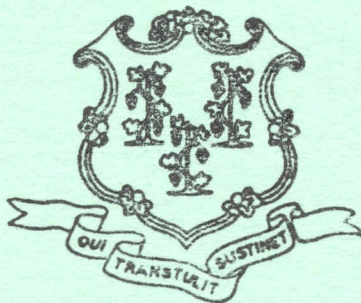STATE GEOLOGICAL AND
NATURAL HISTORY SURVEY
OF CONNECTICUT

THE BEDROCK GEOLOGY
OF THE
ROCKVILLE QUADRANGLE

With Map

Open Map

By

JANET M. AITKEN, PH.D.

Quadrangle Report No. 6

1955

STATE GEOLOGICAL AND NATURAL HISTORY
SURVEY OF CONNECTICUT

THE BEDROCK GEOLOGY

OF THE

ROCKVILLE QUADRANGLE

WITH MAP

By

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GEOLOGY OF THE ROCKVILLE QUADRANGLE

Introduction

GENERAL LOCATION

The Rockville 7½-minute quadrangle is in east central Connecticut (fig. 1). It includes portions of the towns of Vernon, Tolland, Coventry, Andover, Bolton, and Manchester. Rockville, the chief population center, is located close to the north edge of the quadrangle, approximately 18 miles northeast of Hartford.

PREVIOUS WORK

No detailed geologic report of this specific area has been published. The general geology of the bedrock formations has been discussed in the reports of Percival (1842), Rice and Gregory (1906), and Foye (1949). Keppel had completed detailed field work, covering principally the Bolton schist, in 1941, but that work has remained in manuscript form except for an abstract (Keppel, 1941).

Recent work by Collins in the Ellington quadrangle north of Rockville, by Herz in the Glastonbury to the southwest, and by Aitken in the South Coventry to the east (fig. 1) has provided a wealth of new material which has aided materially in the interpretation of the geology of this particular area.

PRESENT WORK

The present report is based on field work completed during the seasons of 1951 and 1952. It includes a study of the lithology and structure of the bedrock and a brief description of the types and distribution of unconsolidated Quaternary sediments.

ACKNOWLEDGMENTS

The project has been carried out under the auspices of the Connecticut Geological Survey under the directorship first of Dr. Edward L. Troxell, now retired, then of Dr. John B. Lucke. The writer is grateful to the Survey Commission for its continued support and encouragement. Special thanks are due Dr. Joe W. Peoples for his suggestions during the course of the field work, and to Dr. John Rodgers for his critical review of the manuscript. I am indebted to Professor G. S. Torrey for his help in preparing the photomicrographs. It is a pleasure also to acknowledge the efforts of Messrs. Phil Dolsen, George Garbarini, Dick Page, and John Adams who were very able field assistants.

Descriptive Text

PHYSIOGRAPHY

The quadrangle is astride the boundary between two reasonably well-defined physiographic, structural, and lithologic provinces (fig. 1). The Central Lowland, with its faulted and warped Triassic sediments (redbeds) and fluvio-glacial cover, occupies the northwestern third of the quadrangle. The remaining two-thirds lies within the area of complicated crystalline rocks and structures of the Eastern Highlands.

The area is dominated by the north-northeast trending cuesta-like ridges of the Bolton area (Box Hill (C) and its counterpart to the east), which stand 200 to 300 feet above the low rolling country of the western third of the quadrangle. The eastern ridge is about 200 feet above a belt of low swampy land that separates it from the higher, irregularly eroded gneissic crystallines to the east.

The eastern ridge of Bolton is the divide between the Connecticut and Thames River drainage in this area. The Connecticut drainage is represented by a series of sub-parallel west-flowing streams. It may be significant that many of these streams, where they cross the zone of the postulated Triassic fault contact, take a curious exaggerated swing, either to the north or south and apparently along the strike of this zone, and then resume a westerly course. Examples of streams exhibiting this behaviour are Hockanum River (NW)[1], Ogden Brook (NW), Lydall Brook (WC), and Birch Mountain Brook (SW).

The Thames drainage lacks any significant trends and exhibits the dendritic pattern common to the area. This drainage is controlled by the lowland occupied by Bolton Lake (C) and the swamps northeast of the Lake. There are strong indications, both from the topography and from the distribution of glacial fill, that at some period, probably late-glacial, this area was a drainage way of considerable proportions, perhaps one-quarter to one-half mile in width and 30 to 40 feet in depth. The numerous outcrops with strongly waterworn surfaces just to the northeast of the aforementioned swamps may be considered as additional evidence of the existence of this waterway.

Approximately two-thirds of the area is dominantly glaciated topography. The east-central sector between Route 6 and the Wilbur Cross Parkway is an area of rolling hills of moderate relief, formed by glacial abrasion and the subsequent deposition of an extensive but uneven mantle of ground moraine. There are very few bedrock outcrops in this area.

The low rolling hills west of the Bolton ridges have less relief than those to the east. Here the deposits are fluvio-glacial or lacustrine with an occasional "island" of moraine-covered bedrock.

BEDROCK FORMATIONS

INTRODUCTION

The eastern three-fourths of the Rockville quadrangle is known to be underlain by metamorphic crystalline rock types characteristic of the Eastern Highlands. The remaining quarter is underlain presumably by the Triassic sediments of the Connecticut River Valley (Central Lowland Province), which in most places are masked by a thick cover of glacial debris.

That the boundary between these two major rock groups is a fault is demonstrated at three localities within this area: 1) south of Highland Park (SW), 2) in the rail cut due east of Talcottville (WC), and 3) near Ogden Brook, northwest of Vernon Center (NW).

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[1] Throughout this report, places in this quadrangle are located with respect to the ninths bounded by 2½ minute parallels and meridians; the ninths are identified by letters as follows: NW, NC, NE, WC, C, EC, SW, SC, and SE.

THE CRYSTALLINE ROCKS

Three formations, Glastonbury, Bolton, and Hebron, are recognized in this area. Their geologic age has not been established with any certainty. Early reports place them in Devonian, but there is a possibility that they may be as recent as Carboniferous. If tentative correlation of the granitoid rocks with the Oliverian magma series proves correct, then the earlier date is more likely.

The formations are distinct lithologic units, but marginal varieties make it difficult to draw definite boundaries in many places. Boundary relationships are further obscured by lack of outcrops along inferred contacts, commonly as a result of glacial deposition in these areas.

The Glastonbury Formation. The Glastonbury formation comprises the westernmost "belt" of crystallines of the Eastern Highlands in this quadrangle. The width of the belt varies from one and a quarter miles at Birch Mountain (SW), to nearly two miles immediately east of Rockville (NC). The trend of the formation is approximately N 10° E.

Outcrops are plentiful and it is comparatively easy to obtain representative samples of the gneiss and its subtypes. Extensive outcrops of the formation that may be considered typical for the Rockville quadrangle are found at Birch Mountain and Green Hill (SW), along the Wilbur Cross Parkway at the Vernon Street intersection (NC) (Plate II), and at the northeast end of Box Hill (C and NC).

The main body of the Glastonbury formation in this area is a streaky or pencil biotite gneiss. Foliation is very poorly developed, except locally. The conspicuous feature is a lineation produced by orientation of lenticles and spindles of biotite, together with a similar alignment of blebs of quartz and small augen of feldspar. This lineation is pronounced throughout the formation, and the pencil gneiss is a reliable guide to field identification (Plate II).

The average grain size ranges from 5 to 10 mm. The mineralogy is quite simple and reasonably constant throughout. Principal constituents include feldspar (40 to 60%), quartz (10 to 25%), and biotite (15 to 30%). Accessory minerals are scarce and are mainly garnet and pyrite. For a detailed microscopic description see Plate IX in the Appendix.

There are several subtypes within the Glastonbury formation. The principal varieties are mineralogical though some noteworthy textural varieties have also been distinguished. These subtypes are discussed in order of geographic occurrence from west to east across the Glastonbury belt.

Near Vernon Center (NW), and at Case Ponds (SW) south of Highland Park, the Glastonbury formation has been intruded by coarse pink granitic material. At Vernon the granitic material is restricted and occurs only in strongly folded dikes. At Case Ponds several well-defined dikes 6 to 12 inches thick cut the gneiss. In addition an appreciable zone of gneiss has been thoroughly impregnated with this pink granitic material. The resulting rock is a distinctive medium-to-coarse augen gneiss. There is a very high percentage of what appears to be secondary chlorite in addition to the pink feldspar, quartz, and biotite. Percentages of these minerals are: biotite and chlorite, (60 to 70%), quartz and plagioclase (15 to 20%), and K-feldspar (15 to 20%).

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A second variety is found between Lydallville and Talcottville (WC); it extends in a band of undetermined length north and south of this area. Here hornblende is the major constituent, producing a narrow belt of amphibolite gneiss one-quarter mile or less wide. Percentages are: hornblende (70%), feldspar (30%), epidote (trace). West of the amphibolite is a highly chloritic zone, consisting of chlorite, quartz, and minor amounts of feldspar and pyrite. These two subtypes interfinger with the more biotite-rich typical Glastonbury gneiss, but there is a gradual transition to highly chloritic material along the northwest margin of the Glastonbury belt from Talcottville (WC) to Rockville (NW).

A third variety was observed in the vicinity of Vernon Center (NW). In this area there is an unusually large number of inclusions or schlieren of fine-grained biotite gneiss or schist ranging in size from 1 inch by 3 inches by ½ inch to 7 feet by 4 feet by 1 foot. They differ markedly from the lenticles of coarse biotite flakes described above. The latter also occur at this locality, and in general the shape and orientation of the two structural elements are similar. It is suggested that the large inclusions represent remnants of some pre-Glastonbury rock that have survived several periods of metamorphism. They are in fact quite similar in texture and composition to some of the biotite-rich zones of the Hebron formation.

A fourth variety has been noted in the outcrops on the Wilbur Cross Parkway about 500 yards west of Walker Reservoir (NC). Here the gneiss shows a noticeable decrease in biotite throughout the rock as a whole, but strong concentrations of that mineral form thin layers that appear on the face of the outcrop as a series of criss-cross lines. There is also a notable increase in the percentage of quartz until it constitutes an estimated 40 to 50 percent of the total rock volume. A similar rock has also been observed in the railroad cut at the north end of Box Hill (C). This increase in quartz is in marked contrast to the decrease of quartz in the gneiss some three miles to the south. Here the general rule seems to be that biotite rather than quartz increases as the Bolton formation is approached.

The development of foliation varies with the percentage of biotite in the Glastonbury formation. In the mica-rich rock, the trend changes from north-south in the southern third of the belt to N 57° E near Walker Reservoir (NC). The dips range from 18°W to vertical and increase as one follows the gneiss south along the strike.

As mentioned above, the conspicuous structural feature of the gneiss is lineation. The lineation is constant throughout, deviating only a few degrees (2° to 6°) from a north-south trend, and plunging gently north, never more than 22° and mostly at angles of 8° to 12°.

Fractures are numerous and fall into five main groups:

a) a set trending N 48°W and dipping 67° to 85°SW, commonly coated with rosettes of black tourmaline (schorlite),

b) a set trending N 63°E with a dip of 47°NW,

c) a set trending N 88°W with a dip of 87°NE—heavy tourmaline coating,

d) a set trending N 43°E with dips ranging from 40° to 60°NW,

e) a set trending N 7°E with a dip of 75°SE.

They appear to be nearly contemporaneous, although set "e" is earliest and set "a" transects all others.

The Bolton Formation. The Bolton formation occurs in a belt a mile wide, east of and nearly parallel to the Glastonbury formation. Outcrops are plentiful, but the most extensive are in the vicinity of the type locality at Bolton Notch (C, SC) (Plate III, Figures 1 and 2), where the formation crops out almost continuously for four miles north and south of the Notch. The combination of railroad cuts and ledges on Box Hill give the most nearly complete cross-section of a formation in the entire region. The recent work extending the Wilbur Cross Parkway has exposed an excellent cross-section approximately half a mile east of the Rockville traffic circle (NC).

There is a variety of rock types in the Bolton formation, but the greater part of the section is composed of garnet or garnet-staurolite phyllitic schists (Plate III, Figure 1; Plate IV, Figure 1; Plate XI) and quartzite of varying degrees of purity. These two types are easily recognized in the field and provide the greatest number of outcrops throughout the area.

The phyllitic schist is a medium- to fine-grained rock. On the fresh surface it has a very distinctive sub-metallic gray appearance. Viewed in a plane normal to the foliation, the rock shows a very high percentage of quartz. In addition to garnet and staurolite, which occur in definite zones rather than scattered through-out the formation, muscovite, biotite, graphite, specular hematite, and tourmaline are present in amounts that differ from place to place. The micas represent from 20 to 50 percent of the total composition, and the quartz has a similar range; the other minerals represent no more than 10 percent of the total volume of any given specimen (Plate XI in Appendix).

The quartzites are a series of interbedded medium to fine (5 to 1 mm) micaceous quartzites and very fine-grained (1 mm) almost pure quartzites (Plate IV, Figure 1; Plates XII and XIII in Appendix). After weathering, all but the very finest varieties show evidence of a muscovite content that may represent as much as 40 percent of the total volume. On the foliation planes, the rock looks much more like a muscovite schist than a quartzite (Plate III, Figure 2).

The mineralogy of the quartzites is also rather simple, for in addition to quartz, muscovite is the only abundant mineral. Accessories include garnet, pyrite, biotite, tourmaline, and occasional staurolite.

Prominent minor varieties include feldspathic garnet-chloritoid gneiss, garnetiferous amphibolite schist, and impure marble.

A narrow belt of the garnet-chloritoid gneiss occurs at the eastern margin of the Bolton formation and it can be traced along the entire length of the formation in this quadrangle.

Exposures are found on Wilbur Cross Parkway east of Mountain Spring Road intersection, and east of Reed Road (NE). Th gneiss has been found also in the eastern part of the railroad cut at Bolton Notch (northern edge of SC) and just north of French Pond (SC). Of these the outcrop on the Parkway is the most satisfactory, as it has been exposed only very recently and is therefore comparatively fresh. The stratigraphic thickness of the exposure is approximately 60 feet.

The rock is a light, fine-grained (1 to 3 mm) crystalline gneiss. It has a rather sugary texture that is accentuated by weathering. The principal minerals are oligoclase and quartz. Biotite and chloritoid together constitute about 10 percent of the rock, and deep red garnets (3 mm or less) are the only accessory of note. Foliation is poor, but clusters of biotite and chloritoid impart a lineation that trends N 10°W and plunges 32° north.

The garnetiferous amphibolite schist is light grayish green and coarse-grained and contains pinkish-red garnets up to an inch in diameter. The principal mineral is gray-green tremolite, which appears to have reverted to muscovite to a very great extent. Granular quartz fills the interstices between the platy minerals.

This amphibolite schist has been found only in the area immediately east of Bolton Notch (SC). It occupies a zone about 10 yards wide, and has been traced for less than 300 yards north and 100 yards south of the railroad cut.

The marble layers have been traced for only a short distance north and south of the cut at Bolton Notch. They occur in a band that varies from 3 to 6 feet in width. The rock is light grayish tan and can be identified in the field by its characteristic ridged and pitted surface. Siliceous layers stand out in relief.

The marble is crystalline, medium- to coarse-grained, the grain size increasing wherever the proportion of actinolite is high. The actinolite grains average 10 to 15 mm in diameter and impart to the rock a highly distinctive splotchy appearance. Accessory minerals include quartz, muscovite, dark green tourmaline, and pyrite.

In contrast to the Glastonbury formation, foliation in the Bolton formation is extremely well developed (Plate III, Figures 1 and 2); it is parallel to bedding wherever bedding can be observed. In the southern part of the quadrangle the foliation strikes N 10° to 15°W but as the belt is followed north, this trend swings to east of north and in the outcrops on the Wilbur Cross Parkway the strike is N 35° to 40°E. The dips remain rather constant throughout, ranging from 25° to 40° always to the west.

There is a strong lineation in the Bolton formation which ranges in trend from N 25° to 35°W and plunges from 12° to 26°N (average approximately 22°N). This lineation is produced in the phyllitic schist by tiny crinkles in the foliation plane (Plate III, Figure 1). In the quartzitic layers parallel arrangement of the colored micas and tourmaline produces the lineation. Furthermore the more siliceous layers, particularly in the western half of the zone, commonly show a series of drag folds, the trend of whose axes ranges from N 45°W to due north and whose plunge ranges from 0° to 27°NW (Plate IV, Figure 2). There are many local irregularities, however, apparently related to local bending around lenses of pegmatite and quartz, or to intraformational slippage.

These secondary folds, which are interpreted as drag folds, are most abundant in the micaceous quartzites that, stratigraphically, occupy the middle third of the Bolton formation. The folded quartzites occur in great plates that range in thickness from 5 to 15 feet (Plate IV, Figure 2). Within these plates there are great differences in intensity of folding and direction of fold axes. The intervening plates of unfolded material range in thickness from 5 to 60 feet or more: the average thickness is estimated to be about 40 feet.

In addition to these folds there is a very prominent fracture system in the Bolton. Best developed is a north-south system, vertical or dipping steeply to the east, which at Bolton Notch approaches a fracture cleavage in the intensity of its development (Plate V, Figure 1). It is interesting to note that the spacing of this particular system diminishes noticeably in the immediate vicinity of any one of the several faults in the cut. The other major directions of fracture that can be distinguished are: a) N 30°E, dip 65° to 70°SE; and b) N 85°E to N 85°W, dip 60° or more S.

Numerous faults, none of very great magnitude, have been observed in the Bolton formation, particularly in the railroad cut at Bolton Notch (SC,C). There appear to have been three directions of movement: 1) bedding plane slip which is thrusting, 2) bedding plane slip which is essentially a strike-slip movement, and 3) normal faulting with the strike of the fault zone due north and the dip 50° to 60°W. Two such normal faults occur 200 and 250 yards east of the highway bridge at Bolton Notch.

The Hebron Formation. The Hebron formation underlies the southeastern third of the quadrangle. It occurs throughout the EC and SE and occupies the eastern part of the C and SC ninths of the quadrangle. Particularly extensive outcrops of typical Hebron gneiss occur at Bolton Pond Brook (northeast corner of SC), on South Street (SE), and in the southern part of the NE ninth.

The lithology of the Hebron formation is fairly constant. "Typical" Hebron may be described as a medium- to fine-grained greenish-gray to dark gray, banded augen gneiss. Locally, either biotite or hornblende may be the dominant dark mineral. Commonly these minerals occur in alternating bands up to 3 inches thick. The lighter bands and augen are composed of quartz and oligoclase feldspar with minor amounts of biotite, and scattered muscovite (Plate V, Figure 2; Plate XV). Accessories differ in distribution and amount. Garnet and pyrite are scattered throughout the Hebron in this quadrangle, and magnetite, sphene, and tourmaline occur sparingly in widely separated localities.

There are two prominent lithologic varieties of the Hebron formation, a skarn and an epidote amphibolite gneiss. Both occur along the western margin adjacent to the Bolton formation (Plate VI, Figure 1) and previously have been considered as members of that formation.

The skarn is composed of scapolite, diopside, tremolite, calcite, garnet, and pyrite (Plate XVI). Large outcrops of this material may be seen on Route 6-A (SE), at the east end of the highway cut one-quarter mile east of Bolton Notch (SC) (Plate VI, Figure 1), and on Wilbur Cross Parkway east of Spice Brook (NE). It is a light greenish gray, rather fine-grained rock, compact, and quite brittle, for fractures are clean and sharp. On a fresh surface it appears to be a siliceous rock and might easily be mistaken for a quartzite. Examination with a hand lens reveals the vitreous material to be tiny plates of scapolite and calcite, both with a high luster.

The skarn is not of uniform composition. There are layers ranging in thickness from the merest fraction to three inches that are rich in garnet; others show an increase in biotite; a few layers near the amphibolite are hornblende-rich. The skarn is interlayered with epidote-amphibolite gneiss along its western margin, and with a granitic gneiss corresponding with typical Hebron gneiss on the east.

A zone of amphibolite gneisses has been found along the entire west margin of the Hebron formation in this quadrangle. It ranges in width from a little over a quarter of a mile to as little as a few hundred feet. North of Bolton Notch (C) the zone splits into three and possibly four bands that interfinger with the highly feldspathic Hebron gneiss. These bands gradually fray out in a zone of hornblende gneiss that grades back into amphibolite in the northeastern corner of the quadrangle.

In addition to the outcrop in the west end of the highway cut and in the east end of the railroad cut at Bolton Notch (SC) (Plate VI, Figure 2), good exposures have been found north of Bolton Lake along Dockerel Road (C), on Hill 1001 north of Old Post Road (NE), and on Route 85 north of French Pond (SC).

The epidote amphibolite gneiss is a dark green to black, medium- to fine-grained gneiss. The gneissic character is imparted by the presence of composition banding. The amphibolite is interlayered with light grayish-green bands and "boudins" of epidotic material. The amphibolitic bands consist of hornblende, with minor amounts of clinozoisite, calcite, and garnet. The light grayish-green layers consist principally of clinozoisite, lesser amounts of calcite, and minor amounts of deep red garnet, and pyrite (Plate XVII).

The reason for including these varieties in the Hebron formation is discussed in detail in the section of this report dealing with geologic interpretation.

The foliation of the Hebron formation in the EC and NE ninths of the quadrangle follows a rather simple arcuate trend, the strike swinging from N 20°E in the western EC ninth to N 45°E in the NE ninth. This pattern is modified by a series of secondary folds (Plate VII, Figures 1a and 1b), whose axes plunge gently northward and radiate to the north-northeast from a center estimated to be in the vicinity of the so-called Willimantic gneiss immediately to the southeast of this quadrangle. Trend and dip range from N 20°E, dip 23°NW, to N 20°W, dip 12°E in less than one-half mile. It is thought that the outcrops in the SE ninth represent a series of at least three northward-plunging folds, whose axes trend approximately N 10° to 15°W. These structures have been described in detail by Aitken (1951, Figures 5 and 6).

Fractures in the Hebron formation resolve into a joint system of three components whose average strikes and dips are as follows: a) North-South, dip 75° to 87°E or W; b) N 63°E, dip 80°SE; and c) a set of diagonal fractures whose strikes and dips are 1) N 47°W, dip 74°NE, and 2) N 37°E, dip 60° to 85°NW. Of these the north-south set and the diagonal set are most prominent, their surfaces are the smoothest and best developed on any given outcrop.

Pegmatites. Large pegmatite lenses are lacking in this area. There are, however, sizable lenses, augen, and stringers of coarse granitic material in all the highland crystallines. They are particularly abundant along the western margin of the Hebron formation and in the phyllitic schists of the Bolton formation.

The mineralogy of these pegmatites is quite similar throughout the area. Principal constituents are quartz and K-feldspar (microcline), and accessories include muscovite, biotite, garnet, pyrite, graphite, and tourmaline. At a very few localities, as at Bolton Hill curve (SE), one finds abundant graphic granite.

Quartz Veins. Quartz veins are abundant along the Bolton-Hebron contact. Large, pure masses, 5 to 6 feet wide and a quarter of a mile or more long, are commonly located between the skarn and a brecciated zone in the Hebron formation.

Similar masses are found in the central section of the Bolton formation along the summit of Box Hill (C) and also along the western margin of the formation. They are seen to best advantage on Box Hill, where they occur as a series of vein quartz knobs, 4 to 5 feet wide, that may be traced for more than a mile on the west flank of the hill. At the north end of the hill numerous veinlets of graphite 2 to 3 inches wide cut across the quartz veins.

Quartz veins are not prominent in the Glastonbury formation. They are found principally as minor secondary vein fillings commonly associated with black tourmaline.

Crystalline Fault Breccia. The brecciated zone in the Hebron formation is located close to its western margin. It has been traced for a distance of a little more than 4 miles.

In the highway cut immediately east of Bolton Notch (SC) and also just north of Bolton Lake (C) the breccia is flanked by skarn on the west and hornblende gneiss on the east. In the southern part of the quadrangle it is flanked by amphibolite gneiss on the west and skarn on the east. Thus, it definitely appears to be discordant, transecting the members of the Hebron formation, rather than a concordant lithologic zone within the formation.

The breccia is readily recognized in the field. It is a light-colored medium- to fine-grained rock composed of angular fragments of pinkish feldspar and gray quartz set in a matrix of gray-green chlorite (Plate XIX). Weathered outcrops and talus fragments usually look more like disintegrating fine-grained conglomerate, or even concrete aggregate, than like the adjacent crystallines.

The trend of this brecciated zone is approximately N 20°E and the dip averages 50° to the west.

THE TRIASSIC FORMATIONS

Graywacke Conglomerate. One very restricted outcrop of Triassic sediment has been found on Birch Mountain Brook near Case Ponds in the extreme southwest corner of the quadrangle. The material is a graywacke conglomerate consisting of angular pebbles and cobbles of quartz, feldspar, Bolton schist, and Glastonbury gneiss in a matrix of sand grains and red hematite. The outcrop, located in the bed and on the very steep south bank of the brook, is, as a result of its location, very badly stained and weathered. The conglomerate was traced for a distance of 250 yards and the vertical extent measured here is 50 feet. It was impossible to find any planar structure to measure, but the trend of the formation is approximately N 20° to 25°E.

Possible outcrops of Triassic in other localities, principally in the WC ninth, have proved to be large boulders, which because of their size, angularity, and abundance are interpreted as marking the approximate boundary of the Triassic sediments and the crystallines of the Eastern Highlands.

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Diabase Dikes. Dikes of Triassic diabase have been found at three localities all in, or close to, Vernon Center (NW). The largest dike is on Hill 572 north of Ogden Brook. It trends N 43°E and is almost vertical, and has been followed along the strike for approximately a quarter of a mile. Because of strong vertical and horizontal joints, the outcrop, which is almost devoid of vegetative cover, may be followed up the hill like a giant staircase, 40 to 50 feet wide, with treads and risers measuring 6 to 10 feet. The central zone of the dike is medium-grained dark greenish-gray dolerite; on either side is a distinct chilled border zone of aphanitic black diabase, approximately one foot in width.

A narrower dike, very possibly a continuation of the above, occurs on the west side of the railroad, almost due west of Vernon Center (NW). The trend of this dike, its composition, and the host rock are identical with those of the larger dike. The relationships of dike and country rock are somewhat obscured, for the entire area of the outcrop is intensely fractured and broken up.

A third dike crops out just south of the intersection of Route 15 and Tunnel Road in Vernon Center (NW). Outcrops are small and scattered but the trend of the outcrop zone parallels that of the other dikes. Outcrops have been traced to the south for a distance of slightly more than one-half mile. The diabase is very fine-grained and is similar to the chilled border phase of the large dike to the north.

Triassic Fault Breccia. A highly silicified breccia of quartzitic, arkosic, and schistose fragments has been found at three localities on the crystalline border in this area. The southernmost is near Case Ponds (SW) where a narrow breccia zone separates Triassic conglomerate on the west from Glastonbury gneiss on the east. Much of the material is a badly weathered spongy or porous mass. Even the freshest material contains numerous cavities, some lined with quartz crystals, others filled with earthy, sooty, black manganese oxide. Such rock fragments as may be identified appear to be metamorphic. Criss-crossing the entire mass are comparatively fresh veinlets of specularite that range in thickness from the merest coating to one-half inch.

A second, more extensive zone of brecciated Triassic occurs in the railroad cut one-half mile east of Talcottville (WC) (Plate VII, figure 2). A third outcrop is to be found on the west side of Hill 360 northwest of Vernon Center (NW). These two occurrences appear to represent a continuous band and are discussed as a unit. The breccia in these outcrops ranges in color from variegated red to light greenish gray. The change depends on the country rock and on the degree of silicification that took place. In both areas the rock is full of cavities lined with tiny quartz crystals and there are numerous veinlets of specular hematite.

The breccia consists of sharply angular fragments, a fraction of an inch to two or three inches on an average (Plate XX). The fragments in the Talcottville breccia are composed of fine-grained quartzite and arkose, with minor amounts of sandstone. The breccia northwest of Vernon Center (NW) is composed of fragments of chloritic schist similar to the metamorphic rock nearby, and smaller angular fragments of gray quartz. In many places the breccia has a faded look, caused apparently by leaching and/or silicification.

The trend of this zone of breccias is N 30°E. Contacts are lacking and the dip can only be inferred; it appears that the zone is vertical or dips steeply to the

west. The width of this brecciated zone is at least 300 feet at Talcottville (WC), but it narrows until it is perhaps only 150 to 200 feet in width on Hill 360 (NW).

Fractures are abundant but extremely irregular so that the outcrops appear to be broken by a shatter zone rather than by a distinct orderly fracture pattern.

QUATERNARY SEDIMENTS

Most of the unconsolidated sediments are glacial or fluvio-glacial in origin. They may be differentiated into two large groups, namely the ground moraine that covers the eastern third of the quadrangle, and the fluvio-glacial deposits that occur throughout the remainder of the area.

The moraine consists of poorly sorted light tan or orange-brown sediments, containing angular fragments of crystalline rocks and quartz pebbles. These fragments bear a marked resemblance to the bedrock of this region and are presumed to be of local derivation (Plate VIII, Figure 1).

The fluvio-glacial sediments include a variety of types. They range from kame terrace deposits capped by coarse boulder beds, as on the west flanks of the Bolton ridges at 600 to 800 feet; to fine-grained, cross-bedded silts, sands, and gravels, such as have accumulated to great thicknesses in the vicinity of Rockville (NW) (Plate VIII, Figure 2). Well records for this area indicate that bedrock is commonly 250 to 300 feet below the present surface.

These finer sediments are composed almost entirely of fragments of red Triassic sediments (fine arkose), and the high tide of fluvio-glacial deposition is easily marked by the limit of the red-hued unconsolidated material. The line of demarcation extends roughly from Mountain Spring Road (NE) along Dockerel Road and Bolton Road (C) and thence southward along a line through Hill 852, Whites Hill, and Rim Road (SC).

Throughout the western area most of the exposures show the well-defined cross-bedding characteristic of a kame terrace deposit. South and southeast of Rockville (NC) the deposits occupy a conspicuously flat lowland. The materials are extremely fine silt, with horizontal rather than crossed bedding, which suggests a lacustrine origin. A similar interpretation might hold for the sediments southwest of Notch Pond (SW). Indeed, Flint has so designated these areas on his map of the glacial geology of the state (Flint, 1930).

It is interesting to note that, on a line running almost due north from Highland Park (SW), huge angular boulders of Triassic sandstones and graywackes are interspersed with the fine fluvio-glacial and lacustrine sediments. One may speculate that they are the surface manifestation of the Triassic-crystalline contact now buried beneath the glacial sediments.

Geological Interpretation

INTRODUCTION

The geological observations presented thus far pose interesting problems. At the same time they provide the data necessary for the construction of hypotheses that attempt to resolve some of these questions.

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For example, the comparative abundance of outcrops (some of great extent) permits delineation of the varied lithologies of the formations represented in such a way as to extend the work done by Percival in 1842. This information leads quite naturally to conjecture as to the origin and metamorphic history of these rocks.

The lithologic varieties present another problem, insofar as they control the decision on where to draw formational contacts. Also, certain special lithologic types appear to be related to the structural history of the area rather than to the metamorphic sequence. A case in point is the chloritic gneiss that occurs on the western border of the Glastonbury gneiss.

One soon learns to appreciate the fact that acceptable answers to these questions, which are essentially petrologic in nature, must be forthcoming before proper evaluation of the structural geology is feasible.

In the Rockville area the structural geology of the formation is of greatest importance; first, insofar as it serves to clarify the structural style of the crystallines of the highland border, and secondly, to the extent that it permits evaluation and interpretation of the eastern border zone of the Triassic. The following discussion will treat each of these topics in turn, after which the problems of regional correlation will be summarized.

Petrology of the Crystallines

INTRODUCTION

The highland crystallines have long been regarded as a composite of igneous (primary) gneisses and granites, and metamorphosed sediments.

The early workers had a tendency to regard all these formations as basically igneous. Shephard (1837) in his brief description of the rocks near Bolton Notch (SC,C), refers directly to those rocks now designated Hebron as gneissic granites, thus implying an igneous origin. The inclusion of gneissic slates, limestone, and mica slates in the sequence at Bolton Notch certainly suggests however that he might have considered this terrane to be sedimentary.

One is left with a similar impression on reading the wonderfully detailed descriptions of Percival (1842). Yet here there is an element of confusion for he has grouped present-day Glastonbury, Bolton, and a part of the Hebron as one unit—presumably of a single origin. There is no question but that he regarded the Glastonbury and Hebron as igneous gneisses, but he is never explicit regarding the nature of the Bolton formation. He has described all the varieties noted here and refers to the quartzites only as coarse crystalline material. There is no suggestion that he thought these represented original sedimentary layers.

Rice and Gregory (1906), following the lead of Westgate, considered the Bolton formation as derived from sedimentary materials, but classified the Glastonbury and Hebron as gneisses principally of igneous origin.

Foye (1949) included a greater number of units in his group of "metamorphics of possible sedimentary origin". Thus he conceived of much of the Hebron (page 5) as having been coarse pelitic and calcareous sediments, perhaps marine in origin.

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Aitken (1951) has taken a similar stand though she has regarded the "igneous" phases of the Hebron formation in the South Coventry area as migmatitic in origin.

Recent work by Herz (1955) in the Glastonbury, and by Collins (1954) in the Ellington quadrangles lends support to the interpretation that these gneisses, formerly regarded as igneous, are of complex origin and most probably represent injection gneisses. It is thought that the injected material was generated within, or adjacent to, the host formations.

An analysis of the data for this report treats each formation separately. Evidence is considered in terms of lithology, rock textures and structures, mineralogy, and the nature of the formation contacts. A discussion of the origin and history of the formation follows. This material is summarized in a general petrologic history.

THE GLASTONBURY FORMATION

The lithology of the Glastonbury formation gives very little hint as to the nature of the original material. The rock is of fairly uniform character with the exceptions noted above. The notable increase in biotite in the gneiss near Rockville (NW), the large masses of layered and banded biotite gneiss as east-southeast of Vernon Center (WC), and elsewhere, and the reddish granite gneiss east of Manchester (SW), may be of significance by virtue of their location and character.

There are few direct evidences of any relict textures or structures (Plates IX and X) to guide us. The rock is massive and nearly equigranular and the texture is granoblastic. As seen in Plate IX the larger grains are ragged quartz and Na-feldspar. There is a notable lack of K-feldspar in the "typical" Glastonbury (Plate IX), but there may be as much as 40 percent in the pink "granitic" Glastonbury (Plate X). Further, it can be seen that Na-feldspar, quartz, and minor amounts of amphibole represent early minerals that are distinguished from later generations of these minerals only by their undulatory extinction. The micas appear to be definitely later material.

In the augen varieties of the gneiss some augen possess an annealed texture. The truly significant structures in the Glastonbury formation are the large schlieren and slabs of dark gneiss that occur as concordant inclusions in the lighter granitic gneiss.

The contacts of the Glastonbury with the Bolton formation in this area give no evidence of a gradation though such a gradation was suggested first by Percival (1842, page 230), and more recently by Collins (1954) and Herz (1955).

In summary it may be said that the lithologic evidence is somewhat inconclusive. The lithologic varieties mentioned in the first paragraph might be construed as representing original sedimentary alternations, but they might with equal validity be cited as evidence of marginal lit-par-lit structure associated with igneous injection. The author prefers the first interpretation.

The textures exhibited by these rocks could be achieved either by direct crystallization from a magma or by recrystallization during intense metamorphism. The presence of annealed augen suggests the latter possibility. The mineralogy

and modal composition suggest that the Glastonbury formation, if igneous, is somewhat atypical, for the percentage of quartz is extraordinarily high for a granodiorite, which it most resembles in other respects. On the other hand, the percentage of K, represented principally by microcline, is astonishingly low for a recrystallized pelitic sediment. At the risk of hedging, it would appear that one must consider the Glastonbury as a gneiss of mixed origin.

The concordant inclusions noted above are considered to lend weight to this argument. One might expect to find more evidence of discordance if these were crystallization phenomena or xenoliths. Furthermore these basic portions closely resemble gneisses included in the Hebron formation, and suggest strongly that they represent remnants of similar material which have escaped complete granitization or other metamorphism.

Contacts, as such, provide little information. If they are gradational, as previous workers contend, then one may make a strong case for representing the Glastonbury formation as a highly granitized sediment, for the sedimentary origin of the Bolton formation is generally agreed upon. Evidence is lacking in this area however.

Nonetheless, the Glastonbury gneiss is envisaged as originally a pelitic sediment, subjected to a mild metamorphism that changed it to a biotite schist or gneiss, depending on variation in original composition. At a later date, as suggested by deformation of quartz and feldspar, the gneisses and schists suffered further metamorphism in the form of recrystallization and granitization, which produced the rock essentially as we see it today.

The possibility that this phase is due to straightforward igneous injection is rejected on the grounds that there is no evidence to indicate how the not inconsiderable amounts of the supposed injection were accommodated by the host rock. The lithology suggests that the invasion would have been on a large scale and should have caused considerable disruption in adjacent formations. One might argue that the complicated secondary structures in the Bolton formation could have been formed in this manner, but they do not conform to the pattern of marginal structures one would expect from such an intrusion.

Hence, the author inclines more toward the view that the Glastonbury formation is of mixed origin, and as the younger minerals differ only slightly from the older, one may hazard a guess that the gneiss is primarily one of recrystallization, with perhaps injection of reconstituted material from infolded portions of the original sedimentary material.

THE BOLTON FORMATION

By contrast, the history of the Bolton formation is a reasonably clear-cut case of regional metamorphism of a series of sediments, dominantly pelitic, interspersed with limey and psammitic members, and an occasional pyroclastic layer.

An attempt was made to compile a measured section of the Bolton formation primarily to assist in structural interpretation. Though at this writing the section remains incomplete, much valuable information concerning the origin and structure of the formation was obtained. Without doubt the evidence provided by the lithologic varieties is most significant in the attempted solution of the problem of its origin.

For example, along the eastern flank of the Bolton range (SC) there is rapid alternation of schists, quartzitic schists, and quartzites in layers up to an inch thick. It is not difficult to imagine that they represent a sedimentary sequence of muds and muddy sands. That they are succeeded by bands of impure marble serves to strengthen the impression that here we have original sedimentary bedding preserved.

Measurement of the section of the Bolton formation in the vicinity of the unparalleled exposures at Bolton Notch (SC,C) was not completed, partly because it was found that there is sufficient change in lithology along the strike to cast doubt on correlation of outcrops. For example, the limestones disappear along the strike, and quartzites and micaceous quartzites interfinger and intergrade. This may explain in part why Percival felt compelled to change designations on some of his formation units as he traced them along the strike. Also it might explain in part the lateral shifting to which he alluded in an effort to explain these changes (Percival, 1842, page 237). One particularly impressive micaceous quartzite with a characteristic surface of pseudomorphs after staurolite measuring as much as $1\frac{1}{2}$ inches by 12 inches (Plate III, figure 2) was considered a fine potential marker bed, yet it could not be traced in the extreme north and south limits of the Bolton formation. These local, fairly abrupt, three-dimensional changes in lithology are strongly suggestive of the sedimentary nature of the Bolton schist.

The chemical analyses of the schists, quartzites, micaceous quartzites, and marbles are characterized by an exceptionally high silica content, and a fairly high K : Na ratio, such as might be expected in impure sands and sandy muds.

The compositional layering, one of the most significant structures in the Bolton formation, is repeated in microbanding (Plates XI and XII). Unfortunately, though graded bedding seemed a distinct possibility in several specimens, it was not incontrovertible and so has not been utilized in this discussion. There is however no definite evidence for considering this banding as a secondary development of flow cleavage.

The formational contacts are gradational into the Hebron formation and may be gradational to the west though direct evidence is lacking in this quadrangle. Interfingering of elements of the Bolton and Hebron formations is well displayed at the east end of the railroad cut in Bolton Notch (SC).

It can be seen from the foregoing that nothing has been discovered that would cause one to reinterpret the Bolton formation as anything but a series of moderately metamorphosed impure sandy and shaly sediments. The present varieties are interpreted as reflecting changes in the original lithology. Thus, as one would expect, the metamorphism of almost pure sands has resulted merely in an impure quartzite (Plates XII and XIII), with a scattering of garnet and staurolite indicating the degree of metamorphism. The originally aluminous sediments are the rocks in which abundant muscovite, garnet, and staurolite are now found (Plate XI).

It is thought that the Bolton formation, together with the adjacent Hebron gneiss, represents the metamorphosed equivalent of a series of sediments in a deepening basin. The Hebron formation would represent perhaps initial, coarse deposition, while the Bolton formation would represent a change from turbid

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conditions producing muds, to more stable conditions under which impure sands were deposited. That these occurred at no very great depth is indicated by the frequent changes in lithology and the frequent interfingering of types. These sediments were then subjected to regional metamorphism in which recrystallization was prominent. The quartz and feldspar were least responsive, for many grains show undulatory extinction indicating adjustment by lattice strain. The micas, garnets, and staurolite are for the most part free from distortion and represent the recrystallization products of the clayey fraction.

THE HEBRON FORMATION

Rice and Gregory (1906) considered the Hebron formation as a gneiss of igneous origin. Foye (1949) thought it a metamorphic product of sediments modified locally by intrusions of the Monson batholith. The origin of the Hebron gneiss has been discussed at length by Aitken (1951). A restudy of that portion of the formation within the Rockville quadrangle has provided much additional information.

Of greatest significance, perhaps, is the inclusion of epidote amphibolite gneiss as well as skarn in the Hebron formation. Thus, Hebron lithology includes a series of banded and augen gneisses, skarn, and amphibolite gneiss.

The dark biotite- and hornblende-rich layers in the gneisses may represent the remnants of an original pelitic source material (Plate XV); the light bands, often closely interlayered with darker material on their margins, could conceivably represent lenses of sandy material in the original sediment.

The skarn is a well-defined lithologic unit rich in lime and magnesium. Undoubtedly it represents one of the numerous impure limestone bands on the east border of the Bolton formation referred to by Percival (1842, page 232). Its mineralogy is very different from that of the marble in the Notch to the west (SC). There is little doubt that it is a distinct unit representing a metamorphosed impure limey sediment, and perhaps it should be classified as a lime hornfels.

The adjacent amphibolite has the characteristics of a metamorphic rock derived from very impure limey sediments that may be partly pyroclastic. Feldspars are relatively rare, and the few grains that do occur show xenomorphic form and simple albite twinning. Quartz and biotite (the latter with abundant secondary chlorite) are abundant. The epidote-rich portions contain principally calcite and clinozoisite with minor amounts of quartz and plagioclase. Some layers are exceptionally rich in hornblende, biotite, clinozoisite, and garnet, with sphene and feldspar in accessory amounts. It is thought that these layers may represent interbedded basic tuffs.

At first glance it may appear that these varied phases are distinct, scarcely related units, with too little in common to warrant grouping them as a formation. Certain mineralogical similarities bespeak a fairly close relationship.

One discovers that gneiss, skarn, and amphibolite gneiss have in common the minerals hornblende and *brown* biotite. These minerals retain similar properties regardless of the rock type in which they are found. This would seem to indicate certain similarities in composition and metamorphism of these contrasting rock types. There is increased significance in the presence of these two minerals

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in all types of Hebron gneiss when one realizes that the Glastonbury formation of the Rockville quadrangle contains scarcely any hornblende. An exception, of course, is the amphibolitic band noted at Lydallville (WC). Furthermore, the biotite in the Glastonbury formation has a distinctive *green* to *greenish brown* pleochroism. Hornblende is entirely absent from the schists of the Bolton formation but *brown* biotite, on the other hand, is relatively abundant in the phyllitic schist. Thus it seems well demonstrated that the particular combination of hornblende and biotite described above is peculiar to the Hebron formation.

Tourmalinization, scapolitization, and development of myrmekite are present in different degrees of concentration throughout the Hebron formation. They have been attributed to late pneumatolytic changes associated with magmatism.

The larger pegmatitic masses contain both plagioclase (An15-20) and microcline. The plagioclase often exhibits complex twinning (Aitken, 1951, page 6). Along the contacts there are concentrations of biotite and occasionally of sillimanite. Such feldspars are often referred to as igneous in type, and the marginal concentrations are interpreted as contact effects. The implication is strong, of course, that the pegmatites represent introduced material that was at a temperature considerably above that of the enclosing rock.

Chemical analyses indicate that the gneisses are moderately rich in silica, fairly high in alumina, and rather poor in potassium and calcium as compared to sodium and magnesium. Such a composition might equally well be that of a granodiorite or an impure graywacke or conglomerate. The analyses of skarn and amphibolite compare favorably with those of muddy limestones.

In general, textures are granoblastic with composition banding the dominant structure. Nothing that might be construed as good relict structure has been observed. In the granitic portions of the banded gneisses and in the augen gneisses feldspar porphyroblasts show annealed structure under the microscope. The grains are badly fractured and show undulatory extinction, but the fragments appear to differ only slightly in optical orientation. It must be conceded that such masses may very well represent partially recrystallized pebbles.

Compositional layering is a very conspicuous structure in the skarn (Plate XVI). The fine layering seems highly characteristic of sedimentary action. Similar interlayering of clinozoisite is found in the amphibolite gneiss (Plate XVII), and wherever structural distortion is intense, boudinage has developed (Plate VI, figure 2).

Thus the rock structures, particularly the gradations, banding, and interlayering, especially in marginal zones, are what would be expected if these subtypes of the Hebron formation represent sedimentary layers.

Finally, one is reminded of the overwhelming evidence that the Bolton-Hebron contact is gradational. Because similar structures are maintained across the contact zone and for considerable distances beyond, the possibility of either a conformable intrusive or a disconformable sedimentary contact may be dismissed. The contact zone is interpreted as representing perfectly normal sedimentary conditions with gradations at times verging on abrupt changes.

Thus it may be seen that one must study the *entire* geologic setting rather than rely on any single criterion of origin. The lithology and textures found in

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the Hebron formation are such as to imply a sedimentary origin. The present lithology is due to moderately high-grade regional metamorphism of pelitic and limey sediments. There is, however, evidence of pneumatolytic changes following metamorphism.

The areas of abundant pegmatite lenses, pods, and augen appear to coincide with areas of greatest structural dislocation, as do the areas of the most highly granitized Hebron gneiss. This relation may be coincidence, but the author believes the granitic material was generated tectonically, and migration and emplacement are essentially synkinematic.

One may conclude that the Hebron formation is more complex in origin than the other formations in this quadrangle. It seems appropriate to classify the gneisses as mixed in origin, though the skarn and amphibolite gneiss may be considered essentially sedimentary.

STRATIGRAPHIC RELATIONS OF THE CRYSTALLINE ROCKS

Inevitably, any discussion of the origin of these crystallines must approach the topic with delineation of formational units as a point of departure.

In the case of the Bolton and Glastonbury formations the distinction is based on clear-cut lithologic differences. The Glastonbury is a feldspathic *green*-biotite gneiss while the Bolton is a quartzose, muscovite, *brown*-biotite phyllitic schist, and impure quartzite. Though there is no evidence of a gradation such as Collins (1954) describes in the Ellington quadrangle, it appears that feldspar content and/or difference in biotites would suffice to mark the boundary even where gradation does occur.

The Bolton-Hebron boundary is quite another matter. So far as can be ascertained the boundary is gradational, although the Bolton and Hebron proper have been distinct lithologies. There is no apparent structural or stratigraphic break between the two, however, and the problem of locating a logical break is a difficult one.

The problem is complicated further by the fact that, although previous reports, notably those of Percival (1842), Gregory and Robinson (1906), and Foye (1949), place a narrow band of Monson gneiss between the Bolton and the Hebron formations, the present writer finds no evidence to justify this.

The zone in question includes (going from east to west) feldspathic hornblende gneiss, skarn, and epidote amphibolite gneiss. It is assumed that the feldspathic hornblende gneiss is the material that has been mapped as Monson gneiss. For the present report all three rock types are represented as the Hebron formation. The reasons for this decision to eliminate the eastern band of Monson (or Glastonbury) gneiss are mineralogical, lithologic, and structural.

The mineralogical evidence concerns the presence of hornblende and types of biotite, and has been outlined above in the discussion concerning the lithology of the Hebron formation. In addition one might point out that the feldspathic gneiss east of Bolton is a hornblende *brown*-biotite gneiss, somewhat more feldspathic, but in other respects showing much closer kinship with gneissic portions of the Hebron formation as seen near South Coventry and Andover than with any of the Glastonbury seen in this quadrangle.

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The feldspathic hornblende gneiss grades into the skarn just east of Bolton Notch (SC). A similar skarn and hornblende gneiss have been found well within the boundaries of the Hebron formation west of Andover on Route 6A (SE). It is difficult to see how a gneiss on the Hebron side of the Bolton formation, which grades into a skarn that is well established as entirely within the Hebron formation, can itself be anything but Hebron.

Skarn and amphibolite gneiss are intimately interbedded and have been interpreted as a continuous sequence.

For these reasons, the boundary between the Hebron and Bolton formations is drawn west of the amphibolites, and Monson gneiss or its Glastonbury equivalent is not shown. Structurally, this division presents far fewer complications than might arise had the amphibolites been included in the Bolton formation. In fact, the latter division leaves one in an almost untenable position as may be seen from the discussion of the structures below.

It is not known whether these criteria are valid for any considerable distance outside the Rockville quadrangle. Present work indicates that gradation in lithology along the strike of these formations is sufficient to nullify any attempt at broad regional generalizations of this type, at least until a reasonably large segment of the highland crystallines has been studied in great detail.

CHLORITIZATION ALONG THE WESTERN BOUNDARY OF THE CRYSTALLINE ROCKS

The zone of chloritic schist that occurs along the western border of the Glastonbury gneiss in this quadrangle illustrates the close relationship of tectonics and metamorphism.

The zone is a prominent one, and the geologist must decide whether to consider it a lithologic unit separate from the Glastonbury formation, or to ascribe its origin to its location in a tectonic zone, e.g., the crystalline-Triassic boundary. As early as 1842 Percival (page 220) noted the occurrence of chloritic gneiss west of Vernon (WC) and remarked that the "chloritic rocks of this section are usually much divided by jointed cleavages . . ."

Davis and Griswold (1894, page 524) had this to say about chloritization of the crystallines close to the border fault:

> "The greater development of chlorite along the borderline is a marked feature . . . the crystallines are broken, simple gneissic and schistose structure is lost. The rock may still remain in this crushed condition, presenting a loose fault breccia, or *it may be recemented into an exceedingly tough rock by quartz and chlorite,* or sometimes barite. It is more enduring than gneisses, yet fragments are not found in the Triassic, therefore it is later than the Triassic . . . the alteration of crystallines is made out clearly only along the meridional portions of the Triassic border." (Italics added, J.M.A.)

In the field, the chloritic gneiss is observed to grade into a coarse biotite gneiss typical of the westernmost Glastonbury of the Rockville quadrangle. In these instances it appears to represent simply a chloritization of the latter, for the basic mineralogy, texture, and structure remain the same. At other localities it appears to be a compact, medium-grained green rock, with little structure discernible as most outcrops are badly fractured. Such material has been found at

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Ogden Brook south of Rockville (NW), at Vernon Center (NW), and at Talcottville (WC). A study of the thin sections of this rock (Plate XIX) reveals that chlorite is definitely later than and replaces badly deformed biotite; early quartz and plagioclase are badly strained and/or shattered; and there is a considerable percentage of fresh, clear quartz (outlining fold in Plate XIX). The rock has the appearance of a contorted mylonite. That it had its origin in structural deformation is evident not only from its physical characteristics noted above, but also from its close proximity to known fault breccia both at Vernon Center (NW) and Talcottville (WC). The writer disagrees with Davis and Griswold at this point only, for one sees chloritization along these diagonal faults, and the effect is not confined to the "meridional" zone as they suggest.

Chlorite gneiss and schist occur along the inferred crystalline-Triassic contact south of Rockville. The float west of the outcrops is predominantly crystalline material. The gneiss here might be considered typical of the "exceedingly tough rock" described by Davis and Griswold.

Collins (1954) has noted similar relationships in the Ellington quadrangle, and the author has observed a comparable lithology along the Triassic border in the Mt. Toby and Greenfield quadrangles in Massachusetts. Thus it seems well established that chloritization is a widespread phenomenon along the eastern fault of the Triassic.

The relationship of silicification, chloritization, and faulting is a well-known phenomenon. It has been described elsewhere, e.g., at Grass Valley, California, in the Great Glen in Scotland, and in the uplands of New England.

These chloritized zones are thought to result from chloritization and silicification by solutions introduced along brecciated fault zones. It is thought that slightly alkaline solutions might cause chloritization of biotite with accompanying concentration of excess iron and manganese as veinlets of oxides, for these are abundant in the breccias.

There is little doubt as to the validity of the chloritization as a useful criterion for recognition of the Triassic border fault system. It would be incorrect to elevate such zones to the status of "individual" units within the crystallines, and such lithologic variations should be studied with great care.

The foregoing evidence appears to corroborate the interpretation of Westgate, reported by Rice (1906, pages 118-119), namely that these chlorite zones are of tectonic origin.

INTERPRETATION OF GEOLOGIC STRUCTURES

THE STRUCTURES OF THE CRYSTALLINES

Early reports (Shephard, 1837; Percival, 1842) of the geology of this area were more concerned with delineation of the various formations than with an analysis of structure. Percival intersperses observations on general structure throughout his report i.e., page 291,

"If we view the Eastern Primary in the Northern part of the state, we find it presenting a series . . . of four parallel ranges."

and page 294,

> ". . . speaking of flexures . . . their general arrangement is . . . a series of undulations in a general North-East direction, alternately more Easterly and more Northerly."

He recognized the major flexure of these formations, best seen in the C, NC, and NE ninths. He suspected that some of his difficulties in establishing the continuity of certain ranges was due to a lateral shift to the east of the Glastonbury, so that it is interrupted by the central portion of the Bolton. Furthermore, he recognized (page 297) the presence of lineation in many of these rocks and considered it as significant in their crystallization history. One can only mourn that it was not the fashion of his day to record structural data on geologic maps! Now, over one hundred years later, his acute observations are reliable and thought-provoking.

Gregory and Robinson (1907) also were primarily concerned with areal distribution of the formations. Foye (1935, 1949) redefined and correlated formations partly on the basis of structural studies, but he devoted most of his discussion to the areas south and east of the Rockville quadrangle. Such reconnaissance as was done in north-central Connecticut seemed to indicate rather simple structures with gentle westward dips prevailing. Keppel (1941, page 506), in a discussion of intrusions along the western border of the highland crystallines, interpreted the structure of the Glastonbury formation as an overturned dome flanked on the east by a westward-dipping monocline of the Bolton and western Hebron formations.

Collins in his recent work on the Ellington quadrangle (1954, page 34) suggests that there is minor buckling between the Glastonbury and Bolton formations, but he finds no evidence of major fold structures and follows Foye in his interpretation of the crystalline structure as relatively simple. In this case the structure appears to be a gentle westward-dipping homocline.

Herz (1955), working in the Glastonbury quadrangle, believes the controlling structure in this western zone of crystallines is an overturned syncline east of the Glastonbury gneiss and an anticline in the gneiss itself.

The Rockville quadrangle is situated in a strategic area of the border zone. As indicated in Figure 1 of the report by Davis and Griswold (1894), the quadrangle encompasses the eastern side of a Triassic salient in the crystalline border. Many of the structural reports have concentrated on an attempt to explain this lateral shift in the Triassic-crystalline contact.

The present writer feels that a fresh approach to the problem will be gained by first studying the crystalline structures in detail in order that the nature of the boundary offset may be more clearly understood.

The general trend of structural elements of the Glastonbury gneiss has already been described (see page 16 and Plate 1). It will suffice here merely to re-emphasize a) that the strike of the foliation swings from north-south in the SW ninth to N 53°E in the EC and NC ninths, and b) that the lineation retains a remarkably constant north-south trend, with a plunge of 8° to 15°N.

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If one assumes that this lineation represents the axial trend of the gross structure, the pattern is that of a northward-plunging anticline which may be overturned toward the east.

The schists and quartzites of the Bolton formation are of uniform dip and strike, giving no direct clues to the structures. One infers from previous reports —and Keppel states it directly—that these rocks represent a monoclinal (i.e. homoclinal) structure. Their tectonic environment, i.e., their position between the folded Glastonbury and Hebron formations, suggests that this relatively simple solution is open to considerable doubt.

If the structure is not homoclinal, then the only alternative interpretation is that the section is isoclinally folded. If this is actually the case, then one must try to determine whether a) there are a series of folds, or b) the Bolton formation represents a single large isoclinal anticline or syncline that has been overturned to the east.

We must return first to the lithology for our clues, as the gross structure offers no information. As mentioned above (page 17), a section across all but a small portion of the Bolton schist has been measured very carefully. If there is isoclinal folding with axial plane(s) dipping gently 26° to 30° to the west, repetition of lithology may be expected within the limits of the section exposed in the ledges and cuts in the vicinity of Bolton Notch (SC) and Box Hill (C). It is believed that the measurements are complete enough to show any repetition that might occur.

In order to approach the problem one must first establish a type section of the Bolton formation. This has been done by measuring the sequence from the eastern border where evidence of gradation into Hebron gneiss seems indisputable. Thus the easternmost types are considered the oldest.

From these measurements and careful field observation the following stratigraphic sequence has been established for the Bolton formation in this locality:

West   10. Micaceous quartzites, some garnetiferous

      9. Staurolite-garnet phyllitic schist

      8. Micaceous quartzites in folded plates

      7. Staurolite-garnet phyllitic schist
            Fault

      6. Impure sandy marble

      5. Micaceous quartzites, some garnetiferous
            Fault

      4. Micaceous quartzites

      3. Garnetiferous-tremolite schist
            Probable fault

      2. Micaceous quartzites

East   1. Feldspathic, garnet-chloritoid gneiss

It appears that units 1 to 8 represent the complete section of the Bolton formation and that units 9 and 10 represent the reappearance of 7 and 5 respec-

tively. Unit 6 is considered to be a local layer that in no way invalidates this sequence.

As indicated above (pages 16 and 17) there are faults between units 7 and 6 and between units 5 and 4, but they are dominantly strike slip faults and therefore do not interrupt or cause repetition in the sequence.

Units 10 and 5 are similar enough in lithology to represent one and the same unit, but there is structural evidence which raises a reasonable doubt about this correlation.

Units 9 and 7 are superficially at least quite similar, for both are garnetiferous, staurolite-mica schists of a somewhat phyllitic character. There are differences, however, that should be duly noted. In unit 9 both garnet and staurolite are much more abundant than in unit 7. Although grain-size of garnets shows a considerable range in both units, the garnets in unit 9 are, on an average, two to three times as coarse as those in unit 7. Staurolite shows the same contrasts, although the range in grain-size is not as striking as for garnet. Lastly, lenses and pods of pegmatite and stringers and pods of quartz are strikingly abundant in unit 7 and apparently less abundant in unit 9, although as stated above (page 11), lenses of quartz and pegmatite are conspicuous along the western flank of Box Hill (C). These appear principally in unit 10.

These differences offer grounds for reasonable doubt as to the propriety of correlating units 9 and 7. It is possible to explain the mineralogical differences on the basis of original differences in composition. The greater abundance of pegmatite in unit 7 may be directly related to a zone of considerable tectonic disturbance as indicated below. If one can accept these suggestions, then correlation of units 9 and 7 appears permissible.

If the above is valid evidence of repetition by folding, then it remains only to decide whether this folding is anticlinal or synclinal.

The structure of the Hebron formation is unquestionably anticlinal and if it is true, as Rice and Gregory (1906, page 121) and the author have suggested, that Bolton schist grades into Hebron gneiss, then an isoclinal fold in the schist, situated as it is between anticlinal structures, must necessarily be synclinal in form.

From the evidence presented thus far it is suggested that the Bolton formation is a simple isoclinal trough, for, with the gentle dips that prevail, multiple folding might have been expected to produce more frequent repetition than has been observed.

The core of the overturned isoclinal structure would be represented by the thick section of micaceous quartzites in unit 8. It seems logical that the intense folding and intraformational slippage observed should occur near the core of such a structure. The presence of highly contorted zones sandwiched between relatively thick (15 to 30 feet) plates of undisturbed quartzites suggests that such folding as occurred was accompanied by considerable shearing. This picture of folding is reasonably clear cut when based on lithologic relationships of the Hebron and Bolton formations and on the lithology of the latter formation.

If, however, the Glastonbury-Bolton contact is not only conformable but also completely gradational, then omission of units 1 to 4 casts a shadow of un-

certainty on interpretation of the Bolton formation as a folded structure. It does not seem reasonable to attempt to solve the dilemma by reassigning these units to another formation; the lithology is so distinctly that of the Bolton formation. It would seem therefore, that, in the event that the nature of the Glastonbury-Bolton contact is established as gradational, one has little choice but to accept the structure as a monocline.

We have already discussed the nature of formational contacts from the point of view of lithology. Let us now, before expressing our opinion as to the nature of the structure in the Bolton formation, reexamine this subject in the light of structural relationships.

The Glastonbury-Bolton contact will be considered first. In the southwestern part of the map the structures in Glastonbury gneiss and Bolton schist are conformable; the strike of foliation is approximately north-south and the dips are steep to the west. In the C and NC ninths there is an apparent disagreement in trend, for the Glastonbury formation strikes N 53°E and dips only 12° to 20° to the north while the Bolton formation strikes only 35° to 40° east of north and dips somewhat more steeply to the west (25° to 30°). Thus it can be seen that there is a slight (18° at the most) discordance in this more northerly section. One might attribute this to the surface expression of disharmonic folding with folds plunging gently northward. It will be seen, however, that the Bolton schist appears to be cut off by Glastonbury gneiss, for the gneiss and phyllitic schist are in close proximity but the quartzite (unit 10 of the Bolton formation) has disappeared. This would suggest that either the quartzite has lensed out (not an impossibility by any means) or the contact is not conformable. Since the question is open to reasonable doubt, let us examine the evidence further.

There is a significant disagreement in trend of linear elements in the two formations which rather weakens the interpretation of the contact as conformable. Lineation is constant throughout the Glastonbury formation, trending almost due north-south and plunging gently to the north. In the Bolton formation the linear elements trend quite consistently N 15° to 23°W and the plunge is northwest 20° to 23°. The divergence in the two formations is not great but the constancy of the directions suggests that a structural discontinuity is a distinct possibility. As pointed out above, there is no gradation in lithology between Glastonbury gneiss and Bolton schist in this quadrangle.

Thus, the data gathered indicate a lack of continuity between Glastonbury gneiss and Bolton schist which is thought to be structural rather than depositional or erosional in origin, despite the close parallelism of the two formations in the SW ninth and the apparent gradation in the Ellington quadrangle to the north. This rather contradictory evidence is interpreted as the result of shear folding which is responsible for the arcuate trend of the formations in the northwest portion of the quadrangle. These relationships become clear only when the regional structure is viewed as a whole. In order to do this we must now consider the relationships of structures in the Bolton and Hebron formations, and then attempt to fit the data into a regional picture.

The trend of foliation in both these formations is remarkably similar, and, even more important, the linear elements are in close agreement. Lineations in the Hebron gneiss radiate slightly from N 18°W to N 23°W, and this general

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trend is carried over into the Bolton schist. It would appear that the two formations responded to the same stresses as a unit.

When this information is coupled with the lithologic evidence for gradation, one sees a much closer parallelism in the history of these two formations than in that of the Bolton and Glastonbury formations. It would appear that these structures are related to a northward-plunging fold with secondary incompetent flowage folding superimposed on this, its western flank (Plate VII, Figure 1a and 1b). This folding would occur in response to an east-west compressive stress, and, judging from the plunge and incompetence of the structure, there appears to have been a strong northeast-southwest horizontal component that produced the secondary structures.

Fracture patterns in the two formations are in close agreement and support the theory that the Bolton and Hebron formations were deformed by the same disturbance.

Thus far we have attempted to evaluate only the portion of the structural history of the crystallines that is concerned with folding. There is ample evidence of faulting also, though most of these structures post-date folding and are closely related to the development of the Central Lowland.

From the evidence in the Rockville quadrangle there is a very strong possibility that the contact between the Bolton and Glastonbury formations is in the nature of an oblique thrust. The boundary cuts out the western Bolton quartzite (unit 10), and in the central part of the quadrangle the discordance of structure is quite apparent.

If this boundary is indeed a fault, then it would be roughly parallel to the supposed Triassic border fault in this area. It is also parallel to a series of faults that are best exposed at Bolton Notch (SC) in the highway and railroad cuts east of the bridges.

The faulting at Bolton Notch may be separated into four groups according to geometric relationships with bedding. First, at the contact of the limestone (unit 6) and garnet staurolite schist (unit 7) there is a bedding-plane thrust which carries the schist up over the limestone as evidenced by the well-developed drag-folding in the former. Second, east of the bridge, there are two well-defined faults that dip steeply to the west; no discernible offset has occurred and slickenside surfaces indicate a strike slip movement with the western block moving to the north-northeast in each case. The shatter zone of each of these faults is approximately a foot in width, and the faults are conspicuous in the cut.

There are numerous bedding-plane slips of a thrust type in the more micaceous zones of the quartzites. The movement was up the dip slope as evidenced by the deep slickenside grooves (half an inch deep and 2 to 4 feet in length). These might easily be mistaken for marks of a power shovel, but they extend beneath the presently exposed surface and must therefore represent natural features.

Finally in the east end of the cut there are numerous small discontinuous normal slips that strike approximately east-west and dip steeply to the south.

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It seems quite clear that this is an area of considerable structural disturbance and, when considered in the light of the regional structures northeast of Bolton Notch, the faults take on added significance. In the Rockville area the Bolton schist appears to grade into the Hebron gneiss, but in the South Coventry and Stafford Springs areas to the east and northeast the Hebron, trending roughly east-west and warped by several folds plunging gently north-northwest, is bounded on the north by the Brimfield schist. The latter shows a north-northeast strike, a fairly steep northwest dip, and no sign of northwest-plunging folds, yet Foye (1949) considered the Brimfield and Bolton schists equivalent. The contact of the Brimfield schist and Hebron gneiss is apparently fairly sharp and may be a structural discontinuity; indeed the faulting at Bolton Notch, which trends northeast or east, may be on the southwestward extension of this discontinuity.

The structures in the Bolton formation around Bolton Notch (SC) perhaps reflect the end phases of the movement that squeezed the isoclinal syncline hard against the more open "Hebron anticline" to the east.

It is not known whether these structures in the crystallines predate Triassic movements by a very great interval or whether they are nearly contemporaneous. The apparent offset of the Triassic dike northwest of Vernon Center (NW) suggests activity along these structures well into the Triassic.

In summary the status of the crystalline structures of the Rockville quadrangle may be stated as follows:

The regional pattern is one of shear or incompetent folding in which the plunge of the structure is to the north, not more than 25°.

The structure appears to be controlled by the Hebron anticline to the east. The Bolton schist is in the form of an isoclinal syncline wedged between the Hebron gneiss and an anticline of Glastonbury gneiss to the west.

The Bolton and Hebron formations appear to be concordant, representing different levels of deformation within the same major fold structure. The relationship of the Glastonbury formation to these structures is not entirely clear, though the weight of evidence here indicates a discordant relationship, possibly an oblique thrust fault.

It is thought that the numerous pegmatite lenses in the Bolton and Hebron formations represent synkinematic injection of migmatitic material. The large quartz bodies and pegmatites, however, seem more closely related to the several fault zones present in the area.

For the most part faulting cannot be dated conclusively, but the fault trends suggest that major displacements are Triassic in age.

With this background on the structures of the crystallines, we are now ready to consider the problem of the nature of the Triassic border zone in the Rockville quadrangle.

THE STRUCTURES OF THE BORDER ZONE

Notable contributions to the study of eastern border zone structures in this area have been made by Davis and Griswold (1894), Davis (1898), Russell (1922), and Wheeler (1939).

Davis and Griswold in their map (Figure 1, page 522) give the general distribution of notable fault structures of the eastern border zone. Davis (1898) presents a detailed analysis of possible mechanisms responsible for the fault patterns that he and Griswold described in 1894. He appears to base his conclusions to a great extent on offset of resistant beds in the Triassic sediments. Russell concerns himself with a reevaluation of the mechanics of the cross faults as set forth by Davis. He questions that Triassic ever existed east of the present boundary and suggests further that displacements on the cross faults are perhaps only minor deflections. Wheeler attempts to relate deflections in the eastern fault to synclinal warps in the adjacent sediments. His evidence is not extensive and serves primarily to point up the fact that the previous theories concerning Triassic faulting were perhaps too restrictive in their approach.

It is interesting to note that the point of departure for these discussions is a consideration of the sedimentary structures. There is little doubt that the Triassic cross faults continue into the crystallines, but apparently little thought has been given the possibility that the nature of the movement might be discovered by studying the relationship of adjacent crystalline structures.

The line of contact as drawn on Plate 1 closely parallels the Triassic-crystalline contact as drawn by Davis and Griswold (Figure 1, 1894), Rice and Gregory (1906), and Foye (1949). The position of the contact is inferred from 1) presence of the chloritized zone of the Glastonbury gneiss; 2) presence of fault breccia; and 3) abundance of large angular blocks of Triassic float, almost to the exclusion of crystalline material, west of this boundary.

In his reports of 1894 and 1898 Davis drew a hypothetical north-south extension of the fault he and Griswold uncovered at Highland Park in South Manchester. Much of the area of this proposed extension is covered with glacial deposits. West of Vernon Center (NW), however, the Triassic dike and the schists are badly sheared and disrupted. Furthermore there is a possible offset between this dike and the dike to the northwest, which might be construed as supporting evidence for the fault line as extended by Davis and Griswold.

Also, the relationship of the previously mentioned major fault structures in the Bolton formation is such as to suggest that they may be a set of complementary shears related to this fault and therefore possibly as late as Triassic in age.

The actual nature of the contact is not clear. The closest outcrop of Triassic material is found half a mile west of the bridge over the Hockanum River west of the WC ninth of the quadrangle. The strike and dip of bedding measured N 85°E, 4°N. The strike of the foliation of the nearest Glastonbury gneiss at Tankerhoosen Lakes and Talcottville (WC) is approximately N 3°E, the dip 50°W. Such a discordance leaves scant room for doubt that the contact here is a fault.

It does seem quite clear, furthermore, that the fault border is not a simple curving fault plane such as might account for the slight westward bulge of crystallines in the WC ninth, but that there is penetration of an en echelon series of faults from the Triassic into the crystallines. Davis and Griswold show two such faults on their map (Figure 1, 1894). One trends northeast through Glastonbury, South Manchester, and Bolton Notch, the other curves into the crystallines between Vernon Center and Rockville and swings northward toward the State line

in the vicinity of West Stafford. The evidence for both these faults is corroborated by the present investigation. The northern one is apparently the fault described by the author as occurring east of Talcottville (WC) and the southern one may be represented by the fault-breccia zone on the Hebron-Bolton boundary.

The bulge is readily identified as that portion of the fault border described by Russell (1922, page 494) as caught between two diagonal faults (presumably those described above). There has been so much disruption and chloritization that it is difficult to determine the nature of the movement along these faults, but the drag folding in the chloritized schists at Talcottville (WC) and Vernon Center (NW) would seem to indicate that the NW (sedimentary) side of the northern fault moved NNE relative to the SE (crystalline) side; the drag-fold axes trend N 5°W and plunge 5° to 10°NW. They are well developed in the chloritized gneiss west of the breccia on hill 350 northwest of Vernon Center (NW), where the dextral pattern is readily apparent.

In the railroad cut east of Talcottville (WC) the folding is not as well preserved, for the chloritic gneiss has been badly shattered. In general these folds seem to preserve a northerly trend and plunge, but the pattern is disrupted completely as the fault zone is approached. The relative movement appears to have been similar to that described above.

The outcrop pattern, i.e., the slight westward penetration of crystallines beyond the general trend of the contact, suggests that the section of crystallines and sediments south of this Talcotville fault represents an elevated segment.

The nature of the Triassic sediments to the west, i.e., alternations of coarse and fine units, with the coarse fragments consisting largely of Glastonbury gneiss and Bolton schist, suggests that these formations must have been topographic highs, raised periodically.

It is thought that absence of a large segment of the western flank of the Glastonbury anticline is in part due to the effects of these diagonal faults that cut across the sedimentary crystalline contact.

These offsets could be accounted for by normal faulting only if it were of great extent, as implied by Davis (1894, pages 91 and 130). Russell (1922, page 496) objected to Davis' theory on the grounds that it required a) too great an eastward extension of Triassic, and/or b) too great a throw along the cross faults, for which no evidence existed. Russell offered no alternative explanation but suggested that a solution to the problem might be found, if presence of fanglomerates and pre-Triassic quartz lode along cross faults could be established. By implication at least it appears that Russell dates the cross faults as pre-Triassic.

The author suggests that Russell's objections might be overcome if one considers that the motion on these cross faults had a strong horizontal component, for then the offsets in both the crystallines and sediments would not require excessive vertical throw. Evidence for this component is the drag folding in the crystallines described above.

The previously established irregularities in the crystallines (e.g., the system of plunging folds, (page 28), would control to a large extent the present divergences in the trend of the Triassic-crystalline contact.

A situation rather similar to that envisaged by Max Willard (1952) in his discussion of bedrock structures of the Greenfield, Massachusetts, quadrangle seems likely. Willard visualized major faulting essentially parallel to the crystalline border. Then at a later period a series of transecting faults cut into the crystallines faulting the Triassic and providing for the accumulation of aprons of coarser sediments along the faults. It seems to the author that a parallel situation may exist here, for the reasons stated above. Therefore the actual border may vary in nature from place to place and may be as much sedimentary as tectonic and possibly for that reason remains obscured.

The area of this quadrangle is so limited with respect to the entire structure that very little can be added to the previous discussions of the mechanics and progression of the faulting. The only observation that appears particularly significant is evidence for the apparently important horizontal or at least oblique component along these faults in the crystallines in response to a couple that is not exactly east-west but is a secondary couple associated with these diagonal faults. In any event the dominant motion in all observed cases appears to be west over east, even in the faults in the Bolton formation.

SUMMARY OF REGIONAL GEOLOGY

Thus far we have been concerned principally with geologic relationships within the Rockville quadrangle itself. These data and interpretations gain full meaning only when they are related to the regional picture. One cannot develop the geology of a quadrangle accurately if one takes an isolationist point of view.

What then are some of the correlations and differences that appear when the geology is viewed on a regional scale?

If, as seems likely, the entire Eastern Highland of Connecticut is pierced by a series of domes, then it would seem to follow that lithologic units, at present differentiated, must be combined in order to conform to the structural data. Specifically, there appears to be very close relationship between varieties of the Bolton and Scotland formations and between the Putnam and Hebron formations.

The question of equivalents hits a snag as one attempts to follow the formations from the Ellington, through the Rockville, and south into the Glastonbury quadrangle.

The Monson and Glastonbury formations have been correlated, and on older maps there are double bands of Monson gneiss on either side of Bolton schist. Such an arrangement does not agree with the facts uncovered by this survey. The eastern belt of Monson gneiss is not recognized. Further it appears that a more careful delineation of the Monson formation in Massachusetts is necessary before this problem can be resolved.

It appears that only the easternmost formations represented in the Glastonbury area carry over into the Rockville area. Similarly the northwestern band of crystallines represented in the Ellington quadrangle is missing in the Rockville area. This is not surprising if one considers that the structures are fold structures whose axes trend north-south or slightly west of north. If they are transected first by north-south normal faulting, and then by northeast-trending diagonal faults, these relationships are exactly what one should expect.

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The age relationships of the formations are somewhat confused. Based on evidence in the Rockville area one may definitely place the Hebron formation as older than the Bolton formation, but where the Glastonbury formation fits is open to question, though the most logical assumption, based on a synclinal structure for the Bolton formation, is that it is older. Since Bolton schist grades into Hebron gneiss one is left with the further assumption that the Glastonbury must also be older than the Hebron formation.

In general this fits into the picture as it is pieced together by Herz (1955) south of this area. The relative position and structural correlation of the Hebron and Middletown formations remain undetermined and, they are likely to continue so until the geology of the Marlboro and perhaps also of the Columbia quadrangle has been completed.

The author wishes to state her emphatic belief that results of this study indicate that we are not yet ready for precise, long-range correlation. Despite obvious similarities in lithology, extreme lithologic changes are demonstrable along the strike, particularly in the Bolton formation. The problem of lithologic and structural equivalents has, therefore, scarcely been touched.

Furthermore, until the relationships of early crystalline structure and the nature and extent of Triassic diagonal (en echelon) faults have been more carefully defined, accurate correlation of formations seems rather hazardous at best.

· Economic Geology

Economically significant mineral deposits of great value are lacking in this area. Commercial enterprises concerned with extraction of mineral raw materials are confined to quarrying of garnetiferous Bolton quartzite for building stone and flag, and utilization of the abundant fluvio-glacial deposits as a source of sand and gravel.

Almost every secondary road west of Bolton Notch (SC) has its own small gravel pit. The largest of these is the State Highway Department pit at Bolton Pond (SC) which utilizes the fine-grained glacio-lacustrine sands and gravels of the area. In the WC, NW, and SW ninths particularly, the deposits are relatively fine sands and fine gravels that have accumulated to great depth, and most are utilized with little or no screening or washing. East of Bolton Notch (SC) the deposits show an appreciable increase in coarse bouldery fragments and must be sorted before they can be used effectively.

There are only three quarry operations in the bedrock. The one at Bolton Notch is fairly active. Most of the material extracted is flaggy garnetiferous muscovite-rich quartzite. Another quarry in this same part of the Bolton formation is located just east of Mountain Spring Road (NE), in and about hill 873. This quarry is interesting in that it has both open workings and a system of tunnels. Though it was at one time a fairly large operation, present activity is sporadic. Since World War II a quarry has been opened in the garnetiferous quartzite on the northwest flank of Box Hill (WC). Most of the material is in small blocks and is used for flagging or fieldstone building construction.

There is ample evidence that the Bolton quartzites were quarried extensively in former years. Old pits are to be seen on the east face of the ridge at Bolton

Notch, and the little settlement, Quarryville (C), attests to the importance of the bygone activity in the local economy. Percival (1842, pages 229, 230 and 232) refers to several quarries in the Bolton and says the rock was used not only for building stone, but also for firestone and grindstones. He forecast the demise of the flagging quarries at Bolton (page 232) when he stated that "this Western dip also renders the working of the Bolton flagging quarries, all of which lie on the east side of the range, peculiarly inconvenient, and perhaps ultimately impracticable". There is no doubt that quarrying costs increased and that they, coupled with a shrinking market, reduced a once flourishing local industry to little more than a memory.

The Glastonbury gneiss appears at first glance to possess very good qualities for building material. It is fairly compact and fine-grained, yet the poorly developed foliation is sufficient to permit the rock to be worked into rough slabs. Most outcrops have badly weathered crumbly surfaces indicating poor durability; also they are rather badly fractured so that it would appear difficult to obtain blocks of any size. Furthermore, in most localities the foliation is nearly vertical, which might discourage the prospective quarryman. The feldspars are not coarse enough to classify them as a source of commercial grades of that mineral. In any event there seemingly were never any demands for the rock itself though Percival (1842, pages 220 and 224) refers briefly to a copper working on the margin of the Glastonbury formation southeast of Manchester. From his description it appears that the mineralization might have been associated with the boundary faults.

The Hebron gneiss, like the Glastonbury gneiss, has found only limited local use as a structural stone and appears mostly in foundation walls of some of the older buildings in the area. The suitable material is in layers too thin and uneven to provide large amounts of good quality, properly sized, dimension stone.

Perhaps it is not amiss to conclude this phase of the report with a few words about the indirect economic resources, namely the soil and the water supply.

As in most of this section of Connecticut, there is but thin soil cover on the crystallines of the Eastern Highlands. As noted above, the hills are covered with heavy deposits of glacial moraine, which is poorly sorted and, in many places, poorly drained. With the exception of the flattish land of the EC ninth little of the eastern two-thirds of the quadrangle has been found suitable for farming on a very extensive scale. In this area farms, for the most part, are dairy or poultry farms.

In marked contrast is the amount and type of agricultural activity found in the western third of the area. In the first place the land is topographically more suitable for farming. There is less relief, and the topography consists of low rolling drumloid hills and flat plains of glacio-lacustrine origin. The soil here is also derived from glacial deposits and, though it has a tendency to be loose and sandy, supports fairly good crops of tobacco and corn. It is derived largely from Triassic sediments, and is characteristically reddish in color. One might note here that the Triassic red beds are surprisingly rich in calcium carbonate matrix and cement, which might be a contributing factor to the comparatively greater richness of these soils compared with those of the highlands to the east.

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The roles of bedrock structure and amount of glacial cover in controlling water supply are neatly illustrated in this area.

In the crystalline highlands, shallow wells, of doubtful reliability, abound where the glacial cover is fairly thick. On the flanks of folded structures, wells drilled into bedrock are the rule. West of the Bolton ridges it is not uncommon for wells to be driven as much as 200 feet below the surface to bedrock. Any water at a lesser depth depends on the presence of a hardpan layer which provides a perched water table. The area is well drained yet the water table appears to be rather close to the surface. It is not within the province of the writer to do more than outline some of the factors that combine to control the distribution of ground water. Each well is an individual problem, and its location and develop- ment are a matter for the expert. Suffice it to say that in general the evidence indicates that the highly fractured plunging-fold structure of the crystallines should provide an excellent reservoir for ground water. In areas of thick glacial sediments the depth of wells will depend to a very large extent on the presence or absence of hardpan—a condition that cannot easily be forecast with accuracy.

In summary one is forced to confess that the natural resources of this area are not of great direct economic significance. It is hoped however that knowledge of the distribution of the various bedrock types, and a general knowledge of their character, will prove useful in the matter of local construction and development both of land and water supply.

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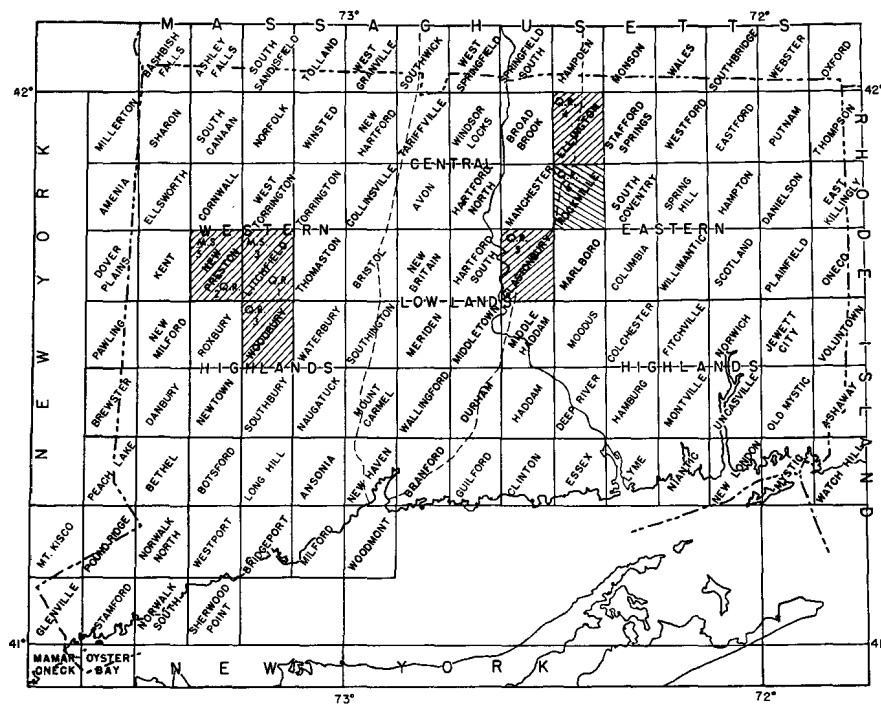
FIGURE 1. Index map of Connecticut, showing location of Rockville quadrangle.

PLATES

PLATE I   Geologic Map (in pocket)

PLATE II FIGURE 1

   Outcrop of typical Glastonbury gneiss on Wilbur Cross Parkway just east of Vernon
Street (NC). Hammer parallels lineation which plunges 12°N 5°W.

PLATE III FIGURE 1
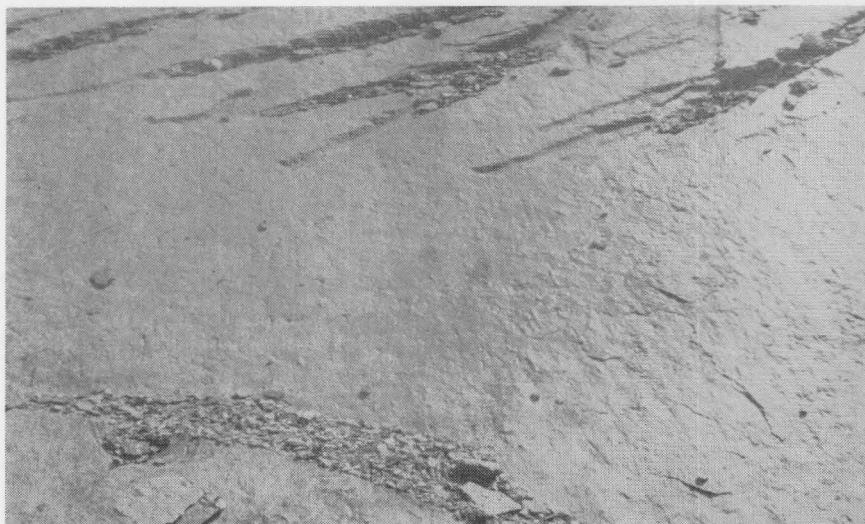
Outcrop of typical phyllitic Bolton schist at west end of highway cut in Bolton Notch (SC). Note luster on foliation surface. Also apparent are 1) the slight crinkling of the layers, producing a lineation seemingly directed toward the observer, plunging 20°N 5°W, and 2) the pitted surface due to garnet metacrysts in the lower center portion of the photograph. Elongate depressions and ridges in the same area mark staurolite metacrysts.

PLATE III FIGURE 2

Close up of large pseudo-staurolite metacrysts in impure quartzite zone of Bolton formation at north end of railroad cut north of Bolton Notch (C). The metacrysts are flattened; length averages 8 to 10 inches, maximum observed 14 inches.

PLATE IV FIGURE 1
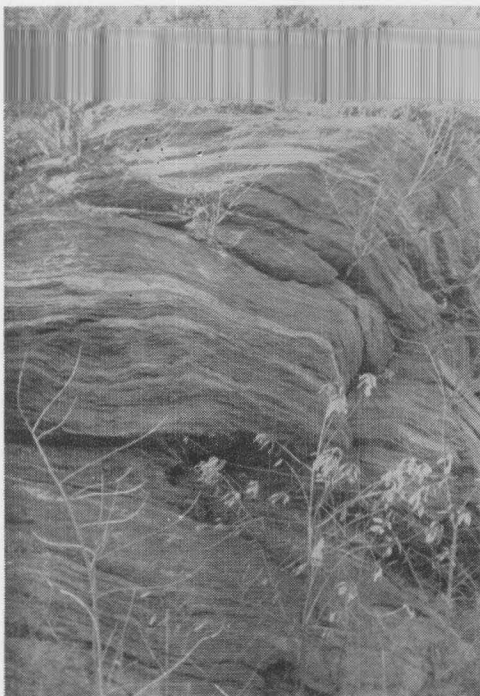
Outcrop of typical micaceous quartzite of the central Bolton formation in north end of railroad cut on east side of Box Hill (C). Light bands are almost pure quartzite.

PLATE IV FIGURE 2

Secondary folding in micaceous quartzites of Bolton formation in north end of railroad cut on east flank of Box Hill (C). Fold axes trend nearly N-S, and at this locality are nearly horizontal. Note variation in character of folds within very short distances. The material above and below this zone is unfolded.
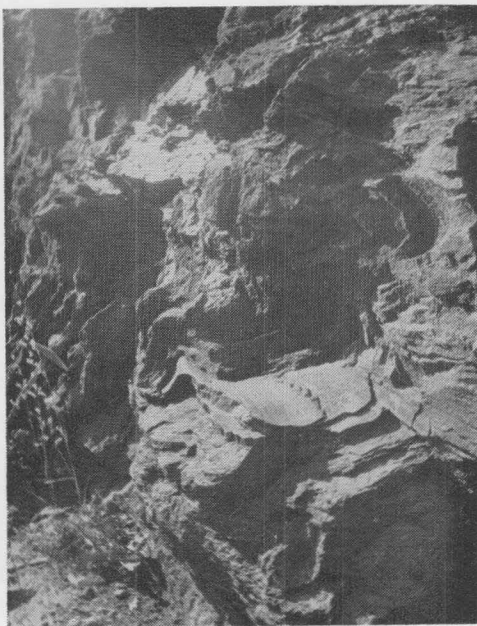
PLATE V
FIGURE 1
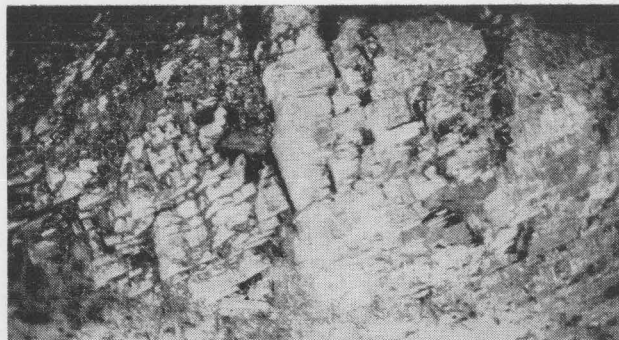
Development of strong fracture system at Bolton Notch (SC). View looking north. Foliation, which dips 23°W, strikes N 30°E. Fractures strike N-S and dip 65° to 80°E.

PLATE V FIGURE 2
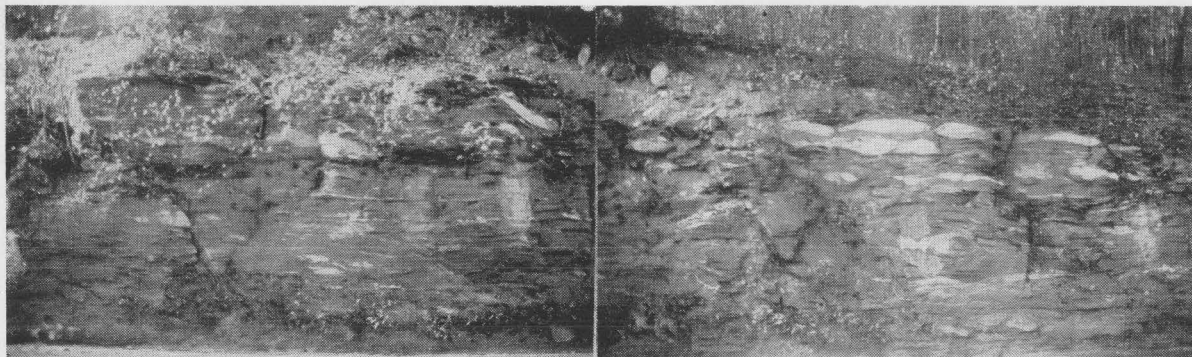
Biotite augen gneiss at intersection of Highway 6 and South Street (SE); photo looking to southwest. The beds dip southwest away from the observer at an angle of 10°. The strike is N 21°S. The fractures strike N 30° to 40°E and dip 72° to 80°NW.

PLATE VI FIGURE 1

Amphibolite and skarn of Hebron formation in cut on Highway 6 east of Bolton Notch (SC). Amphibolite occupies approximately the left half of the photograph; of the remainder, only the extreme right-hand portion is solid skarn; the interval is interlayered skarn and amphibolite. Strike N 20°E; dip 26° to 38°W. Fractures are part of a regional system; strike N-S to N 10°W, dip 65° to 80°E.

PLATE VI FIGURE 2
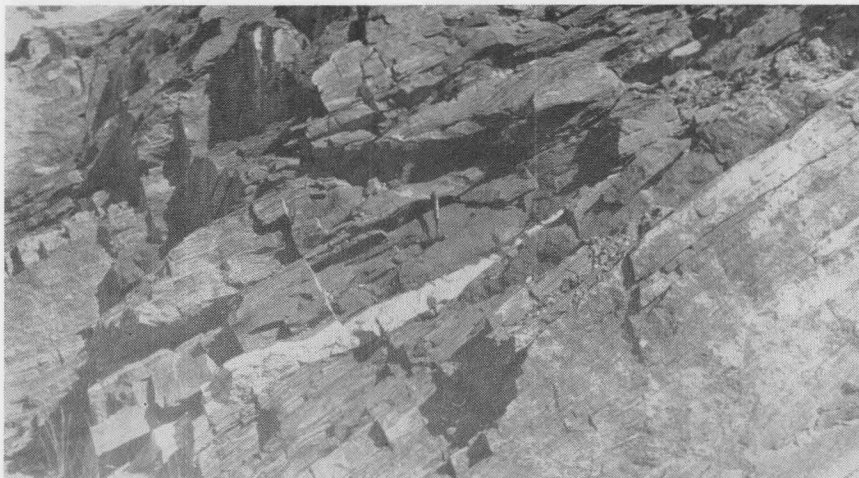
Epidote amphibolite east of Bolton Notch (SC): lighter third of the photograph on the right side is skarn with layers of amphibolite. Light-colored lens is aplitic. Light gray areas in amphibolite are rich in clinozoisite. Note boudinage-like structures below aplite lens in lower left.

PLATE VII FIGURE 1a

Small-scale incompetent folding in Hebron gneiss at Reservoir Brook (SC). Folding is associated with synkinematic injection. Fold axes plunge 15° to 20°N 20°W.

PLATE VII FIGURE 1b

Larger secondary folding in Hebron gneiss at Reservoir Brook (SC). Folding is due to crumpling of incompetent beds in regional anticlinal structure. Fold axes plunge from 58° to 12°N 22°W as the structure flattens abruptly.

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PLATE VII FIGURE 2
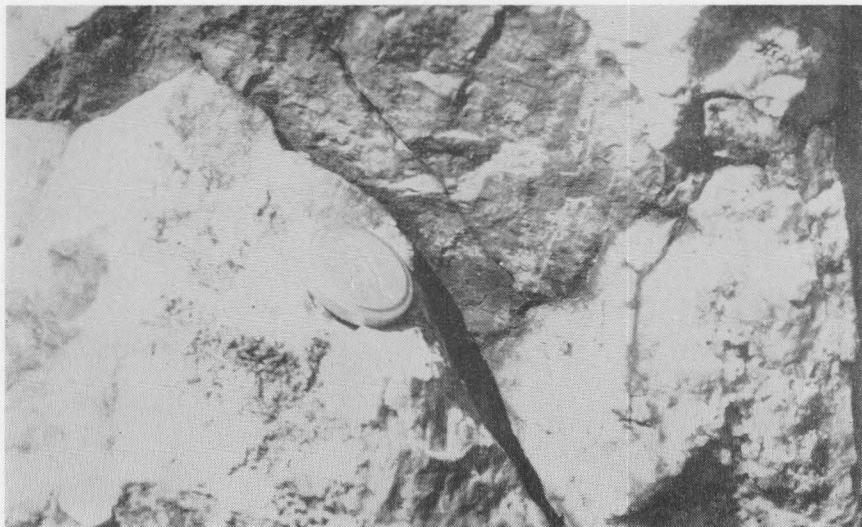
Close-up of Triassic fault breccia in west end of railroad cut 1 mile east of Talcottville (WC). Light areas are nearly pure vein quartz. Dark patches contain recognizable fragments of Triassic arkose. Note quartz crystals in lower right-hand corner of photograph.

PLATE VIII FIGURE 1

Gravel pit on west flank of easternmost ridge at Bolton Notch (east of Old Bolton Road (C) at elevation of about 650 feet). This coarse unsorted material contains very few Triassic fragments. Light-colored boulders are Glastonbury gneiss; dark slabby masses are Bolton schist. Ledge in lower left is Bolton schist bedrock. Material is fairly typical of glacial cover over much of area east of Bolton ridges.

PLATE VIII FIGURE 2
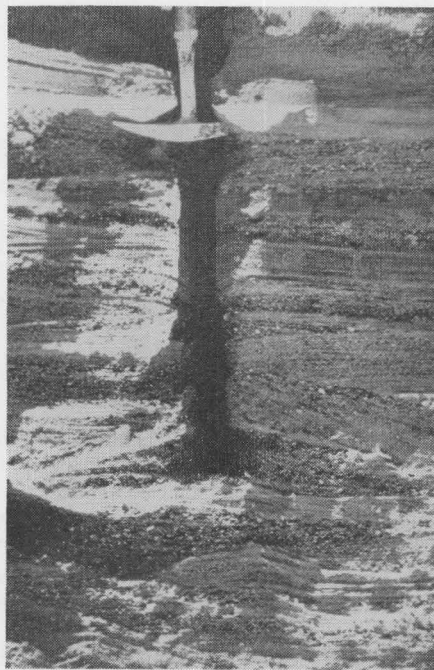
Cross-bedded sand and fine gravel; typical fluvio-glacial material such as covers much of the quadrangle west of the Bolton ridges. Pebbles are predominantly Triassic or quartz with a scattering of small discs of Bolton schist. Photograph of gravel bank on west side of West Street just south of Rockville city line (NW).

PLATE IX

Typical Glastonbury Gneiss

Thin section of "typical" Glastonbury gneiss. Enlargement about 20X. Inset is photo-micrograph of encircled area, enlargement 50X.

General megascopic description

Color—streaky black and white

Rock Type—"pencil" gneiss

    a. grain size—2 to 10 mm, average 4 mm

    b. structure—massive with blebs of quartz, feldspar, and biotite in streaks and schlieren

    c. composition—feldspar, weathered, 60%; biotite, 30%; quartz, 10%.

Microscopic analysis

Description

    a. texture—uneven granoblastic, grains with highly sutured boundaries

    b. structure—massive

    c. mineralogy—An_{12} feldspar, anhedral, 45%; quartz, anhedral, 25%; green biotite, anhedral, 15%; K-feldspar, anhedral, 10%; clinohypersthene, anhedral, 5%.

Comment: Rough orientation of biotites parallels faint lamination produced by c distribu-tion of coarse- and fine-grained feldspar and quartz. Pyroxene appears to be concentrated in clusters which are scattered through the rock. Large amounts of feldspar and quartz have undulatory extinction. Myrmekite is prominently developed on the margins of the feldspars. Pyroxene and biotite are nearly contemporaneous.

The rock appears to be a product of moderately high-grade regional metamorphism. Evidences of disequilibrium suggest more than one phase of activity.

Classification: Medium-grade quartzo-feldspathic gneiss

PLATE X

Glastonbury formation: K-feldspar-rich gneiss

Thin section of K-rich variety of Glastonbury gneiss. Enlargement about 20X. Inset is photomicrograph of encircled area, enlargement 50X.

General megascopic description

Color—mottled deep pink, gray, and green

Rock Type—gneiss

a. grain size—2 to 4 mm

b. structure—massive

c. texture—granoblastic

d. composition—pink feldspar, 60%; gray-white feldspar, 20%; biotite and chlorite, 18%; accessories, 2%

Microscopic analysis

Description

a. texture—granoblastic, grains with sutured boundaries

b. structure—massive

c. mineralogy—K-feldspars, anhedral, 40%; quartz, anhedral, 25%; An_{18} feldspar, anhedral, 20%; biotite and chlorite, anhedral, 7%; clinohypersthene, subhedral, 5%; accessories, 3%.

Comment: Relatively large anhedral masses of quartz and scattered albite grains with undulatory extinction, surrounded by fine-grained mixture of quartz, plagioclase (Na), kaolinitized K-feldspar, and rounded to subhedral poikilitic light pyroxene (clinohypersthene ?). Biotite is almost completely altered to chlorite and has abundant inclusions of what appears to be sphene.

The gneiss has many characteristics of a quartzo-feldspathic granulite possibly gradational with a "gneiss" belonging in the amphibolite facies. Moderately high-grade regional metamorphism of material derived from pelitic sediment.

Classification: Quartzo-feldspathic gneiss (granulite ?).

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PLATE XI

Bolton formation: phyllitic schist
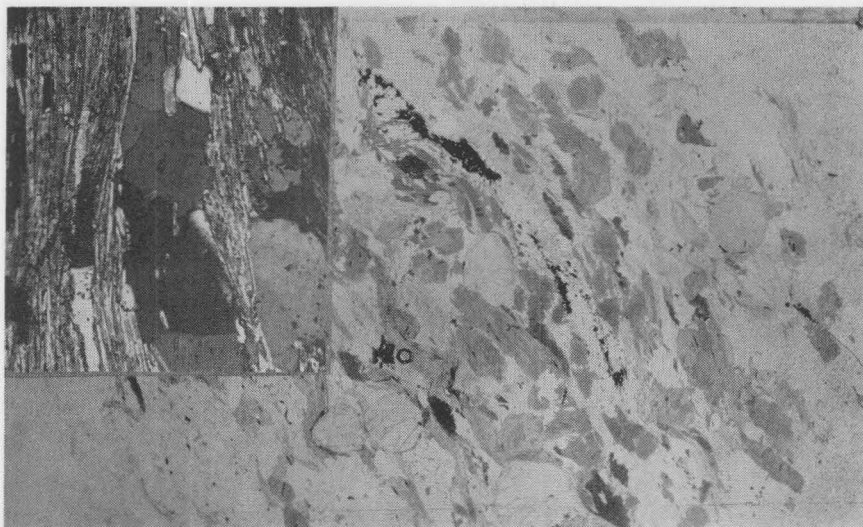
Thin section of Bolton phyllitic schist. Enlargement about 20X. Inset is photomicrograph of encircled area, enlargement 50X.

General megascopic description

Color—gunmetal gray

Rock Type—phyllitic schist
  a. grain size—1 mm to 3 mm
  b. structure—massive foliated
  c. texture—porphyroblastic
  d. composition—quartz, 65%; muscovite, 20%; biotite, 5%; garnet, 4%; staurolite, 1%; others, 5%.

Microscopic analysis

Description

  a. texture—lepidoblastic matrix with porphyroblasts
  b. structure—laminated
  c. mineralogy—quartz and feldspar, anhedral, 62%; muscovite, anhedral to subhedral, 25%; garnet, subhedral, 4%; biotite, anhedral to subhedral, 3%; staurolite, subhedral to euhedral, 2%; accessories including hematite, graphite, and tourmaline, 3%

Comment: Laminae consisting of medium and very fine crushed, rectangular quartz grains.

Finer material has strong preferred orientation. Muscovite-rich laminae are interspersed with quartz laminae. Mica shows no deformation individually but laminae bend around the porphyroblasts of staurolite and garnet. Garnets are relatively clear, but staurolite has abundant rounded inclusions of quartz. Inclusions in the staurolite are distributed in a "ropy" pattern.

The condition of the staurolites and character of the laminae of quartz and muscovite suggest dislocation metamorphism with retrogressive effects seen in the staurolites. The rock represents the results of moderately high-grade regional metamorphism of a pelitic sediment, followed by dislocation metamorphism.

Classification: Phyllonite.

PLATE XII

Bolton formation: micaceous quartzite
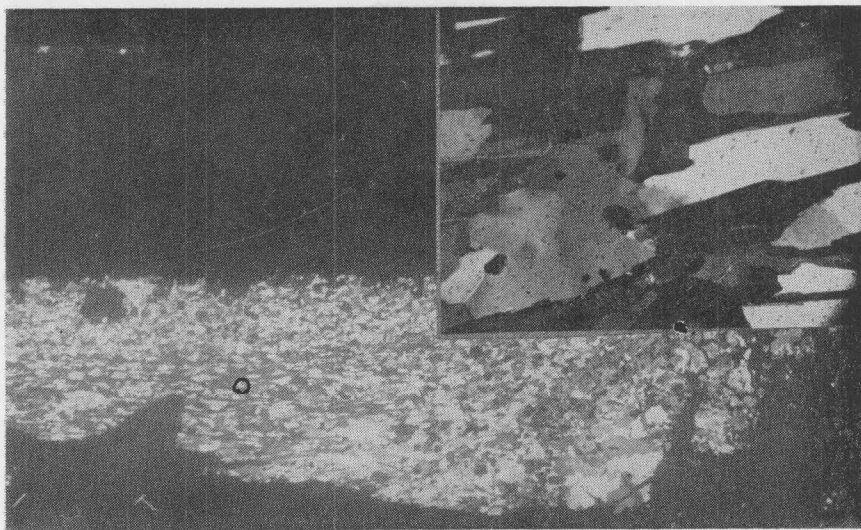
Thin section of Bolton micaceous quartzite. Enlargement about 20X. Inset is photo-micrograph of encircled area, enlargement 50X.

General megascopic description

Color—medium to light gray; silvery on foliation surface

Rock Type—impure quartzite

    a. grain size—1 to 2 mm

    b. structure—banded

    c. texture—granoblastic, locally porphyroblastic

    d. composition—quartz, 85%; muscovite, 12%; others, 3%

Microscopic analysis

Description

    a. texture—granoblastic-lepidoblastic

    b. structure—banded

    c. mineralogy—quartz, anhedral, 52%; muscovite, anhedral, 43%; plagioclase, anhedral, 2.5%; biotite, anhedral, 2.4%; tourmaline, subhedral to euhedral, trace; garnet, subhedral, poikilitic, trace

Comment: Grain size is fairly uniform except for porphyroblastic tourmaline and garnet.

Quartz shows strong undulatory extinction, other minerals normal. Muscovite, tourmaline, and garnet are late minerals devoid of deformation. Garnet contains abundant inclusions of quartz and shows slight alteration to chlorite.

The evidence indicates mild regional metamorphism of an impure quartz-rich sediment (sandstone ?) with recrystallization confined to the pelitic fraction, producing muscovite and accessories.

Classification: Impure quartzite or low-grade quartzo-feldspathic hornfels.

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PLATE XIII
Bolton formation: quartzite
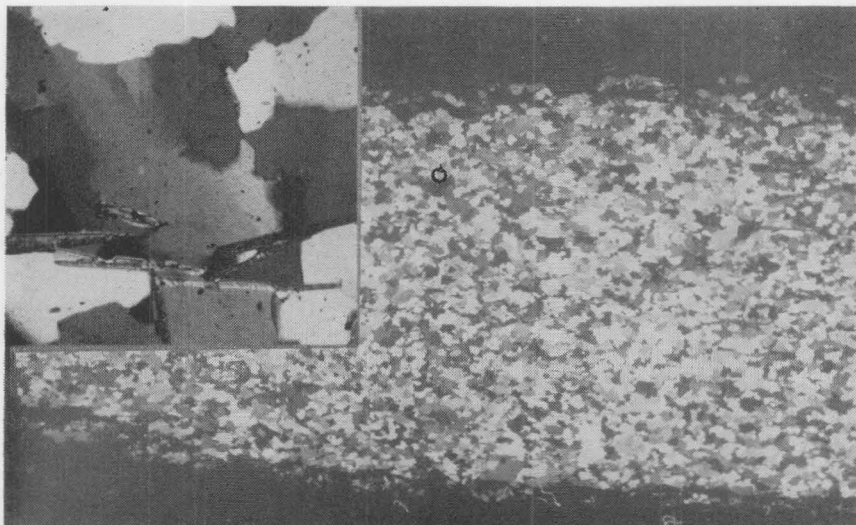
Thin section of Bolton quartzite. Enlargement about 20X. Inset is photomicrograph of encircled area, enlargement 50X.

General megascopic description

Color—medium to dark gray; vitreous luster

Rock Type—quartzite

a. grain size—1 mm or less
b. structure—massive
c. texture—granoblastic
d. composition—quartz, 95%; muscovite and garnet, 5%

Microscopic analysis

Description

a. texture—granoblastic, grains have sutured boundaries
b. structure—massive, slight flattening of grains
c. mineralogy—quartz, anhedral, 91.3%; muscovite, garnet, and biotite, anhedral to subhedral, 8.7%
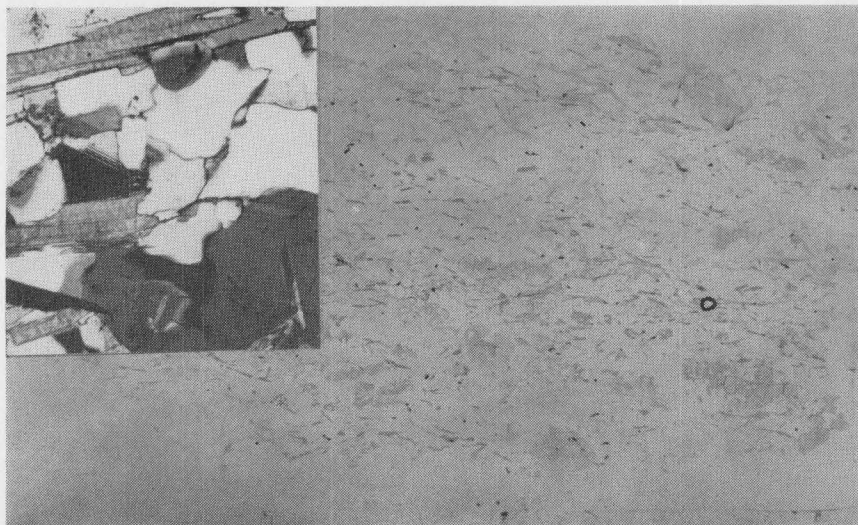
Comment: Remarkably pure quartzite. Most grains show undulatory extinction; a few small quartz grains and the mica are undeformed.

The rock appears to be a product of recrystallization of psammitic sediment of uniform character and composition.

Classification: Quartzite

PLATE XIV

Bolton formation: garnet-chloritoid gneiss

Thin section of garnet-chloritoid-rich variety of Bolton schist. Enlargement about 20X. Inset is photomicrograph of encircled area, enlargement 50X.

General megascopic description

Color—white, mottled with bright green and deep red

Rock Type—gneiss

  a. grain size—1 mm, with porphyroblasts 2 to 3 mm

  b. structure—massive

  c. texture—porphyroblastic

  d. composition—feldspar, 55%; quartz, 40%; chloritoid, 2%; garnet, 2%; muscovite, 1%

Microscopic analysis

Description

  a. texture—granoblastic, inequigranular, grains have sutured boundaries

  b. structure—massive

  c. mineralogy—quartz, anhedral, 45%; An_{12} feldspar, anhedral, 40%; biotite, anhedral, 6%; chloritoid, anhedral, 4%; garnet, subhedral to anhedral, 2%; muscovite, anhedral, 1%; accessories, 2%

Comment: Uneven textured; fairly massive; large sutured grains of quartz surrounded by a finer-grained mass of quartz and feldspar, also with highly sutured boundaries. Micas appear to have formed independent of this structure. Chloritoid characteristically in radiating or sheaf-like aggregates. Garnets are poikilitic and most abundant inclusion is quartz. Chloritoid and garnets appear to be distributed unevenly in zones.

    The gneiss belongs in the greenschist facies and represents a product of low-grade regional metamorphism of a quartzo-feldspathic sediment.

Classification: Quartzo-feldspathic chloritoid gneiss.

PLATE XV
Hebron gneiss

Thin section of typical Hebron gneiss. Enlargement about 20X. Inset is photomicrograph of encircled area, enlargement 50X.

General megascopic description

Color—medium gray

Rock Type—banded gneiss

    a. grain size—medium, 1 to 2 mm

    b. structure—gneissic, composition banding

    c. texture—granoblastic

    d. composition—quartz, 60%; feldspar, clear, glassy, 30%; biotite, reddish-brown, 10%
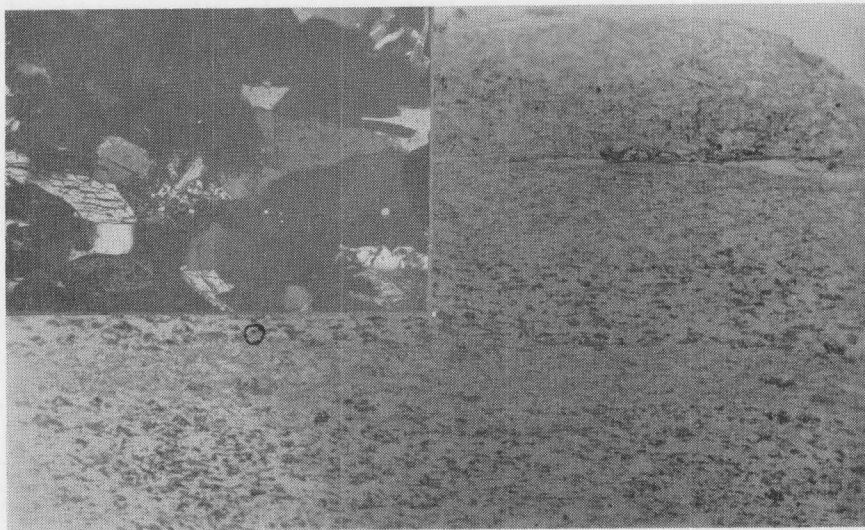
Microscopic analysis

Description

    a. texture—granoblastic

    b. structure—banded, mortar

    c. mineralogy—quartz, anhedral, 55%; An_{20} feldspar, anhedral, 35%; brown biotite, anhedral, 5%; scapolite, anhedral, 2%; magnetite, anhedral, 2%; sphene, anhedral, 1%

Comment: Knots and masses of slightly strained quartz and feldspar are surrounded by a mosaic of smaller quartz, feldspar, and biotite. There is a suggestion that this may be a cataclastic gneiss; a low-grade quartzo-feldspathic product of regional metamorphism.

Classification: Biotite gneiss

PLATE XVI

Hebron gneiss: "skarn"

Thin section of Hebron "skarn". Enlargement about 20X. Inset is photomicrograph of encircled area, enlargement 50X.

General megascopic description

    Color—medium and dark greenish-gray, banded; vitreous luster

    Rock Type—skarn or calc-silicate hornfels

        a. grain size—1 to 2 mm

        b. structure—massive, banded

        c. texture—granoblastic

        d. composition—quartz, 30%; scapolite, 30%; calcite, 15%; chlorite, 10%; actinolite, 10%; others, 5%
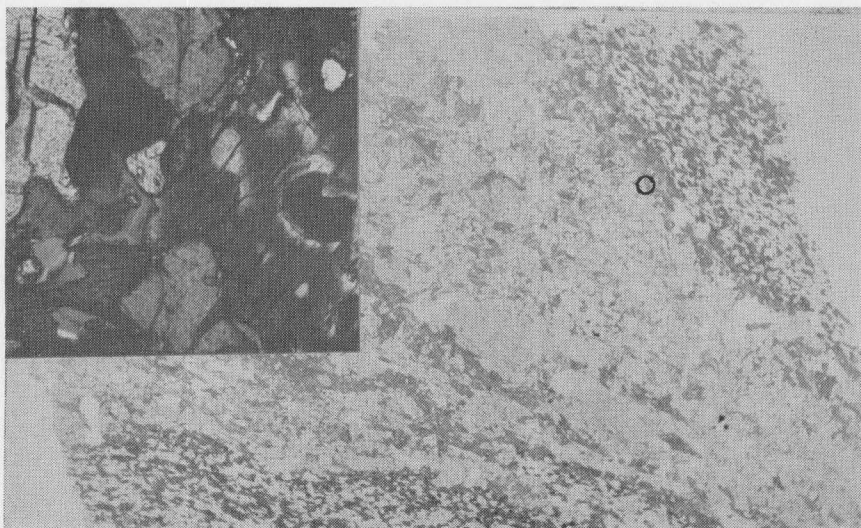
Microscopic analysis

    Description

        a. texture—granoblastic

        b. structure—composition banding produced by amphibole and chlorite

        c. mineralogy—actinolite, subhedral to euhedral, 29.5%; quartz, anhedral to rectangular, 22.6%; scapolite, anhedral, 18%; chlorite, anhedral, 12%; An_{16} feldspar, anhedral, 11.2%; calcite, anhedral, 6%; accessories, 2%

Comment: Quartz and feldspars appear to be earliest minerals with other silicates later and nearly contemporaneous. Much of the chlorite appears to be derived from amphibole, also, it contains abundant black inclusions mostly magnetite, and a small amount of pyrite. Amphibole-rich layers contain abundant sphene.

    The rock appears to be a calc-silicate hornfels derived from moderately intense metamorphism of impure calcareous sediments.

Classification: Calcic hornfels

PLATE XVII

Hebron gneiss: epidote-amphibolite

Thin section of epidote amphibolite variety of Hebron gneiss. Enlargement about 20X. Inset is photomicrograph of encircled area, enlargement 50X.

General megascopic description

    Color—streaky yellowish-green and black

    Rock Type—gneiss

        a. grain size—2 to 5 mm

        b. structure—banded and with augen

        c. texture—granoblastic

        d. composition—amphibole (hornblende), 60%; epidote, 35%; others (calcite, quartz, garnet), 5%

Microscopic analysis

    Description

        a. texture—granoblastic

        b. structure—banded, augen

        c. mineralogy—

            augen: clinozoisite, anhedral to subhedral, 85%; hornblende, subhedral to euhedral, 10%; chlorite, anhedral, 3%; accessories including calcite, sphene, quartz, and Na-feldspar, 2%

            matrix of gneiss: clinozoisite, anhedral to subhedral, 30%; hornblende, subhedral to euhedral, 40%; chlorite, anhedral, 10%; calcite, anhedral, 2%; quartz, anhedral to subhedral, 7%; feldspar, anhedral, 4%; accessories including sphene, garnet 4%

Comment: Granoblastic texture, abundance of actinolitic hornblende and clinozoisite and low percentages of plagioclase suggest that this rock is a product of medium-grade regional metamorphism of impure calcareous sediment.

Classification: Amphibolite gneiss

PLATE XVIII

Glastonbury gneiss: chloritized variety
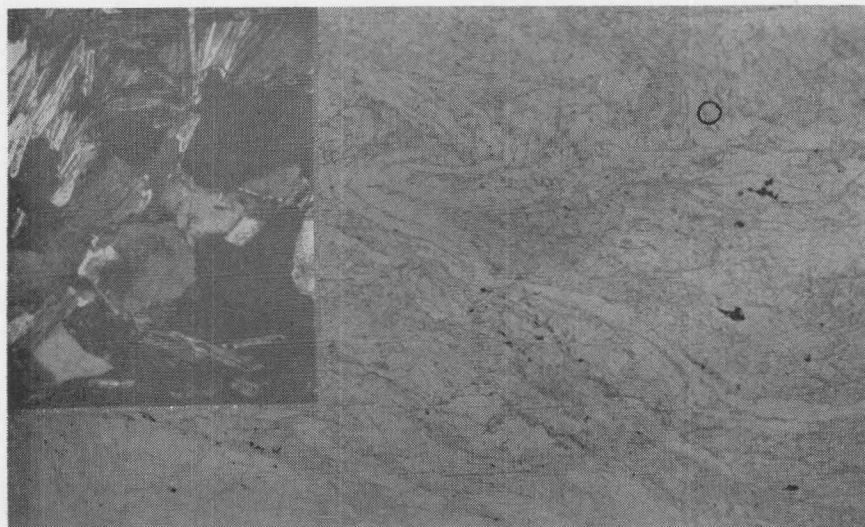
Thin section of chloritized zone of Glastonbury gneiss. Enlargement about 20X. Inset is photomicrograph of encircled area, enlargement 50X.

General megascopic description

Color—lustrous medium to dark grayish green

Rock Type—schist

    a. grain size—1 mm or less

    b. structure—foliated

    c. texture—lepidoblastic

    d. composition—chlorite, 85%; muscovite, 10%; quartz, 5%
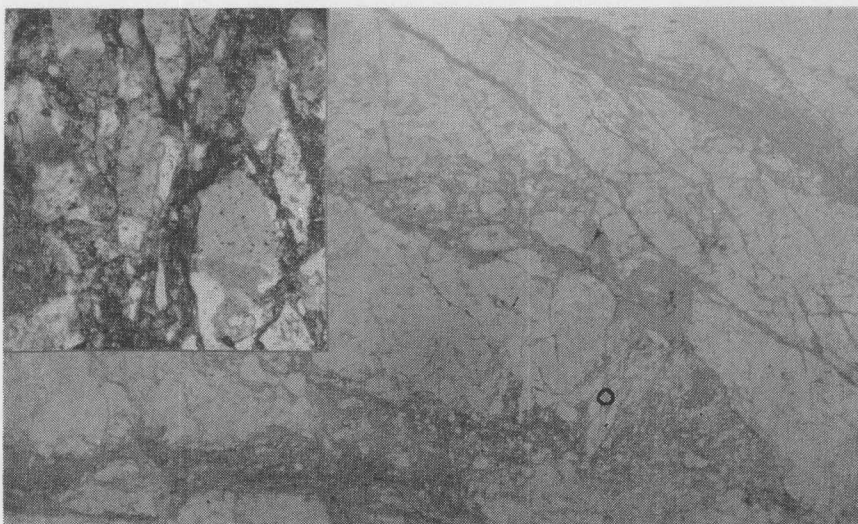
Microscopic analysis

Description

    a. texture—lepidoblastic

    b. structure—laminated

    c. mineralogy—quartz, anhedral, 65%; chlorite, anhedral, 23%; plagioclase(Na), anhedral, 6%; biotite, anhedral, 4%; garnet, subhedral, 1.5%; accessories, 0.5%

Comment: Essentially a quartz-chlorite-biotite schist. Conspicuous flattening of quartz grains, all of which show undulatory extinction. Biotite, which has greenish-brown pleochroism, very largely altered to chlorite. Micro-folding is very prominent but slip cleavage is incipient. Myriads of tiny garnets present (invisible even with the aid of a hand lens).

Approaches a quartzo-feldspathic schist, and in some areas a phyllonite. Granulation of the rock is outstanding; has many characteristics of a low-grade schist produced, at least in part, by dislocation metamorphism.

Classification: Psammitic chlorite schist

PLATE XIX

Fault breccia in Hebron gneiss

Thin section of fault breccia in Hebron gneiss. Enlargement about 20X. Inset is photo-micrograph of encircled area, enlargement 50X.

General megascopic description

Color—green and pinkish white; "pepper and salt"

Rock Type—fault breccia

a. grain size—1 to 2 mm

b. structure—massive with veinlets of chlorite

c. texture—granoblastic

d. composition—pinkish white feldspar, 60%; grayish white quartz, 25%; light green chlorite, 15%

Microscopic analysis

Description

a. texture—cataclastic

b. structure—massive, veined

c. mineralogy—quartz, anhedral, 50%; feldspar, anhedral, 30%; (15%-An_{20} or less) clinozoisite, anhedral, 15%, chlorite, anhedral, 5%

Comment: Outstanding feature is that none of the grains are free from strain shadows; also, fragments enclosed in matrix may include coherent mass composed of quartz and feldspar. Numerous areas found where adjacent fragments could be refitted minus matrix.

Classification: Mylonite or cataclasite

PLATE XX
Triassic fault breccia
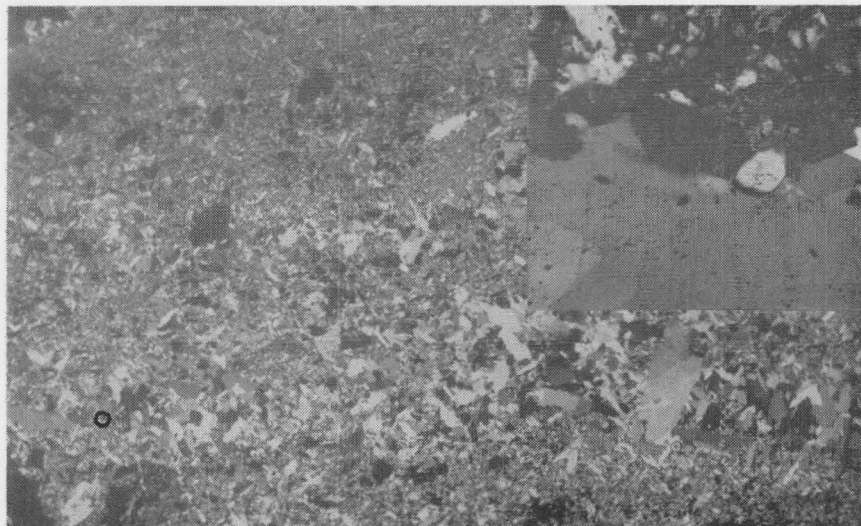
Thin section of Triassic fault breccia. Enlargement about 20X. Inset is photomicrograph of encircled area, enlargement 50X.

General megascopic description

Color—mottled grayish white and rusty red

Rock Type—fault breccia

    a. grain size—fragments up to 3 cm

    b. structure—massive

    c. texture—coarse, angular

    d. composition—feldspathic fragments now largely kaolinitized; angular quartz fragments; silica cement and euhedral quartz crystals in cavities; scattered sooty manganese oxide; veinlets of hematite

Microscopic analysis

Description

    a. texture—medium-coarse in matrix of fine granular material

    b. structure—massive

    c. mineralogy—quartz, anhedral to euhedral, 85%; feldspar, principally orthoclase, anhedral 15%

Comment: Most grains have undulatory extinction, but euhedral quartz grains have normal extinction.

Classification: Fault breccia or cataclasite