed "Descriptions of manganese mines and prospects."

The iron ore at the larger mines was treated in log washers to remove the clay and sand. At some of the mines screens and jigs were used to remove silica and other impurities from the finer sizes of log washer concentrates.

All the large iron mines have been so long abandoned that the walls have slumped and any drifts or shafts have caved. A clear picture of the quantity or quality of the remaining ore is not obtainable. Most of the iron mines seem, however, to have been abandoned because of the difficulty of competing with the large domestic and foreign producers of iron ore, rather than because their deposits were exhausted. Nodules of limonite are present in sufficient abundance on the banks and dumps of several of the mines to justify the conclusion that more ore of the quality originally worked still remains in the ground. Considerable prospecting would have to be done, however, before any estimates of tonnages could be made. The figures in Table 3, which show production of ore with less than 35 percent manganese are approximate, but give some idea of the past production of iron and manganiferous iron from the district. If the known iron deposits of the district were reopened and worked to exhaustion as much iron could probably be produced as has been produced in the past, and possibly much more. In addition to the iron mines named above, and other smaller mines and prospects, float of nodular limonite is common in many places in the district, especially near the Erwin-Shady contact. The more important showings of iron float are indicated on Plate 1.

OTHER MINERAL RESOURCES

Lead and zinc.—Lead and zinc deposits in the Shady dolomite have been mined in Rye Valley and Cripple Creek Valley, and prospecting still goes on from time to time. Currier[22] has described nine lead-zinc mines and prospects within the Glade Mountain district. The most important workings were the Rye Valley lead mine 0.7 mile west-northwest of Sugar Grove and the Keesling mine 0.3 mile east of Cedar Springs.

Barite.—Barite was mined in the 1880's and 1890's at a mine 1 mile east of Atkins and ¼ mile south of the Lee Highway (U. S. No. 11). The mine consisted of an open pit and a shaft of unknown depth.

The main exposure in the open pit is now of yellow residual clay, but a small ledge of the Beekmantown dolomite crops out. Dolomite is also exposed on the hill slopes west of the mine. Pieces of barite are present in the mine dumps. The nature and geologic relations of the ore body are not apparent at the surface.

Limestone.—Two upright kilns, that produce lime for agricultural use, are still active in the district. One of these, ½ mile west of Sugar Grove, is burning Shady dolomite for lime. The other, just south of the Lee Highway two miles east of Atkins, is burning Beekmantown dolomite. Soft coal is used for fuel.

Sand and gravel.—Sand and gravel have been quarried mainly in the Currin Valley area. Three pits high on the mountains south of the valley have worked a coarse, disintegrated sandstone in the Erwin quartzite. A small pit on the Killinger Creek road 1 mile east of the Glade Mountain mine has worked a similar sandstone. The most interesting of these quarries is the eastern of the two, which lies on the north slope of Brushy Mountain a mile southwest of Currin School, where a coarse sandstone in the Erwin quartzite has been strongly brecciated, due to its proximity to a major reverse fault. Subsequent deep weathering has caused the sandstone to disintegrate to the extent that sand can be readily produced from it.

Another large pit on the north side of a steep knob near the lower end of Currin Valley is in a deposit of superficial gravel and coarse sand. This seems to be a remnant of a more extensive gravel deposit laid down at a higher level of Staley Creek, apparently due to the damming effect of the quartzite spur which cuts across Currin Valley just below the quarry. The gravel deposit has been worked in recent years by hydraulic methods.

Road metal.—Road metal quarries are numerous throughout the district. Shale of the Rome formation has been extensively used on unpaved roads. Dolomite and limestone have also been quarried for road metal. Several large quarries are located near the Lee Highway east of Marion in formations younger than the Rome. The Shady dolomite has also been quarried in Rye Valley and Cripple Creek Valley, especially in the vicinity of Sugar Grove.

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IN COOPERATION WITH
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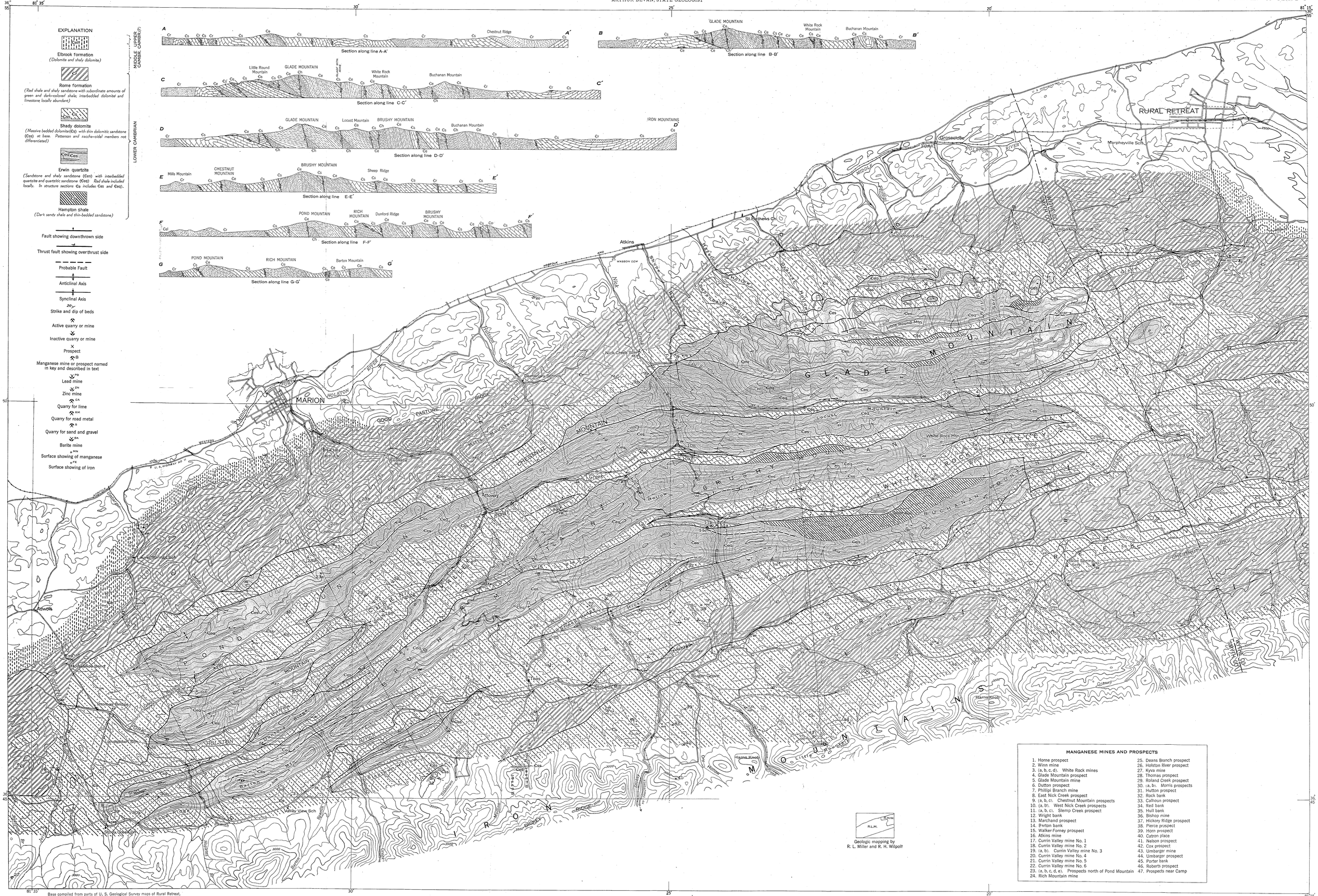


Base compiled from parts of U. S. Geological Survey maps of Rural Retreat, Marion, Mt. Rogers and Mouth of Wilson quadrangles

GEOLOGIC MAP AND STRUCTURE SECTIONS OF THE GLADE MOUNTAIN DISTRICT

SMYTH AND WYTHE COUNTIES, VIRGINIA

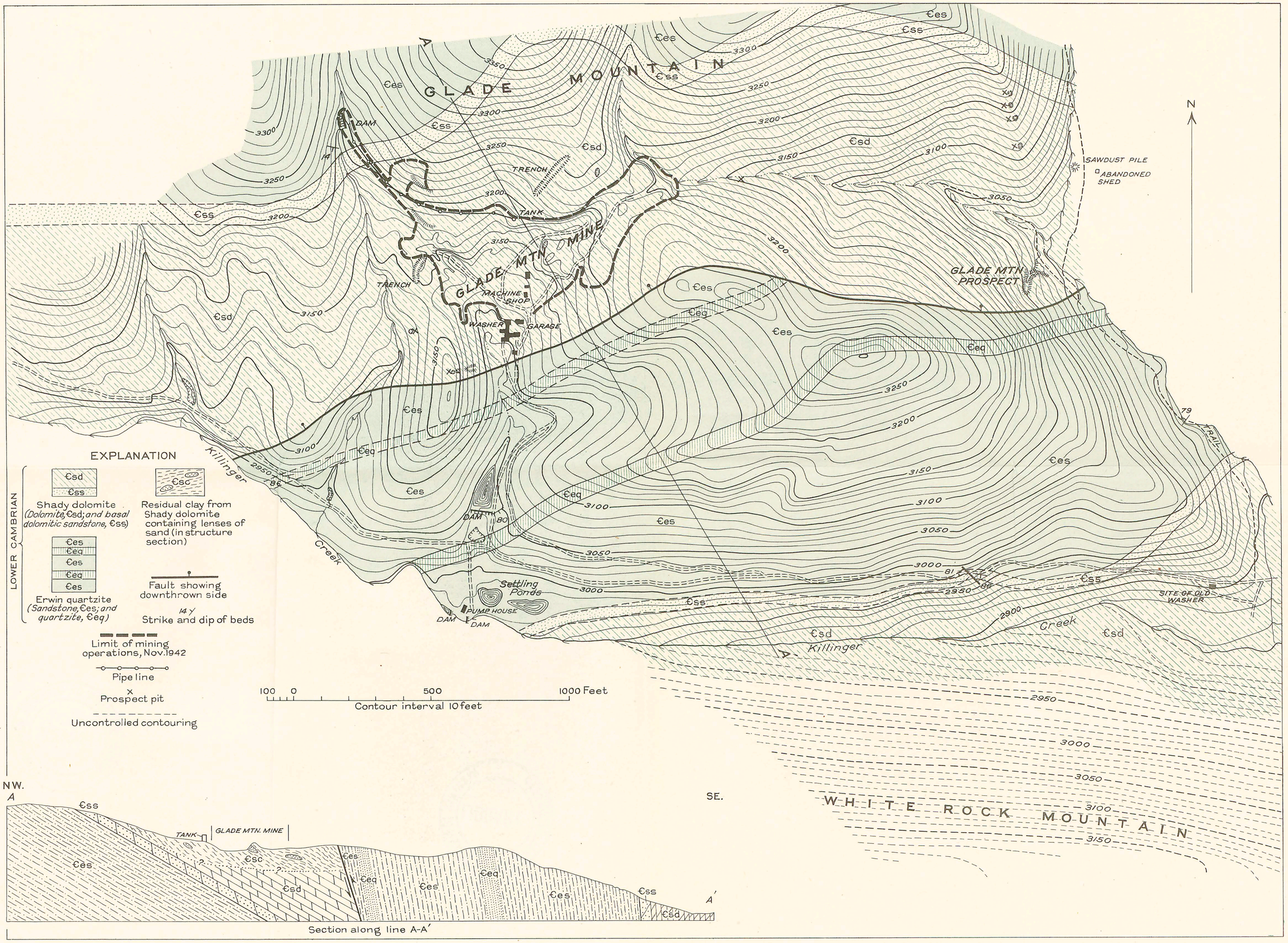
By Ralph L. Miller and Ralph H. Wilpolt

Scale $\frac{1}{81,680}$

1 ½ 0 2 Miles

5,000 0 10,000 Feet

Contour interval 100 feet
Datum is mean sea level



GEOLOGIC MAP AND STRUCTURE SECTION OF THE GLADE MOUNTAIN MINE AND VICINITY

By Ralph L. Miller and Ralph H. Wilpolt