Commonwealth of Massachusetts
Department of Public Works
H. A. MacDonald, Commissioner

U. S. Department of the Interior
Geological Survey
W. E. Wrather, Director

Cooperative Geologic Project
Information Circular 6

May 1944

Graphite deposits near Sturbridge, Massachusetts

by

Earl T. Apfel

45-63

Contents

Figures

Graphite Deposits near Sturbridge, Massachusetts

by

Earl T. Apfel

Introduction

A vein of graphite is exposed and has been mined on the hill southwest of Lead Mine Pond, now known as Quassuck Lake, in the town of Sturbridge, Massachusetts. The mine, long abandoned, is $4\frac{1}{4}$ miles southwest of the village of Sturbridge. The old mine trench is crossed by a country road about a tenth of a mile west of the Lake and approximately a hundred feet above it. The location of the mine is shown on figure 1. In the course of this investigation another graphite deposit, presumably on the same vein, was found on the land of C. O. Cozzens, in the town of Holland and about a mile southwest of the old mine.

The old Sturbridge graphite mine was worked at several times during the past 300 years, but apparently the deposit was not rich enough to permit sustained operations for long periods. The last operation was for a very brief time in 1909.

Graphite of the grade known as "crucible flake", a naturally occurring crystalline variety of the mineral and with a specified range of grain size, has recently been considered a critical war mineral, because the domestic requirements had been met entirely by imports from Madagascar and Ceylon. With the temporary cutting off of these sources of supply owing to war conditions it was necessary to re-examine domestic deposits from which flake graphite had formerly been produced but which had long been idle. Though the domestic sources in earlier decades had been large deposits in New York, Pennsylvania, and Alabama, it was thought desirable to examine also the famous Sturbridge locality to determine, if possible, whether further exploration of this deposit would be justified.

Accordingly a brief study of the area was made under the cooperative geologic program of the Massachusetts Department of Public Works and the United States Department of the Interior, Geological Survey.

It was found that, although the Sturbridge deposit contains crystalline graphite of apparently high purity and in part, at least, of favorable texture, the deposits as disclosed in the old mine workings and at the Cozzens property are too small to encourage further attempt at development. It would be necessary to find exceptionally wide portions of the vein, such as that from which the reported 510 pound lump (see under "Historical background") must have been taken. Though the vein may be more or less continuous between the old mine and the Cozzens property and may continue for some distance to the north and south beyond these points, no indications of workable widths are to be derived from surface data, for rock exposures are sparse and a thick cover of glacial drift lies over most of the area along the course of the vein. Only by drilling and excavation or possibly by geophysical methods could the presence or absence of workable portions of the vein be discovered. It would not be possible, therefore, to select, from surface geological data, definite places along the interpreted course of the vein for such exploration, and inasmuch as the vein, wherever seen, is too narrow for economical mining, and large deposits now being mined elsewhere appear capable of furnishing much more graphite than will be needed for several years on the basis of present requirements, exploration of the Sturbridge vein at this time is not recommended.

Because of the probable recurring interest in these deposits and also to make available the geologic data acquired as a result of this investigation, it seemed desirable to publish this brief report on the Sturbridge deposits.

Acknowledgments

This report is based upon a brief review of the literature and about two weeks of field work in the graphite area and its vicinity. Mr. A. J. Bodenlos assisted the author in the field part of the time and also supervised trenching across the vein at one locality. Mr. Charles A. Dourdelais of Southbridge showed the writer the graphite float by which the position of the graphite vein in a new area was located. Mr. Charles O. Cozzens, owner of the property on which the extension of the vein was found, kindly permitted trenching so that the characteristics of the vein might be determined. Numerous residents around Lead Mine pond, and of more distant parts of the town of Sturbridge, volunteered useful information about the history and exploitation of the graphite deposit.

Historical Background

The first report of graphite in Massachusetts was made by John Oldham, who, during a trip in 1633 to trade with the Indians, had some black lead given to him "whereof the Indians told him there was a whole rock". This story excited the interest of some of the colonists and in 1644 John Winthrop, Jr., son of Governor Winthrop, was granted permission to acquire the land on which the graphite was found. Development was begun in 1658, and it thus became one of the earliest mining ventures of any kind in America. The length of time the mine was worked and its production are not known. The rocks were hard and had to be broken by fire in the crude mining methods used, and a contract to deliver 20 tons of graphite remained unsatisfied at the end of the first mining season of five months.

The mine was not worked again until 1737, when it was opened by another John Winthrop who agreed to deliver 500 tons of "black lead" in six years. The records show that less than three tons of graphite were delivered on this contract. This mining operation ended in 1740.

The graphite mine was opened, by Frederick Tudor, for its longest and most profitable operation shortly after he bought the property in 1828-'29, and for about 20 years Tudor and his associates mined the graphite for making crucibles, lead pencils, stove polish, and lubricants. The operation became unprofitable in mid-century and again the mine was closed. The amount of graphite removed by Tudor was not recorded, apparently, but on the basis of the extent of the workings and the descriptions of the ore body, it is estimated that between 500 and 1000 tons of graphite were probably taken from the mine.

The land on which the mine is located remained in the hands of Frederick Tudor and his heirs until 1899. The Massachusetts Graphite Company bought the property in 1902, pumped out part of the old workings, and produced a small quantity of graphite, including one piece reported to have weighed 510 pounds. 1/

1/ Bastin, E. S., Mineral Resources, 1913, p 200.

The last reported production from the mine was in 1909 when the Imperial Graphite Company of Pennsylvania mined "a few tons" of graphite from the Massachusetts Graphite Company's property. 2/ Since 1909 the mine has not been operated.

2/ Mineral Resources, 1909, p 833.

During the various operations a series of trenches were opened along the vein for a distance of about half a mile and in places to depths of 50 to 60 feet. Two shafts were sunk on the vein to depths of about a hundred feet, and an adit was driven for a hundred feet from the hillside east of the vein. Although this adit crossed the projected vein position, it did not expose a graphite vein. A small shaft was sunk near the south end of the workings to intersect the vein west of its outcrop; the success of this exploration was not determined.

No information concerning graphite occurrences north of Lead Mine Pond could be obtained, though old records refer to "a less well-known and inferior one about three miles north of the mine." 3/ The writer found no graphite vein in this locality.

3/ Haynes, George H., "The Tale of Tantiusques", the Sturbridge Lead Mine, Quinabaug Historical Society Leaflet, vol. 1, No. 13, 1902.

Exploration for graphite seems not to have extended south of the hill on which the mine is located, though the present investigation has shown the presence of graphite a mile southwest of the old mine, along the strike of the rocks.

Geologic Formations

The Sturbridge graphite vein lies within metamorphosed sedimentary rocks. The ore at the mine appears to have occurred in a single bed of the Brimfield schist that strikes east of north and dips steeply westward. The Brimfield schist is folded into the older Paxton quartz schist, the formations being closely folded and in places slightly overturned; both have been intruded by granitic material. An area in which outcrops are composed dominantly of granite occurs slightly more than a mile west of the mine. The areal relations are shown on the map, (figure 1). Several granite sheets up to 50 feet in thickness lie within and parallel with the foliation of the Paxton and Brimfield schists.

Paxton quartz schist

The Paxton quartz schist is a quartzitic mica-schist that in places contains small quantities of garnet, graphite, and aluminous silicates. In many places it has been so invaded by granitic material as to be converted into a granite-gneiss. The contact of this schist with the Brimfield schist lies a few hundred yards east of the mine, indicating that the graphite vein is near the base of the Brimfield.

Brimfield schist

The Brimfield schist is commonly a coarse, red-brown schist containing much biotite, quartz, and pyrite. Graphite flakes are scattered through it. Garnet and the aluminous silicate, fibrolite, are common. Feldspar is present where granitic invasion has occurred. The pyrite causes the rock to weather readily and develop a brown stain, which penetrates deeply and is characteristic of the formation.

Both the Paxton and Brimfield schists have similar lithologic facies and both have been intruded and soaked by granitic solutions with similar results. It is therefore difficult to distinguish one from the other in some exposures though in general the above distinctions appear to be valid.

Hubbardston granite

The coarse, white feldspathic granite known as the Hubbardston granite is prevailingly of pegmatitic texture. Where much schist has been assimilated by the granite, garnet and biotite are abundant. In places these are arranged as gneissoid layers, which apparently reflect the foliation of the schist inasmuch as they have the same general strike and dip as the foliation. Inclusions of the schists are very numerous near the walls of the granite, and in many of them the schistose structure is well preserved.

Stringers and sheets of the granite lie within the schists, and soaking by granitic solutions has caused so much feldspar and quartz to be added to the schists in some places that they appear gneissic in appearance and are harder than the unaffected schist. A small mass of granite, occurring as a sheet parallel with the bedding, underlies the crest of a ridge within a hundred feet west of the graphite mine.

The relationships are shown in figure 2.

Geologic Structure

The graphite appears to occur principally as a thin layer in a sedimentary formation which, through metamorphism, has become a mica schist. In the area of the mine, the dip and strike of the foliation of the schist are parallel or nearly parallel with the bedding and with the graphite layer enclosed by the schist. Because the graphite was more readily deformed than the schist, it has been squeezed into thin lenses and pockets. Irregular walls that moved differentially were apparently responsible for the uneven areal distribution of the graphite, and the variation in thickness, though the original distribution of the carbonaceous material in the bed determined the general area in which the graphite occurs. The deformation has produced some mixing of the country rock with the graphite.

The beds where the graphite occurs dip westward with a range in dip from 40° to 90° with some minor overturning. They are unevenly folded so that both strike and dip vary. The strike is about 20° east of north with ten to fifteen degrees variation from this figure observed locally.

A second type of graphite occurrence is as pegmatite veins in which the graphite flakes lie among the crystalline grains of feldspar, quartz, and mica. Hydrothermal action seems indicated in such places, the graphite having been carried a short distance from its source. This source may have been the graphite bed, because such graphite-bearing pegmatite has been found principally in the vicinity of the graphite vein. Where the pegmatitic solutions invaded the graphite vein, extensive recrystallization of the graphite occurred as described later.

Descriptions of the Deposits

The Sturbridge mine

All the graphite seen in the Sturbridge area is crystalline. It is found as massive veins of almost pure graphite; as flakes in schist and gneiss; as plates and blades in pegmatities; and as veins mixed with pyrite, feldspar, and garnet.

A considerable part of the massive graphite is composed of minute plates of graphite in a felted arrangement. This is thought to have been the principal form of the graphite when it was developed from a carbonaceous layer, perhaps a coal bed. In places, subsequent recrystallization has caused larger plates to be formed, and these commonly occur as veinlets extending through the matrix of finer grains. Where recrystallization extended through the whole mass, other minerals, principally feldspar, were added commonly to the graphite vein. This consistent relationship suggests that the recrystallization was probably of hydrothermal origin.

Small flakes of graphite occur widespread but in small quantity in the Brimfield biotite schist, but a part of the graphite vein consists of the schist or gneiss in which the graphite flakes are abundant enough to make up 10% or more of the rock. The flakes are usually small, and show brilliant faces when the rock is broken. Where granitic solutions have converted the schist into a gneiss, the graphite flakes are broader, thicker, and less numerous than in the schist. They appear to be arranged without regular orientation in a matrix of small feldspar grains.

Pegmatites, especially those in the vicinity of the graphite vein, contain graphite flakes between the grains of other minerals. The flakes are curved or bent; some are wrinkled or folded. Another form of the graphite is as blades up to an inch, or more, and one-eighth of an inch wide. Both the plates and blades lie in various positions in the pegmatites, but for the most part they follow mineral boundaries. Some small graphite flakes occur enclosed in the feldspar and quartz of the pegmatite, and one specimen showed graphite interleaved with biotite mica.

Probably the greatest amount of the graphite occurs as veins in which it is mixed with more or less pyrite, biotite, pink garnet, and feldspar. Recrystallization has affected much of such graphite and it is found in plates and blades which tend to lie at right angles to the surfaces of the minerals against which they rest.

Pyrite seems to have been the last mineral to crystallize. It occurs as granular and nodular masses both along the wall of the graphite vein and within the graphite. In places, fine-grained crystalline pyrite is intimately intermixed with the graphite. Some broken surfaces of the ore show an intricate pattern of pyrite layers between and around the graphite particles. Where the intermixed pyrite has decomposed by weathering it has left the graphite porous and rusty. Pyrite lies along the surfaces of other minerals, and commonly has very small and irregular openings within it which are lined with minute well-formed crystals of pyrite.

Feldspar crystals in the graphite vein commonly have a plump lenticular form, half an inch to an inch long, and in places are completely surrounded by graphite plates.

The minerals that are included within the graphite vein and the recrystallized form of the graphite suggest that hot solutions, perhaps from the cooling pegmatites, carried some mineral substances into the graphite vein where they were deposited, and that the heat assisted in recrystallizing the graphite at the same time. In places the same minerals are found along the wall of the graphite vein, separating the graphite from the schist.

The vein of graphite lies in an envelope of schist rich in biotite and pyrite that is commonly more coarsely crystalline than in the adjacent schist. At distances that range up to approximately three feet from the graphite, the schist is more quartzose, contains less pyrite, and is more resistant to weathering than where it is richer biotite. For the most part, this resistant rock apparently formed the walls to which the mine openings were developed. Where its relationships are visible, the graphite vein lies near the east or footwall side of the biotite-rich envelope, and the width of the whole zone, including the graphite, ranges from zero to five feet. Where soaking with granitic solution was intense, the biotitic wall-rock has been altered to a resistant feldspathic rock. In places pink garnet is abundant along the walls of the graphite vein and in some places crystals of garnet lie in a matrix of graphite flakes. Figure 3 is a sketch showing relationships across the vein as they were observed at the mine openings. This figure is generalized because in some places the gneiss occurs in both walls, at other places in the hanging wall, and elsewhere in the footwall as shown in this sketch. Also, the position of the graphite lenses in the envelope of pyritic schist varies from place to place, as does the thickness of the whole zone.

Some pegmatite veins contain abundant graphite. Pegmatitic solutions that invaded the graphite vein apparently dissolved enough graphite to produce many large graphite crystals in the pegmatites, because so far as observed, the pegmatites rich in graphite are found only near the graphite vein. The most distant pegmatite seen to contain as much as three or four per cent of graphite is about 60 feet east of the vein at the mine, across the strike of the schist, and may represent a much greater distance of travel for the solutions carrying the graphite from the vein.

When first formed, the graphite was probably a mass of minute flakes in random arrangement, but recrystallization has resulted in an increase in size and consequent reduction in the number of plates. The agents that caused recrystallization varied in the intensity of their effect from place to place so that crystals range in size from minute flakes to plates an inch or more across. A similar range of sizes is noted in the graphite that was recrystallized as blades or thick needles.

The graphite vein and the pockets of pure graphite vary considerably in size. Emerson[4/] described the graphite as occurring "in a series of flat pockets three or

4/ Emerson, B. K., The geology of Massachusetts and Rhode Island. U. S. Geol. Sur. Bull. 597, p 71. 1917.

four inches in thickness, placed with the bedding, but not very extensive in this plane." However, the graphite body was observed to range up to 18 inches in thickness, with very irregular walls and therefore variable dimensions. Bastin[5/] cites a

5/ Bastin, E. S., Mineral Resources, 1913, p. 199.

statement that one lump of nearly pure graphite, recovered about 1904, weighed 510 pounds, indicating the presence of at least one rich graphite pocket. Frederick Tudor[6/] reported a vein width of 2 feet and 3 inches of graphite when he was mining

6/Haynes, George H., "The Tale of Tantiuscucs", Quinabaug Historical Society Leaflet, vol. 1, No. 13, 1902.

the vein.

Where deformation was intense the graphite within the vein is mixed with distorted laminae of the wall rock. In other places the massive graphite is interbedded with biotite schist. These rocks reduce the proportion of graphite in the vein, so that in the observable parts less than 50 per cent of the vein is composed of that mineral. Some variation was noted in purity as well as in thickness of the vein in the small exposures that were accessible.

The Cozzens Prospect

In the present study the position of the graphite vein was traced along the strike of the rocks, resulting in the discovery of a deposit of graphite about a mile southwest of the former mine. This seems to be in about the same position with respect to the margin of the Brimfield schist as the mine workings and therefore may well be an extension of the same vein. It is on the land of Mr. Charles O. Cozzens, hence the name "Cozzens prospect".

A shallow trench 45 feet long was dug across the strike of the schist and the graphite vein which here, as at the mine, are parallel. A cross-section as exposed along the trench is shown in figure 4. Two shorter trenches were dug across the vein at distances of 5 and 14 feet respectively north and south of the long trench. A section along the southern trench and the detail of the vein as seen in the long trench are shown in figure 5. The small, northern trench exposed graphite in relationships similar to those in the next trench southward. The surface was stripped between these trenches to expose the vein which here was seen to consist of graphitic layers extending in an irregular pattern through rusty schist. A map of the exposed part of the vein is sketched in figure 6. Heavy cover prevented extending the exploration along the vein either north or south from this place.

The graphite zone is slightly less than 3 feet in thickness. It consists of veins of nearly pure graphite and of rusty graphite from thin films to nine and one-half inches in thickness; the rest of the zone contains a smaller quantity of graphite as flakes and blades. An estimate of 10 to 15% of graphite as the average content of the mineable width of the vein was made on the basis of this exploration.

Another trench 30 feet long was dug across the strike of the vein about 250 feet northward from the stripping described above. Schist was encountered at a depth of three to six feet in the western half of the trench but eastward the rock surface slopes downward to such a depth as to be beyond the limits of exploration in the time available. Where exposed, the foliation of the schist was seen to be nearly horizontal, with small undulations. Blocky layers were displaced and the schist layers at the rock surface were broken and distorted, indicating probable disturbance by glacial ice which once covered the area. No other bedrock exposure in this area was observed to have horizontal foliation, even though exposures occur within 50 feet of the excavation. This disturbance, therefore, is probably local.

Within the schist exposed in the trench there are two pegmatite veins, one about three inches from the top of the schist and the other 18 inches lower. Both are parallel with the foliation. Their thicknesses are variable, ranging up to six inches, and feldspar crystals an inch or more in diameter are scattered through the veins. Large graphite flakes and blades an inch or more long make up an estimated 10% of the pegmatite though some small pegmatite lenses a foot or so long are almost free of the mineral. The maximum thickness of either of the pegmatites does not exceed ten inches in any part of the trench where they were exposed. The main graphite vein was not reached by this trench.

The extent of the vein along the strike and in depth is still unknown. It is probable that the graphite, as elsewhere in the area, occurs here as lenticular masses. It is doubtful if the small amount of work done has exposed either the maximum or minimum thickness of the vein. The thicknesses exposed are much too small for economical exploitation; only the discovery of thicker lenses would warrant further development. That thicker lenses may exist is suggested by one report, cited above, of a single large mass weighing 510 pounds, with a vein width of 2' 3" at one place, but surficial geologic data furnished no clue as to places where prospecting for bodies of workable width would be justified.

Conditions for Prospecting

Ease of prospecting by geophysical as well as other means is determined by the proximity of the bed rock to the surface and the accessibility of the area to trucks and equipment. The available roads are shown on the map, (figure 1). Most of the area is in woodland, with a thick stand of small timber over most of the surface. In the vicinity of the old mine there are several short roads for wood hauling. Hurricane-felled timber still litters the woods about a quarter of a mile south of the mine where there was a stand of large trees.

The Brimfield schist within which the graphite vein lies, is a formation weakly resistant to weathering, except where it was intruded by granitic material. The schist, therefore, usually forms the lowlands and is nearly everywhere covered by glacial drift or by a thick mantle of weathered rock, so that exposures are few and are restricted to certain areas. The granitized parts of the Brimfield schist are less easily weathered, and form ridges or hills, such as that just east of Hamilton reservoir.

There are very few rock exposures along the strike of the graphite vein. South of the old graphite mine a cover of drift almost wholly obscures the Brimfield schist for nearly three-quarters of a mile though the more resistant Paxton quartz-schist, to the east, is exposed in low ridges at several places. Both the Paxton and Brimfield schists are exposed in the first east-west road south of the mine, but no exposures were found along the strike of the vein between this road and the Cozzens prospect 0.7 mile southwest.

The Paxton quartz-schist forms a ridge east of the Cozzens property and a granitized part of the Brimfield schist forms a high hill to the west. The cozzens prospect lies in a saddle between these two topographic features and the closeness of the bed rock to the surface here is probably the result of scour by glacial ice with not enough succeeding deposition to conceal the bed rock. A rock ridge is exposed 30 to 50 feet west of the graphite vein at the prospect, but the vein was found only when a small excavation uncovered graphite float which the writer traced to its source.

A granite ridge lies near the apparent position as extended along the strike of the vein south of the Cozzens exposure, but the schist is covered except in a road cut 0.8 mile northwest of Hashapaug, which is 0.7 mile southwest of the Cozzens prospect. Both the Paxton and Brimfield schists are exposed along or near the road and within about 500 feet of each other, so that at this place the boundary can be located rather closely.

From these exposures southward to the State line, no bed rock is to be seen on the strike of the vein. The Paxton schist (here converted into gneiss) forms the nose of the hill on the Massachusetts-Connecticut state line 0.5 mile northwest of Hashapaug lake, but the Brimfield schist to the west of it is covered.

North of the old Sturbridge mine the graphite horizon probably lies in the depression extending north-northeast from Lead Mine Pond, but thick brush and lack of exposures prevented its discovery, if present then.

Conclusions

The Sturbridge graphite occurs as a nearly vertical vein in the Brimfield schist, a metamorphosed sedimentary rock that is probably of Carboniferous age. The deposit consists of a series of lenses that lie in the plane of the bedding which is also the plane of foliation of the schist. The vein has been mined or explored for nearly half a mile along its outcrop west and southwest of Quassuck

Lake (Lead Mine Pond), to a depth of 40 to 60 feet, and most of the readily accessible graphite along this part of the vein has been removed. Geologic field work has disclosed graphite, apparently along the same vein, about a mile southwest of the old mine. Exploratory work so far has been limited to confirming the presence there of a 9 inch layer of nearly pure graphite in a graphitic zone 2 to 3 feet wide.

The vein appears to be exceptionally rich, being apparently pure graphite, and is somewhat spectacular on that account, but it is also very thin, so that in mining it a large amount of waste rock would necessarily be moved. As the gross value must be computed on the volume of the rock mined and not on the volume of the vein, it is not possible to estimate closely the costs of mining and milling and the probable profit from selling the product. For purposes of obtaining a general idea, however, one can make reasonable assumptions and calculations on the basis of present market prices, which range from 2 to 14 cents a pound for crucible flake and fine graphite.

If an average thickness of 6 inches is assumed for the Sturbridge vein, an average graphite recovery of 30% of the vein width, and an average selling price of 5 cents a pound, the amount of graphite obtainable from a vein length of 100 feet and a mined depth of 100 feet would be about 540,000 pounds, with a gross value of $27,000. But as a width of approximately 4 feet would necessarily be mined, about 6400 tons of rock would be removed, so that the gross value of mined material would be only about $8.40 per ton. When the costs of exploration, mining, milling, and marketing are considered, to-gether with the uncertainty of the post-war market, it is readily seen that, on the basis of the above assumptions, no part of the vein that has been seen could either be worked profitably or could be expected to yield a large quantity of graphite. Even if the vein were uniform and continuous, mining along a mile of the vein to a depth of 100 feet would yield only about 13,500 tons of graphite; only part of this would be of crucible flake grade. The operations would probably have to be extended over several years.

No sizing tests have been made on the vein material, so that the proportion of "flake" graphite in the vein is unknown. The crystalline character of the graphite and its occurrence as a distinct bed or series of lenses are favorable features. If a part or parts of the vein were found of sufficient width for profitable mining it would be desirable to make milling and utilization tests of the vein matter. Wide parts of the vein are not yet known, however, and surface geologic data give no clue to the existence or probable position of such parts, so that any prospecting by drilling or trenching would be costly and of "wildcat" type. The present study has extended the area for such prospecting. Search for graphite might be aided by geophysical methods, starting where graphite is known to be present and the reactions of the body to such methods could be determined. If it is then proved feasible, the method might be used to determine the presence and extents of lenses along the trend of the vein. It is possible that other horizons in the Brimfield schist may have workable beds of graphite, but such are nowhere exposed so far as known. The presence of highly graphitic pegmatites may be an indication of the proximity of a vein.