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DIVISION OF GEOLOGY

BULLETIN 54

GEOLOGY AND MINERAL DEPOSITS OF BUMPASS COVE, UNICOI AND WASHINGTON COUNTIES, TENNESSEE

BY

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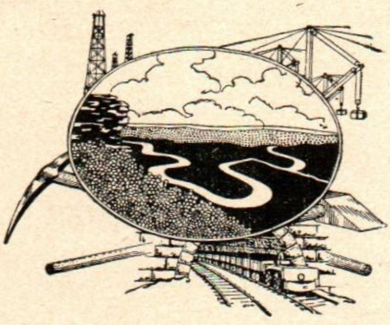

NASHVILLE, TENNESSEE

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FOREWORD

Since the Revolutionary War, Bumpass Cove has been widely known for the variety of its mineral deposits. The cove is a unique mining district in that commercial quantities of lead, iron, zinc, and manganese ores have been mined.

The geologic work on which this report is based was conducted by the U. S. Geological Survey. The Tennessee Division of Geology hopes that by publishing the results it will stimulate further prospecting and exploitation of the area.

This report is the result of careful geologic mapping of the cove and close examination of its mines and records of exploration and production. The inferences and interpretations are carefully thought out and should serve to advise anyone interested in the mineral resources of the cove.

H. B. BURWELL,
State Geologist

ABSTRACT

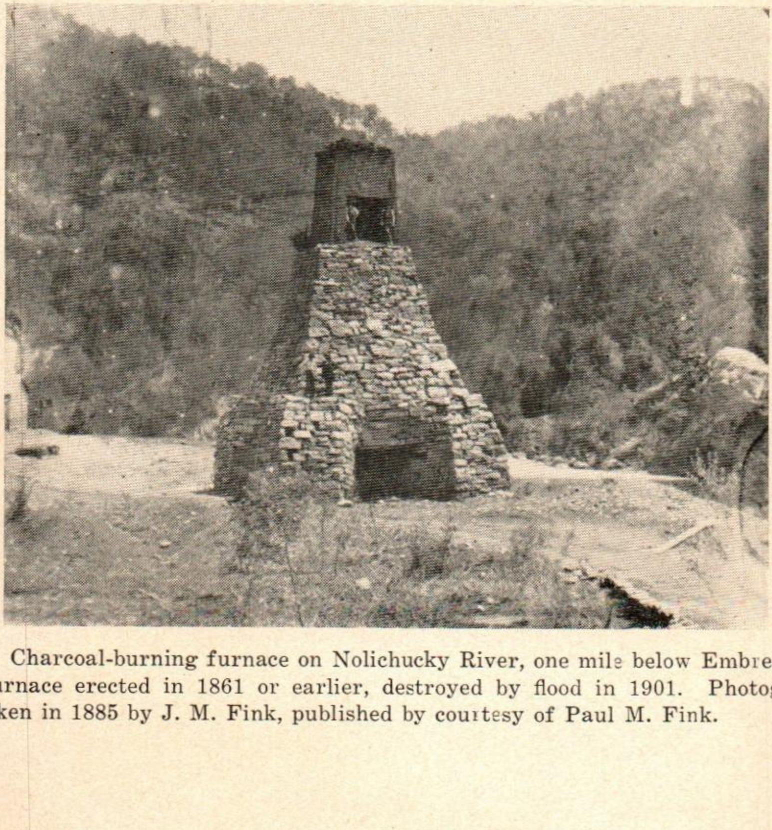
Bumpass Cove is located in Unicoi and Washington Counties in northeast Tennessee. Iron, zinc, lead, and manganese ore have all been mined in the cove. The recorded production of the cove, to the end of 1946, is 493,318 long tons of iron concentrates, 213,286 short tons of zinc concentrates, 29,652 short tons of lead concentrates, and 29,162 long tons of manganese concentrates.

Bumpass Cove is underlain by the Shady dolomite (lower Cambrian), preserved in a syncline surrounded by older clastic formations which underlie the mountains enclosing the cove. Only the basal 500 feet of the Shady dolomite is present. When the rocks were folded, the dolomite was considerably brecciated and recrystallized, especially on the folded and faulted southeast limb of the main syncline. The whole area, including the cove and the enclosing mountains, is part of a large remnant of an overthrust mass, nearly separated by erosion from its roots to the southeast.

Zinc, lead, and iron sulphides occur in the Shady dolomite, and oxidized deposits of zinc, lead, iron, and manganese occur in the residual clay formed by the weathering of the dolomite. The sulphide deposits are closely related to structural features in the cove, especially to two small folds on the southeast flank of the main syncline, and were probably deposited about the time of the folding. Zinc sulphide of commercial grade is present in places near these two folds, but prospecting has not yet shown whether it exists in minable quantities or not.

The oxidized deposits were formed by the concentration of the metallic elements during the weathering of the dolomite. The zinc and lead in the oxidized deposits have come from the zinc and lead sulphides, but the manganese and much of the iron were apparently derived from manganese and iron carbonates disseminated in the dolomite.

Practically all the mineral production of the cove has come from the oxidized deposits in the residual clay of the Shady dolomite. The larger oxidized ore bodies so far discovered in the cove have been mined out. However, some small unmined deposits of each type of oxidized ore are known.



Charcoal-burning furnace on Nolichucky River, one mile below Embreeville. Furnace erected in 1861 or earlier, destroyed by flood in 1901. Photograph taken in 1885 by J. M. Fink, published by courtesy of Paul M. Fink.

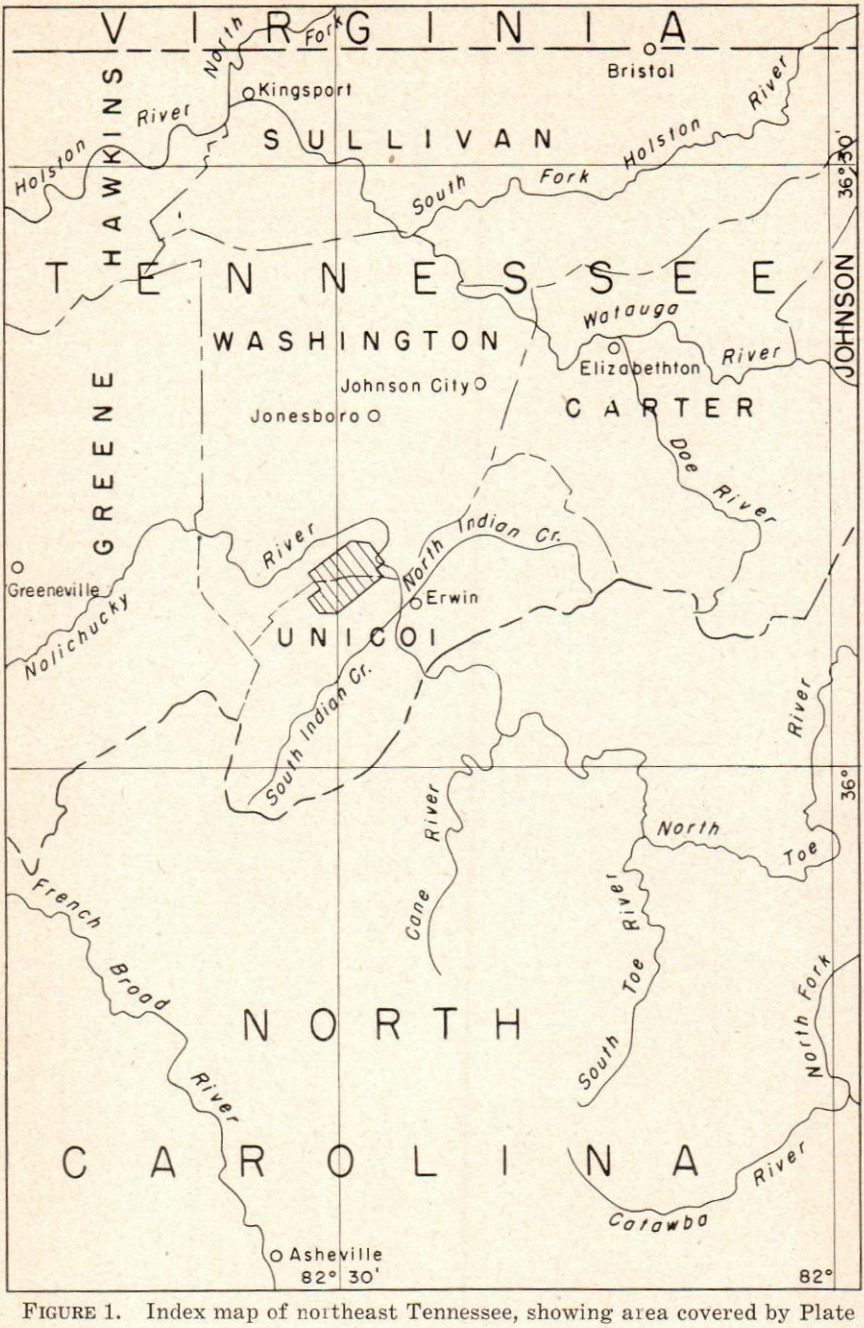


FIGURE 1. Index map of northeast Tennessee, showing area covered by Plate 1.

Geology and Mineral Deposits of Bumpass Cove, Unicoi and Washington Counties, Tennessee*

By JOHN RODGERS[1]

INTRODUCTION

LOCATION AND GEOGRAPHY

Bumpass Cove is located in Unicoi and Washington Counties in northeast Tennessee, 4 miles west and northwest of Erwin and 15 miles southwest of Johnson City (fig. 1). The cove is four miles long from northeast to southwest and, at its widest point, is over a mile wide. It is drained northeastward by Bumpass Cove Creek, a tributary of the Nolichucky River. The floor of the cove ranges from 1,600 to 2,000 feet above sea level, and the divide at its head on the southwest, separating it from the valley of Clark Creek, rises to an altitude of about 2,400 feet.

The cove lies between two subparallel mountains, Embreeville Mountain (locally called Bumpass Cove Mountain or Cove Mountain) on the northwest, which rises 2,900 feet above sea level, and Rich Mountain on the southeast, which rises over 3,400 feet. To the southwest the range of which these mountains form a part extends to the Big Butt, a high mountain at the northern bend of the S-shaped Bald Mountain Range on the state line between Tennessee and North Carolina; to the northeast beyond the gorge of the Nolichucky, the mountain range in which the cove is located extends nearly to Johnson City where it breaks off abruptly in the midst of lowlands. To the northwest this range faces the Appalachian Valley, of which it forms the southeastern limit, and to the southeast the valleys of North and South Indian Creeks separate it from the mountain ranges along the state line.

The nearest village to Bumpass Cove is Embreeville, on the Nolichucky River half a mile northeast of the mouth of Bumpass Cove Creek. A graded gravel road runs the length of the cove and joins the paved road from Erwin to Jonesboro half a mile northeast of Embreeville. Formerly a branch of the Southern Railway extended to Embreeville where it connected with a company railroad into the cove, but it was abandoned in 1938.

Mining is the principal activity in the cove, although some subsistence farming is carried on. The ores mined are treated in two

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[1]Geologist, U. S. Geological Survey.

mills near the center of the cove. The concentrates are trucked to the Southern Railway at Jonesboro, a distance of 13 miles from the mills.

PAST AND PRESENT GEOLOGIC WORK

The mineral deposits of Bumpass Cove were known from an early date and attracted the attention of the first two State Geologists of Tennessee, Troost (1840, pp. 36-41) and Safford (1856, pp. 33 ff.; 1869, pp. 201-202, 223, 451 ff., 485). Safford described the iron, lead, and zinc ores then known in the cove, and his geologic work in east Tennessee laid the foundations for all later work in the region. Later in the nineteenth century, the iron industry in Bumpass Cove was described by J. P. Lesley (1872), who examined the iron resources of the cove for private interests, and by Guy R. Johnson (1896), an official of the Embreeville Iron Co., Ltd.

In the course of mapping much of east Tennessee for the geologic atlas of the United States, Keith (1905, 1907) established the main outlines of the geology of the Bumpass Cove area, and also briefly described the iron-mining operations. After its reestablishment in 1910, the present Tennessee Division of Geology published valuable summary reports on the iron (Jarvis, 1912, pp. 355-358), manganese (Stose and Schrader, 1918, pp. 275-277; 1923, pp. 83-86), and zinc (Secrist, 1924, pp. 141-147) deposits of east Tennessee, which describe the deposits in Bumpass Cove. More recently, the Tennessee Division of Geology has published a new manganese report (Reichert, 1942, pp. 129-136), which includes a partial reprinting of the report by Stose and Schrader. As Mr. Reichert had previously been employed by the Embree Iron Co. and was thus personally familiar with the manganese operations in Bumpass Cove, the material relating to the cove in his report is especially valuable.

The present investigation began as a part of a study of the manganese deposits of northeast Tennessee, a project of the strategic minerals program of the United States Geological Survey. Because of the somewhat unusual combination of manganese, zinc, and lead ores in Bumpass Cove, and the national need for these metals during the war, the geological survey of the cove was extended to cover the zinc and lead deposits as well. The survey of Bumpass Cove was suggested by Hugh D. Miser of the U. S. Geological Survey and was carried out during 1942 under his direction and that of Philip B. King and Charles H. Behre, Jr.

ACKNOWLEDGMENTS

The generous cooperation of the officials and employees of the Embree Iron Co. in all phases of the work is gratefully acknowledged. Elliot Wheeler, president of the company, and N. E. Lewis, general superintendent, gave free access to the company's records, and James C. Ammons, Paul Fink, Nolan Davis, and many others furnished local information and other assistance. Mr. Fink kindly made available much historical material relating to the early iron operations in and near the cove.

To Philip B. King of the United States Geological Survey, who was in charge of the northeast Tennessee manganese project, I am deeply indebted for guidance during the field work and for many fruitful conferences on the geological problems encountered. Many helpful suggestions were made by Walter F. Pond, former State Geologist of Tennessee, and by Hugh D. Miser and Charles H. Behre, Jr., of the U. S. Geological Survey, during several visits to the cove. The interested cooperation of Herman W. Ferguson, who was assigned by the Tennessee Division of Geology to the northeast Tennessee manganese project, is especially appreciated. Lawrence C. Craig and Lawrence E. Smith of the U. S. Geological Survey assisted in the field for short periods. The illustrations were drafted by Mrs. Helene Connell of the Tennessee Division of Geology, and her work on them is gratefully acknowledged. Professor S. J. Shand of Columbia University very kindly made chemical analyses from specimens of the Shady dolomite. The manuscript was critically read by Mr. King, Mr. Miser, Mr. Behre, and Mr. G. F. Loughlin of the Geological Survey, Professor Adolph Knopf of Yale University, and Mr. Pond, former State Geologist of Tennessee, all of whom have greatly contributed to the report by their suggestions for its improvement. The report was a dissertation presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Yale University.

GEOLOGY

ROCK FORMATIONS

The consolidated rocks of the Bumpass Cove area are all sedimentary rocks of early Paleozoic age. Although these rocks have been considerably deformed by folding and faulting, they have not been appreciably metamorphosed. The rocks in and near the cove are part of a conformable sequence belonging to the Lower Cambrian series. Neither the top nor the base of the Lower Cambrian is exposed in the Bumpass Cove area, but both may be seen elsewhere in northeast Tennessee (King and others, 1944, p. 9). The lower part of the sequence consists of clastic rocks and is divided into the Unicoi formation below, the Hampton formation in the middle, and the Erwin formation above. The clastic rocks are resistant to erosion and form the mountains that surround Bumpass Cove. Above the Erwin formation, a thickness of about 500 feet of Shady dolomite is preserved in the Bumpass Cove syncline. As the dolomite is not very resistant, it has been eroded to form the cove. The Shady dolomite and its residual clay contain all the commercial ore deposits of the cove. The Lower Cambrian formations are described beginning with the Shady, which was studied in greater detail than the other formations. At the northwest edge of the area mapped, underlying the Appalachian Valley and separated from the rocks of the mountains by an overthrust fault, are easily eroded limestone and dolomite belonging to the Knox dolomite (Upper Cambrian and Lower Ordovician). As the Knox dolomite was not studied during the present investigation, no description of it is given.

SHADY DOLOMITE

The Shady dolomite was named by Keith (1903, p. 5) for Shady Valley, Johnson County, Tennessee. It is only sparingly exposed in Shady Valley but is well displayed to the southwest in Stony Creek Valley and near the Watauga River northwest of Iron Mountain (King and others, 1944, p. 16 ff., fig. 3). Typically, the formation consists of dolomite with a little interbedded limestone and includes several well marked rock types. In many parts of northeast Tennessee and southwest Virginia, these types are interbedded in fairly thick contrasting units which have been recognized as members of the formation (Currier, 1935, p. 16 ff.; Butts, 1940, p. 41 ff.; King and others, 1944, loc. cit.). In Bumpass Cove, however, the rock types interfinger considerably, and the units, though recognizable in parts of the cove, do not persist throughout and cannot be mapped separately except in limited areas of good outcrops.

Each of the rock types of the Shady is cut or replaced by white coarsely crystalline dolomite in a manner that is highly characteristic of the rock type. For convenience the term "sparry dolomite" is applied to such material in this report; it is further discussed below (pages 12, 13).

Rock types.—One of the most characteristic and prominent rock types in the Shady is white to light gray massive dolomite. Some of this type of dolomite is very compact and has almost the appearance of porcelain, as the grains are so small as to be invisible to the naked eye; some of it is saccharoidal, the grains being a millimeter or more across. Pinkish and yellowish tints occur locally. Here and there this rock type contains small angular pieces of light-colored chalcedonic chert, but silt or other impurities are rare. Samples of white massive dolomite from a small area of Shady outcrop, half a mile northwest of Erwin on the Embreeville road, were analyzed by D. F. Farrar of the Tennessee Division of Geology and found to contain 93.66 to 94.48 percent dolomite and 98.29 to 99.20 percent total carbonates. The alkalis were especially low, not exceeding 0.1 percent. Except where stained with iron, the white massive dolomite in Bumpass Cove is probably equally pure. In places in the cove the white massive dolomite is so severely brecciated that the bedding is obscure. Sparry dolomite occurs in this rock type largely as well defined veins and stockworks, though in a few places in the saccharoidal variety it forms irregular bodies with indefinite contacts. The sparry dolomite scarcely differs in color from the finer-grained country rock.

The commonest rock type in the Shady is blue-gray fine-grained dolomite, which ranges from light to dark and from massive to well laminated. Beds of such blue-gray dolomite that occur within zones of the white massive dolomite are light-colored, but otherwise dark colors prevail. The light varieties tend to be a little coarser-grained than the dark. Nodules and bands of dark-colored chalcedonic chert are found in a few places, and the well laminated varieties normally have rather prominent silty partings. Sparry dolomite occurs as blebs in the more massive varieties and as stringers parallel to the bedding in the more laminated varieties. Certain layers, however, have been brecciated, and in them the sparry dolomite forms the matrix of the breccia. The white color of the sparry dolomite contrasts strongly with the blue-gray of the country rock.

Another prominent rock type in the Shady is blue-gray fine-grained ribboned dolomite. The term ribboned dolomite is used for rock consisting of alternating layers, mostly less than half an inch thick, of dark blue-gray dolomite and light blue-gray or light gray dolomite. The dark layers are slightly finer-grained than the light and probably contain more organic matter; the light layers are commonly slightly silty. Silty partings are present between many of the layers but are not as prominent as in the laminated varieties of the blue-gray unribboned dolomite. Sparry dolomite occurs chiefly in the light layers, where it forms stringers parallel to the bedding, producing a "zebra rock" like that in such districts as Leadville, Colorado (Emmons and others, 1927, pp. 33, 176), and Metaline, Washington (Park and Cannon, 1943, pp. 42-43, pl. 23E). Where the light layers have been entirely converted to sparry dolomite, it appears in the darker layers as well, and in extreme examples the rock resembles a breccia with rather platy fragments of dark blue-gray dolomite set in a matrix of white sparry dolomite.

Closely related to the ribboned dolomite is ribboned limestone, which is the only form of limestone found in Bumpass Cove. It differs from the ribboned dolomite only in that the dark layers are calcitic. Wherever found it forms lenses and patches within bodies of ribboned dolomite, from which it is separated by sharp but highly irregular contacts, which may cut the bedding at any angle. In certain exposures of the ribboned limestone, the dolomitic portion appears to form a matrix around calcitic fragments. Sparry dolomite is very rare in the ribboned limestone, even close to bodies of ribboned dolomite in which it is abundant. It occurs only as small patches in the dolomite layers. Fairly large veins of white coarsely crystalline calcite occur here and there in and near bodies of limestone, but they differ in character from the bodies of sparry dolomite, not being intimately mixed with the country rock but simply cutting across it.

The highly irregular contact between ribboned limestone and ribboned dolomite indicates for the latter an origin by replacement of preexisting lime mud or limestone, perhaps during diagenesis, rather than by direct deposition. The ribboned dolomite is thus not strictly a primary dolomite, although it had certainly become dolomite before its deformation, as recrystallization of the dolomite was one of the important effects of that deformation. No direct evidence on the origin of the unribboned blue-gray dolomite or the white massive dolomite was obtained in Bumpass Cove, but by analogy it seems probably that they likewise were formed by replacement of preexisting lime mud or limestone.

Sequence of rock types.—The sequence of rock types in the Shady dolomite varies from one part of the cove to another, as illustrated by the sections below. Because of the scattered exposures, sections could not be measured in detail, and those given are based on calculations from the outcrops as plotted on the map, supplemented by data from drill records. The thicknesses are only approximate.

Section of the Shady dolomite in Sugar and Yates Hollows and in and near the Jackson mine (6)[2]

	Thickness (in feet)
Upper white member. White and light gray massive dolomite, largely saccharoidal, with a few beds of blue-gray dolomite. The top is not exposed; the basal contact is fairly sharp	over 100
Upper blue member. Blue-gray unribboned dolomite, fairly massive above, more laminated below	100
Ribboned member. Blue-gray conspicuously ribboned dolomite. Beds of unribboned dolomite are rare except close to the very gradational contacts	75
Lower blue member. Blue-gray dolomite. A mixture of poorly ribboned dolomite and laminated unribboned dolomite with every gradation between; also scattered layers or lenses of more massive unribboned dolomite, of well ribboned dolomite, and of ribboned limestone, the last only near the middle of the member	125
Lower white member. White and light gray compact massive dolomite, some with a pronounced pinkish cast; also massive blue-gray dolomite in the upper part, much of it very silty. Rounded quartz grains are present in the basal 10 to 20 feet and in places form sandstone lenses	50
Total	approximately 450

Section of the Shady dolomite near the No. 14 mines (25-28)

	Thickness (in feet)
Upper white member. White and light gray massive dolomite, largely saccharoidal	over 100
Light gray massive compact dolomite, with some beds of blue-gray unribboned dolomite. No saccharoidal dolomite observed	100
Ribboned member. Ribboned dolomite, light gray to dark blue-gray, but with the lighter shades predominating	50 or less

[2]Numbers in parentheses are those assigned to mines on Plate 1.

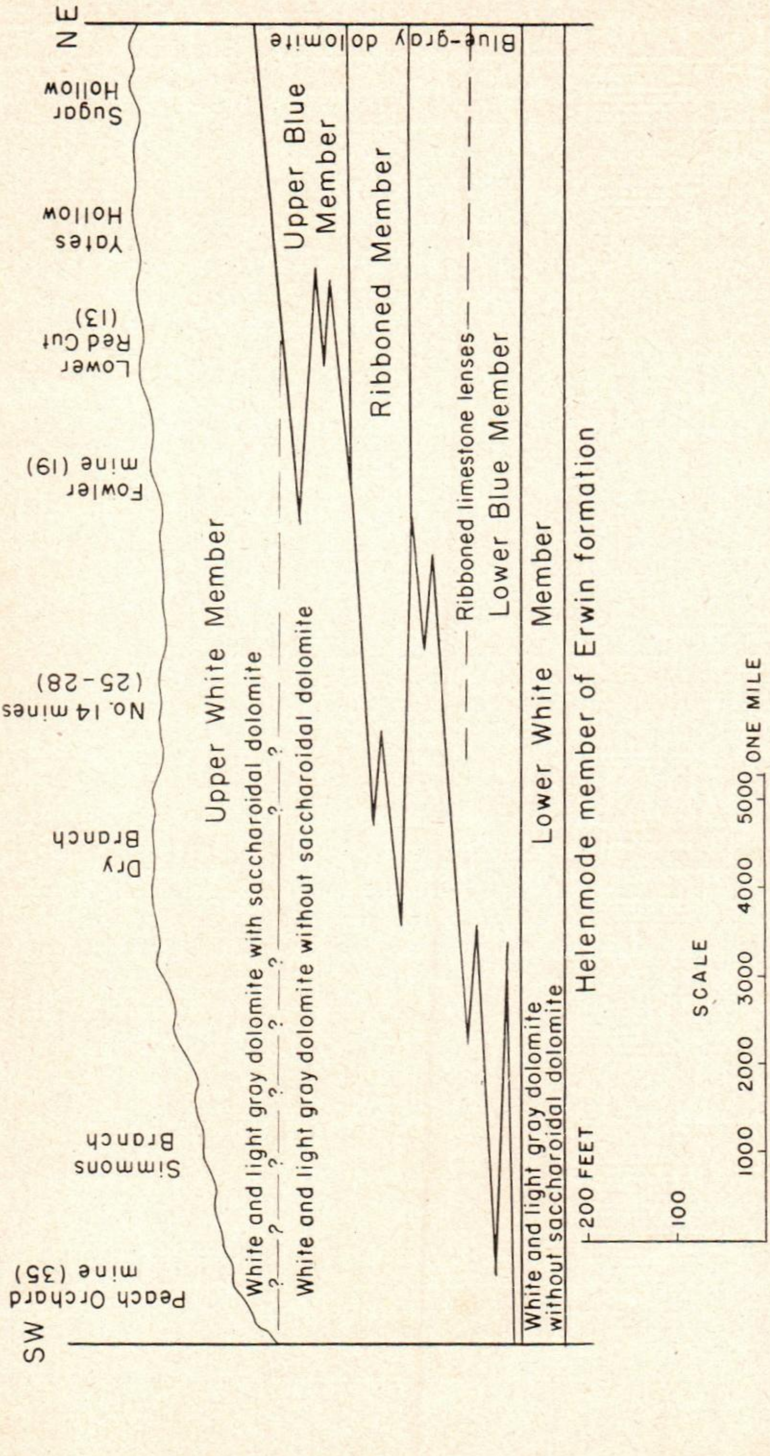

FIGURE 2. Stratigraphic relations in the Shady dolomite of Bumpass Cove.

Light gray massive compact dolomite, with rare beds of blue-gray unribboned dolomite. No saccharoidal dolomite observed	50 or less
Lower blue member (lower part). Blue-gray dolomite, ranging from massive through laminated to poorly ribboned, and including one lens of ribboned limestone. The base is not exposed, but the base of the Shady dolomite is 125 to 150 feet below the top of the unit	over 50
Total of section	over 350
Total of Shady dolomite in this locality	approximately 450

The inferred correlation between the sections is indicated by the assignment of units to members. Farther southwest, beyond Dry Branch, outcrops are few, and most of them expose light gray massive dolomite, rarely saccharoidal. The available evidence suggests that in the southwest end of the cove most of the Shady consists of such dolomite, which is interrupted only by two or three thin beds of blue-gray unribboned dolomite representing part of the lower blue member.

One interpretation of these stratigraphic changes is shown diagrammatically in figure 2. In general the upper limit of blue-gray dolomite descends to the southwest. The upper blue member grades laterally into white dolomite between the Lower Red Cut (13) and the Fowler mine (19), and the upper part of the lower blue member changes west of the Fowler mine. The ribboned member is somewhat lighter in color at the Fowler mine than in Sugar and Yates Hollows, but it persists to the southwest as far as Dry Branch.

After the above discussion was written, the United States Bureau of Mines drilled nine diamond drill holes in Bumpass Cove. One of these holes, located just beyond the northwest edge of the Jackson mine (6) and a little southwest of the normal fault that is exposed in the mine, was drilled to the top of the upper quartzite member of the Erwin formation. Through the courtesy of Harold B. Ewoldt, District Engineer, and Richard L. Sayrs, Project Engineer for the Bureau of Mines, the core of this hole was turned over to the U. S. Geological Survey and the Tennessee Division of Geology for study. The core is now stored at the offices of the Tennessee Division of Geology in Nashville and may be examined by any interested person.

The log of the core is given in the accompanying table. The summary of the log gives the true thickness of the larger units, corrected for the dip of the bedding; through most of the core the dip averages 25°, but near the bottom it is much less.

Log of U. S. Bureau of Mines diamond drill hole No. 1, Jackson mine (6), Bumpass Cove, Tenn.

	Depth (in feet)
Overburden	
Gravel and residual clay	0 – 59
Shady dolomite	
Upper white member	
Dolomite, light-gray, fine-grained, massive; sparry dolomite forms blebs and streaks	59 – 72
Dolomite, light-gray to blue-gray, fine- to medium-grained, in part faintly ribboned; sparry dolomite forms blebs and stringers	72 –104½
Dolomite, medium blue-gray, strongly ribboned; sparry dolomite forms blebs and a few thin veinlets	104½–110
Dolomite, light-gray, fine-grained, fairly massive but mottled with slightly darker dolomite; has some silty partings. Sparry dolomite forms large blebs and veins. Sheared at base	110 –120
Dolomite, medium blue-gray, fine-grained, badly sheared along several fault planes; sparry dolomite forms thin veinlets along fractures	120 –121
Dolomite, light-gray to white, medium- to coarse-grained, massive. Near top some darker finer-grained mottled dolomite. Sparry dolomite forms poorly defined areas, also a few veinlets. Badly weathered; many mud seams. Shear zone at 135 feet	121 –138½
Upper blue member	
Dolomite, medium to dark blue-gray, fine- to medium-grained, strongly ribboned except close to top; some silty laminae. Sparry dolomite forms blebs and stringers parallel to ribbons. Grades into underlying unit	138½–153½
Dolomite, dark to medium blue-gray, fine-grained, forming fragments in a breccia whose matrix is sparry dolomite. Shows ribboned structure in a few places	153½–180
Dolomite, medium to light blue-gray, vaguely mottled, medium-grained	180 –181
Ribboned member	
Dolomite, medium blue-gray, fine-grained, conspicuously ribboned; sparry dolomite forms blebs and stringers, mostly parallel to ribbons	181 –189½
Dolomite, dark to medium blue-gray, fine-grained, partly ribboned, partly brecciated, grading into units above and below. Sparry dolomite forms matrix to breccia and replaces some ribbons	189½–196½
Dolomite, medium to dark blue-gray, fine-grained, conspicuously ribboned. Sparry dolomite form blebs and stringers parallel to ribbons	196½–203½

	Depth (in feet)
Dolomite, dark to medium blue-gray, fine-grained, chiefly brecciated but some is well ribboned, especially at top. Sparry dolomite forms matrix of breccia and replaces ribbons	203½–226½
Dolomite, medium blue-gray, fine-grained, conspicuously ribboned. Sparry dolomite forms blebs parallel to ribbons, also a few veinlets	226½–230½
Lower blue member	
Dolomite, dark to medium blue-gray, fine-grained, irregularly ribboned, brecciated in places. Sparry dolomite as blebs and stringers parallel to ribbons	230½–272
Dolomite, dark to medium blue-gray, fine-grained; ranges from poorly ribboned to somewhat brecciated. Sparry dolomite forms blebs and matrix to breccia, but is much less abundant than above	272 –279½
Lower white member	
Dolomite, light-gray, rarely light blue-gray; chiefly medium-grained but ranges from fine- to coarse-grained; shows vague color banding and many stylolitic partings. No sparry dolomite	279½–305
Dolomite, light-gray to light blue-gray, medium- to fine-grained; one foot at top and one at base well banded and full of glauconite grains; middle foot massive	305 –308
Dolomite, light-gray, medium- to fine-grained; some color banding and a few partings; layer with glauconite grains near top	308 –313
Dolomite, light-gray to white, medium- to coarse-grained, well banded. Much glauconite in some layers, none in others. No quartz grains seen	313 –316
Erwin formation	
Helenmode member	
Coarse well rounded quartz grains in cement of light-gray dolomite. Probably some silt below, some glauconite above. Pink cast at base	316 –324½
Rounded quartz grains in red silty matrix; some dolomitic cement except at base. Grades into underlying unit	324½–326
Siltstone, red. Some quartz grains above. Color change at base is gradational, red bands alternating with green	326 –330½
Siltstone, green, mottled. Red streaks from 337 to 338 and from 340 to 342. Toward base, thin quartzite layers appear, and unit grades into underlying unit	330½–344
Siltstone and quartzite, alternating in thin layers. Siltstone is dark and greenish and contains some quartz grains; quartzite is light. More and more quartzite below	344 –378½
Upper quartzite member	
Quartzite, white, massive, virtually pure	378½–390

Hole bottomed at 390 feet.

Summary of log

Unit	True thickness (in feet)	
Shady dolomite	238 present	
Upper white member		75 present
Upper blue member		38½
Ribboned member		43
Lower blue member		47
Lower white member		34½
Erwin formation	73 present	
Helenmode member		61½
Upper quartzite member		11½ present

The log of this drill hole shows that the thicknesses assigned to the members of the Shady dolomite in the surface sections given above are considerably too great.

Effects of deformation.—The dolomite in Bumpass Cove is brecciated in many places, and two types of breccia can be distinguished. In one type, the rock is broken into block-like fragments by two or more intersecting fracture-sets, each set consisting of many nearly plane subparallel fractures along which there has been little or no movement. In some places these fractures are hardly more than closely spaced joints; in others sparry dolomite was deposited in them, forming veins and stockworks. This type of breccia is commonest in the white massive dolomite, but is found occasionally in the blue-gray dolomite.

In the other type of breccia, irregular fragments of country-rock dolomite are embedded in a matrix of sparry dolomite. Adjacent fragments neither match nor touch, and the form assumed by the sparry dolomite is very irregular. This type of breccia is found only in the blue-gray dolomite and chiefly in the unribboned dolomite; however, every gradation exists from this type of breccia to rock containing only isolated blebs and stringers of sparry dolomite, as in much of the ribboned rock.

The sparry dolomite associated with both types of breccia and also occurring as blebs and stringers in unbrecciated rock is everywhere coarsely crystalline and consists of grains several millimeters across. Small cavities lined with rhombohedral crystals of dolomite occur within bodies of this sparry dolomite. Some of these cavities have been filled with crystalline quartz; this quartz exhibits molds of the dolomite rhombs and also shows imperfect crystal faces where the cavities were not completely filled. The cavity fillings are freed as the dolomite weathers and accumulate in the soil and residual clay.

The sparry dolomite is white or colorless when fresh, and where present in blue-gray country rock, contrasts strongly with it. In many places, however, the borders of bodies of sparry dolomite turn brownish on weathering, and under the microscope the brown color is seen to be caused by minute dust-like inclusions of limonite. Staining of fresh rock with potassium ferricyanide shows that these borders contain an appreciable percentage of iron, whereas the interiors are practically iron-free, and that the associated country rock also contains iron but apparently less than the borders of the bodies of sparry dolomite. On the other hand, analyses of carefully cleaned samples of sparry dolomite (borders and interiors together) and of country rock, made by Professor Shand of Columbia University and quoted in detail on page 27, show that the overall iron content of the sparry dolomite is almost exactly the same as that of the country rock.

The coincidence in chemical composition between country rock and sparry dolomite strongly suggests that the former was the source of the latter. The dolomite was probably reconstituted from one form to the other by the action of solutions. The dolomite now forming veins and stockworks, as in the first type of breccia mentioned above, was probably deposited in open cavities at one place after having been dissolved from the country rock at another. On the other hand, the sparry dolomite now forming isolated blebs and stringers in the ribboned rock does not seem to have moved at all, but rather to have recrystallized in place. In forming the matrix of the second type of breccia, the solutions may have acted both by filling cavities and by aiding recrystallization in place. During the reconstitution of the dolomite, the iron was apparently driven to the edges of the bodies of sparry dolomite, leaving the interiors iron-free. At the same time organic matter in the dolomite was destroyed; in the blue-gray dolomite a strong color contrast between country rock and sparry dolomite has resulted.

The close association of breccia, sparry dolomite, and metallic sulphide minerals indicates that the sparry dolomite was formed during the deformation of the region and by the solutions that introduced the sulphides.

Weathering.—The Shady dolomite is very susceptible to weathering, which takes place principally by solution. The end product is a yellow to brown clay, in a few places silty and laminated but mostly waxy and structureless. In some places, clay rests directly against comparatively fresh, unweathered dolomite; in others, par-

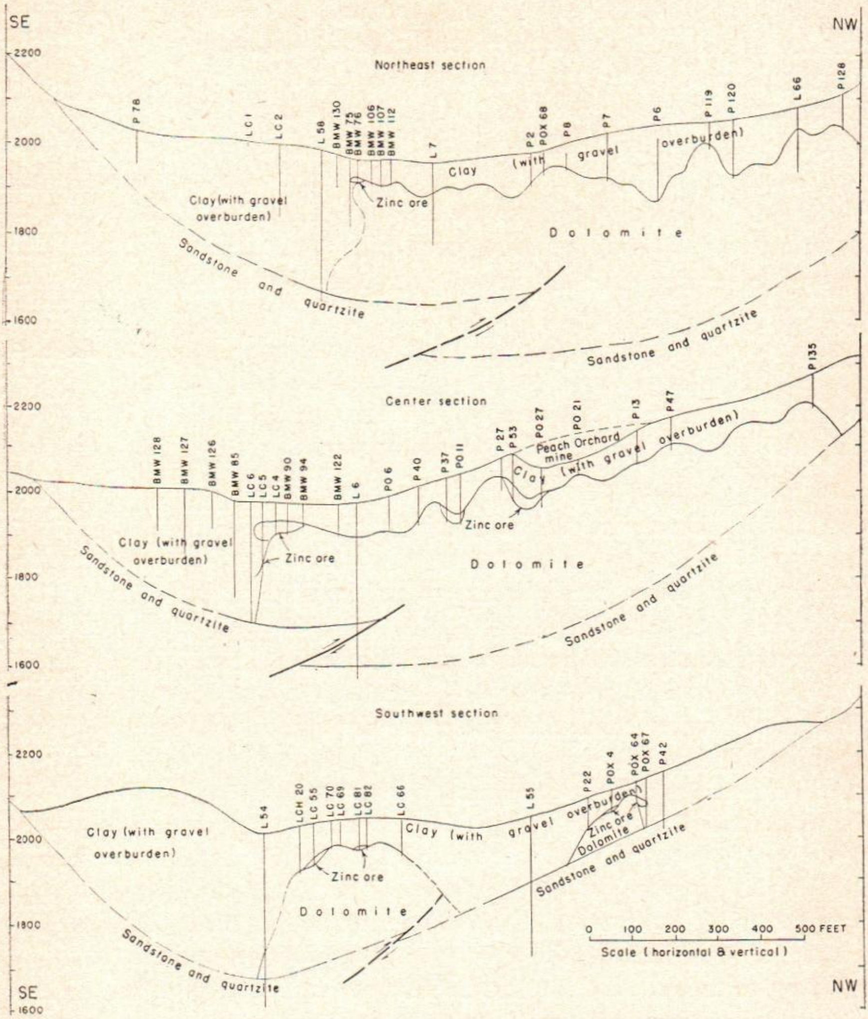

FIGURE 3. Cross-sections of Bumpass Cove near Peach Orchard mine, showing shape of bedrock surface. Compiled from records of Embree Iron Co.; serial numbers of drill holes are indicated.

ticularly where sulphides were present in the dolomite, an outer crust of partly weathered rock intervenes. The dolomite grains in this crust have commonly been loosened from one another but not appreciably dissolved, and the dolomite, especially the coarsely crystalline material, tends to crumble into dolomite sand. Silty dolomite normally has an outer shell of porous rottenrock from which the dolomite has been wholly or partly leached.

Weathering has proceeded especially along the numerous joints and fractures in the dolomite and has widened them into deep crevices, great irregular pinnacles of dolomite remaining between. These crevices and pinnacles are spectacularly displayed in several of the old hydraulic iron mines in the cove. The relief of the upper surface of the dolomite resulting from these pinnacles is normally about 50 feet. The average level of this surface appears to coincide approximately with the present water table, but at the margins of the dolomite outcrop, especially where no structural complications are present, weathering has proceeded hundreds of feet deeper. Drilling in the cove indicates that if the residual clay were entirely removed, the dolomite would appear as a relatively flat-topped mesa bounded on most sides by cliffs 100 to 200 feet high, which would face the quartzite dip slopes. One such "cliff", in an area of intensive drilling just south of the Peach Orchard mine (35), would show a maximum relief of 250 feet (fig. 3).

The greater depth of weathering at the contact between dolomite and quartzite probably results from a concentration of ground-water circulation on the upper surface of the relatively impervious quartzite. Thus more ground water is directed against the basal layers of the dolomite than against the higher layers, and weathering is more rapid.

Besides producing normal decay of the dolomite into residual clay, processes acting in the zone of weathering have concentrated in the residual clay the oxidized ores of iron, zinc, lead, and manganese which have been the object of mining in the cove.

Jasperoid.—A chert-like form of silica, called jasperoid, is widely distributed in the residual clay of the Shady dolomite throughout the southern Appalachian region. It is especially abundant and well displayed in Bumpass Cove. It forms masses ranging in size from small nodules to blocks 20 feet across and exhibiting a great variety of shapes, though commonly they are almost equidimensional. It is predominantly yellowish brown, but red, deep brown, gray, white, and black varieties are found. The coloring matter is chiefly iron oxide but includes some manganese oxide in the darker varieties. The jasperoid is commonly associated with iron and manganese ore, and indeed almost every gradation can be found from slightly ferruginous jasperoid to slightly siliceous iron oxide. However, a similar gradation from jasperoid to manganese ore has not been observed, and manganese oxide occurs in the jasperoid mainly as dendrites and veinlets, or as small replacement bodies.

The jasperoid is made up in some specimens of an intricate and closely-woven stockwork. In most of these specimens both the veins and the interstices of the stockwork are composed of silica, but in a few the interstices are open and the rock is porous or friable. Larger cavities are common and are lined with mammillary cryptocrystalline silica or, more rarely, with drusy quartz. Molds of dolomite rhombs and silicified oolites can be seen in some blocks of jasperoid in Bumpass Cove, and fossils and carbonate cleavage have been preserved in similar rock near Cartersville, Georgia (Kesler, 1939, p. 337; 1940, fig. 5).

In Bumpass Cove, jasperoid occurs only in residual clay, except that close to the Rock Quarry (9) a small amount is embedded in fractured and iron-stained dolomite. It is most abundant in the clay under the higher terrace remnants, where it occurs with the manganese deposits and with the iron deposits associated with them. It is much less common on the lower terrace remnants, where the oxidized zinc and lead deposits are found. Its distribution in the cove shows no relation to any of the known normal or thrust faults.

Another form of silica occurring in Bumpass Cove and possibly related to the jasperoid is porous and friable light-colored fine-grained quartz, which forms veinlets, crusts, and boxworks in the weathered crust of the dolomite and inconspicuous superficial replacements on its weathered surface. In many places such quartz is closely associated with zinc silicate occurring in a similar manner. Outside of Bumpass Cove, at a few places in the outcrop belt of the Shady dolomite in northeast Tennessee and southwest Virginia, this porous, friable quartz can be found in larger masses, both on exposures of dolomite and free in the residual clay. Even here it never penetrates far into the unweathered dolomite but appears to be a superficial replacement accompanying the weathering of the rock. It differs considerably from the typical jasperoid; however, blocks of a medium-grained sugary form of silica (probably quartz) that occur with the jasperoid both in Bumpass Cove and elsewhere may represent an intermediate material.

The origin of the jasperoid is not certainly known. Kesler

(1939, pp. 336-337) has concluded that the jasperoid in the Cartersville district, Georgia, is of hydrothermal origin, having replaced the dolomite along faults and fractures. Later, during weathering, it was freed from the dolomite and stained by iron and manganese oxides, its color being changed from an original dull gray to the present tints. I have had no opportunity to study the evidence at Cartersville on which this theory is based, and the ensuing discussion must therefore be incomplete and indecisive. However, the evidence in Bumpass Cove appears to preclude the application of Kesler's theory to the jasperoid in the cove. The present distribution of the jasperoid and its absence in the extensive exposures of dolomite in the cove, except in one area where the dolomite is weathered and iron-stained, suggest that it was never present at depth in the unweathered dolomite but was deposited in or close to the zone of weathering.

According to another theory, the jasperoid was deposited by the ground-water solutions that caused the weathering of the dolomite and formed the oxidized zinc deposits. However, the form of silica associated with these deposits and actually replacing the dolomite on weathered surfaces is the porous, friable quartz, whereas the jasperoid is rarely found in clay close to dolomite pinnacles but is associated with the manganese deposits on the higher terrace remnants. Thus the distribution of the jasperoid seems to rule out the theory that it was formed by the processes of weathering now acting. However the fossils, molds of dolomite rhombs, silicified oolites, and carbonate cleavage observed in the jasperoid clearly indicate that it has replaced dolomite. Moreover, the intricate stockwork within it resembles somewhat the veinlets and boxworks of quartz and zinc silicate that have certainly formed during weathering. It is suggested, therefore, that the jasperoid was formed by replacement of dolomite during weathering, but only under unusual climatic conditions that prevailed at the time of formation of the higher terraces and of the manganese deposits and that caused more profound chemical action than takes place in this region at present.

ERWIN FORMATION

The Erwin formation was named by Keith (1903, p. 5) for the town of Erwin, Unicoi County, Tennessee. It is well displayed in the gorge of the Nolichucky River south of Erwin, especially just southeast of Unaka Springs (Keith, 1907; King and others, 1944, p. 29 ff., fig. 6). Typically it consists of green siltstone and silty quartzite, with prominent ledge-making beds of white quartzite near the top and base and thinner beds of white and yellow quartzite and purple ferruginous quartzite in the middle. The purple color of the ferruginous quartzite is caused by hematite finely disseminated through the siliceous cement.

The Erwin formation as exposed in the crest and southeast slope of Embreeville Mountain displays all these characteristics. The quartzite beds near the base and top of the formation make prominent ledges and have been mapped as a lower and an upper member. The quartzite of the lower member approaches fine-grained conglomerate, but that in the upper member is rarely conglomeratic, except in the top few inches of each bed. The quartz grains are well rounded and a few are bluish. The middle member of the formation, lying between the two quartzitic members, consists chiefly of green siltstone and silty quartzite but contains thin beds of purple ferruginous quartzite below the middle and massive beds of white quartzite near the top, the latter forming a gradation to the upper member. The contact between the middle and upper members on Embreeville Mountain is therefore somewhat arbitrary; in general only the upper three quartzite beds and the intervening siltstone have been assigned to the upper member. The thickness of the Erwin formation on Embreeville Mountain is about 2,400 feet.

The beds between the base of the Shady dolomite and the highest continuous white quartzite beds of the Erwin are separately mapped as the Helenmode member of the Erwin formation. The Helenmode member was named by King and others (1944, pp. 31-32) for the Helenmode pyrite mine in Stony Creek Valley, Carter County, Tennessee. The member consists of 50 to 100 feet of green thin-bedded siltstone and sandstone with a few lenses of yellow to white quartzite. As in Stony Creek Valley, the top of the member is formed in many places by a layer of coarse-grained sandstone with dolomitic cement, not unlike the sandstone lenses in the lower white member of the Shady dolomite. On weathering, the dolomitic cement is removed, and the sandstone becomes incoherent. Such material is well described by the local term "fish-egg sand".

In some places the Helenmode member can readily be mapped between the highest white quartzite bed of the Erwin and the yellow residual clay of the Shady, but in others the contacts are obscured by gravel and slope wash. The siltstone beds in the member are well exposed in Ike White Hollow, and quartzite beds assigned to it are exposed in Polly and Wolf Hollows.

On the southeast side of the cove, the upper part of the Erwin formation crops out in the row of hills at the foot of Rich Mountain, being separated from the rocks forming the mountain by a major thrust fault. Here only two white quartzite beds are present near the top of the formation, and they, with the intervening green siltstone, constitute the upper member. The middle member is largely green siltstone but includes several beds of purple ferruginous quartzite, particularly in the hills around the head of Sugar Hollow where such quartzite was once mined as iron ore. White conglomeratic quartzite beds crop out on the ridge east of the cove and near the mouth of Patty Creek, dipping under the ferruginous quartzite and green siltstone at the head of Sugar Hollow; these quartzite beds and the intervening siltstone are correlated with the lower member of the Erwin.

HAMPTON FORMATION

The Hampton formation was named by Campbell (1899, p. 3), at the suggestion of Keith, for the village of Hampton, Carter County, Tennessee. It is well displayed in the gorge of the Doe River through Iron Mountain, just north of Hampton (Keith, 1907; King and others, 1944, p. 35 ff., fig. 5). Typically it consists of green siltstone and shale and includes scattered beds of arkose and quartzite which vary greatly in number and thickness.

In the Bumpass Cove area, the Hampton formation is exposed on the northwest face of Embreeville Mountain, where it can hardly be less than 2,500 feet thick. Three prominent ledge-making beds of quartzite are present near the middle of the formation and have been mapped as a quartzite member within it. The highest of the three beds is strongly feldspathic, but the others are nearly pure quartzite; none of them are coarse-grained. The rest of the formation consists of the same rock types as the typical Hampton.

In the block east of the cove, siltstone, shale, and quartzite exposed near the mouth of Bumpass Cove Creek are believed to belong to the Hampton formation. Massive beds of somewhat feldspathic quartzite, forming prominent ledges and flatiron-like spurs just northwest of Embreeville and southwest along the road to Bumpass Cove, are correlated with the quartzite member on Embreeville Mountain. One of these ledges continues northeast from Embreeville to the river bend a mile downstream, where it makes striking cliffs on both sides of the river, and also a prominent riffle and fall in the channel which supplied water power for an iron furnace, forge, and rolling mill during much of the nineteenth century (Safford, 1869, p. 469).

Both the Erwin and Hampton formations are considerably thicker on Embreeville Mountain than elsewhere in northeast Tennessee, as for example in Stony Creek Valley. The rocks in the Bumpass Cove area were probably deposited somewhat to the southeast of those elsewhere in northeast Tennessee and have been brought to their present position by extensive overthrusting. Presumably, therefore, the clastic rocks near Bumpass Cove are thicker and coarser than those in Stony Creek Valley because they were deposited closer to the original source of the clastic material.

UNICOI FORMATION

The Unicoi formation was named by Campbell (1899, p. 3), at the suggestion of Keith, for Unicoi County, Tennessee. It is well displayed in the gorge of the Nolichucky River through the Bald Mountain Range south of Erwin (Keith, 1907, p. 5; King and others, 1944, p. 37 ff., fig. 6). Typically it consists of coarse arkosic sandstone, quartzite, and conglomerate, with lesser amounts of siltstone and shale.

On the northwest side of Embreeville Mountain, the Unicoi formation is represented by float blocks of highly feldspathic conglomerate on the low knobs north of Potato Hill, about 2,500 feet stratigraphically below the base of the Erwin formation. The float blocks lie between exposures of shaly siltstone (Hampton formation) and limestone and dolomite (Knox dolomite). The latter are in the block over which the rocks of Embreeville Mountain have been thrust.

ROCKS EXPOSED ON RICH MOUNTAIN

The correlation of the rocks exposed on that part of Rich Mountain lying within the area mapped is not certain. The 3,470-foot knob at the southeast edge of the map is underlain by four ledge-making beds of white conglomeratic quartzite. Beneath these, there is about a thousand feet of green silty shale, green and brown siltstone, and brown gritty arkose, with at least one layer of purple shale. Near the foot of the mountain, just southeast of and above the major thrust fault that separates the rocks in the mountain from those around the cove, another group of thick ledge-making conglomeratic quartzite beds crops out. The highest of these beds is strongly arkosic.

On the geologic map and the structure sections, the rocks capping the 3,470-foot knob of Rich Mountain are correlated with the lower member of the Erwin formation, and the rocks below are assigned to the Hampton formation, the ledge-making beds near the fault representing the quartzite member in the Hampton. If this correlation is correct, these rocks are an even coarser phase of the Erwin and Hampton formations than those on Embreeville Mountain.

Another possibility is that these beds represent the Unicoi formation, especially the lower part, in a somewhat shaly facies, for elsewhere in northeast Tennessee purple shale such as that on Rich Mountain is known only in the lower Unicoi. However, the correct correlation can be determined only by careful work on Rich Mountain outside the area here mapped.

ROCK STRUCTURE

The rocks of Bumpass Cove and Embreeville Mountain are folded into a moderately gentle trough or syncline. The axis of this trough lies in the Shady dolomite in Bumpass Cove, and the clastic formations on its simple northwest flank underlie Embreeville Mountain. The southeast flank, which is complicated by folds and faults in the southeast part of the cove and the adjacent hills, is overridden by a major thrust fault separating the rocks of the cove from those in Rich Mountain. The shape of the trough is shown by the structure sections (pl. 2) and structure contour map (pl. 3) of the cove.

Through much of the length of the cove, the axis of the syncline is approximately in the middle of the outcrop belt of the Shady dolomite and pitches gently northeast. Toward the east end of the cove, the Shady dolomite is cut by a few normal faults having displacements of 100 feet or more, and northeast of these the axis is much closer to the northwest side of the cove. Even here it pitches northeast, and the cove does not end by a reversal of the pitch but is cut off by a thrust fault. This thrust fault has considerable displacement here, thrusting the Hampton formation upon the Shady dolomite, but to the southwest it enters the complicated zone on the southeast flank of the main syncline, decreases gradually in throw, and finally dies out in the southwest end of the cove.

Minor folds on the flanks of the main syncline are indicated by dips observed in the Shady dolomite. Two such folds are exposed near the No. 14 mines (25-28) ; they do not extend much farther west but can be traced by subsurface data northeast past the Fowler mine (19) and seem to be represented by a sharp flexure near the center of the Jackson mine (6). The possibly commercial concentrations of sulphide minerals in the cove lie near these folds.

An anticline in the Erwin formation on the southeast side of the cove is broken, from Simmons Branch southwest, by a northwest-dipping thrust fault, along which the Erwin overlies the Shady dolomite. This unusual fault is interpreted as a minor feature of the complicated zone in front of the major southeast-dipping thrust fault at the foot of Rich Mountain, which indeed appears to overlap the northwest-dipping fault near the southwest end of the cove.

Except for this northwest-dipping fault, the thrust faults near the cove appear to dip fairly gently to the southeast, as shown by the pattern of outcrops in the stream valleys. However the fault that cuts off the east end of the cove dips 45° due east in that area, as can be seen in exposures near the mouth of Ike White Hollow and inferred from cleavage in the overlying shale elsewhere along that part of the fault.

In the east part of the cove, the ribboned member of the Shady dolomite is offset by three faults striking northwest and downthrown on the southwest side (fig. 5, p. 41). The westernmost of these faults is well exposed in the Jackson mine (6) where it dips 55° SW.; hence this fault is a normal fault and the others are probably similar. The faults converge to the northwest, the two eastern faults uniting near Bumpass Cove Creek. These normal faults do not offset the margins of the Shady dolomite outcrop; apparently they die out to the northwest before reaching the Erwin contact and are overridden to the southeast by the thrust fault that cuts off the east end of the cove.

The Shady dolomite in the cove is well jointed and in some places is severely fractured and brecciated. Sparry dolomite commonly accompanies the breccia. The joints strike in every direction; a careful study of the joints in the Jackson mine (6) revealed no systematic arrangement (see pl. 5). Severely fractured dolomite, cut by a few normal faults too small to map, is exposed in the face of the Rock Quarry (9), but very little sparry dolomite is present here. Both breccia and sparry dolomite are commonest on the southeast side of the cove, and the sparry dolomite is most abundant near the two folds extending from the No. 14 mines (25-28) to the Jackson mine (6). It is particularly well displayed in the Fowler mine (19).

The rocks of the Bumpass Cove area, both those in the cove and Embreeville Mountain and those in Rich Mountain, are part of a great overthrust sheet that was thrust northwestward for some miles to rest on the Knox dolomite exposed at the northwest edge of the area. The fault on which this thrust sheet moved crops out on the northwest face of Embreeville Mountain. That part of the thrust sheet in which Bumpass Cove lies is an outlier, nearly cut off from its roots by the erosion of the valleys of North and South Indian Creeks southeast of Rich Mountain. The outlier forms the range of mountains that lies between the valleys of those creeks on the southeast and the main Appalachian Valley on the northwest. All these relations were clearly recognized by Keith (1907, pp. 8-9, figs. 1, 2). The overthrust sheet which includes Bumpass Cove is the highest of several sheets which have been recognized in northeast Tennessee (King and others, 1944, pp. 11-13, fig. 2), and which were thrust northwestward to their present positions during the intense deformation which created the Appalachian Mountains of late Paleozoic time.

LAND FORMS

After the deformation of the rocks, the ancestral Appalachian Mountains were subjected to erosion, which has continued to the present. As the Shady dolomite is less resistant to erosion than the clastic formations that surround it, the Bumpass Cove syncline has become a stream valley. On the sides of the valley, within the outcrop belt of the Shady dolomite, are numerous benches at various elevations. Many of them are capped by gravel, but most of them are underlain by bodies of residual clay. They are interpreted as remnants of old valley floors formed during periods when Bumpass Cove Creek was not deepening its valley.

Reconstruction of these old valley floors by correlation of the remnants from one ridge to another is difficult and uncertain. The remnants should not be correlated by comparing their sea-level elevations, for, like the present valley floor, the old valley floors sloped northeastward toward the Nolichucky River. The gradient of the present stream is about 100 feet to the mile. Plate 4 shows two projections of the land forms of Bumpass Cove, on which the benches within the Shady outcrop belt have been emphasized. In a rough way, these benches may be grouped into terraces which probably represent old valley floors.

The high benches between Starnes and Rock Quarry Hollows mark the highest terrace in the cove. Between Rock Quarry Hollow and Madcap Branch no remnants of this terrace are present, but it is probably represented by the 2,350-foot knobs at the southwest end of Embreeville Mountain, which are underlain by residual clay capped by a little gravel. This terrace is about 500 feet above the present stream.

Benches ranging from 420 to 370 feet above the present stream are widely distributed in the cove. They are remarkable because all the larger manganese ore bodies have been found in clay beneath them. Some smaller bodies of manganese ore underlie lower benches, but none have been found under the remnants of the highest terrace.

The benches next below the manganese-bearing benches cover more area in the cove than any others. Much iron ore and some small bodies of manganese ore have been found underlying these benches. They range from 290 to 240 feet above Bumpass Cove Creek.

The lower benches in the cove can readily be grouped into two fairly well defined terraces. The upper of these, which is about 160 feet above the stream, seems to be particularly associated with oxidized zinc and lead ore, although such ore also occurs both higher and lower. The lowest terrace is confined to the vicinity of the stream. It probably merges with the present valley floor near the Peach Orchard mine (35), but farther downstream it is about 80 feet above the creek.

MINERAL DEPOSITS

The mineral deposits of Bumpass Cove may be divided into two classes: primary sulphide deposits in the unweathered Shady dolomite, and secondary oxidized deposits in the residual clay. Only the oxidized deposits have been mined. In the sulphide deposits, the zinc, lead, and iron minerals are mixed in varying proportions; in the oxidized deposits on the other hand, the zinc, lead, iron, and manganese minerals occur for the most part in separate ore bodies.

MINERALS OF THE DEPOSITS

ZINC MINERALS

Sphalerite.—Sphalerite (ZnS) contains 67 percent zinc when pure and has a specific gravity of 4.1. It shows a wide variety of colors and occurrences but can be recognized by its characteristic resinous luster and its six-way cleavage.

The sphalerite in Bumpass Cove is light-colored, ranging from light greenish-yellow to yellowish-brown. It probably contains little iron, but the greenish variety contains some cadmium, for greenockite (CdS) occurs as light greenish or yellowish films in cracks in the dolomite in many places where sphalerite has weathered. Sphalerite occurs in the unweathered dolomite either alone or with the other sulphides. It weathers rapidly and is rarely present in the weathered crust of the dolomite or in the oxidized zinc deposits.

Hemimorphite (calamine).—Hemimorphite ($Zn_4(OH)_2Si_2O_7 \cdot H_2O$) contains 54 percent of zinc when pure and has a specific gravity of 3.45. It is a colorless mineral with a sub-adamantine luster. It is best recognized by its characteristic bladed crystals and crystal rosettes, which commonly line cavities, but it may also be massive. It is not as heavy as most metallic minerals and is easily overlooked.

Hemimorphite is the important constituent of the oxidized zinc deposits in the cove. It occurs chiefly as irregular boxworks scattered in the residual clay, but also in places as veinlets in the weathered crust of the dolomite (perhaps the original condition of the boxworks), as crusts on limonite, and rarely as large pure masses.

Smithsonite.—Smithsonite ($ZnCO_3$) contains 52 percent zinc when pure and has a specific gravity of 4.4. It appears to be much less common in Bumpass Cove than hemimorphite. It is not an important constituent of the oxidized zinc deposits in the residual clay but is present in considerable quantity where sphalerite in the bedrock has been attacked by weathering.

LEAD MINERALS

Galena.—Galena (PbS) contains 87 percent lead when pure and has a specific gravity of 7.5. It is a lead-gray mineral characterized by its high specific gravity, metallic luster, and excellent cubic cleavage.

Galena is less widely distributed in Bumpass Cove than sphalerite but is fairly abundant in a few places. In the bedrock sphalerite is always associated with it. However, galena does not weather rapidly, and it is commonly present in the weathered crust of galena-bearing dolomite as small masses protected by veinlets of quartz or hemimorphite or by coatings of oxidized lead minerals. It is reported that large masses of galena, entirely free from the dolomite, were found in bodies of lead carbonate ore during the early operations at the Peach Orchard mine (35).

Cerussite.—Cerussite ($PbCO_3$) contains 78 percent lead when pure and has a specific gravity of 6.5. It is a white mineral with a brilliant adamantine luster. It commonly occurs in characteristic sheaves of needle-like twinned crystals but may also be massive.

Cerussite is the only important constituent of the oxidized lead deposits in the cove. It normally occurs as fairly pure masses but is also found as flakes disseminated through the clay. It is rarely mixed with zinc or iron minerals.

Anglesite.—Anglesite ($PbSO_4$) is locally present in Bumpass Cove as coatings on weathered galena but is of no economic importance.

MANGANESE MINERALS

Manganese-bearing dolomite.—The presence of manganese in the Shady dolomite has been suggested by several authors (Stose and others, 1919, p. 54; Stose and Schrader, 1923, pp. 22, 25) and recently confirmed by analysis (King and others, 1944, pp. 57-59; this report, page 39). The presence of appreciable amounts of manganese in channel samples of sulphide ore in Bumpass Cove (pp. 58, 65) raised the possibility of determining the state of combination of the manganese. Accordingly, samples were taken in the Jackson mine (6) from the site of channel samples N and O and were submitted to Professor S. J. Shand of Columbia University, who kindly consented to study them. From these specimens, Professor Shand prepared powdered samples of country rock, of sparry dolomite, of sphalerite, and of pyrite for analysis.

In preparing the carbonate powders, chips of country rock only slightly contaminated with sparry dolomite and of sparry dolomite practically free from country rock were broken down to fragments 2 to 4 millimeters across and were cleaned of sulphide minerals by careful inspection under a hand lens. This material was then ground to powder in stages, being inspected for sulphides at each stage. As no sulphides were recognized in the powder, the cleaning was virtually complete. The powders were dissolved in dilute hydrochloric acid and analyzed. According to Professor Shand (personal communication, November 18, 1943), "the insoluble residue was examined under the microscope and found to be chiefly quartz with some specks of opaque iron oxide. As the iron and manganese found in these analyses were easily dissolved by hydrochloric acid, both must have been present in the form of carbonate." The analyses are given in the accompanying table.

Analyses of samples of dolomite from Jackson mine (6), Bumpass Cove, Tennessee

(S. J. Shand, analyst)

	Country rock	Sparry dolomite
CaO	28.82	29.55
MgO	19.59	20.38
SrO	not detected	not detected
FeO	1.07	1.02
MnO	0.21	0.12
CO_2*	45.01	46.40
Insol.	4.96	2.45
Total	99.66	99.92

*CO_2 determined by ignition (corrected for oxidation of ferrous oxide); it probably includes a little moisture which was not separately determined.

Recalculated to carbonates, omitting insoluble material:

	Country rock	Sparry dolomite	Theoretical dolomite
$CaCO_3$	54.36	54.19	54.34
$MgCO_3$	43.47	43.94	45.66
$FeCO_3$	1.81	1.68	----
$MnCO_3$	0.36	0.19	----
Total	100.00	100.00	100.00

The powders of the sulphide minerals were prepared in a similar manner by careful sorting under a hand lens. In addition the pyrite was cleaned by boiling with hydrochloric acid. Final inspection indicated that practically no impurities remained. The powders were dissolved in nitric acid and analyzed colorimetrically for manganese. According to Professor Shand (personal communication, April 6, 1944), "the coloration was so faint that it was obvious there was no more than a trace of manganese in each ore." The results are given in the accompanying table.

Manganese content of sulphide minerals from Jackson mine (6), Bumpass Cove, Tennessee

(S. J. Shand, analyst)

	Sphalerite	Pyrite
Percent Mn	0.005	0.0025
Recalculated as MnO	0.007	0.0033

From these results it is clear that the manganese reported in the channel samples mentioned is chemically combined with the dolomite in the form of carbonate.

Material of psilomelane type.—The hard compact blue-black material hitherto referred to as psilomelane is now known to consist of any of several manganese minerals, especially cryptomelane, psilomelane (in the strict sense), and hollandite (Fleischer and Richmond, 1943). These minerals cannot be distinguished from each other except by careful laboratory work, and in the field such material is best referred to as of "psilomelane type". Of these minerals, only cryptomelane has so far been certainly identified in material from Bumpass Cove, but psilomelane and hollandite have been found elsewhere in northeast Tennessee and may well occur in the cove[3]. Pure cryptomelane contains almost 60 percent manganese and has a specific gravity of about 4.3, but the manganese content of the material of psilomelane type in Bumpass Cove probably does not exceed 52 percent, and the specific gravity ranges from 3.0 to 4.5 (Reichert, 1942, p. 12).

Material of psilomelane type is the most important constituent of the manganese deposits in Bumpass Cove and occurs as hard nodules irregularly distributed in the residual clay. Some of the nodules are structureless, others are concentrically banded. Such nodules constitute most of the run-of-mill concentrates shipped from the cove.

Pyrolusite.—Pyrolusite (MnO_2, commonly with a little nonessential water) contains 63 percent manganese when pure and has a specific gravity of about 5.0. It is a blue-black crystalline mineral occurring in both well crystallized and friable varieties.

In Bumpass Cove the well crystallized variety of pyrolusite is found sparingly as nodules in the clay. Most of it has hitherto been referred to the mineral manganite ($MnO(OH)$), but laboratory work has shown it all to be pyrolusite. The nodules commonly exhibit parallel or radiating sheaves of needle-like crystals and some of them are banded with concentric layers of material of psilomelane type. The friable variety of pyrolusite is also found as layers in the nodules but occurs more commonly as a soft powder mixed with the residual clay in irregular stringers and bands. Nodules containing pyrolusite constitute most of the hand-picked high-grade manganese concentrates shipped from the cove, but the

[3]Identifications of manganese minerals in northeast Tennessee have been made by J. M. Axelrod and Michael Fleischer in the laboratories of the U. S. Geological Survey, and are reported by King and others (1944, esp. pp. 263, 270).

soft powder is ordinarily lost when the ore is washed.

Wad.—Wad is soft brown or black amorphous material, consisting of manganese oxide with many impurities. The manganese content ordinarily ranges from 30 to 40 percent. Most of the wad in Bumpass Cove is hardly more than a stain in the clay, and it is of no economic importance.

Perhaps to be classed with wad is certain soft dark homogeneous graphite-like material that occurs in the West Baptist Hollow mine (41) and the West Ore Bank (42) as envelopes around blocks of jasperoid and as stringers in the residual clay. It forms fibrous and flaky masses and is commonly purplish and iridescent. X-ray studies of samples of this material do not give a clear indication of its mineral composition (Axelrod, J. M., personal communication, 1943).

IRON MINERALS

Pyrite.—Pyrite (FeS_2) contains 47 percent iron when pure and has a specific gravity of 5.0. It is a hard brassy-yellow mineral, commonly crystallizing in small cubes or pyritohedra.

Pyrite is common and widespread in Bumpass Cove, but in some concentrations of the other sulphides it is virtually absent. It commonly occurs in knots as much as an inch across in the dolomite. On weathering it decomposes, the iron making rusty stains on the dolomite and the sulphur, oxidized to sulphate, forming alum which accumulates in protected places on the surface of the dolomite.

Iron-bearing dolomite.—The presence of iron in the Shady dolomite has already been mentioned (p. 13). The analytical work done by Professor Shand (p. 27) shows that the iron is present in part at least as carbonate, presumably in ankerite ($Ca(Mg,Fe)(CO_3)_2$).

Limonite.—The hydrous iron oxide minerals are here grouped under the term "limonite". The iron content probably ranges from 50 to 60 percent, and the specific gravity from 3.6 to 4.0.

Limonite is abundant in the residual clay in Bumpass Cove. Although gradations are also present, most of it appears in one or other of two forms: dark-brown crusts and boxworks in clay around dolomite pinnacles, or yellowish-brown nodules in clay banks showing no dolomite. The dark-brown crusts and boxworks are coated in many places with small crystals and crystal aggregates of hemimorphite, and limonite of this type occurs as an impurity in many of the oxidized zinc deposits. The nodular limonite is associated rather with the manganese deposits, in which it is a common impurity, and individual nodules in a given clay bank may have every composition from that of limonite to that of material of psilomelane type. Limonite is practically the only constituent of the oxidized iron deposits of the cove.

Hematite.—Hematite (Fe_2O_3) occurs in Bumpass Cove mixed with the nodular limonite, to which it gives a yellowish-red color. It is also present in the cement of the ferruginous quartzite in the Erwin formation, which was mined as iron ore for a brief period.

GANGUE MINERALS

Dolomite.—Dolomite ($CaMg(CO_3)_2$) is a transparent, translucent, or white mineral with rhombohedral cleavage. It can be distinguished from calcite ($CaCO_3$) by its feeble reaction to cold dilute hydrochloric acid and to staining solutions such as iron chloride and copper nitrate, and also by its indices of refraction and its tendency to crystallize in simple rhombohedra, commonly with curved faces. Dolomite has a specific gravity of 2.9.

In addition to being the major constituent of the country rock, dolomite in coarsely crystalline masses (here called sparry dolomite) is practically the only gangue mineral in the sulphide deposits of Bumpass Cove. Vein calcite is rare in the cove and is nowhere associated with the sulphide deposits.

Quartz and other forms of silica.—Silica (SiO_2) forms both quartz, a hard colorless glassy mineral without apparent cleavage, and various cryptocrystalline substances. The specific gravity of quartz is 2.65, that of the cryptocrystalline forms of silica is but little less.

A number of different forms of silica occur in Bumpass Cove. Sandy and silty impurities, presumably composed chiefly of quartz, and nodules of chalcedonic chert occur in the unaltered Shady dolomite. Cavity fillings of quartz occur in the coarsely crystalline white dolomite associated with the sulphide deposits. Light-colored porous and friable quartz occurs as crusts and boxworks on weathered surfaces of the dolomite and associated with hemimorphite and dark-brown limonite in the oxidized zinc deposits. Small amounts of a cryptocrystalline form of silica occur as thin crusts on nodules in the manganese deposits, and great quantities of jasperoid are scattered through the clay containing the manganese and associated iron deposits, contaminating the ore and often making mining difficult.

OCCURRENCE AND ORIGIN OF THE DEPOSITS

SULPHIDE DEPOSITS

The sulphide deposits of Bumpass Cove consist of sphalerite, galena, and pyrite disseminated in the Shady dolomite in widely varying proportions. They resemble in many respects the zinc and lead sulphide deposits of southern Wythe County, Virginia, which also occur in the Shady dolomite. These deposits have recently been described by Currier (1935) and his conclusions regarding them apply also to the deposits in Bumpass Cove.

The known occurrences of possibly commercial zinc sulphide deposits in Bumpass Cove are restricted to a belt on its southeast side, reaching from the Jackson mine (6) to the Dry Branch mine (29). No sizable deposits of zinc, in either sulphide or silicate form, have been found northeast of the normal fault in the Jackson mine. Channel samples of the sulphide-bearing dolomite in the Jackson and Fowler (19) mines assayed from 2.0 to 7.2 percent zinc, and grab samples from the Jackson mine have assayed as high as 10 percent zinc. The underground workings of the Embree Iron Co. No. 14 mine (27) and of the Dry Branch Mine (29) also encountered sulphides. Blocks of dolomite containing both sphalerite and galena can be seen on the dump at the latter mine, but the workings of both mines have caved and no representative samples could be taken. Southwest of the Dry Branch mine, zinc and lead sulphides were not observed during the present investigation. The evidence at hand does not permit calculations of tonnage and grade of ore anywhere in the belt.

This belt of sulphide deposits closely follows the axes of the two folds that extend from the No. 14 mines (25-28) northeast toward the Jackson mine (6). In the Jackson mine, the sulphide minerals are especially concentrated close to two marked flexures, one at the southwest end of the mine and the other near its center (see pl. 5). The latter is believed to be the northeastern continuation of the folds at the No. 14 mines. In the concentration at the southwest end of the mine, pyrite strongly predominates over sphalerite, and galena is entirely absent, but in the concentration near the center of the mine, from which the channel samples were taken, pyrite is subordinate to sphalerite, and galena is common in some places though absent in most. In these concentrations the sulphides range through a considerable thickness of beds including both white and blue-gray dolomite.

In the Fowler mine (19) on the other hand, concentrations of sphalerite are found in at least five places along the outcrop of a single bed; this is not more than 10 feet thick and now consists largely of breccia cemented by sparry dolomite. The beds above and below this bed also contain much sparry dolomite but are not brecciated and contain little or no sphalerite. In general, however, the sulphide deposits of the cove occur at several stratigraphic levels and are known in all the members of the Shady except the lower white member.

The distribution of the sulphides, even in mineralized areas, is very irregular, spots with a relatively high concentration commonly being surrounded by nearly barren dolomite. The sulphide minerals occur only in rock containing considerable quantities of sparry dolomite. In addition, sulphide concentrations of possible economic value seem to be confined to rock in which the deposition of this sparry dolomite has accompanied brecciation.

In many places, the individual grains of the sulphide minerals show a marked preference for the borders of the sparry dolomite. This relation is especially well shown in parts of the Jackson mine (6) ; in some places in this mine the sparry dolomite forms veins and stockworks cementing a breccia in white massive fairly fine-grained dolomite, and the sulphides occur in large part as very thin but nearly continuous sheets at the borders of the veins. The sphalerite along these borders is greenish gray and occurs in minute grains; contrasting with it in some places are larger grains of golden-brown sphalerite near the middle of the bodies of sparry dolomite. In most places in the cove, however, the sulphide grains are less systematically distributed in relation to the borders of the sparry dolomite, and in some places, especially where associated with breccia in the blue-gray dolomite, they are rather evenly disseminated through both the sparry dolomite and the country rock.

Sulphide minerals have not been found in the numerous cavities in the sparry dolomite. In a few places, they appear to form cross-cutting veins, but some at least of these are replacements of pre-existing veins of dolomite. Comb structure has not been observed.

The close relation of the sulphide deposits to brecciated country rock and the accompanying sparry dolomite and to the two folds mentioned strongly suggests that the deposits were formed at about the time of the deformation that created the structural features, and that the solutions that introduced the sulphide minerals were the same as those that formed the sparry dolomite. It is believed that these solutions ascended from below, and that the zinc and lead were not originally derived locally from sphalerite and galena disseminated in small quantities through the Shady dolomite but were brought up by the solutions from some deeper source.

OXIDIZED ZINC AND LEAD DEPOSITS

The oxidized zinc and lead deposits of Bumpass Cove consist almost entirely of hemimorphite (calamine) and cerussite in residual clay of the Shady dolomite. The two minerals are in general restricted to limited portions of the clay, forming distinct ore bodies with fairly sharp contacts against barren clay, but these ore bodies are very irregular in shape and sporadic in distribution. Given ore bodies contain hemimorphite only or cerussite only, so that satisfactory separation between zinc and lead ore is easily effected during mining, but bodies of both kinds of ore may occur in the same general area. Most of the bodies of oxidized zinc ore lie in contact with the dolomite, either plastered against the sides or tops of pinnacles or situated in pockets or crevices between them. Locally the weathered crust of the dolomite contains enough hemimorphite to constitute ore; at such places smithsonite may accompany hemimorphite. The lead ore bodies normally occur a little higher in the clay and do not hug the pinnacles, but they also are chiefly in the lower part of the residual clay blanket. Figure 4 is a highly idealized diagram showing these relations.

No calculations of the actual percentage of zinc or lead in bodies of clay are available, as assays of oxidized ore in the cove have always been made on washed samples, but in most cases the metallic content of a body of oxidized ore would considerably exceed that of an equivalent volume of sulphide-bearing dolomite of the grade hitherto found in the cove. The actual zinc content, before washing, of an average body of oxidized zinc ore may perhaps be roughly estimated to be between 10 and 15 percent.

Within the ore bodies, the hemimorphite and cerussite occur in masses of all sizes from large lumps to very fine particles. In the Peach Orchard mine (35), masses of cerussite several feet across have been found, and in the mines on Simmons Branch (30, 31) there were masses of hemimorphite so large that blasting was required to remove them. Different bodies of each kind of ore present diverse appearances, depending on the color of the ore-bearing clay and the size of the included lumps or particles of the ore minerals, and the miners have come to recognize and distinguish several types or "colors" of both zinc ore and lead ore. The lumps of hemimor-

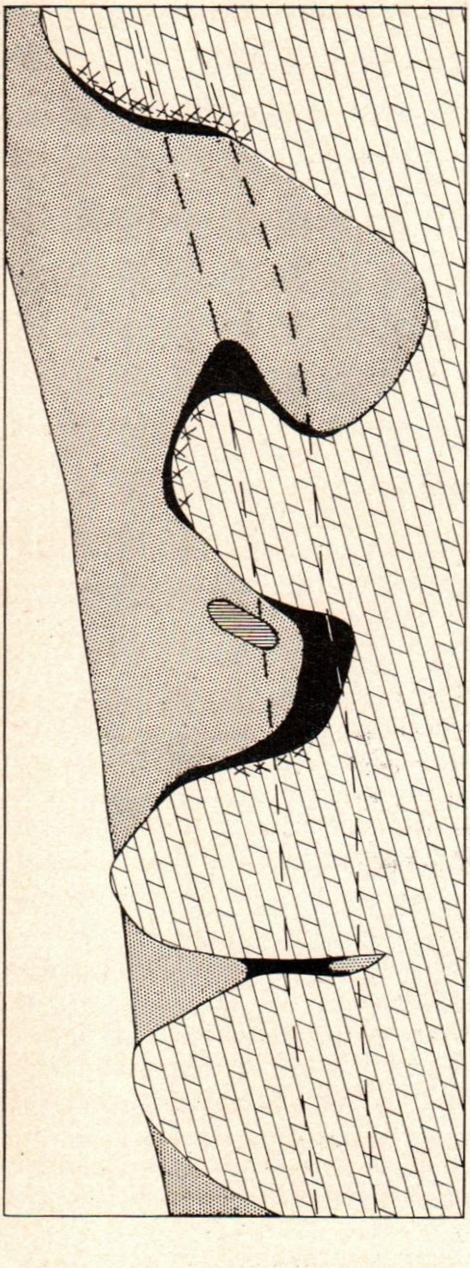

FIG. 4 IDEALIZED DIAGRAM SHOWING RELATION OF OXIDIZED ZINC ORE BODIES AND OXIDIZED LEAD ORE BODIES TO BEDROCK AND WATER TABLE, BUMPASS COVE, TENNESSEE.

phite are commonly in the form of boxworks and in places are contaminated with dark-brown limonite and porous, friable quartz; the lumps of cerussite are more commonly structureless and are normally pure. The finer particles of each are so intimately mixed with the clay that they are not recovered by the milling methods employed but are washed out with the clay into tailing ponds. The hemimorphite occurring in the weathered crust of the dolomite is in the form of veinlets.

Except for an area around the Rock Quarry Hollow zinc mine (22), bodies of oxidized zinc ore have been mined only in a belt along the southeast side of the cove from the No. 10 mine (2) to the Peach Orchard mine (35) and the Lick Log shafts (37). The mines in the eastern part of this belt were iron mines in which zinc occurred as an impurity, but those from the Fowler mine (19) southwest were primarily zinc mines, and the Peach Orchard mine has been the most productive zinc mine in the cove. Some lead ore has been mined in the Jackson mine (6), in the western part of the Fowler mine (19), and in a few other places in the central part of the cove, but most of the lead produced in Bumpass Cove has come from the Peach Orchard mine (35) and its immediate vicinity.

The central part of the belt of oxidized zinc deposits coincides approximately with the belt in which sulphides are relatively abundant. Nevertheless, even in this area there seems to be no relation in detail between the occurrence of sphalerite in the dolomite and that of hemimorphite in the clay, and in many cases bodies of oxidized zinc ore lie against pinnacles of dolomite quite barren of sulphides. Similarly the hemimorphite occurring as veinlets in the weathered crust of the dolomite is by no means confined to rock that contains sphalerite where unweathered. At the Peach Orchard mine (35), although it has been the most productive zinc and lead mine in the cove, neither sphalerite nor galena can be observed in the dolomite pinnacles now exposed.

Bodies of oxidized zinc and lead ore seem to be restricted to clay underlying remnants of the lower terraces. They range as high as the terrace 290 feet above the present stream, but are commonest under the 160-foot terrace. In many places they lie close to the present water table, suggesting that the deposition of the oxidized minerals may be favored at the water table.

There can be little doubt that the oxidized zinc and lead deposits have resulted from the weathering of dolomite containing zinc and lead sulphides, and the alignment of the oxidized zinc deposits along the disturbed southeast side of the cove probably reflects the structural control that governed the deposition of the sulphide deposits. The simplest explanation of their formation would be that the metallic elements were oxidized in place, without appreciable migration. As weathering attacked the sulphide-bearing dolomite, sphalerite was converted to smithsonite and galena became coated with anglesite and cerussite. After the dolomite had been completely dissolved, these minerals remained in the residual clay, and circulating meteoric water continued the process of forming cerussite and converted the zinc to hemimorphite. This water must have been rich in dissolved silica as well as carbonate and may have resembled the solutions that deposited the jasperoid. As a given body of clay represents the residuum of a considerably larger body of dolomite, the percentage of zinc and lead in the clay would be considerably higher than in the dolomite, even if no migration had taken place.

However, oxidation of the sulphide minerals in place explains neither the peculiar distribution of the zinc ore bodies with respect to dolomite pinnacles, many of them barren of sulphides, nor the nearly complete separation of the two metals from each other. These relations indicate that, in addition to oxidizing the metallic elements as outlined above, the circulating water dissolved them, especially in the upper part of the residual clay blanket, carried them downwards, and redeposited them as hemimorphite and cerussite under favorable conditions at or near the water table. The resemblance of the boxwork structure of much of the hemimorphite in the clay to the hemimorphite veinlets found in the weathered crust of the dolomite suggests that much of the zinc was actually deposited within the weathered crust, so that as weathering proceeded ore bodies closely parallel to the retreating surface of the dolomite were built up in the clay adjacent to the dolomite. Moreover, during the erosion of the present stream valley, the water table has continually fallen, and bodies of oxidized ore left above it may have been repeatedly dissolved and redeposited at lower levels. The rich deposits of the Peach Orchard area may thus result from the concentration, into a small body of clay, of the metallic content from great volumes of sulphide-bearing dolomite long since eroded away. The water that accomplished this repeated solution and deposition apparently dissolved zinc salts somewhat more readily than lead salts and thus separated the two metals, carrying the zinc deeper. Naturally such processes could operate only in a humid region with an abundant circulation of meteoric water, yet with erosion never so rapid as to remove the residual clay blanket. The relation of the deposits to the present water table suggests that these processes are still at work.

OXIDIZED MANGANESE DEPOSITS

The manganese deposits of Bumpass Cove consist of several oxidized manganese minerals occurring in the residual clay of the Shady dolomite. They closely resemble the manganese deposits found in the residual clay of the Shady dolomite elsewhere in the southern Appalachian region (Stose and others, 1919; Stose and Schrader, 1923; Kesler, 1940; King, 1943; Knechtel, 1943; Stead and Stose, 1943; King and others, 1944; Miller, 1944).

The manganese ore bodies form irregular streaks and pockets in the clay. Many of them have a long dimension parallel to the strike of the nearest exposed bedrock (in most places the top of the Erwin formation), but the dip or pitch of the bodies is commonly steeper than that of the bedrock, and some of them are nearly vertical. Within the ore bodies, hard nodules of various manganese minerals are scattered through the clay, which they have apparently replaced, and much powdery pyrolusite and some wad are disseminated in certain layers or streaks. Only the nodules are recovered by the milling methods employed. Nodules of yellowish-brown limonite and masses of jasperoid contaminate the ore. An overburden of gravel including large quartzite boulders is present over most of the ore bodies. Dolomite has not been encountered in any of the manganese deposits.

The known manganese deposits lie in a belt along the northwest side of the cove from the Polly Hollow mine (16) to and beyond the Lick Log shafts (37). Thus the belt of manganese deposits intersects the belt of oxidized zinc deposits in the southwest end of the cove. The Baptist Hollow mines (40, 41) and the West Ore Bank (42), which lie near the center of the belt, have produced most of the manganese ore mined in the cove, the West Ore Bank alone being credited with more than half of the total production.

As elsewhere in northeast Tennessee, many of the manganese ore bodies lie close to the top of the Erwin formation, but the East Baptist Hollow (40) and Casey Hollow (39) mines can hardly be less than 250 feet vertically above it, and the clay in those mines may well have been derived from dolomite higher still. The elongation of many of the ore bodies parallel to the strike of the bedrock suggests some stratigraphic control of the ore. The ore bodies do not appear to be related to any structural features, and manganese deposits are rare on the structurally complex southeast side of the cove.

The larger manganese mines from the Casey Hollow mine (39) to the West Ore Bank (42) and the smaller manganese mines and prospects near them are all in clay underlying remnants of the higher terraces, especially those 370 to 420 feet above the present stream. The manganese found in the southwest part of the cove, however, is under lower terrace remnants, and some near the Lick Log shafts (37) is under the present valley floor. Bodies of oxidized zinc and lead ore occur in the same area and have even been mined from the same shaft as the manganese ore, but the manganese bodies lie at higher levels in the clay.

Stose and others (1919, p. 54) have suggested that the manganese deposits in the residual clay of the Shady dolomite were formed by the concentration of manganese "originally widely disseminated as carbonate" in the lower part of the Shady. "When the rocks weathered, the manganese was dissolved as bicarbonate by circulating underground water, was transported along favorable channels, and was deposited as oxides in the clays produced by the previous decay of impure limestone, dolomite, and sericitic shales" (Stose and others, 1919, pp. 54-55). With a view to testing this hypothesis, the core of diamond drill hole No. 1, drilled by the U. S. Bureau of Mines near the Jackson mine (6) (see pp. 9-12), was sampled, and the samples were analyzed for manganese in the laboratory of the Geological Survey. The results are given in the accompanying table.

Manganese content of samples from U. S. Bureau of Mines diamond drill hole No. 1, Jackson mine (6), Bumpass Cove, Tennessee

(W. W. BRANNOCK, analyst)

Depth (in feet)	% MnO	Depth (in feet)	% MnO	Depth (in feet)	% MnO
104 -107	0.23	194 -199	0.63	285 -290	0.18
107 -110	0.33	199 -203½	0.51	290 -295	0.18
110 -115	0.28	203½-209	0.72	295 -300	0.18
115 -120	0.19	209 -213	0.83	300 -305	0.17
120 -125	0.24	213 -217	0.71	305 -308	0.27
125 -131	0.25	217 -222	0.61	308 -313	0.19
131 -138½	0.23	222 -226½	0.61	313 -316	0.18
		226½-230½	0.27		
138½-143½	0.48			316 -320	0.15
143½-148½	0.44	230½-235½	0.29	320 -324½	0.15
148½-153½	0.35	235½-240	0.39	324½-327	0.20
153½-158	0.33	240 -245	0.36	327 -330½	0.05
158 -162	0.34	245 -250	0.40	330½-337	0.06
162 -167	0.41	250 -255	0.30	337 -344	0.04
167 -171½	0.49	255 -260	0.27	344 -350½	0.05
171½-176	0.63	260 -265	0.23	350½-357	0.04
176 -180	0.61	265 -270	0.36	357 -364	0.05
		270 -275	0.32	364 -371	0.03
180 -185	0.42	275 -279½	0.32	371 -378½	0.05
185 -189½	0.54				
189½-194	0.72	279½-285	0.13	378½-390	0.02

Summary

Unit	True thickness sampled (in feet)	Average % MnO
Shady dolomite		
Upper white member	32½ sampled	0.25
Upper blue member	38½	0.45
Ribboned member	43	0.60
Lower blue member	47	0.31
Lower white member	34½	0.18
Erwin formation		
Helenmode member	61½	0.07
Upper quartzite member	11½ sampled	0.02

In addition, the percentage of manganese soluble in dilute nitric acid was determined for several of the dolomite samples, and as these checked closely with the determinations of total manganese, it can be assumed that all the manganese present in the Shady dolomite is in a soluble form, almost certainly manganous carbonate. These results, taken in conjunction with the analyses given on page 27, offer virtually conclusive proof that manganese carbonate, deposited with the original carbonate rock that is now the

Shady dolomite, is the ultimate source of the manganese deposits of Bumpass Cove, and presumably of other similar deposits. It is probably merely a coincidence that both manganese and zinc deposits occur in the cove.

Economic deposits of manganese oxides, not only in Bumpass Cove but elsewhere in northeast Tennessee, occur very largely in residual clay underlying remnants of high terraces. The concentration of the manganese as oxide and of the associated limonite and jasperoid may have been especially favored under unusual conditions which prevailed at the time of formation of the valley floors represented by those terrace remnants, conditions which no longer prevail. What these unusual conditions were is not known, but it is probable that chemical action was more profound than at present, stimulating the solution, transportation, and deposition spoken of by Stose and others (loc. cit.), and it may be suggested that the climate was more tropical and perhaps more humid.

OXIDIZED IRON DEPOSITS

The oxidized iron deposits of Bumpass Cove consist of limonite occurring in the residual clay. In a broad way, the deposits appear to fall into two classes, corresponding to the two forms of limonite that have been recognized in the cove, the boxwork type and the nodular type. Both types were extensively mined before 1909.

The boxwork type of limonite was mined chiefly in the great hydraulic open cuts near Bumpass Cove Creek, from the Fowler mine (19) northeast. All these mines except the Jackson mine (6) expose the ribboned member of the Shady dolomite, and they occur in a belt that follows the outcrop of that member and is offset with it by the normal faults in the eastern part of the cove (fig. 5). Along this belt, the degree of recrystallization of the ribboned dolomite to sparry dolomite ranges from well over 50 percent in the Fowler mine (19) to slight or virtually nothing in the Lower Peedee mine (8), and there is no apparent structural control of the iron ore. All these mines underlie remnants of fairly low terraces, except for the southeast portions of the No. 10 (2), Yates Hollow (4), and Fowler (19) mines; but these portions were excavated chiefly in clay and resemble rather the group of mines next discussed, as the limonite tends to be nodular.

The nodular type of limonite was mined in the many iron mines which were excavated entirely in clay and which commonly show great quantities of jasperoid. One of the largest of these

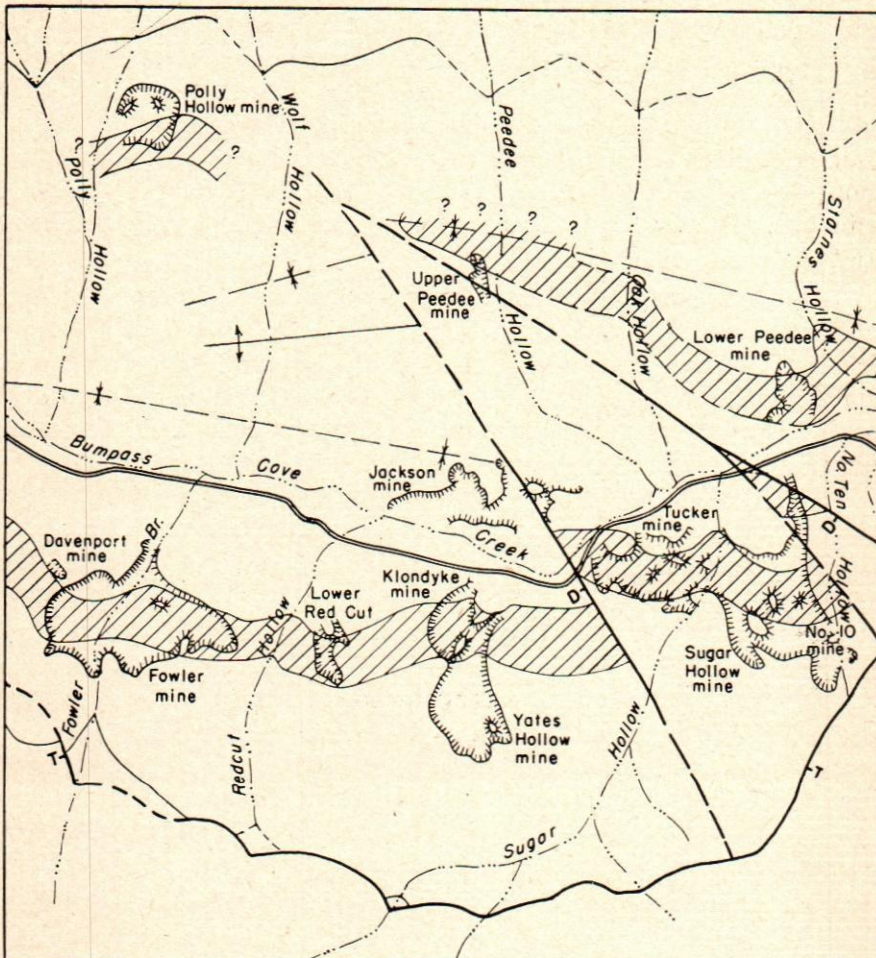

FIGURE 5. Map of part of Bumpass Cove, showing relation of hydraulic iron mines to ribboned member of Shady dolomite. Ruled area represents outcrop of ribboned member.

mines is the West Ore Bank (42); most of them are quite small. They do not show any structural control but are scattered throughout the cove; however, they are almost all in clay under remnants of the higher terraces and in general appear to be fairly low, stratigraphically, in the Shady dolomite. The Polly Hollow mine (16) apparently belongs to this group although pinnacles of dolomite which may belong to the ribboned member are exposed in its lower part. Limonite of nodular type also occurs in the upper, southeast portions of the No. 10 (2), Yates Hollow (4), and Fowler (19) mines, which were excavated in clay underlying remnants of high terraces and containing much jasperoid.

As the boxwork type of limonite is associated in some places with the oxidized zinc deposits, it has probably had a similar history. However, the distribution of this type of limonite shows little relation to the known distribution of the sulphide deposits or to the structural features that controlled them, and the iron probably came not only from pyrite but also from iron-bearing dolomite, occurring especially in the ribboned member. The intimate association of the nodular type of limonite with nodular manganese ore suggests that the nodular limonite was deposited under the same unusual conditions that brought about the deposition of the manganese, and that the source of the iron was iron-bearing dolomite in the lower part of the Shady dolomite.

The purple ferruginous quartzite beds in the middle member of the Erwin formation have attracted attention as a possible iron ore and were once mined from a group of adits known as the Tunnel mine (11), near the head of Sugar Hollow. Assays of this rock, quoted by Jarvis (1912, pp. 330, 357), indicate a maximum of 40 percent iron and a minimum of 36 percent silica (see p. 60). The material was soon found to be unsuitable as iron ore, and the mine was abandoned.

HISTORY AND PRODUCTION[4]

The lead and iron deposits of Bumpass Cove attracted the attention of the earliest settlers in east Tennessee. According to local tradition, iron ore was first mined in the cove during the Revolutionary War by John Sevier, who later became the first governor of Tennessee, and bullets of lead from the Jackson mine (6) were used by him and his men in the battle of Kings Mountain in 1780. Lead

[4] In preparing this summary of the history of mining in Bumpass Cove, I have had the benefit of many discussions with Mr. Paul M. Fink of Jonesboro, Tennessee, who through many years has been assembling information on the early history of the cove (Fink, 1944).

was probably mined here for bullets as late as the Civil War.

Early in the nineteenth century, a charcoal iron furnace was built in the cove at the mouth of Red Cut Hollow; it operated on limonite from the central and eastern parts of the cove. The iron produced by the furnace was treated in a forge and rolling mill located at the riffle in the Nolichucky River, about a mile below the present site of Embreeville. In the 1830's, another furnace was built on Clark Creek at the mouth of Furnace Stack Hollow, just west of the cove, using ore carried over the mountain from the West Ore Bank (42); this furnace was operated only for a short time, but it is still standing. Later, perhaps as late as the Civil War, a large furnace was erected at the riffle in the Nolichucky (see Frontispiece), ore being barged down the river from the cove. In 1854, the iron works on the Nolichucky was the most important in northeast Tennessee (Safford, 1856, pp. 51, 56), and during the Civil War it was a significant source of iron for the Confederate States. After the war, the furnace was operated for a few years in the 1870's and then was abandoned (Killebrew, 1881, p. 26).

In 1889, during a widespread iron and land boom in the South, most of Bumpass Cove was bought by the Embreeville Freehold, Land, Iron & Railway Co., Ltd., an English corporation. Grandiose schemes for industrial development were made and a city was laid out on the present site of Embreeville. In 1890 a branch of the Southern Railway was completed to the town, and in 1891 and 1892 a 100-ton iron furnace of Pittsburgh type was constructed there. After the furnace had been in blast about a year, the company failed in the panic of 1893, and development ceased.

In 1895 the property came into the possession of George Babington Parker of London, England, and late in that year operations were resumed. In 1896 Parker assigned the property to the Embreeville Iron Co., Ltd.; in 1899 it was sold to the Virginia Iron, Coal & Coke Co., an American concern which was then mining iron in other parts of northeast Tennessee and southwest Virginia. This company introduced hydraulic mining into the cove, but operated there only a little more than a year. In 1903 the present Embree Iron Co. bought the property and resumed hydraulic mining. The furnace, however, was not well adapted to the Bumpass Cove limonite and demanded more ore than the mines were ordinarily able to supply, so that iron ore had to be shipped in from other districts. As a result operations became unprofitable, and in 1909 the company went into receivership.

The excellent quality of the iron produced at Embreeville was known throughout the South. "The pig iron has always been unusually low in phosphorous for ores of this class, very low in sulphur, and with 0.4 to 0.6% manganese. The tensile strength is very high, tests showing it to be 24,000 pounds per square inch". (Jarvis, 1912, p. 356, who abstracted this information from Johnson, 1896.)

The presence of zinc and lead in the iron ore in Bumpass Cove was known for many years (Troost, 1840; Safford, 1869, p. 451) and zinc dust from the furnace flues was occasionally shipped, but in general the zinc was merely regarded as an undesirable impurity. While the Embree Iron Co. was in receivership, C. A. Morris, who had previously been associated with zinc mining in the Bertha-Austinville district in southern Wythe County, Virginia, and who was in charge of the Embreeville property, conducted experimental tests and early in 1913 shipped as zinc concentrates rock that had been discarded as waste during the iron operations. When these shipments proved that the zinc silicate ore was of commercial value, the Embree Iron Co. was reorganized and the production of zinc began in earnest (Maxwell, 1913; Byrne, 1913; anonymous, 1913). An intensive campaign of churn drilling was carried on from 1913 to 1921, and a number of fairly large bodies of zinc silicate ore were located. In 1913 mining began in certain of the preexisting hydraulic cuts, especially the Fowler mine (19), and shortly afterwards the No. 13 (23) and 14 (27) mines and the Peach Orchard mine (35) were opened. The present mill was completed early in 1915. The drilling also disclosed bodies of lead carbonate ore, especially in the Peach Orchard area, and lead shipments commenced in 1917. Some iron ore was produced as a byproduct from 1915 to 1918; however it was not smelted in the furnace at Embreeville but was shipped to other furnaces. The Embreeville furnace was dismantled in 1918.

When the presence of commercial zinc ore in the cove became known, the Tennessee Zinc & Lead Co. was organized to mine zinc in certain tracts in the cove that were not under the control of the Embree Iron Co. This company operated without much success from 1913 to 1917; its production is unknown but was probably small. No further mining has been done on these tracts; about 1940 the Embree Iron Co. acquired title to them.

In 1926 mining in the cove virtually ceased, but at about the same time a new drilling campaign was begun. A number of fairly small bodies of oxidized zinc ore lying between the Fowler mine

(19) and the Peach Orchard mine (35) were discovered, and beginning in 1928 the Embree Iron Co. mined these ore bodies. In addition, much mining was done under contract, particularly in the older mines, and from 1931 to 1935 such contract work was the only mining done in the cove, as the company confined itself to milling the ore produced.

Manganese was first discovered in the cove not long after 1900, but no effort was made to exploit it. In 1918 some prospecting was done and bodies of ore were discovered, but at that time no manganese was shipped (Stose and Schrader, 1923, pp. 83-86). In 1935 the company began underground mining in these manganese ore bodies. At about the same time, drilling and mining for zinc and lead were resumed, particularly in the Peach Orchard area, but the production of manganese quickly outstripped that of zinc and lead. Churn drilling was begun in the manganese area in 1937 and larger bodies of ore were blocked out; from 1938 to 1941 these ore bodies were mined by power shovel in large open cuts. In 1939 the Embree Iron Co. was the largest producer of metallurgical-grade manganese concentrates in the United States. However, the ore available to power-shovel methods was quickly exhausted, and early in 1941 all mining in the cove was suspended.

In the spring of 1942 hand mining of zinc, lead, and manganese was resumed, partly on ore previously blocked out, and partly following a drilling campaign in the Peach Orchard area. The ore bodies mined were small, one being opened up as another was exhausted. Early in 1943 power shovels and carryalls were installed to strip the overburden from ore bodies in the Peach Orchard mine (35) and the West Ore Bank (42), but the ore laid bare was mined by hand.

In July 1943 the Embree Iron Co., holdings in Bumpass Cove were sold to the Tennessee Zinc Co., Inc., of Embreeville.

Mineral production of Bumpass Cove

Compiled from records of Embree Iron Co. and Tennessee Zinc Co. (a) and reports of Chief Mine Inspector of Tennessee (b).

Year	Iron conc. (c) (long tons)	Zinc conc. (d) (short tons)	Lead conc. (e) (short tons)	Manganese concentrates Metallurgical (f) (long tons)	Manganese concentrates Chemical (g) (short tons)
1896	67,000	------	------	------	------
1897	90,000	------	------	------	------
1898	61,500	------	------	------	------
1899	56,721	------	------	------	------
1900	27,108	------	------	------	------
1901	------	------	------	------	------
1902	------	------	------	------	------
1903	------	------	------	------	------
1904	2,002	------	------	------	------
1905	40,907	------	------	------	------
1906	52,912	------	------	------	------
1907	58,726	------	------	------	------
1908	21,225	------	------	------	------
1909	7,882	------	------	------	------
1910	------	------	------	------	------
1911	------	------	------	------	------
1912	------	------	------	------	------
1913	------	907	------	------	------
1914	------	4,874	------	------	------
1915	2,167	8,633	------	------	------
1916	3,501	20,273	------	------	------
1917	1,412	30,438	4,586	------	------
1918	218	17,959	2,843	------	------
1919	------	19,098	3,804	------	------
1920	------	14,558	3,375	------	------
1921	------	10,303	------	------	------
1922	------	7,842	1,352	------	------
1923	------	16,816	1,881	------	------
1924	------	9,337	1,580	------	------
1925	------	14,520	671	------	------
1926	------	5,756	1,296	------	------
1927	------	48	------	------	------
1928	------	2,018	------	------	------
1929	------	4,439	------	------	------
1930	------	4,685	29	------	------
1931	------	3,746	25	------	------
1932	------	1,574	389	------	------
1933	37	1,099	675	------	------
1934	------	3,361	453	------	------
1935	------	2,021	543	1,290	------
1936	------	715	1,368	2,470	435
1937	------	2,445	720	1,432	1,916
1938	------	273	1,071	2,678	688
1939	------	428	990	6,827	513
1940	------	985	991	4,445	306
1941	------	996	42	2,056	------
1942	------	896	384	1,889	------
1943	------	890	325	1,918	------
1944	------	------	------	713(h)	------
1945	------	393	76	------	------
1946	------	960	183	------	------
Totals	493,318	213,286	29,652	25,718	3,858

(a) Published by permission of Embree Iron Co. and Tennessee Zinc Co.

(b) Tennessee Bureau of Labor, Mines and Statistics, 6th to 19th Annual Reports, Nashville, 1897-1910.

(c) Grade unknown. Figures for 1896, 1897, and 1898 are approximate; prior production is unknown.

(d) Averaging approximately 40 percent zinc. Does not include shipments of zinc concentrates before October, 1913, which may have totalled over 2,000 tons (Byrne, 1913), or flue-dust shipments before 1910.

(e) Averaging approximately 60 percent lead. Local production during the nineteenth century for bullets, etc., is unknown.

(f) Averaging 38 percent manganese.

(g) Averaging 74½ percent manganese dioxide.

(h) Does not include approximately 2,500 long tons of manganese tailings (averaging 14 percent manganese) shipped in late 1944 and early 1945.

METHODS OF EXPLOITATION

Prospecting.—During the large-scale iron operations from 1892 to 1909, the clay blanket in the cove was prospected for iron ore by hundreds of dug wells, many of them as much as 50 feet deep. Some of these wells are still open, but no written record of any of them remains.

In 1913 the Embree Iron Co. began prospecting for zinc and lead by churn drilling. From that time on, the company depended largely on this method of prospecting, although the drilling was supplemented at times by shallow pits, dug wells, or auger holes. The early prospecting for manganese, first in 1918 and again from 1934 to 1936, was done entirely by test pitting, but in 1937 the churn-drill method used for the zinc and lead ores was applied to the manganese deposits with satisfactory results. More than 2,400 churn-drill holes have been put down in the cove, penetrating for the most part only to the upper surface of the bedrock. Records of most of these holes are available.

In all the drilling, whether for zinc, lead, or manganese, samples were taken every four feet, and the material was examined and logged by the driller. At first every sample was assayed, but the drillers soon learned to distinguish ore from barren ground, and in recent years only those samples which in the driller's judgment contained ore were saved for assay. The samples were washed free of clay at the drill, and assays were made only on the material of lump or sand size remaining. In grade the assays thus approximated closely the washed but unpicked concentrates to be expected from the ground drilled, but no information was obtained on the bulk recovery ratio of crude ore to unpicked concentrates. An attempt was made in 1937 to determine this ratio for certain bodies of manganese ore by weighing the drill samples before and after washing, but as some of the clay had already been washed away in drilling, the results were erratic and unreliable. However, the ratio was usually such as to permit profitable operations, and the miners learned by experience to judge the ratio during mining and to avoid ore of too low a grade.

Mining.—During most of the history of the cove, mining was carried on by hand with pick and shovel. Most of the iron ore that was mined by hand, as well as much of the zinc, lead, and manganese ore, was mined in open cuts, but the deeper bodies of zinc, lead, and manganese ore were mined underground. Because of the erratic distribution of the various ore bodies in the residual clay, the underground workings followed no general plan; usually they were driven to ore bodies discovered by some drill hole or group of drill holes, and the ore was then followed until it pinched out. As the zinc ore bodies were normally close to dolomite pinnacles, they required especially tortuous workings, and occasionally drifts were driven through pinnacles to reach ore beyond. All the underground workings in the clay required much timbering and became unsafe as soon as much ore had been mined out; moreover ground once mined could not ordinarily be reworked with safety. Hence some of each kind of ore was left behind, but in view of the unpredictable shape and distribution of the ore bodies, this waste probably could not be avoided.

Twice during the history of the cove, however, operations have been on a larger scale. Hydraulic mining was introduced in 1899 and was employed until the end of the iron mining operations in 1909. The limonite-bearing clay and its overburden were sluiced to washers, of which there were at one time as many as five in the cove. However, even these large-scale operations did not produce enough ore to keep the blast furnace supplied.

More recently, from late 1938 to early 1941, manganese ore was mined in open cuts by power shovel, the overburden being stripped by an angle-dozer and the ore bodies mined selectively in terraces (Newton, 1941; Reichert, 1941, 1942). During this period manganese concentrates were produced in greater quantities than had been possible by hand methods, but their grade was appreciably lower. In 1942 the company returned to hand mining, but in 1943 made use of power equipment to strip overburden from certain bodies of zinc, lead, and manganese ore which were then mined by hand.

Milling.—For each of the oxidized ores in Bumpass Cove, the object of milling has been to separate the hard lumps of metallic minerals from the clay in which they occur. In the richer deposits of each ore, some lumps were separated from the clay during mining and were shipped without further treatment; indeed many carloads of high-grade zinc and lead concentrates were produced in this way. However, the clay had to be removed from the bulk of the ore by washing. Unavoidably, the finer particles of each metallic mineral were washed out with the clay and were lost or at best remain mixed with the clay in tailing ponds.

During the later iron operations, the iron ore was washed in double-log and triple-log washers. The larger pieces of jasperoid were picked out by hand, but no other treatment was necessary before the limonite went to the furnace.

The milling procedure adopted in 1915 for the zinc silicate ore also made use of log washers. In addition, jigs and magnetic separators were installed to remove the siliceous materials and the limonite from the washed product, and at one time the zinc middlings were further concentrated by tabling. However, neither jigs nor tables gave satisfactory results because of the slight difference in specific gravity between hemimorphite and the impurities, and when zinc mining shifted from the old iron mines to the new zinc mines farther southwest in which limonite is not common, the magnetic separators were no longer needed. Hence after 1918 the company relied entirely on hand picking to clean the zinc washer product, which was then crushed to pebble size and dried.

The lead carbonate ore was found to be too friable to permit the use of a log washer and was merely washed through a screen by a fairly strong stream of water. Because of the high specific gravity of cerussite, however, jigging and tabling of the lead ore gave very satisfactory results. Harz-type jigs and Diester tables were used.

The manganese ore was washed in log washers. Harz-type jigs were found to be unsatisfactory, but in 1938 McLanahan and Stone jigs, operating on a closely sized feed, were installed. However, hand picking of the impurities remained an important operation, particularly for the coarser material, and a high-grade concentrate was also obtained from the picking belts. The manganese milling methods of the Embree Iron Co. have been described in detail by Newton (1941) and Reichert (1941, 1942).

Considerable zinc, lead, and manganese slimes have accumulated in tailing ponds in the cove. The Embree Iron Co. made several attempts to find methods for recovering the zinc slimes, which aggregate about 15,000 tons averaging 13 percent zinc. So far such attempts have been unsuccessful; chemical methods have failed because the zinc is present as silicate, and mechanical methods because of the low zinc content and the fine grain of the material.

ECONOMIC POSSIBILITIES

The bodies of each type of oxidized ore in Bumpass Cove are irregularly distributed in the residual clay of the Shady dolomite. Prospecting for such bodies is best done by sinking holes, whether dug wells or drill holes, on a fairly systematic grid pattern, starting from known occurrences of ore. Because of their erratic shape and distribution, individual ore bodies can be projected only a short distance from the prospect holes in which they were encountered, as has repeatedly been shown during mining. Thus intensive drilling delimits mineralized areas but is inadequate to serve as a basis for accurate estimates of tonnage or grade of ore within those areas. This does not mean, however, that prospecting is unnecessary or valueless, for, when combined with experience in mining such deposits, it furnishes the only available clues as to what ground can be mined profitably and what cannot.

The oxidized zinc and lead deposits of the cove offer good examples of such irregular distribution. Thus the several spurs on the southwest side of the cove between Red Cut Hollow and Big Moccasin Branch do not differ greatly from one another in their geologic features, yet sizable bodies of zinc ore were found on some of the spurs and others were barren. On the east side of Rich Hill, a pair of wildcat drill holes (U-205 and U-206) each found 20 feet of zinc ore, but a dozen holes drilled in a circle around them found virtually nothing. Of 90 holes of the N line drilled on the spur west of Dry Branch, 18 encountered zinc ore of fair or good grade and 14 more encountered shows. Although these ore holes are in general grouped in an area 400 feet square, many of the barren holes are in the same area, and the distribution of ore holes and barren holes within the area is erratic. Moreover in many places the ore encountered in adjacent ore holes was at different levels. In short, whether this deposit could be profitably mined or not could be judged only on the basis of experience with other bodies of the same type that had been both drilled and mined.

As a matter of fact, practically every deposit of oxidized zinc or lead discovered by the extensive drilling in the cove was opened up and was mined as long as the workings remained safe. The chief exceptions are certain deposits of zinc silicate in which the proportion of iron oxide is high. Thus, where the available drill records indicate zinc ore, most of it was later removed. Both prospecting and milling methods, however, were directed entirely toward the recovery of that part of the oxidized zinc ore that occurred in hard lumps, and the zinc silicate that occurred only in finely divided particles in the clay was ignored in prospecting or was lost in milling. In the Big Moccasin mine (34), a large proportion of the zinc silicate was found to be too soft and friable to pass the log washer. The mine was therefore abandoned before all the ore outlined by drilling had been removed, and a considerable body of such ore probably remains in that area. Elsewhere in the cove, however, most of the clay containing appreciable quantities of finely disseminated zinc silicate also contained hard lumps and the greater part of it was mined for the hard lumps, the finely divided particles being washed into the tailing ponds.

During the course of zinc mining in the cove, the size of the ore bodies mined has steadily decreased. In the first period of zinc mining, from 1913 to 1922, the large deposits of the Fowler (19), No. 14 (27), and Peach Orchard (35) mines were exploited; from 1922 to 1926, outlying ore bodies in the same areas were mined. From 1927 to 1931 a group of new mines was opened, in which the ore bodies were considerably smaller. After 1931, the older mines were reopened, but only small ore bodies that had escaped notice during the earlier operations were mined. The developments of 1942 and 1943 were in still smaller pockets or in bodies like those around the Lick Log shafts (37) that had not previously been opened because of mining difficulties. Prospecting in 1942 proved the presence of additional zinc and lead ore bodies under the valley floor between the Peach Orchard mine and the Lick Log shafts, and further prospecting in this part of the cove is warranted.

The deposits in the Lick Log area rest on an irregular surface of dolomite 50 to 100 feet below the present stream. Just to the south and southeast, however, the residual clay is much deeper, and drill holes in that area have reached the Erwin formation at depths of 200 to 300 feet without encountering any dolomite (see fig 3, p. 14). The presence of this deep pocket of clay near the most productive zinc and lead mine in the cove (the Peach Orchard mine) suggests the possibility of deep-lying bodies of oxidized zinc and lead ore in the pocket. However, the few drill holes that have penetrated the pocket are barren. Moreover, the water table in this area stands at about the level of the upper surface of the dolomite on which the deposits near the Lick Log shafts rest and is far above the deeper parts of the clay pocket. Hence, the deeper clay would be saturated with water, and dewatering and mining such clay would be especially difficult.

The manganese deposits in the cove are also irregular in their shape and distribution. As with the zinc deposits, most of the larger known bodies have been exploited. However, certain bodies of manganese ore discovered by prospecting have not yet (1943) been mined, either because the deposit contains too much iron oxide—for example, the body on the west side of Casey Hollow—or because it lies too deep for shovel operations—for example, small deep ore bodies near the West Baptist Hollow mine (41) (Reichert, 1942, pp. 134-135, pls. 9, 10). Moreover, the prospecting for manganese has not been as exhaustive as that for oxidized zinc and lead, and other bodies of manganese ore may yet be found in the cove. The association of the larger bodies with terrace remnants 370 to 420 feet above the present stream suggests that further search should be directed to other remnants of the same terraces —for example, the spur southwest of the West Ore Bank (42) over the Madcap mine (43), or the broad spur southeast of the Yates Hollow mine (4).

The oxidized iron deposits of the cove were abandoned as uneconomic in 1909. However, in view of the recent revival of interest in the known iron ores of the Appalachian region, the deposits in Bumpass Cove may deserve consideration. Almost no evidence is available on the possible location of unmined deposits in Bumpass Cove, for no prospecting has been done for iron in many years. Limonite can be seen in many of the clay banks in the cove, and some of the spurs on the southeast side of the cove—for example, those on either side of the Yates Hollow (4) and Klondyke (5) mines—may warrant prospecting.

Although the sulphide deposits of the cove attracted attention at an early date (Safford, 1869, p. 451), they have never been systematically mined. From 1915 to 1917 the Tennessee Zinc & Lead Co. drilled about 25 churn-drill holes into the dolomite in and near the Jackson mine (6). Several of these holes encountered zinc sulphide, but it was very irregularly distributed. From 1922 to 1925 the Embree Iron Co. drilled 70 churn-drill holes in the search for sulphides, more than half of which reached the Erwin formation. Most of these holes were in two groups: a smaller group near the Peach Orchard mine (35) and to the southwest, and a larger group in the central part of the cove. The holes near the Peach Orchard mine encountered only traces of zinc, but several holes northwest of the Fowler mine (19) and a few south of the Jackson mine (6) found over 2 percent zinc as sulphide. However, adjacent holes did not show zinc sulphide at comparable levels, and no ore bodies were blocked out.

Some of the drill holes put down for oxidized zinc ore, for example certain holes near the No. 14 mine (27), also entered the dolomite, and the records of some of them indicate the presence of zinc well below the upper surface of the rock. None of the records show, however, whether the zinc occurs as sulphide, carbonate, or silicate, and in view of the possibility that the holes intersected deeply weathered crevices, no inference is possible. In the latter part of 1942 the company again became interested in the sulphide deposits and began drilling near the No. 14 mine in an effort to check these earlier records, but the dolomite was found to be badly broken and churn drilling in it was difficult. The drilling was therefore transferred to the Jackson mine (6), where sphalerite is exposed in considerable concentrations. Grab samples from these exposures have assayed as high as 10 percent zinc, and channel samples (p. 58) have shown from 2 to 7 percent zinc and from 1 to 2 percent iron. However, the results of the churn-drilling in the mine were not very favorable; none of the 4-foot samples averaged more than 3 percent zinc as sulphide, and concentrations over 2 percent were limited to a small area northeast of the center of the mine.

The total volume of dolomite in Bumpass Cove is limited, as the Shady dolomite is preserved in a trough or syncline and is everywhere underlain by the Erwin formation at depths not greater than 500 feet and at most places considerably less. Moreover, at the Austinville mine in the similar zinc district in southern Wythe County, Virginia (Currier, 1935, pp. 79-80), zinc sulphide is mined only in the upper part of the Shady dolomite. Although correlation is uncertain, most of the 500 feet of dolomite preserved in Bumpass Cove appears to correspond to the lower part of the Shady dolomite of southern Wythe County, in which sulphide deposits are extremely pockety though locally rich, and have not been successfully mined. Only the upper white member of the Shady dolomite in Bumpass Cove is comparable to that part of the formation in which zinc is being mined at Austinville, and most of the upper white member has been removed by erosion in the part of the cove in which the sulphide deposits occur.

To recapitulate, zinc sulphide of commercial grade is present in the cove, but the drilling to 1943 has not been adequate to determine whether minable quantities exist or not. However, even this limited drilling proves that the sulphides occur very irregularly and that no large volumes of evenly mineralized rock should be expected.

MINES

IRON MINES

Sugar Hollow and No. 10 mines.—The Sugar Hollow (1) and No. 10 (2) mines are on the southeast side of the cove near its east end. The two mines were started in Sugar Hollow and No. 10 Hollow respectively and have coalesced to form the present opening, which lies athwart the lower end of the spur between the hollows. Both were hydraulic iron mines and were probably operated fairly late in the period of hydraulic mining. A small hydraulic cut that lies on the other side of No. 10 Hollow from the upper end of the No. 10 mine was probably opened at the same time. However, iron was mined in Sugar Hollow long before hydraulic mining began in the cove. Lesley (1872) states that the charcoal furnace on the Nolichucky River was largely supplied from the Sugar Hollow area, and according to local tradition the first iron ore mined in the cove came from Sugar Hollow, though it may not have come from the site of the present Sugar Hollow mine. Between 1913 and 1916 and again for a brief period in 1933 zinc silicate was mined here, particularly in the No. 10 mine. In 1942 a few shallow prospect pits were dug for zinc silicate within the opening, but no mining was done.

The two mines taken together form the second largest opening in the cove, as they cover about 17 acres. Great pinnacles of dolomite with a maze of passageways between characterize much of the opening; clay remains on the floor, in the walls, and in projections from the walls, especially along the line where the two mines coalesced. The upper end of the No. 10 mine, however, was excavated entirely in clay which contained much jasperoid.

Most of the rocks exposed in the opening are ribboned dolomite belonging to the ribboned member of the Shady, but the highest beds include more massive layers and form a transition to the upper blue member. The rocks dip fairly gently northwest and show little sparry dolomite, but the upper beds are brecciated. The dolomite exposed is mostly fresh. Most of the openings probably underlay benches ranging from 160 to 290 feet above Bumpass Cove Creek, but the upper end of the No. 10 mine reaches into clay under a bench of the 370-foot terrace.

Small quantities of sphalerite were observed in a few places in the dolomite, and pyrite is sparsely but widely distributed. Hemimorphite is present in some of the clay, as is shown by the recent prospecting, but limonite is more common and widespread. Bodies of zinc silicate may still exist in and near the mines but they would probably be contaminated by considerable limonite.

Tucker mine.—The Tucker mine (3) is on the southeast side of the cove and lies on the lower end of the spur west of Sugar Hollow. Two hydraulic openings, started on opposite sides of this spur, have coalesced to form the mine. It was probably opened early in the period of hydraulic iron mining. As far as is known, no zinc has ever been mined here.

The mine has a very irregular outline and covers about 7 acres. In it are the most spectacular dolomite pinnacles in the cove; a ragged knife-edge partition of dolomite separates the two hydraulic cuts and is flanked by dolomite pinnacles over 100 feet high, honeycombed with caves and chimneys from which the clay has been washed.

The rocks exposed in the mine are mostly ribboned dolomite belonging to the ribboned member of the Shady, but more massive layers are present above and below. They dip fairly gently northwest and contain much sparry dolomite. The rocks are fairly fresh. The original surface over the mine was part of a large remnant of the 160-foot terrace.

Pyrite occurs here and there in the dolomite, and sphalerite was observed at one place. Hemimorphite is present in a few places as scales on the surface of the dolomite, but none was observed in the remaining residual clay. However, limonite is present in much of the clay. There is little promise of commercial zinc ore in the mine.

Yates Hollow and Klondyke mines.—The Yates Hollow (4) and Klondyke (5) mines are on the southeast side of the cove; the former occupies most of Yates Hollow and the latter lies just to the southwest. The ground originally separating the two mines has been washed out so that they now connect. Both were hydraulic iron mines, and the Klondyke mine, opened in 1899, was the first hydraulic mine in the cove. A little zinc silicate was mined in the Klondyke mine about 1933 and perhaps earlier. According to reports, some oxidized lead ore was also found there.

The Yates Hollow mine differs from most of the mines in the cove in being elongate perpendicular to the strike. It covers about 8 acres and the Klondyke mine covers about 4. High dolomite pinnacles are present in the Klondyke mine and along the southwest side of the Yates Hollow mine, but most of the Yates Hollow mine exposes only low pinnacles, and its southeast end is a great wall of clay and slope wash.

The rocks exposed in the Klondyke mine and in the northwest part of the Yates Hollow mine are ribboned dolomite belonging to the ribboned member of the Shady, but those in the rest of the Yates Hollow mine consist of alternating unribboned blue-gray dolomite, ribboned dolomite, and ribboned limestone, and are assigned to the lower blue member. The rocks dip northwest. Sparry dolomite is abundant in the ribboned member but nearly absent in the lower blue member, though the latter shows some brecciation. The dolomite exposed is largely fresh, except that some of the ribboned dolomite has a disintegrated and weathered crust. The Klondyke mine underlies benches representing the 80-foot and 160-foot terraces, but the southeast end of the Yates Hollow mine is cut back into a large remnant of the 370- to 420-foot terrace.

Sulphide mineralization in these mines is meagre and seems to be confined to the ribboned member. Pyrite is scattered through the dolomite in this member, and small amounts of sphalerite were also observed. Hemimorphite occurs in the Klondyke mine both in the weathered crust of the dolomite and in the residual clay. Limonite is common in both mines and is not restricted to any part of them. Small bodies of oxidized zinc ore and possibly of lead may remain in and near the Klondyke mine, but they would probably be contaminated with considerable limonite.

Small pellets of manganese oxide are present in the clay at the southeast end of the Yates Hollow mine. The terrace remnant into which this part of the mine is cut is the largest remnant in the cove of the terrace that elsewhere overlies the chief commercial manganese ore bodies. It is believed therefore that this locality deserves further prospecting for manganese ore.

Jackson mine.—The Jackson mine (6) lies on the north side of Bumpass Cove Creek and is almost in the middle of the cove at its widest point. The lead mined in the cove before the Civil War came from this area. During the period of hydraulic iron mining, several open cuts were begun here which coalesced into the present opening. At a later stage of the iron operations, a little dolomite was quarried for flux in the southwest end of the hydraulic mine.

In 1913 this part of the cove was bought by the Tennessee Zinc & Lead Co., which for a few years mined oxidized zinc and lead ore by hand in several parts of the mine. In addition, about 25 churn-drill holes were put down into the dolomite, some of which encountered 2 to 3 per cent zinc, but unfortunately the records do not distinguish between sulphide and silicate. Bedrock mining of lead sulphide was also attempted, an adit and an inclined shaft being sunk in the southwest part of the mine. In 1917 this company ceased operations. Later the property came into the hands of the Embree Iron Co., which conducted a campaign during the first part of 1943 to explore the possibilities of zinc sulphide ore in the mine; the old inclined shaft was reopened, 15 churn-drill holes were sunk, and 82 samples of surface exposures were assayed.

The present opening is long and irregular, and the total area from which the sod has been stripped is about 10 acres. Spectacular pinnacles are present in many parts of the mine; in others the clay has been little disturbed and only the tops of the pinnacles are showing. The later hand mining was done largely in fissures between the pinnacles.

Plate 5 is a structural map of about three-fourths of the mine. A normal fault is exposed near the northeast edge of the area mapped. The fault plane dips fairly steeply toward its southwest wall, which has been downthrown about 100 feet. The beds exposed northeast of the fault belong to the upper blue member of the Shady, here consisting largely of massive blue-gray dolomite but including one light gray bed. The beds immediately southwest of the fault belong to the upper white member and are largely white and light gray massive dolomite. Two discontinuous beds of blue-gray dolomite occur within the member; the lower of these is massive and is commonly brecciated, but the upper is well laminated and even shows a ribboned structure in places. The upper white member continues to the southwest, but the upper blue member reappears beneath it along the southern edge of the mine, where it includes some ribboned dolomite.

The structural map shows the prominent joints in the mine area. Solution has changed many of them into fissures and crevices of considerable width, in which the exact position of the original joint is not always clear. For lack of exact information they have all been drawn as straight lines, but many of them might equally well be slightly curved; however, some at least are remarkably straight for considerable distances. They exhibit no pattern other than a tendency to parallelism in certain restricted areas.

The map also shows the dip and strike of the bedding in most of the joint blocks. The strike is somewhat irregular, particularly near the normal fault, but two consistent flexures stand out, one at about the center of the mapped area and the other at the southwest end. In each place the strike swings abruptly until it makes a large angle with its normal course; farther on it swings as abruptly back.

The dolomite of the upper white member has been brecciated considerably, especially near the normal fault and at the point where the two blue bands within the member cross the eastern of the two flexures. Sparry dolomite is common in all the rocks exposed in the mine and is particularly evident near the two flexures and in those places where the white member is brecciated.

Some of the dolomite exposed is quite fresh, but in places a thick weathered crust of disintegrated dolomite has formed. There is a fairly close correlation between the distribution of this crust and the distribution of the sulphide minerals; the sulphides presumably gave rise on weathering to acid solutions which promoted the disintegration of the dolomite. The northeastern part of the mine was cut around the edges of a remnant of the 80-foot terrace, the southwestern part in a remnant of the 160-foot terrace.

The different areas of sulphides indicated on the structural map show differing proportions of the several sulphide minerals. The dissemination in the upper white member near the normal fault is largely sphalerite with varying amounts of galena and pyrite. The concentration in the central part of the mine, coinciding with the eastern flexure, consists of sphalerite with some pyrite and sporadic galena. The concentration at the southwest end of the mine, coinciding with the western flexure, is mostly pyrite; some sphalerite is present, especially in the light gray dolomite, but no galena was observed. The dolomite blocks on the dump at the old lead shaft show a strong concentration of galena and sphalerite.

Three channel samples, taken in the central part of the mine close to the eastern flexure, were analyzed in the laboratories of the U. S. Geological Survey. The analyses are given in the accompanying table.

Analyses of channel samples from Jackson mine, Bumpass Cove, Tennessee

(MICHAEL FLEISCHER, analyst)

	N	O	P
Zn	4.3	7.2	2.0
Pb	---	---	0.1
Fe	1.5	0.5	1.9
Cu	---	---	---
Mn	0.20	0.34	0.23

N. Central part of Jackson mine; 4½-foot channel cut from white dolomite between blue bands. Overlain by 50 feet of less mineralized dolomite, underlain directly by sample O.

O. Central part of Jackson mine; 5-foot channel cut from white dolomite between blue bands. Overlain directly by sample N, underlain by 20 feet of less mineralized dolomite above sample P.

P. Central part of Jackson mine; 8-foot channel, upper 2½ feet cut from lower blue band in upper white member, lower 5½ feet cut from less mineralized white dolomite below. Overlain by 20 feet of less mineralized dolomite below sample O, underlain by white dolomite, generally barren but with some rich pockets.

The churn drilling and surface sampling done by the Embree Iron Co. in 1943 was carried on chiefly between the concentration around the eastern flexure and the normal fault. The 82 surface samples showed as high as 10 percent zinc and averaged over 3 percent zinc and less than 2 percent iron, but these samples were grab samples taken for the most part at favorable showings. On the other hand none of the churn drilling indicated ore carrying over 3 percent zinc as sulphide and the distribution of ore carrying 2 percent zinc as sulphide was too irregular to permit any estimates of tonnage. However, the churn-drill samples appear to have been diluted with considerable clay from the overburden. These results are clearly inconclusive but suggest that if ore bodies exist they will be irregular in shape and distribution.

Upper Peedee mine.—The Upper Peedee mine (7) is on the northwest side of the cove and lies on the southwest side of Peedee Hollow. It is one of the smaller mines opened during the period of hydraulic iron mining. The ore-bearing clay was washed down a long sluice from this mine to a washer which stood on the bank of Bumpass Cove Creek and also served the Jackson mine (6). The Upper Peedee mine is on the same tract as the Jackson mine and was bought in 1913 by the Tennessee Zinc & Lead Co., but so far as known, that company did no mining here.

The mine consists of a pair of gully-like cuts on the side of Peedee Hollow and covers a little more than an acre.

The dolomite in the northern part of the mine belongs to the ribboned member and the lower blue member of the Shady, but at the south end of the mine white saccharoidal dolomite is exposed. This white dolomite is interpreted as belonging to the upper white member, having been brought against the lower blue member, or perhaps the top of the lower white member, along an important normal fault. Although the mine is well northwest of the center line of the cove, all the rocks in the mine dip northwest, for the synclinal axis is just northwest of the mine. The dolomite exposed shows little breccia or sparry dolomite and is quite fresh. The hill to the southwest, on the side of which the mine was excavated, is a large terrace remnant about 290 feet above Bumpass Cove Creek.

No sphalerite, pyrite, or hemimorphite, and very little limonite were seen in this mine. There is little likelihood of commercial bodies of zinc ore in this area.

Lower Peedee mine.—The Lower Peedee mine (8) lies on the northwest side of Bumpass Cove Creek, a little southwest of the mouth of Starnes Hollow. It is a small cut opened during the period of hydraulic iron mining.

The mine exposes closely spaced dolomite pinnacles with clay between and covers about an acre and a half.

The rocks are mostly ribboned dolomite belonging to the ribboned member of the Shady, but the highest beds exposed are more massive and form a transition to the upper blue member. They dip very gently northwest toward the synclinal axis only a few hundred yards away. Sparry dolomite and breccia are virtually absent, and the dolomite exposed is fresh. The top of the hill in which the mine is excavated is a remnant of the 160-foot terrace, but much of the opening is cut into a bench representing the 80-foot terrace.

No zinc minerals were observed in or near this mine, but pyrite and limonite are present in a few places. There is little likelihood of commercial bodies of zinc ore in this vicinity.

Tunnel mine.—On the southwest side of the basin at the head of Sugar Hollow, at an altitude of 2,200 feet, three adits (11) have been driven into purple ferruginous quartzite belonging to the middle member of the Erwin formation. They were opened about 1892 (Johnson, 1896), and the hematite-bearing quartzite was used in the blast furnace, but it was soon found to be unsuitable as iron ore. Jarvis (1912, pp. 330, 357) gives the following analyses of material from the locality.

Analyses of samples from Tunnel mine, Bumpass Cove, Tennessee
(Analyst not given; analyses probably made by Embree Iron Co. or one of its predecessors)

	1	2	3
Fe	40.1	30.8	15.8
SiO_2	36.8	48.6	73.6
CaO	1.0	1.4	0.8

1. Select ore.
2. General average.
3. Sample from underlying red sandstone beds.

Red Cuts.—Two open cuts in red slope wash and yellow residual clay lie just east of Red Cut Hollow, on the southeast side of the cove. They are not far northeast of the Fowler mine (19). Both were operated during the period of hydraulic iron mining, but the upper cut was also worked as early as 1892. The Upper Red Cut (12) to the southeast produced iron ore of such purity that no washing was required and all mining was done by hand (Jarvis, 1912, p. 358); the Lower Red Cut (13) to the northwest was a hydraulic mine.

The upper cut covers about half an acre, the lower about an acre and a half. The upper cut is entirely in clay overlain by slope wash, but the lower cut has uncovered a few pinnacles of dolomite. Masses of jasperoid are common in both cuts.

The dolomite in the Lower Red Cut apparently belongs to the upper part of the ribboned member and the lower part of the upper blue member, but light gray dolomite, such as is present farther southwest in the stratigraphic position of the upper blue member, is also present. The bedding dips northwest, and the dolomite exposed contains considerable sparry dolomite but is fairly fresh. The Upper Red Cut lies in a bench representing the 290-foot terrace, but the Lower Red Cut is about 200 feet above Bumpass Cove Creek on an even slope showing no benches.

Limonite is present in both cuts, but neither zinc nor manganese minerals were observed. Drilling in the vicinity found no zinc ore; the possibilities of manganese ore on the hill to the east are discussed in the description of the Yates Hollow mine (4).

Davenport mine.—The Davenport mine (14) is on the southeast side of the cove and lies on the northeast side of Woodcut Hollow just west of the Fowler mine (19). It is a small cut opened during the period of hydraulic iron mining and was probably intended to open some of the ground later reached by the hydraulic operations in the Fowler mine.

The cut is barely 150 feet long and was excavated in clay below a thick cover of gravel. The gravel underlies a large bench of the 160-foot terrace. Limonite may be present in the clay but was not observed.

Starnes mine.—The Starnes mine (15) is on the southeast side of the cove and lies on the west side of Simmons Branch. It consists of two small cuts on the east side of Rich Hill, which lies between Simmons and Big Moccasin Branches just southeast of Bumpass Cove Creek. The mine was opened during the period of hydraulic iron mining or perhaps even earlier. Between 1926 and 1929, during drilling for zinc ore on Rich Hill, some manganese oxide was discovered; later, in 1939, additional holes were drilled to determine if a commercial body of manganese ore were present, but the results were disappointing. In 1942 a little manganese ore was taken from the old Starnes cuts; otherwise no manganese has been mined on Rich Hill.

The Starnes cuts are each about 200 feet long and 75 feet wide. They were excavated in residual clay with little overburden, in and below a bench representing the 160-foot terrace. However, the top of Rich Hill has a fairly thick cover of gravel which underlies a terrace remnant about 240 feet above Bumpass Cove Creek. Limonite, jasperoid, and a little manganese oxide were observed in the Starnes cuts.

Polly Hollow mine.—The Polly Hollow mine (16) is on the northwest side of the cove and lies on the northeast side of Polly Hollow. On the southwest side of the hollow and on the spur between the forks of Polly Hollow Branch are other, smaller cuts (17). All these cuts were opened during the period of hydraulic iron mining, and they were probably operated as a unit. There are also smaller pits in the vicinity, some of which may have been opened still earlier. A little manganese ore was mined in the Polly Hollow mine about 1936.

The Polly Hollow mine covers about 5 acres, and the other hydraulic cuts cover an additional acre. They were excavated in residual clay containing great quantities of jasperoid and overlain by a thick layer of gravel and slope wash. Near the bottom of the Polly Hollow mine a few pinnacles of dolomite have been uncovered.

The rocks exposed in the mine are ribboned dolomite overlying light gray dolomite. The latter is too far from the outcrop of the Erwin quartzite to belong to the lower white member and too close to belong to the upper white member. As the exposures are isolated, it is not possible to correlate them certainly with the sequence recognized elsewhere in the cove, but the ribboned dolomite may represent the ribboned member, and the underlying light gray dolomite may correlate with the light gray dolomite near the No. 14 mines (25-28) that is stratigraphically equivalent to the upper part of the lower blue member. The rocks dip southeast and show little sparry dolomite but considerable brecciation. Although the tops of the spurs on each side of Polly Hollow reach the 500-foot terrace, the cuts themselves are excavated in benches representing the next lower terrace.

No zinc minerals and no pyrite were observed in the mine, but limonite is abundant.

Small unnamed iron mines.—Small cuts opened for iron ore but not operated since 1909 are present in many parts of the cove. Many are hydraulic cuts opened during the period of hydraulic iron mining, but some at least are older. Prominent cuts of this sort, designated on the map by the number 18, are located as follows: seven or eight at the head of Sugar Hollow; one in a ravine southeast of the Fowler mine (19); four near Dry Branch, of which one was called the McNabb mine; one on the west fork of Simmons Branch, in an outlying area of residual clay mapped as Shady; two or three on Rich Hill, between Simmons and Big Moccasin Branches; one at the contact of the Shady and Erwin formations on the west side of Big Moccasin Branch; three or four in the southwest end of the cove, beyond Lick Log Hollow.

In addition, many of the later mines, for example the large manganese mines on the northwest side of the cove, represent enlargements of older iron mines.

All these cuts were excavated in residual clay, commonly under an overburden of gravel or slope wash. Masses of jasperoid are present in most of the cuts and are abundant in many of them. Terrace remnants are present at many of the cuts, but no general correlation with terraces was observed.

ZINC MINES

Fowler mine.—The Fowler mine (19) is on the southeast side of the cove, just southeast of the concentrating mill. It is the largest of the great hydraulic iron mines and consists of two big cuts facing each other across Fowler Branch, which flows through the middle of the mine. Unlike the other hydraulic iron mines, however, the Fowler mine has been an active producer through most of the period of zinc mining as well. It was probably the first zinc mine in the cove, and from 1913 to 1924 it was operated continuously. Since then, except between 1926 and 1931 when no work was done here, mining has been carried on spasmodically in pockets of ore overlooked in the earlier operations. Oxidized zinc ore has been found in every part of the mine except along the northwest edge, and in addition oxidized lead ore has been mined in the southwest part.

The mine is elongated parallel to the strike of the rocks and covers an area of 18 acres. Dolomite pinnacles are especially prominent in the center of each of the two hydraulic cuts, but the walls of the cuts are mostly in clay covered by gravel or slope wash. The southeast side of the mine exposes a great thickness of residual clay containing much jasperoid. Zinc ore has been mined in many small open cuts, tunnels, and shafts lying within the hydraulic opening.

Most of the rock in the mine is ribboned dolomite belonging to the ribboned member of the Shady, but much of it is distinctly lighter in color than the ribboned dolomite that occurs in the area around Yates and Sugar Hollows. Near the middle of the member is a bed or series of lenses of dark blue-gray dolomite. The light ribboned dolomite grades upward directly into light gray massive dolomite, believed to be the stratigraphic equivalent of the upper blue member. Beneath the ribboned member are alternating beds of unribboned blue-gray dolomite and poorly ribboned dolomite, much like the beds in the lower blue member as exposed in Sugar Hollow.

The rocks dip fairly steeply northwest and irregularities in strike and dip are common. The ribboned dolomite is intensely recrystallized in a manner that emphasizes the ribboned structure; in many specimens more than half the rock has been changed to sparry dolomite. Much sparry dolomite has also formed in the bed of dark dolomite within the ribboned member, but there it forms the matrix of a breccia.

The dolomite exposed in the mine is rarely fresh; most of it has a weathered crust, in places as much as two inches thick. The original land surface at the Fowler mine was mainly a broad bench representing the 160-foot terrace, but to the southeast it sloped up toward remnants of the 420-foot terrace that lie southeast of the mine.

Sphalerite and pyrite occur in moderate concentrations in several places in the west half of the mine, but all these concentrations appear to be in the bed of brecciated dark dolomite. A small amount of galena was observed at one place. Two channel samples, taken in the Fowler mine, were analyzed in the laboratories of the U. S. Geological Survey. The analyses are given in the accompanying table.

Analyses of channel samples from Fowler mine, Bumpass Cove, Tennessee

(MICHAEL FLEISCHER, analyst)

	Q	R
Zn	3.3	6.4
Pb	---	---
Fe	1.8	2.4
Cu	---	---
Mn	0.23	0.63

Q. Central part of Fowler mine; 8-foot channel. Underlain by mineralized dolomite with some rich pockets of ore.

R. Southwest part of Fowler mine; 4-foot channel. Underlain by essentially barren dolomite.

Drill holes penetrating the Shady dolomite in the area northwest of the Fowler mine indicate a pair of low folds or a structural terrace which appears to connect the eastern flexure in the Jackson mine (6) with the folds exposed near the Embree Iron Co. No. 14 mine (27). Several of these holes encountered better than 2 percent zinc as sulphide, but the distribution of the showings suggests that the dolomite is very irregularly mineralized. If minable bodies of zinc sulphide ore are found near the Jackson mine (6), the area northwest of the Fowler mine would warrant prospecting.

No. 5 mine.—The No. 5 mine (20) is on the southeast side of the cove and lies at the lower end of the spur southwest of Woodcut Hollow. It was opened in 1928 to exploit oxidized zinc ore blocked out by drilling in that and previous years. A tunnel was driven about 200 feet into the foot of the hill and a shaft was sunk to meet it. After the ore body had been mined out, the workings were abandoned, and all are now caved.

The dump shows recrystallized ribboned dolomite as light-colored as that in the Fowler mine (19), with which it should probably be correlated. The workings are about 100 feet above Bumpass Cove Creek at the edge of a large remnant of the 160-foot terrace.

Little Polly Hollow mine.—The Little Polly Hollow mine (21) is a group of shallow cuts and pits not far northwest of Bumpass Cove Creek, on the northeast side of Polly Hollow. About 14 tons of oxidized zinc ore were taken from this locality in 1930.

The dolomite underlying the zinc pits is exposed just to the west in a small flux quarry on the east bank of Polly Hollow Branch. The dolomite is light gray to white and belongs to the upper white member; it dips gently to the southeast and shows strong fracturing and brecciation but contains little sparry dolomite. The zinc pits are on a vague bench that may represent the 80-foot terrace. Nothing can now be seen in the pits.

Rock Quarry Hollow zinc mine.—The Rock Quarry Hollow zinc mine (22) is on the northwest side of the cove and lies on the north side of Rock Quarry Hollow. In 1934, oxidized zinc ore was discovered by drilling but was not immediately exploited. Early in 1942, a shaft was sunk; the zinc ore was quickly mined out and the shaft abandoned.

The dump shows blocks of recrystallized ribboned dolomite which may belong to the ribboned member of the Shady. The collar of the shaft is on a vague bench about 240 feet above Bumpass Cove Creek.

Embree Iron Co. No. 13 mine and adjacent Tennessee Zinc & Lead Co. shafts.—The Embree Iron Co. No. 13 mine (23) is a shaft on the spur west of Rocky Branch, on the southeast side of the cove. It was operated from 1914 to 1917. The workings around this shaft were not very extensive, and the mine did not produce much zinc ore. It was reopened briefly in 1933.

Shafts Nos. 1 and 2 of the Tennessee Zinc & Lead Co. (24) are not far northeast of the No. 13 shaft. The workings from Shaft No. 1 connected with the No. 13 mine and the two were operated as a unit. Shaft No. 2 was a separate operation and connected with a 400-foot tunnel driven from the foot of the slope to the north. The mining was done between 1914 and 1917. No great quantity of zinc ore was obtained.

The dumps show blocks of blue-gray laminated and ribboned dolomite and blue ribboned limestone, probably from the lower blue member of the Shady. The collars of the Tennessee Zinc & Lead Co. shafts are on a bench representing the 160-foot terrace; that of the Embree Iron Co. No. 13 mine is somewhat higher.

Tennessee Zinc & Lead Co. No. 14 mine and adjacent shafts.—The Tennessee Zinc & Lead Co. No. 14 open cut (25) is on the southeast side of the cove, low on the broad spur northeast of Dry Branch. During the period of hydraulic iron mining, a small cut was opened here. In 1913 the Tennessee Zinc & Lead Co. bought the tract of land lying next south of Bumpass Cove Creek between Rocky and Dry Branches. This company greatly enlarged the old open cut; hydraulic methods were used to strip the overburden, and oxidized zinc ore was then mined in the floor of the open cut and from short tunnels and shafts. West of the open cut are Shafts Nos. 3 and 4 of the Tennessee Zinc & Lead Co. (26). All these mines were operated between 1913 and 1917, and apparently they furnished the greater part of the zinc ore mined by this company. No mining has been done on the tract since 1917.

The open cut covers about 2 acres. Large dolomite pinnacles are exposed in the upper part of the cut, but the lower part is chiefly in clay overlain by a thick layer of gravel.

The rock at the head of the open cut is light-colored ribboned dolomite and represents the western continuation of the ribboned member of the Shady. Overlying it and cropping out to the north is light gray compact dolomite with occasional layers of blue-gray dolomite; these beds are probably the stratigraphic equivalent of the upper blue member. The bedding dips northwest. Sparry dolomite is not noticeable except in certain beds of ribboned dolomite. The main body of the open cut is in a bench representing the 160-foot terrace, but part of the opening extends above and part below this level.

No zinc minerals were observed in the cut. However, small bodies of oxidized ore may be present in the clay, and the bedrock beneath may contain zinc sulphide.

Embree Iron Co. No. 14 mine and extension.—The Embree Iron Co. No. 14 mine (27) is on the southeast side of the cove and lies on the broad spur northeast of Dry Branch. At least three cuts were opened on this spur during the period of hydraulic iron mining. Beginning about 1914, oxidized zinc ore was mined in one of these open cuts on the southwest side of the spur, but at the same time deeper ore bodies were discovered by drilling, both under the open cut and elsewhere. Three adits were therefore driven from different sides of the spur, and from 1914 to 1918 and again from 1922 to 1924 the ore was mined by a complicated system of underground workings.

Drilling in 1926 and 1927 proved the existence of bodies of oxidized zinc ore southwest of the previous workings. Accordingly new shafts were sunk, and the older underground workings were extended into that area. This extension (28) was sometimes called the Dry Branch East or the No. 15 mine; it was operated from 1928 to 1933. Since then all the workings in both mines have caved.

Late in 1942 churn drilling was again begun in this area, with a view to blocking out bodies of sulphide ore. However, drilling and sampling difficulties were encountered, and the attempt was abandoned.

The stratigraphic section near the No. 14 mine is given on page 7. The dolomite pinnacles encountered underground were probably in the ribboned member and the underlying light gray dolomite. The rocks in the area form an anticline and a syncline whose axes pass just northwest of most of the workings. Some sparry dolomite is evident in the surface exposures, and the rocks are severely fractured in many places. The crest of the spur over the mine is a broad remnant of the terrace 290 feet above Bumpass Cove Creek.

No sulphides were observed in the exposed dolomite near the No. 14 mine, but Secrist (1924, p. 146), who had access to the workings, reports sphalerite and pyrite, and the records of some early drill holes that entered the dolomite suggest the presence of sulphides. A few of the more recent drill holes found 2 to 3 percent zinc as sulphide, but the showings were irregularly distributed and the drilling was inadequate to test the possibilities of the area.

Dry Branch mine.—The Dry Branch mine (29) (also called the Dry Branch West or McNabb mine) is on the southeast side of the cove and lies just southwest of Dry Branch. Drilling in 1926 and 1927 proved the existence of zinc silicate ore, and an adit was driven about 500 feet into the hill, part of the way through relatively fresh dolomite, to reach the ore body. The mine was operated from 1928 to 1932 and may have produced some oxidized lead ore as well. The adit has since caved.

The rock on the dump is blue-gray partly recrystallized dolomite, some ribboned and some brecciated, and may represent either the ribboned member or the lower blue member of the Shady. The spur over the mine shows benches corresponding to the 160-foot and 240-foot terraces.

Some of the dolomite on the dump carries a considerable percentage of sulphides, galena predominating over sphalerite. A few of the drill holes on the spur above also apparently encountered sulphides. The area around this mine is considered to have some promise for sulphide ore.

Simmons Branch mine, Frog mine, and adjacent mines.—The Simmons Branch group of zinc mines is on the southeast side of the cove, near the forks of Simmons Branch. Drilling from 1927 to 1929 and again in 1930 and 1931 discovered several bodies of oxidized zinc ore. The Simmons Branch mine (30) was opened in 1928 by an adit on the east side of the branch a little above the forks and was operated for about a year. The Frog mine (31), between the forks of Simmons Branch, was opened by an adit and a shaft in 1929 and was operated until 1931. In 1932 and 1933, a small pocket of ore on the east side of Rich Hill southwest of the forks was mined from a shaft called the No. 205 shaft (32) from the serial number of the discovery drill hole, U-205. Another small pocket on the north side of Rich Hill and others northeast of Simmons Branch as far as Davenport Hollow were mined by adits and shafts (33), probably about 1932. All of these workings have since caved.

Most of the rock on the dumps of these mines is light gray massive compact dolomite, but some is blue-gray dolomite which may represent the stratigraphic equivalent of the lower blue member. Considerable sparry dolomite is present in each rock type. Several of the mines appear to be related to benches of the 160-foot terrace.

The Frog mine and, to a lesser extent, the Simmons Branch mine were noted for the size and purity of the masses of zinc silicate encountered; some were so large that blasting was necessary. As the workings have since caved, the zinc silicate can no longer be observed. Oxidized zinc ore may still be present in the area, but the dolomite shows no evidence of sulphides.

Big Moccasin mine.—The Big Moccasin mine (34) is on the southeast side of the cove and lies at the lower end of the spur southwest of Big Moccasin Branch. Drilling in 1929 and 1930 discovered sizable bodies of oxidized zinc ore in this area. In 1930 an adit was driven into the base of the spur, and some of the ore was mined by a complicated system of underground workings. However, little of the zinc silicate was in lump form, and the ore proved unsuited to the milling methods employed, an unusually large part of the zinc being lost in the slimes. The mine was therefore abandoned in 1931. The failure of the Big Moccasin mine was one of the factors that led the company to cease mining, turning all mining operations in the cove over to contractors. Some of the ore in this vicinity was later mined from the Lick Log shafts (37).

As the workings have all caved, no evidence could be obtained as to the geology of the mine. The spur over the mine is a remnant of the 160-foot terrace.

If an economic method of recovering finely divided zinc silicate from clay were introduced, much of the clay around the Big Moccasin mine would become zinc ore.

Peach Orchard mine.—The Peach Orchard mine (35) is on the northwest side of Bumpass Cove Creek, northeast of Lick Log Hollow. The mine was opened in 1916 and quickly became the leading producer of both oxidized zinc and oxidized lead ore in the cove. The ore was mined by a complicated system of adits and levels, and operations were continuous until 1926, when the mine was abandoned as worked out.

In 1931, when contractors took over all mining in the cove, they reopened the Peach Orchard mine. In 1933 and 1934 more drilling was done in the area, and from 1935 to 1941 the Peach Orchard mine was again the chief producer of zinc and lead ore in the cove. Some of this later work was done underground, but much of it was in open cuts. In 1942 additional pockets of oxidized zinc and lead ore were discovered by drilling, and these were later mined by hand, although in 1943 some of the overburden was stripped by power equipment.

Pinnacles of light gray massive compact dolomite are exposed in the open cuts. The rocks dip gently southeast, and show little sparry dolomite but much brecciation. Part of the dolomite exposed is fresh but part has a disintegrated crust of weathered material. The original surface at the mine was a bench of the 160-foot terrace.

Hemimorphite and cerussite can still be seen here after more than 20 years of mining. Masses of galena have been found in the cerussite, and Secrist (1924, p. 146) reports sphalerite, but no evidence of sulphides can now be observed. The area around and south of the Peach Orchard mine is still the most promising in the cove for oxidized zinc and lead ore.

New Peach Orchard and Lick Log shafts.—Under the flood plain of Bumpass Cove Creek south of the Peach Orchard mine (35) and near the mouth of Lick Log Hollow, numerous pockets of oxidized zinc and lead ore have been discovered by drilling at various times. Being below the valley floor, these pockets could not be mined by the adit methods employed in the Big Moccasin (34) and Peach Orchard (35) mines. From 1931 to 1935 the contractors attempted to mine them by shafts sunk near the mouth of Lick Log Hollow, but much water was encountered and the shafts had to be abandoned. In 1942 four new shafts were sunk in this area; water and saturated incoherent clay were encountered in the deepest one, but by continuous pumping from the upstream shafts the water table was sufficiently depressed to permit mining. In addition to zinc and lead ore, some manganese ore has been mined in the area, chiefly from the southwesternmost shaft. The northeast shaft, close to the mouth of the Peach Orchard mine, is referred to as the New Peach Orchard mine (36) ; it was the first of the shafts to be opened in 1942 and was abandoned before the end of the year. The other shafts are near the mouth of Lick Log Hollow and are referred to as the Lick Log shafts (37).

The rock encountered in the workings is light gray massive compact dolomite showing little breccia and no sparry dolomite. The surface of the flood plain in this area is probably an undissected part of an old valley floor, which is represented farther downstream by the 80-foot terrace.

The ore discovered by drilling has not all been mined (1943), and other bodies of oxidized ore may be discovered in the area.

MANGANESE MINES

Rock Quarry Hollow manganese mine.—The Rock Quarry Hollow manganese mine (38) is on the northwest side of the cove and lies on the north side of Rock Quarry Hollow uphill from the Rock Quarry Hollow zinc shaft (22). An adit was driven into the hill about 1936, and high-grade manganese ore was found. In 1938 drilling proved that the ore bodies were small and not adapted to shovel operations. In 1942 two small open cuts were dug by hand, and the shallower ore was mined out.

The open cuts pass through red surface wash into yellow residual clay containing considerable jasperoid. They are between 370 and 420 feet above Bumpass Cove Creek.

The surface wash contains many small nodules of manganese oxide, but the high-grade ore, which was largely nodular pyrolusite, was all in the clay.

Casey Hollow mine.—The Casey Hollow mine (39) is on the spur between Casey and Rock Quarry Hollows, on the northwest side of the cove. In 1938 a sizable body of manganese ore was discovered here by drilling, but the overburden was too great to permit profitable shovel operations. In 1942 two tunnels were driven into the spur at different levels from the side of Rock Quarry Hollow, and the ore was mined from these tunnels in drifts and stopes, some of which broke through to the surface.

The ore is in residual clay at a considerable distance from the outcrop of the Erwin formation. The crest of the spur is a remnant of the 420-foot terrace level. The ore body was roughly a lens striking northeast and dipping steeply southeast.

Surface pits on the west side of the spur show some manganese oxide in the clay. A small amount of drilling in 1938 failed to prove the presence of any sizable ore bodies, but the showings still warrant further prospecting.

East Baptist Hollow mine.—The East Baptist Hollow mine (40) is on the northwest side of the cove, east of the forks of Baptist Hollow Branch. A small pit close to the branch was opened for manganese ore about 1936. In 1937 and 1938 the shape of the ore body was determined by drilling, and in 1938 and 1939 the shallower ore was mined by power shovel. This operation was the first of the power-shovel operations in the cove. During 1942 ore was mined by hand in the floor of the shovel cut.

The open cut is 400 feet long and covers about an acre. It was excavated in residual clay under gravel and slope wash; at one point a considerable thickness of pink well-sorted sand intervenes between the clay and the gravel. The mine is farther from the outcrop of the Erwin formation than the West Baptist Hollow mine (41) or the West Ore Bank (42) and is somewhat lower in elevation than those mines. It heads against a remnant of the 370-foot terrace but was not excavated under it.

The open cut exposes two streaks of manganese-bearing clay. These streaks strike northeast and dip steeply toward each other; they are separated by a downward-tapering wedge of barren clay. In the southeastern streak, hard nodules of material of psilomelane type are embedded in clean yellow clay, but the clay in the northwestern streak is intimately mixed with soft powdery pyrolusite, although some hard nodules are also present. In general, mining has followed the southeastern streak, as the soft pyrolusite could not be saved in milling.

Manganese ore of good grade was still visible in this cut in 1943, and drill records suggest that some ore still remains below the bottom of the cut. However, the steep walls of the cut are continually sliding in and would make any mining operations difficult.

The clay under the spur north of the mine and that between the mine and the outcrop of the Erwin formation has not been adequately prospected. The east side of the spur has been drilled, and ore bodies were discovered, but the ore is low grade, the iron content being as high as the manganese content. Nevertheless, the whole area deserves further exploration and perhaps development.

West Baptist Hollow mine.—The West Baptist Hollow mine (41) is on the northwest side of the cove and lies west of the forks of Baptist Hollow Branch. In 1918 several prospect pits were dug on the spur, but no mining was undertaken. In 1934 prospecting was resumed, and in 1935 three adits were driven into the hill at different levels from the side of Baptist Hollow. From 1935 to 1938 the deeper ore under the hill was mined in these underground workings. In 1937 and 1938 drilling disclosed a large body of shallower ore, and in 1939 and 1940 this ore was largely mined out by power shovel. In 1942 a little ore was mined by hand on the floor of the shovel cut. According to company officials, the West Baptist Hollow mine has produced about a quarter of the manganese ore which has been mined in the cove.

The open cut is irregular in shape and covers a little more than an acre. Its longest dimension is about 400 feet. It was excavated in clay overlain by some gravel. In the center of the mine is a large block of jasperoid[5], over 20 feet in each dimension. The mine lies fairly close to the outcrop of the Erwin formation, under a remnant of the 370-foot terrace.

The manganese-bearing clay occurs in streaks which are more irregular in distribution than those in the East Baptist Hollow mine (40) or the West Ore Bank (42). The ore consists of nodules of material of psilomelane type and of pyrolusite embedded in waddy clay containing some powdery pyrolusite. An envelope of soft dark graphitic manganiferous material of unknown composition (p. 29) sheathes the great block of jasperoid.

Drill records indicate that some deep bodies of manganese ore still (1943) remain in and near this mine.

West Ore Bank.—The West Ore Bank (42) is on the northwest side of the cove and lies on the spur northeast of Madcap Branch. Iron ore was mined here during much of the nineteenth century. Before 1844 it was carted over Embreeville Mountain to a furnace on Clark Creek; later it was used in the charcoal furnace below Embreeville and after 1892 in the furnace at Embreeville. Prospecting for manganese began in 1918. Stose and Schrader (1923, p. 86) report that several tons of high-grade ore were mined at

[5]Interpreted as a quartzite boulder by Reichert (1942, pl. 10).

this time, but there is no record of any shipment of manganese concentrates.

In 1934 prospecting was resumed, and in 1935 underground mining was begun, adits being driven from two sides of the spur. In 1937 and 1939 the ore bodies were outlined by drilling, and from 1939 to 1941 they were mined by power shovel. In 1942 some of the ore left by the shovel was mined by hand in open cuts and underground workings. In 1943 power equipment was used to strip overburden from deep-lying ore that had been inaccessible to the shovel, and this ore was then mined by hand. Company officials estimate that over half the manganese ore produced in the cove has come from the West Ore Bank.

The main open cut is a trench extending across the spur not far southeast of the outcrop of the Erwin formation; it is 700 feet long and about 150 feet wide and covers about 2½ acres. Another, much smaller shovel cut was opened on the south side of the spur, but it encountered only lean ore and was abandoned. The cuts are in clay containing many large blocks of jasperoid and overlain by slope wash with many quartzite boulders. The jasperoid blocks in the clay have made mining, particularly by power shovel, difficult. The spur is a remnant of the 370-foot terrace.

The manganese-bearing clay in the main cut occurs in two streaks dipping steeply southeast and separated by barren clay. Most of the nodules in the clay are composed of material of psilomelane type, but some contain pyrolusite. Some of the clay, especially that in the northwestern streak, is mixed with powdery pyrolusite. Stringers of the same soft graphitic material that occurs in the West Baptist Hollow mine (41) are present, especially close to masses of jasperoid.

Madcap mine and adjacent adit.—The Madcap mine (43) is on the northwest side of the cove and lies on the west side of Madcap Branch south of the West Ore Bank (42). A small ore body was discovered here by drilling in 1939 and was mined by power shovel in 1940 or 1941.

The cut is not more than 200 feet long and was excavated in residual clay under considerable overburden of slope wash. It lies a little more than 200 feet above Bumpass Cove Creek at the point of a long spur running east from the 2,510-foot summit of Embreeville Mountain.

About 500 feet southeast of the open cut and a little higher on the spur is a caved adit (44), probably opened about 1936. A few pieces of manganese oxide were observed on the dump.

Drilling on the long spur mentioned has so far been confined to the immediate vicinity of the Madcap cut and a small area near the crest of the mountain. The intermediate part of the spur, opposite the West Ore Bank at about the level of the 370- to 420-foot terrace, deserves prospecting for manganese ore, although a thick overburden of gravel is probably present.

Manganese mines in southwest end of cove.—About 1936 manganese was discovered on the slope northwest of the Peach Orchard mine (35), and a short adit (45) was driven into the hill. In 1938 and 1939 the area was drilled for manganese, but the results were considered unpromising. In 1942 a little manganese ore was mined from an adit lower on the slope, at the northwest edge of the Peach Orchard mine.

In 1942 drilling and trenching proved the existence of bodies of manganese ore in the area southwest of the Peach Orchard mine, some of them lying under the valley floor of Bumpass Cove Creek but above the deposits of oxidized zinc and lead in the same area. Some manganese ore was mined in the southwesternmost of the Lick Log shafts (37) ; in addition ore was mined in two small open cuts, one (46) in Lick Log Hollow, and one (47) farther southwest, close to Bumpass Cove Creek.

The open cuts expose alternating streaks of brown waddy clay and yellow clay. The ore is chiefly in the brown clay.

Similar manganese deposits may be present elsewhere in this part of the cove, especially farther southwest, and prospecting should be continued in that direction.

QUARRIES FOR FLUX

The large rock quarry (9) just west of the mouth of Rock Quarry Hollow was opened during the iron mining operations in the cove and was the principal source of flux for the blast furnace at Embreeville. The face of the quarry is about 50 feet high and its floor covers about 2 acres. Apparently the overburden was stripped by hydraulic methods.

The quarry exposes white and light gray dolomite belonging to the upper white member of the Shady and is approximately on the axis of the main syncline of Bumpass Cove. The rock is severely fractured and in places brecciated and is cut by several small normal faults, but there is very little sparry dolomite and sulphide mineralization is absent. At the north end of the quarry, shattered iron-stained dolomite has been replaced to a small extent by silica differing only in its occurrence from the jasperoid so common in the clay banks of the cove. Jasperoid is not known in the dolomite at any other place in the cove.

Dolomite was also quarried for flux in the southwest end of the Jackson mine (6) and in a small quarry on the east side of Polly Hollow Branch near the Little Polly Hollow mine (21). Another flux quarry was apparently projected about 2,000 feet southwest of the first Rock Quarry (9), on the northwest side of Bumpass Cove Creek between Casey and Baptist Hollows, for the overburden in this area (10) has been stripped by hydraulic methods. Fractured and brecciated dolomite, belonging to the upper white member and lying close to the axis of the main syncline, is exposed in this stripped area.

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