The Geology of the Shepaug Aqueduct Tunnel

Litchfield County, Connecticut

By

WILLIAM MACDONOUGH AGAR, Ph.D.
Assistant Professor of Geology, Yale University

with a chapter by

ROBERT A. CAIRNS, C.E.
City Engineer, Waterbury, Conn.

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PREFACE

This bulletin presents the results of a detailed study of the geology of the Shepaug Aqueduct Tunnel and the area immediately surrounding it in the town of Litchfield, near the center of the western upland of Connecticut.

The tunnel was drilled by the city of Waterbury as a part of an extension of its reservoir system, and this bulletin contains a chapter by R. A. Cairns, C.E., city engineer of Waterbury, giving the history of the project and the city's reasons for going to this particular region for additional water.

The geological investigation was undertaken in the tunnel in order to study the seven-mile section so exposed before any part of it was hidden by lining. It was an unusual opportunity to examine a continuous section of the complicated metamorphic rocks of the western upland of Connecticut, and much has been learned concerning the details of structure and petrography of the Berkshire and Hartland schists, the two most widespread formations, as well as of many less widely distributed. Such details are presented here as a record of the geology of the region itself and because of their bearing upon the problems of the geology of western Connecticut and the neighboring areas.

The field work occupied part of the summers of 1925 and 1926, and the petrographic work was done in the laboratory of Yale University during the winter of 1926-1927.

The writer wishes to thank Mr. R. A. Cairns and the whole engineering staff in the field, particularly Mr. I. F. Story, engineer in charge, for unfailing interest in the work and for assistance rendered in many ways. He also wishes to acknowledge the helpful criticism of Mrs. A. Knopf and the help of Professor A. Knopf in the identification of certain minerals in thin section.

GEOLOGY OF THE SHEPAUG AQUEDUCT TUNNEL, LITCHFIELD COUNTY, CONNECTICUT

WILLIAM M. AGAR

INTRODUCTION

The Shepaug tunnel bears in a general northwest-southeast direction across that part of Litchfield County immediately south of Litchfield village. It is designed to carry the waters of the West Branch of the Shepaug River under the intervening hills and the bed of Bantam Lake to the West Branch of the Naugatuck River above the northern extremity of the Morris Reservoir, part of the present Waterbury water system.

The tunnel level is such that it comes to the surface at the crossing of the Bantam River, two-fifths of a mile southwest of Bantam village, and lies above bed rock in a low swampy area one-quarter of a mile west of there. This made it possible to drill the tunnel in three separate sections without sinking any shaft. The westernmost section is a straight tunnel bearing south 81° 27′ east. This part was drilled east from the valley of the Shepaug at a point about one and a quarter miles north of Woodville—the intake point—and west from the westernmost end of the swamp referred to above. An open cut was made through the swamp and this was later cemented and filled. A short section was drilled west from the Bantam River crossing on the same bearing, to meet the eastern edge of the swamp. The grade of this part of the tunnel is 0.08%.

The eastern section begins just across the Bantam River valley and follows the same bearing for 6180 feet with a 0.5% grade to the broad base of Dempsey's Point on the north shore of Bantam Lake. From there it bears S. 35° 46′ E. for 4540 feet, passing under the lake and skirting the shore of Marsh's Point to the bottom of the bay, and then turns again to S. 81° 30′ E. and holds that direction as far as the outfall above the Morris Reservoir. The grade is 0.1% from the first corner to the outfall. This section of the tunnel was drilled from the Bantam River and outfall ends and the tunnels met 2.15 miles from the outfall.

The total length of the tunnel is 38235.67 feet or 7.24 miles and all but the 570 feet under the marsh and the 697 feet at the Bantam River crossing are drilled through solid rock. The difference in elevation between the intake and outfall amounts to 62 feet.

TOPOGRAPHY AND DRAINAGE

The region underlain by the tunnel lies near the center of the western upland of Connecticut. It is maturely dissected with hills rising to more or less accordant levels, lower on the southeast and higher on the north and west. Much of the surface has been built up above its pre-Pleistocene level by glacial deposits and lake or swamp deposits and shows youthful features superimposed upon the mature topography. Besides this the ancient erosion surface that was elevated and dissected was far from smooth, and many irregularities remained to form the high points in the present erosion cycle.

Mount Prospect, 1365 feet, northwest of the center of the area, and Rabbit Hill, 1340 feet, along the western edge, are the highest elevations, while Mount Tom, Little Mount Tom, and Mount Rat, a group of steep hills in the southwest corner, compose the most rugged part of the region. The lowest point is also in the southwest corner where the Shepaug River leaves the map area at an elevation of 560 feet after receiving the Bantam River as a tributary.

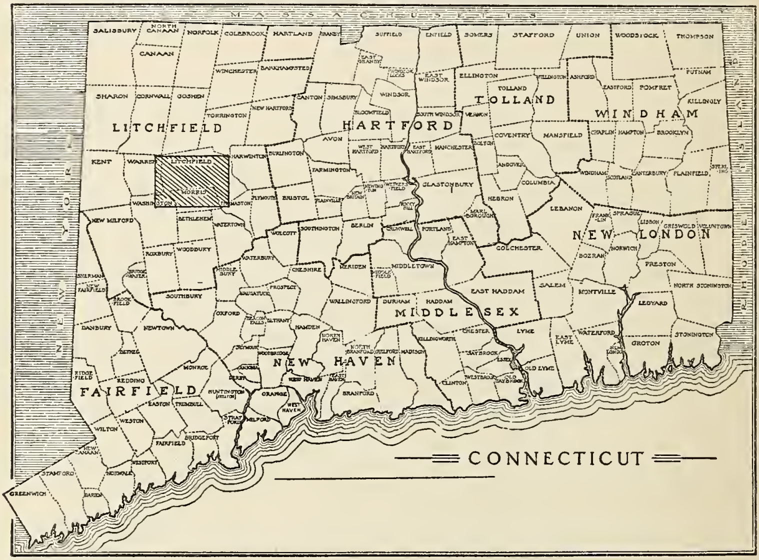

FIG. 1.—Index map of Connecticut. Shaded portion shows area included in this report.

Bantam Lake lies in a depression in the south central part of the region. It is bounded on the northeast by a swamp and a sand plain several square miles in extent, and on the southwest by another swamp bordered by rolling, sandy hills. A number of interesting discoveries relating to the pre-Pleistocene surface under the north end of Bantam Lake were made during the construction of the tunnel and will be mentioned at the end of this report.

The region is drained by three streams (Fig. 2). The Bantam River has the largest watershed. It includes Bantam Lake and cuts through the center of the map and joins the Shepaug River near the southwest corner. The westernmost watershed and the next largest is drained by the Shepaug River, while the smallest one of the three is occupied by the West Branch of the Naugatuck along the eastern margin of the area. The Bantam River enters the Shepaug and together they are tributary to the Housatonic further west. The West Branch of the Naugatuck drains into the main Naugatuck which itself is tributary to the Housatonic some miles south of where the Shepaug enters that stream.

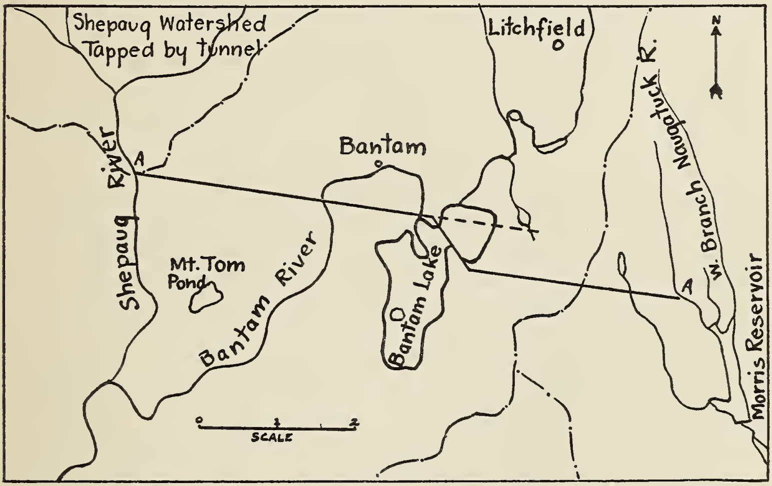

Fig. 2.—Map showing watersheds in area discussed. —.—.—.—.—, Watersheds. AA, Tunnel line. — — — — — — —, Line of diamond drill holes (see Fig. 3).

There are a number of small tributaries, ponds, and marshes included within these drainage systems, but Mount Tom Pond, the largest body of water next to Bantam Lake, though it lies within the area drained by the Bantam River, has no visible inlet or outlet and, on the surface, at any rate, belongs to none of them.

History of the Project

By R. A. Cairns, City Engineer, Waterbury

The Shepaug Tunnel became a necessary adjunct of the water supply system of the City of Waterbury as a natural step in a development resulting from a long series of happenings beginning with the initial construction of reservoirs and distribution mains in 1869. Much criticised and objected to at that time as of doubtful wisdom, the project of a public water supply was successful from the start and from decade to decade the demand for water unfailingly and soon exceeded the capacity of reservoirs frequently enlarged.

In 1893 the futility of frequent and small additions was recognized and the city took the radical step of penetrating into the Litchfield hills, securing diversion rights to 18 square miles of watershed on the West Branch of the Naugatuck River in the towns of Watertown, Thomaston, Morris and Litchfield, creating a reservoir many times larger than any it had built before, and laying a 36-inch pipe line ten miles long. But although this was believed to be almost a final solution of the potable water supply for Waterbury and its suburbs, the continued growth of the community at a rate totally unexpected by the conservative citizen, compelled a serious study as early as 1907 of the possibilities of further resources on a still larger scale.

There were several areas from which an additional supply of substantial size could be obtained. Of these, the natural and most readily accessible was that above the village of Litchfield along Bantam River. Opposition was offered to this scheme on the ground that it would be destructive to the attractions of Bantam Lake, which has a large summer colony bringing trade to the adjoining towns and benefiting them by the creation of a large amount of taxable property. This opposition succeeded in obtaining from the State Legislature an act prohibiting the City of Waterbury from diverting any water from Bantam Lake or from any of the tributaries. A similar act was afterward passed in relation to Waterbury taking water from the Naugatuck River above Torrington.

There then remained as the most feasible project the diversion of water from the Shepaug River, where that stream forms the dividing line between the towns of Litchfield and Warren. Here it was seen that a reservoir of large size could be formed having tributary to it about 37 square miles of sparsely settled hilly country, largely wooded and with a very small percentage of swamps. Analysis of the water showed it to be of satisfactory quality, unusually soft, coming from a region devoid of limestone or other formations tending to produce a hard water. A further attraction is that the area is subject to very little attrition during periods of heavy rain.

The chief legal difficulty in connection with this undertaking lay in obtaining rights to divert the water from one watershed into another and in obtaining satisfactory adjustments with the many interests along the Shepaug and Housatonic Rivers. These matters, however, were finally settled in a manner apparently satisfactory to all parties concerned, provision being made to maintain a certain minimum flow in the stream, some properties being purchased outright, conditional agreements for deferred takings being made with others and in one instance a substantial payment in money representing present value of estimated future damages.

The main physical problem in this Shepaug development lay in finding the best method of conveying water to the City. In this part of the State, as indeed in most others, the water courses run north and south, separated by ridges of hills. It was found that a gravity pipe line could be built which would carry water all the way to the City without tunnels or excessively deep cuttings, but it must follow such a devious course that its length would exceed 21 miles, and much of it would lie in regions not easily reached by vehicles. Other and shorter routes to the City were studied, involving varying lengths of tunnel. It was found that a line almost due east would take water to existing reservoirs in the West Branch Valley, but that its length of about 7¼ miles would of necessity be substantially all so far below the surface of the ground as to require tunneling. No satisfactory site for a regulating reservoir near the City appearing, and direct connection with existing reservoirs by tunnel presenting certain advantages over the long pipe line of necessarily limited capacity, it was finally determined to undertake the driving of the long tunnel.

After careful surveying of the line, a large number of diamond drill borings were made to determine the elevation of rock and to get some information as to its character and its water-bearing qualities. Particular attention was given to the Bantam Lake Basin, containing the largest natural body of fresh water in the State. Here a serious difficulty was encountered. It was found that the northern part of the lake consisted of a deep bowl in the rock filled in to a thickness of a hundred feet or more with sand and silt. Here the surface of the rock lies below the grade line of a self-draining tunnel, necessitating an inverted syphon to keep in the rock. Such a drop in the tunnel would form a pocket a mile long, expensive to construct, always full of water after operation of the aqueduct began, and requiring special pumping arrangements to make it accessible for inspection.

Desiring to avoid this condition, and tunnel driving under air pressure at such a depth being quite impracticable, thus barring any location except in rock where work proceeds under atmospheric pressure, a reconnaissance with the diamond drill was undertaken and it was found that on a line crossing the lake at the narrows and continuing under Marsh's Point to Sandy Beach the rock was high enough at all points to afford at least a minimum amount of cover for the tunnel. The original location was accordingly changed and the tunnel driven on this line, having two angles in it, instead of being straight as originally proposed.

Driving of the tunnel was begun in December, 1921. The westerly section between Shepaug and Bantam Rivers was holed through in April, 1926, and the easterly section was holed through in September of the same year. For much of the way the rock strata was found so solid or so interlocked as to make it unnecessary to support the roof, either temporarily or permanently. A singularly small amount of water was encountered, even where for more than a mile the tunnel penetrated under Bantam Lake and its basin. No especially troublesome faults were found.

General Geology

The region is underlain by igneous and metamorphic rocks that comprise two schist series; a diorite intrusion, in part gneissic; a hornblende gneiss; and still younger granite and pegmatite intrusions.

The two schists, the Berkshire and the Hartland, are the oldest rocks of the region. They are quite distinct in the field and are not believed to be of like age. They lie next to each other in many places but occur in discontinuous, scattered outcrops without any visible contact and, unluckily, the tunnel cuts through an area where the two are separated by several miles of diorite, intrusive into both.

The legend attached to the accompanying map does not assign any definite geological age to the formations exposed in this area. It is thought best to place the rocks in their relative positions according to the structural and petrographic evidence in the region and to await dating the series until work in the surrounding regions affords more convincing evidence than any on hand at present. The map is taken from the Litchfield Quadrangle, Conn.-N.Y., published by the United States Geological Survey.

In 1894 R. Pumpelly[1] made the Hoosac schist, on the east flank of Hoosac Mountain, equivalent to the whole of the Stockbridge limestone, Berkshire schist, Bellows-pipe limestone, and part at least of the Greylock schist lying west of that same mountain. Pumpelly[2] believed he had evidence that the Stockbridge limestone graded laterally into the Hoosac schist along the western base of Hoosac Mountain and in the valley of the Hoosic River. The Cambrian Vermont formation and the pre-Cambrian Stamford gneiss underlie the Hoosac schist and compose the core of the Mountain.

The Hoosac Mountain ridge marks the beginning of the Green Mountain anticlinorium in Massachusetts, an elevated plateau that extends north and south through the western part of the State and separates the lowland of the Connecticut River on the east from the Housatonic Valley on the west. The plateau is composed of

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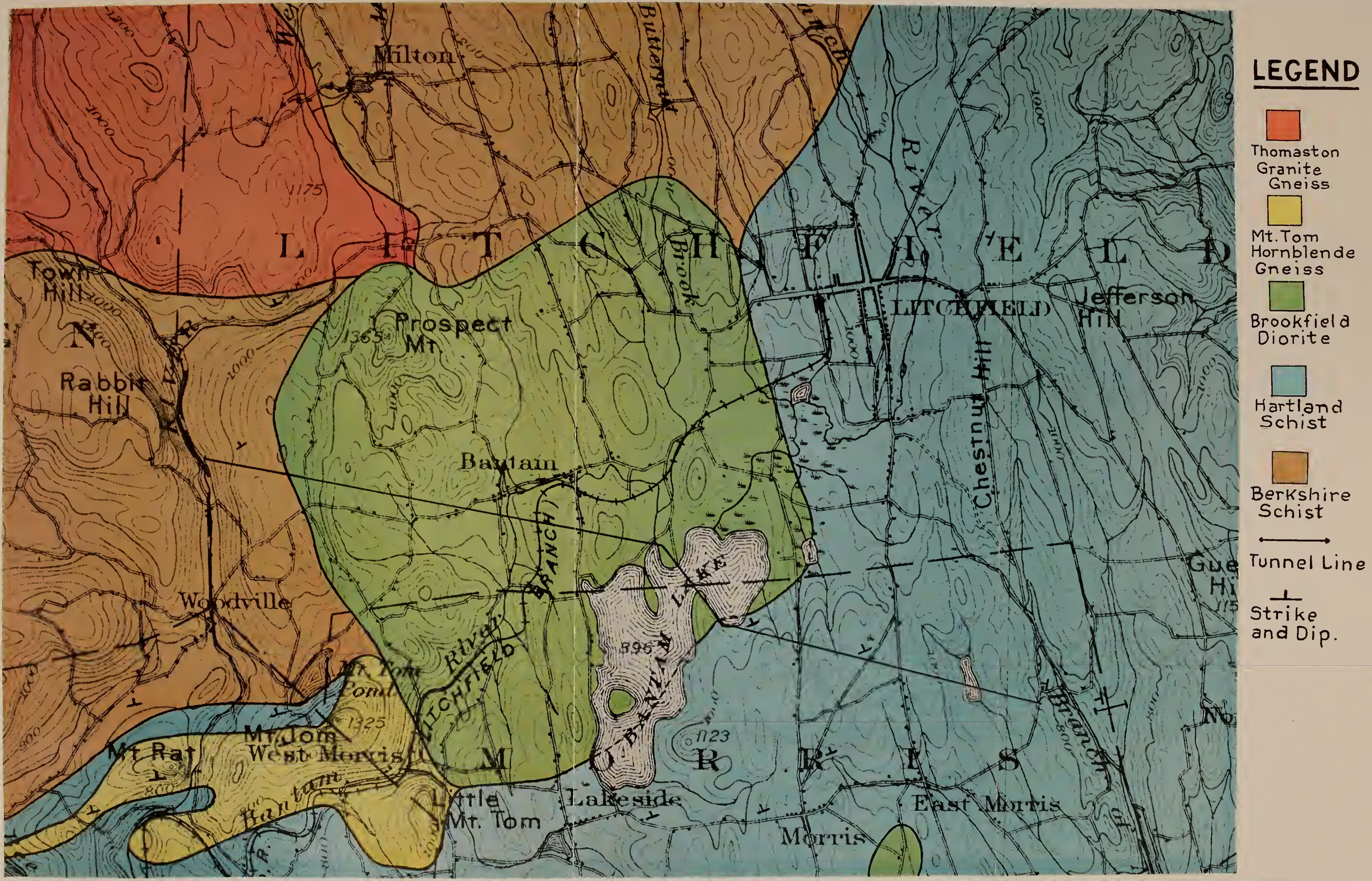
[1] Geology of the Green Mountains in Massachusetts, by Raphael Pumpelly, T. Nelson Dale, and J. E. Wolff, U. S. G. S. Monograph 23, 1894.

[2] Op. cit. pp. 14-17.



Geological Map of the Tunnel Area

Bull. 40, Conn. Geol. & Nat. Hist. Survey pre-Cambrian rocks flanked on the east by the Hoosac schist overlain by the Rowe schist, and on the west by the Dalton formation, the Cheshire quartzite, the Stockbridge limestone, and the Berkshire schist. The Stockbridge limestone is the valley formation of the Housatonic lowland. The Cheshire and Dalton lie as isolated patches along the border of the upland or project into it as spurs and, together with the Berkshire schist, form the isolated hills that rise above the valley floor. This area has been the subject of a number of papers by B. K. Emerson, culminating in "The Geology of Massachusetts and Rhode Island," published in 1917 as Bulletin 597 of the United States Geological Survey. In the correlation tables facing page 17 the Hoosac schist and Rowe schist are made the equivalent of the Berkshire—all of Ordovician age. That is, the Hoosac is taken entirely out of the Cambrian and much restricted in the Ordovician.

The Green Mountain anticlinorium enters northwestern Connecticut as the Norfolk Hills and passes out of the State into southeastern New York as a belt of highlands including Barrack Mountain, Cream Hill, and Sharon Mountain. It is intersected by the Housatonic River which leaves the westerly swinging limestone valley to cross the highlands in a narrow north-south gorge.

The Hoosac schist passes down into Connecticut as a continuous strip of varying width lying along the eastern edge of this anticlinorium and is known as the Hartland schist.[1] The Dalton formation, the Cheshire quartzite, Stockbridge limestone and Berkshire schist maintain their position on the west of the axis until the latter swings southwest out of the State. At this point the supposedly younger series bridges the pre-Cambrian plateau and the Berkshire schist is widely developed in the hills of Cornwall and Kent and comes into contact with the Hartland schist in the neighborhood of Litchfield. The Cheshire quartzite and the Stockbridge limestone are also at present[2] represented as occurring south of the plateau in long narrow bands though there is considerable doubt concerning the equivalence of these to the formations north of the plateau.

A word must be included here concerning the Berkshire formation as it is now mapped in Connecticut. (See reference above.) It forms at least two very distinct types, namely, that on the Mount Washington range, the extension of the Taconic Mountains into Connecticut, a greenish sericite, chlorite schist with considerable albite and local development of garnet; and the Canaan Mountain type, a quartz, biotite schist or a gneiss with as much as ten per cent of oligoclase and considerable amounts of garnet, staurolite

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[1] The Hartland schist may represent in part the Rowe schist of Massachusetts that overlies the Hoosac. It is tentatively considered here as being equivalent to the Hoosac as stated by Rice & Gregory, Manual of the Geology of Conn., Conn. Geol. & Nat. Hist. Survey, Bull. 6, 1906.

[2] H. E. Gregory and H. H. Robinson, Preliminary Geological Map of Connecticut, Bulletin No. 7, Connecticut Geological and Natural History Survey, 1907.

and sillimanite irregularly distributed. The hills that rise above the Housatonic valley floor between these two nearly connect the types petrographically as well as areally, and there seems to be little question that they belong to the same formation.

The Canaan Mountain type of Berkshire is the one that laps over the Green Mountain anticlinorium and that comes into contact with the Hartland schist both north and south of Bantam Lake. The latter two rocks are quite dissimilar and are believed to have suffered a different amount of metamorphism. In fact, if the correlation be based upon this region alone and the western series, discontinuous with the Berkshire to the North, can be proved without question to be the Berkshire, then the Berkshire must be called the older rock.

The Brookfield diorite, a medium to coarse-grained greenish diorite and quartz diorite with gneissoid and even schistose phases, cut by later dikes of diorite porphyry, granite, pegmatite and dark green biotite hornblendite, and including stringers of the Hartland schist, forms the central part of the area. It stretches from the outskirts of Litchfield village on the northeast to Mount Tom on the southwest and underlies most of Bantam Lake. At its northwestern extremity on Mount Prospect it is intersected by a complex set of intrusives, gabbros and related rocks correlated by W. H. Hobbs[1] with the Cortland Series near Peekskill, New York. That area is being studied in detail by E. McKnight and is not described in any detail in this bulletin.

At the southwest extremity of the diorite there lies an irregular area of green and white hornblende gneiss. It forms Mount Tom, Little Mount Tom, and Mount Rat, and projects about one mile to the southwest of the latter hill. This rock, known as the Mount Tom hornblende gneiss, forms dikes in the Hartland schist along the northwest slope of Mount Rat and has a much more perfectly developed foliation in the dikes and along its edges than near the center of the mass. It represents an intrusion that suffered deformation before its solidification was completed.

It will be seen that this surface distribution of rocks eliminates the area of Poughquag quartzite featured on the geological map of Connecticut of 1907[2] as underlying Bantam Lake and covering considerable areas both to the east and west, south of the lake. The reason for this change will be discussed in detail further along. Briefly, it is that the ledges that outcrop over this area are quartz schist identical with many of the layers forming an important part of the Hartland schist series as exposed in the tunnel.

The northwest section of this region is underlain by the Thomaston granite gneiss. It occurs throughout the neighboring

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[1] On Two New Occurrences of the "Cortland Series" of Rocks within the State of Connecticut. W. H. Hobbs, Festschrift zum Siebzigste Geburstage H. Rosenbusch, 25-48 Stuttgart 1906.

[2] Gregory and Robinson, Bull. No. 7.

quarters miles long nearly at right angles to the strike of the foliation and gives the longest continuous section of the schist in the State of Connecticut.

The Hartland formation as exposed in this state was described in some detail by Rice and Gregory.[1] They state on page 97: "The rock is everywhere a mica schist of definable character, but exhibits great variation in texture, composition, and field appearance. Its aspect has been rendered still more complicated by the intrusion of igneous rock on a large and a small scale. Where least affected by intrusion, the rock appears as a highly fissile schist . . . In color it ranges from clear metallic muscovite in West Granby, to a black biotite mixed with graphite further south." Garnet is said to be almost always present and cyanite to be scattered sparingly throughout almost the whole extent of the schist, while staurolite is only locally developed.

The general description summarized above fits the Hartland of this section in a broad way but there is one very important difference. There are two distinct facies of schist exposed in the tunnel and in the neighboring outcrops, namely a fissile, lustrous schist corresponding to the above description, and a quartz schist of totally different aspect. The latter type is a greenish white to brown or bronze rock which cleaves along planes due to the development of mica in bands but shows a great deal of quartz when broken across the cleavage. The two types represent original differences in composition, since they alternate as do sedimentary strata, and first one and then the other will form the dominant rock.

The base of the Hartland (Hoosac) schist exposed along the eastern edge of the Green Mountain anticlinorium in Massachusetts is a coarse garnetiferous mica gneiss. It rests unconformably upon the underlying rocks and is overlain by a non-garnetiferous series of alternating sandy and micaceous layers.[2] Such a succession parallels the distribution of the series in Connecticut where with a westerly dip, the eastern beds are characteristically full of garnets while the upper layers, represented by the tunnel section, are prevailingly non-garnetiferous quartz and mica schists.

The structure of the series as a unit, the amount of repetition by folding or by thrust faulting, are still undetermined. It is believed that the detailed study of the surrounding areas, now under way, will clear up much that is now in doubt. The evidence available from this particular region will be discussed further along.

There are a number of outcrops of the quartz schist in the area north of Morris and south of the tunnel line and again along

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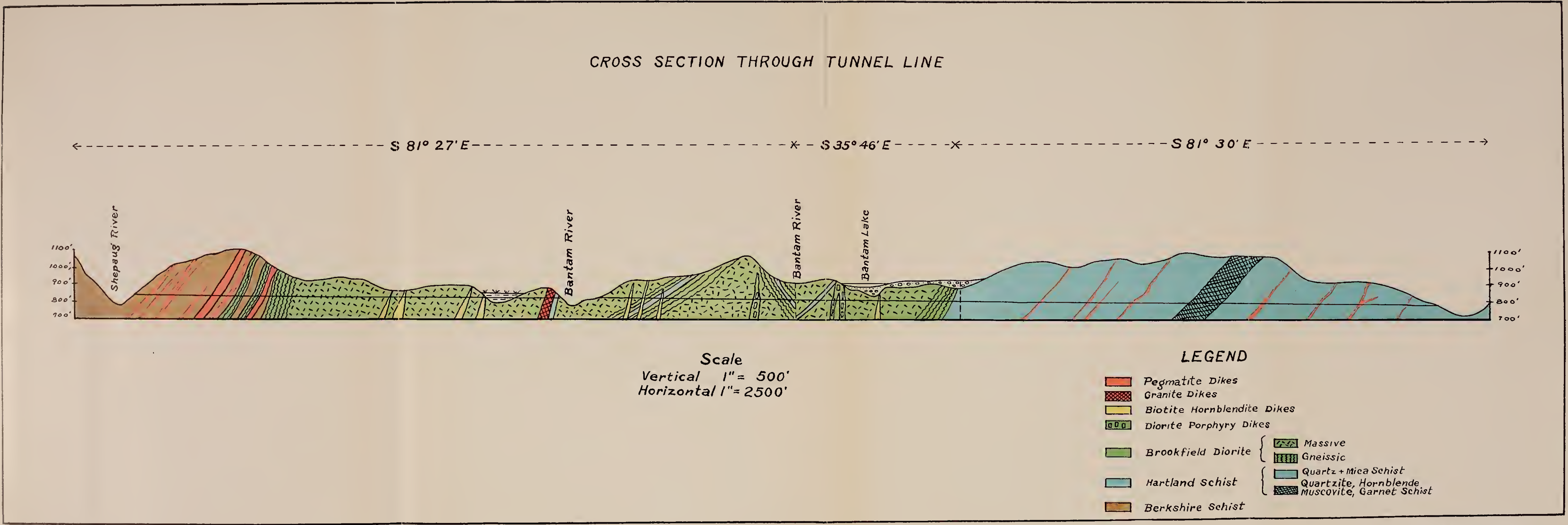
[1] Manual of the Geology of Connecticut. Conn. Geol. and Nat. Hist. Survey, Bull. 6, pp. 96-100, Hartford, 1906.

[2] Joseph Barrell, unpublished typewritten manuscript.



Profile Map of Tunnel

Bull. 40, Conn. Geol. & Nat. Hist. Survey the main highway west from Morris to Lakeside, south of Bantam Lake. The outcrops of the latter set are intersected across the strike of the foliation by the road cuts and show their quartzite character but, if examined along the foliation planes, they closely resemble the mica schist type. It is apparently this series of outcrops coupled with several similar ones occurring near Bantam village and at "The Jams" in the Bantam River, both north of Bantam Lake, that caused the area of Poughquag quartzite underlying Bantam Lake and stretching to the south of it to be placed on the Preliminary Geological Map. The exposures underground show that the quartz schist south of the lake is a part of the Hartland series and that that to the north represents fragments of the Hartland included in and metamorphosed by the diorite to a greater degree than the rest of the formation.

In its first 6500 feet west from the outfall end, the tunnel cuts a monotonous repetition of quartz and mica schist diversified only by the prevalence of first one and then the other type and by the varying number of intrusions of granite and pegmatite.

The mica schists are uniformly fine grained with smooth shiny surfaces and a micaceous luster. There is little fine crumpling and, where the rock is entirely free from injected igneous matter, it has almost the luster of a phyllite. Under the microscope this rock appears as an aggregate of biotite, muscovite, and quartz with subsidiary cloudy plagioclase, rare, rounded grains of apatite and variable amounts of pyrite. The proportion of biotite to muscovite varies and quartz ranges from less than one-half the volume of the rock in the true mica schist to more than seventy per cent in the quartz schist. The latter has the same mineral composition as the mica schist except for the greater amount of quartz.

The foliation of both types is due to the development of discontinuous bands of orientated mica laths. The space between these bands is filled by medium-grained quartz partly elongated parallel to the mica and partly in smaller equidimensional grains. The texture is crystalloblastic (Plate VI a). There is no sign of granulation but there is an occasional slight tendency for the mica to be wrapped around the larger elongated quartz crystals.

This section of the schist has been cut by many pegmatite dikes and a lesser quantity of granite dikes and quartz veins. It is generally true that the intrusives parallel the foliation but some intersect it and all lack the foliation characteristic of the other rocks so that they must date from near the end of the period of folding or subsequent to it. The igneous rocks inject the schist on a small scale as well and locally turn it into a coarse-grained gneiss.

The next one thousand feet of the tunnel pass through an interesting series of quartzites and sericite, hornblende, and garnet schists. The first variant to be encountered is a ten-foot bed of soft, white, lustrous muscovite schist. It differs from the normal mica schist, when examined under the microscope, only by the development of a greater amount of muscovite, almost complete absence of biotite, and the restriction of the quartz to a few layers. One hundred and two hundred feet beyond here there occur a fifteen-foot and a forty-foot bed of grayish white quartzite with very little banding. This is composed of eighty per cent quartz in grains with rather plain edges and mosaic texture, fifteen per cent clinozoisite, a little magnetite and colorless amphibole.

This is followed by a series of garnet, hornblende and sericite schists about one hundred and fifty feet thick. The first is a coarsely crystalline, massive mixture of andesine, quartz, staurolite, unorientated muscovite and biotite, and rare garnets. Certain layers in this rock are composed of large, well-crystallized garnets containing inclusions of quartz and magnetite and altering to chlorite and some epidote. These are set in a ground mass of plagioclase, quartz and chloritized mica. Next follows a thirty-foot bed of dark green hornblende schist speckled with pink garnet crystals a few millimeters in diameter. This rock is composed practically entirely of a fibrous green hornblende in short irregular laths and in aggregates of many crystals, and quartz. Rare grains of apatite and a little magnetite and plagioclase are seen throughout. The small equidimensional garnets cut irregularly across the foliation. This is followed by a twenty-foot bed of dark green hornblende schist without any garnets and with a greater proportion of iron oxide. The last of this series is a muscovite schist full of pinkish garnets and lesser amounts of titanite that give it a rough gneissoid appearance.

The next few hundred feet of the tunnel contain a few more bands of white muscovite schist from five to ten feet thick followed by two thousand feet of quartz and mica schist exactly like the first part. From there to a point within five hundred feet of the eastern corner in the tunnel the rock alternates between a dark green, fine-grained hornblende or hornblende mica schist and a sandy mica schist (Plate v b). From there to the contact between the Hartland and the Brookfield diorite, one hundred ninety-five feet northwest of the corner, the schist returns to its normal alternation of quartz and mica types. These persist right up to the contact where considerable black tourmaline, garnet, and staurolite are developed in the otherwise normal mica schist. The tourmaline alone of these minerals is not to be found in many parts of the rock and may represent additions from the diorite magma intruded into the schist.

STRUCTURE

Throughout the length of the Hartland section exposed in the tunnel, the dip is invariably to the west and the strike east of north. Readings on the dip show a gradual increase from twenty-five degrees west at the contact to fifty-four degrees west at the portal with no great variation at any one point. The strike veers from north forty-five degrees east near the diorite, where it appears to parallel the contact, to a maximum of north seventy-five degrees east just west of the central portion and then swings irregularly back to north two degrees east at the portal. A short tunnel, 1635 feet long, drilled under the southern extension of Guernsey Hill one half a mile east of the outfall of the seven-mile tunnel (see map facing page 16), exposes a section with the dip averaging forty-five degrees west but with a strike of north ten degrees west. The rock here exposed is a repetition of quartz and mica schist.

Outcrops of the Hartland schist are rare in the area mapped. In the hills east and northeast of Litchfield village there are a good many surface exposures of coarsely crystalline garnetiferous mica schist with a north-south strike and a dip west of vertical, while south and southeast of Bantam Lake there are a number of outcrops of fine-grained mica and quartz schist that strike from north seventy to north eighty east and dip northwest. At the southwest corner of the area near Mount Rat the Hartland—a lustrous, somewhat sandy, fine-grained mica schist—forms a number of irregular re-entrants into an intruded mass of hornblende gneiss. The strike is nearly east-west and the dip north.

It can be seen from this that the surface exposures give no more idea of the amount of folding that may have taken place than does the underground section. Either the beds compose one thick series all tilted one way or a series of overturned folds with isoclinal dip planed off by erosion and intersected by the tunnel far from the ends of the folds so that the dip of the original strata and the schistosity coincide. If the first be true, a series of immense thickness is present, more than eight thousand feet for the tunnel section alone, and that is but a small part of the whole. In considering the second case it is true that any amount of repetition could be present in the main tunnel and in the short east section without changing the endless sequence of quartz and mica schist intersected by dikes of pegmatite. A consideration of the great thickness required by the first assumption is in itself enough to make repetition by folding almost a certainty. The amount of such repetition cannot be determined but we can at least assign a minimum thickness to the series. The sequence of sericite, hornblende and garnet schists described previously and located near the central part of the main tunnel represents an easily recognized sequence which assuredly is not repeated in a linear distance of a little under two miles. With an average dip of forty degrees the thickness of the formation in this distance is 6500 feet, and if the telltale series were to come in immediately beyond the exposed area, the thickness of the formation without repetition of this series would be 3250 feet.

FAULTS

There are a number of faults exposed in the underground section. Most of them are small normal faults with a relatively flat westerly dip. Only in one instance could an exact measure of the throw be made. Two vertical faults with the downthrow block on the west cause the repetition of two narrow calcareous bands of the schist with a combined throw of one hundred seventy feet. The strike of all these small faults averages nearly north-south.

About one mile east of the eastern corner in the tunnel there is a fault of some magnitude. It strikes north sixty-four degrees east and dips twenty-four degrees north. Several feet of clay gouge accompany the fault and the foot wall rock is badly shattered for a distance of nearly one hundred feet. Due to the fractured character of the rock, it is impossible to determine the direction of the throw. There is no surface expression of the line of weakness nor can the fault affect the calculation of the minimum thickness of the schist given above since it lies to the west of the area considered.

METAMORPHISM OF THE HARTLAND SCHIST

The Hartland schist, in common with the other rocks of the region, has undergone a rather complicated set of changes. An original series of normal sedimentary strata made up of sandstone, shale, and relatively rare calcareous layers was so compressed by forces acting in a general east-west direction that the beds were greatly folded and overturned over considerable areas. Intrusions of granite on a regional scale accompanied the folding both as stocks several miles in diameter and as dikes and fine injections of granite and pegmatite. The stocks are in part strongly gneissoid with a cataclastic texture showing that they preceded some of the folding, but the dikes, probably later offshoots from the same magma, show no sign of mashing.

The schist is completely recrystallized and, in general, at least throughout the area here discussed, the foliation is parallel with the original bedding. There is no granulation of the minerals and no suggestion of straining after the crystalloblastic texture developed.

The area of Hartland schist covered by this report is entirely free from large granitic intrusions. To the east of this section the Thomaston granite and the pegmatite dikes form a large proportion of the surface outcrops and the schist is very thoroughly cut up and intimately penetrated by the igneous rocks. The granites nearly give out in the tunnel region but the pegmatites persist in great numbers and locally penetrate the schist to such an extent as to form a migmatite.

A more complete study of the whole Hartland schist is needed in order fully to appreciate the varying effect of igneous impregnation and injection upon the rock. The sandy, micaceous, and garnetiferous types with crystalloblastic texture far from any intrusives are certainly to be explained by dynamic metamorphism but the presence, at that time, of molten magmas underlying the area must have had an effect. The change from a simple recrystallized schist to a coarse injection gneiss that takes place in the neighborhood of the larger dikes and stocks of granite, is the effect of a cause that was doubtless at work to a lesser degree over a much greater area.

One-eighth of a mile south of the outfall on a new road that skirts the valley into which the waters of the tunnel will flow, there is an exposure of closely folded schist and quartzite cut by pegmatite dikes in part earlier and in part later than the folding. These quartzite beds are worthy of note because they show a development of hornblende drawn out into pencils, small fragments of apatite, large skeletal crystals of garnet that appear to the naked eye as blurred, reddish brown spots on a white background; biotite, zircon, and a little magnetite. These minerals are best developed near the contact and, together with some granulation of the quartz, give the rock a distinct foliation. These minerals are due to the recrystallization of the impure parts of the original sandstone near the contacts. There are a number of narrow bands of similar rock in the tunnel.

There is another type of alteration in the same rock in which hornblende and garnet are developed and the hornblende forms unorientated laths. This type is associated with the small pegmatite dikes that cut the quartzite and schist and is believed to be due to contact metamorphism by solutions emanating from the pegmatite. Some of the "pencils" of hornblende mentioned under the first type of alteration seem to be cut off abruptly or eaten into by quartz later than the recrystallization. Veins or irregular patches of crystalline calcite are common in certain parts of the quartzite.

Two narrow calcareous beds in the short tunnel under the southern end of Guernsey Ridge represent a third type of alteration. They are composed of granular quartz, hornblende in unorientated blades, garnet, zoisite, titanite, muscovite, apatite, calcite, and considerable plagioclase with an index higher than that of quartz. None of these minerals are strained or crushed and the rock appears to be a mixed type—an impure limestone layer recrystallized and then penetrated by quartz and plagioclase. There are no large dikes in the neighborhood so that the solutions must have traveled far and performed a selective replacement.

The part that such impregnations and replacements have played in the total metamorphism of the area here under discussion is relatively slight, but it is believed that the neighboring areas, where intrusions are common, will show a greater proportion of such changes.

The Berkshire Schist

The Berkshire schist is a widespread formation in northwestern Connecticut and extends north into Massachusetts and southwest into New York. It varies considerably in its mineralogy and in the amount of metamorphism that it has undergone. The Berkshire that extends into this map area is the same general type as that which forms Canaan Mountain—i. e., a coarse quartz, biotite schist with locally sufficient feldspar to be a gneiss.[1] It is cut off from the Canaan Mountain mass in the north by a narrow belt of gneisses belonging to the Becket formation but is almost certainly a continuation of the Canaan Mountain rock. It is intruded by a large stock of Thomaston granite gneiss in the northwest corner of this area and is cut by many dikes of pegmatite.

The areal distribution of the formation as mapped in the present report differs considerably from that on the former map.[2] The whole region about the Shepaug River west of the Brookfield diorite and north of Mount Tom is mapped as Berkshire, and the Becket, shown here on the former map, is omitted altogether. The first three thousand feet of the tunnel pass through a contorted, variable mica gneiss and open up a section not hitherto observable. Reasons are given below for regarding this rock as a part of the Berkshire formation, though such an assignment is certainly subject to change when a more detailed study of that whole formation is completed.

The Becket gneiss as originally mapped and described[3] includes a great variety of metamorphic rocks in part originally igneous, in part sedimentary. Some parts are undoubtedly pre-Cambrian and some are of questionable age. The writer has begun to remap those areas and finds the following three main types: 1. The Becket granite gneiss typified by the slightly gneissoid rock at Becket, Massachusetts, and Norfolk, Connecticut.[4] This is a white or grey quartz, microcline, oligoclase, biotite and (or) muscovite granite grading into a strongly gneissoid type with a cataclastic texture. 2. A paragneiss consisting of the Becket injected into some pre-existing biotite schist series. 3. An older series of metamorphosed sediments—the Hinsdale gneiss of B. K. Emerson[5] made up of quartzite, altered limestone layers, and a siliceous biotite gneiss. The gneiss is very variable but is characterized by large amounts of microcline, dark brown biotite with

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[1] See bottom of page 17 of this report.

[2] Preliminary Geological Map of Connecticut, H. E. Gregory and H. H. Robinson.

[3] Manual of the Geology of Connecticut, W. N. Rice and H. E. Gregory, Conn. Geol. and Nat. Hist. Survey Bull. No. 6, page 93, and Preliminary Geological Map of Connecticut by H. E. Gregory and H. H. Robinson.

[4] Geology of Massachusetts and Rhode Island, B. K. Emerson, U.S.G.S. Bull. 597, pp. 154-155, 1917.

[5] Op. cit., page 10.

bent or broken lamellae, quartz with sutured boundaries and undulatory extinction, and considerable sillimanite. Apatite and garnet may be present.

The Berkshire schist of the eastern belt described above and exclusive of the tunnel section is a very variable rock, but it may be characterized as a biotite schist or gneiss containing much quartz and up to ten per cent of oligoclase. Apatite is always present as small rounded grains and both garnet and staurolite are commonly formed. The biotite is frequently bent and where most disturbed sillimanite has formed and the quartz is partially granulated. This rock is intruded and injected by variable numbers of pegmatites and, in the Canaan Mountain section, is full of irregular knots of feldspar and garnet.

The rock exposed in the first three thousand feet of the tunnel is a highly contorted biotite gneiss containing much quartz and oligoclase. Apatite, garnet and sillimanite may be present. The biotite lamellae are frequently warped but the quartz is only rarely granulated. These three thousand feet contain more than six hundred feet of pegmatite exclusive of the dikes only a few inches wide and the thin layers interlaminated with the schist.

It is evident, therefore, that this rock does not resemble the Hinsdale gneiss. It contains no microcline and lacks the quartzite and metamorphosed limestone bands. On the other hand, its microscopic resemblance to the Berkshire is very striking and, bearing in mind what a variable formation the Berkshire is, there appears to be no reason for establishing a new series here. It is tentatively regarded, then, as a representative of the eastern belt of the Berkshire schist somewhat more thoroughly cut up by pegmatites than most of that rock.

The strike of the foliation in the tunnel varies between north twenty and north thirty degrees east. The dip is prevailingly west at an angle of eighty degrees or more, though it occasionally flattens to forty-five degrees west, or stands vertical, or is very slightly overturned towards the east. Pegmatite dikes cut the schist at all angles and have very irregular contacts. In large part they lie parallel to the foliation but even then their boundaries are irregular (Plate IV). A pegmatite may cut across several layers of schist as a fine dike only to spread out as a large bulb some distance from the main mass. This igneous or aqueo-igneous material has not replaced the schist to any noticeable extent but has confined its activity to an injection in fine layers and intrusion on a larger scale.

There is one pegmatite two hundred and fifty feet thick that outcrops at the surface as well as underground. For the most part these dikes are composed of quartz, white microcline, albite and garnet, and exhibit no foliation, but there is one dike two hundred feet wide made up of pink microcline, quartz, some magnetite, garnet, and very little green pleochroic biotite, and muscovite. It exhibits a coarse banding parallel to that of the wall rock.

The contact between the Berkshire schist and the Brookfield diorite is very irregular. Diorite dikes have penetrated the schist several hundred feet from the contact and thick bands of the schist are included within the igneous rock but no intimate mixing of the two formations has taken place.

It is impossible to draw conclusions concerning the structure and metamorphism of the Berkshire schist as a whole from the small section here described. Certain characteristics may be pointed out, however, that serve to distinguish it from the Hartland schist with which it comes in contact both north and south of the tunnel. In the first place, there is no constant relation between the foliation and the former bedding planes. The foliation is due to coarse bands of oligoclase (in some cases albite) and quartz, rarely somewhat granulated, alternating with relatively thin layers of crumpled and strained biotite and much finer grained quartz. It lacks the simple crystalloblastic texture of the Hartland schist. The rock was thoroughly recrystallized and injected in fine bands by quartz and feldspar, after which a slight movement gave it an incipient cataclastic texture and bent and folded the biotite laths that had formed in response to the first metamorphism (see Plate VI b).

Due to the similarity of various parts of this rock, the lack of any sign of original bedding and the number and size of the dikes that cut it, it is impossible even to estimate the thickness of the series.

The Brookfield Diorite

The Brookfield diorite forms a nearly circular mass in the center of the area described and separates the Hartland schist on the east from the Berkshire schist on the west. The tunnel passes through this formation from west to east and serves to locate its boundaries in this direction with great accuracy. The line of bore holes bored along the course originally proposed for the tunnel across the broad upper end of Bantam Lake served to locate the Brookfield-Hartland contact under Cranberry Pond and swamp. The contact in the tunnel itself is a little northwest of the angle near the base of Marsh's Point, and the western contact with the Berkshire is located almost beneath the highest point of the first hill in the tunnel line east of the Shepaug River.

Little Mount Tom, near the southwest corner of the map, is now known to be composed of the same hornblende gneiss as Mount Tom (see next chapter), so that the diorite boundary swings along the northeast foot of both those hills. The rest of the boundary is taken from the Preliminary Geological Map of Connecticut. The contact is everywhere covered and no reason is known to change it.

A smaller mass of the same diorite lies immediately south of East Morris and extends north onto the southerly edge of this map in the midst of the Hartland schist. It is about one mile long and one-quarter of a mile wide.

The Brookfield diorite is not a single simple intrusive but represents a number of different textural and mineralogical types. The characteristic diorite from which the formation was named is a green and white, mottled, medium-grained rock with a granitic texture (Plates II b and VII a). It is essentially a hornblende, biotite, andesine or oligoclase diorite with variable but usually large amounts of apatite and titanite, occasionally some diopside and small amounts of quartz. There are two variants of this massive type, one a light-colored quartz diorite composed of quartz, biotite and andesine, the other a fine-grained, granular, porphyritic diorite similar in composition to the first type described but with the addition of scattered andesine phenocrysts from one-eighth to one-quarter of an inch in length. There are recurrent masses of fine-grained, schistose diorite or coarse diorite gneiss throughout the tunnel that do not differ mineralogically from the granular textured types. The foliation is due to the development of more biotite, sometimes at the expense of the hornblende, with definite orientation and with the consequent formation of bands richer in hornblende and biotite, or in feldspar as the case may be; and to some straining and bending of the biotite and plagioclase and granulation of the quartz when present.

The strike of the banding in the foliated diorite parallels that of the surrounding schists as a general rule but veers toward the northwest both east and west of the northern angle in the tunnel. The trend of the intruded porphyry dikes and the inclusions of Hartland schist changes with the diorite and the dip swings to the northeast or east. This does not bear any relation to the trend of the diorite border since, before the Hartland schist is reached, the strike swings back to the northwest and the dip to the west, the normal dip and strike in the area, parallel with the foliation of the schist and nearly parallel with the contact.

So far as can be determined from the surface outcrops, this change in strike and dip does not occur in the other formations but is confined to the diorite and its inclusions.

Dikes of gneissoid, quartz monzonite porphyry from a few inches to twenty feet thick cut the diorite throughout its extent and outcrop at various places, such as on the tip of Dempsey's Point on the north shore of Bantam Lake. This rock is conspicuous because of white or pinkish phenocrysts of microcline from one-quarter to more than three inches in length (Plate V a) set at all angles in a groundmass of quartz, potash feldspar, green biotite and andesine. Pyrite, apatite, and muscovite form the accessory minerals. The groundmass of the dikes usually possesses a rough gneissoid banding due to the segregation of the biotite into separate layers and the granulation of much of the quartz, especially that surrounding the microcline phenocrysts and some crushing of the microcline itself.

Still another vastly different type of dike rock occurs. That is a biotite hornblendite composed in large part of those two minerals together with some apatite, pyrrhotite and magnetite, a little colorless amphibole and, in one instance, monoclinic pyroxene, in another, a little andesine and quartz. In plane polarized light the hornblende is light green but shows strong pleochroism—blue-green parallel with Z and light yellow-green parallel with X with a maximum extinction angle of twenty-nine degrees. It frequently merges into a colorless, non-pleochroic amphibole with a slightly lower extinction angle and birefringence. This is not a case of sharp zoning. The two usually blend irregularly with green at the center or are patchily distributed one within the other. The texture of this rock is massive and the biotite is commonly developed along the prismatic cleavage planes of the hornblende. (Plate VII b.)

Three small dikes of this type occur near the eastern edge of the diorite but the great majority are grouped around the central section of the tunnel just east and west of the Bantam River crossing. They all strike north to northeast and are between ten and two hundred feet thick.

There is no identical rock that outcrops in this or in neighboring regions. The norites, gabbros, and related rocks of Mount Prospect[1] approach it most closely. They are unmetamorphosed intrusives younger than the main mass of the diorite and though they usually contain considerable monoclinic or orthorhombic pyroxene, some are nearly all hornblende and mica.

There is some similarity, then, between the two groups, especially since the biotite hornblendite dike in the tunnel nearest to Mount Prospect contains a good deal of monoclinic pyroxene, and pyrrhotite is a constant accessory in the dikes as well as being the cause of the long-abandoned nickel prospects on Mount Prospect itself.

The complexity of types grouped here under the term Brookfield diorite is considerable and does not represent a simple sequence of intrusions. A hand specimen three by three inches will often show both coarse and fine-grained types with a good deal of difference in the amount of feldspar present, and the coarse-grained diorite grades quickly but evenly into the fine-grained, granular type with small but distinct plagioclase phenocrysts. A certain amount of segregation or differentiation in place has occurred but that cannot explain all of the variations. The granodiorite and the microcline porphyry types are distinct dikes and, as was pointed out above, much of the diorite is rather strongly foliated. Those

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[1] On Two New Occurrences of the "Cortland Series" of Rocks within the State of Connecticut. W. H. Hobbs, Fest. H. Rosenbusch, pp. 25-48, Stuttgart, 1906.

parts have no peripheral or other regular arrangement nor are they always marked off sharply from types with a granitic texture. The varying degree of foliation represented shows that these various parts were intruded at slightly different dates, ranging from before the end of the regional pressure till after the cessation of all metamorphism.

The biotite-hornblendite dikes, like their supposed relatives on Mount Prospect, are unmetamorphosed. They were intruded late in the sequence and nearly always occur within a schistose area of diorite or between a schistose and a massive type.

The Schist Inclusions in the Diorite

The diorite contains a considerable number of inclusions of quartz and mica schist, mostly too small to be mapped on the scale employed, clearly related to the Hartland schist. These are most plentiful near the central part of the diorite and disappear entirely within a few thousand feet of the Brookfield-Berkshire contact on the west. As was mentioned before, the strike and dip of these included layers varies with that of the foliation in the diorite.

The mineralogy of these inclusions is much the same as that of the rest of the Hartland series. Quartz, biotite, muscovite, some plagioclase, garnet, apatite, and pyrite are the common minerals. Rare titanite, sillimanite, calcite, and in some cases considerable diopside are the additional minerals not found in other parts of the schist. These bands represent the quartz and mica schist facies of the Hartland only slightly changed chemically but with very different textures. In place of the simple recrystallization textures seen before, we find cataclastic textures with a true mortar texture in some cases (Plate VIII a). In these the quartz is crushed around large and slightly strained feldspars, the biotite is bent around these more resistant masses and much sillimanite is formed in curved rods or bundles. In certain cases a good deal of granitization of the inclusion had taken place before it was incorporated into the diorite and bands of quartz and orthoclase with a little micropegmatite alternate with quartz, biotite and sillimanite foliae. Both of the bands show crushing. In one instance the schist inclusion is directly alongside a dike of rather gneissoid Thomaston granite and itself contains an unusual amount of quartz and some fresh microcline grains.

The calcite that is found in most of these schists as well as in the diorite itself is very rarely if ever formed in place from the alteration of the plagioclase but is usually introduced along microscopic veins and faults. Only one case is known where the calcite is present in appreciable quantity as small irregular grains throughout the rock and that is in the quartz diopside schist at the entrance to the tunnel just west of the Bantam River crossing. Pyroxene forms ten per cent or more of this rock and quartz eighty to eighty-five per cent with a very little muscovite, pyrite, plagioclase and calcite.

Close to the western boundary of the diorite there are two areas of mica gneiss included within the main igneous mass. These are undoubtedly related to the Berkshire schist but exhibit a more advanced stage of crushing than that outside of the diorite. The texture is schistose—that is, they have been recrystallized along with the rest of the Berkshire—but the minerals so formed have suffered further deformation to a greater degree than those in the mass of the schist. The quartz is slightly to nearly completely granulated and the biotite is moulded around the more resistant garnet and plagioclase crystals. The difference in the degree of crushing is about the same as that between the Hartland schist and its representatives included within the diorite.

The Mount Tom Hornblende Gneiss

The three prominent hills in the southwest corner of the region, Mount Tom, Little Mount Tom, and Mount Rat, are composed of a dark green or green and white hornblende gneiss. The irregular area occupied by this rock is two miles broad on the east, where it abuts against the Brookfield diorite, and projects in two long spurs to the southwest into the Hartland schist. The longest of these spurs is more than three miles long and forms the ridge of Mount Rat.

The gneiss is composed chiefly of green hornblende and andesine with smaller amounts of quartz and with titanite and magnetite forming rare accessories. The texture is nearly everywhere strongly gneissoid though it is more massive near the center of the area than along the borders. The foliation is due to the very complete granulation of the plagioclase and the parallel orientation of the hornblende laths. Quartz is present in considerable quantities and always in much larger individual grains than the plagioclase (Plate VIII b). Some of it occurs in lenticular groups of grains which strongly suggest a certain amount of granulation but much less than the pulverized andesine. The hornblende laths sometimes end in fine rods that pass out into the ground-up plagioclase. They are only in part crushed and do not seem to show as great effects of pressure as it would seem should accompany such complete crushing of the feldspar. The rock has about the same composition as the quartz-bearing types of the Brookfield diorite, with a little more hornblende, but it must not be confused with the gneissic derivatives of the diorite. Those have a cataclastic texture developed by pressure that affected an already solidified rock. The Mount Tom gneiss, on the other hand, has a protoclastic texture developed through pressure during solidification after the plagioclase had crystallized but before the quartz was formed. The fine, unbroken rods of hornblende appear to show that the recrystallization of that mineral had just begun when the pressure ceased.

On the southwest slope of Mount Rat, northeast of the road that crosses between the two high knobs, the hornblende gneiss is exposed in a field as a series of dikes or sills cutting a silvery white, fine-grained type of the Hartland schist. The foliation of the two rocks is parallel and strikes nearly east and west. One of the intrusions has a very irregular contact zone with fragments of the schist included in the gneiss and a light green epidote schist developed in nodules along its edge. The microscope shows that these nodules are similar to the main gneiss with the addition of large amounts of epidote.

The protoclastic texture and the igneous contact of the gneiss are of particular interest since they prove the igneous character of the rock and establish something with which to compare the many other hornblende gneisses among the metamorphic rocks of western Connecticut. There are hornblende gneisses in the Berkshire schist and in the areas now mapped as Becket gneiss that resemble this rock very closely. There are others in the Becket and in the Hartland schist that have been formed out of original sediments.

The Thomaston Granite Gneiss

The Thomaston granite gneiss is an intrusive rock that is rather widely developed in the western upland of Connecticut, particularly in the central and southern parts. The texture varies from that of a massive granite with no sign of foliation to a decidedly gneissoid type with a secondary development of mica and considerable granulation of the quartz. The least metamorphosed part, as at the Plymouth quarry at Thomaston, was described in the Manual of the Geology of Connecticut, page 109, as follows: . . . . "the rock is remarkably white in color, has a medium grain, and is flecked by numerous small scales of mica (biotite). The white base of the rock is made up of about equal parts of a white feldspar (microcline) and quartz. Locally, as in the Wilton area, it is distinctly porphyritic with phenocrysts of microcline which sometimes reach one-half an inch in length."

Only one considerable mass of the Thomaston granite gneiss occurs in this map area. It intrudes the Berkshire schist in the northwest corner of the area and projects some distance beyond it to the north and northwest. It is a gneissoid quartz, microcline, muscovite, and biotite granite with considerable oligoclase, micropegmatite and some apatite. The biotite is dark brown with strong pleochroic halos around minute zircons. The texture is usually cataclastic and the foliation is due to the parallel orientation of the mica flakes and the granulation of the quartz grains.

There are two large dikes of exactly this same character cutting the Brookfield diorite just west of the Bantam River opening in

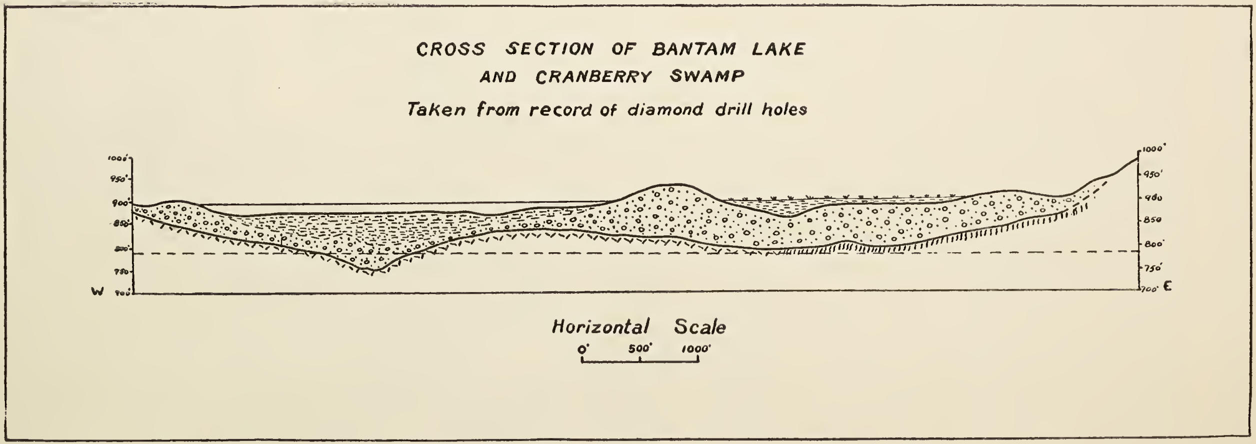

Fig. 3.—Cross Section of Bantam Lake and Cranberry Swamp.

the tunnel. The remaining granite dikes that occur in the tunnel—to some extent in the diorite but to a much greater degree in the Hartland schist—are granitic textured rocks that have the same composition as the gneiss noted above but lack its foliation. Great quantities of pegmatite dikes, large and small, cut the Brookfield diorite and the Berkshire and Hartland schists throughout the tunnel. Some of these dikes show a distinct foliation and small ones are apt to be folded with the schists, but the majority are massive and cut across the foliation planes of the older rocks.

Buried Surface Features Exposed by the Tunnel and the Diamond Drill Holes

It is not the purpose of this report to describe the glacial phenomena of the region in detail but certain features that have been exposed to view by the tunnel excavation or by the diamond drill holes that preceded the excavation can properly be included.

PRE-PLEISTOCENE WEATHERING PRESERVED SOUTH OF MOUNT PROSPECT

It is generally true in this region, as would be expected in a recently glaciated area, that the rock underlying the rather thin cover of till has undergone very little weathering since the products of pre-Pleistocene decay were swept away by the advancing ice. There is one notable exception to this rule immediately west of the peat bog that lies in the path of the tunnel fifteen hundred and sixty feet west of the Bantam River crossing. For a distance of nearly two thousand feet the tunnel was driven through soft, rotten rock that made considerable trouble for the engineers since it necessitated continual timbering. A number of small faults occur in this part and both the diorite and biotite-hornblendite are crushed and slickenslided in several places, but these faults are neither large enough nor common enough to be the direct cause of the weakness of the rock, though they may have helped to cause the unusual depth of decay. This area of deep pre-glacial weathering was apparently partly protected from glacial erosion by the higher lands to the north and some part of the weathered rock was preserved.

THE PRE-GLACIAL SURFACE UNDER THE NORTH END OF BANTAM LAKE

The diamond drill holes that were bored into the bed of the lake to determine the thickness of the rock cover above the proposed tunnel line directly across the northern part of the lake showed a surprising depth of sand, gravel and heterogeneous boulder beds lying below the lake silts (Fig. 3). The proposed tunnel would have passed out of the solid rock into the glacial till and a change in plan was necessitated. Borings across the narrows between Dempsey's Point and Marsh's Point showed a safe thickness of rock above the tunnel but uncovered a gorge between these two headlands (Profile Map—central part). Evidently the pre-Pleistocene Bantam River flowed through a broad valley to the north and a relatively restricted gorge under the present narrows of the lake. The difference in the level of the bed rock must be explained by depth of weathering or glacial scour or both. South of the lake a seemingly trivial glacial divide blocked off the original course of the stream and caused it to flow out of Bantam Lake to the north within a short distance from where it enters the lake.

The original line of bore holes also shows that the long north-south ridge between Bantam Lake and Cranberry swamp has no corresponding rock ridge beneath it. The hill is composed entirely of glacial debris and the old land surface rose only slightly from the river's bank to fall again beneath the present swamp, then rose steeply to the east to form high rocky ridges.

Marsh's Point is also composed of glacial till though the rock surface rises nearer to the present surface than in the first case.

The extensive sand plain to the north of the northern expansion of Bantam Lake lies at about the same level as the swamp and only a few feet above the lake itself. The bore holes run south of this plain so that the depth at which the bed rock lies is not known.

SUMMARY

It may be stated in conclusion that this area was chosen for a special report because of the construction of the tunnel that exposed many features otherwise hidden from view. To be sure, it is a critical area because the two schist series come together, though, unluckily, an actual contact has not been found; but it is a difficult area to treat as an entity separate from the rest of the western upland because it touches many problems that cannot be solved in the area itself. The details are here presented with full recognition that they represent only a part of a vastly greater whole, but with the conviction also that they will aid in the solution of the problems connected with them.

The tunnel section and the examination of the outcrops in the surrounding region have caused a number of changes on the areal map. First, the Poughquag quartzite shown on the former map around Bantam Lake is not present at all, but there are many outcroppings of a quartz schist that forms a part of the Hartland series. Second, the Becket gneiss formerly mapped along the Shepaug River at the entrance of the tunnel is also non-existent. That area is now tentatively placed as a part of the Berkshire schist. Finally, the rock forming Mount Tom and the neighboring hills is not a true amphibolite but a hornblende gneiss with a protoclastic texture, and Little Mount Tom is composed of the same rock and not, as previously mapped, of Brookfield diorite.

Besides these definite changes the areal distribution of certain formations has been altered considerably; the boundaries between the Brookfield diorite and the neighboring schists have been located more accurately; the diorite itself has been shown to be a composite of many closely related intrusions, and the Berkshire schist to be considerably older than the Hartland.

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a. View looking up the Shepaug River Valley, soon to be turned into a reservoir. Tunnel entrance to the right of the shacks. Photograph by B. H. Walden.

b. View looking into entrance of tunnel from across the Shepaug River, along the line of the proposed dam.

PLATE II.

a. View looking down the Shepaug River from below the site of the proposed dam. Part of the dump from the tunnel excavation is shown at the left.

b. View showing the massive character of the Brookfield diorite at the entrance to the tunnel east of the Bantam River crossing.

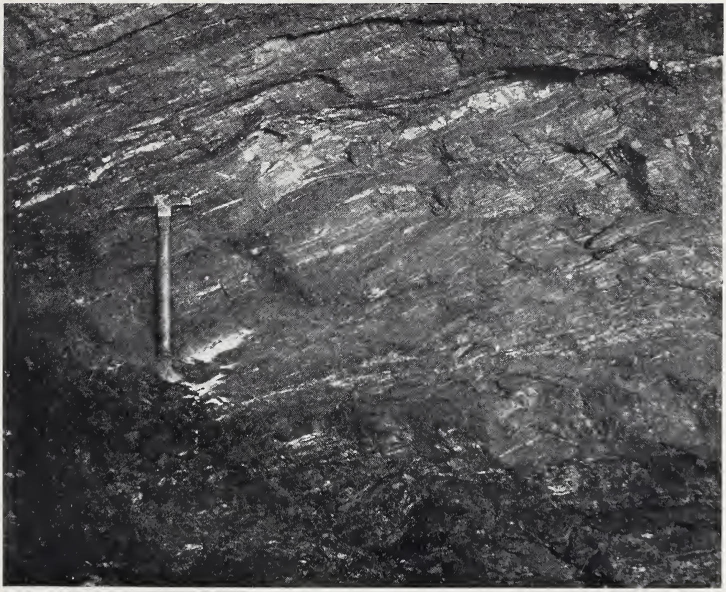
a. View looking across the narrows of Bantam Lake from Dempsey's Point to Marsh's Point. The tunnel passes under the lake between these points.

b. Valley of the West Branch of the Naugatuck River above the present Morris Reservoir and just below the tunnel outfall, where the waters of the Shepaug River will be brought through the tunnel and impounded.

PLATE IV.

Irregular contact between the Berkshire schist and a pegmatite dike in the tunnel, 1000 feet east of the tunnel entrance at the Shepaug River. Two drill holes are shown in the schist at the left. Photograph by B. H. Walden.

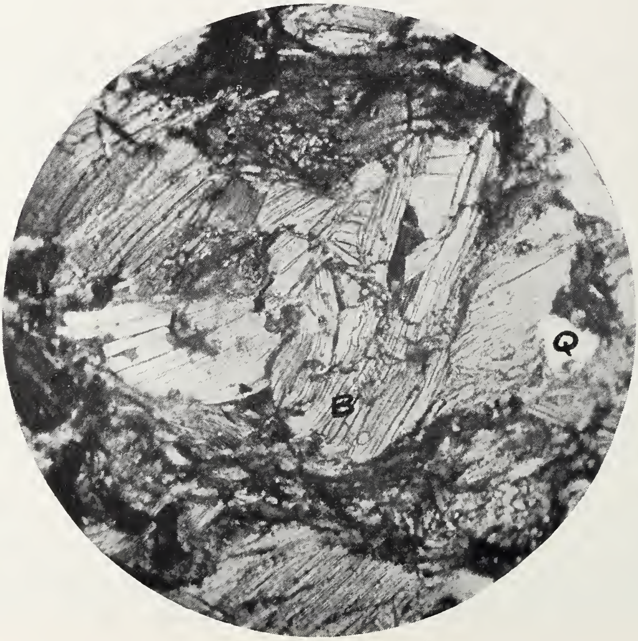
a. Quartz monzonite porphyry dike cutting the massive diorite in the tunnel under Bantam Lake. Photograph by B. H. Walden.



b. Pegmatite lenses parallel with the flat dipping foliation of the Hartland mica schist, 1000 feet east of the southernmost corner in the tunnel. Photograph by B. H. Walden.

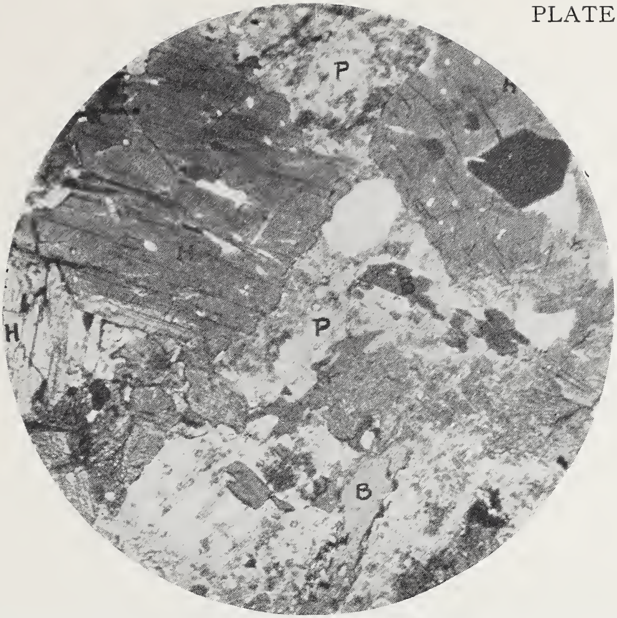
PLATE VI.

a. Hartland mica schist showing crystalloblastic texture. Crossed nicols x 25.



b. Berkshire schist from west end of tunnel showing curved biotite flakes (B) and quartz (Q) partly granulated. An incipient cataclastic texture superimposed upon a crystalloblastic texture. Crossed nicols x 25. Photograph by D. Selchow.

PLATE VII.



a. Brookfield diorite near center of tunnel showing texture of crystallization. (H) hornblende; (B) biotite; (P) plagioclase (mostly andesine). Plane polarized light x 40.

b. Biotite hornblendite near center of tunnel showing texture of crystallization. (H) hornblende; (B) biotite; (T) colorless amphibole grading into the hornblende. Plane polarized light x 40.

a. Hartland schist included in Brookfield diorite showing large crystal of andesine, strained throughout and somewhat crushed along the edges and in a line through center; granulated quartz, and biotite bent around the more resistant fragment. Shows mortar texture. Crossed nicols x 25.

b. Mount Tom hornblende gneiss showing pulverized plagioclase (P), larger individuals of quartz (Q), and hornblende (H), projecting as fine needles into pulverized plagioclase. Protoclastic texture with beginning of recrystallization. Crossed nicols x 40. Photograph by D. Selchow.

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1. First Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1903-1904; 18 pp., 23 cm., 1904.

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