GEOLOGIC PROBLEMS IN THE
SWEETWATER BARITE DISTRICT, TENNESSEE*

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ABSTRACT. Residual barite deposits, derived from vein and breccia fillings in carbonate rocks of Ordovician age have been mined extensively in three parallel strike belts near Sweetwater, Tennessee. Geologic problems germane to the further exploitation of this mineral resource include the origin and age of the primary deposits and the breccias which contain them; relation of the barite deposits to zinc deposits of East Tennessee; weathering of the carbonate rocks, including accumulation of the residual mantle; solution, transportation, and deposition of barite, fluorite, and silica; and the extent of ancient terrace deposits. The district presents a promising field for coordinated research in economic geology, geochemistry, geophysics and geomorphology.

INTRODUCTION

Barite occurs at many localities in the Valley and Ridge physiographic province from Pennsylvania to Alabama; most of the commercial production, however, has come from two major districts—Cartersville, Georgia and Sweetwater, Tennessee, with minor production from many scattered districts and localities.

Barite in Tennessee was first reported in 1818 (Kain, 1818, p. 63) from Sevier County, but the earliest commercial production in the state appears to have been about 1870 from the Sweetwater district (Gordon, 1918, p. 72). However, galena, with barite and fluorite which were discarded as gangue minerals, was mined at the Carter mine, three miles east of Sweetwater, as early as 1826 (Safford, 1869, p. 485).

The Sweetwater district (fig. 1) is between the Tennessee and Hiwassee Rivers, in Monroe, McMinn, Loudon and Roane Counties, Tennessee, about half way between the cities of Knoxville and Chattanooga, and about 50 miles southwest of the Mascot-Jefferson City zinc district. The district is traversed

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by U. S. Highway 11 and a main line of the Southern Railway System. Although early records are incomplete, it is reasonably certain that about one and a half million tons of barite were shipped from the Sweetwater district between 1870 and 1959 and that approximately half of this total came from the Stephens mine in the southeastern part of the district.

The earliest report of barite production in the Sweetwater district was by Killebrew and Safford (1874, p. 270). Curiously, no mention is made of the barite deposits in the Kingston and Loudon folios (Hayes, 1894; Keith, 1896), although most of the district is in these two quadrangles. Probably this omission resulted from the fact that the district was almost completely unproductive between 1875 and 1899 (Gordon, 1918, p. 72). Other early descriptions of the district were by Judd (1907), Fay (1909), Henegar (1912), Grasty (1913), and Watson and Grasty (1915), but most of these were more concerned with mining and milling methods than with geology or exploration.

In 1918 Gordon published a paper which summarized the geology of the district and included descriptions of 22 mines and prospects. This report remains the most complete geological report on the barite deposits of the Sweetwater district. Later papers, dealing chiefly with the origin and structural control of the primary deposits, were those of Secrist (1924), Laurence (1939), Dunlap (1945, 1955) and Kesler (1950). Penhallegon (1938), Rankin and others (1938) and Gildersleeve (1946) described mining and concentration, with brief descriptions of the deposits. Part of the district was mapped geologically by Rodgers (1952, 1952a), who also provided a brief description of the barite deposits in one of the quadrangles (1952). The most recent publication is a brief summary by Brobst (1958). Exploration for zinc sulfide deposits was carried on by two mining companies in the early 1950's, and at least two companies have recently done some systematic exploration for residual barite deposits, but the results of these projects have not been made public.

GEOL OGY OF THE DISTRICT

The Sweetwater district is underlain by more than 7,000 feet of sedimentary rocks of Lower Cambrian to Middle Ordovician age, which have been folded and faulted so that they are in several separate outcrop belts (Rodgers, 1952). The barite deposits are in the Knox group, which has been subdivided as shown in table 1 (Rodgers, 1952; Dunlap, 1947):

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Formations of the Knox group</th>
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<td></td>
<td>Formations</td>
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<tr>
<td>Lower Ordovician</td>
<td>Mascot dolomite</td>
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<tr>
<td></td>
<td>Kingsport formation</td>
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<tr>
<td></td>
<td>Upper member (dolomite)</td>
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<td></td>
<td>Lower member (limestone)</td>
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<td>Longview dolomite</td>
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<td>Chepultepec dolomite</td>
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<tr>
<td>Upper Cambrian</td>
<td>Copper Ridge dolomite</td>
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With few exceptions, these formations strike northeast and dip less than 30 degrees to the southeast; they form several blocks separated by low-angle thrust faults which dip to the southeast. These faults, whose traces traverse the district from northeast to southwest, are major structural features which extend far beyond the district (Rodgers, 1953). From southeast to northwest, the major thrust faults are the Chesteeue, Knoxville, Saltville, Beaver Valley, and Copper Creek. Their relationship to the major subdivisions of the Sweetwater barite district is shown diagrammatically in figure 2.

Fig. 2. Diagrammatic cross section of the Sweetwater barite district.

The barite deposits occur in three linear belts, mainly along the outcrop of the Kingsport formation. Gordon (1918, p. 55) called these areas the Howard, Garrison, and Culveyhouse veins but now they are commonly known as the eastern, central, and western belts. The northern part of the western belt forks to form two belts, due to repetition of the Kingsport formation by a minor fault associated with the Beaver Valley thrust fault. Between the eastern and central belts is another outcrop belt of the Kingsport formation, which is not known to contain any barite deposits and is therefore called the barren belt. There are also four belts of the Kingsport formation to the southeast and four to the northwest of the district; only a few minor barite prospects are known in those to the southeast and none at all in those to the northwest.

The rocks of the district have been subjected to weathering and erosion since the close of the Paleozoic era, and this has produced the typical features of the Knoxville-Chattanooga segment of the southern section of the Valley and Ridge physiographic province (Fenneman, 1938, p. 271-272). These are two prominent levels, the upper one (Harrishburg peneplain) at 1,200 to 1,400 feet above sea level on ridges held up by cherty dolomites and sandy shales, and the lower one (Coosa peneplain), which lies at an elevation of 800 to 900 feet in the alluviated valleys underlain by non-cherty limestones and calcareous
Geologic Problems in the Sweetwater Barite District, Tennessee

shales. Throughout much of the area of carbonate rocks, bedrock is covered by residuum, which ranges from a few feet to more than 150 feet thick, and natural exposures, especially of the Knox group, are relatively scarce. Evidence of old, high-level alluvial terraces is seen in the presence of scattered cobbles of quartzite and vein quartz derived from Cambrian and Precambrian rocks of the Blue Ridge province.

THE BARITE DEPOSITS

All commercial production from the Sweetwater district has been from residual deposits, but primary deposits are exposed in the bedrock in the deeper parts of several of the mines. In fact, no mine which has been worked down to bedrock has failed to expose primary deposits. These occur as veins in intensely brecciated beds of dolomitized limestone, similar to the well-known "recrystalline" of the Mascot-Jefferson City zinc district (Oder and Hook, 1950, p. 75-81). No large, persistent veins are known. Generally only a few inches in width, the veins commonly expand at intersections into large, irregularly shaped masses, and elsewhere thin into mere stringers. The contact between vein and wall rock is commonly sharp. The principal minerals of the veins are barite, fluorite, and pyrite, with minor galena, sphalerite, and calcite. Fluorite and galena are apparently more common in the eastern belt and the northern part of the western belt, but this may be simply the result of better exposures in those places. A large unmined zinc deposit occurs at Eve Mills, at the northeastern end of the eastern belt (Dunlap, 1947).

Almost all the exposed deposits are in the limestone member of the Kingsport formation, and most of the residual deposits are in residuum derived from that member. Table 2 shows the stratigraphic distribution of 112 mines and prospects, partly from data by Rodgers (1952) and an unpublished manuscript by J. C. Dunlap. It should be noted that these deposits are in the residuum of the formation indicated.

| Table 2 |
| Stratigraphic distribution of barite deposits |
| Formation | Eastern Belt | Central Belt | Western Belt |
| Mascot | 6 | 4 | 7 |
| Kingsport (upper member) | 8 | 6 | 6 |
| Kingsport (lower member) | 44 | 4 | 12 |
| Longview | 3 | 1 | 3 |
| Chepultepec | 4 | 0 | 0 |
| Copper Ridge | 0 | 0 | 0 |

The residual deposits consist of nodules and larger masses of barite, chert and limonite in reddish or yellow clay. Individual masses or "dornicks" of barite may measure as much as two feet in the longest dimension, although they are commonly less than six inches long. Barite-bearing clay may crop out at the surface, but it is ordinarily concealed, especially in the eastern belt, by a relatively thin cover of barren clay. The barren overburden ranges up to
about 15 feet thick. The greatest depth to which barite-bearing clay has been found is more than 100 feet, at the Stephens mine. In most mines, barite lumps are scattered irregularly through the clay, but in some they are aligned along the vestigial bedding. In the eastern belt the ratio of clay and chert to barite (by weight) is about 7 to 1; in the central and western belts it is about 16 to 1.

**GEOLOGIC PROBLEMS**

Although the Sweetwater barite deposits have been exploited for more than 80 years, they present many as yet unresolved geologic problems whose solution is important to further economic development of the area.

*Origin and age.*—It has generally been considered that the primary deposits are of hydrothermal origin and that the breccias in which they occur are of tectonic origin and of Appalachian age, the deposits thereby being late Paleozoic or post-Paleozoic in age. Most geologists would include these deposits in the “Mississippi Valley type.”

Barite deposits occur at intervals along the strike of the Kingsport formation in the three belts, but primary deposits in bedrock are exposed only where residual deposits have been mined. They occur over a greater strike length in the central and western belts than in the eastern belt. Because of the limited exposures, it is difficult to ascertain the structural setting of the deposits. Dunlap (1945), by detailed mapping of exposures at the top of the Mascot dolomite and in the overlying Chickamauga limestone, demonstrated the presence of minor flexures trending northwestward, about normal to the regional strike, and as the axes of some of these flexures, projected from the exposed areas across the covered portion of the barite belts, passed through or near barite deposits, he concluded that they were responsible for the brecciation and thus controlled localization of the barite. This is the best interpretation of the structural control of the deposits that has been offered. These cross-folds are a ubiquitous feature of the outcrop belts of the Knox group, both in and beyond the Sweetwater district. It is the writer’s opinion that they represent minor warping which took place at the close of Mascot time, when the Knox group was uplifted and subjected to weathering, before being submerged by the Chazy sea.

Minor angular unconformity between the Knox group and the overlying formations, though not detectable in any single exposure, was noted by the writer (unpublished TVA report) in a section constructed from closely-spaced drill holes at Douglas Dam, Sevier County, Tennessee, and by J. M. Kellberg (unpublished TVA report) in a similar section of an area near South Holston Dam in Sullivan County, Tennessee. Oder (1958, p. 53) mentions a similar situation in the Mascot-Jefferson City zinc district, Kendall (1958) has presented evidence which led him to conclude that some of the zinc deposits in the Kingsport formation at Jefferson City may have been deposited in breccias which are primary sedimentary structures. Thus, although direct evidence from the Sweetwater district is not available, there is a possibility that the minor flexures and the breccias are of Ordovician rather than late Paleozoic or post-Paleozoic age. Similarly, the barite deposits could be as old as Middle Ordovician. Unfortunately, the scanty exposures and the absence of underground
workings do not permit detailed study of the bedrock structures, and the answer to this problem may have to come chiefly from analogy with the zinc district.

There is general agreement that the residual deposits are the insoluble material left behind after removal of the soluble carbonates of the Knox group. The process by which the deposits were formed, however, was probably not a simple enrichment by removal of soluble matter; there was apparently solution, transportation and redeposition of the less soluble constituents, barite, fluorite and silica. One evidence of this is that both barite and chert occur in the residuum in much larger masses than have been seen in the bedrock. Adequate quantitative data are not available to establish the correct volumetric ratio between insoluble content of the bedrock and of the resulting residual deposits, but it appears that in many mines there may be more barite in the residuum than was available in the rock that was weathered to yield the residuum. Concentration by simple removal of soluble content should, especially in the areas of less than 15-degree dip, result in a wide scattering of barite in the residuum of the older, underlying formations. Yet in all mines which have been worked down to bedrock, residual deposits are concentrated directly above primary bedrock deposits, usually in the sub-outcrop of the lower member of the Kingsport formation, and a line drawn on the map through the stratigraphically lowest mines would coincide almost exactly with the trace of the Kingsport-Longview contact, except at places like the Stephens mine where there are prominent cross-folds. Unfortunately no bedrock is exposed at the deposits which are in residuum of the Longview and Chepultepec formations and it is not known whether they rest on primary deposits at the sub-outcrop, or were derived from deposits in the Kingsport formation which formerly overlay the area.

Removal of fluorite.—As a corollary of the situation just discussed is another problem, what became of the fluorite during weathering? Fluorite is a relatively insoluble mineral; in the Kenucky-Illinois fluorspar district residual fluorite, known as “gravel spar”, has been an important commercial product, overlying the unweathered portions of the veins (Sutton, 1953, p. 143). Yet, in the Sweetwater district, fluorite, which is present in practically all exposed bedrock deposits, is not present in the shallower parts of the ore bodies. When fluorite begins to appear in the washer product, the mine operator recognizes it as a sign that the mine is approaching bedrock. Why did solution remove fluorite and not barite, and where did the fluorite go?

Relation to zinc deposits.—Deposits of barite and sphalerite occur in carbonate rocks—especially the Kingsport and Shady formations—throughout the Appalachian Valley, and although most deposits of one of these minerals contain the other, deposits containing commercial amounts of both are not known. The Eve Mills zinc deposit (Secrist, 1924, p. 130-133; Dunlap, 1947) which contains very little barite and fluorite, is directly along strike from and adjacent to the eastern belt, but seems to be entirely separate from it. The barite deposits of the Sweetwater district are closely similar to the Mascot-Jefferson City zinc deposits in structural and stratigraphic position. However, these two
types of mineralization do not appear to represent related zones of one mineral district (Laurence, 1939, p. 197-198), although that has been suggested (Behre, 1950, p. 38; Ohle, 1959, p. 773). Too little is known about the occurrence and distribution of the sulfide minerals in the Sweetwater district to permit any definite conclusions at this time about zoning within the district. Much more must be known about the occurrence and distribution of barite and fluorite beneath the residual deposits before their relation to the zinc deposits can be established. It is the writer's opinion that the two events—deposition of barite and fluorite at Sweetwater and deposition of sphalerite at Mascot-Jefferson City, may be entirely unrelated; the similarity results from the fact that the processes were similar and that both found favorable conditions in the same type of host rocks.

Physiographic position of barite deposits.—Barite mines occur at various elevations ranging from 760 feet above sea level near the Tennessee River at the northern end of the district and near the Hiwassee River at the southwestern end, to 1,100 feet in the middle portion of the district. They may be at or slightly above the alluviated bottoms of the Coosa level, or they may be only slightly below the upland (Harrisesburg) level. However, many of the largest mines, including the Stephens which has produced at least half of the district's output, are in the middle part of the belt, near the divide between the Hiwassee and Tennessee Rivers and on or near divides from which drainage goes into three different tributaries. This suggests that the principal accumulation of barite was related to the development of the Harrisesburg surface, and that the best place to find barite is on remnants of that surface.

The barren belt.—One of the more puzzling problems of the Sweetwater district is the apparent absence of barite in the barren belt. It may be noted that the same structural block contains the Mascot zinc deposits 45 miles to the northeast, and a small abandoned barite mine at Cleveland, Bradley County, 15 miles to the southwest (Swingle, 1959, p. 58-62), yet there are no mines or prospects in this belt within the Sweetwater district and, so far as the writer knows, not a single lump of barite has been turned up by the plow in this belt.

There are no obvious geologic or physiographic differences between the barren belt and the productive belts. Large areas of weathered Kingsport formation at favorable topographic elevations occur throughout the length of the belt. Neither the published cross sections (Rodgers, 1952, 1953, pl. 15) nor the alternative structural interpretations tried by the writer indicate any reason why the Kingsport formation of this structural block should not have been accessible to the barium-bearing solutions which mineralized the Kingsport formation of the other three blocks.

Examination of the soil map of McMinn County (Bacon and others, 1957) indicates one difference which may be significant. Soils overlying the Kingsport formation in the productive belts are classified chiefly with the Clarksville and Fullerton series, but those of the barren belt belong mainly to the Dewey (and, to a less extent, Decatur) series. All four of these series are considered to be of residual origin. The Clarksville and Fullerton are very cherty and are yellowish below the A1 horizon. The Dewey and Decatur series are distinctly reddish; the Decatur is non-cherty and the Dewey contains only small chert
fragments in the deep subsoil (Bacon and others, 1957, p. 88-90). Examination of many exposures of these soils shows that the small chert fragments are stratified horizontally and that the reddish upper zones are actually old terrace deposits, probably related to tributaries rather than to the rivers. These old alluvial deposits are almost entirely restricted to the eastern and barren belts, though patches of them do occur farther to the west. They are composed almost entirely of material derived from Knox group residuum, though an occasional quartzite or vein quartz pebble can be found at most exposures.

Practically all the barite deposits in the eastern belt were covered by a noncherty red silty clay, 1 to 15 feet thick, described by many geologists as "colluvium" but properly identified by Gordon (1918, p. 58) as alluvium. The soil scientists, who are more concerned with utilization of soils than with their genesis, have mapped most of this clay with the residual soils. Superficially it looks much like the Dewey soils of the barren belt and also resembles red upland soils of the Blockhouse area in nearby Blount County, Tennessee, which were long called residual but recently were found by Neuman and Wilson (in press) to be ancient terrace deposits. There is some difference of opinion among the soil scientists, as expressed in oral discussions, as to whether all the soils mapped as Dewey are true residual soils. The writer suggests, as a possible explanation of the apparent absence of barite in the barren belt, that the widespread deep red soils represent ancient terraces which conceal the true residuum of the Kingsport formation and that barite deposits may actually underlie these soils, well below plow depths, in structurally and physiographically favorable areas. There is no obvious reason why the terrace deposits should be thicker and more extensive in the barren belt than in the eastern belt, but they appear to be so.

_Silicification._—Residual chert which accompanies the barite deposits was derived from silica in the bedrock. It includes (1) primary, syngenetic chert, (2) epigenetic, (hydrothermal ?) chert, possibly related to the barite mineralization, and (3) silica derived from these two types but dissolved during weathering and redeposited as chert masses in the residuum. Most observers have commented on the enormous amount of chert which accompanies the barite, especially in the central and western belts. In part, this is undoubtedly due to the normally siliceous character of the formations of the Knox group, especially their western facies. One of the vexing problems yet to be solved in this district is the question of how much, if any, of the chert was originally deposited as epigenetic, hydrothermal silica along with the barite and fluorite deposits. As quartz does not occur in the mineralized veins, any such silica that is present must have replaced the country rock.

_Suggestions for Exploration_

Most of the exploration for barite in the Sweetwater district has been by digging of test pits or churn drilling in areas where barite was accidentally turned up by the plow or bulldozer, in digging wells or cisterns, or by uprooted trees. As the area has been settled and farmed for more than 150 years, it seems reasonable to assume that most residual deposits occurring within plow
depth have already been discovered. Since, moreover, the bedrock deposits are not of economic value at present prices, exploration must be aimed at possible residual deposits which are below plow depth. Gravity surveys have been useful in Missouri (Uhley and Sharon, 1954) and should be tried in the Sweetwater district. A recent paper (Bloss, 1959, p. 37) suggests that geochemical prospecting of soils may also serve as a guide.

The writer suggests that the most favorable places for finding new barite deposits would contain two or more of the following features: (1) weathered lower member of the Kingsport formation, (2) a strong northwest-trending minor anticline crossing the regional strike, (3) location on or near a divide between two and preferably three major tributaries of the Hiwassee and Tennessee Rivers, (4) moderate elevation above the alluvial bottoms of the Coosa level, and (5) deep red soils of alluvial or colluvial origin.

This district presents a promising field for coordinated research in economic geology, geochemistry, geophysics, and geomorphology.

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Geologic Problems in the Sweetwater Barite District, Tennessee


