STATE OF TENNESSEE
DEPARTMENT OF EDUCATION

DIVISION OF GEOLOGY

Wilbur A. Nelson, State Geologist.

BULLETIN 31

ZINC DEPOSITS
OF
EAST TENNESSEE

By MARK H. SECRIST.

NASHVILLE, TENNESSEE
1924

BOARD OF NATURAL RESOURCES

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The Zinc Deposits of East Tennessee

By MARK HOWARD SECRIST

PREFACE

The area upon which this report is based lies in the Great Valley region of East Tennessee. It extends from Virginia, on the north, to Georgia, on the south; on the east it is bounded by the Unaka Range of mountains, and on the west by the Cumberland Tableland.

Within this section of the State much prospecting and small-scale zinc mining has been carried on for many years but few accounts of such activity are available. Since 1911, upon the entry of the American Zinc Company into the field, Tennessee has taken rank as an important producer of zinc in the United States. Almost the entire production comes from the Mascot district.

In this report an attempt has been made to systematically describe the features of the scattered deposits of the region and, by grouping together those localities which contain geologically related deposits, to indicate roughly the horizons in which future prospecting will most probably locate additional ore deposits.

The assignment of this problem was made in May, 1921, as the result of an agreement between the Department of Geology of Johns Hopkins University and Mr. Wilbur A. Nelson, State Geologist of Tennessee.

The field work was conducted during the field seasons of 1921 and 1922. During each season Dr. J. T. Singewald, Jr., spent a few weeks in the field with the writer, and later supervised the writing of the report.

Except where otherwise stated, the analyses accompanying this report were made by D. F. Farrar, chemist for the Tennessee State Geological Survey.

Both a preliminary and a complete report of the United States Bureau of Mines, based upon special work in the Evanston district, have been included in this report.

The writer takes this means of expressing his gratitude to the members of the Geological Department of the Johns Hopkins University for their interest and assistance given him during several years he has been a student in the Department.

He wishes to express his particular appreciation to Dr. J. T. Singewald, Jr., under whose direction this report has been made and from whom he has received much helpful criticism in both the field and laboratory. Thanks are also due Mr. Wilbur A. Nelson, State Geologist of Tennessee, for his splendid cooperation at all times during the progress of the work and for his permission to use the results for a dissertation.

HISTORY

The history of zinc mining in East Tennessee dates back to 1856, when the Mossy Creek mine at the eastern edge of Jefferson City was discovered. The name of the discoverer is unknown. The finding of surface exposures of the oxidized ores in the outcropping limestones and residual clay soon led to the discovery of the sulphide ores in the underlying unaltered limestones.

The "Lead Mine Bend" or Powell River mines also date back many years. The exact time of their discovery has not been recorded. From all accounts the deposits located in the Straight Creek area have been known and worked from time to time for many years. The same might be said of practically all the zinc deposits of East Tennessee. There is scarcely a county in the eastern part of the state where some prospecting for zinc ores has not been undertaken.

As far as can be learned, prior to the systematic development of the Mascot district in 1911, no large scale or successful operation of any of the zinc deposits was carried on. But in that year, after several companies had made considerable progress in developing the Mascot area, and had proven a relatively extensive body of low grade sulphide ore, the American Zinc Company entered the field. It introduced, for the first time in Tennessee, modern methods of prospecting and mining the ore. From the first the success of its management was apparent and too great credit can not be given this company for its pioneer work in a previously unimportant field. Throughout the history of its operations, the American Zinc Company has confined its efforts to underground mining of the sulphide ore, sphalerite.

It has been the experience of this company that successful results in zinc mining in East Tennessee can be achieved only through the expenditure of large sums in prospecting and blocking out bodies of pay ore of sufficient magnitude for large scale operations. This should be kept in mind by whoever expects successful results in the developments of other deposits.

The history of operations at Embreeville presents a rather colorful picture. This mine started as a producer of lump iron-ore washed out of the residual clay covering the limestone in Bumpass Cove. After the company had passed through alternating periods of successful operation and failure as an iron mine, in the course of which much of the clay had been washed away, the presence of large quantities of lead and zinc ores in the clay was realized, and the mine entered upon a long period of prosperity as a zinc mine.

PRODUCTION

No accurate figures of the zinc production of East Tennessee prior to 1912 are obtainable but the output in those years was small. Since 1912 the output has grown to large proportions as shown by the following figures taken from the Mineral Resources of the United States published by the United States Geological Survey.

East Tennessee Zinc Production since 1912

Years	Mine production (crude ore) in short tons
1912	32,347
1913	171,392
1914	357,437
1915	525,829
1916	702,326
1917	883,341
1918	598,742
1919	649,844
1920	598,742
1921	319,764
1922	411,484
1923	579,022

The rapidly increasing output after 1912 was due to the operations in the Mascot district. Until the Embree Iron Company started producing ores in 1919 almost the entire production came from the Mascot area.

The peak of production was realized during the recent war, in 1917, when 883,341 tons of crude ore were mined, and East Tennessee ranked seventh along the producing districts of the United States. Since then lower prices and a decreased demand have caused a falling off in production.

GEOGRAPHICAL DISTRIBUTION

Without exception, all the deposits of zinc described in this report are limited in their geographical distribution to the Great Valley province. The area upon which this report is based lies entirely within the Great Valley district of the Appalachian province and extends from the Tennessee-Georgia line, on the south, northeastward to the Tennessee-Virginia line; it is bounded on the southeast by the Unaka chain of mountains; and on the west or northwest, by the eastern escarpment of the Cumberland Tableland. To the northeast this area is continuous with the Valley of Virginia; to the southwest it extends into Georgia and Alabama. It is, in reality, but a part of a long, great and complex trough, the Appalachian Basin, that extends roughly from the Susquehanna River, in Pennsylvania, southwestward to the Coosa and Black Warrior rivers in Alabama.

Although mining and prospecting have been carried on in scattered localities throughout the length of the Valley in Tennessee, that is from northeast to southwest, by far the greater part of such activity has been confined to the northeastern half, approximately northeast of a line transverse to the direction of the Valley and passing through Knoxville. A little prospecting, and even mining, was carried on scme years ago in the southwestern part, namely at the Dollie D mine and the Hardwick mine, both in Bradley county, but at these localities, from all reports, the principal production was in lead ores and not zinc. In fact, no mines south of Knoxville have been successfully operated for the production of zinc ores.

As will be realized in the descriptions of the various localities, zinc minerals have been found in most of the Valley counties. But in a majority of the localities that have been prospected the grade of the ore and the size of the deposits have been discouraging. However, several promising regions do occur but the extent of developments in most cases is too limited to make definite predictions as to the value of the deposits.

GEOLOGICAL DISTRIBUTION

The occurrence of zinc and lead ores in the Valley is confined almost entirely to the Knox dolomite formation. There are two exceptions, viz: the mines at Embreeville where quantities of oxidized zinc and lead ores are mined from the residual clay of the Shady limestone of Cambrian age, and at Evanston where small, non-commercial deposits of sphalerite have been found in a dolomite bed of the Rome formation.

The ore deposits in the Knox dolomite are found in horizons varying from near the top to near the bottom of that formation. A significant feature which is treated more fully in the discussion of their origin is that practically all of the deposits in the dolomite are associated with brecciated horizons.

PHYSIOGRAPHY

The Great Valley, or Appalachian Valley, although considered in a broad sense as a great Valley, is in reality an area made up of subordinate, closely parallel valleys and ridges which have a general northeast-southwest trend and thus conform to the structural axes of the Appalachians.

The ridges are very numerous and differ somewhat in sharpness of outline and height; however, each one is remarkable for the uniformity of character it preserves from one end to the other—a distance, in scme instances, greater than 100 miles. The differences among them result largely from the nature of the rocks of which they are composed and hence are due to geologic causes. For the most part the ridges are fairly high and medium to steep-sided; in many places presenting a relief of one thousand feet or more.

At irregular intervals the Valley is partially intersected by sharp ridges or spurs breaking off from the main ridges and lying at nearly right angles to them.

Near the Virginia line the elevation of the valley floor is about 1,350 feet and the crests of the ridges average about 2,000 feet in height. The average elevation of the valley floor gradually diminishes southwestward to about 800 feet at the Georgia line, that is, in a distance of about 175 miles. Therefore, the slope of the floor of the valley is almost uniformly to the southwest.

On the east the Unaka Range, so named by Professor Safford, is a southwestward continuation of the Blue Ridge Range of Virginia. The Unaka Range, forming the boundary between Tennessee and North Carolina, varies in elevation along the State line from about 6,500 to 3,000 feet. On the west of the Valley, the Cumberland Mountains, or "Tableland," is much lower and varies in elevation along its eastern rim from 2,000 to 3,000 feet.

The Valley occupies a belt of intensely folded strata, which in many cases, have been faulted and thrust for considerable distances out of their original position. Its rocks are almost wholly sedimentary and are in a large measure calcareous. The strata, which must have originally been laid down in a horizontal position, now intersect the surface at various angles and in narrow belts. The surface, or topography, of the Valley as it now exists, is due to the chemical composition of the rocks and their structural relations so that sharp ridges and narrow valleys of great length follow narrow belts of hard and soft rock respectively.

DRAINAGE

The entire valley region of East Tennessee is drained by the Tennessee-Holston river system with its many tributaries. All of the rivers have, in general, a southwesterly course following the general slope of the valley. However, locally, where the streams break through the ridges and form narrow and deep gorges, a distinct northwesterly direction obtains. But their course in this direction is of only short length except in the case of a few of the rivers in the southeastern part of the valley.

The tributary rivers which flow out of North Carolina all pursue a westerly or northwesterly course until they unite with the Tennessee or its continuation, the Holston river.

The tributaries on the eastern side of the Tennessee-Holston system are more numerous and rapid than those on the west and are fed by many more small streams. Principal among them in their order from northeast to southwest, are the Watauga, the French Broad, the Little Tennessee, and the Hiwassee on the east. The Clinch is the only important tributary on the west. Each of these rivers is fed by smaller rivers and they, in turn, by smaller streams—all combining to effect a most efficient drainage-system for the entire valley.

STRATIGRAPHY

ROCK FORMATIONS

GENERAL FEATURES

The following discussion of the stratigraphy is based largely upon the reports of Keith[1], Campbell[2], and Hayes[3] and free use of their publications has been made.

The rocks of the Valley district consist almost entirely of sedimentary deposits and range in age from lower Cambrian to lower Carboniferous. They include conglomerates, sandstones, shales, and limestone, arranged in regular sequence in accordance with the several periods of depression and elevation mentioned above. However, a given formation does not always maintain the same composition and appearance but often shows considerable variation across the strike of the beds. The degree of metamorphism also varies from place to place, so that the strata show local lithological and structural variations because of it.

In the geologic tables, Figures 1 and 2, is given the general geologic section as it occurs in various parts of the Valley. Due to the great length of time that has elapsed since its final emergence as a land mass, erosion has worn down the younger rocks so that now only a few scattered remnants of lower Carboniferous strata remain.

During the deposition of the sedimentary rocks an ancient land mass, known as Appalachia, existed in the east and southeast. The various formations accumulated largely from the decomposition of sediments which were eroded from this land mass and carried into the adjacent Appalachian sea.

The zinc deposits, contrary to the reports of earlier investigations, are not restricted in their distribution to any one formation but have been found from the Shady limestone, of lower Cambrian age, to the Knox dolomite, of Cambro-Ordovician age. Nevertheless, by far the higher number of these deposits, in fact, practically all of those of economic importance so far discovered, lie at various horizons within the Knox dolomite.

The rocks of the metamorphic group are restricted entirely to the northwestern slopes of the Unaka Range and have not been known to contain any economic deposits of zinc. As shown in the table they consist of slates, quartzites, and conglomerates and represent sedimentary beds which have almost entirely lost their original appearance and texture through metamorphism.

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[1]Keith, Arthur, U. S. Geol. Survey, Geol. Atlas, Knoxville folio (No. 16), 1895.
Loudon folio (No. 25), 1896.
Morristown folio (No. 27), 1896.
Maynardville folio (No. 75), 1901.
Greeneville folio (No. 118), 1905.
Roan Mountain folio (No. 151), 1907.

[2]Campbell, M. R., U. S. Geol. Survey, Geol. Atlas Estillville folio (No. 12), 1894.

[3]Hayes, C. W., U. S. Geol. Survey, Geol. Atlas, Cleveland folio (No. 20), 1895.

CLASSIFIED AND CORRELATED LOWER PALEOZOIC FORMATIONS IN EAST AND CENTRAL TENNESSEE

Compiled by W A Nelson from published and manuscript tables prepared by E O Ulrich.

System	Series	Group	General time scale	Western part of valley (North / South)	Knoxville trough (West / East)	Athens trough (West / East)	Central Tennessee East	Central Tennessee West
SILURIAN			Cayugan series	Sneedville limestone				Decatur limestone
	Niagaran		Lockport group (N.Y.)					Louisville, Bob, Beech River, Dixon, Waldron, Laurel, Osgood ls and shale
			Clinton group (N.Y.)	Clinton form.				
	Medinan		Alexandria group	Clinch ss. / Whiteoak ss. / Rockwood f.	Clinch ss.			Brassfield ls.
			Richmond group	Sequatchie form 500'	Sequatchie			Richmond formations
ORDOVICIAN	Cincinnatian	Maysville	McMillan (O)					
			Fairview (O)	Fairview formation 400'	Fairview form		Usually absent	Leipers formation
			Eden group (O)	Eden shale 1000'+	Eden shale 1500'	Eden shale 300'-800'		
	Mohawkian	Trenton	Catheys	Catheys limestone 0'-75'	Trenton limestone 565'		Catheys 0'-50'	Catheys 50'-100'
			Cannon	Cannon limestone 300'			Cannon ls 50'-250'	
			Bigby	Bigby limestone 0'-50'			Usually absent	Bigby limestone 100'
			Jessamine (Ky)					
			Hermitage	Hermitage shale 200'			Hermitage shale 100'	
		Black River	Chambersburg 600' (Pa. Md. Va.)					
			Leray (N.Y.)	Upper Black River ls. 250'	Moccasin limestone (Bays ss) 400'-800'	Moccasin ("Typical" Bays ss.) 300'-1100'		
			Lowville (N.Y.)	Lowville limestone 456'	Lowville limestone 350'	Lowville limestone 325' / Sevier shale	Carters limestone 110'	
	Chazyan	Blount	Ottosee		Ottosee shale 2400'	Ottosee shale 700'-2600'		
			Tellico		Tellico f. 400'	Tellico formation 800'-1500'		
			Athens / Whitesburg			Athens shale 1200'-4000'		
			Holston	? Holston limestone 110'	Holston marble 350'±	Whitesburg limestone 50'-600'		
		Stones River	Lebanon	Stones River limestone 600'-1000'			Lebanon limestone 100'	
			Ridley		Lenoir limestone 600'	Lenoir limestone 0'-100'	Ridley limestone 80'	
			Pierce				Pierce shale 27'	
			Murfreesboro				Murfreesboro limestone	
			Big Buffalo series (Ark 500')	?	Mosheim limestone 50'	Mosheim limestone 5'-50'		
CANADIAN	Up. Canadian		Yellville	?	Upper Canadian 2000'	Upper Canadian / Jonesboro ls.	Upper Canadian (Cotter dol.)	
	Mid Canadian		Longview	Longview dol. 1000' (Included in Knox dolomite)	Longview dol.			
	Low Canadian		Tribes Hill					
OZARKIAN	Up. Ozarkian		Chepultepec	Chepultepec dol. 1000'				
	Mid Ozarkian		Copper Ridge	Copper Ridge dol. 2000'	Copper Ridge dol. 1000'	Copper Ridge 0'-500'		
			Lower Ozarkian			Greenville dol. 400'		
			Cambrian formations					

In this bulletin the Author uses the name Knox dolomite, which is equivalent to the formations here listed under Cambrian and Ozarkian.

FIGURE 1. Correlation table of Lower Paleozoic formations.

System		Greeneville Folio (Central)		Cleveland Folio (Southern)		Roan Mtn Folio (Eastern)	Bristol Folio (Northeastern)	Maynardville Folio (Western)
Ordovician		Athens shale		Athens shale		Athens shale	Sevier shale	
Ordovician		Chickamauga ls.		Chickamauga ls.			Chickamauga ls	Chickamauga ls
Ordovician		Knox dolomite		Knox dolomite		Knox dolomite	Knox dolomite	Knox dolomite
Cambrian		Nolichucky shale	Conasauga sh.	Nolichucky sh.		Nolichucky sh.	Nolichucky sh	× Conasauga sh.
Cambrian	Honaker ls.	Maryville ls.	Conasauga sh.	Maryville ls.		Honaker ls.	Maryville ls.	
Cambrian	Honaker ls.	Rogersville sh.	Conasauga sh.	Rogersville sh.			Rogersville sh	
Cambrian	Honaker ls.	Rutledge ls.	Conasauga sh.	Rutledge ls.			Rutledge ls.	
Cambrian		Rome formation		Rome form		Watauga shale	Russell form.	Rome form
Cambrian				Rome sandstone				Rome ss.
Cambrian		Shady limestone		Apison shale		Shady ls.		
Cambrian	Metamorphic Group	Hesse quartzite				Hesse quartzite		
Cambrian	Metamorphic Group	Murray slate	Chilhowee Series	Murray shale	Hampton sh	Murray slate	Hampton shale	
Cambrian	Metamorphic Group	Nebo quartzite	Chilhowee Series	Nebo sandstone	Hampton sh	Nebo quartzite		
Cambrian	Metamorphic Group	Nichols slate	Chilhowee Series	Nichols shale	Hampton sh	Nichols slate		
Cambrian	Metamorphic Group	Cochran cong.	Chilhowee Series	Cochran cong.	Unicoi form.	Cochran cong.	Unicoi formation	
Cambrian	Metamorphic Group	Hiwassee slate	Chilhowee Series	Sandsuck sh.	Unicoi form.	Hiwassee slate		
Cambrian	Metamorphic Group	Snowbird form	Chilhowee Series	Starrs cong.	Unicoi form.	Snowbird form.		

FIGURE 2. Correlation table of Cambrian formations.

CAMBRIAN SYSTEM

SHADY LIMESTONE

When the sequence is clear the metamorphic rocks are overlain by the Shady limestone. This formation, consisting of limestone, and dolomite of various kinds, is not widespread but is limited in extent to several small areas or basins most notable of which are Shady Valley, Johnson county (the type locality) and Bumpass Cove, in Washington county.

Several kinds of limestone are represented in the formation. For the most part they are bluish-gray or gray color and weather with a dull gray or black surface, a rather characteristic and distinguishing feature. Some of the layers are mottled gray, blue or white and are often seamed with calcite. Dolomite beds are intercalated in irregular manner throughout the formation and, in a few places, siliceous impurities in the form of chert and sandy limestone are found. The Shady limestone has at its top, just under the overlying Watauga shale, thin beds of blue and gray shale.

Ores of lead and zinc have been found in the rocks of this formation at but one locality, Bumpass Cove. Here erosion has reduced the thickness to about 500 feet. The oxidized ores of zinc, lead, and iron are scattered through the heavy soil overburden and some sulphides are found in the unaltered rock; but their occurrence in so limited an area indicates little as to their probable presence in other areas in the same formation. The total thickness of the Shady limestone is about 1,000 feet.

WATAUGA SHALE

The Watauga shale has the same general distribution as the Shady limestone but does not occur in Bumpass Cove. The strata were deposited at practically the same time as those of the Rome formation farther west and the Russell formation toward the north in the Great Valley, that is, in Virginia. Its position in the sequence of Cambrian strata and its character indicate that it is equivalent to the Russell and Rome formations.

The formation consists of a series of interbedded limestone, red, green, and variegated shales, and red sandstone. The limestones are blue and gray in color but are not numerous and rarely exceed 10 feet in thickness. Much the greater part of the formation is made up of red, brown, purple and yellow shales, in some places calcareous, in others arenaceous, and generally argillaceous. The bright colors are due to considerable amounts of iron oxide disseminated through layers.

The frequency of ripple marks and changes in sediment from sand to mud are evidence that the formation was deposited in shallow water under conditions closely approximating those of the formation of mud flats. In the equivalent Rome and Russell formations fossils of lower Cambrian age have been found, but no fossils have been found in the Watauga.

The thickness of the formation is fairly constant and ranges between 1,000 and 1,100 feet. No deposits of either lead or zinc of economic importance have been discovered in the Watauga shale.

The equivalent of the Watauga shale in the Valley is called the Rome formation. The name is taken from the exposures at Rome, Floyd County, Georgia.

Toward the northwestern part of the Valley the limestone beds become more prominent and attain a maximum thickness of 135 feet in River Ridge and Short Mountain, Hancock County. At these localities, described in greater detail under the Evanston mining district, ores of zinc have been found and mined.

RUTLEDGE LIMESTONE

The Rutledge formation occurs in all the areas which show the Rome formation, except in southeast Tennessee, Georgia and Alabama. It is named from its fine development in the valley of Rutledge, in Grainger County, Tennessee. As a whole the strata are limestone, but there are many beds of green and yellow, calcareous shale toward the base which form the passage from the Rome formation. The limestones are massive and range in color from blue to dark blue, gray and black. In the valley of Rutledge the formation varies from 200 to 500 feet, and steadily diminishes in thickness farther north and west as well as to the southwest. The highly calcareous nature of the rock causes it to weather easily, and it invariably forms either valleys or slopes along Rome sandstone ridges.

No deposits of zinc ores have been found in this formation in East Tennessee.

ROGERSVILLE SHALE

This shale, like the preceding limestone, can be distinguished in all of the zones of the Cambrian rocks northwest of the Holston river. The name is derived from the town of Rogersville, in Hawkins County, Tennessee, where the formation is splendidly exposed. It consists chiefly of bright-green argillaceous shales, with occasional beds of thin, red, sandy shale and local thin beds of shaly limestone. The formation varies in thickness from 70 to 250 feet. Outcrops are frequent but the rock is soft and forms only small knolls in the limestone valleys.

MARYVILLE LIMESTONE

This limestone occurs in the same belts of Cambrian rocks as the preceding formation. It receives its name from its great development at Maryville, Blount County, Tennessee. The formation consists of massive, blue limestone with numerous earthy, siliceous bands and occasional grayish-blue and mottled beds. In thickness the formation ranges from 500 to 800 feet. The limestone decays readily by solution and forms a deep red clay. It is generally found either in valleys or, together with the Nolichucky shale, in a series of low hills.

HONAKER LIMESTONE

The rocks of this formation are of dark gray or blue color and have in general the same characters as the corresponding Rutledge and Maryville limestones. The thickness of the formation ranges from 700 to 1,800 feet. The type locality of this formation is Honaker, Virginia.

No zinc deposits are known to occur in the Honaker limestone.

NOLICHUCKY SHALE

The Nolichucky shale is one of the most persistent and widespread formations of the Cambrian system. It is named from the Nolichucky river along whose course in the Greenville region the shale is exposed. It is composed of calcareous shales and shaly limestones with a few beds of massive limestones in its upper portion.[1]

Bluish-gray and gray colors predominate in the shales and shaly limestone when fresh, but, due to weathering, these colors are changed into various shades of yellow, brown and green.

As previously stated, this formation is very persistent and is valuable as a horizon marker for the overlying Knox dolomite, the important ore-bearing formation of the Valley. No ores have been found in the Nolichucky shale. Frequently the break between the shale and the dolomite is characterized by a few feet of peculiar limestone containing knots or eyes. The formation is the most fossiliferous of the Cambrian rocks and contains abundant animal remains, especially trilobites and lingulas.

The shale varies considerably in thickness, averaging about 450 feet. Its maximum thickness is over 700 feet, in the Rutledge valley.

CONASAUGA SHALE

In the western and southern portions of the Valley, the Rutledge limestone, Rogersville shale, Maryville limestone, and Nolichucky shale are united under the single term Conasauga shale. These strata represent the more muddy sediments which accumulated during the deposition of the above-named series. The formation is named from the Conasauga Valley, Georgia, where the entire series is well developed. In its characteristics of soil and topography the formation is identical with the Nolichucky shale.

[1]There is no true transition from the Nolichucky to the Knox in East Tennessee, here as a rule, a great break between the two is indicated by absence of thousands of feet of limestone that are found locally in Alabama and Pennsylvania between beds that correspond to the Nolichucky and the Knox. W.A.N.

OZARKIAN AND CANADIAN SYSTEMS[1]

(Cambro-Ordovician.)

KNOX DOLOMITE

This division is the most massive formation of calcareous strata in the Valley, and is the most widespread. Its name is taken from the city of Knoxville, Tennessee, which is located on one of its areas. Northeastward, in the valley region of southwest Virginia, the Knox dolomite has been correlated with the Shenandoah limestone. Campbell[2], however, has shown that the Knox dolomite represents but a part of the Shenandoah limestone, the latter including all the Knox formation and at least 500 feet of Cambrian strata beneath it.

The Knox dolomite has been considered in part Cambrian and in part Ordovician in age.[3]

The formation consists of a great series of blue, gray and whitish limestone and dolomite most of which is very fine-grained and massive. The term "dolomite" is used, but in reality the proportion of magnesium in the rocks makes them magnesium limestone. Many of the beds are banded with thin, brown, siliceous streaks. Quite generally, in the formation, there are beds of white calcareous sandstone a few feet thick which consist of fine, rounded sand grains embedded in a calcareous cement. Two horizons of these beds are most noticeable, one a little above the Nolichucky shale, the other near the middle of the dolomite.

In certain sections throughout the Valley the lower part of the formation is composed of numerous white and sandy layers. These are particularly noticeable in the Copper Ridge exposure. Throughout the formation are included many masses and nodules of chert and at places these form intercalated beds. The chert horizons are more abundant near the base of the formation but occur irregularly throughout the entire thickness.

As the dolomites reach the contact of the overlying Chickamauga limestone, the uppermost beds become increasingly calcareous. In certain localities the uppermost layers of the dolomite are distinguishable by a breccia or angular conglomerate of limestone.

In the northern portion of the Valley in Tennessee the Knox dolomite ranges in thickness from 2,500 to 3,500 feet; in the southern portion it is somewhat thicker, ranging from 3,800 to 4,200 feet.

Varied types of topography occur in the Knox dolomite areas; but, for the most part, due to the presence of the chert layers, this formation is characterized by ridges and valleys. When the strata dip at a low angle the ridges are generally broad and rounded, and, when

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[1]New Classification of E. O. Ulrich.

[2]Campbell, M. R., U. S. Geol. Survey, Geol. Atlas, Pocohontas folio (No. 26), p. 2, 1896

[3]The sequence of Upper Cambrian and pre-Ordovician formations in the Appalachian Valley varies greatly from place to place. And the Knox dolomite nowhere contains either Middle or Upper Cambrian fossils. The "Shenandoah" limestone on the contrary does in places include Cambrian rocks, and these may be succeeded directly by any one of five or six distinguishable Ozarkian and Canadian formations. In Tennessee and Alabama three or more Ozarkian formations and at least two Canadian formations have been recognized and mapped. W.A.N.

chert predominates "knobby regions" prevail. When the strata are much inclined the ridges are generally very long and unbroken except for occasional stream gaps.

On account of the solubility of its materials the dolomite weathers rapidly and is generally covered to a considerable depth by a mantle of red clay through which is scattered the insoluble chert. Areas of cherty soil are generally characterized by the presence of large and numerous sink holes.

This formation suffered much deformation during the course of the orogenic movements to which the region was subjected. At times the strata were closely folded and even overturned; again faulting resulted and adjacent beds were thrust over each other for great distances. These movements, whether expressed in folds or faults, frequently resulted in intense brecciation of certain horizons in the dolomite and it is in these horizons that mineralizing waters circulated and deposited their burdens.[1]

ORDOVICIAN SYSTEM

CHICKAMAUGA LIMESTONE[2]

The Knox dolomite is generally overlain by the Chickamauga limestone which consists of massive blue and gray limestones, and variegated marbles. As a rule the beds are very fossiliferous and contain abundant remains of corals, brachiopods and gasteropods. The formation is named from its development at Chickamauga Creek, Hamilton County, Tennessee.

The thickness of the limestone is quite variable ranging from a few feet along the eastern edge of the Valley to more than 2,000 feet in the western and northwestern parts.

ATHENS SHALE

This formation was deposited at about the same time as the Chickamauga limestone and is the argillaceous sediment accumulated near shore, while the more calcareous material was deposited farther away.[3] Along the eastern border of the Valley the Athens shale overlies the Knox dolomite. The contact is sharp and in all cases indicates a sudden change in the relations of land and sea at that time.

The formation receives its name from Athens, in McMinn County, Tennessee. The shales are black to bluish-black and calcareous, and abound in graptolites. They range in thickness from 400 to more than 2,000 feet.

Neither of the last two formations have been known to contain deposits of zinc.

[1]These locally mineralized zones occur in definitely indicated horizons at stratigraphic breaks or unconformities, and part of the brecciation of these beds resulted from causes other than those given above. W.A.N.

[2]The term Chickamauga Limestone has been used in widely different senses. Much of this varied usage is indicated graphically in Ulrich's Revision of the Paleozoic Systems. (Bull. G. S. A. 1911.)

[3]As is now clearly established the Athens shale was not deposited while any part of the Chickamauga limestone was being laid down elsewhere. W.A.N.

STRUCTURE

GENERAL FEATURES

The rocks of the Valley region of East Tennessee present a striking uniformity in their structural relations. From their original horizontal positions, when they were laid down in the sea bottom, they have suffered profound disturbances. The disturbances are now manifested in that type of structure widely known as "Appalachian structure," that is, the strata have been compressed into long narrow folds, generally parallel among themselves, and sometimes overturned and overthrust. In the Valley the strata have been steeply tilted, bent into folds and broken by faults.

FOLDS

The folds and faults of the Valley region are about parallel to one another and to the northwestern shore of the ancient continent, or differently stated, they extend from northeast to southwest in either approximately straight or curved lines. In proceeding across the strike alternate anticlinal and synclinal areas are met, all of which have their axes roughly parallel. All varieties of folds occur from the simple, low open folds to the highly compressed or even overturned fold. Most of them are symmetrical and have a rather long southeast slope. Due to the intensity of the compressive forces which frequently resulted in overturning the folds, relatively few areas are to be found in which northwestward dips prevail.

FAULTS

The reverse fault is the common type in East Tennessee. In Virginia, closely pressed folds, many of them closed, are the rule, but faults occur; while in Tennessee the folds are more broken by faults. In the central part of the Valley the folds are so obscured by faults that the strata form a series of narrow, overlapping blocks of beds dipping southeastward. The long parallel faults are due largely to compressive forces which acted in a southeast-northwest direction. However, compression was also exerted, but to a much less degree of intensity, in a direction transverse to that of the main force. To this second, or transverse force, are due the cross folds and faults which occur at random throughout the district. They apparently bear no relation to the major structural features.

In many cases the strata were not competent to withstand the intense tangential pressure imposed upon them so that breaking, or faulting, resulted. According to Willis[1], who discusses this district: "These

[1]Willis, Bailey: The mechanics of Appalachian structure: U. S. Geol. Survey, 13th Ann. Rept., pp. 227-228, 1891-92.

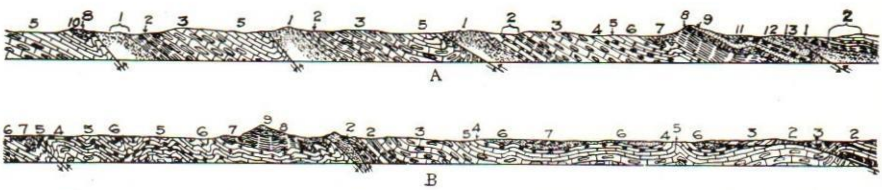

FIGURE 3. (A) Northwest-southeast section passing northeast of Maynardville, Union county.
(B) Northwest-southeast section near Strawberry Plains, Jefferson county.

13. Newman limestone.
12. Grainger shale.
11. Chattanooga shale.
10. Rockwood formation.
9. Clinch sandstone.
8. Bays formation.
7. Sevier shale.
6. Tellico sandstone and Moccasin limestone.
5. Chickamauga limestone.
4. Holston marble in Chickamauga limestone.
3. Knox dolomite.
2. Conasauga shale.
1. Rome formation.

(Keith)

thrusts give character to a belt which extends from southern Virginia to the overlap of Mesozoic formations in Alabama. They are wonderfully persistent; they all present a fault dip to the southeast, and are in a general way parallel among themselves and to the outline of the Archean continent. . . . The faults usually arise in a simple anticline and in a longer or shorter distance the northwestern dip disappears beneath the overthrust, leaving an isoclinal southeasterly dipping structure, in which the fault dip is often parallel to the bedding of one or the other series of strata. . . . Inspection shows that they are intimately associated with folds, and whenever a fault fades out it is in the northwestern side of an anticline and in the direction of anticlinal pitch.

"These faults of great length dividing the superficial crust into crowded scales, have provoked the wonder of the most experienced geologists. The mechanical effort is beyond comprehension, but the effect upon the rocks is inappreciable. The strata beside a great fault are but rarely brecciated, squeezed or rendered schistose. The shearing planes are sharp and clean, the movement of overthrust was concentrated as by a knife cut, and the passing layers ground little grist one from another. Great vertical pressure and very slow movement probably conduced this result, but however explained, the fact is conspicuous that Appalachian thrusts are not associated with alteration of the faulted strata.

"The strata sheared by these faults include all known horizons of the province from the lowest Cambrian to the Carboniferous, but nowhere do they bring up crystalline rocks older than the Cambrian. From the parallelism of the strikes and the coincidence of relief with the occurrence of hard and soft rocks arises the marked topographic characteristic of the district, the monoclinal ridge."

JOINTS

Although jointing is generally well developed in the several formations in which ore bodies have been found, in very few instances is it apparent that jointing and ore deposition are related.

The joint systems trend in all directions and result in great complexity in the fracturing of beds—a feature, that, where well developed, is advantageous to mining operations in that the rock is more readily broken. In general, two systems of joints are prominent. The one set trends in a northeast-southwest direction and is more prominent; the second set trends in a general northwest-southeast direction. Thus it is recognized that the two sets of joints approximate roughly the regional strike and dip directions respectively. It has been shown[1], that where sedimentary rocks are folded two sets of vertical joints are usually developed, a major set parallel to the strike of the fold, and a minor set normal to this direction, and hence parallel to the dip.

Joints have further been classified as due to either tensional or compressive stresses resulting from folding. That the Appalachian Province is one in which intense tangential compressive forces prevailed has been well shown by the works of Bailey Willis and others. Also the great strike-faulting and folding of this Province have been attributed to this pressure. The coincidence between the most prominent direction of the folding and faulting and that of the fracturing is strongly indicative of a relation between the two.

Open joints commonly indicate tension while tight or closed joints indicate compression. The great majority of the observed joints in this district were tightly closed, except in those instances where percolating waters have attacked the walls and enlarged the openings. The very tightness of the joint-walls is a further indication that the jointing resulted from compressive stresses.

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[1]Leith, C. K. Structural geology, pp. 14-28, 1913.

ORES AND ASSOCIATED MINERALS

The ore minerals in the region are limited, as to species, to a few of the common forms of zinc, lead and sulphur. The sulphide forms of both zinc and lead, that is sphalerite and galena, are found below the zone of oxidation or ground-water level. Associated with them in the sulphide zone are pyrite and chalcopyrite. The oxidized forms, derived from alteration of the sulphides, are found above ground-water level in the clay and disintegrated remnants of country rock. These minerals include smithsonite, calamine, cerussite, and limonite.

In addition to the above, a number of non-metallic minerals are found closely associated with the metallic forms. Named in the order of their abundance they are dolomite, calcite, quartz, chert, barite and fluorite. In most of the localities barite and fluorite are not found.

ZINC ORES

SPHALERITE (ZnS)

The theoretical composition of the pure mineral is 67.15 per cent. of metallic zinc and 32.85 per cent. of sulphur. The specific gravity ranges from 3.9 to 4.1. Sphalerite has many names depending chiefly upon its color due to the amounts of impurities which it contains, usually in the form of iron. The most familiar of these names are "blende," "black-jack," "jack," "resin jack," and "strawberry jack." It varies in color from a light straw yellow through a reddish, somewhat transparent variety, to a jet black. In most of the East Tennessee deposits the color is a light-brown, but all variations occur. Sphalerite is by far the most important ore of the district and it is the original zinc mineral. As it occurs commonly below the zone of oxidation, or ground-water level, the early mining activities, devoted to exploiting its oxidized forms in the clay, failed to reveal its presence except where the clay was shallow in depth, or absent.

Its customery mode of occurrence is in the form of disseminated grains, irregular masses and stringers in the country rock. Locally, it is associated with varying amounts of galena, pyrite, and chalcopyrite resulting in a rather complex ore which is difficult to mill; and correspondingly its market value is decreased if the impurities exceed a specified percentage.

The absence of crystal forms or crystal aggregates of sphalerite in Tennessee is noticeable. It is commonly massive in form and possesses perfect dodecahedral cleavage but is devoid of outward crystal form.

SMITHSONITE ($ZnCO_3$)

Smithsonite, the carbonate form of zinc, is composed theoretically of 64.8 per cent. of zinc oxide and 35.2 per cent. of carbon dioxide. The equivalent of metallic zinc is 52.06 per cent. when pure. The specific gravity varies from 4.30 to 4.45. It crystallizes in the rhombohedral group of the hexagonal system. By the miners smithsonite is commonly known as "carbonate" or "drybone," the latter name indicating resemblance to its light, porous condition.

Smithsonite is a secondary mineral formed by the alteration or oxidation of sphalerite; hence it is found near or above the groundwater level in the clay overburden. Practically all of the zinc deposits of East Tennessee have surface outcroppings of smithsonite or calamine. In some of the mines where a deep mantle of clay occurs, smithsonite has been the only zinc ore mined, viz: the mines of the Embree Iron Company in Bumpass Cove, Washington County, and the Grasselli mine, near New Market in Jefferson County.

The mineral smithsonite occurs most frequently as porous masses, usually of a brownish or yellowish color, which have a decided earthy appearance and are difficultly recognizable. Again it forms thin coats or encrustations of the country rock and is then white or pink in color.

HYDROZINCITE ($ZnCO_3.2Zn.(OH)_2$)

This is the basic zinc carbonate and contains 60 per cent. of metallic zinc. The specific gravity ranges from 3.58 to 3.80. It is a soft mineral and white to gray in color. It is commonly known as "zinc bloom." This mineral is not generally recognized in the district. It is frequently associated with smithsonite and they are so alike in appearance that it is difficult to distinguish them from each other.

CALAMINE (H_2ZnSiO_5)

Calamine is a hydrous silicate of zinc and theoretically contains 67.5 per cent. of zinc oxide, 25.0 per cent. of silica, and 7.5 per cent. of water. The specific gravity varies from 3.4 to 3.5. This mineral generally occurs in intimate association with smithsonite which it closely resembles. Granular, massive, and honeycomb forms of calamine are common and occasionally it is found as stalactites with mammillary surfaces in cavities in the country rock.

BUCKFAT

Buckfat is a mixture of smithsonite, calamine, and clay and therefore does not seem to constitute a mineral. The term is applied locally by miners, especially in the Embreeville district, to the very lean, low-grade ore. In East Tennessee, the term is generally applied to the soft, plastic material made up of the components mentioned above. Occasionally the percentage of ore, either calamine or smithsonite, is so high that the material is concentrated.

LEAD ORES

GALENA (PbS)

This mineral is the sulphide form of lead and is frequently called "galenite." The composition is 86.6 per cent. of lead and 13.4 per cent. of sulphur. The specific gravity ranges from 7.4. to 7.6.

Galena is lead-gray in color, opaque and has a bright metallic luster on a freshly broken surface. It is readily recognized by its cubic crystallization, high specific gravity, and perfect cubic cleavage.

Galena occurs in more or less abundance in several localities in East Tennessee and is practically always associated with zinc minerals. In some of the old mines, notably the Dollie D mine, near Cleveland, in Bradley County, the Felknor mine, near Leadvale, in Jefferson County, and New Prospect mine, at Powell River in Union County, galena was the principal mineral mined.

Lead ore commonly contains a small amount of silver. In the East Tennessee lead ores this is not the case as the analyses of several samples collected from the various localities failed to show even the slightest trace of silver.

Galena is the original mineral from which the oxidized forms of lead are derived.

CERUSSITE ($PbCO_3$)

The mineral, when pure, contains 83.5 per cent. of lead oxide and 16.5 per cent. of carbon dioxide or 77.5 per cent. of metallic lead. The specific gravity varies from 6.46 to 6.57. Cerussite is generally known as "carbonate" or "white lead ore." It is an oxidation product derived from galena and frequently occurs as minute, colorless crystals coating masses of galena.

The largest quantity of cerussite in East Tennessee is found in the Embree mines, in Washington County. There it is distributed through the clay overburden and the disintegrated limestone as formless masses or clusters and crystal aggregates. Many beautiful specimens have been taken from the Embree district. Elsewhere this ore of lead is not important and is not mined.

ANGLESITE ($PbSO_4$)

This mineral is not known to occur in the East Tennessee deposits. It consists of 68.3 per cent. of metallic lead and 264 per cent. of sulphur trioxide, or, 73.6 per cent. of lead oxide. The specific gravity is 6.3. Like cerussite, this mineral is derived from galena by oxidation.

GREENOCKITE

This is the principal ore of cadmium. Small quantities of it are found in practically all of the mines and prospects in East Tennessee but it has never been found in abundance. Cadmium sulphide coats and fills cracks in both the ore and rocks. Much of it is formed near and usually a little above the ground-water level through the breaking down of zinc-sulphide. Greenockite is honey-citron or orange yellow in color. Whether the sulphide occurs in the primary ore or is isomorphous with zinc sulphide is uncertain.

IRON ORES

Iron ores are found throughout the zinc and lead area of East Tennessee but in sufficient abundance to warrant mining in only one district, viz: Embreeville. The iron occurs principally in three forms, the sulphide, pyrite and marcasite; the oxide, hematite; and the hydrous oxide, limonite.

PYRITE (FeS_2)

Pyrite is frequently found in association with sphalerite and galena in the unaltered rock below the ground-water level. In some of the mines the quantity is sufficiently great to become objectionable, but in most cases it is scattered in its occurrence. Thin sections of the ores show that pyrite commonly occurs as very small particles disseminated through the country rock. Marcasite has the same chemical composition and appearance as pyrite, but differs from it in habit of crystallization, pyrite being isometric, and marcasite orthorhombic. Probably some of what has been called pyrite in the ores is really marcasite.

HEMATITE (Fe_2O_3)

This mineral is not common in association with the zinc ores. It is the coloring constituent of the deep red clays which are so abundant throughout the valley.

LIMONITE ($2Fe_2O_3.2H_2O$)

This is the most abundant form of iron. It occurs throughout the valley in the clay overburden. In the early days of mining at Embreeville, before the presence of zinc and lead was known, limonite was extensively mined. It is an alteration product resulting from the oxidation and hydration of the sulphide, pyrite, above the ground-water level.

MELANTERITE ($FeSO_4.7H_2O$)

This mineral is also known as "copperas," "iron vitriol," and "green vitriol," and is found in some of the mines, notably at Straight Creek. It is formed by the decomposition of pyrite.

COPPER ORES

Only a few localities are known to contain copper ores. In a few of the mines small crystals and disseminated masses of chalcopyrite

($CuFeS_2$) have been found in association with the zinc ores but no large quantities of the mineral have so far been found. On exposures, chalcopyrite becomes oxidized and alters to the carbonate forms, malachite and azurite.

MANGANESE ORES

The presence of small quantities of manganese is quite widespread throughout the Valley. Frequently joints or fractures of the country rock have been coated with tree-like forms of wad, or black oxide of manganese, and such occurrences are quite common in the clays.

ASSOCIATED MINERALS

The minerals associated with the zinc deposits though abundant in amount are limited in variety. Generally they consist only of dolomite and calcite which form the matrix of the brecciated country rock. Locally variable amounts of barite are found, and fluorite has been observed in the Sweetwater district.

DOLOMITE ($CaMg(CO_3)_2$)

It is the most common gangue mineral in the deposits. Dolomite is quite similar to calcite. The former may be distinguished from the latter by its tendency to possess curved crystal faces and by effervescing only in hot hydrochloric acid and not in cold acid as does calcite. Throughout the zinc deposits it was noticed that the dolomite is less transparent than calcite, the masses of the latter mineral possess better cleavage, and they tend to be in more perfect crystal form.

CALCITE ($CaCO_3$)

This mineral occurs with dolomite as a fracture filling of the country rock. Generally it is in small detached masses associated with the dolomite which may partly or entirely surround it. At no locality was calcite found in greater abundance than dolomite.

BARITE ($BaSO_4$)

It is generally known as "barytes" or as "heavy spar." In the vicinity of Sweetwater it is found in great abundance and has been mined there for many years. At other scattered localities, notably in the Fall Branch district, a considerable amount of barite is found in association with the zinc ores. Due to its great resistance to disintegration it is frequently found as large masses embedded in the clay overburden.

FLUORITE (CaF_2)

Small quantities of this mineral have been found in association with the barite deposits near Sweetwater. Some specimens contain sphalerite, galena, barite, and fluorite. The occurrence of fluorite seems to be limited to this one locality in the East Tennessee region.

CHERT

This is a cryptocrystalline variety of silica and is very commonly associated with the ores. Chert nodules and irregular-shaped masses are common as constituents of the breccia filling; also, in thin section, much of the country rock is seen to be cherty.

MODE OF OCCURRENCE OF THE ORES

The zinc ores of East Tennessee were not originally desposited in the manner in which they now occur but represent a concentration in local areas resulting in general from solution, transportation and re-deposition by circulating ground waters.

THE SULPHIDE ORES

Except where ore has undergone superficial alteration and oxidation, the zinc ores consist of the zinc sulphide, sphalerite. This occurs disseminated in the limestone or dolomite both as a replacement of the rock and as the cement in brecciated beds. As a rule the process of replacement has played an important role in the ore formation. Breccia fragments sometimes show solution and replacement by both ore and gangue minerals. But again, the breccia fragments are extremely sharp-angled and show no replacement. In such cases the minerals are confined entirely to the matrix, or breccia cement. Both types of ore are widespread and grade into each other. No instances were observed in the field where only one type of ore occurred.

As has been repeatedly stated, the ore is associated with brecciated horizons in the country rock. The origin of the brecciation is not at all times clear, particularly when no visible planes of movement can be seen. On the other hand, at the Felknor mine, the Fall Branch mine, New Prospect, etc., direct evidence of brecciation associated with faulting is at hand.

The breccia is usually made up of sharp-angled fragments of the country rock cemented by a matrix which consists of variable amounts of white or gray dolomite, some calcite, chert, sphalerite, galena and pyrite. It should be mentioned that galena is found only in a few districts and is not a widespread constituent of the breccia filling. In some localities, notably at Friendsville, Eve Mills and Fall Branch, considerable quantities of barite are associated with other minerals in the breccia. Thus it is seen that the complexity of the ore varies at different localities. At Mascot, practically no minerals other than sphalerite, dolomite, small amounts of calcite, chert and pyrite are found.

As is typical of breccia or broken ground deposits, not all the parts of the brecciated horizons are mineralized but the ore is distributed in bodies, or pockets, in random fashion in the horizons. Such localization entails great uncerta nty in mining operations where advance prospecting to determine the extent of the richer bodies has not been employed.

The question naturally arises at this point as to whether the majority of the ore bodies occur at any particular horizon in the Knox dolomite. Whenever possible the stratigraphic position of the mineralized horizons was measured. As a result of these determinations it was found that the most persistent mineralized horizon occurs at a little less than 1,000 feet below the top of the formation. But even this position is not constant over extensive areas. As shown in the reports of individual localities, the mineralized horizons of the Mascot district occur at this level, but those in the Copper Ridge district range from 500 to 1,000 feet. It is a significant fact that practically all of the known deposits in the Knox dolomite in the central and eastern part of the Valley occur within 1,000 feet of the top of that formation. In the western part of the Valley, as in the New Prospect district, the mineralized horizons are found near the base of the Knox dolomite and none, so far as known, near the top of that formation.

So it appears that two fairly well defined horizons occur, the one within the upper half of the formation and the other near the base.

Where galena and sphalerite occur in association they are in general so intricately intermingled, as at the New Prospect and Felknor mines, that no well defined sequence of deposition is evident. Many parts of the country rock, both large and small, show all sphalerite with only occasional areas of galena in the rock. Other parts of the country rock, usually smaller in area and confined to those levels nearer the surface, show a preponderance of galena with little or no disseminated sphalerite.

Similar relations are true of the pyrite. Taking the areas as a whole, this mineral seems to increase slightly in quantity in depth. In higher levels it is intermingled with either galena or sphalerite, or both.

THE OXIDIZED ORES

The important oxidized ores of the district are smithsonite, calamine, and cerussite, derived from the alteration of the sulphides, sphalerite and galena. The larger bodies of oxidized ores are found in the clay and disintegrated ground which overlies the deeper and unaltered sulphide deposits. As a rule the clay overburden is thick, averaging about 60 feet. The surface of the underlying dolomite is very uneven, consisting of irregularly shaped pinnacles and chimneys which vary in height.

Concentration of the oxidized ores has taken place principally at and near the bottom of the residual clays and just above the surface of the underlying rock. At both the Embreeville and Grasselli mines, the only mines from which appreciable production of the oxidized ores has been realized, the ores occur as lumps and crystalline aggregates of intermixed ore and clay which are scattered through the overburden but are more abundant immediately above the unaltered rock. Also the most productive parts are the pockets, or basins, lying in the depressions between the pinnacles. The manner in which these ores accumulate is explained in the descriptions of Embreeville and Grasselli. The occurrence of such oxidized ores has also been well described and illustrated by Watson[1].

In the open pit of the Grasselli mine the surface of the pinnacles is often coated with a thin film of oxidized ore, generally smithsonite. Again, a network of veinlets on the pinnacle surfaces may represent the oxidation of sphalerite in the place. In such instances, by breaking off small pieces, the actual alteration from sulphide to oxidized ore may be traced.

The prevailing color of the clay is dark brown to a deep red, due to the presence of iron. The highly ferruginous character of the clays in Bumpass Cove has long been known and in the early years of that district they were mined and smelted for the recovery of iron. At times considerable limonite is found in more or less concentrated form in the clays. The limonite represents, in part at least, the oxidation of pyrite which occurs in the unaltered rock and associated with the sphalerite and galena.

Small quantities of oxidized ores are frequently found mixed with clay in solution channels in the country rock. But such occurrences are of small size.

A small amount of oxidized ores also occurs in the outcrops of the sulphide ore bodies.

DESCRIPTION OF DISTRICTS

ARCADIA DISTRICT

Arcadia Bowman prospect No. (1)

This locality is on the Frank Bowman farm in the southeastern part of Scott County, Virginia, about one mile south of Lucille Post Office, and one and one-half miles northwest of Arcadia, in Sullivan County, Tennessee. The prospects are 300 feet north of the state line.

About 25 years ago a small amount of prospecting was done by open cut methods at the westernmost opening. A part of the property, including this opening, was later purchased and was developed to its present extent by a Mr. Graves of Bristol, Tennessee. The work consisted only of prospecting and no production of ore was ever made.

The openings at the east end of the district were started in 1906 by Mr. Frank Bowman and were worked at intervals until the fall of 1917. In 1918 he erected a small mill equipped with a crusher, one 3-compartment jig (Joplin style), and two tables. About 25 tons of zinc concentrates had been made when operations ceased.

[1]Watson, T. L., Lead and zinc deposits of Virginia: Va. Geol. Survey, Bull. 1, pp. 51-52, 83-92, 1905.

GEOLOGY

A narrow belt of Knox dolomite, the upper and lower limits of which terminate in faults, occurs at this locality. The ores have been found along the southern boundary of the dolomite. The ore-bearing rock is dark-gray, fine-grained, crystalline, thick-bedded dolomite with which occur numerous thin beds of light-gray chert. The presence of chert indicates that the horizon is in the lower part of the Knox formation. The average strike is N. 80° W., and the dip 80° S.

The geological map[1] of this locality shows that the Knox dolomite is succeeded on the south of the fault by the Honaker formation which, in the area adjacent to the fault, consists of dark-gray, crystalline, thick-bedded, magnesian limestone very similar in appearance, colcr and texture to the Knox dolomite.

The minerals are dark, reddish-brown sphalerite (black jack), pyrite, chalcopyrite, dolomite and calcite.

Sphalerite is the most abundant ore mineral and occurs in roughly parallel veins which conform to the strike and dip of the country rock. There is great variation in the size of the veins; some, particularly in the west opening, attain a thickness of ten inches and consist almost entirely of sphalerite; others, generally of less width but greater length, consist of narrow bands of sphalerite along the walls sharply terminated against a core of dolomite-calcite gangue. The well-defined vein type of mineralization is not so extensively developed in the east part of the area where veinlets and irregular shaped masses of ore and gangue are more common.

Pyrite and chalcopyrite, when in the ore, appear as small, detached masses in either sphalerite or gangue, or in both. In this section the country rock is wholly crystalline and fine-grained with no admixture of mineral other than dolomite and the ores. For a short distance on either side of a vein the country rock has been re-crystallized and into this area project microscopic stringers of sphalerite which either follow along cleavage cracks or ramify along the sutures between individual crystals. Within the vein occur sphalerite and dolomite. As a rule, disconnected masses of sphalerite exhibiting good cleavage but no crystal faces form the walls of a vein and confine a corps of large-grained, allotriomorphic crystals of dolomite. Replacement of dolomite by sphalerite has apparently taken place and is suggested by small stringers of the latter mineral projecting into the former along cleavage cracks.

Most of the sphalerite is composed of individual aggregates which display zonal banding in alternate dark and light zones symmetrically arranged around a centre. (Plate II.)

Veinlets and irregular shaped masses of pyrite and chalcopyrite are quite abundant as interstitial replacements of gangue dolomite and,

[1]Campbell, M. R., U. S. Geol. Survey., Geol. Atlas, Bristol folio (No. 59), 1899.

PLATE II.

Alternate light and dark bands showing zonal growth of sphalerite. The white mineral around the border is dolomite. Bowman prospect, Arcadia. x40.

to a less extent, the masses of sphalerite which they rim and slightly invade along cleavage lines.

Paragenesis

1. County rock.
2. Dolomite.
3. Sphalerite.
4. Pyrite and chalcopyrite.

STRUCTURE

A strike fault of the reverse type, with its plane dipping parallel to the bedding planes of the country rock, forms the structural feature which gave rise to the ore body. The hanging wall is well defined and consists of unbrecciated, compact Honaker limestone, but the footwall is obscure due to a series of minor, roughly parallel displacements within the Knox dolomite adjacent to the hanging-wall. This displacement zone varies in width up to a maximum of approximately 15 feet and constitutes a sheeted zone in which mineralization has taken place.

It is reported that at the depths reached in the shafts no transverse fractures were found and that, like at the surface, mineralization was confined to the country rock which constituted the sheeted zone.

DEVELOPMENT

A sketch map of the openings is shown in Figure 4. The prospect at the eastern end of the developed area consists of a shaft, 87 feet deep, which followed the dip of the fault. The shaft was filled with water at the time of this investigation. The mineralized portion of the country rock for a distance of 40 feet to the west of the shaft has been exposed by an open cut. Near the center of the cut a second shaft was sunk to a depth of 45 feet from the bottom of which a tunnel was driven for a distance of 20 feet to the west.

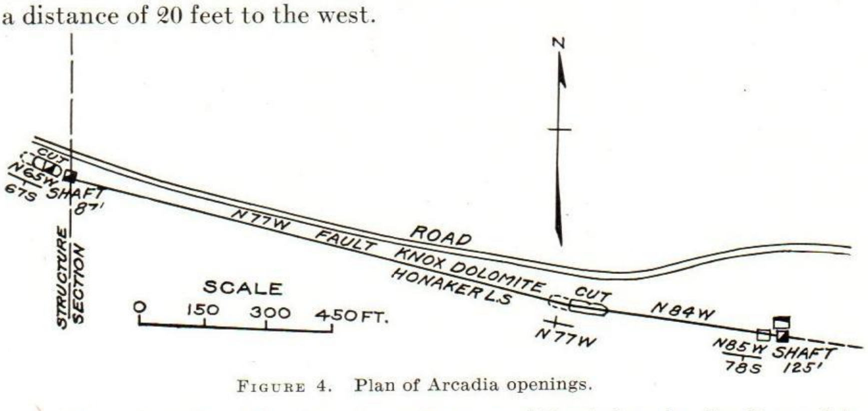


FIGURE 4. Plan of Arcadia openings.

The mineralized horizon is well exposed both longitudinally and in cross-section in the open cut. It consists of several parallel veins of varying thickness in which dark-brown sphalerite occurs. These veins are exposed throughout the length and depth of the cut and constitute ground from which much high-grade ore could be taken. The south, or hanging wall, is often a fracture plane beyond which is barren limestone. The north, or foot-wall, is not so well defined.

The two prospects at the eastern end of the developed area are still owned by Frank M. Bowman, Blountville, Tennessee. The first distant 1,155 feet in a S. 77° E. disrection from the Graves prospect, consists of an open cut 90 feet in length along the strike and is 15 feet in width. An additional area 40 feet in length and 15 feet in width at the western end of the open cut has been stripped of the overburden exposing the ore-bearing horizon. The open cut which was filled with water, is said to be 20 feet in depth. In this opening the rock is sheeted but most of the ore occurs in a few very narrow veins at the eastern face of the stripped area and in a small brecciated area at the eastern end of the open cut. The bedding plane strike N. 77° W. and dip vertically.

The second prospect is 410 feet in a direction S. 84° E. from the first, or along the strike of the same ore horizon. The development consists of a shaft which is 125 feet deep. The shaft is now inaccessible. According to Mr. Bowman the mineralized zone consisting of narrow veins of sphalerite and some pyrite continued throughout the depth of the shaft. He also stated that a vein of sphalerite, accompanied by pyrite and chalcopyrite, was encountered at the 85-foot level. The vein widened in depth and the amount of pyrite and chalcopyrite increased. That chalcopyrite does become relatively abundant in depth is evident from the quantity of that mineral contained in the rock lying on the ore-pile near the mouth of the shaft. The concentrates made by Mr. Bowman in 1918-1919 were derived from the ore mined from this shaft.

NEW PROSPECT DISTRICT

NEW PROSPECT MINE AND VICINITY (2)

The New Prospect mine is near the northeastern corner of Union County and about one-half mile southeast of the junction of Hunting Creek and Powell River. This general locality has long been called "Lead Mine Bend" of the Powell River. The following historical account has been taken from the report of A. H. Purdue[1]: "According to Mr. T. J. Davis, of Sharp's Chapel, this mine was opened in 1883, by Squires and Manning, of New York. These men hauled the ore to Powell River, and shipped by water to Clinton, Tennessee, and from there by rail to New York. They worked the mine until 1888. About 1889, the property was taken over by the Eades, Mixter, and Heald Zinc Company. This company built the first mill, which consisted of a crusher and hand jig, in 1890. The present mill was built in 1891. It has eight jigs with a capacity of 100 tons. The company operated the mine until 1897. In 1899, the property was leased to the American Metals Company, of New York City, who worked it till 1901. Since

[1]Purdue, A. H., The zinc deposits of northeastern Tennessee, Tenn. Geol. Survey, Bull. 14, p. 48, 1912.

1901 it has not been operated except for three weeks in 1903, by a man named Joseph D. Hardin, but who shipped no ore.

"While the Eades, Mixter and Heald Zinc Company was operating, the ore was shipped to Clinton, Tennessee, where it was smelted. The American Metals and Mining Company shipped the ore to Marion, Indiana. A part of it was shipped by water to Clinton, and from there by rail, and a part was hauled in wagons to Caswell Station on the Cumberland Gap and Louisville Railroad. Approximately 1,000 barge loads of concentrates are said to have been shipped by river, averaging 65 tons to the barge. The amount hauled by wagon to the railroad was not ascertained."

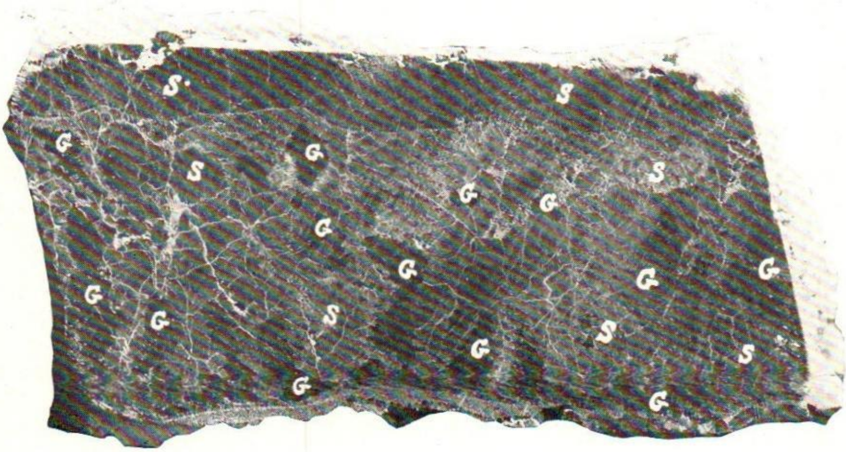
In 1914, the property was acquired by Mr. Geo. Blow of Knoxville. Tennessee, and worked by him under the name of the Union Zinc Company at intervals during the following four years. Mostly additional prospecting and the re-opening of previous developments were engaged in and no production of ore was realized. The mine has been idle since 1918.

COUNTRY ROCK AND MODE OF MINERALIZATION

The ore body occurs in the lower measures of the Knox dolomite, the bedding of which varies greatly in strike, averaging about N. 40° W., and lies nearly horizontal with a slight dip to the north. The locality is just south of the crest of the Powell anticline and is one in which considerable movement, chiefly of a horizontal nature, took place as is evidenced by both vertical and horizontal planes of movement on which east-west slickensides or grooves are frequently visible.

Mineralization and fracturing are closely related and combine to form an ore body of rather definite outline. The floor of the mine is composed of dark-grey, fine-grained dolomite the upper surface of which is a horizontal shearing plane and is locally polished and slickensided. This bed separates the underlying barren rock from the fractured and mineralized rock above. At a distance of 22 feet above the floor, and parallel to it, a second well-defined shearing plane occurs. This plane forms the roof of the mine. Above it the rock is less fractured and accordingly, less mineralized.

Movement was not limited in its expression to the horizontal planes but also occurred in two well defined parallel, vertical breaks, separated by 65 feet of broken and mineralized rock. These breaks, known as the north and south faults, respectively, strike nearly due east and west and were loci of the richest ore bodies. As a consequence mining operations consisted chiefly in following these faults and also in extracting the ore from the broken, mineralized rock between them. Although fracturing extended a short distance both north of the north fault and south of the south fault, mineralization in those areas was extremely variable and pockety, persisting for only a few feet beyond



Polished specimen of zinc-lead ore from New Prospect mine, showing intergrowth of sphalerite (S) and galena (G). Nat. size.

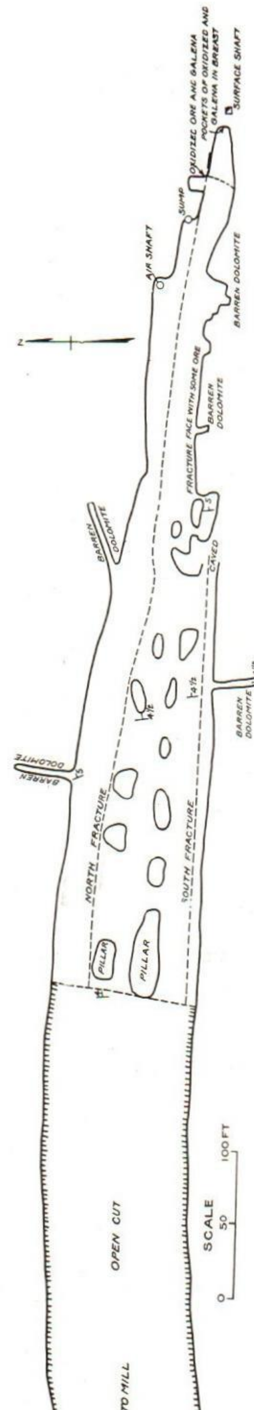


FIGURE 5. Plan of New Prospect mine.

either fault. In the few cross cuts which have been made in both the north and south walls of the mine little ore was found. So, the ore body seems limited in extent to the broken rock confined within the two parallel, horizontal shearing planes, 22 feet apart, and within the two parallel, vertical fractures, 65 feet apart.

As shown in Figure 5, the north fault is of greater length than the south fault and was followed more closely in working the mine. Also, a fracturing and shearing were more pronounced on the north side. The movement, visible in slickensides which coincide in their orientation with those of the horizontal shearing planes, occurred in several closely-spaced parallel planes. This fault zone averages several feet in width and consists mostly of rotten rock, clay gouge, and lumps of oxidized ores. Except for its shorter length and lesser width, the south fault is quite similar to the north. The north fault penetrates the horizontal shearing plane which forms the floor of the mine but it has not been followed below that plane so that it is not known whether the ore extends below it or not. Both faults penetrate the upper horizontal shearing plane and continue through the roof of the mine to the surface.

The plan of development is shown in Figure 5. Both carbonate and sulphide ores were taken from the open cut, which extends west from the underground workings on top of the hill. Within the mine local pockets of carbonate ore were found along the vertical fractures through which circulation of ground water occurred.

Except for the pillars between the two vertical faults, the ore body appears to have been practically exhausted. Here and there in both pillars and along the south wall just east of the eastern termination of the south fault, there are local pockets of rich sulphide ore but without exception they are of limited extent. As previously stated, for the most part the walls are barren.

Some prospecting has been done by sinking shafts to the east of the mine in the hope of locating an eastern continuation of the ore body, but with little success. Most of these shafts have caved and are no longer accessible. The following accounts of them were given by Mr. T. L. Davis who is familiar with the development of the entire locality.

Along the approximate continuation of the north fault, at a point 10 feet east of the extreme eastern extent of the underground workings, a shaft bed has been sunk to a depth of 62 feet and from it considerable quantities of both oxidized and sulphide zinc ores had been removed.

Davis No. 1 shaft

The Davis No. 1 shaft is 365 feet east of the above-mentioned shaft. It was 72 feet deep and at 43 feet passed through 2 feet of 7 per cent. sphalerite. Davis No. 2 shaft is 55 feet northwest of No. 1. It was 83 feet deep and encountered only barren clay and rock throughout its depth. The Jarvis shaft is 300 feet southwest of Davis No. 1 shaft. It was sunk to a depth of 80 feet in the expectation of striking the eastern continuation of the south fault. However, neither carbonate nor sulphide ores were found.

A series of small cuts was made under the direction of Mr. Davis about half a mile almost due east of the mine.

Davis north cut

Davis north cut consists of a series of shallow trenches cutting transversely across the strike which is here N. 46° W.; the bedding dips 17° SE. The dolomite is greatly fractured and contains small amounts of sphalerite and galena with some pyrite. A small amount of carbonate was taken from the clay overburden.

Davis south cut No. 1

Davis south cut No. 1 is 160 feet S. 20° E. of the north cut and extends 33 feet in a N. 3° W. direction into the hillside. It exposes dark-red to brown dolomite which contains disseminated masses of dark-brown sphalerite but no galena.

Davis south cut No. 2

Davis south cut No. 2 is 120 feet S. 75° W. of No. 1. It is 25 feet in length and shows conditions of mineralization similar to those in No. 1. In both cuts small amounts of carbonate ores were taken from the clay overburden. These cuts are probably located near the eastern continuation of the north fault zone as extreme fracturing and jointing of the rock indicate a zone of movement. The joints run east-west and are prominent. Several hundred feet to either the north or south of these prospects the dolomite is regularly bedded and but slightly disturbed.

Davis cut No. 3

Davis cut No. 3 is 600 feet S. 70° W. of the Davis home and extends 55 feet N. 70° E. into Knox dolomite. The country rock is only slightly fractured and apparently contains no ore. Mr. Davis believes that this cut is located on an eastern continuation of the south fault. He states that 36 tons of carbonate zinc ore were taken from the clay overburden.

Cox prospect (3)

This prospect consisting of an open cut extending 25 feet in a S. 85° W. direction into the hillside, is three-fourths of a mile south of the mine. Mr. Davis stated that sphalerite was found in a vertical vein in the Knox dolomite and that the cut followed the vein. About 8 tons of carbonate ore were taken from this cut and concentrated at the mill at the time.

The sulphide ore consists of intermixed masses and veinlets of sphalerite and galena with which are associated small amounts of pyrite, gangue dolomite, and calcite. Some of the ore presents a banded or laminated appearance but most of it consists of closely associated sphalerite and galena which have invaded and replaced the broken and fractured country rock. The oxidized products are cerussite, smithsonite, and small amounts of calamine and limonite. Both oxidized and sulphide ores are frequently coated with a thin film of greenockite.

Paragenesis of New Prospect District ores

1. Country rock.
2. Dolomite.
3. Sphalerite.
4. Pyrite.
5. Galena.
6. Dolomite.

This investigation showed that sphalerite, and not galena, was the more abundant ore mineral.

Thin sections of the rock examined under the microscope, show the country rock to consist of small, anhedral crystals of dolomite disseminated in a groundmass composed of extremely minute dolomite grains. The entire mass of country rock is stained a dull, reddish-brown from iron solutions and, locally, small grains of pyrite are disseminated through crystals of white dolomite or occur along their edges.

The country rock grades into and is replaced by larger anhedral crystals of dolomite. The transition zone is invariably indicated by narrow veinlets of limonite which frequently obscure the actual contacts between the two varieties of dolomite.

Sphalerite is later than both country rock and the coarse-grained, gangues dolomite both of which it replaces in a very irregular manner. Quite frequently a narrow seam of pyrite-limonite rims the sphalerite and projects into it with slight replacement, along cleavage cracks.

When galena occurs it appears to be later than sphalerite. The contact between the two minerals is very irregular. At places small projections of galena invade the sphalerite, sometimes along cleavage cracks, or again, very minute galena grains are found entirely within the sphalerite close to the galena contact. No pyrite is associated with the galena.

Where fracturing within the galena has occurred, the openings have been filled with coarse-grained dolomite.

L. F. SNIDER PROSPECT (4)

This property is on Slate Creek approximately one and one-half miles south of Powell River and 6 miles northwest of New Tazewell, a station on the Cumberland Gap Branch of the Southern Railway. The opening is in a steep-sided ravine and about 600 feet lower than the wagon road which is on the crest of the ridge to the southwest.

The first work was done in 1902 by a man named O'Hara from Kentucky. He sold the property to J. T. Snider and son, L. F. Snider. They developed the property by sinking a shaft to a depth of 18 feet in the stream bed (all traces of the shaft have disappeared), and by making an open cut which was 40 feet long, 10 feet wide, and 15 feet deep at the face. Mr. Snider states that ore was found all the way to the bottom of the shaft. The open cut exposed horizontally-bedded Knox dolomite which is bluish-gray in color and fine-grained. Near the base of the cut a horizontal brecciated bed is exposed and it is in this bed that the ore was found. Several narrow veins of oxidized ores, parallel to the bedding, were observed in the walls of the cut but no sulphide ore was seen in the place.

Samples collected from the dump showed the ore to consist of sphalerite with which are associated small amounts of galena and pyrite. These minerals occur intimately intermixed and, accompanied by varying amounts of gangue dolomite and chert, form replacements of the breccia fragments of country rock in the brecciated horizon. Where oxidation has taken place, the carbonates, smithsonite and cerussite, occur and they are frequently coated with thin films of greenockite. Many small vugs, or cavities, lined with crystals of the ore and gangue minerals indicate that solution and mineral deposition were not contemporaneous.

The prospect is near the axis of the Powell River anticline, mentioned in connection with the structure at the New Prospect mine. Although the beds lie horizontal, two sets of joints are well developed. The most prominent set runs N. 40°—60° W., and the second set runs N. 40° E. No faults or planes of movement are visible.

In view of the fact that some very rich samples were taken from the ore on the dump and much of it appeared amply rich for milling, it is unfortunate that the condition of the prospect permitted so little opportunity for observing the ore in place. However, its inaccessibility to transportation would prove a serious handicap to profitable operation.

LYNCH PROSPECT (5)

This property is near the head of Sugar Creek and is one and one-half miles southwest of the Snider property.

The first work is reported to have been done in 1910 under the supervision of a Mr. Clark, of Morristown, Tennessee. The present development was made in 1916 by Messrs. Arch and Paris Ritchie, and Dan C. Swab, of New Tazewell, who own the mineral rights.

The horizon is near the base of the Knox dolomite and consists of horizontally bedded, bluish-gray, fine-grained dolomite, with thin, intercalated beds of chert. Jointing is prominent, two sets having been observed running N. 65° W. and N. 25° E. respectively. Mineralization is more pronounced in the direction of the first set of joints. The ores consist of sphalerite and galena, which associated with small amounts of pyrite, gangue dolomite and chert, occur in masses and veinlets as fracture fillings and replacements in the country rock. Locally, the rock has been richly mineralized but such areas are of small extent.

The development consists of an open cut, a shaft and a tunnel. The tunnel is 40 feet in length and passes through fractured and jointed but barren dolomite. The shaft is 20 feet deep and, it is claimed, ore was found all the way to the bottom. A very prominent N. 65° W. joint plane, along which some movement took place, forms the south wall of the shaft and marks the northern limit of the mineralized zone. For a distance of 50 feet to the south of this plane, fracturing, accompanied by brecciation, was extreme and it is in this zone that the richest part of the ore body is localized. The open cut extends southward from the shaft and after passing through the mineralized and fractured zone exposes only jointed and barren rock.

The mineralization, though extremely local, is rich. Minor movements are thought to have caused the jointing which afforded suitable channels for the circulation of mineralizing solutions. The ore seems to have terminated sharply before extending as far east as the tunnel while its western limit does not extend as far as the drill hole. On the north it terminates at the shaft, and 30 feet south of the shaft, it passes into barren rock. So its limits are well defined.

Microscopic examination of a thin section of the ore from this prospect shows that the country rock consists of both cryptocrystalline and fine-grained dolomite. A few isolated and coarse-grained, subhedral crystals of gangue dolomite occur and their contacts with country

Intricate association of country rock, chert (C), sphalerite (S), and pyrite (P), and a little galena (G). Lynch prospect. x48.

rock show that replacement of the latter by the former has taken place. Most of the section consists of cryptocrystalline chert in which small, rounded grains of quartz are abundant. The invasion, absorption, and replacement of both country rock and gangue dolomite by chert is plainly evident. The transition is generally gradual although, locally, chert and unaltered country rock are in contact without any gradational change. A few small areas of chalcedcny, as an alteration product of chert, appear.

Scattered masses and veinlets of sphalerite are shown as replacements of country rock, gangue dolomite and chert. Several small veinlets of galena occur as replacements of the chert and, where in contact with sphalerite, galena appears to be later than it. Pyrite mineralization appears to have been subsequent to both sphalerite and galena, and is of frequent occurrence as small veinlets separating those two minerals as well as invading and replacing them. Small grains of pyrite are scattered through all the non-metallic materials and frequently it has been altered to limonite producing a reddish-brown stain upon the adjacent areas.

Paragenesis

1. Country rock.
2. Gangue dolomite.
3. Chert.
4. Sphalerite.
5. Galena.
6. Pyrite.

ELI GOIN PROSPECT (6)

This prospect is about two miles southwest of the Lynch property but a definite location could not be made owing to its isolated position with respect to creeks and roads.

The development consists of an open cut 100 feet long 20 feet wide and 20 feet deep at the face. Most of the cut was made in clay, but rock is exposed near the inner end and is horizontally bedded, bluish-gray, cherty Knox dolomite which is fractured and jointed. Two sets of joints, running N. 65° W. and N. 20° E. respectively, are prominent. The north wall of the cut followed a N. 65° W. fracture plane on which horizontal slickensides are visible.

Due to the rotten and disintegrated condition of the country rock no sulphide ore was seen in place, and only a small amount of oxidized ore. A few lumps of smithsonite and cerussite were observed on the dump near the open cut.

F. M. DAY PROSPECT (7)

This prospect consists of a small cut 40 feet long, 10 feet wide, and 5 feet deep at the face. It is approximately one mile west of the L. F.

Snider workings and in the bed of a small spring branch which empties into Sugar Creek at the foot of a steep-sided ravine.

Bluish-gray, fine-grained dolomite near the base of the Knox dolomite formation has been exposed in the open cut. The beds lie horizontal and strike about N. 50° E., which is the direction of the regional strike. Both above and below the ore horizon chert beds are frequent.

The ore minerals are sphalerite and galena and occur in about equal amounts as small masses, associated with vein dolomite, chert, and pyrite, either as replacements of the country rock or as breccia filling. The mineralized horizon is one in which some brecciation occurred but mineral deposition is very irregular and lean and no milling grade ore was observed. Two sets of joints are prominent, viz: N. 40° W. and N. 40°—50° E. In several instances the mineralizing solutions circulated along the joint planes and replaced the country rock.

A small amount of both sulphide and oxidized ores were observed on the dump near the cut.

STRAIGHT CREEK DISTRICT

STRAIGHT CREEK MINE (8)

This, the only mine of the Straight Creek group, is located on Straight Creek in Claiborne County, four miles west of Lone Mountain Station, on the Cumberland Gap Branch of the Southern Railway.

It is reported to have been opened first about 1880, and since that time it has been worked at intervals by several different companies. The earliest work consisted of mining carbonate ore in open pits at the west end of the ore body. The ore was hauled by wagon to Clinch River, five miles away, and thence boated to Clinton, Tennessee, where it was smelted. Later the property was sold to a Mr. Richburg who sank a 90-foot shaft and mined carbonate ore, shipping it, as had been done before, down the Clinch River to Clinton. Some years later the Eades, Mixter, and Heald Zinc Company bought the property and erected a mill which was equipped with a crusher, hand jigs, and rolls. They drove the present entrance tunnel and mined both carbonate and sulphide zinc ores which were hauled to Lone Mountain and shipped to Clinton.

About 1906 the Tennessee Zinc Company, Cincinnati, Ohio, acquired the property, built the present mill, and engaged actively in mining and prospecting for a period of two years. Since then the mine has been idle. As in previous operations, the ore was hauled to Lone Mountain.

COUNTRY ROCK AND ORE

The country rock is the Knox dolomite, which is dark-gray, fine-grained, and compact and contains much bituminous matter in places. The average strike of the bedding plane is N. 60° E. and the dip is

40° SE. The ore body occurs along a major fault which, in general, coincides with the dolomite bedding in strike and dips 70° SE. The upthrow was from the southeast. On the southeastern side of the fault the dolomite is considerably crushed and broken and it is in this zone, averaging about 40 feet in width, that the ore is found. The brecciation terminates abruptly against the foot-wall which presents a slickensided, unmineralized surface.

The ore consists mostly of sphalerite with small amounts of galena and pyrite and but little gangue dolomite and calcite. Sphalerite occurs in all gradations from small veinlets filling fractures up to large masses almost entirely replacing the country rock. The extensive replacement of the country rock by sulphide ores in the absence of gangue dolomite and calcite is quite noticeable.

Considerable oxidation of the sulphide ores has taken place along fractures and openings in the country rock and especially in the western part of the mine, oxidized ores extend to the lowest mine workings. Both oxide and sulphide ores are frequently coated with thin films of greenockite.

In thin section, under the microscope, the country rock consists of fine-grained, anhedral crystals of dolomite which have locally been invaded and replaced by veinlets of coarse-grained gangue dolomite. Disconnected areas and veinlets of sphalerite are scattered throughout the country rock. The ore mineral is distinctly later than both country rock and gangue dolomite. Granular aggregates of pyrite, partly altered to limonite, occur throughout the areas of both country rock and gangue dolomite. Frequently, the contacts between country rock and dolomite are obscured by small veinlets of limonite and pyrite. To a limited extent the iron-bearing solutions have invaded and replaced sphalerite along its edges and in cleavage cracks.

Paragenesis

1. Country rock.
2. Gangue dolomite.
3. Sphalerite.
4. Pyrite.

No galena was observed in this section.

DEVELOPMENT

The present state of development of the mine can be seen in Figure 6. The surface workings were made by the early companies and produced only oxidized ores. Numerous open pits and shallow shafts, operated by winch and bucket, were developed along the outcrop of the ore body for over a distance of 350 feet. Subsequent underground mining has caused much of the surface to cave.

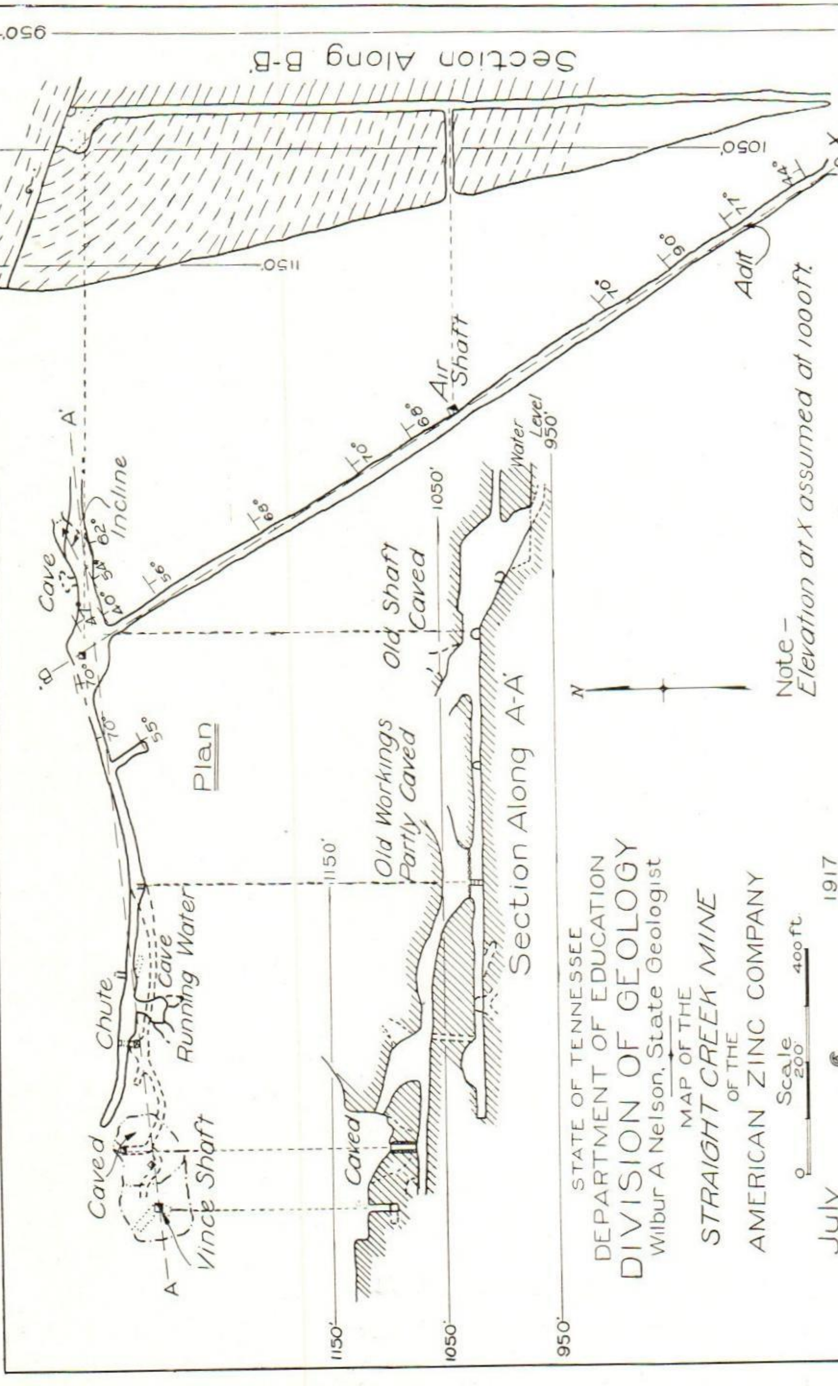


FIGURE 6. Plan of Straight Creek mine, showing cross sections.

Access is had to the underground workings through a tunnel 6 feet wide and 7½ feet high driven N. 40° W. from the base of the hill for a distance of 750 feet until it intersects the fault. From this point the ore body was worked along the strike by means of drifts and stopes from the main level. The developments indicate that the ore body is an easterly pitching shoot with a stope length of 400 to 500 feet. It has been mined from two levels. The main level, at the same elevation as the tunnel, follows the ore body for a distance of 425 feet west of the tunnel. Overhead stopes near the west end connect it to a second and higher level which rises to the surface at the extreme western end of the mine.

Development to the east of the tunnel consisted of an incline which connected with a lower level. It is reported that this incline was sunk to a depth of 30 feet below the main level. At the time of this investigation the incline was filled with water.

A 100-ton mill is located on the hillside near the mouth of the tunnel. It is equipped for wet concentration of the sulphide ore. The ore was hauled up an incline to the ore bin and then fed to a 14-inch jaw crusher and thence directly to a set of 15-inch rolls. It was then elevated to a trommel with 0.1 inch circular openings from which the oversize was reground in a second set of rolls and the undersize went to a classifier. From the classifier, the coarse passed to a 7-compartment jig and the fine to a spitzkasten, the settlings of which were distributed to two Overstrom concentrators. The jig tailings were discarded and the first two compartments made lead concentrates; the last three spigots off the screens were re-ground in a third set of rolls and the last five hutch products passed to a second 7-compartment jig. The last two screen spigots and first settlings of tailings were passed through a 5-compartment jig. The first two hatches from the first jig made lead concentrates, the rest of the concentrates were zinc.

The chief hindrance to development and operation of this property has been lack of transportation facilities. Some years ago, in 1907, the Tennessee Zinc Company made a railroad survey from the mine to the northeast to connect to the Southern Railway. However, the road was never constructed.

The main level has been rather thoroughly worked out in the western end. However, the occurrence of rich masses of veinlets of high-grade sulphide ore in the roof and walls of the east incline, continuing down to water level, indicates that the ore body continues in an eastern direction along the fault.

DEVELOPMENTS IN THE VICINITY OF THE MINE

A series of prospects extends at intervals from the Straight Creek Mine northeastward to the Southern Railway. In most cases the development was limited to little more than ascertaining the presence of ore along the strike of the same formation exposed at the mine. There follows a brief account of each prospect in order northeast from the mine.

G. L. Phelps prospects (9)

There are three small prospect pits on this property on the north side of Straight Creek. The pits extend over a distance of 1,000 feet in a line running N. 80° E. It is reported that the work was done about 1892, and at the time of this investigation they had caved and filled in to such an extent that no observations could be made.

A fourth and larger pit on the north side of Straight Creek, lies at a distance of about 500 feet beyond the easternmost of the above-named series of pits. It is about 20 feet above the creek bed and extends 80 feet in a N. 65° W. direction and is 10 feet wide. The country rock is Knox dolomite and the horizon coincides with that in the mine. The bedding strikes N. 60° E. and dips 40° SE. Neither faulting nor fracturing were seen. No ore is visible but it is reported that several tons of smithsonite were taken out of the cut.

Lewis Phelps prospects (10)

These prospects, consisting of two open cuts, are on the south side of Straight Creek on the Lewis Phelps farm which adjoins the G. L. Phelps farm on the northeast. One cut was entirely filled in. Around the opening were scattered lumps of ore containing sphalerite, galena and pyrite, all more or less coated with greenockite.

The second open cut, 900 feet northeast of the first, extends 125 feet in a N. 70° E. direction, and is 20 feet wide. In this cut the bedding strikes N. 58° E. and dips 33° SE. One set of fractures running E-W. 62° N. is well developed. Small masses and veinlets of sphalerite accompanied by some galena and pyrite form replacements in the slightly brecciated country rock. Where disintegration and oxidation have taken place, the ores consist of smithsonite, calamine, and cerussite intermixed with clay.

Oley Bull Jones prospect (11)

This prospect is on the south side of the wagon road and approximately 1½ miles northeast of the mine. The work was done in 1916 by J. B. Irwin and consists of an open cut, 15 feet wide, extending for a distance of 75 feet in a N. 80° E. direction. The bedding strikes N. 65° E. and dips 55° SE. In this cut a minor fault is exposed, the plane of which strikes N. 80° W. and dips 35° N. For a distance of 10 feet on either side of this fault plane the dolomite has been extremely fractured but apparently very little mineralization occurred.

Williams Moss Jennings prospect (12)

The extreme northeastern point at which prospecting was carried on in this general horizon of the Knox dolomite was in a railroad cut (Southern Railway) located 1,300 feet south of Woodward Hollow trestle. This locality is about three miles northeast of Straight Creek mine. An open cut had been made in 1916 by J. B. Irwin but was later filled in. The property is owned by William Moss Jennings. It is reported that a small amount of carbonate ore was taken from the cut.

Although all of the pits above described follow the general strike of both country rock and the fault in the Straight Creek mine, in none were conditions of mineralization observed which make it probable that the Straight Creek ore body is continuous along the line of these prospects. It is thought that the ore body dips below the surface east of the mine and that, therefore, the several pits have exposed only pockets of ore resulting from the fracturing to which the rocks of the entire district were subjected.

Wylie Burch prospect (13)

This prospect is on Burch Creek, two miles west of Straight Creek mine. In 1892[1], a company known as the American Association, first prospected this locality for zinc and lead ores by sinking a shaft and making a small open cut. This work was followed by that of Snow and Moore who sank a second shaft and made another small cut. The ore was hand sorted, hauled to Lone Mountain and shipped. Work at this prospect ceased during the panic in 1892.

The ore horizon is near the base of the Knox dolomite which is bluish-gray, thin-bedded, and finely crystalline. The bedding strikes N. 82° E. and dips 58° NW., the reverse dip indicating that this horizon is in close proximity to the major fault of the region. No direct evidence of the fault, however, was seen.

Development was carried on, on both sides of the creek. On the east side, for a distance of 120 feet, a cut was made along the strike into the hillside. The width of this cut is 20 feet and the depth at the face is 20 feet. Compact pinnacles of dolomite, exhibiting little fracturing, were exposed, but no ore, either in sulphide or oxidized form, was observed. A small quantity of smithsonite and a considerable amount of limonite were lying on the dump at the entrance to the cut.

On the west side of the creek a tunnel had been driven S. 75° W. for a distance of 45 feet. The walls and roof consist of compact, unbroken dolomite, similar to that in the cut, and are barren of ore.

[1]Purdue, A. H., The zinc deposits of northeastern Tennessee, Tenn. Geol. Survey, Bull. 14, p. 55, 1912.

EVANSTON DISTRICT

Evanston, about four miles southwest of Sneedville, the county seat of Hancock County, lies in a small valley bounded by Short Mountain on the northwest and by River (Comby) Ridge on the southeast. Lone Mountain, a station on the Cumberland Gap Branch of the Southern Railway is 22 miles west of Evanston and is the nearest shipping point.

The discovery of zinc ores in the rocks of Short Mountain led to an investigation of the district by Messrs. Dougherty and Simmons, of Morristown, Tennessee. In 1916 they optioned about 13,000 acres of land in the district and later in the year sold a six-months drilling option covering the entire acreage to Messrs. S. P. Wetherill, of Philadelphia, and A. Hecksher, of New York. After drilling and prospecting for a period of five months, Wetherill and Hecksher offered to purchase a certain restricted portion of the property. This proposition was declined and the investigation ceased.

After the option held by Dougherty and Simmons had expired, D. M. Evans, of Jefferson City, Tennessee, secured new options and in May, 1917, organized the Southland Exploration Company. This company bought outright 600 acres of land on Short Mountain and River Ridge.

During the years 1917, 1918, and 1919, the company expended about $400,000 of which amount $100,000 was used in erecting a Joplin style mill and the remainder in building a town, improving roads, etc.

The mill was operated for a period of two weeks and turned out about 20 tons of non-commercial concentrates from about 800 tons of ore.

The company was soon brought to the realization that several factors essential to successful mining and mill operation had been overlooked. In the first place the mill had been constructed upon the assumption that large quantities of high-grade ore could be extracted from the rocks; secondly, it was taken for granted that a Joplin style mill was suitable for concentrating the ore; and finally, the long haulage distance to the railroad was not considered prohibitive.

Investigation has shown that favorable conditions for the presence of an extensive and high-grade ore body are lacking, also laboratory tests and microscopic examination of the ores have proven that a Joplin style mill is unsuited for its concentration.

After a brief period of operation, activity ceased, and the company went into the hands of receivers in April, 1921.

In September, 1922, Mr. John Cuningham, of Memphis, who was a large stockholder in the Southland Exploration Company, bought in the entire property at court sale. It is reported that he has organized and secured a charter for the Clinch River Zinc Company and intends to further prospect the property by drilling.

GENERAL GEOLOGY OF THE DISTRICT

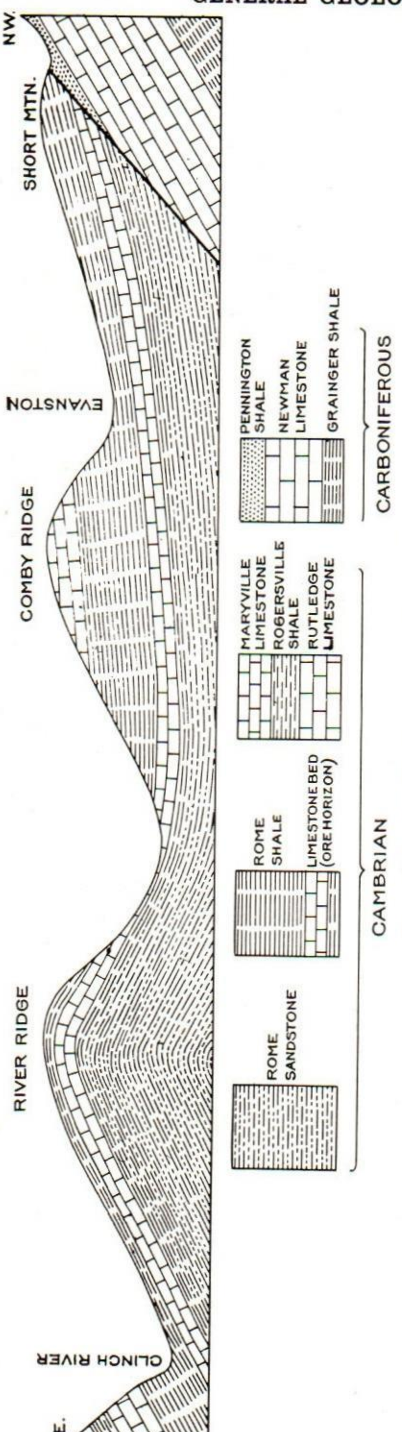


Figure 7. Idealized structure section at Evanston.

The strata exposed in River Ridge and Short Mountain consist of several hundred feet of sandy and calcareous shales with thin, intercalated beds of sandstone and magnesian limestones and comprise the upper horizons of the Rome formation of lower Cambrian age.[1]

A section extending from the Clinch River on the southeast to Newman Ridge on the northwest, shows that the area is structurally the low-dipping southeastern limb of a broad anticline in which local flexuring in the region of River Ridge produced minor bending of the strata. The structure is shown in Figure 7. The topographic depression between Short Mountain and Newman Ridge marks the strike-line of a major fault of great displacement resulting in the superposition of strata of the Rome formation over beds of Newman limestone of lower Carboniferous age.

The ore-bearing horizon of the Rome formation is limited to a thin intercalated bed of arenaceous and magnesian limestone, averaging about 135 feet in thickness. This bed is exposed in the sections in the several hollows and stream gaps of River Ridge and Short Mountain.

NATURE OF MINERALIZATION

All of the openings, with exception of Livesay cut, are

[1]Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Morristown folio (No. 27), 1896.

very small open cuts made into the upper levels of the limestone. Without exception these cuts have proven that the ore was confined to a narrow horizon, averaging about 10 feet in thickness, at the top of the limestone. Even in this narrow horizon mineralization was local and pockety.

The ore mineral, sphalerite, occurs as small replacement veinlets and disseminated flakes and masses in the tight, country rock. Gangue dolomite and calcite generally accompany sphalerite but are quite subordinate in amount. Mineralization occurred solely as a replacement of unbroken country rock and is not associated with fracturing and brecciation. Locally, fracturing and jointing are well developed but bear no relation to mineral deposition. So, it may be said, that structural features favorable for the accumulation of a workable body of ore are lacking.

DESCRIPTION OF OPENINGS

Livesay or Mill cut (14)

Most of the development undertaken by the Southland Exploration Company was done at Livesay cut. It is about one mile northwest of Evanston on the west side of Briar Creek Hollow in Short Mountain.

The overlying shales have been stripped from the limestone exposing an uneven contact surface furrowed by solution crevices. The ore horizon is about 10 feet in thickness and although it lies within a few feet of the top of the formation the transition of ore into barren rock is so gradual that definite limits can not be assigned.

In one of the open cuts the ore-bearing limestone overlies a thin-bedded, crumpled, fractured and jointed variety of limestone which varies from 4 feet to 7 feet in thickness. The latter overlies in turn, the steeply dipping Newman limestones along the overthrust fault plane. No relation between the faulting or jointing and ore deposition is apparent.

The other open cut A is 103 feet long, averages 22 feet wide and is 25 feet deep at the face. It exposes, therefore, the 10 feet of the ore-bearing horizon and about 15 feet below. Although jointing is prominent throughout the cut, no mineralization is connected with it as the walls and face are practically barren. The failure of the ore to extend continuously along the strata of the ore-bearing horizon or to persist deeper than the uppermost 10 feet of the limestone, as illustrated by this exposure, is typical of the prospects in Short Mountain.

The shaft had penetrated about 75 feet of barren shale and had just exposed the upper levels of the limestone when operations ceased.

The mill was erected at the base of the hillside below the open cut. The equipment consists of a jaw crusher, coarse- and fine-grinding rolls, three sets of jigs, trommels, elevators, and fourteen Wilfley style tables. The flow sheet is shown in Figure 8. The power equipment consists of two boilers, two horizontal engines, and one Ingersoll-Rand compressor.

Microscopic examination of a thin section of the ore from Livesay cut shows that the bulk of the non-metallic material consists of rather uniformly medium-grained dolomite with individual grains averaging

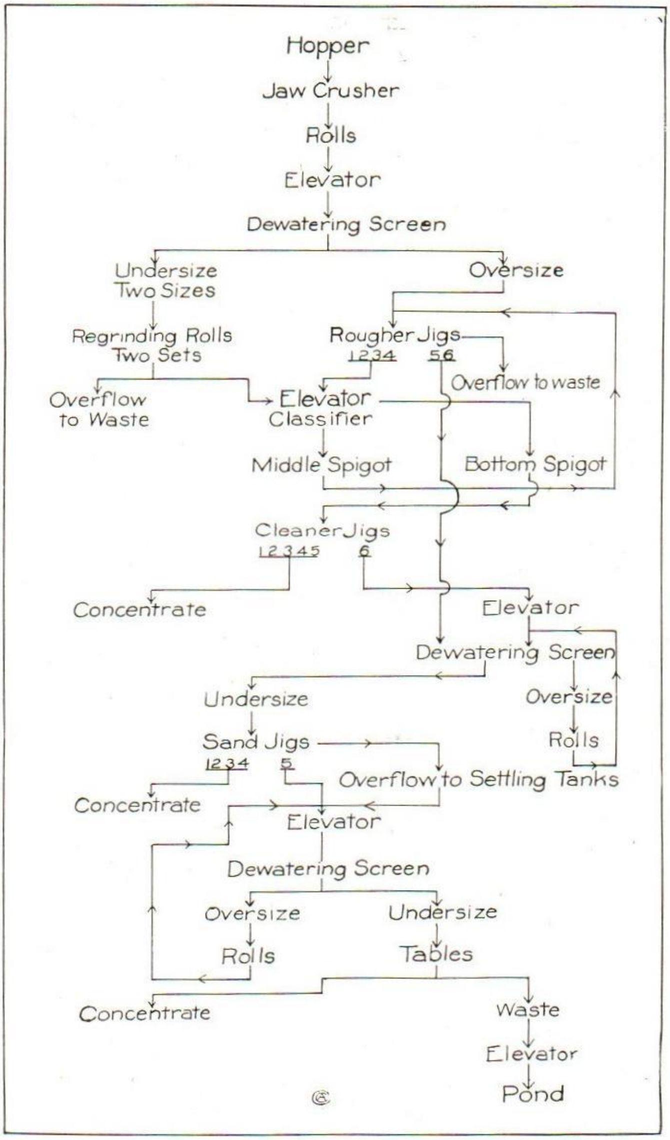


FIGURE 8. Flow sheet, Southland Exploration Company, Evanston, Tenn.

from 0.25 mm. to 0.40 mm. in diameter. Coarse-grained dolomite is absent. A few small grains of quartz occur either at the contact of country rock and sphalerite or within the individual country rock grains. Sphalerite, ranging in color from white to yellow (reddish-brown when iron-stained) occurs in irregular, detached masses as replacements of the country rock. Fine-grained pyrite is disseminated throughout the country rock, and, to a less extent, in the sphalerite. Practically all of the pyrite has been altered to limonite and thin seams of that mineral are prevalent wherever replacement is taking place.

Paragenesis

1. County rock, including scattered grains of quartz.
2. Sphalerite.
3. Pyrite.

Purkey cuts (15)

This prospect consists of two small openings made into the ore-bearing horizon of limestone where it outcrops on the hillside on the east side of Briar Creek.

The bedding strikes N. 63° E. and dips 33° SE—the same as at the Livesay cut on the opposite side of the creek. In the southern cut no ore, either carbonate or sulphide, was found. The northern cut passed through a small amount of carbonate ore in the clay overburden and exposed scattered, patched and small discontinuous veinlets of sphalerite in a 6-foot face of limestone. The ore is of the disseminated type appearing as flakes and masses averaging less than one-eighth inch in diameter. As in the Livesay cut, a very subordinate amount of gangue occurs.

Givens cuts (16)

These prospects located on the Jess Givens farm, consist of two adjacent small cuts exposing ore in limestone on the east slope of the hollow in Short Mountain; and one very small cut on the west side.

With respect to stratigraphic position both the limestone and the ore-bearing horizon coincide with the exposures at the Livesay cut except that about 100 feet of sandy shale intervene between the Cambrian limestone and the Newman limestone at the fault. The ore-bearing limestone is approximately 135 feet thick and is conformably overlain by thin-bedded shale. The strata strike N. 71° E. and dip 21° SE. Two sets of joints, running N. 20° W. and N. 70° E. respectively, were developed but apparently had no influence upon ore deposition.

The two cuts on the east slope, with the exception of 30 feet of unremoved rock separating them, expose the ore horizon for a distance of 100 feet along the dip. They have an average depth of 8-10 feet and are approximately 15 feet wide. As at the Livesay cut, mineralization was limited to the deposition of variable amounts of sphalerite and dolomite occurring as disseminated masses and veinlets in a 10-foot horizon near the top of the limestone. Locally, however, pockets of high-grade ore occur but are not continuous over any great extent. Near the top of the limestone there is a 6-inch bedding seam of argillaceous shale which acted as an effective barrier to the ascent of ore-bearing solutions. The limestone above this seam is barren while immediately below it the highest grade ore occurs.

The cut on the west slope of the hollow was made at a somewhat lower horizon in the limestone and failed to reveal any ore.

No production of ore was realized from the development of the cuts on this property.

Microscopic examination of a thin section of the ore from this locality shows the country rock to consist of finely granular dolomite and calcite, averaging 0.10 mm. in diameter. The variation in size appears to have been in part a characteristic of the original country rock and in part the result of re-crystallization of the smaller grains into the larger. Vein dolomite, coarse-grained and showing good cleavage, has locally replaced both varieties of country rock. A few rounded grains of quartz occur disseminated through areas of fine-grained country rock and appear to have been deposited contemporaneously with the country rock. Sphalerite, of light-brown color, occurs as a replacement of both country rock and dolomite. Many small crystal aggregates of the earlier minerals are embedded within sphalerite masses and are undergoing replacement. Small grains of pyrite are disseminated through both country rock and dolomite, and seams composed of limonite and partly altered pyrite, are of frequent occurrence, rimming masses of sphalerite and projecting variable distances into it, along cleavage or fracture lines.

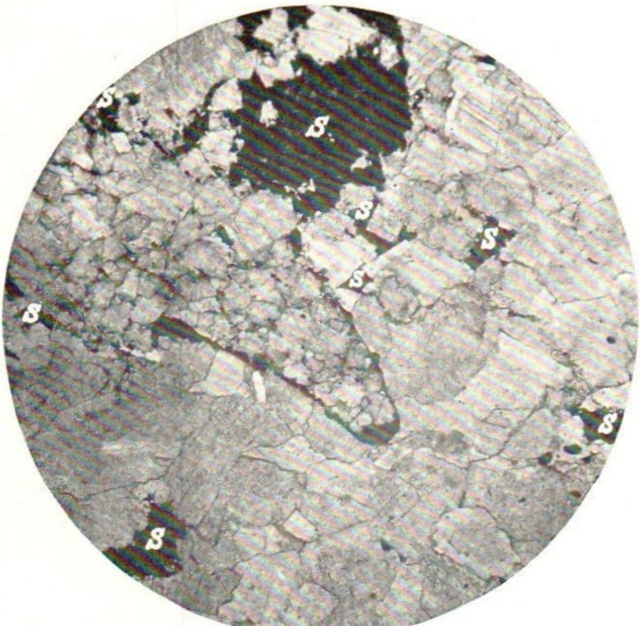
Paragenesis

1. Country rock including scattered grains of quartz.
    a. Original.
    b. Recrystallized.
2. Dolomite.
3. Sphalerite.
4. Pyrite.

Clint Brewer prospect (17)

A small open cut was made into the ore-bearing limestone on the Clint Brewer farm which adjoins the Livesay farm on the west. Several samples collected from this opening show the sphalerite to be finely disseminated through the country rock. Gangue dolomite is practically absent. In its mode of occurrence the ore appears similar to that of the other prospects, in Short Mountain. The area exposed by the open cut,

PLATE V.



Fine-grained country rock and coarse-grained dolomite undergoing invasion and replacement at their contacts by pyrite veinlets (black). Small areas of sphalerite (S) are disseminated through the dolomite. Brewer prospect, Evanston. x40.

only a few square feet, is so small that no idea of the extent of mineralization could be gained.

Under the microscope a thin section of the ore appears essentially similar to that of the localities described above. Several narrow, roughly parallel remnants of fine-grained country rock show the extent to which recrystallization and replacement by later minerals have proceeded. The remnants of the country rock are frequently surrounded by a thin seam of pyrite-limonite. Vein dolomite, except for the slightly larger size and tendency toward idiomorphic boundaries of its crystals, is difficult to distinguish from the larger-grained, recrystallized country rock. Sphalerite of a light brown color is limited in its occurrence to the recrystallized country rock, and especially where it is in contact with vein dolomite. Replacement by sphalerite has been very irregular and that mineral appears more as disseminated masses through the rock.

Grains and veinlets of pyrite occur in country rock, dolomite and sphalerite. The latter mineral is generally rimmed and stained by limonite veinlets many of which project well within its mass along fracture and cleavage cracks.

Paragenesis

1. County rock.
2. Dolomite.
3. Sphalerite.
4. Pyrite.

Keaton prospect (18)

The Keaton open cuts, located on the Keaton farm two miles southwest of the Livesay farm, were made into the ore-bearing limestone outcropping on the western slope of a hollow in Short Mountain. It is said that the prospecting was done by Wetherill and Hecksher.

The larger cut is 50 feet long, 12 feet wide and 30 feet deep at the face. It was made in a S. 45° W. direction, or diagonally across the strike and dip which are N. 72° and 20° SE. respectively. At the time of this investigation the sides and face had caved to such an extent that only a limited examination could be made. Small masses and veinlets of sphalerite, accompanied by subordinate amounts of gangue dolomite, occur as disseminated replacements of the tight country rock. Within the mineralized horizon, which has an average visible thickness of about 10 feet, the ore is so irregularly scattered that its extraction would require the handling of much barren rock.

As at Livesay Cut, the highest grade ore occurs near the surface and, as the limestone is penetrated, it becomes leaner and within a distance of 15 feet from the surface it grades into barren rock. It cannot be emphasized too strongly that this lack of persistency of the ore when followed along the strike or down the dip, or at right angles to the stratification, is typical of the deposits in Short Mountain and an outcrop of high-grade ore can not be accepted as evidence of the presence of a workable ore body.

The second cut is 200 feet northwest of the first and was made into the upper 10 feet of the limestone and several feet of overlying shale. It extends 40 feet in a S. 60° E. direction, is 8 feet wide, and 10 feet deep at the face. Except for a few scattered areas of zinc carbonate and disseminated sphalerite, and one small lump of galena, occuring near the top of this limestone exposed in the face, the rock is barren.

In the thin section of ore from the larger open cut, the country rock, consisting of the fine-grained, anhedral crystals of dolomite which average from 0.10 to 0.15 mm. in diameter, has been extensively replaced by coarsely granular vein dolomite. As a rule, where the two varieties of dolomite are in contact, they are separated by narrow seams of limonite carrying minute grains of pyrite.

Light-brown and yellow sphalerite has replaced much of the dolomite. The contacts of the two minerals are extremely irregular and are denoted by small veinlets and shoots of sphalerite embaying along cleavage cracks or between individual grains of dolomite.

Limonite, carrying minute pyrite grains, generally rims sphalerite and also follows along cleavage cracks of the mineral producing a reddish-brown stain upon the adjacent surface.

Small, irregularly shaped masses of galena are included in the sphalerite.

Paragenesis

1. County rock.
2. Dolomite.
3. Sphalerite and galena.
4. Pyrite.

Lamb cuts (19)

The Lamb farm is approximately three and a half miles southwest of Evanston and extends from the crest of River Ridge southeastward to Clinch River.

As stated in the general description of the Evanston district, River Ridge is a low, open minor anticline, with a northeast axis, superimposed upon the southeastern limb of the regional anticline. The folding produced local crumpling within the less competent shales and brecciation and fracturing in the limestones. The stratigraphic thickness of the limestone is approximately 135 feet.

The ore-bearing horizon has been prospected by two open cuts situated near the top of the ridge on the east slope of a steep-sided hollow. The larger cut is 60 feet in length in the direction of the strike

(N. 52° E. 25° SE.), averages 20 feet in width and is about 40 feet in depth at the face. The occurrence of ore is restricted to the upper 20 feet of the limestone and the lower 2 feet of the overlying shale into which the limestone grades. Within these beds, especially in the upper part, fracturing and brecciation occurred. Mineralization took place in the a matrix of pink and white dolomite, calcite and sphalerite. The brecciation, intense in the upper beds of the limestone, gradually diminishes downward and grades over into undisturbed, thick-bedded, barren limestone.

The chief ore mineral is dark-brown sphalerite and it occurs either as finely disseminated particles in the shale and limestone or, deposited with dolomite as narrow, discontinuous veinlets and stringers in the breccia matrix. A small amount of the chalcopyrite, appearing as disseminated grains and veinlets in the dolomite, occurs throughout the mineralized portion of the limestone. Also, a thin bed of the overlying shale is impregnated with galena.

The Lamb cut shows a longer continuous mineralization in the direction of the strike than any of the prospects on Short Mountain. However, in the smaller pit, situated 150 feet southeast of the larger, in which the same horizon is exposed for a distance of 20 feet down the dip and a few feet along the strike, the rock is only slightly brecciated and only a small amount of finely disseminated sphalerite was observed. Thus it appears that the mineralization was confined to the brecciated beds and, furthermore, the two open cuts, one mineralized and the other not, but exposing the same horizon of rock within so short a distance, indicate the limited extent of the brecciation.

Jointing is pronounced in both open cuts but appears to have had no connection with mineralization. Three sets of joints were observed, viz: N. 25° W., N. 55° W., and N. 48° E.

When examined in thin section under the microscope, the country rock is seen to consist of fine- to medium-sized grains of dolomite and calcite. In many instances the smaller grains appear to have been replaced by the larger, suggesting that some recrystallization of the country rock took place.

Vein dolomite occurs in unusually large crystals which have invaded and replaced the country rock in a very complex manner. At times the line of demarcation between dolomite and country rock is well defined, especially where large crystals of the former terminate against small grains of the latter; again, the two grade into each other by a gradual increase or decrease in size of adjacent crystals.

The finely crystalline variety of country rock contains an appreciable amount of interstitial quartz. Crystal boundaries of the quartz are lacking but several examples indicate that it was deposited in the sutures between grains of country rock and the surrounding mineral was partly replaced by the quartz. A few scattered grains of quartz occur between adjacent crystals of vein dolomite.

Light-brown sphalerite, showing zonal growth of darker bands, occurs as disseminated replacements of both country rock and dolomite.

With exception of one large particle 1.20 mm. in diameter appearing as a replacement in the dolomite, the occurrence of chalcopyrite is limited to small grains and short veinlets disseminated through the country rock. Thin seams of limonite habitually rim sphalerite and spread out into the surrounding country rock giving it a reddish-brown stain.

Paragenesis

1. Country rock.
2. Dolomite.
3. Quartz.
4. Sphalerite.
5. Dolomite (filling fractures in the sphalerite).
6. Chalcopyrite and pyrite.

Lee Dodson prospect (20)

At the northern end of the Lee Dodson farm a small open cut was made into the mineralized horizon of the limestone and shale. This prospect, near the top of the ridge, is about half a mile southwest of the Lamb prospect and along the strike of the formation. The cut is but a few feet in length and width and exposes a 4-foot face of ore-bearing rock, similar in all respects to the upper beds at the Lamb cut. Brecciation and fracturing of both shale and limestone resulted in replacement by dolomite, sphalerite, and a small amount of pyrite. Also, a thin bed of shale contains disseminated galena. Alteration of sphalerite to smithsonite has proceeded to some extent at the surface.

A thin section of the ore shows the country rock to consist of fine-grained dolomite and calcite with the grain sizes ranging in diameter from 0.03 mm. to 0.30 mm. The grains possess irregular, interlocking edges and many show the polysynthetic twinning characteristic of calcite.

Vein dolomite is not abundant. It replaces country rock. The grains show well developed cleavage and generally one or more edges are crystal planes.

Both country rock and dolomite are replaced by light-brown sphalerite. This mineral is quite abundant. That replacement has not been complete is indicated by numerous inclusions of country rock and dolomite within the sphalerite masses. The presence of isolated grains of quartz in association with these (country rock-dolomite) inclusions, and its absence from the country-rock and dolomite not undergoing replacement by sphalerite, indicate that quartz mineralization was closely followed by sphalerite mineralization in the same areas.

Minute grains of pyrite, generally oxidized to limonite, occur in disseminated form in all minerals. Invariably the contacts of replacing minerals, espec'ally the sphalerite, are denoted and somewhat obscured by thin seams of limonite. No galena was seen in the section.

Paragenesis

1. Country rock.
2. Dolomite.
3. Quartz (in part contemporaneous).
4. Sphalerite (in part contemporaneous).
5. Pyrite.

W. H. Green prospect (21)

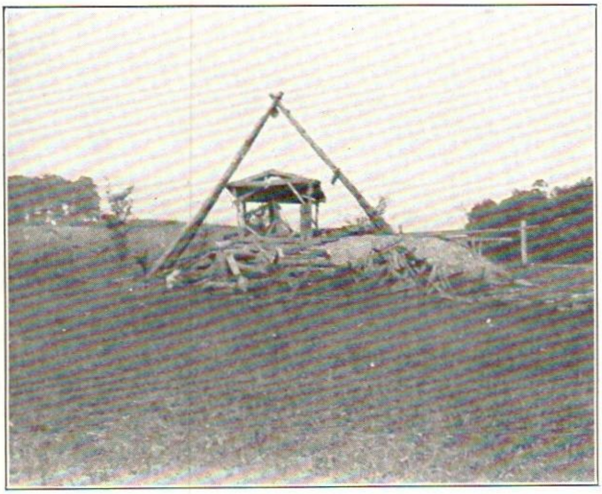
Structural conditions similar to those in Short Mountain prevail in War Ridge, where the southeastern slope is composed of shales, sandstones, and the limestone bed of Rome formation.

In 1919, when mining activity at Evanston was at its height, prospecting for zinc was carried on in the War Ridge country and resulted in finding carbonate and sulphide ore in the upper horizon of the limestone bed. The prospect is on the farm of W. H. Green and is about two miles northeast of Luther and five miles southeast of Evanston.

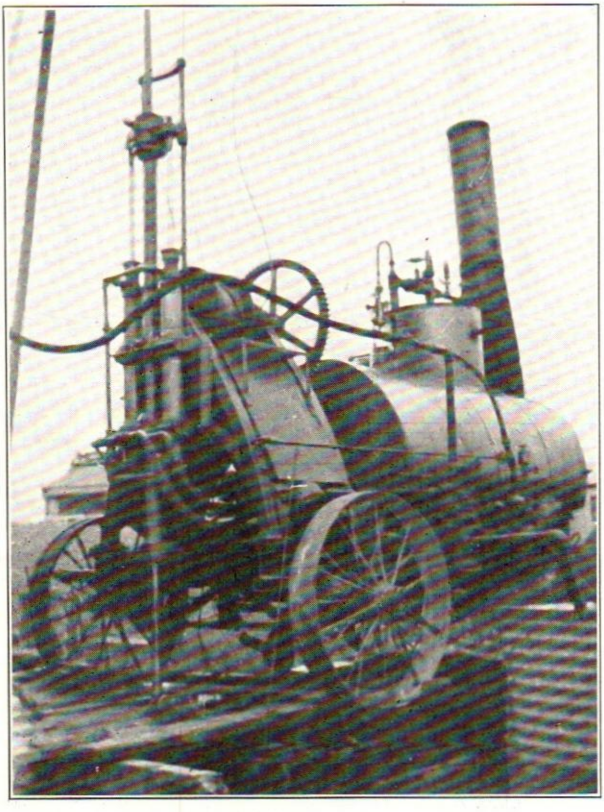
The ore is exposed in an open cut, 15 feet in length along the strike (N. 60° E.)and 5 feet in depth at the face. The beddings dips 15° S.E. The ore, similar to that occurring in Short Mountain, consists of a finely disseminated sphalerite in a tight, unbrecciated country rock. Dolomite gangue is practically absent and neither galena nor pyrite were observed. The mineralized zone is parallel to the bedding and ranges in thickness from 1 foot to a maximum of 3 feet, its lower boundary terminating sharply against a chert bed intercalated in the limestone. Jointing is prominent; two sets were observed running N. 45° W. and 60° W. respectively. There is no relation apparent between jointing and mineral deposition.

Mr. George J. Salmon, mining engineer of the U. S. Bureau of Mines, spent the week of September 12-18, 1921, in the field with the writer. During that time 600 pounds of ore-samples were collected from the several prospects in Short Mountain and River Ridge. The prospect in War Ridge was not included.

The purpose of sampling, as stated in Mr. Salmon's report, was to obtain sufficient ore for mill treatment tests and not to determine the average zinc content of the ore. The percentage of zinc in the samples is much higher than the average zinc content of the ore in any of the prospects because in order to obtain the necessary ore for sampling it



(A)



(B)

(A) Prospecting at New Market.
(B) Diamond drilling at Mascot.

was necessary to take samples from only the richest places in the cuts. Therefore, the analyses show a zinc content much higher than that of the ore bodies. The Bureau of Mines report follows:

REPORT ON SAMPLING ZINC DEPOSITS OF HANCOCK COUNTY, TENN.

PURPOSE OF INVESTIGATION

In April, 1921, at a conference between Messrs. Bain and Lyon of the Bureau and Mr. Wilbur A. Nelson, State Geologist of Tennessee, at St. Louis, Missouri, it was tentatively agreed that the Bureau would cooperate with the Tennessee Geological Survey in its investigation of the zinc deposits of East Tennessee.

The nature of the cooperative work of the Bureau was to be the sampling of the deposits in Hancock County with the intention that such samples were to form the basis and material for a mill treatment test at Rolla. It was desired to know whether these ores were possible of concentration and the best method of treatment determined.

GENERAL

For purposes of this report the zinc deposits near Lee Valley, Hawkins County, are included with those of Hancock County. Hancock County is one of the northern tier counties of Tennessee, bounded on the north by the States of Virginia and Kentucky; on the east by Hawkins County; on the south by Hawkins and Grainger counties and on the west by Claiborne County. Sneedville is the county seat and is four miles east of Evanston, Tennessee.

The district is undeveloped but the outcrops uncovered are persistent over a large territory. Intensive drilling would be necessary to determine the extent and commercial importance of the mineralized limestone beds.

The Southland Exploration is the only company that has ever operated in this field, but although some $300,000 were expended by this company, the mine exploration and development work was almost nil. A Joplin type mill of good construction was erected near Evanston, but in the opinion of the engineer entirely unsuited for the ore to be treated. This company is now in the hands of the receiver and the information available shows that operations ceased after one week of mill operation in which time twenty tons of non-commercial concentrates were produced from eight hundred tons of rock.

Evanston was the base from which the examinations were made and is twenty-six miles northeast of Lone Mountain, Tenn. There are no railroads in Hancock County; the nearest railroad outlets are Lone Mountain and Rogersville stations on the Southern Railway.

The Clinch River would be a source of water supply and hydro-electric power.

Examination was made the week of September 12, 1921, in company with Mr. Mark H. Secrist of the Tennessee Geological Survey. Sampling was started September 13 and completed September 18, 1921.

SAMPLING

Samples were taken from various outcrops scattered over the territory within a ten mile radius of Evanston, but the vast majority of the samples were taken within a radius of four miles. Six hundred (600) pounds of samples were taken and shipped to Rolla, Missouri. The character of the samples taken within the four-mile radius is finely divided sphalerite in a tight blue limestone; whereas the samples taken from the only deposit lying within the ten-mile radius and outside of the four-mile radius, shows the sphalerite in much larger concentration in a brecciated limestone.

The samples were not taken with any idea of ascertaining what would be the probable mineral content in the various outcrops exposed, but were taken to obtain a representative sample of ore to be treated. In other words the various faces were cut and the sample obtained representative of the character of ore to be treated and suitable for making a mill test.

Outcrops were sampled on the following properties:

Dodson property, Hancock County.
Lamb property, Hancock County.
Keaton property, Hancock County.
Givens property, Hancock County.
Southland property, Hancock County.
Zinc prospect near Lee Valley, Hawkins County.

Various samples of feeds and concentrates in the mill circuit were also taken so as to be a guide to the investigator.

DETAILED LIST OF SAMPLES

Nos. 153 and 154 represent samples taken from the face of open cut on Lee Dodson property and of boulders previously broken from that face.

Nos. 155 and 156 represent samples cut from the face of open cut on the Lamb property.

Nos. 157, 158, 159 represent samples from the mill feed bin. These samples were sorted out of the mill hopper; the total sample consisting of three kegs of material.

No. 160 represents sample cut from outcrop on Keaton property.

No. 161 is a sample taken in open cut about fifteen feet east of sample 160 on the Keaton property.

No. 162 represents sample cut from outcrop at south end of open cut on Givens property.

No. 163 represents sample cut from outcrop at north end of open cut on Givens property.

No. 164, A, B, C, D, E and F represents sample taken from open cut of Southland property, known as the Mill cut.

No. 165, A, B, C, represents a composite sample taken from various boulders scattered about at the open cut and on the dumps of Mill cut.

No. 166 represents sample taken from a zinc prospect near Lee Valley to show genesis of ore for geological study.

No. 167 represents sample cut from above deposit, the sample was cut in small adit and over face of the outcrop.

No. 168 represents sample of table concentrates.

No. 169 represents sample from settling tank.

No. 170 represents sample of mill concentrates being products from all machines

Sample No. 171 represents rougher jig feed.

Sample No. 172 represents cleaner jig feed.

Sample No. 173 represents sand jig feed.

Sample No. 174 represents ore from dump of Lee Valley prospect.

ANALYSES OF SAMPLES

The Missouri State Mining Experiment Station reports the results of analyses as follows:

Sample No.	Percent Zn.	Percent Fe.
153	13.88	2.66
154	11.69	2.61
155	9.95	3.47
156	15.63	3.52
157	7.70	2.71
158	7.08	2.85
159	6.01	2.80
160	5.62	2.52
161	3.32	2.76
162	10.34	2.61
163	6.01	2.57
164-A	5.90	2.95
164-B	7.87	2.42
164-C	33.21	1.42
164-D	2.14	2.71
164-E	35.01	1.42
164-F	2.30	2.85
165-A	34.73	1.57
165-B	12.42	2.14
165-C	7.64	1.76
167	9.84	2.85
168	9.61	1.42
169	4.27	3.04
170	13.66	2.66
171	2.36	2.95
172	5.79	2.76
173	4.83	2.97
174	5.96	3.09

The ores subject to investigation have been classified as "finely disseminated" and "free milling." The "finely disseminated" corresponds to the engineers classification, "finely divided sphalerite in a tight, blue limestone," and the term "free milling" refers to the coarser concentration of sphalerite in a brecciated limestone.

The complete analyses on the complete sample of "finely disseminated" samples consisting of samples Nos. 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, and 165 is reported as follows:

Finely disseminated ore:

Insoluble	2.64%
Iron (Fe)	3.04
Lime (CaO)	25.68
Magnesia (MgO)	12.06
Zinc (Zn)	7.70
Sulphurs	3.08

The complete analyses on composite sample of "free milling" samples consisting of Nos. 167 and 174 is reported as follows:

Free milling ore:

Insoluble	12.26%
Iron (Fe)	1.43
Lime (CaO)	23.09
Magnesia (MgO)	14.35
Zinc (Zn)	6.46
Sulphur (S)	4.23

MILL TREATMENT INVESTIGATION

Samples Nos. 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, and 165 represent the material that will be used as basis for the investigative work being carried on by Mr. Elmer List, fellow at the Missouri School of Mines.

Samples Nos. 168, 169, 170, 171, 172, and 173, represent samples taken as accurately as possible of the various mill feeds and products, so as to assist the investigator in the determination of the proper crushing point for liberation of the zinc ore contained in the limestone.

Samples Nos. 167 and 174 represent second type of ore found in Hancock county district, but there is no necessity that these be included in the investigation as inspection shows that no milling problem exists in the treatment of such ores.

Sample No. 166 is only a geological sample and not a part of the investigation.

The sampling is completed and investigation under way.

CONCLUSION

The milling problem exists only in regard to the "finely disseminated" ores as inspection shows that no problem is involved in the case of the "free milling" ore. Fine crushing followed by tabling and flotation alone will be the best probable mill treatment of the finely divided sphalerite in the tight, blue limestone.

Respectfully submitted,

GEO. J. SALMON,
Mining Engineer.

St. Louis Missouri,
October 31, 1921.

EXPERIMENTS ON TENNESSEE ZINC ORE MADE AT THE INTER-MOUNTAIN EXPERIMENT STATION, U. S. BUREAU OF MINES

STATEMENT OF THE PROBLEM

As a result of the cooperative agreement between the Tennessee Geological Survey, and the U. S. Bureau of Mines, it was agreed that certain experiments be made on typical samples of finely disseminated Tennessee zinc ores. These samples were obtained by Geo. J. Salmon, Bureau of Mines Engineer, and the samples were sent to the Intermountain Experiment Station for concentration and flotation experiments.

The general character of the investigation was to determine the most simple process whereby the zinc could be recovered from the ores in a marketable product. The question of carrying on experiments on a scale sufficiently large to determine the best scheme of treatment, the best machines to install in a commercial plant, and the discussion of the design of the plant, are matters the commercial concerns should take up, so that the experiments and the results obtained only indicate what can be expected in the way of recoveries by flotation treatment.

DESCRIPTION OF THE ORE

As this matter is described in detail in Mr. Head's microscopic examination, which is a part of this report, it is needless to say further that the zinc is finely disseminated throughout the ore and requires fine crushing to liberate the same. Coarse crushing and treatment by jiggs and tables are not practical so that the only treatment method left outside of hydrometallurgical processes is flotation treatment. The sample of ore treated assayed as follows:

	Zn.	Fe.	CaO.	MgO.	S.	Insol.	BaSO4.
Original	8.54	2.70	24.94	15.24	3.88	4.17	0.00
Duplicates............	8.72	2.70	24.96	15.65	3.92	4.17	0.00

Contrary to previous reports, no barium sulphate was found in the ore.

AVAILABLE DATA AS WORKING BASIS

As soon as this problem was assigned the present mill practice of the Tennessee Zinc Company, Mascot, Tennessee, was looked into. The ore treated by the Tennessee Zinc Co. is much coarser and a certain amount of it can be removed by jigg and table concentration. However, it looked reasonable that the same reagents used on these ores would be amenable to the sample treated. The reagents used by the Tennessee Zinc Co. were about 2 pounds crude oil paraffin base .4 of a pound of copper sulphate and .75 lbs. of pine oil. Their recoveries by flotation were better than 90% with concentrates assaying 61% zinc. Most of the ore treated by flotation, in fact 80%, was finer than 200 mesh.

It developed that the General Engineering Company, Salt Lake City, Utah, had recently done some experimental work for the Tennessee Zinc Co. and they gave us the information on the improved practice at that plant. Their statement was that a mixture of 20% thio carbanilide and 80% ortho toluidine had given excellent results. This company was good enough to furnish us with some of this material and the results of its use are indicated in the tabulated results.

PREPARATION OF ORE FOR EXPERIMENTS

All of the material received (approximately 60 lbs.) was crushed to pass 10 mesh screen size and very thoroughly mixed and sampled. By such procedure each sample of ore tested contained the same amount of zinc and did not necessitate an assay of a head sample for each test.

METHODS OF EXPERIMENTATION

In each test a sample of the ore was crushed in a small ball mill either with or without the flotation reagent. The charge was left in the mill long enough to grind the ore to the desired degree of fineness. This was first determined by some preliminary experiments, to determine the time necessary to leave the ore in the mill to insure proper grinding. After this had been accomplished in each case the crushed charge was removed to the flotation machines and the reagents were added and thoroughly mixed throughout the pulp. The proper dilution of water was also added. After this procedure the frothing oils were added and the flotation product removed.

The tailings were not treated further, but the concentrate was recleaned in a smaller machine making three final products, namely, a concentrate, a middlings or cleaner tail, and a final tailing. No attempt was made to clean any of the products more than once.

MACHINES USED IN EXPERIMENTATION

The ball mill used was 12 inches in diameter and about 12 inches long. The small iron balls were used for crushing the ore.

Flotation machines used were the mechanical type, somewhat similar to the mineral separation type and designed by A. W. Fahrenwald. This machine seemed to give very good results although almost any standard flotation experimental machine should give equally as good results.

REAGENTS USED

In nearly all the tests, copper sulphate was added. This was due to the fact that such was the common practice at the Tennessee Zinc Co. In some of the tests, substitutes were used for this material. In most of the experiments a crude petroleum was used and a very light pine oil. Several special oils were used which are all indicated in detail in the tabulated report.

A mixture of ortho toluidine and thio carbanilide was used in some of the tests and seemed to materially aid in the flotation of the zinc.

There is a strong probability that some of the zinc, probably a very small amount, is present in the ore in some form other than the sulphide. Some sodium sulphide was added as indicated in some of the experiments and it is believed that this aided somewhat in increasing the zinc recoveries.

DISCUSSION OF RESULTS

As will be seen by referring to the tabulated results, recoveries as high as 87.7% of the total zinc have been obtained, and tailings as low as .4% zinc. Several of the tests have indicated very low recoveries and a very poor grade of concentrates. However, these were results obtained by using different mixtures and there is no reason to believe but what most of the results could be duplicated in actual practice. The concentration ratio in a plant should be about 9 to 1, and it should be possible to get a grade of zinc better than 50%, or even higher by reclaiming the concentrate more than once.

In the results tabulated, no attempt was made to recover any of the zinc from the middlings or cleaner tailing product. This product represents about 10% of the original material treated and contains about 8% of the total zinc. It should be possible in practice to recover a considerable amount of zinc from this material.

In conclusion it might be stated that as a result of these experiments there should be no doubt as to the feasibility of recovering the zinc from a grade of ore similar to that experimented with. It would, however, be necessary and advisable before any commercial plant were installed, to consult a reliable metallurgist to carry on further experiments and on a somewhat larger scale in order the obtain data for the construction of a commercial plant.

Respectfully submitted,

THOMAS VARLEY,

Superintendent.

DETAILED REPORT OF FLOTATION TESTS ON TENNESSEE ZINC ORE

Test 1.

1,000 gms. ore and 1,500 cc. water with 5 drops of yaryan pine oil placed in ball mill and ground for 35 minutes, then put in rougher flotation machine with 10 cc. $CuSO_4$ (10% solution) and ran for 15 minutes. Concentrate put in cleaner machine and treated for 5 minutes. The three products were dried, weighed and assayed as follows:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	6.89	31.5	21.26	25.69
Cleaner Tail	6.87	8.19	5.52	6.48
Tailing..........	86.24	6.44	54.42	64.36
Totals.....	100.00		81.16	96.53

Test 2.

1,000 gms. ore and 1,500 cc. water ground for 35 minutes in ball mill. Placed in rougher flotation machine with 10 cc. $CuSO_4$ and 5 drops SS. pine oil. Ran 15 minutes and then ran concentrate through cleaner for 5 minutes. The three products were dried, weighed and assayed as follows:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	4.74	35.97	16.44	19.76
Cleaner Tail	6.05	5.15	3.00	3.61
Tailing..........	86.21	7.05	60.63	72.87
Totals.....	100.00		80.07	96.24

Test 3.

1,000 gms. ore and 1,500 cc. water ground for 35 minutes in ball mill, placed in rougher machine with 10 cc. $CuSO_4$ and 8 drops of 50% Barrett No. 4 and 50% K. and K. oil. Ran for 15 minutes and then placed the concentrate in the cleaner machine with one drop of the same oil. Ran five minutes. The three products were dried, weighed and assayed as follows:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	1.90	49.6	9.03	11.17
Cleaner Tail	2.04	35.6	6.94	8.39
Tailing..........	96.06	6.86	61.11	73.94
Totals.....	100.00		77.08	93.50

Test 3a.

Same conditions as in test 3, but the machines were run 25 and 10 minutes respectively. The weights and assays are:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	5.56	33.0	24.38	29.1
Cleaner Tail	7.28	12.55	8.86	10.5
Tailing..........	87.16	6.78	59.09	60.0
Totals.....	100.00		92.33	99.6

Test 4.

1,000 gms. ore and 1,500 cc. water placed in ball mill and ground for 35 minutes. Placed in rougher flotation machine with 10 cc. $CuSO_4$ and 3 drops of Cleveland Cliffs hardwood creosote. Ran 15 minutes adding one more drop oil toward end of run. Placed concentrate in cleaner machine and added one drop more same oil. Ran 5 minutes. The weights and assays of the products are as follows:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	1.21	25.95	3.06	3.63
Cleaner Tail	2.68	10.55	2.76	3.27
Tailing..........	96.11	8.02	75.39	89.32
Totals.....	100.00		81.21	96.22

Test 5.

1,000 gms. ore and 1,500 cc. water were ground in ball mill for 35 minutes and then placed in rougher machine with 10 cc. ammonium hydroxide, 5 drops SS. pine oil. Ran machine for 20 minutes and then placed concentrate in the cleaner machine; ran 5 minutes. The weights and assays are:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	6.38	11.90	7.18	8.68
Cleaner Tail	3.93	6.25	2.36	2.85
Tailing..........	89.69	8.07	69.40	83.87
Totals.....	100.00		78.94	95.40

Test 6.

1,000 gms. ore and 1,500 cc. water placed in ball mill and ground for 35 minutes. Placed in rougher with 10 cc. $CuSO_4$ and 8 drops crude petroleum and 3 drops SS. pine oil. Ran 20 minutes and then put concentrates through the cleaner for 10 minutes. The weights and assays are:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lo
Concentrate	12.62	42.9	52.25	61.65
Cleaner Tail	4.00	9.75	3.84	4.53
Tailing..........	83.38	3.00	24.57	28.99
Totals.....	100.00		81.76	95.17

Test 6a.

Ditto and placed in rougher flotation machine with 10 cc. $CuSO_4$ and 8 drops of crude petroleum and 3 drops SS. pine oil. Ran 20 minutes. Placed concentrates in cleaner machine and ran 10 minutes. The weights and assays are:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	12.22	44.10	52.39	62.46
Cleaner Tail	5.99	8.34	4.86	5.79
Tailing..........	81.79	3.04	24.17	28.79
Totals.....	100.00		81.42	97.04

Test 7.

Same item 35 minute . Placed in rougher flotation machine with 10 cc. $CuSO_4$ and 5 drops crude pine oil and 2 drops SS. pine oil. Ran 20 minutes and then put concentrate in the cleaner machine; ran 10 minutes. The weights and assays are:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	7.95	37.25	29.24	34.30
Cleaner Tail	4.26	8.96	3.77	4.42
Tailing..........	87.79	5.42	47.03	55.16
Totals.....	100.00		80.04	93.88

Test 8.

Ditto put rougher with 20 cc. $CuSO_4$ and 8 drops crude petroleum and 3 drops SD. pine oil. Ran 20 minutes and then put concentrates through cleaner for 10 minutes. The weights and assays are:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn recovered or lost
Concentrate	10.44	40.20	41.57	48.66
Cleaner Tail	4.51	12.72	5.67	6.63
Tailing..........	85.05	3.97	33.43	39.13
Totals.....	100.00		80.67	94.42

Test 9.

Conditions and reagents same as in Test 8 except 30 cc. $CuSO_4$ is used.

	Weight Percent.	Assay Percent. Zn	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	8.48	44.10	37.04	42.96
Cleaner Tail	4.14	14.50	5.95	6.90
Tailing..........	87.38	4.27	37.32	43.29
Totals.....	100.00		80.31	93 15

Test 10.

Same as Test 8 except no $CuSO_4$ was used.

	Weight Percent.	Assay Percent. Zn	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	2.06	14.70	3.00	3.51
Cleaner Tail	3.89	7.84	3.03	3.66
Tailing..........	94.05	8.00	74.40	86.99
Totals.....	100.00		80.43	94.16

Test 11.

Same as Test 8 except that 5 cc. $CuSO_4$ were used.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	12.53	44.4	54.37	64.47
Cleaner Tail	4.99	8.13	3.96	4.69
Tailing..........	82.48	2.79	22.46	26.63
Totals.....	100.00		80.79	95.79

Test 12.

1 kilo ore in 1,500 cc. water. Ground for 35 minutes in ball mill. Placed in rougher flotation machine with 15 cc. $CuSO_4$, 7 drops crude petroleum and 2 drops pine oil. Ran 20 minutes and then the cleaner for 10 minutes. Results:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	7.53	45.60	34.12	39.89
Cleaner Tail	4.78	21.40	10.14	11.86
Tailing..........	87.69	4.71	40.93	47.86
Totals.....	100.00		85.19	99.61

Test 13.

Same as Test 11 except for 5 cc. $CuSO_4$, 5 drops crude petroleum and 4 drops SD. pine oil. Results:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	12.48	40.40	50.22	58.42
Cleaner Tail	4.89	6.47	3.15	3.67
Tailing..........	82.63	3.68	30.29	35.24
Totals.....	100.00		83.66	97.33

Test 14.

Same as Test 12 except the oil was placed in the ball mill and the concentrates were cleaned by passing them back through the rougher. Results:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn recovered or lost
Concentrate	5.24	41.2	21.5	24.96
Cleaner Tail	16.60	11.0	18.2	21.13
Tailing..........	76.16	5.44	42.4	49.23
Totals.....	100.00		82.3	95.32

Test 15.

Same as Test 14 but the pine oil used contained sulphur. Results:

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn recovered or lost
Concentrate	7.82	50.3	39.0	45.55
Cleaner Tail	9.46	19.8	18.6	21.73
Tailing..........	82.72	2.79	22.9	26.75
Totals.....	100.00		80.5	94.05

Test 16.

Conditions same as Test 12 but used 10 cc. $CuSO_4$.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	4.19	43.6	18.1	21.15
Cleaner Tail	10.13	22.43	22.6	26.39
Tailing..........	85.68	5.44	46.3	54.19
Totals.....	100.00		87.0	101.73

Test 17.

1 kilo ore and 1,500 cc. water ground for 35 minutes. Put in larger Fahrenwald flotation machine with 10 cc. $CuSO_4$ and 10 cc. of a mixture of 80% ortho toluidine and 20% thio carbanilide and 2 drops of SD. pine oil. Ran the machine 12 minutes and then passes the concentrates back through the same machine for 10 minutes.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	16.39	42.9	69.5	81.67
Cleaner Tail	8.35	2.11	1.9	2.23
Tailing..........	75.26	1.32	9.7	11.39
Totals.....	100.00		81.1	95.29

Test 18.

1 kilo ore and 1,500 cc. water and 2 gms. Na_2S were ground for 35 minutes. Ran 12 minutes in rougher flotation machine with 10 cc. $CuSO_4$ and 2 drops of pine oil and 10 drops of ortho toluidine and thio carbanilide. Concentrates were recleaned for 10 minutes in the same machine (the larger Fahrenwald).

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	12.57	52.4	65.2	76.17
Cleaner Tail	8.31	3.53	2.9	3.39
Tailing..........	79.22	1.25	9.8	11.45
Totals.....	100.00		77.9	91.01

Test 19.

Same charge as Test 18 ground with 4 gms. Na_2S. Ran 12 minutes in larger Fahrenwald machine with 10 cc. $CuSO_4$ and 5 cc. ortho-thio. No pine oil. Cleaned in same machine 10 minutes.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	19.92	36.4	71.6	83.98
Cleaner Tail	7.89	2.45	1.9	2.21
Tailing..........	72.19	0.95	6.8	7.96
Totals.....	100.00		80.3	94.17

Test 20.

Conditions same as Test 19 but added 2 drops of pine oil.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	15.55	48.8	75.6	87.77
Cleaner Tail......	8.29	2.74	2.3	2.67
Tailing..........	76.16	0.40	3.0	3.47
Totals.....	100.00		80.9	93.96

Test 21.

1 kilo ore and 1,500 cc. water with 2 gms. Na_2S ground for 35 minutes in ball mill. Ran 12 minutes in larger Fahrenwald machine with 10 cc. $CuSO_4$ and 2 drops pine oil and 2½ cc. ortho-thio. Cleaned concentrates in the same machine for 10 minutes.

	Weight Percent.	Assay Percent. Zn	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	13.79	50.4	69.6	81.72
Cleaner Tail......	7.59	28.4	2.1	2.46
Tailing..........	78.62	1.01	7.8	9.16
Totals.....	100.00		79.5	93.34

Test 22.

500 gms. ore and 750 cc. water, 3 drops petroleum and 2 drops SD. pine oil were ground for 35 minutes in ball mill. Put in little Fahrenwald machine with 3 cc. $CuSO_4$ and 3 drops of ortho-thio. Ran 15 minutes and then cleaned concentrates for 7 minutes. The impeller of this machine run 2,800 r. p. m.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	20.28	30.20	30.2	70.99
Cleaner Tail......	20.69	2.96	3.0	7.09
Tailing..........	59.03	2.08	6.0	14.20
Totals.....	100.00		32.9	92.26

Test 23.

500 gms. ore 750 cc. water and 2 gms. Na_2S ground for 35 minutes. Placed in little Fahrenwald machine with 3 cc. $CuSO_4$ and 3 drops crude petroleum and 2 drops SD. pine oil and 3 drops ortho-thio. Ran 5 minutes and then cleaned concentrates in same machine for 4 minutes.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	21.81	18.05	19.7	46.70
Cleaner Tail......	21.58	5.14	5.4	12.80
Tailing..........	56.61	5.46	15.1	35.79
Totals.....	100.00		40.2	95.29

Test 24.

500 gms. ore 750 cc. water and 2 gms. Na_2S ground for 35 minutes. Ran in little Fahrenwald machine for 35 minutes with 3 cc. $CuSO_4$ and 4 drops crude petroleum and 3 drops SD. pine oil. Cleaned concentrates for 4 minutes in same machine.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	25.75	12.26	15.46	36.58
Cleaner Tail......	25.83	7.25	9.14	21.62
Tailing..........	48.42	7.06	16.75	39.62
Totals.....	100.00		41.35	97.82

Test 25.

250 gms. ore 400 cc. water and 1 gm. Na_2S ground for 35 minutes. Ran 5 minutes in little Fahrenwald machine with 3 cc. $CuSO_4$ and 4 drops of ortho-thio and 2 drops SD. pine oil. Cleaned concentrates in same machine for 4 minutes.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	26.61	22.74	14.96	71.40
Cleaner Tail......	24.84	2.85	1.72	8.19
Tailing..........	48.55	2.46	2.88	13.78
Totals.....	100.00		19.56	93.37

Test 26.

500 gms. ore and 750 cc. water ground for 35 minutes. Placed in larger Fahrenwald machine with 5 cc. $CuSO_4$ and 16 drops ortho-toluidine and thio carbanilide and

5 drops of SD. pine oil. Ran 12 minutes as rougher and 10 minutes to clean concentrates.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	12.37	49.9	30.68	71.53
Cleaner Tail......	7.34	3.73	1.36	3.17
Tailing..........	80.29	1.23	4.90	11.42
Totals.....	100.00		36.94	86.12

Test 27.

500 gms. ore and 750 cc. water and 2 gms. Na_2S were ground for 35 minutes in ball mill. Placed in larger Fahrenwald machine with 5 cc. $CuSO_4$ and 16 drops of ortho toluidine and thio carbanilide and 5 drops of SD. pine oil. Ran 12 minutes as rougher and 8 minutes to clean the concentrates.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	16.55	42.9	35.39	84.30
Cleaner Tail......	13.96	1.96	1.33	3.17
Tailing..........	69.49	1.59	1.98	4.71
Totals.....	100.00		38.70	92.18

Test 28.

500 gms. ore and 750 cc. water and 2 gms. Na_2S were ground for 35 minutes in ball mill. Put in larger Fahrenwald machine with 5 cc. $CuSO_4$ and 2 gms. of Na_2HPO_4 and 4 drops of SD. pine oil. Ran 15 minutes and then 10 minutes to clean.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	3.73	48.0	8.88	20.48
Cleaner Tail......	7.52	7.90	2.95	6.88
Tailing..........	88.75	6.45	28.38	66.19
Totals.....	100.00		40.21	93.55

Test 29.

500 gms. ore and 750 cc. water and 2 gms. Na_2S were ground for 35 minutes in ball mill. Put in larger Fahrenwald machine with 5 cc. $CuSO_4$ and 10 drops of Pensacola Tar and Turpentine Company's No. 15 special resin oil, and 2 drops SD. pine oil. Ran 15 minutes to rough and 10 minutes to clean concentrate.

	Weight Percent.	Assay Percent. Zn.	Content Gms. Zn.	Percent. Zn. recovered or lost
Concentrate	3.46	18.35	3.12	7.36
Cleaner Tail......	17.60	8.60	7.44	17.56
Tailing..........	78.94	7.20	27.90	65.85
Totals.....	100.00		38.46	90.77

Highest recovery in concentrates Test 20, 87.77% zinc.

Best grade of concentrates, Test 18, 52.4% Zn.

Lowest tailing, Test 20, 0.40% Zn.

Best recovery without ortho toluidine and thio carbanilide, Test 11, 64.47% Zn.

Best recovery without use of Na_2S, Test 17, 81.67% Zn.

Tests 6, 8, 9, 10, 11 and 12, indicate the best recovery is secured with the use of 1 or 2 lbs. per ton of $CuSO_4$.

Tests 6 and 11 point to the possibility that an increase of crude petroleum above 0.4 lbs. per ton might give a better extraction.

COMPARATIVE SUMMARY OF FLOTATION TESTS

Test No.	Concentrates Weight Percent.	Concentrates Assay Percent. Zn.	Rec. Percent. Zn.	Middlings Weight Percent.	Middlings Assay Percent. Zn.	Tailings Weight Percent.	Tailings Assay Percent. Zn.
1	6.9	31.5	25.7	6.9	8.2	86.2	6.4
2	4.7	36.0	19.8	6.0	5.2	89.2	7.1
3	1.9	49.6	11.2	2.1	35.6	96.0	6.9
3a	5.6	33.0	29.1	7.3	12.6	87.2	6.8
4	1.2	26.0	3.7	2.7	10.6	96.1	8.0
5	6.4	11.9	8.7	8.9	6.3	89.7	8.1
6	12.6	42.9	61.7	4.0	9.8	83.4	3.0
6a	12.2	44.1	62.5	6.0	8.4	81.8	3.0
7	8.0	37.3	34.3	4.3	9.0	87.8	5.4
8	10.5	40.2	48.7	4.5	12.7	85.1	4.0
9	8.5	44.1	43.0	4.2	14.5	87.4	4.3
10	2.1	14.7	3.5	4.0	7.9	94.1	8.0
11	12.4	44.4	64.5	5.0	8.2	82.5	2.8
12	7.6	45.6	40.0	4.8	21.4	87.7	4.7
13	12.5	40.4	58.4	4.9	6.5	82.6	3.7
14	5.3	41.2	25.0	16.6	11.0	76.2	5.5
15	7.8	50.3	45.6	9.5	19.8	82.8	2.8
16	4.2	43.6	21.2	10.2	22.5	85.7	5.5
17	16.4	42.9	81.7	8.4	2.2	75.3	1.3
18	12.6	52.4	76.2	8.3	3.6	79.3	1.3
19	19.9	36.4	84.0	7.9	2.5	72.2	1.0
20	15.6	48.8	87.8	8.3	2.8	76.2	0.4
21	13.8	50.4	81.8	7.6	28.4	78.7	1.0
22	20.3	30.2	71.0	20.7	3.0	59.0	2.1
23	21.8	18.1	46.7	21.6	5.2	56.7	5.5
24	25.8	12.3	36.6	25.9	7.3	48.5	7.1
25	26.6	22.7	71.4	24.9	2.9	48.6	2.5
26	12.4	49.9	71.6	7.4	3.8	80.3	1.3
27	16.6	42.9	84.3	14.0	2.0	69.5	1.6
28	3.7	48.0	20.5	7.6	7.9	88.8	6.5
29	3.5	18.4	7.4	17.6	8.6	79.0	7.2
Over	11.7	39.7	50.0	9.9	10.7	78.4	4.3

PHOTOGRAPH AND GRAIN SIZE OF SPHALERITE IN THE ORE

R. E. HEAD, *Mineralogist.*

Miscroscopic examination of polished surfaces of this ore indicates that the entire zinc content is apparently represented by the sulphide mineral, sphalerite. Judging from a number of polished sections of the ore, it is evident that the grain sizes of the sphalerite vary considerably, ranging from an average minimum diameter of 0.06 mm. (about 240 mesh) up to a maximum diameter of 3 mm. (6 mesh). The grains having the smaller dimensions occur both in disseminated form and as stringers filling fractures in the gangue. In the sample studied it is estimated that but a comparatively small portion of the gross zinc content occurs in this extremely fine state of division and a comparison of the results obtained by measuring the diameters of a large number of the average type of disseminated grains indicate that 0.12 mm. (passing a 100 mesh screen) might be considered as being representative size. While larger grains than this were noted, they are exceptional since the major portion of the gross zinc value is clearly carried by the greatly predominating number of grains ranging close to 0.12 mm. in diameter. Small particles of pyrite occur disseminated through the sample examined, but they are not associated with the sphalerite and exist in an extremely fine state of division, being comparable in size to the sphalerite particles of minimum diameter.

The iron content of the ore appears to be quite small and is probably not represented entirely by the pyrite since siderite in varying amounts is not unusual in ores of this character. No effort was made to determine the presence of siderite as its occurrence would have no immediate effect on the recovery of the zinc content by flotation. Thin sections prepared from such uncrushed ore as was obtainable corroborated the evidence obtained in regard to grain sizes noted during the study of polished surfaces.

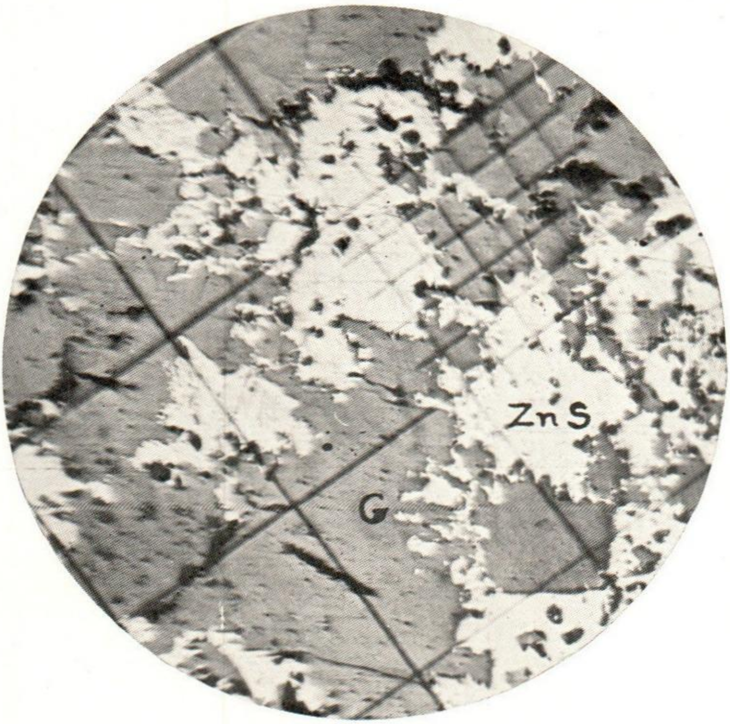
Microscopic examination of some of the tailing products from the earlier flotation tests showed that the sphalerite was by no means removed by the reagents used and suggested that higher recoveries would probably result if more suitable reagents and conditions could be devised. Checking up the amount of sulphur and zinc in the Tennessee ore indicates the possibility of the presence of zinc in some other form than the sulphide since the sulphur content is not sufficient to satisfy both the zinc and the iron. The appearance of the sphalerite leads to the belief that it is fairly pure zinc sulphide and probably varies but a small percentage from conforming to the formula given in Dana's Minerology for sphalerite (sulphur 33%—zinc 67%). A number of samples of crushed material were examined in an effort to ascertain whether zinc carbonate or zinc in other forms were present but the work resulted in negative results. Judging from the amount of sphalerite found in tailing samples, it is believed that if a satisfactory recovery of the sphalerite is made that the question of zinc in other forms may be considered to be of minor importance.

The accompanying photomicrograph was made from a typical area of the disseminated ore specimen at a magnification of approximately 125x. The large squares of the micrometer which have been projected into the field have a calibrated value of 0.22 mm. and since one square is divided into fifths, these smaller divisions have a diameter of 0.044 mm. Comparison of the ore particles with the rulings of the micrometer conveys some idea of their relative dimensions. Zns—Sphalerite. G—Gangue.

COPPER RIDGE DISTRICT

Copper Ridge is one of the narrow, continuous, parallel ridges so common to the Valley of East Tennessee. The ridge rises near the junction of Roane, Loudon, Anderson, and Knox counties and continues northeastward in a relatively straight line into the State of Virginia. The portion of the ridge in which zinc ores have thus far been found extends from Washburn Station, in Grainger County, almost to the Tennessee-Virginia line. Whether mineralized horizons exist to the southwest of Washburn Station is not known. However, in view of the fact that there is no structural change in the ridge throughout its extent it is probable that mineralization is more or less continuous in that direction. Unauthenticated reports state that the Copper Ridge ore zone has been followed some distance into Virginia.

Throughout its length in Tennessee the ridge maintains an average elevation of about 1,600 feet. It is broken through transversely by numerous stream-cuts. The ridge is a structural unit made up of the



Photomicrograph of Evanston ore showing grain size of the sphalerite.

regular sequence of Rome formation, Rutledge limestone, Rogersville shale, Maryville limestone, Nolichucky shale, and Knox dolomite, all striking northeast and dipping at variable angles to the southeast. All of the above mentioned formations are exposed in narrow bands on the northwestern slope of the ridge. The lower portion of the Knox dolomite is highly siliceous in character and contains many massive beds of chert. The ridge owes its topographic expression to these more resistant beds. The Knox dolomite also forms the crest of the southeast slope of the ridge continuing into the valley where it is overlain by the Chickamauga limestone. An idealized structure section through the ridge is shown in Figure 9. The ore-bearing horizons are confined to the Knox

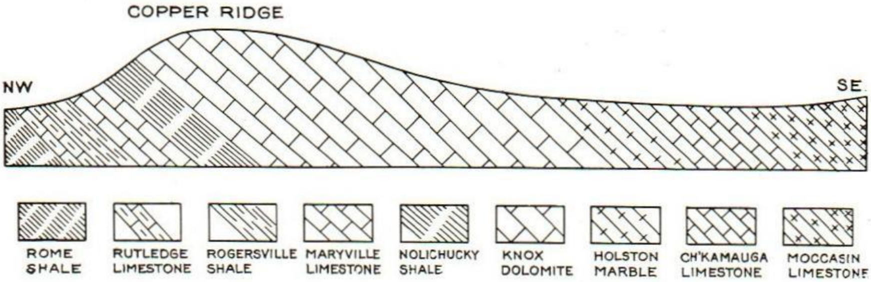


FIGURE 9. Idealized section through Copper Ridge.

dolomite. The entire thickness of this formation was measured at several localities and is given in the following table, together with the depths at which the ore horizons occur.

Locality	Stratigraphic thickness feet	Stratigraphic depth of ore horizon feet
Washburn Station	2,100	700, 735
W. S. Mallicoat	....	840
Thorn Hill	2,400	660
Comstock	2,400	420, 540, 650
Tandy Dalton	....	690
L. L. Mallicoat	....	525
C. S. Davis	2,390	720—1,015
Henry N. Johns	....	900
Shilo	2,320	650
E. J. Lee	....	550

From the above table it is evident that the thickness of the formation is relatively constant. However, there is considerable variation in the stratigraphic position of the several ore-bearing horizons, ranging from 420 feet at Comstock to 1,015 feet at the C. S. Davis locality. The very lack of traceable continuity of the horizons, prohibiting their correlation from point to point, suggests that, though many local ore-bearing horizons may be found, their extent both along the strike and down the dip is limited. Apparently the character of the dolomite for any particular bed is not consistent through great extent and that the forces exerted by pressure, incident to the deformation of the strata, were expended irregularly by the brecciation of many horizons. The mineralizing solutions later followed the more permeable channels of the brecciated beds.

With exception of the Comstock and Shilo prospects, activity has thus far been limited to making small open cuts or blasting off faces of outcrops to expose the ore. No production has been realized.

Washburn Station (22)

Washburn Station on the Cumberland Gap Branch of the Southern Railway lies at the southeastern base of Copper Ridge in the northwestern corner of Grainger County.

About one-half mile north of the station the railroad passes through a low gap in the ridge. The railroad cut exposes a continuous section of Knox dolomite which was found to be approximately 2,100 feet thick. From the top to the base the color and texture of the dolomite is quite variable. The color ranges from dark-brown to bluish-white and the texture from fine- to coarse-grained. Near the base the dolomite becomes increasingly siliceous with frequent intercalated beds of chert, some of which are oolitic. The transition into the underlying Nolichucky shale is conformable.

In the dolomite along the east side of the track, in the railroad cut, two small outcrops of sphalerite were observed. The higher outcrop is at a distance of 700 feet, statigraphically, below the top of the formation; the lower is 35 feet below the upper. The intervening beds of dolomite, where exposed, are barren. At both horizons the ore consits of small masses and veinlets of sphalerite associated with gangue dolomite and chert in a tight, unbrecciated country rock. The strike and dip are N. 68° E. and 41° SE. respectively. No prospecting has been undertaken.

W. S. Mallicoat prospect (23)

In 1918, C. B. Comstock conducted some prospecting for zinc ores on land owned by W. S. Mallicoat. This prospect is on Puncheon Creek and is about 5½ miles northeast of Washburn Station.

Two open cuts were made in the dolomite on the east side of the creek. The north cut is 50 feet long, 20 feet wide, and 15 feet deep at the face; a second cut, 110 feet to the south is 15 feet long, 10 feet wide, and 10 feet deep at the face.

The horizon at which it is said that ore was found is restricted to a two-foot brecciated bed in the north cut. The bed strikes N. 60° E. and dips 39° SE. This horizon is 840 feet, stratigraphically, below the top of the formation.

No ore was seen in place in either cut. However, in the north cut, several boulders lying on the dump contained small veinlets and irregular-shaped masses of dark-brown sphalerite associated with gangue dolomite, calcite and chert, forming a matrix in brecciated, light-blue and fine-grained dolomite. It is stated that no ore was found in putting down a churn drill hole to a depth of 90 feet. The site of this hole is on the western side of the creek and opposite the south cut.

Thorn Hill (24)

Thorn Hill, lying in the valley at the southeastern slope of Copper Ridge, is 11 miles northeast of Washburn Station. About one mile northwest of Thorn Hill, along the east side of the road leading to Clinch River, a small exposure of sphalerite occurs in a narrow brecciated bed of the Knox dolomite. The property on which this exposure is located is owned by E. J. Kincaid. The brecciated bed varies from 10 to 18 inches in thickness and is 660 feet, stratigraphically, below the top of the formation. At this horizon the bedding plane strikes N. 59° E. and dips 42° SE.

The country rock in the brecciated bed is bluish-gray, fine-grained dolomite. The ore occurring as a matrix cementing breccia fragments, consists of small concentric rosettes of sphalerite in a gangue of dolomite, chert, and a small amount of pyrite. The rosettes, formed by a rather concentric arrangement of alternating light and dark-brown bands of sphalerite, give to the rock a striking, mottled appearance.

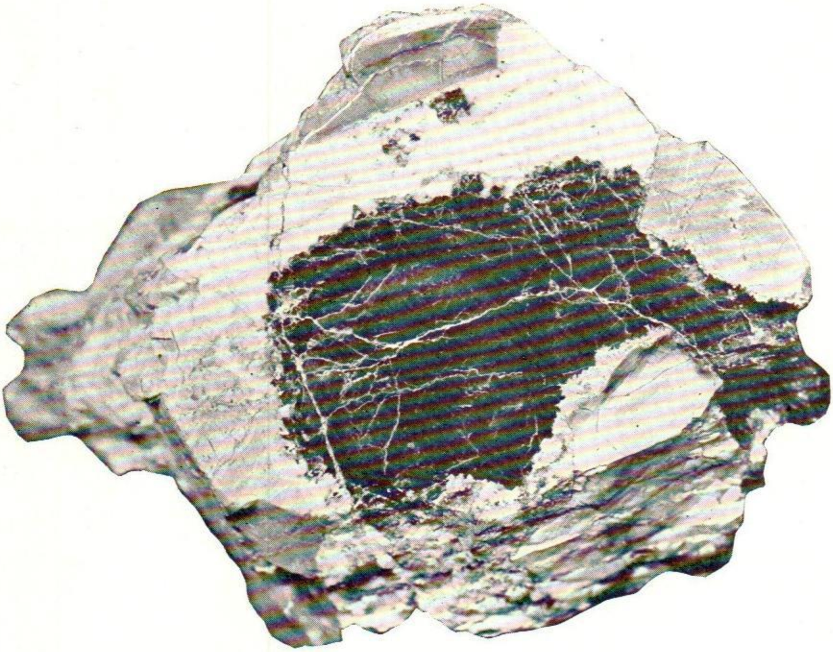
A complete section of the Knox dolomite at this locality in Copper Ridge attains a stratigraphic thickness of approximately 2,400 feet, or an increase of 300 feet over the section measured at Washburn Station. The dolomite below the ore horizon becomes increasingly siliceous and contains frequent white and gray chert beds which occasionally attain several feet in thickness.

Comstock prospect (25)

The most extensive prospecting in the Copper Ridge region has been conducted by C. B. Comstock, of New York. The area in which development has been undertaken is situated in a narrow stream-gap in Copper Ridge about one mile north of Idol, and two miles northeast of Thorn Hill. The property is owned by J. H. Shockley and brother, both residing at Idol.

COUNTRY ROCK

The entire thickness of the Knox dolomite at this locality is 2,400 feet. Prospecting has thus far revealed three mineralized horizons, the upper occurring 420 feet, stratigraphically, below the top of the formation, the middle at 540 feet, and the lower at 650 feet. In addition to



Polished specimen of ore from Comstock prospect, showing concentric "rosette" development of sphalerite. Nat. size.

these three horizons, several only slightly mineralized horizons have been exposed so that it is evident that irregular mineralization of the rock, between the 420-foot and the 640-foot levels, occurs. No attempt has been made to determine the continuance of any of the mineralized horizons along the strike, and their persistence is not known.

MINERALIZATION

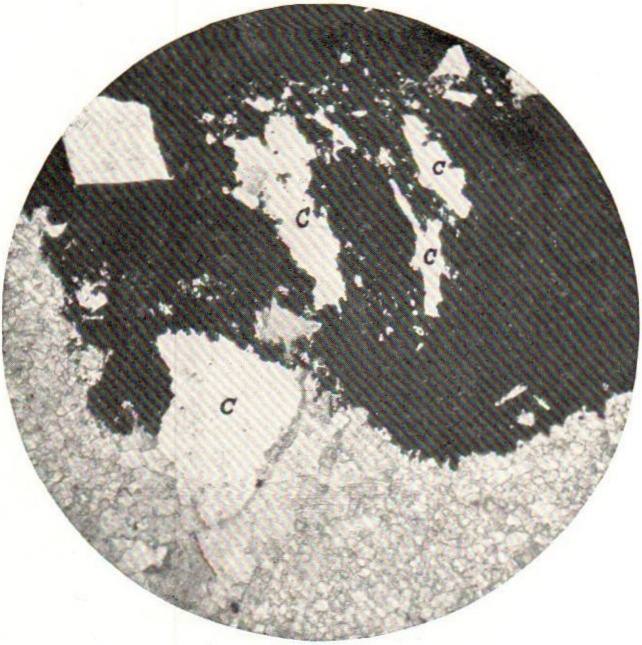
The character of the ore and its mode of occurrence are practically the same in each horizon. The ore consists of irregularly intermixed masses and veinlets of sphalerite, dolomite, chert, and some calcite and pyrite deposited as a matrix cementing angular breccia fragments of country rock. Within the brecciated horizons, which coincide with the strike (N. 88-60 E.) and dip (34-49 SE.) of the bedding, mineralization varies widely within small limits so that the richer bodies of ore are confined to local areas separated by low grade or barren ground.

In the several ore-bearing horizons the development of concentrically banded rosettes is quite characteristic. Most of the rosettes are small and imperfectly formed but large and perfectly formed ones do occur. They consist of a dark-brown or black center around which light-brown and dark-brown bands alternate in a concentric arrangement. This tendency of the sphalerite towards concentric banding is even more strikingly shown where the mineral has been deposited in a narrow fracture or as the matrix between two parallel breccia fragments. Although the opening may be no larger than a quarter of an inch in width it sometimes is filled with concentrically banded sphalerite with radii much longer than the width of the opening so that the ore looks like a section of that width cut from a perfect rosette. Thin sections of the rosettes present optical characteristics no different from those of the common variety of sphalerite found in the ore.

Microscopic examinations of several thin sections of the ore taken from the Comstock group of prospects show that the country rock consists of fine-grained anhedral crystals of dolomite with an average diameter of 0.05 mm. The uniformity of grain-size is noticeable, larger grains being exceptional. This grades either sharply or gradually into a later coarse-grained dolomite. The latter variety has frequently invaded the country rock in the narrow ramifying veinlets. Small remnants of the country rock with corroded edges clearly show the extent of replacement.

Both country rock and gangue dolomite have been in part invaded and replaced by cryptocrystalline chert in which small, anhedral grains of quartz are at times very abundant. The chert is very irregular in its distribution.

Sphalerite is later than country rock, gangue dolomite, and chert. It tends to occur in larger masses in those areas where it has invaded



Typical association of fine grained country rock, dolomite, chert (C), and sphalerite. The replacement of chert by sphalerite is clearly indicated. Comstock prospect. x45.

along the contacts of country rock and gangue dolomite, replacing both minerals. Frequently the peripheries of sphalerite masses are characterized by reentrant angles which correspond to the cleavage angles in the dolomite grains.

Pyrite, either as individual grains or in granular aggregates, is distributed in variable quantities in all of the above minerals. However, it is most abundant as interstitial replacements in the sutures between the grains of country rock. Much of the pyrite has been altered to limonite. This material is quite common as fine veinlets which have invaded along the contacts of adjacent minerals and also have extended variable distances into the individual grains along their cleavage cracks. Many of the pyrite grains are characterized by borders altered to limonite.

Paragenesis

1. Fine-grained country rock.
2. Medium- to coarse-grained dolomite.
3. Chert.
4. Sphalerite.
5. Pyrite.

DEVELOPMENT

The development consists of two tunnels, eight open cuts, and four, 4-inch core drill holes.

The plan of development is shown in Figure 10.

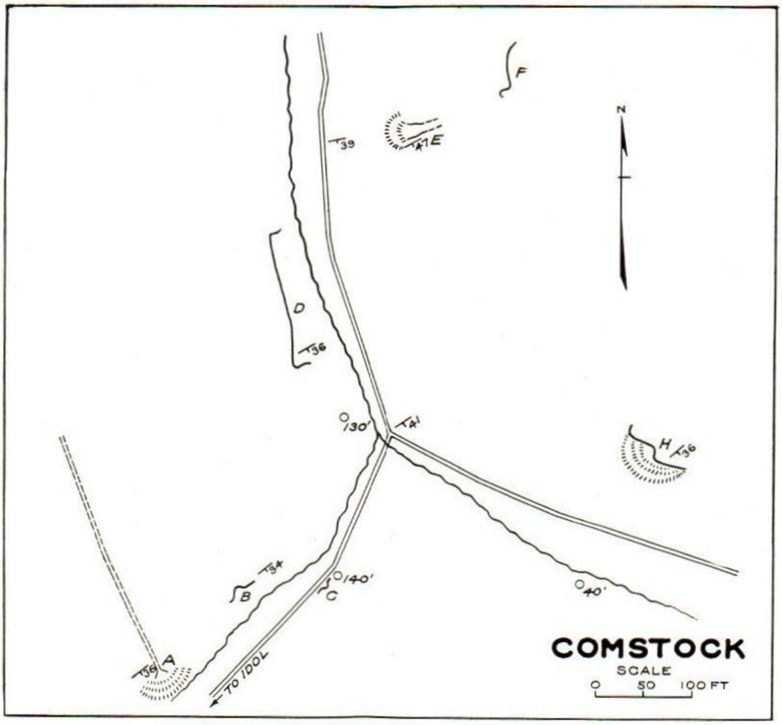


FIGURE 10. Plan of Comstock prospect.

"A" tunnel

The main development work consists of a 6x6-foot tunnel driven for a distance of 265 feet at approximately right angles to the strike of the formation. The floor of the tunnel is about 3 feet higher than the bed of the creek. The hanging-wall of the middle ore horizon was encountered at a distance of 60 feet from the mouth of the tunnel. This horizon, attaining a thickness of 15½ feet at its exposure in the tunnel, although uniformly brecciated throughout its exposed portion is not uniformly mineralized. It terminated rather sharply against a foot-wall composed of several thin beds of dark-gray chert.

With exception of a 4-foot bedding seam of light-green selvage, which is immediately underlain by a ½-inch layer of carbonaceous material, occurring at a distance of 118 feet from the mouth of the tunnel the remainder of the rock penetrated consisted of unbroken, finely crystalline, light-gray dolomite.

"B" open cut

This is a small cut situated 100 feet northeast of the mouth of "A" tunnel, on the west side of the creek. The cut is 20 feet long, 10 feet wide, and 12 feet deep at the face. The dip of the bedding plane is 34° SE. The ore horizon exposed, at a slightly higher stratigraphic level than that in the tunnel, attains a thickness of 4 feet and consists of breccia fragments of country rock cemented in a matrix of sphalerite, dolomite, chert, and a small amount of pyrite. The mineralization is very irregular.

"D" open cut

This cut, 150 feet north of "B" and also on the west side of the creek, is 140 feet long, 15 feet wide, and 10 feet deep at the face. A narrow brecciated horizon, 2½ feet thick, containing a small amount of sphalerite, dolomite, and chert, is exposed at the extreme southern end of the cut. The remainder of the rock is barren.

"E" tunnel

At a distance of 300 feet north of the road-fork, and 100 feet up the hillside on the east, a tunnel, 40 feet in length, was driven into the dolomite and parallel to its strike. The exposed ore-bearing horizons attains a thickness of about 20 feet and is limited to a brecciated bed which dips 45°—50° SE. It is the lowest horizon thus far exposed at this locality. The ore consists of concentrically banded rosettes of sphalerite deposited with small amounts of gangue dolomite as replacements of the country rock. Mineralization is not continuous throughout this horizon.

"H" open cut

This open cut is 250 feet east of the road-fork and 150 feet up the hillside to the north of the road. The opening is 30 feet long, 10 feet wide, and 5 feet deep at the face.

It exposes a brecciated, ore-bearing horizon which lies in the bedding plane of the formation and is the highest mineralized horizon thus far exposed. The breccia, accompanied by mineralization is continuous throughout the length and depth exposed by the cut and consists of angular fragments of country rock cemented by a matrix of sphalerite, dolomite, calcite, chert, and locally a small amount of pyrite. The concentric rosettes of sphalerite are best developed in this horizon and many attaining a diameter of two inches, perfectly formed, were observed.

Four drill holes, the location of three of which are shown in the sketch, were made. In one hole the drill broke and stuck at a depth of 12 feet.

Mr. Comstock reported the following results of drilling:

140-foot hole. . . . no ore.
130-foot hole. . . . ore from 12 feet to bottom.
40-foot hole. . . . no ore.

At a point approximately 1,900 feet S. 80° W. of the mouth of "A" tunnel and on top of the ridge, a small opening had been made into the dolomite. It revealed a mineralized, brecciated horizon similar in its nature to that exposed in the tunnel. Measurements showed that it is the surface outcrop of the horizon encountered in the tunnel.

Tandy Dalton prospect (26)

This prospect is on land owned by Tandy Dalton and is reported to be the locality at which the first discovery of zinc ore was made in Copper Ridge. The date of discovery is not known.

The prospect is approximately 2 miles northeast of the Comstock group and is along the west side of the road which runs parallel to Cedar Creek. A small surface of the Knox dolomite had been exposed by blasting and above a highly brecciated horizon in which small rosettes of sphalerite, associated with gangue dolomite and chert, also a little pyrite, occur locally as breccia fillings. Most of the rock is barren. The ore horizon lies in the bedding plane and strikes N. 62° E. and dips 37° SE. It is 690 feet, stratigraphically, below the top of the formation. The extent of the mineralized horizon could not be determined from this limited exposure.

L. L. Mallicoat prospect (27)

This prospect is in Indian Creek Gap in Copper Ridge, approximately 2½ miles southwest of the intersection of Grainger, Hancock and Hawkins counties. The property is owned by L. L. Mallicoat.

It is reported that in 1912 some prospecting for zinc ores was carried on by a Mr. Dougherty of Morristown. This work consisted of exposing a small area of Knox dolomite in the creek bed and also in the hillside east of the creek. The horizon is 525 feet below the top of the formation. Only a limited amount of brecciation is visible and the matrix cementing the breccia fragments consists mostly of gangue dolomite in which are scattered minute flakes of dark-brown sphalerite. Very little ore is visible.

C. S. Davis prospect (28)

A complete section of the Knox dolomite is exposed in a stream-gap cutting through Copper Ridge at a distance of about one mile northeast of the intersection of Grainger, Hancock and Hawkins counties. In this section the dolomite attains a thickness of 2,390 feet.

At a stratigraphic depth of 720 feet the highest exposed mineralized horizon appears. Continuing downward through a thickness of 295 feet, several additional, generally narrow, mineralized horizons occur. The lowest one was found at a depth of 1,015 feet, stratigraphically, below the top of the formation. However, the thickness of 295 feet is not continuously mineralized. At irregularly spaced intervals, narrow brecciated beds in the dolomite occur and these contain variable amounts of sphalerite, either in the form of small masses or veinlets, associated with gangue dolomite, calcite, chert, and some pyrite. These minerals form the matrix of the breccia fragments of the country rock. No horizons were observed which attained sufficient thickness or richness of mineralization to warrant prospecting. But these observations were made along the outcropping ledges where no prospecting had been done so that no definite knowledge of the continuation of mineralization in depth could be gained. The average strike of the bedding is N. 70° E., and the dip 41° SE.

The above described outcrops are on land owned by C. S. Davis, on the west side of the creek and wagon road.

Henry N. Johns prospect (29)

The Johns farm, on which this prospect is located, is one half mile northwest of Treadway. The development consists of two small cuts into the Knox dolomite which strikes N. 72° E. and dips 37° SE. These cuts have exposed a mineralized, brecciated horizon of several feet in thickness lying parallel to the bedding plane of the country rock. The horizon is about 900 feet, stratigraphically, below the top of the dolomite. At this locality the exact stratigraphic position could not be determined due to the prevalence of a thick soil overburden which concealed the dolomite outcrops.

In each open cut the mineralized horizon showed breccia fragments cemented in a matrix composed of masses and veinlets of dark-brown sphalerite, gangue dolomite, chert, and small amounts of pyrite. Locally, in pockets of small extent, the mineralization appears quite rich.

In the zone of oxidation alteration of the sulphide to the oxide forms, smithsonite and calamine, has taken place. The partly oxidized sulphide ore is frequently coated with greenockite.

It is reported that in 1916 the American Zinc Company of Tennessee carried on some prospecting at this locality and extracted a small amount of smithsonite from the clay overburden.

Shilo prospect (30)

Shilo is located at the southern foot of Copper Ridge about 7½ miles due northwest of Rogersville. The prospect is one-half mile northwest of Shilo and along the east side of Richardson Creek. The creek has cut a narrow, steep-sided gap through the ridge thereby exposing a complete section of the Knox dolomite. The stratigraphic thickness of the dolomite in this section is 2,320 feet; the average strike and dip are N. 61° E. and 47° SE., respectively. The ore zone exposed at the prospect lies 650 feet below the top of the formation.

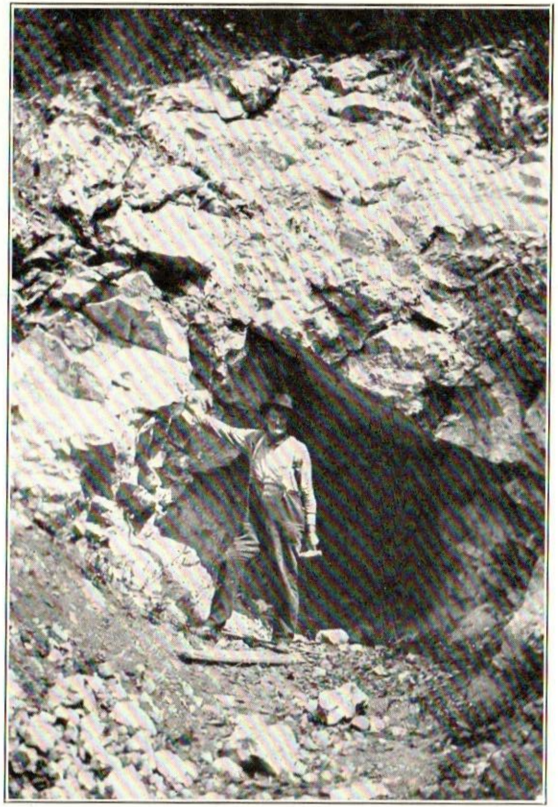
Prospecting was carried on during 1920 by Messrs. Grant Green and Gonce, of Shilo, and Frank Mathis, of Sneedville. Their work consisted of driving a 6x6-foot tunnel for a distance of 10 feet parallel to the strike and of blasting the outcropping ledges of rock for a distance of 50 to 100 feet in strata both above and below the tunnel. Along the west side of the creek, in line with the tunnel, a trench, 3 feet deep and 12 feet long, was cut into the rock at right angles to the strike.

COUNTRY ROCK

In the region about the ore horizon the dolomite is bluish-gray in color, finely crystalline, and both thick- and thin-bedded. Occasional intercalated beds of chert occur. As lower strata are met the amount of chert increases, until near the base of the formation massively bedded chert constitutes the rock. At a point 100 feet north of the tunnel a bed of dark-gray chert, 4 feet thick, is intercalated in the bedding plane of the dolomite. No ore was observed in strata below this bed. Approaching it from the tunnel, the successively lower strata become less fractured and consequently less mineralized, while below the level of the chert bed the fracturing and mineralization disappear entirely.

MINERALIZATION

The ore horizon is a brecciated bed in the dolomite and attains a thickness of 18 feet. Sharp-angled fragments of both country rock and chert are cemented in a matrix of sphalerite, gangue dolomite, calcite, chert, and some pyrite. Nodules of dark-blue chert are frequent.



(A)

(B)

(A) Shiloh prospect.
(B) Fair Garden prospect. Showing two methods of prospecting; one by tunnel and one by open cut.

Sphalerite occurs both in the form of dark-brown concentrically banded rosettes (similar to those described at Comstock) and in small veinlets of variable length which ramify through the broken rock and vein material in extremely irregular manner. As is the case in all the ore-bearing horizons in Copper Ridge, the richest mineralization follows the more intensely fractured and brecciated beds. The veins, though generally narrow, at times attain appreciable length and are not confined to one bed of rock, but, after following along a bedding plane for some distance cut abruptly across the bedding and then again follow the bedding plane of the formation. Where the veins are more abundant and intersect this arrangement gives rise to locally enriched areas.

Several thin sections of ore examined microscopically show that the country rock consists of fine-grained dolomite crystals of uniform size with an average diameter of 0.07-0.10 mm. Medium- to coarse-grained gangue dolomite, exhibiting good cleavage, replaces the country rock. The transition from fine-grained country rock to coarse-grained dolomite is abrupt, but numerous small irregular masses of country rock remain as remnants within the dolomite areas. Both country rock and dolomite are replaced by cryptocrystalline chert which locally contains anhedral crystals of quartz, some of which, when cut parallel to the basal section, show good hexagonal outline. The chert area occur at random throughout the dolomite but are more abundant along its contact with the country rock.

Sphalerite replaces all of the above-mentioned minerals. It occurs either as small irregular masses or discontinuous veinlets which show a tendency to greater persistence along the contacts of either gangue dolomite and country rock, or gangue dolomite and chert. The sphalerite seems to have more readily replaced gangue dolomite than the other minerals. Its distribution throughout both country rock and vein material is extremely irregular.

Small grains or granular aggregates of pyrite are numerous and are scattered throughout the mass of country rock. Pyrite is most abundant in those zones where country rock is being replaced by dolomite or chert, or, where dolomite and chert are being replaced by sphalerite. A few grains occur within the sphalerite masses. Most of the pyrite has a fresh, unoxidized appearance and very few limonite stains appear.

Paragenesis

1. Country rock.
2. Gangue dolomite.
3. Chert.
4. Sphalerite.
5. Pyrite.

The development and extent of the openings have been described above. Here, as elsewhere in Copper Ridge, no attempt has been made to follow the ore horizon for any appreciable distance either along the strike or along the dip so that the persistence of mineralization is not known. The face of the tunnel stopped in intensely brecciated rock which appeared relatively rich in ore. However, the small trench on the opposite side of the creek was opened on approximately the same horizon and failed to expose any ore in the rock so that wide variation in mineralization within short distances seems to obtain.

About 50 tons (rough estimate) of rock, most of which contains ore, are piled along the creek near the mouth of the tunnel. Some of the ore is extremely rich. The highly brecciated character of the rock has resulted in a coarse-textured ore that can be easily milled. As stated previously, a little pyrite occurs, but the amount is so small and so well distributed through the ore that it should not interfere with the sphalerite concentration.

Considering the limited amount of development this locality appears the most favorable of any observed in Copper Ridge. Samples collected and analyzed by a representative of the U. S. Bureau of Mines averaged:

Sample	Zinc	Iron
167	9.84	2.85
174	5.96	3.09

The complete analysis of a composite sample of this ore is:

Free milling ore:	
Insoluble	12.26%
Iron (Fe)	1.43
Lime (CaO)	23.09
Magnesia (MgO)	14.35
Zinc (Zn)	6.46
Sulphur (S)	4.23
Total	61.82

Sufficient water for the operation of a mill is obtainable from Richardson Creek.

The isolation of this locality from the railroad is an objectionable feature.

E. J. Lee prospect (31)

This prospect is 2 miles northeast of Shilo and along the road leading from Sneedville to Rogersville. At this point a branch of Richardson Creek has cut through Copper Ridge. The land on which the prospect occurs is owned by E. J. Lee.

The development consisted of exposing several ledges of Knox dolomite in the creek bed. The horizon is at a depth of 550 feet below the top of the formation. This horizon is at the same stratigraphic level as that at the L. L. Mallicoat prospect and the two occurrences are quite similar in the appearance of the mineralization.

Very little ore was seen. It consists of minute dark-brown masses of sphalerite disseminated through the country rock. The horizon is not one of intense fracturing and brecciation. The strike is N. 51° E., and the dip 46° SE.

FALL BRANCH DISTRICT

FALL BRANCH MINE (32)

Fall Branch Mine is on Fall Branch Creek, in southwestern Sullivan County, two miles northeast of Fall Branch in Washington County, and ten miles south of Kingsport, a city on the Carolina, Clinchfield and Ohio Railway.

About 1890 several deposits of barite were discovered in the Knox dolomite a few miles southwest of Fall Branch. In following the barite zone to the northeast, zinc ores were discovered at the site of the present mine. A company was organized and mined two carloads of carbonate ore from the clay overburden and the disintegrated dolomite pinnacles. The ore was hauled by wagon to Jonesboro, 18 miles distant, from where it was shipped.

In 1906, the East Tennessee Mining Development Company of Lima, Ohio, acquired five acres of the property and began to develop it by sinking an inclined shaft and extended open cuts to the southwest. In 1908 they erected a mill which was equipped with a 125 h. p. tandem engine, a Clifford dry concentrator, four sets of rolls, seven concentrating tables, and one dryer. Soon after the completion of the mill, the Company became involved in litigation and discontinued operation.

The heirs of the T. L. Murrell estate, Kingsport, now own the property.

GEOLOGY

The ore horizon is about 1,000 feet stratigraphically below the top of the Knox dolomite which, at the mine, consists of bluish-gray, fine-grained, crystalline, thick-bedded dolomite in which occur thin beds of light gray chert. As the contact with the overlying Athens shale is approached, the formation becomes thin-bedded and includes thin beds of pure limestone. The prevailing strike of the formation is N. 45° E. and at the time the beds dip 50° SE. The dip, in the vicinity, however, is variable, due to folding.

MINERALS

The chief ore mineral is sphalerite of a rosin-brown color and occurs either associated with dolomite or calcite as veinlets in the country rock, or as irregular shaped masses which have replaced breccia fragments of the limestone. Scattered through the breccia filling and in veinlets with the sphalerite are small masses of pyrite and chalcopyrite, the latter mineral, judging from the samples taken from the dump, increasing in quantity in depth. Although the amount of pyrite in the ore exposed in the surface workings is small, it is the most abundant mineral in local areas and its presence in the ore would give rise to complications in milling.

Sphalerite is not uniformly distributed through the ore horizon but much barren or only slightly mineralized ground intervenes between the more highly mineralized areas. In this respect the deposit is like the prevailing type of Tennessee zinc deposits and demands the use of judicious mining methods in order to be successfully exploited.

Where disintegration of the country rock has taken place near the surface and along solution channels the ores have undergone oxidation so that the clay overburden locally contains small deposits of the oxidized ores, smithsonite and calamine. Where barite occurs in the underlying rock it is also found associated with the oxidized ore.

When examined in thin section, the country rock consists of fine- to medium-sized crystals of dolomite and calcite, many of which show crystal outline and good cleavage. A considerable amount of brown limonitic and pyritic material occurs as slender ramifying veinlets in the interstices between grains of the country rock. At places this material has almost entirely replaced small grains so that it constitutes distinct areas in which the main mass consists of the replacing material with minute, crystal remnants of the country rock embedded in it. That the limonitic material is secondary is evident where it is seen as a replacement of grains of the country rock.

By a sudden transition, the country rock grades into large crystals of dolomite. The transition zone is denoted by very irregular boundaries and the absence of crystal faces; also, the actual contact is frequently obscured by the presence of crystalline masses of pyrite which replace both country rock and dolomite. Individual crystals of dolomite are generally delineated by well-defined boundaries which are parallel to cleavage lines.

Country rock and dolomite are replaced by sphalerite which occurs in irregular-shaped masses with small veinlets projecting into the surrounding materials, generally along cleavage lines. This mode of replacement is particularly well displayed where the larger crystals of dolomite are replaced. In such instances the sphalerite is in part pseudomorphous after the dolomite.

Where sphalerite and pyrite are in contact, the former is invaded along cleavage cracks by small stringers of the latter.

Several narrow fractures within the pyrite masses have been filled with coarse-grained dolomite of a later period of mineralization.

Paragenesis

1. Country rock.
2. Dolomite.
3. Sphalerite.
4. Pyrite.
5. Dolomite.

STRUCTURE

Pressure from the southeast resulted in bending of the strata into folds which, where breaking did not follow, were occasionally overturned, a condition shown a short distance to the southeast of the mine. Again, certain horizons of the rock which were not competent to withstand pressure broke, and adjoining beds slid over each other. The sketch shows two faults: one at the mine and the other northwest of the mine at contact of the dolomite with the Athens shale, which were produced by such a process. Faulting generally produced brecciation and through the brecciated zone ore-bearing solutions circulated.

It is said[1], that slickensides were visible on the hanging-wall of the shaft and that the strike and dip of the fault conform to those of the dolomite. The shaft was inaccessible at the time of this investigation.

Brecciation of the country rock was limited to a zone 12 feet in width occurring entirely on the foot-wall side of the shaft. Mineralization also was confined to this zone and the hanging-wall was absolutely barren. It is not known whether similar conditions existed in depth.

DEVELOPMENT

The surface workings are scattered over an area extending northeast from the mine for a distance of two miles. At the mine, within a distance of approximately 800 feet, considerable development was done. A trench of open cut averaging 30 feet in width and 10 feet in depth was made along the strike for a distance of about 600 feet and at its northeastern extremity exposes a brecciated zone from the surface of which a considerable amount of carbonate ore was mined. In the cut in the vicinity of the shaft the exposed breccia shows the nature of the mineralization in a splendid manner and it is here that the greatest amount of sulphide ore occurs. Continuing southwest along the strike, an open cut 70 feet in length giving access to a tunnel 120 feet in length is located on the west side of Fall Branch Creek. Ore was not seen in either the open cut or the tunnel.

The main development consists of an inclined shaft which follows the dip of the fault and is said to be 150 feet in depth. Operations ceased before production from this shaft was realized.

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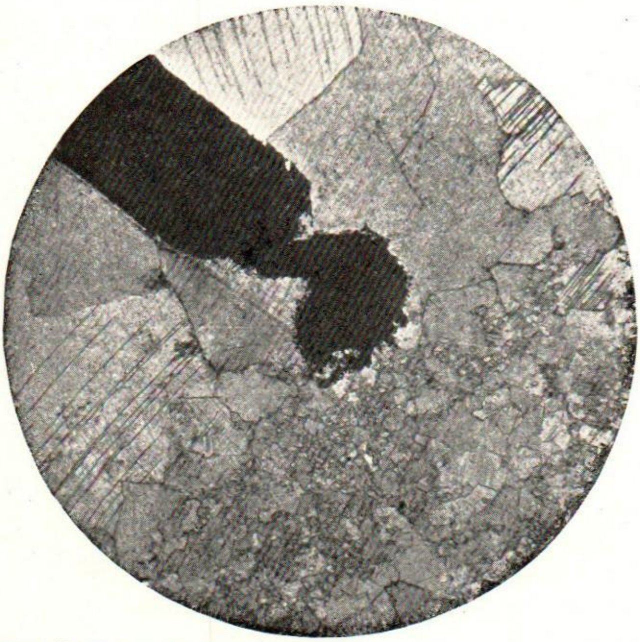
[1]Purdue, A. H., The zinc deposits of northeastern Tennessee, Tenn. Geol. Survey, Bull. 14, 59, 1912.



Recrystallization of fine-grained country rock and replacement by coarse-grained dolomite. The cleavage of the dolomite is well shown. The invasion of small stringers of sphalerite (black) along cleavage lines indicates initial replacement stages. Fall Branch mine. x50.

The mill is in good condition and much of the machinery is still in place. However, it is not likely that the ore can be successfully treated by a dry concentration process.

It is reported[1], that the ore as mined averaged 9.3% zinc. But it is admitted that this represented only the richest ore available, so that the average grade of the deposit is much lower. The ore was screened and the fine ore taken to the fine ore pile. The coarse was washed and carried over a picking table. A sample of the picked ore averaged 18.42% zinc. The ore was then crushed and concentrated. The concentrates averaged 58.28% zinc.

The ore horizon exposed at Fall Branch Mine has been prospected along the strike by a series of shallow pits and open cuts for a distance of two miles northeastward from the mine. Many of these pits were either filled in to such an extent as to prohibit investigation or had completely disappeared. However, the fact that ore has been found in them proves the continuation of the ore horizon in this direction.

Murrel Farm prospects (33)

These prospects are one-half mile northeast of Fall Branch Mine. The workings had fallen in. The following account was taken from the report of Purdue's investigation.[2]

"The protracted ore body is a northeastward continuation of the vein extensively mined by the East Tennessee Mining Development Company. The strike is N. 40° E. and the dip is to the southeast. Judging from the distance that the hanging and foot walls are apart, the bed of fractured and brecciated rock is from five to six feet thick. It is prospected by frequent shafts, pits, and one tunnel, all of which cover a distance of about a quarter of a mile. The shaft is said to pass through 100 feet of clay and then 50 feet into the rock below.

"Some ore is present on the dump. It consists of blende and a small amount of smithsonite, and is associated with white and pinkish dolomite in magnesian limestone. It resembles the ore at Fall Branch Mine, and consists mainly of black-jack associated with more or less dolomite and a considerable amount of iron sulphide and iron oxide. A small amount of barite occurs with these minerals. Black-jack containing a large amount of pyrite was taken from the tunnel on this property."

Wells prospect (34)

These prospects are located on the ore zone at a distance of 3¼ miles northeast of Fall Branch. The property is owned by J. W. Wells, of Fall Branch. The following account was taken from Purdue's report:

[1]Bowron, W. M., Private report on the Fall Branch mine.
[2]Purdue, A. H., The zinc deposits of northeastern Tennessee, Tenn. Geol. Survey, Bull. 14, p. 61, 1912.

"The rock formation is the upper part of the Knox dolomite, which here strikes about N. 30° E. and dips about 65° SE. There are no visible evidences of faulting at this locality. The prospect work consists of ten small pits, eight of which are apparently on the same ore-bearing bed of rock, which is brecciated and fractured magnesian limestone. This bed in places reaches a thickness of at least six feet. The eight prospects extend in practically a straight line for a distance of more than a quarter of a mile. The vein filling and cementing material of the breccia fragments is dark rosin-jack, which is associated with white dolomite. A little smithsonite is present near the surface. A small amount of pyrite, scattering crystals of chalcopyrite, and a hydrocarbon compound occur in places. Barite was not observed to be associated with the ore. Two other pits, which are on the north slope of the hill, are very small, but both sphalerite and smithsonite are present in them.

Cox prospect (35)

"This prospect is on the top of a ridge three and a half miles northeast of Fall Branch on land owned by R. G. Cox of that place. The rock formation is the upper part of the Knox dolomite which here strikes N. 25° E. and stands almost on edge. The prospect is a small pit about 30 feet southwest of the pit fartherest to the southwest on the Wells farm. The shallow residual clay has been dug away from the rock, exposing the ore-bearing rock. The minerals are rosin-jack associated with much white dolomite and a small amount of barite."

Several pits on the Cox farm at a higher stratigraphic level in the Knox dolomite showed the presence of barite, but no sphalerite.

McCurry prospects (36)

There are three small prospect pits still visible on the McCurry farm which adjoins the Cox farm on the northeast. The location is about 3¾ miles northeast of Fall Branch. Two of the pits are about on a line with the ore zone exposed at the mine and very shallow but show a fair amount of sphalerite in the brecciated rock. Accompanying minerals are much white dolomite as a vein filling together with small amounts of scattered crystals of pyrite and chalcopyrite. A carbonaceous compound was also observed in the mineralized horizon. The third pit is about 600 feet southeast of the other two and shows essentially the same conditions of mineralization. As the Knox dolomite has an almost vertical dip (86° SE.) at all three openings, this horizon occurs at a somewhat higher stratigraphic level than those previously described.

It is reported that some prospecting for zinc ores was undertaken along the strike of the ore horizon southwest of Fall Branch Mine. Nothing definite concerning the success of the venture could be learned. Structural conditions indicate that the orebody should continue for some distance in that direction.

GREENEVILLE DISTRICT

NAFF PROSPECT (37)

This prospect, owned by Messrs. Naff and Bitner, of Greeneville, is 9 miles southwest of Greeneville and 3 miles south of Midway, a station on the Bristol and Chattanooga Branch of the Southern Railway.

According to reports the property was first worked about 1870 for barite in the clay overburden. Later, after zinc ores had been found associated with the barite, the Eades, Mixter, and Heald Zinc Company did some prospecting for zinc but soon abandoned the project. Again in 1912 a small amount of prospecting for zinc ores was carried on by the Dougherty brothers, of Morristown. The last work was done in 1919 by the Rollins Chemical Company. It is reported that they made a series of open cuts along the strike of the formation and also put down four drill holes, two of which struck pyrite at 100 feet and 124 feet respectively, but no zinc.

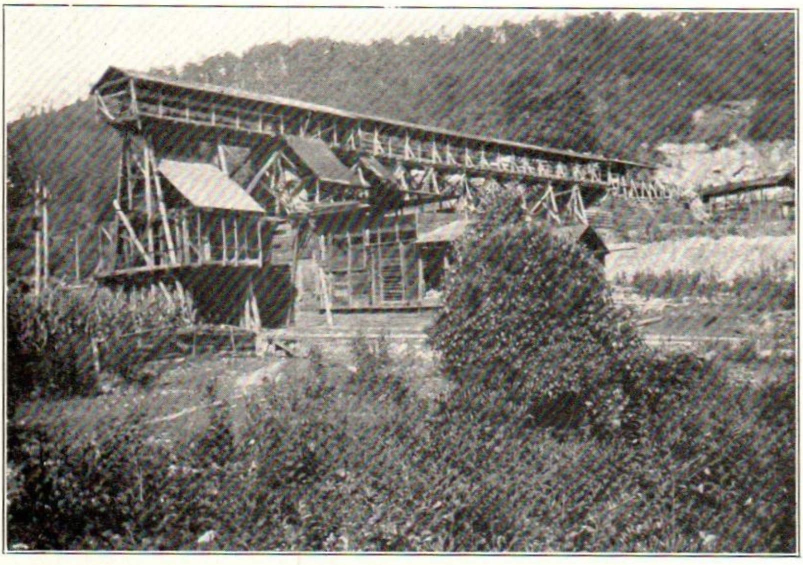
The ore-bearing horizon is confined to the upper levels of the Knox dolomite and is 170 feet, stratigraphically, below the overlying Athens shale. Bluish-gray, fine-grained dolomite with intercalated thin beds of limestone constitute the country rock of the ore-bearing horizon. It terminates sharply against an underlying lighter-colored dolomite from which it is separated by a thin bedding seam of carbonaceous material. No ore was observed in the dolomite below the seam. The strike of the bedding is N. 58° E., and the dip is 59° NW.

This prospect is on the northwestern limb of a small anticlinal roll the axis of which coincides in strike with that of the formation. Although no distinct brecciation and fracturing of the rock was observed, the presence of the carbonaceous seam and the tendency of the ores to occur as thin veins parallel to the bedding suggest that slipping of adjacent beds occurred and formed channels for the circulating, mineralizing solutions.

Most of the open cuts had caved so that very little sulphide ore was seen in place. It is reported that two ore-bearing horizons were found; the lower lying a few feet above the carbonaceous seam, consisted mostly of pyrite and barite forming narrow seams and veinlets in the bedding but locally widening into workable veins; the higher was situated from 15 to 20 feet above the former, and, in addition to pyrite and barite, it contained variable amounts of sphalerite which at places formed pockets sufficiently rich to be worked.

The ore consists of intricately intermixed masses and veinlets of sphalerite, pyrite, barite, gangue dolomite, some quartz, and the unreplaced remnants of country rock. Locally, bituminous matter is abundant in the ore.

(A)



(B)

(A) Mossy Creek mines open pit work.
(B) Peach Orchard mine, Embreeville.

Development, in addition to the four drill holes, consisted in making a series of shallow pits and narrow, trench-like open cuts scattered for a distance of 200 feet along the strike. Most of these passed through a thick mantle of clay overburden, in which occurred lumps of barite, limonite, and smithsonite or calamine, and barely exposed the underlying unaltered country work.

MOSSY CREEK DISTRICT

MOSSY CREEK MINE (38)

The Mossy Creek Mine is on the east side Mossy Creek, at the eastern end of Jefferson City. The history of the mine dates back to 1856 when, according to various reports, the first discovery of zinc ore in Tennessee was made at this locality. However, no attempt was made to mine the ore until 1868. Again in 1881, 1893, and 1901, small-scale mining was carried on for short periods of time, but activity soon ceased.

In 1910, the Osgood Exploration Company, Knoxville[1], was organized and did some prospecting and mining during the following year; but the project failed and again the project was abandoned. From 1916 to 1919 the property was leased and operated by the American Zinc Company of Tennessee (Mascot). They enlarged the open pits and extracted large amounts of sulphide ore which was shipped to Mascot for milling. Since 1919 the mine has been idle.

The ore-bearing rock is bluish-gray, medium-grained Knox dolomite in which thin chert beds are common. The ore horizon, determined by a major fault of unknown dip and throw, is at about the middle of the Knox formation. The line of faulting extends northward through the mine with the upthrow from the east and southeast. The strike of the formation and fault coincide, and the prevailing dip is at a low angle to the southeast.

The ore body is localized in the broken and brecciated rock along both sides of the fault. The developed extent shows it to be roughly lenticular in shape with a strike length of approximately 800 feet and a maximum width of about 300 feet. Within these limits most of the rock has been more or less brecciated and, locally, brecciation has been more intense, such areas forming the loci of the richer pockets of ore.

NATURE OF MINERALIZATION

The ore consists of angular fragments of country rock cemented in a matrix of sphalerite, vein dolomite, chert, calcite, and small scattered masses and veinlets of pyrite and chalcopyrite. The vein materials due to the complexity of brecciation, occur without system. Dolomite and some calcite are practically everywhere in abundance in the breccia

[1]Osgood, S. W., Zinc mining in Tennessee, Geol. Survey Bull. 2-G, p. 11, 1910.

horizon while masses and veins of sphalerite are more limited in their distribution, occurring in greater abundance, as a rule, where brecciation has been more intense or where minor east-west joints intersect the main fault.

DEVELOPMENT

Figure 11 shows a plan of the development. At one time a small mill for rough-crushing the ore was located near the west opening but all machinery has been removed. At the time of this investigation the pits were filled with water so that the manner of occurrence of the ore in depth could not be learned. The rock in the small pit to the southeast is uniformly-bedded, unbrecciated dolomite and thin-bedded limestone and was worked, presumably, as a quarry for obtaining ballast and road metal.

It is reported that some drilling was done in the area surrounding the mine by both the Osgood Exploration Company and the American Zinc Company but the results are not available.

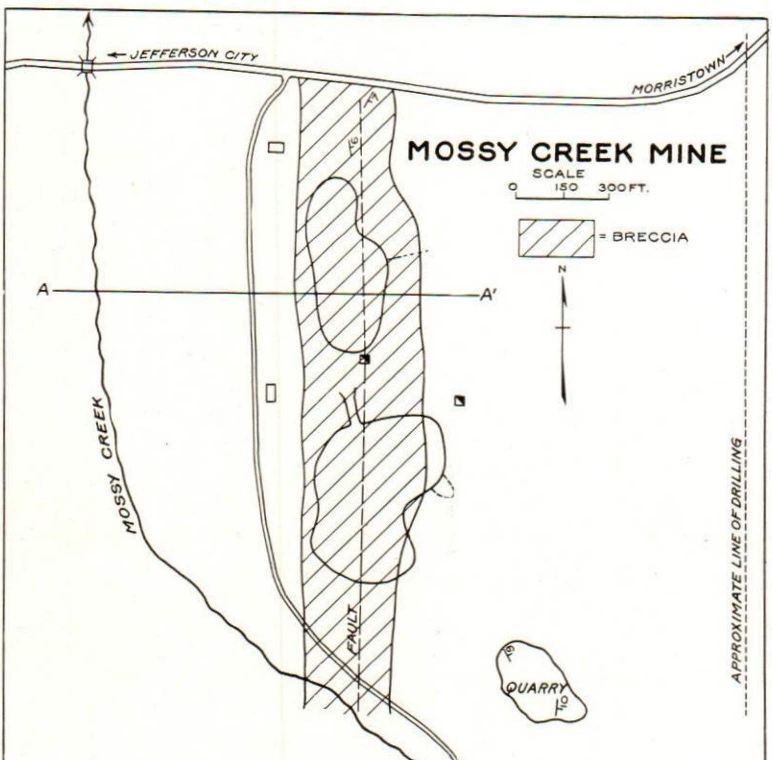


FIGURE 11. Plan of Mossy Creek mine.

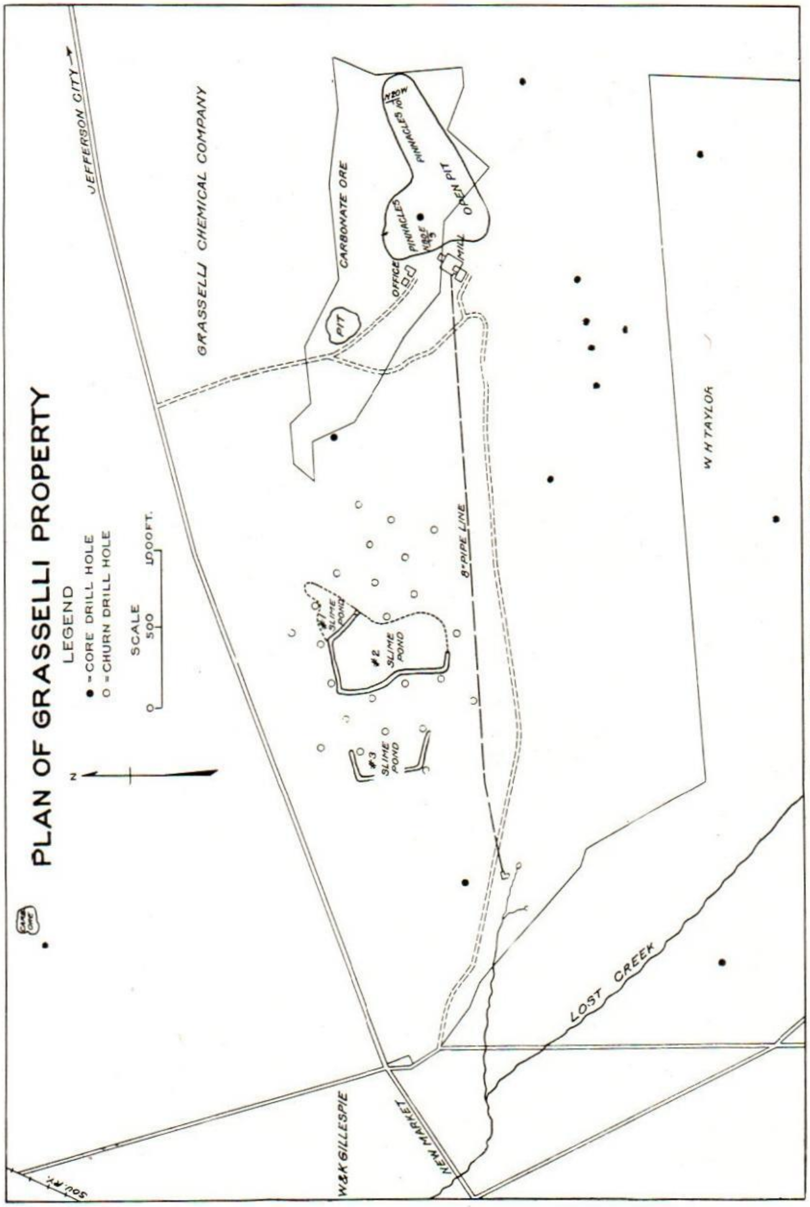


FIGURE 12. Plan of Grasselli mine.

NEW MARKET DISTRICT

GRASSELLI MINE (39)

One of the largest and most successfully operated mines for the production of oxidized zinc ores is situated one mile southeast of New Market.

The eastern pit, Figure 12, was opened about 1892[1], and worked for a period of from 12 to 15 months during which time a large quantity of the oxidized ores, smithsonite and calamine, were mined and shipped to Marion, Indiana. In 1904, the western pit was opened and worked for over a year. The oxidized ores from this pit averaged 44 per cent. zinc, and were shipped to the Bertha smelter at Pulaski, Virginia.

Some years later, the present owners, the Grasselli Chemical Company, Cleveland, Ohio, purchased the property and were continually engaged in mining oxidized ores in the western pit until 1913. Since that year the mine has been inactive.

During the summer and fall of 1922, at the time of this investigation, the Grasselli Chemical Company was actively engaged in core-drill prospecting for sulphide ore to the south and southwest of the old mine on land owned by Dr. W. H. Taylor, New Market. The drilling had at that time indicated the presence of a low grade sulphide ore body of unknown extent. The depth at which it occurred, ranging from 250 to 400 feet, further indicated that it is the downward continuation, along the dip, of the same ore body which had been worked in the pits of the old mine.

COUNTRY ROCK AND ORE

The ore horizon is confined to brecciated beds of the Knox dolomite and is at approximately the same stratigraphic level as the ore body mined at Mascot. However, in the New Market district oxidation of country rock by circulating ground waters has progressed to such depths that the sulphide ores have become oxidized, enriched and localized into an economically workable deposit. The zone of oxidation, extending to an average depth of 60-80 feet, consists of a thick mantle of residual clay overlying pinnacles of partly disintegrated country rock. Where disintegration has not completely destroyed the original nature and texture of the rock in the pinnacles, the prevalence of breccia is evident. The brecciated beds are of variable intensity and thickness and ore deposition was limited to such horizons. Thin beds of chert are abundant throughout the mineralized horizon.

Disintegration of the country rock resulted in the chemical alteration of sulphide ore, sphalerite, to the oxidized forms, smithsonite and calamine. These, relatively insoluble in the circulating solutions, either collected as masses distributed through the clay and covering the surfaces of pinnacles or remained as a complex system of veinlets in the partly disintegrated rock of the pinnacles.

[1]Watson, T. L., Lead and zinc deposits of the Virginia-Tennessee region: Amer. Inst. Min. Engrs. Trans., vol. 36, p. 732, 1906.

Three distinct types of country rock are noticeable:

1. Extremely brecciated beds, generally more advanced in disintegration, in which sphalerite deposition was more extensive.
2 A finely crystalline, bluish-gray dolomite in which only slight brecciation occurred. It contains variable amounts of sphalerite as small disseminated masses.
3. Thin-bedded, laminated beds of blue, argillaceous limestone which are continuous along the strike and dip and show little or no fracturing. These thin beds are invariably more resistant to weathering, and, in the pinnacles, are conspicuous as projecting ledges.

The chert beds are limited to the second type of country rock and frequently form the contact with a brecciated horizon.

Weathering has left but little sphalerite in the rocks of the brecciated horizon and, where found, it has generally been partly transformed into smithsonite.

STRUCTURE

The average strike of the beds is N. 60° W. and the dip about 10° W. The mine is about one mile east of a major fault which, due to movements apparently more complex than simple, thrust pressure from the southeast, has a very irregular trace extending from Straw Plains to a few miles northeast of Morristown. It is thought that the same movement[1] which resulted in faulting caused brecciation within the formation. Although no actual displacements were observed, flexuring of the beds, with the development of small, parallel anticlines and synclines, and the presence of thin, argillaceous seams often in contact with brecciated horizons indicate that some intraformational movement has occurred.

DEVELOPMENT

Only the partly caved and filled-in pits with the upper portions of the exposed pinnacles are now visible. The eastern, and larger pit, was approximately 1,100 feet in length from east to west, about 1,000 feet in width, and had reached a depth of about 60 feet.

In order to extract the oxidized ores from a pinnacle small shafts were sunk into the rock and short drifts were run out into the mineralized portions from the base of this shaft. It is reported that this method of mining resulted in a high recovery of ore.

The western pit, also caved from long disuse, is roughly circular in shape with a diameter of about 200 feet.

A mill, now dismantled and in ruins, was erected at the west end of the eastern pit. It was equipped with log washers, crushers, jigs and tables.

[1]Keith, Arthur, Recent zinc mining in east Tennessee; U. S. Geol. Survey Bull. 225, p. 209, 1904.

C. T. Caldwell prospect (40)

The C. T. Caldwell farm is approximately one mile S. 70° E. of the Grasselli mine. Mr. Caldwell has sunk about 50 "monkey holes," or shafts, on his farm from most of which carbonate ore of zinc has been recovered. These shafts, averaging 3 to 4 feet in diameter, are sunk through the clay overburden to the top of the dolomite. The shafts average 5 to 60 feet in depth. When exceptionally rich pockets of ore are encountered, they are mined by means of short drifts run out from the base of the shaft

The mixture of ore, clay and disintegrated country rock is hauled to a concentrating plant situated along Lost Creek at the eastern edge of New Market. The ore is crushed and passed through two sets of jigs, of 4 cells each, resulting in a carbonate concentrate which averages 40 per cent. zinc. The concentrates are hand-picked to remove chert fragments and other pieces of gangue. The product is shipped to the Grasselli Chemical Company. The capacity of the plant is three tons of concentrates per day.

EAST TENNESSEE ZINC COMPANY MINE (41)

This mine, consisting of two open cuts and a mill is a'ong the wagon road on the north side of Lost Creek at a distance of about two miles southeast of New Market.

Zinc ore was discovered on this property in 1894. Shortly after the discovery Mr. John G. Long mined and shipped several carloads of the oxidized ores. In 1898, the Ingalls Zinc Company purchased the property, erected a mill for the concentration of sulphide ore, and operated an open pit for three years. In 1901, Mr. George Currens purchased the property and operated it for one year. He then leased it to the New Market Zinc Works and it was operated by them for six months. Mr. Caswell Heine of New York City leased the property in 1907, prospected for one year, and then, under the name of the Tennessee Mineral Company, purchased it. It is reported[1], that the extreme purity of the concentrates produced by this Company commanded a market price of $2.00 a ton in excess of Joplin concentrates. The Tennessee Mineral Company operated until January, 1911, and then leased to the American Zinc Company of Tennessee, who operated until July, 1911.

During the war the property was acquired by the East Tennessee Zinc Company and operated until 1918 since which time it has been idle. This company enlarged and modernized the mill and did considerable dril ing on their own and adjacent properties. The holes range in depth from 50 feet to a maximum of 500 feet.

In 1922, the property was acquired by the Mechanics Bank and Trust Company, Knoxville, Tennessee.

[1]Osgood, S. W., Zinc mining in Tennessee; Tenn. Geol. Survey, Bull. 2-G, p. 7, 1910.

COUNTRY ROCK AND ORE

The ore-bearing horizon is a brecciated zone averaging about 50 feet in thickness[1] and is near the top of the Knox dolomite formation at approximately the same stratigraphic level as the horizon mined by the Grasselli Company to the northwest. However, the former horizon is less intensely brecciated. The country rock is bluish-gray, finely crystalline dolomite with narrow intercalated, lens-shaped beds of limestone, and also thin beds of chert. The average strike is N. 65° E. and the dip is 20° SE., but variable.

The ore consists of breccia fragments of country rock cemented by a matrix of gangue dolomite, sphalerite, calcite and chert. The relative abundance of sphalerite is quite variable throughout the breccia. The mineral appears either as small veinlets along fractures or in irregular-shaped masses as replacements of both country rock and vein material. Most of the sphalerite is light-brown in color with some zonal development of darker bands. Occasional masses and short disconnected veinlets of pyrite occur in both country rock and vein material.

Near the surface oxidation has altered the sphalerite to smithsonite and calamine, but the ground water level is so high that only a limited amount of oxidation has taken place. Much of the oxidized ore is stained and coated with thin films of greenockite.

The following observations were made in microscopic examination of thin sections of ore from this mine.

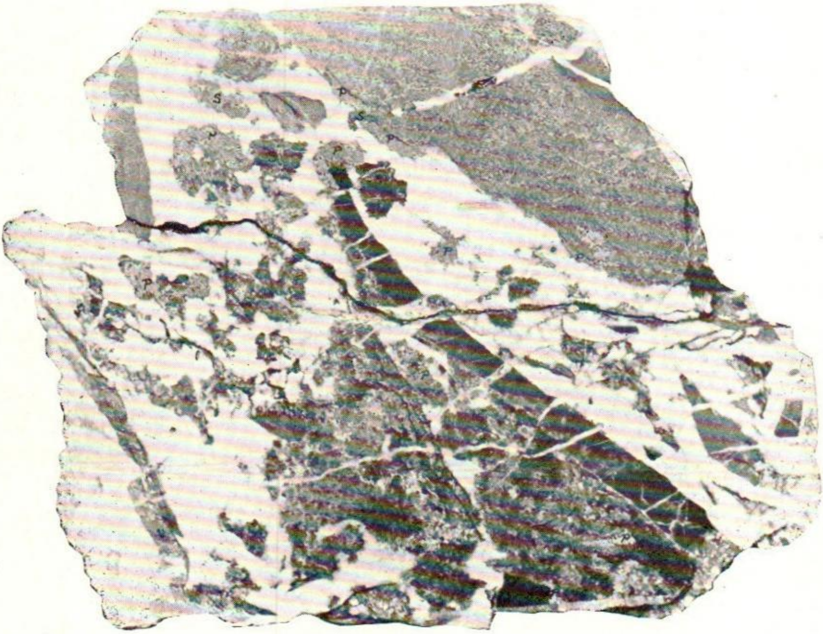
The unaltered country rock consists of medium-grained anhedral crystals of dolomite. The country rock, by a rather sharp transition, grades into and is replaced by coarse-grained, subhedral crystals of gangue dolomite, which constitute the bulk of the slide.

Both country rock and gangue dolomite have been locally replaced by cryptocrystalline chert in which are included scattered grains of quartz.

Sphalerite appears to be later than the chert. However, mutual invasions are so common as to suggest that silicification of the country rock and dolomite continued throughout the period of sphalerite deposition. The sphalerite occurs as large, irregular-shaped masses scattered through the country rock, dolomite, and chert could be readily concentrated by crushing, jigging and tabling.

Granular aggregates and veinlets of pyrite occur promiscuously throughout the dolomite and chert and also frequently form narrow seams which ramify along the edges and into the cleavage cracks of the sphalerite, locally replacing that mineral.

[1]Watson, T. L., Lead and zinc deposits of the Virginia-Tennessee region: Amer. Inst. Min. Engrs. Trans., vol. 36, p. 732, 1906.



Polished specimen of ore from Mascot No. 2 mine, showing gangue dolomite carrying isolated masses of sphalerite (S) and pyrite (P.) ½ size.

Paragenesis

1. Country rock.
2. Dolomite.
3. Chert.
4. Sphalerite.
5. Pyrite.

DEVELOPMENT

Both pits were filled with water at the time of this investigation. It is reported that the depth of the smaller pit was 25 feet, and of the larger, 70 feet, both pits bottoming in ore.

The capacity of the mill is 100 tons. The ore was carried from the open cut by an aerial tram to the mill feed-storage bin. It was fed into a 14-inch jaw crusher and then ground in the first set of rolls. The ground product passed through a trommel with 9/25 circular holes; the oversize was re-ground in a second set of rolls and returned to the trommel; the undersize was treated in a 5-compartment jig. The oversize and the jig tailings were further ground and sized in a series of three rolls and two trommels with 2/25-inch circular openings, and concentrated in a 6-compartment jig and four Wilfley style tables. The tabling middlings were reground in the rolls and again passed through the circuit.

The power equipment of the mill consists of two boilers, a Corliss type engine, and one air compressor, all apparently in good condition.

MASCOT DISTRICT

Mascot Mines (42)

The Mascot Mines of the American Zinc Company of Tennessee are situated along the Southern Railway in the Holston River Valley, Knox county, about 13 miles northeast of Knoxville. Mr. H. I. Young, Mascot, is manager of the mines.

Considerable mining and prospecting had been done by several companies prior to the acquisition of this property by the American Zinc Company. Previous to 1900 only open pits, which were worked for oxidized ores were operated and the production was small.

In 1900 the Roseberry Zinc Company was organized. That Company sank a shaft (now known as No. 3 shaft of the American Zinc Company) to a depth of 187 feet. The upper 30 feet were in residual clay, the remainder in brecciated and massive dolomite. Ore was encountered at a depth of 104 feet. Short tunnels were driven from the base of the shaft to tap the ore body but most of the production of the Roseberry Company was derived from the large open cut (No. 3 open cut), located on the west bank of Roseberry Creek. Both carbonate and sulphide ores were mined. A few years later the property was purchased by the Grasselli Chemical Company and in 1915 by the American Zinc Company.

In 1903 the Holston Zinc Company began operations in both carbonate and sulphide ores just west of the Big Flat Creek. Their workings are now known as No. 1 open cut of the American Zinc Company. They sank a shaft to a depth of 170 feet, at a location of 670 feet to the north of the present No. 1 shaft of the American Zinc Company. This shaft was later abandoned. It is said that ore was found from the 120-foot to the 160-foot level.

Both the Roseberry and Holston Companies carried on extensive prospecting by drilling. Mills for crushing and concentrating the ore were erected by each company and operated for a short time.

In 1911 the American Zinc, Lead and Smelting Company entered Tennessee, and, under the name of the American Zinc Company of Tennessee, acquired the property formerly owned by the Holston Zinc Company. Their output consists of sulphide ore only and they are the only Company in Tennessee continuously engaged in mining the sulphide ore of zinc.

The present holdings of the American Zinc Company consist of 3,200 acres of land in Knox County and 400 acres in Jefferson County. The ore body has been developed for a length of 7,900 feet along the strike and a distance of 1,200 feet down the dip.

In May, 1913, the Mascot mill with 1,000 tons daily capacity was completed. Additions to this mill were finished in July, 1915, bringing its daily capacity up to 2,400 tons. Power is obtained from the Tennessee Power Company's hydro-electric plant at Parksville, Polk County, 100 miles distant from Mascot, from which a 66,000 volt transmission line is run direct to the mines. The zinc company has an emergency power plant consisting of a 100 h. p. steam turbine sufficient to carry the pumping load at any time.

COUNTRY ROCK

The ore-bearing formation is the Knox dolomite. Throughout the mine many varieties of dolomite are exposed, but it may be generally considered as a fine- to medium-grained, crystalline, light-blue, heavy-bedded, magnesian limestone with brecciated zones of variable thickness occurring at several horizons. An analysis of the barren country rock is as follows:

SiO_2	9.64%
Fe_2O_3 and $A_{12}O_3$	3.48
$CaCO_3$	50.95
$MgCO_3$	35.84
	99.91

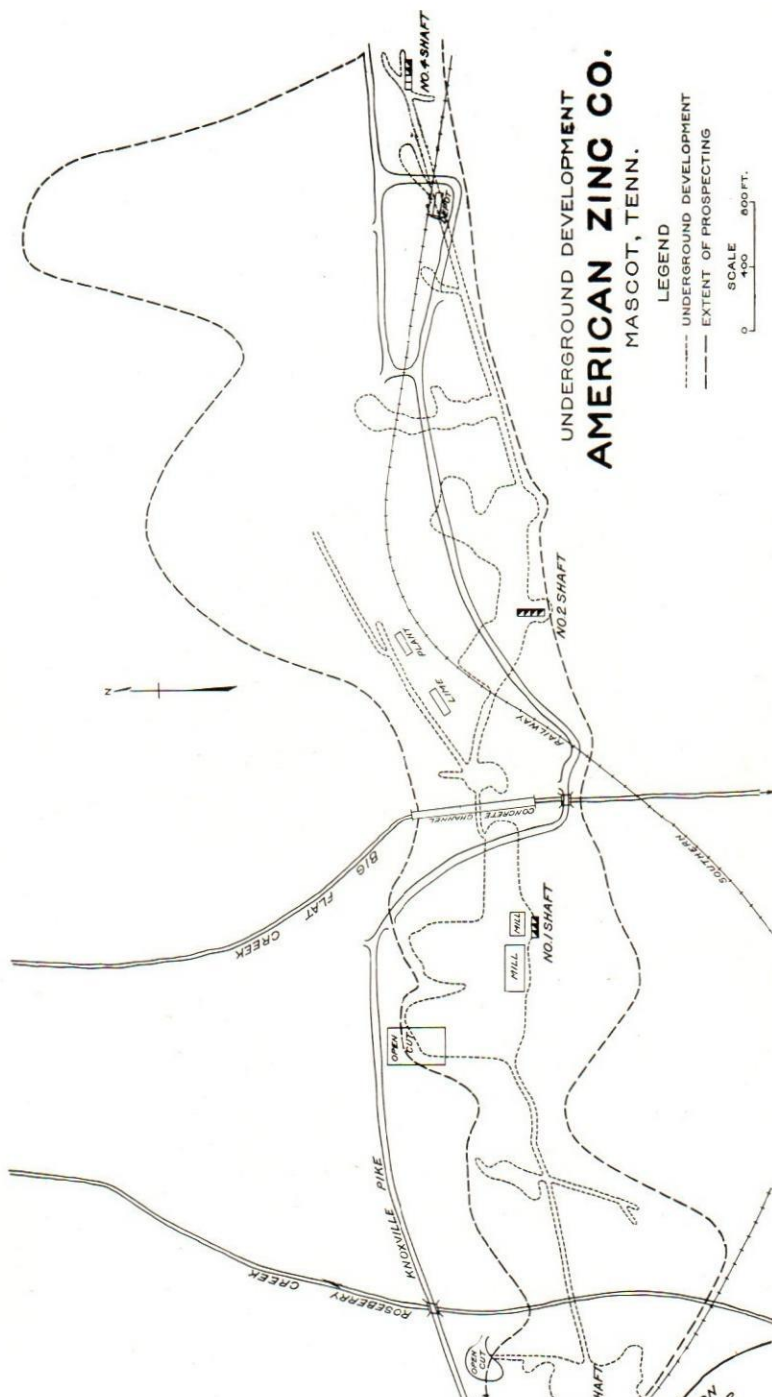
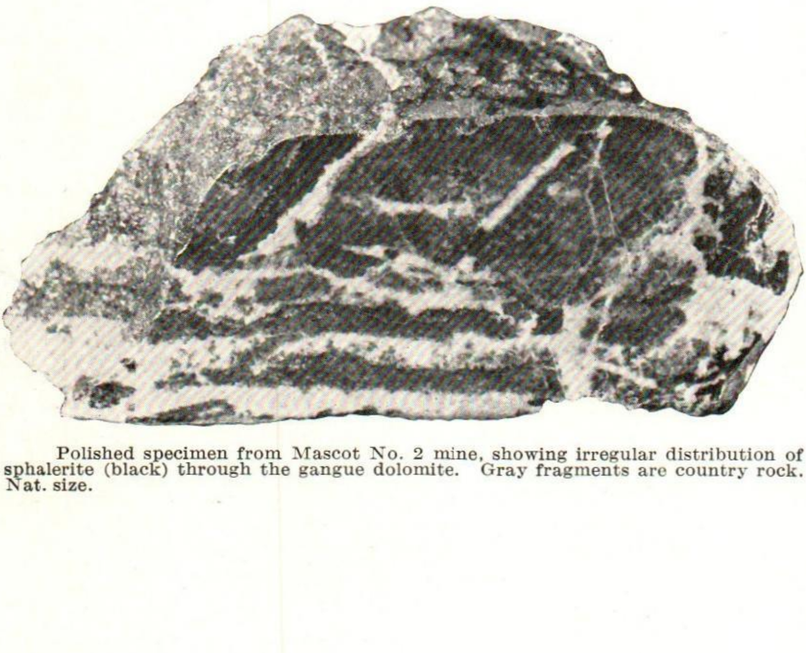


Figure 13. Plans of underground workings of the American Zinc Company at Mascot.



Polished specimen from Mascot No. 2 mine, showing irregular distribution of sphalerite (black) through the gangue dolomite. Gray fragments are country rock. Nat. size.

American Zinc Company's Plant, Mascot, Tenn., December, 1911. (Purdue).

The general strike of the dolomite for the immediate area is N. 70° E., and the dip, 20° SE. Some chert, both nodular and as secondary replacement masses and veins, is associated with the dolomite.

The roof of the ore horizon occurs at approximately 900 feet stratigraphically below the top of the Knox formation and pay ore has been found to a depth of 120 feet below the roof. The ore horizon coincides with a prominent zone of brecciation. There are indications of deeper ore horizons.

MINERALS

The chief ore mineral of the mine is sphalerite. Near the surface and in solution channels where oxidation has taken place, the sulphide has been altered to smithsonite and calamine. Most of the sphalerite of the Mascot mine, is extremely light-yellow in color. It occurs in the brecciated horizon as veinlets, irregular masses of variable size, fracture fillings and breccia cement. Gangue minerals occurring with the sphalerite are dolomite and calcite. The quantity of sphalerite is variable, generally being greater in the more intensely brecciated rock. Drilling and mining have shown that the brecciation is irregular both vertically and horizontally in that the bodies of pay ore may pinch or widen within relatively short distances, or even disappear entirely only to reappear as detached ore bodies at some distance away.

Accessory ore minerals are practically absent. Locally pyrite occurs but its quantity is negligible.

A carbonaceous compound sometimes occurs along fracture planes; also occasional pockets or masses of barite are found. The gangue consists almost entirely of dolomite, calcite, and the country rock.

Microscopic examination of thin sections of the ore show that the country rock consists of fine-grained, anhedral crystals of dolomite which are mutually interlocking and possess, in general, well-developed rhombic cleavage. The average diameter of the grains is about 0.10 mm.

Minute, isolated grains of pyrite, frequently altered to limonite, are disseminated through the country rock and tend to occur in the interstices between individual crystals.

The vein, or replacement, minerals have been deposited in the following order:

1. Dolomite.
2. Sphalerite.
3. Pyrite.
4. Dolomite, when present.

The vein dolomite is coarsely crystalline and shows good rhombic cleavage. Generally the contact of country rock and dolomite is well-defined and clearly shows replacement of the former by the latter, but a narrow seam of limonite frequently obscures the actual contact and has partly corroded the edges of the crystals adjacent to it.

That the contact zone of the country rock and dolomite was readily susceptible to replacement by later minerals is evidenced by the presence of variable amounts of sphalerite and pyrite. The pyrite occurs in small grains many of which show distinct crystal outline and, locally, complete replacement of the earlier minerals has resulted in the formation of short, discontinuous veins of pyrite.

The mode of occurrence of sphalerite is similar to that of pyrite in that it tends to be more abundant in the contact zone of country rock and dolomite. Small, disconnected masses of sphalerite, with veinlets protruding along interstitial openings between crystals, or along their cleavage cracks, occur promiscuously throughout country rock and dolomite, and locally attain a considerable size.

In one or two instances narrow fractures within masses of sphalerite and pyrite had been filled with a coarse-grained dolomite similar to that which has replaced the country rock. The fracture filling was not accompanied by replacement.

Where pyrite and sphalerite are in contact, the order of deposition is frequently not clear although some unmistakable evidence of pyrite invading along cleavage cracks of sphalerite and replacing that mineral are apparent.

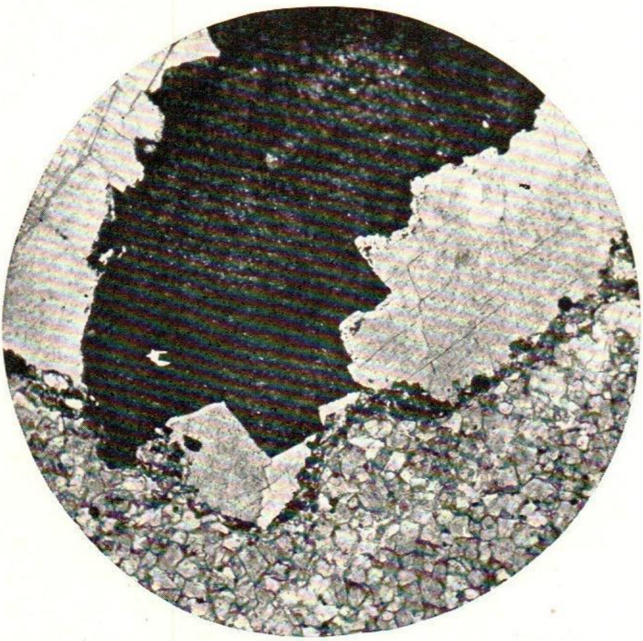
Paragenesis

1. Country rock.
2. Dolomite.
3. Sphalerite.
4. Pyrite.
5. Dolomite, when present.

NATURE OF MINERALIZATION

The structure of the region is that of a monocline dipping at an average angle of twenty degrees to the southeast. Minor flexures and warpings cause local flattening, steepening, or even reversal of the prevailing dip. The ore body parallels the bedding plane for the most part and consequently its dip conforms closely to the regional dip. Mining operation so far have disclosed no faults of great displacement which have cut off the ore body. Minor breaks are numerous but the movements may generally be measured in inches. Some movement has occurred subsequent to mineralization as is evidenced by the slight displacement of veins and beds along fractures.

The extent of the main ore body is not definitely known as prospecting is still being carried on. An ore body of commercial grade has been proven to extend from Roseberry Creek on the west to a point one-half mile east of Mascot Station, a distance of three-fourths of a mile. Intensive drilling has been carried on over this area, both along the strike and down the dip. It is reported that this drilling indicates the ore body to be roughly lenticular in shape although its limits down the dip have not been reached.



A frequent relation between country rock, dolomite, and chert. The contact between country rock and dolomite (the white crystalline mass in the central section) is obscured by an invasion of pyrite-bearing chert (lower part of photo). Sphalerite (upper edge of photo) is replacing dolomite. No. 2 mine, Mascot. x50.

Within the mineralized zone there is considerable variation in the zinc content as can be observed from the manner in which the ore occurs in pockets which follow no definite direction. The American Zinc Company has mined only those areas or pockets that contain the highest grade of ore. The intervening ground has been avoided although it is not absolutely barren and may even contain small but high-grade masses of ore.

MINING[1]

Four shafts and two emergency exits give access to the mines. One emergency exit opens in the south wall of No. 1 open pit; the other is the abandoned No. 3 shaft of the Holston Zinc Company.

No. 1 shaft, situated on Holston Hill approximately 1,200 feet west-northwest from the Southern Railway bridge, is 300 feet in depth. It is a 3-compartment shaft consisting of two skipways and one cageway. From the main station, cut at a depth of 200 feet, the main level crosscut was driven due north through the ore body. Drifts were driven east and west from the main level along both the foot-wall and the hanging wall. These drifts are connected by crosscuts at 100 foot intervals. Raises extend upward from the crosscuts into the ore body.

In the east part of the mine the shrinkage system of stoping was tried for mining the ore above the main level. This was not successful because the rock broke into large slabs which choked the pull holes.

The underhand system, now being used, has proved to be the most satisfactory method. With this system an 8-foot heading is cut along the hanging-wall and the roof made safe before the bench is removed. As these headings advance, sublevel trams are established, the ore being dumped into raises which were driven in advance. As a rule one raise accommodates two sublevel trams which enter at different elevations.

In addition to the underhand stoping system a mill hole system has been used with good success and has been of material assistance in keeping up the tonnage when the supply of labor was short. In this system 8 by 8 foot raises are driven to the top of the ore body. Then stoping is started and all of the ore is drawn into the raises and delivered to the main haulage level thereby eliminating the shoveling of any of the ore. This system has been very satisfactory in working ore bodies of forty feet or more in thickness.

For entering the headings of the lower runs of ore the open stopes are used, but for the upper runs a protected manway with staggered ladderways is employed, which also takes care of the air and water lines. Below the main level, inclines are put down on the foot-wall and after

[1]Coy, H. A., and Henegar, H. D., Mining methods of the American Zinc Company of Tennessee: Amer. Inst. Min. Engrs. Trans., vol. 58, pp. 36-47, 1918.

Coarse-grained dolomite (light) undergoing replacement by sphalerite (at upper edge) and pyrite (black). The granular form of the pyrite is well shown. No. 2 mine, Mascot. x48.

cutting in lower stations, drifts are driven east and west and the same mining system used as above the main level.

No. 2 shaft located 2,800 feet due east of No. 1, was the second shaft sunk by the American Zinc Company. It is a four-compartment shaft consisting of two skipways, one cageway and one pipe and manway. The shaft is 612 feet in depth, the main station being cut in the west side at 520 feet which is at an elevation of 445 feet above the sea level. From this drift a haulage drift encircles the shaft and is widened out on the north side where there are two short haulage drifts, one of which goes due east to the head of the east incline, the other due west to the foot of the west incline which connects through to No. 1 mine. The east incline dips at 20 degrees for a distance of 350 feet; the west incline rises at 24 degrees for a distance of 824 feet.

Stoping methods similar to those in No. 1 mine are used. However, for handling the ore above the main level the incline system is used in place of the sublevel system.

The main or first level was driven 2,400 feet northeast from the shaft. It is the main haulage level. The fifth level, 125 feet below the first, or 325 feet above sea level, was driven 1,700 feet northeast from the east incline; the ninth level, 235 feet below the first, or 210 feet above the sea level, was driven east-northeast from the foot of the east incline. The ninth level is 2,400 feet in length at which point it intersects No. 4 shaft.

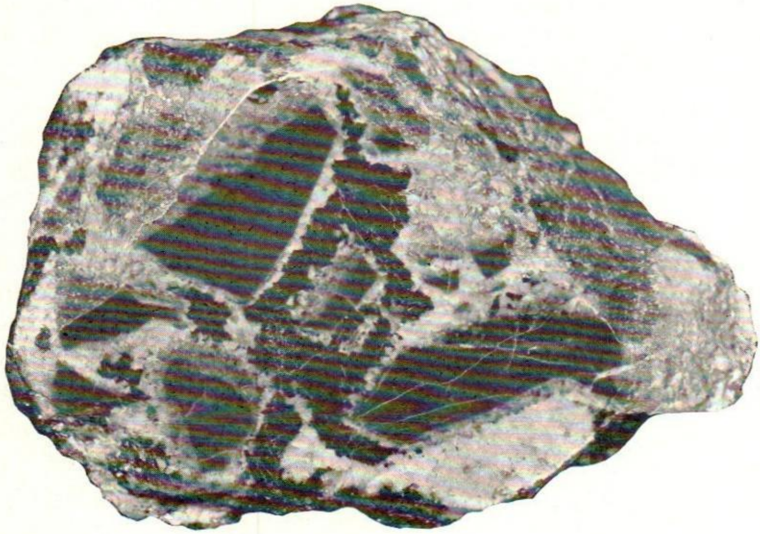
At the present time most of the ore is mined in No. 2 mine and is taken from the main and fifth levels. Only a small amount of mining is being carried on in the ninth level. The levels are connected by the incline upon which haulage is made, and by manways down the stopes.

No. 4 shaft, situated 3,200 feet N. 73° E., is equipped with a fan and used only for ventilation purposes.

No. 3 shaft, which is approximately 3,000 feet due west of No. 1, is now abandoned. The American Zinc Company enlarged it into a 2-compartment shaft. About 50,000 tons of ore had been taken out by the previous operators at a point 187 feet below the collar. The present owners worked the mine by means of drifts, raises, crosscuts, and stopes, using a system similar to that described for No. 1 mine. All the mining was done from one level and was confined to an area north, east and south of the shaft.

Production of zinc in the Mascot district, before underground mines were developed, was derived entirely from several small pits and two large open cuts which were made by the pioneer operators.

No. 1 open cut first worked by the Holston Zinc Company is situated about 900 feet northeast of No. 1 shaft. The opening is rectangular in shape, 370 feet in length and 200 feet in width. At the northern



Polished specimen from Mascot No. 2 mine, showing relations of country rock breccia, gangue dolomite, and sphalerite (black). Nat. size.

end the depth is about 30 feet but this increases to about 60 feet at the southern end where an emergency exit connects with No. 1 mine.

The oxidized ores, smithsonite and calamine were mined from the clay overburden and the partly disintegrated dolomite pinnacles throughout the open cut, but in the southern half where the depth exceeded the lower limits of oxidation, a considerable amount of sphalerite was mined.

The northern end of this open cut roughly marks the surface outcrop of the foot-wall of the brecciated horizon which is mined in No. 1 mine.

No. 2 open cut, which was worked by the Roseberry Zinc Company, is situated on the west bank of Roseberry Creek at a distance of approximately 600 feet northeast from No. 3 shaft.

The opening covers about two acres and attains an average depth of about 30 feet. Both oxidized and sulphide ore were mined. At places the brecciation of the country rock was intense and in such local areas ore deposition was greater. The ore is typical of the breccia type and consists of angular fragments of country rock cemented by a matrix of vein dolomite, calcite, sphalerite, and some chert and pyrite.

MILLING

The ore at both No. 1 shaft and No. 2 shaft is hoisted in 50-ton skips to a receiving bin which automatically feeds a gyratory crusher that breaks it to less than 4-inch size. It is then conveyed to a plate screen with 2-inch circular holes. The oversize passes through a disc crusher with 1-3/16-inch maximum opening and joins the undersize to be conveyed to the fine crushing plant. This is done from No. 2 shaft by an aerial tram and from No. 1 by a conveyor.

The ore in the fine crushing plant is passed through two 54 by 20 inch Garfield rolls and thence through eight trommels with 5/8-inch circular holes. The oversize of the trommels is returned to the rolls and the undersize goes to a 2,500-ton storage bin.

From the storage bin the ore is distributed to four 6-cell Cooley type rougher jigs with openings of 1/8 by 1 inch in the grates. The tailings are dewatered on four stationery dewatering screens and the waters pass to a Dorr tank. The oversize from each screen goes to a 3-cell Cooley type bull jig with a plate with 1/4 inch circular holes. All of the bull jig hutches make middlings that join the middlings of the first jigs. The tailings are automatically sampled and elevated to the ballast loading station from which they are shipped in railroad cars as ballast, sand, and roofing gravel.

The middlings of the seven jigs are dewatered in an Akins classifier and distributed to four trommels with 1/8-inch circular holes. The oversize is crushed in a set of 43½ by 16 inch Garfield rolls and returned to the trommels. The undersize is distributed to two 4-cell

Cooley type sand jigs with cast-iron grates with 1/16 inch openings. The tails go to the Dorr tank at the head of the table room. The hutch product of the sand jigs joins the hutch product of the rougher jigs. The combined product is dewatered in dewatering cones and treated in two 7-cell Cooley-type cleaner jigs with 1/12 by 1/16 inch grate openings. The hutch product of the first 6 cells is concentrate; that of the last cell is returned to the cleaner-jig feed. The tails go to the Dorr tank at the head of the table section.

Until the middle of 1922 the table feed was ground in tube and ball mills, dewatered and classified in Anaconda classifiers, and treated on a series of 66 tables of coarse sand feed and 22 of fine sand feed.

The overflow of the Dorr tank and the dewatering classifiers of the table section were dewatered and subjected to flotation concentration. The flotation plant comprised two units of Butte and Superior roughers each consisting of 3 mixer, 2 double, and 6 single agitator cells and one unit of altered Janney roughers consisting of 1 mixer, 2 double spitz, and 5 single spitz machines. The froth from the double agitator machines and the first double spitz machines was cleaned in 2 single spitz Janney cleaners and in 1 double spitz Janney recleaner to produce finished concentrate. The froth of the other cells and machines was returned by way of a Dorr tank to the original feed. The tails of the flotation unit go to the lime plant for the preparation of ground limestone.

About the middle of 1922 the tables were cut out and the entire table feed was treated by flotation. As a result of improvements in the flotation practice, despite the increased load, the flotation plant was handling all of its feed on only a part of the flotation machines that had been in use before the change.

In October, 1922, the mill was treating 2,000 tons daily. The mill heads averaged 3½ per cent. zinc. The jig tails ran about 0.9 per cent. zinc and the flotation tails about 0.07 per cent. zinc. The jig concentrate and the flotation concentrate carried 61 per cent. zinc. The mill recovery averaged about 85 per cent.

FUTURE PROSPECTS

The American Zinc Company has been actively engaged in drilling both as a means of prospecting prior to their acquisition of the property in this area and later in order to prove the extent and character of their ore body. Due to the low grade of the ore, averaging about 3.75 percent. zinc and the presence of areas of unworkable ground it is essential that underground mining be guided by surface drilling. The success of the company is due in large measure to the realization and recognition of that fact and is a splendid demonstration of what can be achieved under skillful and efficient management. Both diamond and churn drills are used. The surface diamond drilling is done under contract with H. R. Ameling Prospecting Company, of Rolla, Missouri. The churn drills and underground diamond drilling are operated by the American Zinc Company.

The nature of the ore body is such that it can be profitably and successfully worked only as a large scale operation with large tonnages of ore developed well in advance of mining. Despite the extensive area already proved by the drill, the limits of the deposit are still undetermined.

The enterprising character of the American Zinc Company is further illustrated by its ability to dispose with profit of its mill tailings through its subsidiary, the American Limestone Company, instead of having them accumulate to its great inconvenience about the mill.

The American Limestone Company operates a lime plant in connection with the mine and mill of the American Zinc Company. The limestone-dolomite gangue of the ore is thereby utilized so that there results a minimum waste of all the rock mined.

OUTLYING PROSPECTS

Prospecting along the approximate southwestward continuation of the ore horizon worked at Mascot has resulted in the finding, from time to time, of small zinc deposits. As a rule the openings are small and consist of open cuts made in the clay and extending short distances into the underlying rock.

They are given in their order of location southwest from Mascot.

Spout Hollow (43)

Spout Hollow pit is situated on Spout Hollow run, about two miles west of Mascot station and on the north side of the Knoxville Pike.

The first work was done about 1882 and again in 1892 additional prospecting and mining of the oxidized ores were carried on.

The pit is roughly square in shape and covers about an acre. The average depth is about 30 feet. Removal of the clay overburden exposed pinnacles of country rock which consists of bluish-gray, fine-grained dolomite and intercalated beds of limestone and chert. The strike of the formation is N. 80° E., and the dip, 20° SE. The horizon occurs at approximately the same stratigraphic level as that exposed in No. 1 and No. 2 open cuts, but here the rocks are less brecciated.

The unoxidized ore mineral is light-brown sphalerite which was deposited with vein dolomite, calcite and chert as a breccia cement. In the zone of oxidation, smithsonite and some calamine occur as alteration products of sphalerite.

McMillan pit (44)

Some prospecting and mining of zinc ores were conducted in 1900 by the Seven Day Zinc Mining Company at a point one-half mile north of McMillan Station, on the Southern Railway, along the wagon road leading to the Knoxville Pike.

An open cut 100 feet in length, 30 feet in width, and 15 feet in depth, exposed the same type ore body as those occurring at several localities in the district. The strike of the country rock, Knox dolomite, is N. 55° E., and the dip is 23° SE.

Sphalerite of a light-brown color occurs as small flakes disseminated through the country rock, and deposited with vein dolomite and calcite it forms a breccia filling of limited extent.

A high ground-water level prevails in this area so that smithsonite and calamine are limited to a shallow zone which extends only a few feet below the surface of the ground

Woods Creek

This prospect, which is situated along the east bank of Woods Creek at a point three-fourths of a mile northeast of Caswell station, on the Southern Railway, consists of a small pit 10 feet square and 15 feet deep.

The ore, consisting of small masses and veinlets of light-brown sphalerite associated with vein dolomite, occurs in a brecciated horizon in the Knox dolomite. This horizon, although displaying a brecciation of less intensity, occurs at about the same stratigraphic level as the ore horizon exposed at Loves Creek. The lower limit of the brecciated horizon is marked by massive beds of chert in cherty dolomite in which no mineralization has taken place.

At the time of this investigation the sides had caved in to such an extent that only a superficial examination was possible.

Loves Creek (45)

This property is on Loves Creek, about 5 miles northeast of Knoxville and one-half mile north of the Southern Railway.

The first work at this locality was done prior to 1900 by the Knoxville Zinc Mining Company. Numerous depressions, marking the locations of the caved pits and shafts, are the only visible remains of that work. About 1914 the American Zinc Company of Tennessee carried on a small amount of surface prospecting and also drilled the property. It is reported that the drilling located some ore at various depths.

Several small partly caved pits located along both sides of the creek show that the ore-bearing horizon is one of brecciation. It lies approximately 800 feet, stratigraphically, below the top of the formation and thus coincides roughly with the horizon worked at the Mascot mine. The country rock is variable and consists of alternating beds of thin-bedded, blue limestone, much of which has been re-crystallized, and bluish-gray, fine- to medium-grained, cherty dolomite.

In its mode of occurrence the ore is similar to that at Mascot and consists of irregular-shaped masses and discontinuous veinlets of sphalerite, accompanied by vein dolomite, calcite, chert, and some pyrite, constituting a matrix of the breccia fragments of the country rock. Locally, light-green, siliceous selvage seams and bituminous matter are abundant. Invariably, the mineralization has been more concentrated in such areas.

FRIENDSVILLE DISTRICT

FRIENDSVILLE PROSPECT (46)

This prospect is on John Jones farm, 1½ miles north of Friendsville, in Blount county, and 1½ miles west of the Louisville and Nashville Railroad.

The first work was carried on at this locality about 1907. At that time prospecting for barite was rather widespread throughout this region. During the prospecting the association of galena and sphalerite with barite was discovered. The most recent work was done by the American Zinc Company in 1918. Their efforts were confined to prospecting to determine the extent and richness of the ore body. The developments consisted of opening a few prospect pits, starting two shafts (which have fallen in), and some drilling.

COUNTRY ROCK AND ORE

The ore horizon is limited to a narrow brecciated bed 250 feet stratigraphically below the top of the Knox dolomite and consists of dark-gray, fine-grained, thick-bedded dolomite. The average strike of the bedding is N. 14° E. At the prospect the dip is horizontal, but for the region as a whole, the bedding dips at a low angle to the southeast.

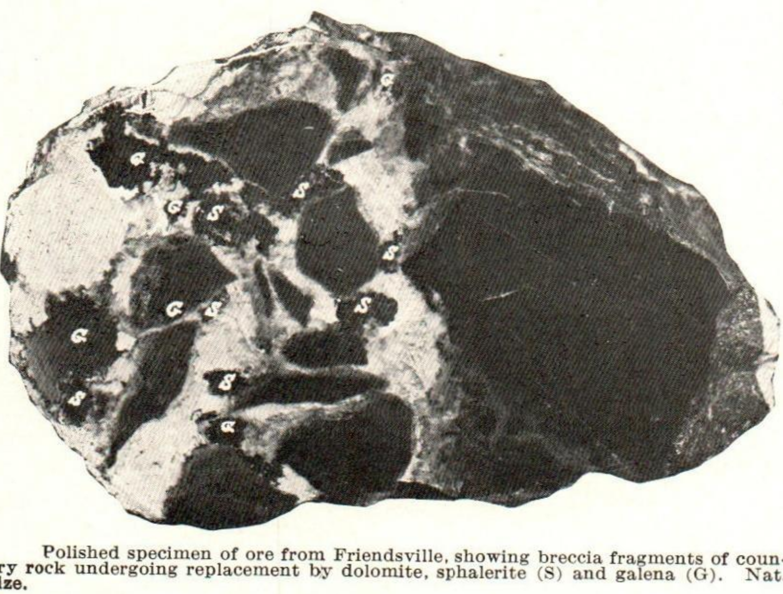
The valuable minerals in order of their abundance are: barite, galena, and sphalerite. Vein dolomite, calcite and pyrite with a little fluorite, comprise the gangue.

The barite mineralization is rather consistent throughout the horizon, but galena and sphalerite occur only in detached pockets of various sizes and are found only in the brecciated horizon either as replacements of breccia fragments or as small veinlets associated with the gangue minerals of the matrix.

Oxidized ores in limited quantity intermixed with clay occur in the weathered outcrops of the ore zone.

The microscopic examination of a thin section of the ore shows that the gangue consists of intricately intermixed areas of country rock,

PLATE XX.



Polished specimen of ore from Friendsville, showing breccia fragments of country rock undergoing replacement by dolomite, sphalerite (S) and galena (G). Nat. size.

made up of fine-grained, anhedral dolomite crystals and coarse-grained gangue dolomite. Transitions from country rock into the later dolomite are generally abrupt and the contacts plainly show absorption or replacement of the former by the latter. Neither chert nor sphalerite occur in the section.

Minute grains of pyrite are disseminated throughout the areas of country rock but do not occur in the gangue dolomite, suggesting that some of the pyrite occurs as an original constituent of the country rock. Massive areas of later, or vein pyrite, occur as replacements of both country rock and dolomite.

Paragenesis

1. Country rock.
2. Dolomite.
3. Fluorite.
4. Sphalerite.
5. Barite.
6. Galena.
7. Pyrite.

DEVELOPMENT

The development consists of open workings. The old pits have practically disappeared. It is reported that no ore was ever shipped. Some hand-sorted barite and galena are lying on a dump near the wagon road.

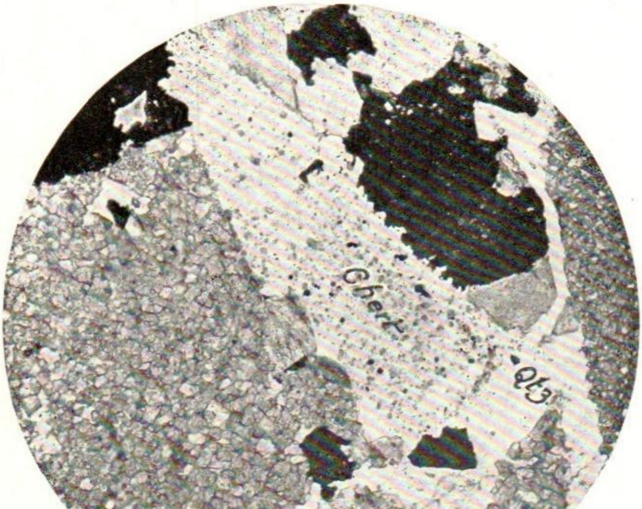
EVE MILLS DISTRICT

EVE MILLS PROSPECT (47)

Eve Mills, in the northern part of Monroe County, is located on Fork Creek, 7 miles south of Loudon and 9 miles east-northeast of Sweetwater.

The ore-bearing rock is Knox dolomite. The horizon is approximately 950 feet stratigraphically below the overlying Chickamauga limestone. The beds immediately above the ore horizon are composed of fine-grained, blue-gray, cherty dolomite which is massively bedded. Some veins of white calcite and dolomite, but no ore, occur in this zone. The ore zone, which is about 70 feet thick consists of gray, thin-bedded, finely crystalline dolomite, much of which has been brecciated and recemented by vein dolomite, calcite, and sphalerite. Considerable white and blue chert, both as nodules and as breccia filling, occur in this zone.

The strata underlying the ore horizons consist of blue non-crystalline limestone, scattered irregularly, through which are numerous quartz grains. No ore occurs in this horizon. Strata of finely crystalline, barren dolomite underlie it. Both strike and dip show local variations: the average is N. 41° E. and 16° SE., respectively.



Association of fine-grained country rock, gangue dolomite, chert (carrying minute grains of pyrite), and sphalerite. Eve Mills prospect. x46.

ORE AND NATURE OF MINERALIZATION

Sphalerite is the chief mineral. Associated with vein dolomite, calcite, chert and barite, it occurs as irregular replacements of the country rock throughout the ore zone and is not confined to definite veins or shoots. It varies in color from very light yellow to black (black-jack).

Pyrite, in small crystal aggregates either forming minute veinlets or isolated patches within the dolomite, is quite prevalent throughout the ore zone, especially where recrystallization of the country rock is most pronounced. With an increase in the amount of gangue dolomite there is a decrease in the amount of pyrite.

Smithsonite occurs as masses in the clay overburden and as coatings on the weathered surface of the ore zone. Solution cavities following cavities in the rock generally contain considerable quantities of the oxidized ore.

In thin sections of the ore, the country rock appears as more or less isolated areas of fine-grained, anhedral crystals of dolomite generally entirely or partly replaced by cryptocrystalline chert in which small quartz grains are at times abundant.

The Vein dolomite is medium to coarse grained, and where unaltered, shows good cleavage. An occasional crystal showing polysynthetic twinning suggests the presence of a small amount of calcite.

Much silicification of the country rock and particularly of the vein dolomite has occurred. Cryptocrystalline chert has invaded the rock along irregular channels and has partly or totally replaced the minerals with which it has come into contact. The absorption and replacement of dolomite is well shown. First a crystal is partly surrounded and then veinlets of chert invade and absorb the mineral destroying its cleavage and producing a corroded appearance accentuated according to the extent of replacement. Chert apparently does not follow cleavage directions in the dolomite but attacks the crystal with equal facility from any direction.

Small areas of sphalerite occur in random fashion throughout the section. They show a tendency to more readily replace country rock and vein dolomite, especially where the two have been in contact. From the sphalerite mass small stringers project into the surrounding minerals, generally following the cleavage directions or ramifying along the sutures between adjacent crystals.

Small granular aggregates of pyrite abound in zones where either replacement of country rock by both dolomite or chert occurs, or, where dolomite is being replaced by chert. The pyrite appears to have been introduced subsequent to initial silicification. Much of the chert and sphalerite are slightly stained by iron solutions.

Neither barite or galena were seen in the sections.

Paragenesis

1. Country rock.
2. Dolomite.
3. Chert.
4. Sphalerite.
5. Pyrite.

DEVELOPMENT

The development work was done in 1911-12 by the American Zinc Company, who hold a lease on the property. This work consisted of opening a series of open cuts at irregular distances along the strike, most of which have since fallen in. Previous to the work of the American Zinc Company, the Emma Mining Company had done some prospecting but the extent of their work is not known. The largest open cut is 90 feet long in a N. 20° E. direction, averages 20 feet in width and 8 feet in depth. At the northern end the overlying clay had been tunneled for a short distance to recover carbonate ore. It is reported that a shaft had been sunk but all traces of it have disappeared.

Several core drill holes were made but the results are not available. The location of one of them is given in the sketch.

That mineralization continues to the northeast has been proven by open cuts and drilling made on the property of W. G. Blackman, one-half mile northeast of Eve Mills. A small open cut made on this farm is claimed to have exposed sphalerite in a brecciated country rock. None, however, was seen in place although it did occur in rocks on the dump. This horizon is considerably higher, stratigraphically, than the one described above. Mr. Blackman states that drilling on his land proved an ore body to exist at the same depth as the one prospected at Eve Mills.

SWEETWATER (48)

Barite mining has been carried on for many years in the vicinity of Sweetwater. Various reports exist as to the finding of minerals such as galena, sphalerite, pyrite and fluorite in association with the barite. One abandoned mine was visited where the forementioned minerals are claimed to have been found. This is known as the "Stoner Mine," and is located one-eighth of a mile south of the Madisonville road and four miles southeast of Sweetwater. The ore occurs near the top of the Knox dolomite.

Samples obtained showed an intimate association of barite, galena, pyrite and fluorite, and a small amount of sphalerite. It is possible that sphalerite does exist in this section as the region is near the southwest strike-line of the ore horizon at Eve Mills.

Examination of several thin sections of Sweetwater barite ore was made for the purpose of determining what genetic relations existed between the several minerals and whether the barite and fluorite showed any unusual relations to the sphalerite. In only one section was a combination of sphalerite, barite and fluorite obtained. In the others, the regular order of deposition, viz: country rock, dolomite, chert, sphalerite, galena (contemporaneous with sphalerite) and pyrite, occurred. In the first section a sharp-angled, brecciated fragment consisting of fine-grained, anhedral dolomite crystals, is surrounded successively by veins or bands of fluorite, sphalerite, fluorite, barite, and fluorite. The above order seems to prevail with the addition of pyrite as the final mineral. The fluorite and barite, both possessing good cleavage, occur in the alternating bands the edges of which mutually interlock and do not denote replacement.

The presence of several isolated, anhedral crystals of dolomite within the bands and entirely surrounded by barite and fluorite indicates movement during the deposition of those minerals.

C. C. PATRICK PROSPECT (49)

The Patrick farm is located about three miles northwest of Loudon along the west side of the Hotchkiss Valley road. During the years 1916-17 an Alabama barite mining company did some work on this property for barite. The country rock belongs to the upper part of the Knox dolomite which here carries considerable nodular chert. The formation strikes N. 48° E. and dips 30° SE. It is massively bedded, finely crystalline, gray dolomite.

Development consisted of driving a tunnel into the hillside for a distance of 100 feet in a S. 30° E. direction; also several small pits scattered about in the vicinity of the tunnel indicate that both surface and underground mining of barite was carried on.

In addition to barite which is the most plentiful mineral, galena, pyrite, and some sphalerite occur as replacements of the country rock, also gangue dolomite and calcite as associated with the above minerals in varying amounts. The sphalerite occurs in association with galena and pyrite, all having been deposited contemporaneously. Occasional crystals of purple fluorite rim the barite. The barite and galena have a wavy or crinkled structure, indicating that movement took place subsequent to their deposition.

No minerals were seen in place, due to the fallen-in condition of the tunnel and pits. The conditions of mineralization were ascertained from samples lying on the dump at the mouth of the tunnel.

CHARLESTON DISTRICT

THE HAMBRIGHT MINE (50)

This mine is located on land now owned by J. Robert Davis (Charleston, Tenn.), about four miles south of Charleston, in Bradley County, and near the middle of the Chatata Valley.

The ore-bearing rock is Knox dolomite, approximately 320 feet, stratigraphically, below the overlying Chickamauga limestone. The dolomite is massively bedded with alternating layers of compact, blue limestone. The dolomite is finely crystalline and blue-gray in color. The workings have been abandoned and are filled with water to such an extent that no idea of the ore in place could be learned. Some hand samples showed the ore to occur as small replacement veinlets of sphalerite, galena, pyrite, and gangue dolomite and calcite in the pure limestone beds. No brecciation was observed.

The following account was taken from Safford's "Geology of Tennessee," 1869, p. 485:

". . . I have been at this point several times but never found the excavations open. The following information was given me by Mr. Hambright: 'The lead vein, when worked showed a layer averaging eight inches in thickness, and dipping with the rocks (about an angle of 15 degrees) to the southeast. The gangue was heavy spar. The galena exposed was a continuous layer, ranging from one to four inches in thickness, and associated with more or less blende, and other ores of zinc. Where the layer of galena was thin, the enclosing rocks held more or less of the ore in grains.'

"Masses of galena have been found in the neighborhood of the vein, weighing from 200 to 300 pounds. A flat mass, weighing 53 pounds was taken from the vein. Two or three tons have been dug out of the earth near the vein since 1850.

"At this locality are old and quite extensive 'diggins' about which the oldest inhabitants, and the Indians before them, knew nothing. They were, doubtless, made for loose pieces of galenite in the soil."

The developments consist of an open cut extending 50 feet S. 70° E., a shaft 90 feet deep, located 20 feet beyond the face of the open cut, and an incline which continued through a short tunnel, following the ore to the shaft and 100 feet beyond. Numerous depressions in the surrounding fields indicate that small pits had been worked years before.

In 1915, John Adams, of Charleston, did some mining for the Chatata Lead and Zinc Company, of Asheville, N. C. One ton of ore was shipped. He also did some work in 1919. Since that year the property has been idle and the openings are now filled with water.

Microscopic examination of thin sections of the ore shows that two distinct varieties of country rock occur:

1. A cryptocrystalline variety which shows no optical characteristics.
2. A fine- to medium-grained variety in which the individual crystals are generally subhedral and possess the excellent rhombic cleavage and polysynthetic twinning of calcite. The hand specimens tested with 1.12 HCe_1, show violent effervescence.

Both varieties of country rock are intermingled in an extremely complicated manner and the formation of elongated areas of the crystalline variety within the cryptocrystalline suggests that it crystallized after original deposition.

A later form of calcite dolomite occurs as medium- to coarse-grained polysynthetically twinned crystals. Generally, these large crystals, anhedral or subhedral in outline, show absorption and replacement of the fine-grained country rock and also contain many minute, corroded inclusions of the earlier minerals. Frequently the boundary is obscured by narrow, intervening seams of dark-brown limonite.

Light-brown sphalerite occurs as irregular-shaped masses replacing both the country rock and gangue minerals. The contacts are often marked by the intervention of limonite veinlets. Generally the sphalerite-country rock contacts are sharp and are only occasionally broken by sphalerite stringers ramifying into the adjacent material.

Granular pyrite is found in small quantity throughout the country rock and is quite abundant, locally, in masses intervening between the sphalerite and the earlier minerals.

Movement subsequent to sphalerite deposition occurred resulting in the fracturing of that mineral. These fractures were then filled with fine- to medium-grained calcite-dolomite.

Paragenesis

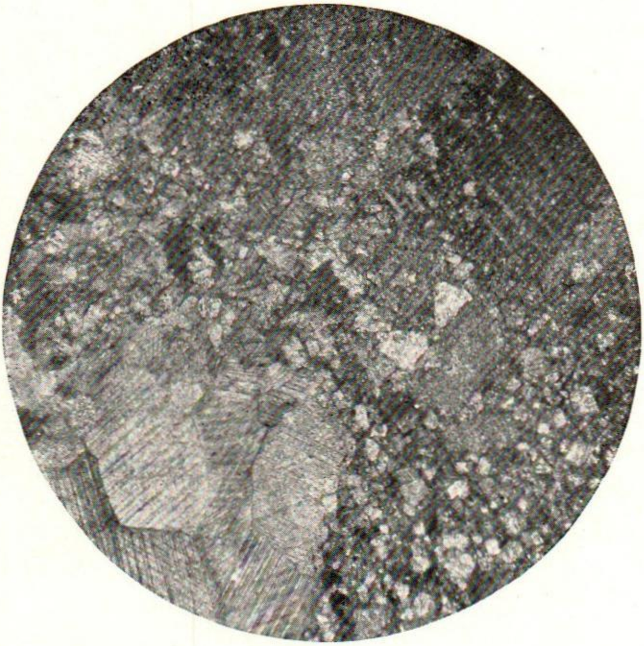
1. Country rock.
   a. Cryptocrystalline.
   b. Fine-grained.
2. Gangue calcite-dolomite.
3. Sphalerite.
4. Pyrite.
5. Calcite-dolomite.

No galena was observed in the section.

CLEVELAND DISTRICT

"DOLLIE D" OR HARDWICK MINE (51)

This mine is situated within seven-eighths of a mile of the Southern Railway and four and one-half mile south of Cleveland, in Bradley County.



Recrystallization of limestone country rock. Both the cleavage and polysynthetic twinning of calcite are shown. Hambright mine. Crossed nichols. x50.

The mine was abandoned about 1906 and has been inactive ever since. The two shafts have fallen in so that no underground observations were possible. No ore was seen to outcrop on the surface. The mill is in ruins. The following account was taken from the Fifteenth Annual Report, Mining Department, State of Tennessee, 1905, (pp. 216-17-18.)

"This property was operated under a 17-year mining lease by the Southern Lead Company, from the year 1905, with W. D. Ham, General Manager, with home office at Chattanooga, Tennessee. The mine was first opened up on adjoining land about 1892 by natives finding small deposits of top or clay ore, and for several years no attempt was made to go beyond a few feet in depth, and while the work was done in a crude and expensive manner, enough ore was produced to pay for development.

ORE ZONE

"The ore zone at the Dollie D. lead mine is what is termed in the western lead district an ore shoot or chimney, consisting of a deposit similar in shape to an inverted funnel, widening gradually as the descending water found 'open ground' along a wide fracture in the dolomite, near the great fault, that from present indications will contain even greater deposits than now being mined in the fractures.

"The fractures opened about as follows: No. 1 shaft 210 feet deep and crossing the fault at about 135 feet from the surface. No. 2 shaft, located about 250 feet north of shaft No. 1, is 140 feet deep, and should cross the fault in 10 to 40 feet more, when it should reach open ground; and ore cross seams from a fracture are already exposed in the bottom of shaft No. 2. In shaft No. 1 at the 110 foot level, a drift or tunnel has been cut out to a fracture and just tops the ore body. This drift was then abandoned and No. 2 drift cut out from the shaft to the ore body at a depth of 135 feet. This drift has been sunk about 100 feet in each direction along the fracture and fault, and from this drift which measures 5 to 7 feet in width, 20 to 25 feet in height and about 200 feet in length, has been cut more than $50,000 worth of ore. Drift No. 3 has been run out more than 180 feet on a fracture, and from an opening about the same space as No. 2 about $70,000 worth of ore (based on present prices) has been extracted.

MINERALOGY

"The ore mined is very closely disseminated ore consisting of about 6 per cent. galena, 3½ per cent. zinc and 3 per cent. lime carbonate, 2 per cent. iron, 5 per cent. heavy spar, difference gangue, magnesian lime (dolomite), etc., which, when reduced to concentration will give:

Lead concentrate	*Zinc concentrate*
75.5 lead sulphide	51.25 zinc sulphide
6.2 zinc sulphide	8.50 lead sulphide
1.2 iron	2.40 iron
Difference—lime.	Difference—lime.

"This is the best separation obtainable under present conditions, but a small additional outlay in new machinery would produce a product worth from 10 to 25 per cent. more in the market and would get more concentrates from the ore.

OUTPUT

"The daily output is 80 tons of crude ores, or hoisted material."

Examination of a thin section of the ore picked up on the dump at this time shows that the non-metallic material consists of an intricate mixture of medium- to large-grained subhedral crystals of dolomite. Adjacent crystals interlock in a manner denoting contemporaneous formation and no absorption and replacement of the smaller crystals by the larger. Rhombic cleavage is well developed.

Interstitial invasion and partial replacement of the dolomite crystals has taken place by light-brown cryptocrystalline chert, carrying minute quartz grains. Throughout the chert mass small grains of pyrite are abundant.

Both dolomite and chert terminate abruptly against sphalerite. Many of the contacts show that the sphalerite is replacing the other materials, while within its mass occur many enhedral crystals or aggregates of crystals of unreplaced dolomite.

The sphalerite exhibits a concentric zonal coloration, or development. The centre is light-brown in color and around its periphery contains a narrow circular band of both radially and crystallographically arranged elongated laths of dull-black color, denoting a zone of higher iron content. The size of the laths is widely variable, some being quite thin and long, others thick and short possessing generally very irregular edges. In some of the thick laths, however, adjacent edges are planes which intersect at an angle of 90 degrees. Also two sets of elongated laths, if projected to intersect, meet at an angle of 90 degrees. Such right-angled relations indicate the mineral to be sphalerite and not wurtzite—as might be suggested from circular and radially zonal arrangement.

A second zone of light-brown sphalerite, free from dark-colored laths, surrounds the zone just described. Beyond it, at the edges of the sphalerite mass, a second lath zone is just forming where dolomite is being replaced.

Pyrite grains of various size, several showing true crystal outline, are scattered through the dolomite especially as interstitial replacements. Very little pyrite occurs within the sphalerite. No galena was seen.

Paragenesis

1. Country rock (dolomite).
2. Chert.
3. Sphalerite.
4. Pyrite.

WATAUGA DISTRICT

WATAUGA POINT PROSPECT (52)

This prospect is on the Sam Crow farm, along the Watauga river, at Watauga Point, a station on the East Tennessee and Western North Carolina Railway. According to report the work was done about 1900 and consisted of opening three small pits, each approximately 20 feet long, 20 feet wide, and 15 feet deep, located at short intervals along the strike which is N. 32° E. The bedding dips 80° SE.

The ore horizon is about 3 feet in width and is near the base of the Knox dolomite which here consists of dark-blue, fine-grained, thin-bedded limestone. Although no brecciation of the rock is apparent, the presence of thin seams of carbonaceous matter which frequently possess slickensides indicates that intraformational movement occurred.

Small flakes and masses of sphalerite and galena and pyrite, associated with some gangue dolomite and calcite are disseminated through the country rock as replacements in the mineralized horizon. Frequently fractures which formed after the deposition of the sphalerite and galena are encrusted with small crystals of pyrite and chalcopyrite. Much of the galena has a stretched and wavy appearance indicating movement subsequent to its deposition. In the zone of oxidation, that is, in the clay overburden, smithsonite, calamine, and cerussite are found in small quantity.

Microscopic examination of a thin section of the ore shows that, although even very small areas of the original country rock are practically absent in the section, a few remnants in various degrees of alteration and replacement, indicate that it consisted of fine- to medium-grained, anhedral crystals of dolomite and calcite. Gangue dolomite is limited to one small area of a few medium-sized crystals. Numerous veinlets and irregular shaped masses of cryptocrystalline chert, with included grains of quartz, occur throughout the slide. It appears that partial silicification of the country rock and gangue dolomite preceded ore deposition, as the siliceous material is later than both the country rock and the dolomite but is earlier than sphalerite, galena or pyrite.

An advanced stage of country rock replacement by sphalerite is apparent. Small areas and elongated relicta of country rock occur as scattered remnants either partly or entirely surrounded by sphalerite. Galena is later than sphalerite and shows a tendency to more readily replace it along contact zones with the country rock.

Small masses and elongated veinlets of pyrite occur throughout the slide. This mineral appears to have replaced all the others with equal facility and is especially prevalent in the interstices between two adjacent minerals.

Paragenesis

1. Country rock.
2. Gangue dolomite.
3. Silicification (chert).
4. Sphalerite.
5. Galena.
6. Pyrite (and chalcopyrite).

EMBREEVILLE DISTRICT

Embreeville is situated along the Nolichucky River in the southeastern part of Washington County and is distant 14 miles by rail from Johnson City.

The site of the town marks the northeastern limit of Bumpass Cove, a topographical and structural depression between Bumpass Mountain on the northwest and Buffalo Mountain on the southeast. The Cove extends to the southwest for a distance of four miles where it terminates at the junction of the two enclosing mountains. The greatest width of the Cove is 1½ miles at its central-cross section, and from this point gradually decreases to the northeast and southwest.

Drainage is effected by Bumpass Creek which empties into the Nolichucky River at the northeastern end of the Cove.

Throughout its early history Embreeville was noted for its iron mines.[1] As early as 1836 a forge was located there; later a charcoal furnace was built and operated, but upon the advent of coke iron and low prices it was forced to shut down.

In 1890 an English company was organized and bought the large boundary now controlled by the Embree Iron Company. This Company spent large sums in improvements such as grading and macadamizing streets, building several fine homes for the officers and better class of employees, and also constructing a 100-ton furnace for smelting the iron ore. In a short time the venture proved a failure. Later the Embree Iron Company was organized and after a period of successful operation a slump in the iron market and a lack of capital caused the company to go into the hands of receivers.

It was known at each repairing of the furnace that large quantities of zinc were recovered which resulted from smelting iron ores mined near the plant. Some of the operators knew that carbonate of zinc was passing out of the open cuts and through the washers, but as the

[1]Maxwell, H. V., The Embreeville zinc field; Manufacturers' Record, vol. 64, No. 1, p. 57, July 10, 1913.

company was working iron, and not zinc, and was at all times crowded to the limit to supply the furnaces with ore, no attention was paid to the zinc ore.

When the Embree Company went into the hands of receivers, C. A. Morris, formerly of Bertha, Va., who was familiar with the mining operations of that district, was placed in charge of the properties at Embreeville. Convinced that quantities of pay ore of zinc were contained in the clays of the district, he undertook experimental methods and even had analyses made at his own expense until finally he succeeded in interesting the owners to make an investigation.

The first shipment was made in 1911 and consisted of ore picked up along the flume line where the carbonates had been thrown away as waste. Additional shipments were made of ore collected from the waste piles around the washers. Returns from the first shipment amounted to $900 and subsequent returns on later shipments proved the value of the zinc ore.

Immediately steps were taken by the receivers to protect the owners and secure sufficient funds for mining the ore. At first the dumps and waste piles of the old mines were re-worked and the carbonate taken from them; later, after prospecting had determined additional ore bodies, new mines were opened.

After a period of idleness the mines were re-opened in 1919 under new management and a modern mill for the concentration of the oxidized ores was erected. Since then constant production has been maintained.

GENERAL GEOLOGY OF THE DISTRICT

The formations exposed in the Cove are of middle Cambrian age and consist of the Hesse quartzite, which forms the upper half of the southeastern slope of Bumpass Mountain, and the Shady limestone, which conformably overlies the Hesse quartzite. The Shady limestone forms the basin of the Cove and continues half-way up to the northwestern slope of Buffalo Mountain, terminating sharply against the Cochran conglomerate of lower Cambrian age, which has been brought up from the southeast by faulting. See Figure 14, showing the structural relations.

The ore deposits occur in the Shady limestone. It is normally 750–1,000 feet in thickness[1], but in the Cove it has been eroded down to a thickness of about 400 feet.

The Shady limestone consists of fine-grained, crystalline and massive, dark-blue, heavy-bedded limestone and dolomite which weather with a dull-gray or black surface. Some of the beds are mottled gray, blue

[1]Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Roan Mountain folio (No. 151), p. 6, 1907.

Calamine ore from Peach Orchard mine, Embreeville, Nat. size.

or white, and are seamed with calcite. Silica, in the form of chert, is common. The following analysis is fairly representative of the composition of the limestone:

SiO_2	57.60%
Fe_2O_3 and Al_2O_3	8.16
$CaCO_3$	18.90
$MgCO_3$	15.27
	99.93

The limestone undergoes rapid weathering as is evidenced by the thick mantle of dark red clay which overlies it. It is in this clay overburden that the oxidized ores are generally found.

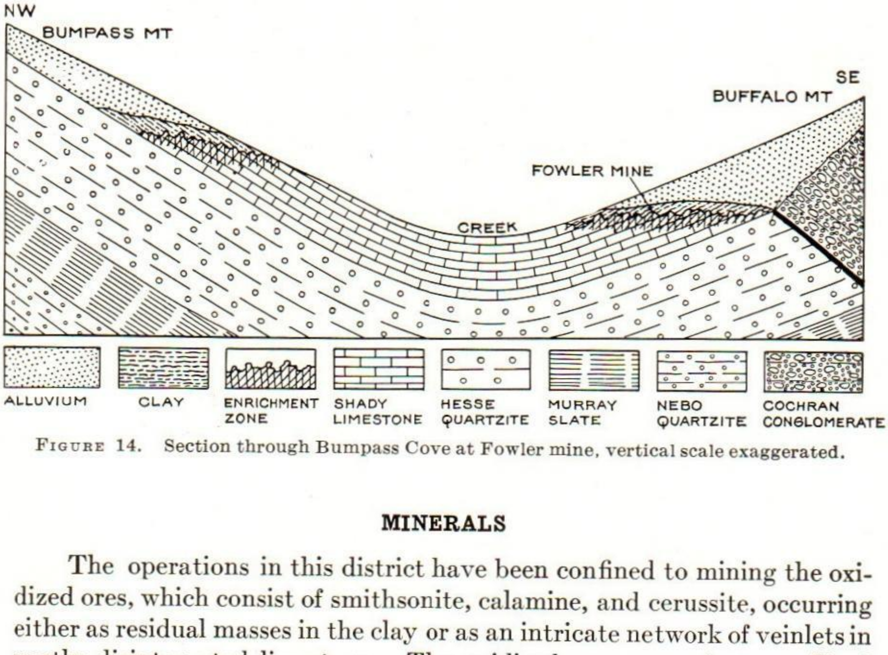


FIGURE 14. Section through Bumpass Cove at Fowler mine, vertical scale exaggerated.

MINERALS

The operations in this district have been confined to mining the oxidized ores, which consist of smithsonite, calamine, and cerussite, occurring either as residual masses in the clay or as an intricate network of veinlets in partly disintegrated limestone. The oxidized ores occur in crystallized form, rarely being found massive; and due to their high lustre and tendency to form large aggregates are readily discernible in the clay. The masses or aggregates of ore were formed on top of the limestone in clay pockets between pinnacles. The accumulation of the ore protected the underlying limestone and the pinnacles became the loci of most rapid disintegration and were themselves reduced to clay which, however, contains only small and scattered veinlets of ore, or is barren. Consequently the mode of occurrence of the ore is in pockets of oxidized zinc and lead minerals in a matrix of clay which are separated by areas of almost barren clay.

Where oxidation has not taken place, the unaltered limestone usually contains sphalerite, pyrite, and some galena either as small veinlets or as finely disseminated particles. Locally the sulphides are more abundant.

NATURE OF MINERALIZATION

The structure of the basin, shown in Figure 14, is that of a symmetrical syncline, the axis of which coincides roughly with the bottom of the basin. This natural basin, underlain by a limestone containing disseminated particles of sulphide ores, affords an ideal structural condition for the concentration of the sulphides by descending surface waters. A relatively low angle slope allows the clay and limestone to be penetrated by meteoric waters which take the minerals in solution and later deposit them at lower levels. Minor structural features and topographic variations unite to produce favorable circulation channels in which localization of the ores occur. That such a concentration has taken place is suggested by the irregular manner in which the oxidized ore bodies lie upon the limestone along both limbs of the syncline.

MINING

Although numerous cuts have been made in the Cove in the past years for mining ore, only four localities have been developed for mining zinc and lead ores.

FOWLER MINE (53)

This was the first zinc mine developed by the Embree Company and is 2½ miles southwest of Embreeville near the base of the northwestern slope of Buffalo Mountain. It is approximately 1,600 feet in length along the strike, which is N. 60° E., and 600 feet in width. The average depth is 50 to 60 feet. The upper limit of the open cut is terminated at the junction of the Shady limestone and the Cochran conglomerate.

Open cut methods have been used for mining the ore in the clay overburden and pinnacles. The pay ore in the numerous solution channels within the pinnacles was mined by means of short tunnels and winzes but resulted in the recovery of only a part of the ore. The complex occurrence of ore in the less altered limestone has presented difficult mining problems.

Localization of the richer pockets of ore in the clay between the pinnacles, with veinlets projecting into the less altered limestone, splendidly exhibits the extreme extent to which enrichment has proceeded. The veinlets and pockets occur without system and consequently there is no way of discriminating between mineralized and barren ground.

No. 14 MINE (54)

This mine is one-half mile southwest of the Fowler mine. It was abandoned in 1920. The development consisted of driving a tunnel N. 30° W. for a distance of 500 feet. Small pockets of smithsonite and calamine were found where disintegration of the limestone has taken place, but most of the rock is unaltered and contains some sphalerite and considerable pyrite both in the form of small veinlets and as small masses disseminated through the rock. No lead, either in sulphide or oxidized form has been found. The production, consisting of zinc ores and pyrite, was small.

No. 14 open cut (55)

It is situated in a small ravine on the southwestern slope of Buffalo Mountain, and is 600 feet southwest of the mouth of No. 14 mine. The cut is approximately 300 feet in length in a southeast direction and 100 feet in width. The method of mining was the same as that used in the Fowler mine and exposed numerous pinnacles of partly disintegrated limestone carrying veinlets and clusters of oxidized ores of both zinc and lead, and sulphide ore of zinc. A prominent feature exhibited in these pinnacles is the occurrence of thin seams of calcite interlaminated with the bedding plane of the limestone.

PEACH ORCHARD MINE (56)

The only mine in active operation at the time of this investigation was Peach Orchard Mine, situated near the base of the southeastern slope of Bumpass Mountain and within half a mile of the southwestern end of the Cove.

The ore body is confined to a local structural depression or basin, in the Shady limestone, and is approximately 800 feet in length along the strike, which is N. 50° E., and 500 feet in width. The prevailing dip of the formation is at a low angle to the southeast, but within the ore body slumping has resulted in dislocation of the bedding.

The main level was established by driving two adits, one from near the southwestern end of the ore body and the second from the northeastern end, through the clay and disintegrated limestone to the northwestern limits of the basin. Drifts were run from these tunnels and the overhead ore was stoped out allowing the roof to cave. By means of this method most of the ore was recovered.

A similar system is used in the second level which is connected to the main level by an interior shaft 80 feet in depth.

Smithsonite, calamine, and cerussite occur in pockets and veinlets in the disintegrated limestone and clay, and where alteration is less advanced, sphalerite and galena are found. Production is limited to the oxidized ores which are loaded into cars on the main level and hauled to a tipple where, after sorting, they are placed into storage bins.

MILLING

The ore is concentrated in a 100-ton mill which is situated in the Cove below the Fowler Mine. After preliminary crushing, the ore passes through a series of log washers for removal of the clay. It is then ground in rolls, roasted in rotary kilns to produce a slight magnetism of the iron, and passed through magnetic separators which remove the iron. Final concentration of zinc and lead is effected by tabling. The concentrates average 42 percent. zinc and 62 percent. lead.

FUTURE PROSPECTS

The highest grade zinc and lead ore is not always contained in that portion of the clay overburden in which the greatest amount occurs; in fact, all of the clay in the Cove contains a considerable quantity of iron, but the areas from which pay ore of zinc and lead can be taken are rather limited. This fact has been proven by drilling and mining. Similarly, the sulphide ores are not uniformly distributed through the limestone but are encountered locally in masses of limited extent. It is reported that the Embree Iron Company has been actively engaged in systematic drilling during 1922 for the purpose of locating commerical bodies of sulphide ore.

FELKNOR MINE (57)

The Felknor mine is in Jefferson County, three miles southwest of Leadvale and the same distance south of White Pine, both of which places are stations on the Morristown and Paint Rock Branch of the Southern Railway.

The oldest record of mining activity at this locality dates back to the time of the Civil War when lead was mined, smelted, and cast into bullets which were used by Confederate troops. Since that time many attempts have been made to operate the mine, but all were of short duration.

The property is owned by the Felknor estate and controlled by A. M. Felknor, of Dandridge, Tennessee.

GEOLOGY

The ore body occurs in a faulted and brecciated horizon of limestone and dolomite near the top of the Knox formation. This horizon, where bedding has not been obscured by movement, consists of thick-bedded, bluish-gray, laminated limestone interbedded with fine-grained, gray dolomite. The strike is N. 38° E., and the dip is 10° SE.

MINERALS AND NATURE OF MINERALIZATION

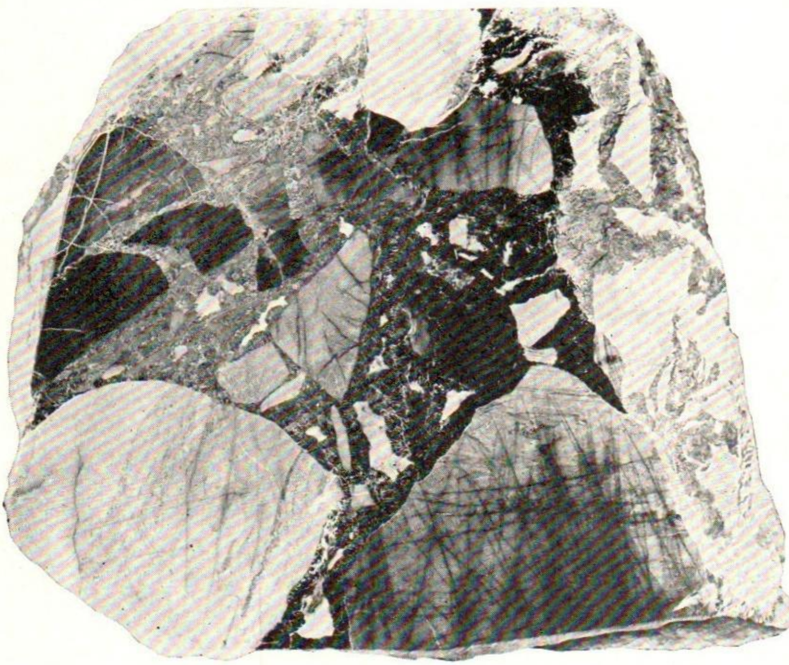
The ore consists of approximately equal amounts of sphalerite and galena deposited either in small veins which occasionally show banding, or in irregular openings of the breccia. The minerals are generally intermixed in such an intricate manner that concentration of the ore would give rise to milling complications.

Two types of ore occur: one is confined to fractures in the country rock and consists of veins of sphalerite and a dolomite-calcite gangue. The contact between the wall rock and the vein filling is sharp. Adjacent to the wall rock is sphalerite showing a regular zonal arrangement in which a dark-brown color adjacent to the wall rock suddenly grades into a reddish-brown, forming an intermediate zone, which is succeeded in turn by a narrow band of a light-brown color. The center of the vein consists of calcite and dolomite. The second type of ore consists of intermixed masses and veinlets of sphalerite, galena, small amounts of pyrite and chalcopyrite, dolomite, and calcite. This type is by far the more abundant and occurs throughout the visible extent of the brecciated country rock. Pyrite and chalcopyrite occur in so small a quantity that they need not be considered in concentrating the ore.

Microscopic examination of thin sections of the ore shows that the country rock is made up of fine-grained, anhedral crystals of both dolomite and calcite. Some recrystallization of the fine-grained material into coarse-grained dolomite and calcite is evident. Much of the non-metallic material of the rock consists of cryptocrystalline chert which forms masses of elongated shape in which occur scattered grains of both pyrite and quartz. Generally the edges of the chert masses are denoted by areas in which are abundant inclusions of dolomite-calcite remnants of the original country rock. All stages of country rock replacement by chert are to be seen.

Detached and scattered areas of sphalerite occur as replacements of both country rock and chert. The sphalerite areas are generally massive and are not disseminated throughout the country rock in small particles. By the manner in which pyrite-limonite veins conform to the irregular outline of the sphalerite masses, which they so frequently rim, it is evident that the iron solutions were of later age.

Sphalerite and galena are closely associated. At places the edges of the two minerals are so mutually interlocked, without invasion along cleavage cracks, that their contemporaneity of deposition seems indisputable. Again, small areas of sphalerite are entirely enclosed by galena and also, in several instances, small stringers of galena do apparently project into sphalerite along cleavage lines. Commonly the area of sphalerite adjacent to galena is marked by the presence of minute,



Polished specimen of ore from Felknor mine, showing breccia fragments of country rock cemented in a matrix of intergrown sphalerite and galena. Nat. size.

detached grains of galena which appear to be oriented roughly in a disconnected rim in advance of the main mass of that mineral—suggesting some replacement of sphalerite by galena.

The galena splendidly exhibits triangular pitting and innumerable small triangular depressions, which are spaced adjacent to each other and in continuous, straight or wavy lines, give at first glance a scrt of laminated appearance to the mineral. These triangular depressions are oriented in accordance with crystallographic directions.

Paragenesis

1. Country rock possibly followed by some recrystallization
2. Chert.
3. Sphalerite } in part contemporaneous.
4. Galena }
5. Pyrite.

The oxidized minerals, smithsonite, calamine, and cerussite, resulted from alteration of the sulphide ores. A certain amount of enrichment accompanied the alteration. Early mining was restricted to the clay overburden and the disintegrated country rock in which the oxidized ores were located. Along the main fault and in fractures considerable alteration of sulphides to oxides has occurred and in places extends deeper than the mine workings. However, such conditions are local and the average limit of the zone of oxidation is not more than 10 feet below the surface.

STRUCTURE

The beds dip at a low angle to the southeast forming a monocline which has been disturbed by a fault with horizontal displacement, as is shown by slickensides on the north wall of the tunnel. The fault plane is almost vertical and strikes N. 60° E. To the south of the fault very little brecciation of the country rock took place, but to the north it was intense gradually decreasing in intensity away from the fault. The brecciated zone paralleling the fault is approximately 150 feet in width, but mineralization is confined to only a half of that distance. Several minor breaks or joints, which strike N. 60° W., extend for short distances into the brecciated zone from the fault. Without exception, mineralization has been greatest where such breaks intersect the fault.

DEVELOPMENT

The development consists of a series of shallow pits and shafts sunk into the clay overburden and penetrating the country rock. Much of the intervening ground has been removed so that the entire area is an irregular open cut of lenticular shape extending north, east, and west from the main shaft.

The main shaft is 34 feet deep and was sunk with its north wall coinciding with the north wall of the fault. From the base of the shaft a tunnel was driven for a distance of approximately 65 feet in a N. 60° E. direction along the south side of the fault. At 40 feet from the mouth of the tunnel a N. 60° W. fracture was encountered and followed for about 30 feet. The underground workings were partly filled with water so that only a limited examination could be made. Examination of the walls of both the shaft and the tunnel revealed the presence of small, scattered masses of oxidized and sulphide ores.

A large pile of hand-sorted sulphide ore is located about 200 feet south of the mine. It is reported that most of this ore was mined from the tunnel. Much of it is of high grade and contains sphalerite and galena in the approximate ratio of 5:1.

FAIR GARDEN PROSPECT (58)

This prospect is about 1½ miles south of Fair Garden, in Sevier County, and about 8 miles east of Sevierville.

Zinc ores were first discovered in the rocks of this section in 1900 in a small open cut located one mile northeast of this prospect. At that time a Capt. Fry, of Shady Grove, Tennessee, was working the pit for barite and upon blasting out the hard country rock discovered that barite and zinc (sphalerite) were associated in the same vein.

Several other attempts were made to find zinc ores in the rocks in that locality, but without success. Early in 1922, however, W. E. Spence, of Sevierville, discovered sphalerite at this prospect and having observed that the trend, or strike, of the rocks was southwest, concluded that the horizon was the same as that exposed by Capt. Fry.

Mr. Spence, aided by several associates from Sevierville, decided to develop the property and made an open cut 42 feet long, 10 feet wide, and 15 feet deep at the face, into the rock in a S. 50° E. direction. This cut penetrated three narrow, mineralized horizons occurring in brecciated beds of the Knox dolomite.

The dolomite is fine-grained and black in color. The strike is N. 57° E. and the dip, 27° SE. Narrow brecciated horizons were produced by slipping of adjacent beds with a resulting crushing of the foot-walls, while the hanging wall remained unbroken and was separated from the foot-wall by a thin seam of gouge.

The first brecciated horizon was encountered three feet from the entrance of the open cut. It is one foot in thickness and contains a small quantity of sphalerite deposited in irregular masses as a breccia filling. The second horizon is five feet from the face of the open cut and is one foot in thickness. It also contains a small amount of ore. The third horizon, three feet in width, is exposed in the face of the open cut and contains a higher percentage of ore than the other two.

The following analysis, made of a relatively rich sample of ore taken from the third horizon, shows the chemical composition of the country rock as well as its mineral (zinc) content.

Analysis of ore from Fair Garden prospect

SiO_2	19.14%
ZnS	8.22
FeS_2	.36
Fe_2O_3	2.12
$A_{12}O_3$	2.14
$CaCO_3$	41.07
$MgCO_3$	26.84

Analysis by D. F. Farrar, chemist.

The ore, which in each horizon is limited to the crushed and brecciated rock, consists of angular fragments of country rock cemented in matrix of variable amounts of sphalerite and dolomite. The sphalerite occurs as small flakes and masses uniformly distributed through the matrix.

When viewed in thin section under the microscope the country rock is seen to consist of fine- to medium-grained, subhedral crystals of dolomite most of which have been discolored a dark-brown by invading solutions. Absorption and replacement of country rock by coarse-grained dolomite has taken place in irregular manner. Both country rock and dolomite, especially the former, have been invaded and replaced by cryptocrystalline chert which abounds in small quartz grains. Locally, the chert contains abundant remains of country rock and also possesses a flow-structure in which the longer axis of the remnants are parallel to the direction of flow. In this zone the chert is very dark-brown, due apparently to the greater abundance of oxidized pyrite.

Country rock, dolomite, and chert have been replaced by sphalerite. Frequently, a narrow seam of pyrite, or limonite, rims the sphalerite and has slightly invaded it along cleavage cracks. Parallel fractures within the sphalerite, filled with a medium-grained dolomite, indicate that movement subsequent to ore-mineral deposition took place.

Paragenesis

1. Country rock.
2. Dolomite.
3. Chert.
4. Sphalerite.
5. Pyrite.
6. Movement and dolomite.

PARAGENESIS OF THE ORES

In the absence of mineral-filled cavities in the ore deposits of the region, and because of the irregular distribution of both non-metallic and metallic minerals in veins and breccia fillings, no definite order of mineral deposition could be made out from megascopic observation.

Inspection of the several photographs made of polished surfaces of the ores shows that the minerals occur in all manner of relations to both country rock and each other. Either one or both sides of the dolomite in a fracture may be replaced by either sphalerite or the gangue minerals. At times sphalerite occurs consistently on one side of the fracture and next to the country rock in which case the filling presents a sort of banded appearance. Again, gangue dolomite and calcite are in contact with the walls and the sphalerite occurs in them as either small, disseminated masses or as ramifying, disconnected veinlets.

In the New Prospect and Felknor ores, galena and sphalerite are so closely intergrown that they must have been deposited contemporaneously.

Pyrite is rather widely distributed but generally in such finely disseminated grains that, without the aid of the microscope, it is not visible. When it is visible in the ore its manner of occurrence is similar to that of sphalerite.

Microscopic examination of thin sections of the ore yielded fuller information concerning the order of mineral deposition. The descriptions of those examinations are given in connection with the reports of the individual deposits so that only a summary of those observations need be given here. In general a rather definite order of deposition was established, viz:

1. Fine-grained country rock.
2. Gangue dolomite and calcite.
3. Chert.
4. Sphalerite } largely contemporaneous.
5. Galena }
6. Pyrite.
7. Dolomite, filling fractures.

No conclusive evidence was obtainable to show that any one mineral was deposited independently of the others. In fact, the evidence suggests that the periods of formation of the various minerals were overlapping and thus, in part at least, contemporanoues.

Deposition of the sulphides was closely associated with re-crystallization of the country rock to coarse-grained dolomite aggregates.

As a rule, sphalerite was formed slightly in advance of galena although in most cases the two minerals are so intimately intermixed that contemporaneous deposition is indicated.

Pyrite formed earlier than sphalerite and galena has not been extensively noted. At times the fine-grained country rock is impregnated in such a manner with minute grains of pyrite that the mineral is considered to have been an original constituent of the rock. But in the great majority of cases, the relation of pyrite to the other minerals in its manner of occurring in the interstices of adjacent minerals and showing a greater affinity for the non-metallics, especially chert, and also its tendency to rim masses of sphalerite and galena and slightly replace them along cleavage cracks indicates that it was the last ore mineral to be deposited.

In many of the sections a dark-brown or dull-black material, generally associated with pyrite, was observed. It is more prevalent in the chert areas. The material has been called limonite, but the identifications were not at all times conclusive. Some of the material may be a hydrocarbon compound which has been brought in by the mineral-bearing solutions.

CHEMISTRY OF THE ORES

In accordance with the explanation of the genesis of the East Tennessee zinc ores set forth in this report, the metallic content of the ore deposits has been taken into solution at least twice. First, the rocks of the old continent of Appalachia must have had a zinc and lead content in some form or other, as original constituents of igneous rocks or as epigenetic disseminations or veins. This metallic content was oxidized, dissolved, and carried down into the Appalachian sea and deposited in the sulphide form minutely disseminated through the Cambro-Ordovician strata. Second, the minute zinc sulphide content of the Cambro-Ordovician rocks was again dissolved, transported to points favorable to deposition, and concentrated to form the ore deposits.

An attempt will be made to describes briefly the solution, transportation, and redeposition of these sulphides.

SOLUTION AND TRANSPORTATION

Solution and transfer of the metals takes place in varying ways under varying conditions among which the nature of the circulating waters is of great importance. In the zone of oxidation the sulphides of the metals coming into contact with air or oxidizing solutions are changed to sulphates according to the following reactions:

$$ZnS+4O=ZnSO_4$$
$$PbS+4O=PbSO_4$$
$$FeS_2+7O+H_2O=FeSO_4+H_2SO_4$$

It is probable that the formation of sulphates is restricted to depths but slightly in excess of the ground-water level. At greater depths, on coming into contact with an underground circulation carrying earthy bicarbonates, organic matter, carbon dioxide, and hydrogen sulphide, the sulphates react with the earthy carbonates or bicarbonates to form zinc carbonate. In the presence of an excess of carbon dioxide the zinc bicarbonate is retained in solution.

The underground circulation will carry more or less carbon dioxide. This carbon dioxide is in part brought down by the meteoric waters themselves and in part is generated by sulphuric acid, formed through the oxidation of iron sulphides with which the oxygenated waters come in contact, acting on the carbonate rocks through which these waters circulate. As such carbon dioxide-laden, or carbonic acid, waters circulate through the rocks they take into solution the sulphides of the disseminated metals in accordance with the following reactions:

$$ZnS+CO_2+H_2O=ZnCO_3+H_2S$$
$$PbS+CO_2+H_2O=PbCO_3+H_2S$$

or

$$ZnS+{}_2CO_2+2H_2O=Zn(HCO_3)_2+H_2S$$
$$PbS+{}_2CO_2+2H_2O+Pb(HCO_3)_2+H_2S$$

With an excess of carbon dioxide the more soluble bicarbonates of zinc and lead are formed and retained in solution. The excess of carbon dioxide also prevents the redeposition of the sulphides by the hydrogen sulphide. The latter is carried along in solution until such time as conditions are favorable to the loss of carbon dioxide when this inhibition is removed and the sulphide is again precipitated.

DEPOSITION

Many precipitants have been involved in transforming the zinc sulphate or bicarbonate back into the sulphide. Among the possibilities are hydrogen sulphide, organic matter, and iron sulphide. The most effective of these is probably hydrogen sulphide. The reactions are as follows:

$$ZnSO_4 + H_2S = ZnS + H_2SO_4$$
$$ZnCO_3 + H_2S = ZnS + H_2O + CO_2$$

The formation of carbonates and bicarbonates of the metals by the action of carbonic acid (H_2CO_3) upon the sulphides releases hydrogen sulphide. The hydrogen sulphide is taken into solution and, together with the solutions of the metals, is carried along in the underground circulation until pressure is diminished as in approaching the surface. There the carbon dioxide escapes and hydrogen sulphide is again free to precipitate the metals as sulphides.

Pure carbon is chemically inactive at ordinary temperatures, but hydrocarbon compounds which arise from the decay of organic matter do precipitate metallic sulphides. Natural waters containing metallic sulphates also carry sulphates of the alkaline earths. It has been demonstrated experimentally that the latter are reduced by these hydrocarbons to sulphides and the sulphides decomposed with the liberation of hydrogen sulphide in accordance with the following reactions:

$$CaSO_4 + CH_4 = CaS + CO_2 + 2H_2O$$
$$CaS + CO_2 + H_2O = CaCO_3 + H_2S$$

From which facts Siebenthal[1] rightly concludes that whether or not the sulphates of the metals are reducible to sulphides by organic matter is immaterial because decomposable organic matter will cause the formation of hydrogen sulphide concerning the ability of which to precipitate metallic sulphides from solutions there is no question.

No definite relation between the sulphide deposits and organic matter could be made out although in several of the mines, notably at Fall Branch and certain parts of the Mascot mine, the two appeared in close association. Hence organic matter may have been a factor in the precipitation of the ores, but it certainly was not an important factor in most cases.

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[1]Siebenthal, C. E., Origin of the zinc and lead deposits of the Joplin region: U. S. Geol. Survey, Bull. 606, pp. 62-64, 1916.

Purdue[1] is of the opinion that the most common precipitating agent of the zinc carried in the mineralizing solutions was iron sulphide. This will precipitate zinc sulphide from either the sulphate or carbonate forms. The reactions may be written as follows:

$$ZnSO_4+FeS_2+2O=ZnS+FeSO_4+SO_2$$
$$ZnCO_3+FeS_2+2O=ZnS+FeCO_3+SO_2$$

There is no evidence in the case of the Tennessee deposits to warrant the consideration of iron sulphide as an important precipitating agent. When iron sulphide has played such a role on a large scale there are generally pseudomorphs of spha'erite after pyrite. No such pseudomorphs were observed. Furthermore the paragenesis of the ores shows that the little pyrite they now contain is for the most part later than the zinc and lead sulphides, and there are no remnants of an earlier generation of iron sulphide that has been largely used up in the precipitation of the other sulphides.

It is concluded, therefore, that hydrogen sulphide was the most active agent in precipitating the sphalerite in the Tennessee zinc deposits. The only adequate source of that hydrogen sulphide could have been the minute, widely disseminated zinc sulphide content of the country rock itself. The amount of hydrogen sulphide available is thus directly equivalent to the amount of the metals taken into solution. Both the metals and the hydrogen sulphide were carried along in the same waters but were prevented from reacting by the presence of carbon dioxide. As the waters approached the surface and entered more open circulation channels, carbon dioxide was liberated, the zinc and sulphur recombined, and sphalerite was again precipitated.

[1]Purdue, A. H., The zinc deposits of northeastern Tennessee: Tenn. Geol. Survey Bull. 14, p. 17, 1912.

GENESIS OF THE ORES

Purdue[1] calls attention to the fact that the structural conditions are as favorable for the occurrence of zinc in formations of the area other than the Knox dolomite as they are in the Knox dolomite itself. But in view of the fact that no other formations (at that time) were known to contain ore he concludes that the zinc was deposited originally in finely disseminated particles at rather definite horizons in the Knox formation, and was later concentrated into workable deposits by ground-water moving along zones of fracturing that resulted from crustal movement. He states that the meteoric waters took the disseminated zinc particles in solution, carried the zinc downward, and later precipitated it as sulphide, carbonate, or silicate.

However, he does not believe that all the concentration of the ores took place by downward movement of water. In the concentration process he states that the ground-water carrying the solutions may have flowed laterally, upward or downward, depending upon the head under which it moved. In this respect he follows in part the theory of Van Hise for the movements of mineral-bearing, circulating ground-waters.

To summarize, Purdue employs a combination by both downward and upward moving waters, chiefly the former, to account for the ocalization of the ores.

Watson's[2] theory, which is based on the zinc deposits of the adjoining Virginia region, also starts out with the assumption of widely disseminated zinc particles in the country rock of the zinc deposits. The zinc, together with the other constituents of those rocks, was derived from the Appalachian land mass and deposited in the early Paleozoic sea.

He believes that the underground water circulation dissolved the disseminated zinc particles, carried them in solution into trunk channels of free circulation where they were again precipitated as sulphides. The precipitation was caused by contact with organic matter of the country rock or by mingling of solutions of different compositions.

The ore forms replacement deposits and cavity fillings in breccia and are associated with dolomite and calcite as gangue minerals. In a few deposits very small amounts of fluorite have been found.

HYPOTHESIS OF THE ORIGIN OF THE ZINC AND LEAD ORES

The hypothesis of the origin of the zinc and lead ores of the Valley region of East Tennessee set forth in this report assumes that the ores

[1]Purdue, A. H., The zinc deposits of northeastern Tennessee: Tenn. Geol. Survey Bull. 14, pp. 15-23, 1912.

[2]Watson, T. L., Lead and zinc deposits of Virginia: Va. Geol. Survey, Bull. 1, pp. 128-133, 1905.

existed originally as more or less finely disseminated particles in the pre-Cambrian igneous rocks which constituted the land mass, Appalachia, situated to the east and southeast of the Valley, and from which were derived the sediments which were laid down in the sea bottom to form the succeeding rocks, ranging in age from Cambrian to late Carboniferous. The metallic compounds of those igneous rocks were leached by the ordinary processes of weathering, were carried into the sea, and were there deposited contemporaneously with the sediments in finely disseminated form.

The immediate source of the ores is considered to be largely in the Knox dolomite though to some extent in the underlying calcareous formations. Upon the establishment of an underground circulation in these strata, the finely disseminated sulphides of the Paleozoic beds were dissolved, transported to loci of precipitation, and there concentrated into the ore deposits. The waters which brought about this concentration circulated under temperatures and pressures not much higher than those of the surface. The complex structure of the region, due to faulting, permitted circulations of only limited extent both vertically and horizontally and no well-defined horizons of circulation can be postulated. The localization of the deposits in the Knox dolomite resulted from the combination of chemical and physical environment especially favorable to their deposition.

THE UNDERGROUND CIRCULATION

The general geologic and structural features of East Tennessee have already been described. It has been shown that the area is one of intense folding and faulting in which a general southeast dip of the rocks prevails. Though faulting does not necessarily destroy circulation over wide areas, it does render such circulation improbable. The structural conditions are consequently unfavorable to the development of extensive regional underground circulation and each structural unit must be considered as an area unto itself with its own underground circulation.

It has been shown by Van Hise[1] that the complex movements of underground water may be resolved into two components, a horizontal or lateral movement, and a vertical movement. Meteoric water sinks into the ground by gravity and by circuitous routes which follow along the openings and pore spaces in the rocks becomes involved in the general underground circulation. This circulation moves from areas of high pressure to those of lower pressure. In regions such as the one under discussion the circulating waters flow toward and concentrate in the larger openings and other channels of free circulation such as brecciated horizons, fault- and joint-planes, etc., which are in reality areas of lower pressure. Each structural unit of the region might have developed within itself such a circulation, irrespective of its area ex-

[1]Van Hise, C. R., A treatise on metamorphism: U. S. Geol. Survey, Mono. 47, pp. 572-576, 1904.

tent, whether large or small. Where anticlines occur, such as in the Mascot-New Market area and the Powell River anticline, conditions are favorable for a greater than average convergence of the circulation and such areas should be especially favorable loci of ore deposition.

THE WORK OF UNDERGROUND WATERS

The chemistry of the work of underground waters has been discussed. Meteoric waters dissolve oxygen, carbon dioxide, and other constituents from the air. On entering the ground they take into solution, more or less mineral matter depending upon the solubility of the materials with which they come into contact. Limestone is one of the most soluble of rocks. As the waters descend and temperature and pressure increase, their dissolving power increases. Such waters, passing through minute pore spaces, dissolve out a portion of the mineral matter contained therein. In this manner the zinc, lead, and iron, which occur in finely disseminated particles, are taken into solution. As the waters migrate onward in the underground circulation the saturation point is reached and solution ceases. Then comes a point in the course of the circulation when the upward component prevails. Pressure then decreases and precipitation commences. Precipitation is dependant largely upon three conditions, viz.: (1) decrease in temperature; (2) decrease in pressure; and (3) chemical reactions. In view of the fact that ascending currents are moving from high to low pressure areas the first two conditions are satisfied more and more fully as open ground is approached. Decreasing temperature and pressure are important factors in bringing about precipitation. The mingling of the ore-bearing solutions with other solutions and especially the ore-bearing solutions coming in contact with the wall rock are likewise of extreme importance in producing precipitation. In some localities the country rock contains an appreciable amount of organic matter, where zinc deposits are now found. In such cases the location of the deposits is in large part connected with precipitation resulting from reactions between the mineral-bearing solutions and the organic matter.

PHYSICAL FACTORS OF ORE DEPOSITION

Ore precipitation and concentration are due to both chemical and physical causes, and of these, especially in the region under discussion, the latter are considered to be of equal importance with the former. The physical causes include not only those conditions which direct the course of the underground circulation, but more especially those which prevail immediately at the point of deposition of the ores.

As has been pointed out above, the ore bodies are intimately associated with folds, faults, and brecciated beds, that is, the concentration of the ores took place not where chemical conditions alone were favorable but where the physical conditions likewise were especially suitable.

That the physical factor of brecciation has been very important is evident from the fact that in practically all instances the ore deposits are located in brecciated horizons.

PROCESS OF CONCENTRATION

No large scale tests of the dolomite and limestone have been made to prove the presence of extremely small quantities of zinc in the Knox dolomite away from the present localized deposits so that their presence can only be inferred. In other zinc and lead districts analyses of the rocks have been made which show the presence of extremely minute quantities of the metals. According to analyses made by J. D. Robertson of Cambrian and Ordovician dolomites in Missouri[1], the average zinc content was 0.00425 per cent. In Wisconsin, Grant[2] quotes an estimate "of the amount of impregnation that would occur if the entire quantity of ore taken from the Potosi district were uniformly distributed through the adjacent rock." The result was one fourteenth-hundredth of one per cent., or a little more than seven-millionths part of the rock.

From the above figures it is reasonable to assume that if the relatively small quantity of ore now concentrated into deposits in East Tennessee were evenly distributed through the rocks in a finely disseminated state, it would escape detection in the ordinary methods of analysis.

The presence of zinc and lead in the Shady limestone and the dolomite bed of the Rome formation, both of lower Cambrian age, indicates that these metals were deposited contemporaneously with the formation of these rocks and later concentrated into the present deposits. Several limestone horizons intervene between the Rome formation and the Knox dolomite so that the question arises as to why ore deposits are not found in them. The writer refers to the physical factors which have been shown to govern the localization of deposits in this region. At no place, during the field investigation, were the intervening limestone beds observed to be brecciated; but in all cases they were extremely compact. It is held that the absence of favorable physical conditions in large measure prevented the circulation of ore-depositing solutions in them. The deposits in the Evanston district are not associated with any great amount of brecciation, but they do occur in a country rock that has been extensively jointed and is overlain by a relatively impervious shale. The localization, in all cases, of the deposits near the top of the limestone and under the shale strongly indicates their deposition from ascending solutions.

The Embreeville deposit is an exception to the general rule. As treated in detail under the description of that district, the structural features there lead to the conclusion that descending solutions oxidized and concentrated the ores from sulphides originally disseminated in the country ores.

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[1]Winslow, Arthur, Lead and zinc deposits: Mo. Geol. Survey, vol. 7, p. 480, 1894.
[2]Grant, U. S., Lead and zinc deposits of Wisconsin: Wisc. Geol. and Nat. History Survey, Bull. 14, p. 78, 1906.

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PRACTICAL SUGGESTIONS TO GUIDE FUTURE PROSPECTING

Mining operations thus far have shown that the zinc deposits of East Tennessee are confined to several horizons in the Knox dolomite. There are two exceptions, namely: the oxidized zinc and lead ores occurring in the Shady limestone formation near Embreeville, and the several small non-commercial deposits occurring in the limestone member of the Rome formation near Evanston, Hancock County.

Within the Knox dolomite the ore bodies are irregularly distributed so that one cannot forecast in what localities new deposits may be found. In practically all cases the ores are associated with brecciated horizons of the dolomite. But it does not necessarily follow that a brecciated bed will contain ore, nor, conversely, that all ore deposits that will be discovered in the future will be found in brecciated horizons.

The ore bodies so far discovered occur in general at two distinct horizons: the one at an average stratigraphic level of from 500 feet to 1,000 feet below the top of the Knox dolomite, and the other near the base of that formation. The former horizon is that of the Mascot ore zone and the latter that of the New Prospect group. These two horizons have a rather well-defined geographic position in the East Tennessee Valley, as shown on the geologic map. Ore deposits in the upper horizon have thus far been found at scattered localities in the eastern and central part of the Valley from its extreme southern to its northern limits. But mineralization at this level appears to have been more pronounced in the northern half of the Valley.

The Copper Ridge district has thus far been the fartherest point west at which ore deposits have been found in the upper horizon.

The lower or New Prospect horizon is of less extent geographically and seems to be limited to the northwestern part of the Valley, extending from New Prospect eastward to Tazewell.

Future prospecting should be carried on with the general geographic distribution of these two horizons and of the maximum known mineralization within them taken into consideration.

The frequent localization of ore bodies along faults is worthy of consideration in prospecting. Faults are not easy to recognize in the Valley limestone, particularly where the displacement is restricted to a single formation, as is so frequently the case in the Knox dolomite. It is advisable that the prospector provide himself with geological maps of the area to be investigated and thereby become acquainted with the location of the faults. It must not be inferred that ore deposits accompany all faults, for many carry no ore at all, and none of considerable size carry ore throughout their extent. The occurrence of ore at any point in or near a fault does not mean that it will be found at all other points along the same fault. Some ore deposits are associated with faults which are not shown on the geologic maps, for example, New Prospect, Fall Branch, and Felknor Mine, so that the prospector should also be on the lookout or faults that are not mapped.

In those areas in East Tennessee where a mantle of clay overlies the unaltered rock, outcrops are either very infrequent or lacking. It is in this clay overburden that most of the oxidized ores, especially smithsonite, occur. Practically all of the districts which have had a production of ore first mined the smithsonite from the clay and on working down eventually discovered the deposits of sulphide ore in the unaltered rock below. Accordingly, in following the general direction, or strike, of an ore body, careful examination of the clay should be made to determine the presence of smithsonite, and when found the clay should be penetrated to determine whether a sulphide ore body occurs in the unaltered, underlying rock.

The oxidized ores are generally localized and concentrated in pockets in the clay and at only shallow depths below the surface. The limestone weathers with extreme irregularity and below the clay presents a roughened surface of alternating pinnacles and saddles. The oxidized ores are chiefly concentrated in the depressions, or saddles, between adjacent pinnacles, but often extend some distance up their sides, and occasionally pass over the pinnacles.

It has been found in the larger oxidized ore mines, namely, Embreeville and Grasselli, that rich streaks or pockets of oxidized ore frequently continue for considerable distances into the partly altered country rock which forms the pinnacles. High recoveries of ore occurring in this manner have been made by sinking a small shaft through the base of the saddle until the unaltered country rock is met. Tunnelling out from the sides and base of this shaft makes it possible to recover most of the ore.

In prospecting for sphalerite it is advisable to examine such places where outcrops of the unaltered country rock occur, as ledges exposed in stream beds or on adjacent slopes. If sphalerite is discovered in brecciated beds of dolomite, the continuation of the mineralized horizon can be determined by observing the strike and dip of the strata and by the aid of them tracing out the position of the brecciated horizon beyond the outcrops. If the sphalerite is associated with a fault, the determination of the direction of the fault will serve in the same way to aid in following the ore body beyond the visible outcrops. It is also important to observe whether the ore occurs in beds on one or on both sides of the fault.

Various methods of prospecting to determine the size of the ore body have been followed. The earliest and most widely used, but most unsatisfactory method, was open quarrying or sinking of shallow pits. Far more satisfactory results have been obtained by the use of churn and diamond drills. By this method both the horizontal and vertical extent of the sulphide deposits may be determined with a degree of accuracy dependent upon the spacing of the drill holes.

The American Zinc Company has relied entirely upon churn and diamond drills to determine and "block out" in advance their ore body. In intensive drilling it is possible to locate and determine the extent of the more richly mineralized portions of the ore body and thus restrict underground mining to those areas. As has been pointed out previously, the ore bodies are distributed very irregularly within the mineralized horizons, so that low-grade or barren areas alternate with the higher grade areas. It is evident that a pre-determination of the distribution of the workable ore shoots is essential to laying out the most practical system of mining and to efficiency of mining operations.

In conclusion it is believed that efficient prospecting with the drill will reveal additional ore bodies if the above described geologic features of the occurrence and distribution of the zinc deposits of East Tennessee be kept in mind.

The average zinc content, about 3¼ per cent., of the Mascot ores may be taken as indicative of what is to be expected in the larger ore bodies of the region. Consequently prospecting should be carried on with large scale operations in view.