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Geology of the Plainfield-Hawley Area

(with special reference to deposits of manganese and iron minerals)

by

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Illustrations

Tables

***** Report retyped from poor copy -- Figures 1 through 8 have not been located therefore are not available with this report copy.

Geology of the Plainfield-Hawley area of Massachusetts

(with special reference to deposits of manganese and iron minerals)

Abstract

The bedrock of the Plainfield-Hawley area consists of the Savoy schist and the Hawley schist, both probably of Ordovician age, the Goshen schist, probably of Silurian age, and a hitherto undescribed body of gneiss, which is somewhat younger than the schists, but probably also of early Paleozoic age. All are greatly deformed and somewhat metamorphosed. The regional structure is simple; both schistosity and bedding trend north-northeast and dip steeply to the east except where they "wrap around" the body of gneiss. Evidence is cited to show that the contact between the Savoy schist and the Hawley schist is not a fault contact, as had been supposed, but that the contact between the Hawley schist and the Goshen schist is a fault, at least in part. In contrast to the simple regional structure are the complicated minor folds.

Of the several mineral deposits which appear to be genetically related to each other, only the "Taconic mines" on the Betts property have been worked recently. Since 1938 they have produced somewhat over 7,000 tons of carbonate and silicate ore, but the rate of production had decreased at the time of this study. All of the known manganese deposits are within a fine-grained graphitic mica schist facies of the Savoy schist. The two ore bodies of the Betts property appear to be on the noses of drag folds having vertical axes, and the manganese minerals appear to have replaced quartzite beds. The ores are chiefly manganese carbonates with lesser amounts of manganese silicates and with minor amounts of manganese oxides along the joints. Associated with the manganese minerals is an assemblage of sulphides, silicates, and oxides characteristic of high temperature hydro-thermal deposits.

The tenor of the ore, which is generally about 20% to 25% manganese gives no indication of increasing in depth. Core drilling by the United States Bureau of Mines indicates that the north deposit decreases in size with depth and that the south deposit extends down at least 150 feet.

It is suggested that inasmuch as mangetite is a common associate of the known manganese ores additional deposits or the extensions of known deposits now hidden by glacial deposits might be discovered by magnetic surveys.

Introductory statement

Deposits of manganese and iron minerals have long been known to occur for a distance of nearly twenty miles along a narrow belt of schist of early Paleozoic age between West Cummington and Heath, Massachusetts. In the northern half of this belt, chiefly in the towns of Howe and Charlemont, deposits of pyrite, in part copper-bearing, were mined for many years until about 1910. In the southern half of this belt are several deposits of iron and manganese minerals, which have been prospected and mined to a small extent at several times. Mining of the iron ore ceased about 1890. The manganese deposits in the southern part of Plainfield were reopend about 1925, and the most active mining has occurred since 1939.

During the Second World War the threatened shortage of manganese imports made it desirable to examine and explore domestic resources of manganese ores throughout the country. The Plainfield deposits are low-grade carbonate-silicate ores, and as such are not suitable for the manufacture of ferromanganese or spiegeleisen, however, because they have been used in the manufacture of manganiferous pig iron, it was considered desirable to study the geology of the mineral belt as an aid to further exploration. This project was carried out under the cooperative geologic program between the Federal Geological Survey and the Massachusetts Department of Public Works.

The mapping of the West Cummington-Rowe mineral belt was divided into two projects, the first covering the southern part (Plainfield-Hawley area), in which the manganese and iron mines and prospects occur, and the second covering the Charlemont-Heath pyritic area. (See fig. 1.) This report presents the results of the study of the first of these projects, covering the area from West Cummington to Hawley, shown in plate 1. For the study of the active manganese

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Pl. 1. Geologic map of Plainfield-Hawley area, Massachusetts.

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property in the southern part of Plainfield, a large-scale plane-table map (pl.2) was made as a base for geologic studies. The rest of the area was

Plate 2. Geologic map of the manganese deposits on the A. G. Betts property, Plainfield, Massachusetts.

mapped on advance topographic sheets (photo-compilation sheets) of the Plainfield and Worthington quadrangles, supplied by the Topographic Branch of the Geological Survey. The writer was assisted by D. M. Henderson and Gilbert Corwin.

Mapping of the Plainfield-Hawley area was planned to coincide with an exploratory project of the Federal Bureau of Mines, which had requested geologic data as a guide for drilling. For this reason the first part of the geologic project was devoted to making a plane-table base map and detailed geologic study of the Betts manganese property, known as the Taconic mines. The Bureau of Mines and the Geological Survey worked in close cooperation throughout this part of the mapping project, so that the geologic study was coordinated throughout with the drilling project.

The field work for the entire belt from West Cummington to the Davis pyrite mine was performed from June 16 to October 18, 1943.

Acknowledgements

The writer acknowledges indebtedness to several people who aided the work in various ways. Mr. Anson G. Betts, owner of the Taconic mines, allowed free access to all parts of the property and supplied much information about geologic conditions exposed during earlier operations. Mr. M. L. Thomas, Project Engineer in charge of the drilling program of the Bureau of Mines, cooperated by exchanging information. Professors E. S. Larsen and R. E. Gibson of Harvard University visited the mines and made helpful suggestions. Professor M. P. Billings of Harvard University spent several days in the field and contributed much toward the interpretation of the complicated structures of the surrounding country rocks. Mr. L. W. Currier, geologist in charge of the Massachusetts cooperative geologic program, helped with suggestions in the field and office.

Previous studies

The presence of manganese minerals was noted briefly in Hitchcock's early reports (6;7;8). Emerson gives more information in his later reports.

Numbers in parenthesis refer to publications cited in list of references, at end of this report.

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but the fullest account of both the mineral deposits and the regional geology is given in his "Geology of Old Hampshire County, Massachusetts" (3). In this report, Emerson stated that the deposits herein referred to as the Betts deposits and another 1.6 miles north, herein referred to as the Frizzell deposit, lie along a fault between the Savoy schist on the west and the Hawley schist on the east. He stated further that the manganese rock at Cummington near the William Cullen Bryant homestead occurs only as boulders, the parent ledge presumably being on the Betts property approximately 2.4 miles north-northwest.

Further brief descriptions of mineral localities in this vicinity are given by Perry (9). The writer also had access to unpublished notes by D. R. Hewett of the United States Geological Survey who visited the Betts deposits in 1930 and again in 1933.

Regional geology

Stratigraphy

General statement

Rocks exposed within the area herein described include the Savoy schist, the Hawley schist, and the Goshen schist of Emerson (3;4), and a gneiss not heretofore described. The distributions of these formations is shown on the geologic map, (pl. 1).

Emerson considered the Savoy and Hawley schists to be of Ordovician age, although no fossils have been found to support this conclusion. He considered the Goshen schist to be of Silurian age because it appears to overlie the Hawley schist unconformably and to lie stratigraphically beneath the fossiliferous Bernardston formation of Devonian age. The present field study was not carried far enough into adjacent areas to discover any new evidence regarding the ages of these rocks, but it did reveal that the small folds seem generally to agree with the conclusion that the Savoy schist is the oldest and the Goshen the youngest of this sedimentary sequence. The present study suggests further that the apparent unconformity between the Hawley and the Goshen schists may equally well be explained by faulting between them or by increasing thickness of the Hawley schist toward the north. There is, however, no conclusive reason for disagreement with Emerson's assignment of the Goshen schist to the Silurian system.

Savoy schist

The Savoy schist, the oldest formation exposed in this area, includes three main rock types: impure quartzite, quartz-muscovite schist, and amphibolite. Intermediate phases of these types occur as interbedded and generally discontinuous lenses. Certain beds, particularly of amphibolite, may be traced for several hundred feet in a few areas of abundant exposures, but where outcrops are scattered, as is more common, it is not possible to trace and correlate beds or even zones with assurance.

Studies of thin sections reveal that the principal constituents of the Savoy schist are quartz, untwinned oligoclase, muscovite, and biotite. Hornblende is common, but garnet is generally not abundant in the quartzite beds. All gradations between quartzite and amphibolite and between quartzite and muscovite schist may be found. Accessory minerals include magnetite, ilmenite, pyrite, chlorite, apatite, and a variety of epidote whose optical properties resemble those of zoisite. The original material must have been deposited as a somewhat impure sand.

Quartzite.--The lower part of the Savoy formation as mapped contains much more quartzite than the upper part. In the vicinity of the Davis mine. about 6 miles north by east of the area A shown on plate 1, it was feasible to map the quartzite as a separate zone, but in the Plainfield-Hawley area the contact between the lower quartzitic facies and the schist facies is too gradational and irregular to be mapped.

Good exposures of typical quartzite beds within the Savoy schist may be seen, however, in road cuts extending for a quarter of a mile east from the village of West Cummington. Other good exposures may be seen on most of the hill tops about three-quarters of a mile west of the contact between the Savoy and Hawley schists (see plate 1); at most of these places the quartzite is greatly contorted. Exposures of the quartzite occur also in the bed of the Chickley River along the west side of Forge Hill.

Quartz-muscovite schist.--The beds of quartz-muscovite schist in the Savoy schist beds are generally light tan to silvery gray. Commonly the foliation planes show small crenulations. The main constituents are muscovite, quartz, garnet, and biotite. The garnets reach a maximum of 3 centimeters in diameter. They cut across the grain of the muscovite and are most common where small folds occur in the schist; some of the garnets, indeed, appear to have been rolled during their formation, for they show a striking spiral pattern in thin section (see fig. 2A.) Many of the biotite crystals are discordant to the foliation of the rock. Scattered feldspar and bright-green chlorite grains are visible on many foliation surfaces. Accessory minerals are magnetite, ilmenite. chlorite, zircon, apatite, tourmaline, and pyrite. The sediment from which this rock was derived apparently consisted chiefly of mud with sand grains of quartz, and possibly of feldspar, although the feldspar grains may have been introduced by later solutions.

Amphibolite.--Beds of amphibolite in the Savoy schist range from light to dark gray in color, depending on the proportion of amphibole present.

The hornblendic beds range in composition from hornblendic quartzite to amphibolite, and in thickness from several hundred feet to discontinuous beds a few inches thick. Conglomeratic texture is preserved in some of the lighter facies. The origin of these rocks is problematical. The composition of the darker bands is very similar to that of certain igneous rocks, except that the amphibolite generally contains 5 to 10 percent of calcite. The thin and discontinous character of the bedding, however, together with the gradations to quartzite and muscovite schist, and the conglomeratic texture, indicates that the formation was deposited as sediment that contained various amounts of detritus possibly derived from the rapid erosion of volcanic rocks. Volcanic explosions may have added some material directly to the sediment.

The amphibole occurs commonly as medium-sized needles, but in the more quartzitic phases it appears as strikingly large plumose crystals, forming the "fasciculite" rock of Emerson.

In thin section, the amphibole generally shows pleochroism as follows: X - light yellow, Y - green, Z - bluish green: ZYX. The indices of refraction, though variable, are commonly about Greek alpha = 1.662, Greek beta = 1,675, Greek gamma = 1.683. These properties indicate that the amphibole is either hornblende or pargasite. Other main constituents are quartz, calcite, oligoclase, and iron-poor epidote, approximating zoisite in optical properties. Garnet, consisting chiefly of almandite, is common to abundant. Accesoory minerals include pyrite, magnetite, and ilmenite.

Fine-grained schist.--Along the eastern margin of the zone mapped as Savoy schist there is a bed of finer-grained feldspathic mica schist, 500 to 1200 feet wide, in which the manganese deposits occur. This rock, designated Osf in plate 1, is composed principally of biotite, muscovite, quartz, feldspars, garnet and graphite. It is generally fissile and shows many small folds. Near the Betts mine it was possible to subdivide this fine-grained schist and map it as two beds--feldspathic mica schist and graphitic mica schist, (see pl. 2). There are also small discontinuous beds of chlorite schist near the workings. This zone of finer-grained rock resembles the Goshen schist to the east and Emerson (3, pl. 24, sec. 4) drew a cross-section on which he indicated it as a part of the Goshen schist separated from the main mass by folding and faulting. This is a possible explanation, even though the westward dips shown by his section do not exist. Furthermore, the presence of faults is to be expected in rocks as greatly deformed as these. Faulting here has not been demonstrated, however, and all of the items of evidence cited by Emerson as indicating a fault seem to the writer not to be valid; this question of interpretation is more fully discussed in a later part of this report. The contact between this fine-grained facies and an amphibolite bed of the Savoy schist is exposed in the brook about 1,000 feet north by east of the northeast corner of the area represented by plate 2, and about 300 feet upstream from the bridge. At this place, the contact is marked by an eighteen-inch quartz vein. As the contact shows no evidence of faulting, the fine-grained beds are interpreted as a different sedimentary facies near the top of the Savoy formation. A quartzite facies of this bed as shown on the map of the Betts property (Osgm, plate 2) contains the manganese deposits described beyond.

Chloritic schist.--Along the west side of a body of gneiss lying three or four miles to the north is a bed of Savoy schist that contains considerable chlorite. This, too, seems to be a local sedimentary facies.

Hawley schist

The Hawley schist is exposed along a zone about one-third of a mile wide just east of the Betts mines, and about two miles wide in the vicinity of the Hawley iron mine. (See pl. 1.) The greater width of outcrop to the north may be due mainly to a greater thickness of the formation or to faulting, but is also due in part to lesser dips around the east side of the large gneissic mass that lies in the west-central part of the area. (See gn, pl. 1.) This gneiss is described beyond.

The Hawley schist contains beds of amphibolite, calcareous rocks, chlorite schist, feldspathic mica schist, and quartzite. Most of the beds are dark green to black, although light-colored beds are common. Schistose structure is well-developed throughout most of the formation in the area mapped, but massive beds are more abundant in areas to the north.

The principal mineral constituents are green to very dark green amphibole, similar to that of the Savoy schist, iron-poor epidote, ankerite (iron-calcium-magnesium carbonate), quartz, chlorite, and oligoclase, Each of these minerals is the main constituent in different places. Garnet, biotite, muscovite, and magnetite are common. Accessory minerals include rutile and pyrite.

Amphibolite beds are the most abundant of the formation, the fine-grained beds being commonly green and the coarser beds almost black. Both usually contain considerable quartz and as much as 10 percent of ankerite.

In the lower part of the Hawley schist, ankeritic rocks most commonly form beds as much as six inches thick, alternating with green amphibolite. The ankerite constitutes not more than 30 percent of the rock in most places, the rest being composed of quartz, oligoclase (partly in myrmekite intergrowths), and epidote; in a few thin beds epidote is the main constituent.

The amphibolite grades into quartzite and feldspathic schist containing small proportions of amphibole. Many of these beds have a conglomeratic texture, and in them the "fasciculite" rock is especially common. In some beds there are garnets up to an inch in diameter at the centers of large radial amphibole blades. The feldspathic rocks to the north especially resemble metamorphosed volcanic rocks of rhyolitic composition.

The Hawley schist appears to have been formed as a succession of sedimentary beds, including considerable volcanic debris, quartz sand, unweathered feldspar, and calcareous material. It is rather unusual in having an exceptional amount of iron carbonate for a dominantly clastic sediment.

Goshen schist

The Goshen schist is believed to overlie the Hawley schist. Only the lower part occurs in the area described in this report. Good exposures of this part of the formation may be seen in a quarry on the main road slightly more than a mile and a half east of West Cummington and in low road cuts extending several hundred feet westward from the quarry. It consists mainly of black graphitic schist and dark quartzite. Thin sections reveal that the main constituents of the schist are muscovite and quartz. Schistocity is well-developed and is transected by large biotite flakes. As in the Savoy schist, numerous small irregular garnets contain quartz inclusions oriented in such a way as to suggest that the garnet crystals were rolled during their growth while the rock was being metamorphosed. (See fig. 2B.) Accessory constituents are magnetite, graphite, pyrite, and tourmaline. The quartzite beds differ from the graphitic schist chiefly in having a greater proportion of quartz. The schist and quartzite generally split into such unusually large flat slabs, that they formerly were quarried rather extensively for flagstones.

Near the base of the Goshen schist is a 15-foot bed so graphitic that it was once mined for graphite in a small way at a locality about 1.4 miles east and slightly north of the Davis mine in the Charlemont-Heath area. It contains numerous small pyrite cubes. Similar rock is exposed in the brook a quarter of a mile southeast of the Betts mines.

Approximately 65 feet stratigraphically below the graphitic bed is a 30-foot bed of fine-grained, thin bedded quartzite that contains many tiny crystals of spessartite (manganese garnet) and scattered microscopic grains of ankerite. This bed is exposed in the brook east of the Betts mines and has been traced for a half-mile northward on the hillside. Associated with it are discontinuous beds a few inches thick that contain cummingtonite, a brown manganiferous amphibole.

Gneiss

Underlying an oval area about two miles long and a mile and half wide north and east of Plainfield Pond (see pl. 1.) is a body of gray, medium-grained gneissic rock that has not been mapped or described in any previous report. Large blocks of it are prominent in the drift. Outcrops are not numerous, but the rock is well exposed in a few small cuts along the "Hallockville road", which extends northward from the road junction three-quarters of a mile east of Plainfield Pond toward Charlemont; good outcrops may also be seen in the nearby brook and in the fields to the northwest. The structure is distinctly gneissic, with the foliation generally trending north-northeast, parallel to the regional structure, but dipping under the schist near the contacts. Small folds in the gneiss are abundant near the borders.

Thin sections reveal that the rock is more metamorphosed than is apparent in hand specimen. The quartz is broken, strained, and arranged in bands. The feldspars are replaced by muscovite and iron-poor epidote to such a degree that it is difficult to determine their original compositions. The principal constituents are apparently oligoclase, orthoclase, micropegmatite, and quartz, in such proportions as to indicate an original composition of quartz diorite or possibly granodiorite. Other constituents are biotite, chlorite, hornblende, sphene, zircon, and pyrite.

Alternative explanations of the origin of the gneiss are (1) that it was formed as an intrusive igneous body or (2) that it represents Savoy schist and quartzite beds that were here so completely soaked and replaced by granitic solutions as to assume the mineral composition of quartz diorite. The uniformity of the texture and mineral composition, the presence of sharp angular inclusions and schlieren, and the sharpness of the contacts with typical Savoy schist suggest an intrusive origin as more probable. These features may be seen at and near the small exposures of the contact on the hillside about three-quarters of a mile east and slightly south of Plainfield Pond and at the outcrops near the northwest corner of the gneiss area.

The facts that the inclusions possess schistosity, and that the schistosity of the bordering country rock bends around the gneiss body indicate that the intrusion took place during a late stage in the process of metamorphism; however, the further facts that the gneiss itself is considerably metamorphosed and that aplite dikes in it are contorted suggest that the intrusion occurred before the metamorphism had ceased. These facts also indicate that the gneiss probably solidified during the mountain-making episode that affected this part of New England. The date of this episode cannot be determined within the small area studied by the writer, but general information suggests that it may have occurred during late Devonian time.

Geologic structures

Regional structure

After the deposition of the thick sequence of sedimentary and volcanic rocks the region was subjected to lateral compression that folded the beds and promoted metamorphism. In the main, the resulting schistosity was developed parallel to the original bedding and both were crumpled into many small folds. Although small drag folds are numerous and complex, the regional structures are strikingly simple, in that boundaries extend across the country for many miles without large or sharp departures from the general N 5° -25°E strike and 60°-85° easterly dip. The one prominent and significant departure from the general regional strike and dip, where the schist bulges around the gneiss mass, is described in a later section of this report.

Contact between the Savoy and the Hawley schists

The writer considers the contact between the Savoy and the Hawley schists to be a normal sedimentary contact, in striking contrast to Emerson's map (3, pl. 34) on which one of the major structural features is the "Great Hawley fault" shown as recurring between these two formations. This interpretation was based on his belief that the amphibolite beds in the Hawley formation trend obliquely and discordantly into the Savoy-Hawley contact, and that the ore deposits, including the Davis mine to the north, are near this contact, indicating that it is a permeable zone along which ore-forming solutions circulated.

The writer doubts both of these points of evidence and does not consider that there is any other good evidence for a fault at this contact. The amphibolite beds are so variable and discontinuous that it does not appear possible to trace them so far as Emerson showed on his map; consequently the discordant relation indicated by him may be due to incorrect correlation of beds across large areas where no exposures occur, Furthermore, as stated above, the exposed contact of the Savoy and Hawley schists a short distance northeast of the Betts mine shows no evidence of faulting. As to his second point of evidence, several of the mineral deposits seem related more to other features, and several are at considerable distances from the Savoy-Hawley contact. The Betts mines, the Packard manganese showing, and the Frizzell prospect (A, B, and C on pl. 1) are, indeed, only about 500 feet east of the contact, but the more significant relation seems to be their location within the bed of fine-grained schist. The quartz-spessartite-magnetite deposit near the Hawley town house is 3800 feet east of the contact. The old Hawley iron mine and several prospects on the hill to the south are chiefly within 500 feet of the contact. Of the deposits to the north, which are to be described in a later report, the Hawks mine, just southwest of the village of Charlemont, is almost a mile and half east of the contact; the Mary Louise mine, almost four miles north and slightly west of Charlemont, is approximately one-half mile northwest of the contact; and the Davis mine is about 1500 feet southeast of it. Altogether, the association of these mineral deposits with the Savoy-Hawley contact is not definite enough to constitute sound evidence for a fault.

Contact between the Hawley and the Goshen schists

A fault is known to lie along the Hawley-Goshen contact to the north, but exposures are not sufficient to show whether it extends into the Hawley-Plainfield area. The waterfalls at Dell, about three miles north and slightly east of Charlemont, are over a bluff that shows a fault zone 30 feet wide between the Hawley and Goshen schists. Within this fault zone the beds are broken, stained by weathering, and contorted. The fault zone and the beds on both sides dip about 75° E., coinciding with a bedding-plane. Drag folds in the fault zone indicate that the downthrow side is probably on the east, indicating a normal fault.

Similar relations are shown in the railroad cut 2750 feet east of Charlemont station. Mapping between these two exposures of the fault has not revealed any certain discordance or stratigraphic throw along the fault. About three to three-and-a-half miles just west of the Hawley village, however, the strikes of the Hawley schist appear to be at a small angle to the contact. Such a relation, together with the marked narrowing of the band of outcrop of Hawley schist southward, suggests that the fault may extend into the Plainfield area where it ceases to be a bedding-plane fault and cuts sharply across the beds. The Hawley-Goshen contact, whether fault or otherwise, appears to cut deeply into the Hawley formation in

Plainfield, but seems to be essentially parallel to the basal graphitic member of the Goshen schist from the Westfield River to the graphite prospect a mile north of Dell, a distance of approximately 14 miles.

Structure of the gneiss area

The area of gneiss east and northeast of Plainfield Pond has a distinct foliation concordant with that of the surrounding Savoy schist with the contact between the two formations. From the Betts mines northward to a point approximately three-quarters of a mile south of the gneiss, the contact between the Savoy and Hawley schists trends in the usual northerly to north-northeasterly direction; thence it swings gradually more to the eastward for about two miles. From this point it bends northwesterly around the gneiss. Thus it conforms rather closely to the direction of the gneiss. North of the gneiss it resumes its common northerly trend. Dips are less steep around the east and northeast sides of the gneiss area than elsewhere. The same conformity follows the west side of the gneiss, along which the dips in both the gneiss and the adjoining lower quartzite member of the Savoy schist are to the west, an unusual attitude in this region. Especially near the north and the south ends of the gneiss area the beds are so greatly contorted as to obscure the general trend. Altogether, the structural relations indicate that the present erosion surface is near the top of a concordant intrusive body which crowded the schist and quartzite beds aside as it made its way upward. The accompanying geologic cross-section, (fig. 10) indicates the writer's interpretation of the structure.

Minor geologic structures

In contrast to the simplicity of the larger structures is the complexity of the small folds. Isoclinal folds are to be seen at many places; (see fig. 3); they range in size from mere "ripples" in the schistocity to folds a hundred feet or more across, as at the Betts mines. (See pl. 2.) These small folds appear not to belong to any simple or obvious system, for their axes were seen to lie in several directions, some being horizontal, some vertical, and others at various intervening angles, and at several places the axes and axial planes were seen to be contorted. Many of these minor folds are drag folds incidental to the compression of the region. Their complexity and irregularity are probably due to irregularities within the beds and to the fact that continued compression imposed later folding on the earlier structural features. This complexity is especially prominent near the north and the south ends of the gneissic area. Although the fold axes plunge in various directions and although there are exceptions, the small folds generally indicate that the beds are not overturned, so that the beds to the east are younger and those to the west are older. Figure 3 shows an exception to this general rule.

A striking example of "boudinage" structure is illustrated in the road cut 0.7 miles east of the village of West Cummington, where an amphibolite bed has been so stretched that it has been pulled apart, the adjoining beds flowing into the gap thus created. (See fig. 4.) Other examples may be seen at several places in the woods and in the cut on the Charlemont-Rowe road 2 miles northwest of Charlemont station.

Where the amphibole needles show a linear arrangement, it is generally almost vertical and at several places it is almost perpendicular to horizontal fold axes. At many other places, however, the relationship of lineation to fold axes cannot be determined. The vertical lineation appears to indicate stretching or elongation in an almost vertical direction.

Along the road east from West Cummington certain of the quartzite beds of the Savoy schist show a well-developed cleavage which generally strikes approximately N 35° E and dips about 65° W. (See fig. 5.) The same structure has been seen at several other places to the north. This cleavage may be due to a deformation later than the main folding and metamorphism.

Metamorphism

It is clear form the complicated structures of the rocks here and throughout western Massachusetts that they were subjected to great compression, which developed the major structures and schistosity. A consideration of the minerals of the schists reveals that moderately high temperature must also have prevailed during their formation. An additional factor in developing the present condition of these rocks was their permeation by solutions which may have been either the connate waters originally included in the interstices of the sediments or water invading the rocks from some other source or both. The combined effect of pressure, high temperature, and chemical reaction inducted by the solutions was to recrystallize the rocks and change their original structure and texture--a process known as metamorphism.

The original sedimentary rocks consisted of sand grains of quartz, feldspars, and probably such iron-bearing minerals as hornblende and pyroxene, clay particles, iron oxides, and such carbonate minerals as calcite and dolomite. These minerals were essentially stable under conditions of sedimentation, but when subjected to the deep-seated conditions noted above their chemical components recombined into minerals more stable under the new conditions. The quartz grains for the most part generally remianed as quartz, although they recrystallized so completely as to change the original fragmental texture to one of interlocking, irregular quartz crystals. The clay minerals, either recrystallized directly or combined with potash, introduced in solution, forming muscovite, and consequently clay or shale beds became muscovite schist. Garnet was formed by replacement of quartz and muscovite in the schist and quartzite beds where favorable proportions of iron, alumina, and perhaps lime were present. The beds of volcanic debris, being richer in iron and magnesia, recrystallized into amphibolite, chlorite schist. and feldspathic schist. Impure limestone beds became ankerite-amphibole-epidote rocks.

The outstanding physical effect of metamorphism was that the newly formed minerals of tabular or flaky habit (micas and chlorite) and those of rod-like or needle-like habit (hornblende) grew in parallel, thus developing the foliations or schistosity characteristic of most metamorphic rocks.

By comparison of their grain sizes and mineral compositions with those of metamorphic rocks elsewhere, these local rocks appear to have undergone a moderate degree of metamorphism, equivalent ot the "medium-grade" as defined by Grubenmann and Niggli (5, pp. 368-412).

The gneiss was intruded after the sedimentary and volcanic rocks had been recrystallized to form schist, quartzite, and amphibolite, but the crushing of its quartz and feldspar grains, and the alteration of its feldspars to epidote and muscovite show that the process of metamorphism had not then been completed. The gneissic structure is evidently due in part to the intrusion under pressure and in part to continued metamorphic pressure which partly washed the crystals of the newly consolidated rock and favored the development of muscovite.

Mineral Deposits

Introduction

The deposits described here, in order from south to north, are the Betts (or Taconic) manganese mines, the Packard manganese showing, the Frizzell manganese prospect, the vein of magnetite and spessartite near the Hawley town house, and the Hawley iron mine with its associated prospects. Of these, only the Betts mines were accessible for detailed study. The locations of these mines and prospects are indicated on plate 1.

Betts Manganese mines

Previous mining and present condition.

The deposits owned and operated by Mr. Anson G. Betts of West Cummington, Massachusetts, are situated in the southwestern part of the town of Plainfield, about one mile east-northeast of the village of West Cummington on a low spur that extends from the southeast side of Deer Hill. They are reached by a good country road leading northward from U. S. route 9, which follows the Westfield River through the northern part of the town of Cummington.

These deposits have been known for many years, and several attempts were made to mine them before the property was acquired in 1925 by the present owner; however, very little material was mined up to that time. The most active mining was during the period 1939-42 when, according to Mr. Betts, from 10,000 to 12,000 tons of low-grade manganese ore was mined. According to the U. S. Bureau of Mines 230 long tons were shipped 1938, 649 in 1939, 1,900 in 1940 and 4,000 in 1941 (11). Operations during 1943 were on a small scale, partly because of the

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U. S. Bureau of Mines Minerals Yearbook for 1942, p. , 1943.

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difficulty of getting labor, and partly because the workings had reached or were approaching the stage where open-pit mining was difficult. At the time of this study, June and July 1943, the north pit was so full of water that only the upper few feet of the walls could be studied. One of the pits in the south deposit was in operation, but the southernmost pit was so filled with rubble that the floor could not be studied. The north pit had been worked to a depth of about 30 feet and the southern pits were about 20 to 25 feet deep when last seen by the writer.

One of the first known occurrences of the manganese ore in this vicinity is a group of boulders on Bryant Road in Cummington a little more than a half mile east of the homestead of William Cullen Bryant. Emerson (3, p. 171) examined diggings at this locality and reported that all the manganese was in boulders, with no ledge exposed either naturally or by excavation. In 1943 these diggings were almost obliterated. Examination of them and their immediate surroundings, however, indicated that the cover of glacial drift over bed rock was thick and that the boulders referred to were no indication whatever that the local bedrock contained any manganese ore. In spite of Emerson's statement, certain local people cling firmly to the belief that ledges of the manganese were reached by the old diggings here. As the Betts deposits lie approximately 2¼ miles N 30° W of these boudlers and the glacial scratches at the Betts property trend almost N 50° W, it seems probable that, as was suggested by Emerson, the Betts ledges are the source of the boulders.

Tenor of the ore.

The ore minerals are chiefly manganese carbonates and silicates, all of which contain a smaller percentage of manganese than do the oxide minerals. Statements by Mr. Betts and the unpublished notes of D.F. Hewett of the Geological Survey indicate that most of the ore contained between 20 and 35 percent manganese; the Minerals Yearbook for 1941 (11) states that this mine supplied a ferruginous ore averaging 20 percent manganese. From these data and from assays of the drill cores of the Bureau of Mines, shown in Table 1, it appears that the ore generally contains 20-25 percent manganese.

Mineralogy

The chief manganese minerals here are carbonates and the silicates rhodonite, tephroite, and spessartite. The carbonate ranges in color and composition from the bright-pink rhodochrosite containing up to 61.7 percent MnO to a pale pinkish-gray carbonate, probably a manganiferous ankerite containing only a small amount of manganese. This pale carbonate weathers rapidly to dark brown An unimportant amount of pyrolusite and other manganese oxides has resulted from weathering along joints in the ore. Other manganese minerals in small amounts are neotocite (hydrated silicate of manganese and iron) which forms a few dark-brown veinlets cutting the pink ore, and cummingtonite (brown manganiferous amphibole) which forms radial fibers in massive spessartite rock and along the borders of small quartz veins. Hewett reported alleghaneyite and bementite, which were not seen by the writer.

Among the considerable variety of minerals other than those containing manganese are the sulfides pyrite, pyrrhotite, arsenopyrite (as small crystals in carbonate ore), and molybdenite. The molybdenite was seen in only a few blocks of quartz and spessartite which, according to Mr. Betts, came from the south wall of the north pit.

Oxides other than manganese oxides include quartz, magnetite, specular hematite, ilmenite, rutile, and limonite. The quartz was formed at several different times during the development of this deposit and under different conditions.

Additional silicates in the ore zone are actinolite, muscovite, biotite, chlorite, chloritoid, and epidote.

A few small veinlets of calcite were seen.

Hewett reported barite also, but this mineral was not observed by the writer.

At the time of this study the ore, as revealed by the mine workings, the dump material, and drill cores, was predominantly of pink carbonate. Thin sections show that even the ore that appears to consist chiefly of tephroite or rhodonite contains a considerable proportion of carbonate ore. The north mine is reported to have furnished much light gray manganese carbonate and some massive spessartite.

Quartz is the most abundant impurity. The ore of the south mine appears to contain very little of such objectionable impurities as sulphides and phosphates, but sulphides are common in the dump material which is reported to have come from the north mine.

Mineral relationships

In the ore, purplish to brownish masses of tephroite appear as cores surrounded by pink material containing considerable rhodonite; the rhodonite is in turn surrounded by light-colored ore composed chiefly of carbonates and quartz. These relations indicate that tephroite was the first manganese mineral to form and that the carbonates were last.

Quartz veins, some with spessartite crystals along the edges, cut the carbonate ore. Granular quartz seems to have been formed early, but certain quartz veins are clearly later than the rest of the minerals, A veinlet of quartz, pyrrhotite, and molybdenite was seen to cut spessartite rock, and a veinlet of pyrrhotite to cut a rock composed of magnetite and light-gray carbonate.

Neotocite was found in a veinlet formed by the alteration of pink manganese ore. The manganese oxides and limonite are obviously due to subsequent weathering.

Present exposures do not reveal a systematic arrangement of different minerals, although the walls of the north pit suggest that quartz, spessartite, and pale greenish muscovite flakes form a south border to that deposit.

Hewett recorded in his unpublished notes that the north deposit contained a central layer, 10 feet thick, of mixed carbonate and silicate of manganese, of which tephroite seemed most abundant, although considerable alleghaneyite was present in some specimens. He further stated that on both the east nad west sides of the central layer were layers of rhodonite rock as much as 10 feet thick, and that on the south side, the steeply inclined layers of manganese silicates terminated abruptly upward against a horizontal layer of spessartite, muscovite, and pyrite, about 5 feet thick. The peninsula in the north pit, according to Mr. Betts, grades downward from quartzite to ore; he also reports that magnetite is more abundant at depth in this pit.

In the south deposit, a siliceous low-grade body changes downward into ore.

Origin of the ore

Excepting the oxidation products derived by superficial alteration and some of the quartz veins, the manganese and genetically associated minerals are the result of replacement of an older rock under deep-seated conditions. The peninsula in the north pit and much of the rock around the north edge of the south deposit are composed chiefly of granular quartz which has the texture and general appearance of quartzite, and it is therefore probable that the host rock was quartzite. The assemblage of minerals indicates deposition through the action of solutions at rather high temperatures and at considerable depth. So far as the mineralogical evidence goes, the deposit might extend to considerable depth below the present surface, though structural or other factors may limit the vertical extent. Surface indications are not sufficient for determining the depth to which the ore minerals extend; the drilling records, however, seem to indicate a considerable narrowing of the deposits at shallow depths.

Ore deposits of this general class are commonly believed to have been formed by solutions emanating from cooling and crystallizing intrusive igneous bodies at depth. In many western mining districts the ores are clearly associated in time and place with igneous activity; in others the parent intrusion is not exposed and the relationship may only be inferred by analogy. The deposits in western Massachusetts cannot be definitely correlated with any exposed intrusive rock.

Structure

The general trend of the beds in this vicinity is modified at certain places by small folds, the most striking of which is in the vicinity of the Betts mines; it is believed that these had controlling effect on the origin and distribution of the deposits.

The two main deposits on the Betts property show similar structures. Exposures are better at the south deposit, where the south and west walls show that the bedding and schistosity of feldspathic schist curved around the ore body in a fold with a nearly vertical axis. Plate 2 shows the writer's map interpretation of the pattern of the folds at the two deposits and in the intervening area. These are drag folds with axes pitching about 90° and plunging approximately parallel to the general dip of the beds. The ore is believed to have replaced a bed or several thin beds of quartzite which was more brittle than the feldspathic schist.

At the northeast side of the north deposit are small folds with approximately vertical axes and with limits following the general steep eastward dip. They appear to be on the inside of the folded and mineralized bed.

The ore at the south deposit is limited sharply by the schist bed, and traces of the bedding of the quartzite can be followed in the ore to within a few inches of the schist. Along the south edge there is a discordance between the bedding of the quartzite and that of the schist wall whereas they are parallel along the west edge. The discordance may be explained as due to fracturing of the brittle quartzite and the bending of the schist around the broken ends of the quartzite beds; in other words, the discordant contact is essentially a minor fault contact. It is quite possible that the quartzite beds are not so continuous between the two deposits as they are shown to be, but rather that they have been broken into blocks or wedges and separated during deformation. The mineralization must have occurred after the folding as the ore deposits show no effects of this deformation. The folding localized the ore mineralization in part by breaking and separating the beds of the host rock and in part by creating permeable zones on the noses of the folds where the tendency for the beds to separate was greater. The ascending ore-forming solutions penetrated these premeable zones and replaced the fragmented quartzite bed. In view of the general irregularity of the small folds in these beds it may be inferred that the ore deposits, too, are probably irregular. A steep east dip of the beds is a rather persistent feature, however, and it is probable that the deposits have a similar dip. Both the irregularity and the east dip are born out by drilling.

Drilling by the Bureau of Mines

Surface study by the writer indicated that there is no mineralogical evidence against the continuation of these deposits to considerable depth. Neither is there any structural evidence against it, although the structures appear to be very irregular and show very little system. On the basis of such evidence, the United States Bureau of Mines decided to core-drill the deposits in order to get definite evidence concerning the downward extension.

Hole #1, north deposit:--Based on surface data as to pitch of the ore body, hole #1 was drilled from the southeast into the north deposit (see figure 6) and was inclined 40^{o} from the horizontal. It was calculated to penetrate the ore body at a depth of 150 or 200 feet.

The rock penetrated by the drill is described in the accompanying log Table 2. The only mineralized ground of significance in this hole is that from 227 feet to approximately 250 feet, where there is considerable quartz, some light carbonate (probably manganiferous ankerite), spessartite, and muscovite. However, the material appears to be very low grade and is very similar to that along the south margin of the north pit; it appears to represent the entire thickness of the ore deposit at the depth reached by the drill, approximately 175 feet.

This mineralized zone differs from the ore at the surface by a lack of pink manganese minerals, molybdenite, and appreciable amounts of magnetite, pyrite, pyrrhotite, and chalcopyrite. A further difference is the fact that the material in the drill core is much more mixed or interspersed with rock material than was apparently true at the surface.

A significant result of the drilling of this hole is the indication that the dip of the deposit is steeply to the east, as was predicted from surface structures of the schist. The main evidence for this eastward dip, aside from surface indications, are (1) the position of the mineralized zone, to the east of the center of the surface pit, (2) the resemblance of the last 49 feet of the core to the feldspathic schist exposed west of the ore body, and (3) the fact that the schistosity is at a high angle, even almost 90^{0}, to the hole throughout its length; a westward dip would have caused the schistosity to stand at an acute angle to the length of the core.

The log of drill hole #1 follows (Table 1).

Table 1

Log of drill hole #1, north deposit.

Length of hole in ft.	Rock	Degree of Mineralization
0-22	Fine-grained graphitic muscovite-biotite-garnet schist.	Very little.
22-128	Fine-grained, light-to dark-gray feldspathic biotite-muscovite-garnet schist.	Very little; a few quartz veins, usually with chlorite on both sides, small stringers of pyrite.
128-131	Fine-grained light-green chlorite schist, largely replaced by quartz and light carbonate probably manganese ankerite.	Considerable
131-133½	Fine-grained biotite-garnet schist, partly replaced by quartz and light carbonate.	Considerable
133½-134	Fine-grained quartz, magnetite, chalcopyrite, and garnet.	Much
134-137	Vein quartz, light carbonate, garnet, and biotite	Much
137-138½	Veins of quartz and light carbonate	Much
138½-146	Coarse-grained greenish gray chlorite-biotite-garnet schist, with veins of quartz and light carbonate.	Moderate
146-148	Fine-grained biotite-garnet schist, partly replaced by quartz, light carbonate, and spessartite.	Much
148-149	Fine-grained biotite-garnet schist, partly replaced by quartz, light carbonate, spessartite, and pyrite.	Much
149-160	Fine-grained feldspathic biotite-garnet schist replaced and veined by quartz, and light carbonate.	Moderate
160-180	Medium-coarse-grained, light-gray quartz-amphibole schist with veins of quartz and light carbonate.	Little
180-202	Biotite-garnet schist and chlorite-garnet schist with veins of quartz and light carbonate.	Little
202-214	Coarse-grained chlorite-amphibole-biotite-garnet schist with veins of quartz and light carbonate.	Little
214-227	Light-greenish chlorite-biotite-garnet schist with light carbonate stringers.	Considerable
227-229	Light carbonate, light green muscovite and spessartite.	Complete
229-290	Fine-grained biotite-chlorite-garnet schist with quartz and light carbonate.	Much to moderate
290-304	Fine-grained biotite-muscovite-garnet schist	Very little

Hole #2, north deposit.--The mineralized zone of hole #1 is so small and so poor that it was considered possible that the main ore body might pitch to the north or south in such a way that it was missed by the drill. Hole #2 was planned to test that possibility. It was oriented to take account of the eastward dip of the deposit.

Table #2 is a log of this hole. It will be noticed from the log and Figure

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Table 2. Log of hole #2, north deposit.

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6 that this hole penetrated the same mineralized zone as hole #1, but at a shallower depth, where the mineral composition of the zone is more like that in the open cut. The thickness of the zone is greater than in hole #1, and the manganese content appears to be somewhat greater, though not of ore tenor. These facts provide evidence that the north deposit diminishes gradually in depth. The eastward dip is substantiated by the position of the mineralized zone.

Conclusions about north deposit.--These two drill holes cut only meager, small, and very low-grade mineralized zones which seem to represent the main deposit at depth. It is therefore concluded that no large tonnage can be developed at this deposit, although two drill holes are not sufficient to eliminate all possiblity of deeper extension of an ore body that is more irregular than indicated by available data. However, the surface structures and drilling give no evidence that the ore body lies to the west of the area tested by drilling.

Table 2

Log of hole #2, north deposit.

Length of hole in feet	Rock	Mineralization
0-17	Glacial till	
17-27	Medium-coarse-grained quartz-ampibole-garnet schist.	Moderate; quartz and light carbonate
27-65	Chlorite-garnet-biotite-amphibole schist	Little; quartz and light carbonate
65-66	Remnants of chlorite-garnet schist	Much; light carbonate, a little quartz
66-95	Medium-coarse-grained biotite-garnet schist	Considerable; stringers of quartz and light carbonate.
95-96		Much; quartz and light carbonate.
96-103	Medium-coarse-grained biotite garnet schist.	Considerable; quartz and light carbonate.
103-113	Remnants of fine-grained biotite-garnet schist	Much; fine quartz and light carbonate.
113-135	Medium-coarse-grained chlorite-garnet schist.	Very little.
135-145	Medium coarse biotite-garnet schist.	Very little.
145-158	Medium-coarse-grained biotite-chlorite-garnet schist.	Moderate; quartz and light carbonate.
158-162		Much; muscovite, light carbonate, spessartite, a little chalcopyrite.
162-185		Complete; light carbonate, spessartite, muscovite, magnetite, pyrite pyrrhotite. 3" faint pink carbonate at 160'.
185-209	Coarse-grained chlorite-garnet schist.	Considerable; light carbonate.
209-218	Coarse-grained biotite-garnet schist.	Considerable; light carbonate and quartz.
218-241	Coarse-grained quartz-amphibole schist.	Moderate; quartz, light carbonate, a little pyrite.
241-252	Medium-coarse-grained biotite-garnet schist.	Little; quartz and light carbonate.
252-265½	Medium-coarse-grained biotite-garnet schist.	Considerable; vein quartz.

Table 4

Log of hole #3, south deposit.

Length of hole in feet.	Rock	Degree of Mineralization
0-46	Fine-grained dark biotite-muscovite-garnet schist.	Very little.
46-49	Fine-grained dark biotite-muscovite-garnet schist; quartz & light carbonate	Moderate.
49-52	Quartz and pale rhodochrosite.	Complete.
52-64	Quartz, considerable pyrrhotite, very little light carbonate, spessartite.	Complete.
64-65	Biotite, garnet, pyrrhotite.	Complete.
65-81	Fine-grained biotite schist remnants, with quartz, pyrrhotite, spessartite, pyrite, magnetite, chalcopyrite.	Much.
81-83	Fine spessartite, magnetite, quartz.	Complete.
83-94	Quartz, very little spessartite, magnetite, sulfides.	Complete.
94-97	Quartz, fine spessartite.	Complete.
97-107	Quartz, spessartite, pyrrhotite, a little light carbonate.	Complete.
107-116	Fine-grained biotite-garnet schist with light carbonate, a little pyrite.	Considerable.
116-121	Quartz, light carbonate, spessartite, pyrrhotite	Complete.
121-180	Rhodochrosite, quartz, spessartite, pyrite, tephroite.	Complete
180-190	Quartz, spessartite, rhodochrosite.	Complete.
190-204	Coarse-grained chlorite-garnet schist with quartz, light carbonate, chalcopyrite.	Considerable.
204-210	Fine-grained biotite-garnet schist, with quartz and light carbonate.	Moderate.
210-211	Coarse-grained chlorite-garnet schist.	Very little.
211-227	Fine-grained biotite-garnet schist.	Very little.
227-232	Medium to coarse-grained chlorite-amphibole-garnet schist, with quartz, light carbonate veins.	Little.

Hole #3, south deposit:--Hole #3 was intended to serve as a test of as many parts of the irregular south deposit as possible. In figure 7A the surface outline of the deposit has been projected to various depths, for the purpose of determining where the drill might intersect the deposit if it continues downward with the same shape and direction. In this diagram the pitch is assumed to be 90°.

The log (Table 4) and the cross-section (Fig. 7) show that the mineralized zone was met at a shallower depth and farther south then was expected. This difference indicates that the mineralized ground, which was sharply limited at the surface by the folded schist bed, penetrates irregularly into the schist below. The deposit is therefore even more irregular than is indicated by surface exposures. A wide mineralized zone was encountered and part of it, from 116 to 190 feet deep, consisted of ore equal or superior to that being shipped. This finding agrees with surface indications that only part of the mineralized zone is of commercial grade.

Hole #4, south deposit:--Hole # 4 was planned to test the width and extension of the ore zone penetrated by hole #3, and to explore a possible mineralized area just west of the excavation. After the hole was completed, it was learned that the drill had been deflected from the intended dip of 72°; it is believed that Figure 7B represents approximately the true course.

This hole penetrates a considerable mineralized zone but only a few small zones of rhodochrosite ore (see Table 4). This deposit, too, seems to decrease in tenor with depth. The position at which the footwall was encountered verifies the eastward dip of the deposit. No indication of the possible mineralized zone to the west was found.

Conclusion about south deposit:--The drilling indicated that no great tonnage can be developed by deeper mining of the known ore body. Good ore was found at a depth of 136 feet and some extends to 185 feet. The size of the rhodochrosite bodies is apparently not large, but may justify small scale mining to 150 feet or somewhat deeper.

Middle prospect:--During drilling operations, Mr. Betts directed further excavation at the middle prospect (see plate 2), which revealed 6 feet of non-mineralized schist east of a thin zone of light carbonate ore. This appears to indicate that there is no large body of ore at this place.

Table 4

Log of hole #4, south deposit

Length of hole in ft.	Rock	Degree of Mineralization
0-59	Fine-grained gray biotite-muscovite-garnet schist.	Very little.
59-64	Medium-grained gray chlorite-biotite-garnet schist, with quartz and light carbonate veins muscovite.	Considerable.
64-89	Medium-grained gray feldspathic chlorite-biotite garnet schist, with quartz and light carbonate veins, and a few amphibole needles.	Moderate.
89-123	Fine-grained biotite-garnet schist, with quartz, light carbonate in veins and replacements.	Moderate.
123-124½	Mainly quartz.	Complete.
124½-125½	Rhodochrosite, quartz.	Complete
125½-140	Remnants of fine-grained biotite schist, with quartz, light carbonate, a little magnetite, pyrite, very little rhodochrosite.	Much.
140-149	Quartz, pale rhodochrosite, fine spessartite, pyrite, magnetite.	Complete
149-170	Very few schist remnants, with quartz, small masses of granular magnetite, little pyrite, garnet, light carbonate.	Complete.
170-171	Rhodochrosite, quartz, spessartite, tephroite.	Complete.
171-174	Quartz.	Complete.
174-184	Rhodochrosite, quartz, tephroite, spessartite, pyrrhotite.	Complete.
184-185	Meduim-grained coarse biotite-garnet schist, with quartz, light carbonate.	Moderate.
185-186	Quartz, light carbonate, spessartite, pyrrhotite.	Complete.
186-188	Fine-grained biotite-muscovite-garnet schist, with quartz, light carbonate.	Moderate
188-195	Coarse-grained biotite-chlorite-garnet schist, with quartz, light carbonate.	Moderate.
195-221	Fine-grained, feldspathic biotite, muscovite-garnet schist.	Little.
221-234	Fine-grained light green chlorite-garnet schist.	Little.
234-273	Fine-grained feldspathic biotite-muscovite-garnet schist.	Very little.

Packard manganese showing

The Packard manganese showing (plate 2) consists of a few small outcrops along a brook at the side of the road. No mining has been attempted here, but more of the mineralized rock is said to have been exposed when the nearby road culvert was installed. The mineralized ground shown by these few small exposures is in the form of a massive pink rock consisting of rhodochrosite, rhodonite, and spessartite. Nearby outcrops of schist have the general regional attitude without any indication of unusual folds such as those at the Betts deposits. Nearby exposures of schist indicate that the deposit probably is not large.

Frizzell mangenese prospect

The prospect on the property of E. R. Frizzell (plate 2) is in a meadow where outcrops are very scarce. A pit about 15 feet long, 10 feet wide, and 7 feet deep has been dug and enough soil has been scraped away to show scattered areas of bedrock over an area almost 50 feet in diameter. Most of the rock is fine-grained black schist with strike and dip in accord with the usual regional structure. The mineralized rock is very similar to that at the Betts mines, although no such variety of minerals has been revealed here. Rhodonite, light-gray manganiferous carbonate, rhodochrosite, tephroite, spessartite, pyrite, and manganese oxides are exposed. There is no evidence of unusual folding of the type at the Betts deposits, but that lack may be due to the scarcity of outcrops. Exposures are not sufficient to indicate the size of the deposit.

Vein of magnetite and spessartite near Hawley town house

In the small gorge below the Hawley town house (plate 2) is a fourteen-foot vein of quartz, magnetite, and spessartite, which because of its mineral composition, appears to be related genetically to the other deposits here described (3 p. 175). The vein is parallel to the schistosity of the enclosing chlorite-ankerite schist, which strikes about N. 30° E. and dips 75° E. Some of the quartz is clearly younger than the magnetite and spessartite. At no place does this vein appear to be rich enough for mining. No mining has been done, but the deposit is reported to have been sampled for analysis.

Hawley iron mine

The site of the Hawley iron mine is now much overgrown by trees, but some of the workings may still be seen and blocks of mineralized rock can still be obtained from the dumps. An open trench extends parallel to the schistosity of the connecting rocks, about N. 10° E., for 300 feet. Only Savoy schist is exposed in the walls. About 6 feet west of the north end of this trench and partly overlapping it is another trench 100 feet long. The longer trench appears to have been in a body containing magnetite, spessartite, and quartz. Specular hematite was the principal ore mineral at the shorter trench. The full width of neither lens is exposed, but it could hardly have been greater than seven feet and probably was only three or four feet. Emerson states that a shaft reached a depth of 50 feet and that mining was done in 1891, as well as earlier (3, p. 173-174). A few small prospects in similar, though poorer, material are found as far as three-quarters of a mile to the south and in about the same stratigraphic position. The iron mine lies within the Savoy schist and is a little more than 300 feet west of the contact with the Hawley schist, rather than exactly on it as Emerson believed. These deposits, like that at the town house, are veins parallel to the schistosity, with no unusual structures associated.

Suggestions for further prospecting

The drilling program of the Bureau of Mines indicated that ore extends deeper at the south Betts deposit, but also that no large output is to be expected from these deposits. It does seem possible, however, that significant output might result if several similar deposits were worked simultaneously; a few suggestions for prospecting are therefore offered.

It will be noticed that all of the known manganese deposits are within the narrow, fine-grained member of the savoy schist. (See pl. 1). It is therefore logical to limit prospecting for manganese to that belt.

The association of the Betts ore bodies with locally folded structures provides another possible clue for prospecting. Careful field work over the area shown by plate 1 failed to discover any other such structures; however, this failure may be due to lack of exposures.

A further clue for prospecting was suggested by the magnetic deflection discovered during the plane-table mapping of the Betts deposits. This is presumably due to the presence of magnetite in the ore. Some type of magnetic survey in drift-covered areas within the belt of fine-grained schist might lead to the discovery of any hidden deposits. A suitable place for this type of prospecting is the Frizzell manganese prospect, for manganese mineralization is known to have taken place there and the drift cover is too great for the extent of mineralized ground to be learned from surface observations. The Packard manganese showing might also be investigated, although the surrounding schist outcrops indicate that the deposit is probably not large.

The Hawley iron mine and the vein near the Hawley town house contain manganese only as the silicate minerals spessartite and rhodonite, and therefore offer no promise of being commercial sources of manganese. They are too small to be regarded as commercial sources of iron under present conditions.

A fact unfavorable to the possibility of discovering other important manganese deposits in this region is that no boulders of manganese ore have been discovered in the drift except where they could have been derived from the known deposits on the Betts property.

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