Bedrock Geology of the Bristol Quadrangle, Hartford, Litchfield, and New Haven Counties, Connecticut

U.S. GEOLOGICAL SURVEY BULLETIN 1573

Prepared in cooperation with the
State of Connecticut
Geological and Natural History Survey

Bedrock Geology of the Bristol Quadrangle, Hartford, Litchfield, and New Haven Counties, Connecticut

By HOWARD E. SIMPSON

Prepared in cooperation with the
State of Connecticut
Geological and Natural History Survey

Metamorphosed sedimentary strata of inferred Middle Ordovician to Early Devonian age, and sedimentary strata of Late Triassic age underlie the Bristol quadrangle

U.S. GEOLOGICAL SURVEY BULLETIN 1573

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE [1989] Revised 1990

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data
Simpson, Howard E.
Bedrock geology of the Bristol Quadrangle, Hartford, Litchfield, and New Haven Counties, Connecticut.

(U.S. Geological Survey bulletin ; 1573)
Bibliography: p.
Supt. of Docs. no.: I 19.3:1573.
1. Geology, Stratigraphic—Ordovician. 2. Geology, Stratigraphic—Devonian. 3. Geology, Stratigraphic—Triassic. 4. Geology—Connecticut—Bristol Region.
I. Title. II. Series.
QE75.B9 no. 1573 557.3 s 86–607922
[QE660] [557.46]

CONTENTS

PLATE
[Plate is in pocket]

FIGURES

Bedrock Geology of the Bristol Quadrangle, Hartford, Litchfield, and New Haven Counties, Connecticut

By Howard E. Simpson

Abstract

Metamorphosed strata of sedimentary origin underlie the upland surface of western Connecticut. The metamorphic rocks consist chiefly of micaceous schists and gneisses with small to negligible amounts of pegmatite, amphibolite, metaquartzite, and serpentinite. These metamorphic rocks represent four formations. In order of decreasing age upward they are the Taine Mountain Formation, Bristol Gneiss, Collinsville Formation, and The Straits Schist. These formations may correlate with the Moretown Formation, Hawley Formation, and Goshen Formation of central western Massachusetts, which are inferred to range in geologic age from Middle Ordovician to Late Silurian and Early Devonian. Regional metamorphism and doming of the strata most probably occurred during the Acadian orogeny at or near the end of Early Devonian time.

Nonmetamorphosed sedimentary strata underlie the adjacent central lowland of Connecticut, known also as the Hartford Mesozoic basin. These strata are composed mainly of Upper Triassic sandstone and conglomerate assigned to the New Haven Arkose of the Newark Supergroup of Late Triassic age. These sedimentary strata are inclined moderately downward toward the east, are commonly massive, and are poorly exposed.

Gravimeter traverses across the upland-lowland boundary suggest the presence of a normal fault of a few hundred feet of vertical displacement downthrown on the east. Traces of copper mineralization are found locally in the vicinity of the boundary fault, and at least one mine produced copper ore during the 1800's. Jointing and foliation planes in the metamorphic rocks can affect slope stability and the ease of excavation.

INTRODUCTION

The bedrock formations of the Bristol quadrangle, Connecticut (fig. 1), are almost wholly mantled by surficial deposits of sand, gravel, and till ("hardpan") that vary in thickness (Simpson, 1961). The bedrock in the western two-thirds of the quadrangle consists of metamorphic rocks; these underlie part of a broad upland that characterizes western Connecticut. Sedimentary rocks that are much younger underlie the eastern one-third of the quadrangle, which constitutes part of the central lowland of Connecticut. The two areas are separated by a prominent topographic boundary that trends north-south just east of the city of Bristol.

Structurally, the metamorphic rocks form a broad dome that is elongate in a south-southwesterly direction. The central core of the structure is exposed just north of the Bristol quadrangle and is surrounded by a gently dipping sequence of light-colored feldspar-rich gneisses (pl. 1). The greater erodibility of one of these units has resulted in the formation of an irregular topographic basin on the southeastern flank of the dome. This basin, from 2 to 4 mi (mile) across and as much as 750 ft (feet) deep, is now partly occupied by the city of Bristol. Geologically, the dome has thus been known for many years as the "Bristol Dome," and that name is here formally assigned to the structure.

ROCK STRATIGRAPHIC UNITS AND THEIR CORRELATION

Since the late 1940's, numerous geologists involved in detailed field mapping in southwestern New England have named rock-stratigraphic units and attempted their correlation with the work of others. Most of these proposed correlations have received little acceptance. Coordinated efforts by Hatch and Stanley (1973), based on detailed mapping mainly in western Massachusetts coupled with reconnaissance studies throughout the region, appear to offer a reasonable regional solution to past correlation problems.

The relation of rock units of inferred Ordovician, Silurian, and Devonian age in selected quadrangles and areas of southern and western New England, in part as interpreted by Hatch and Stanley (1973, pl. 2), is shown

The present U.S. Geological Survey Bulletin 1573 is a revised and updated version of an earlier, smaller format book with the same number. The author thanks Diane C. Schnabel for her editorial and geological contribution to both books.

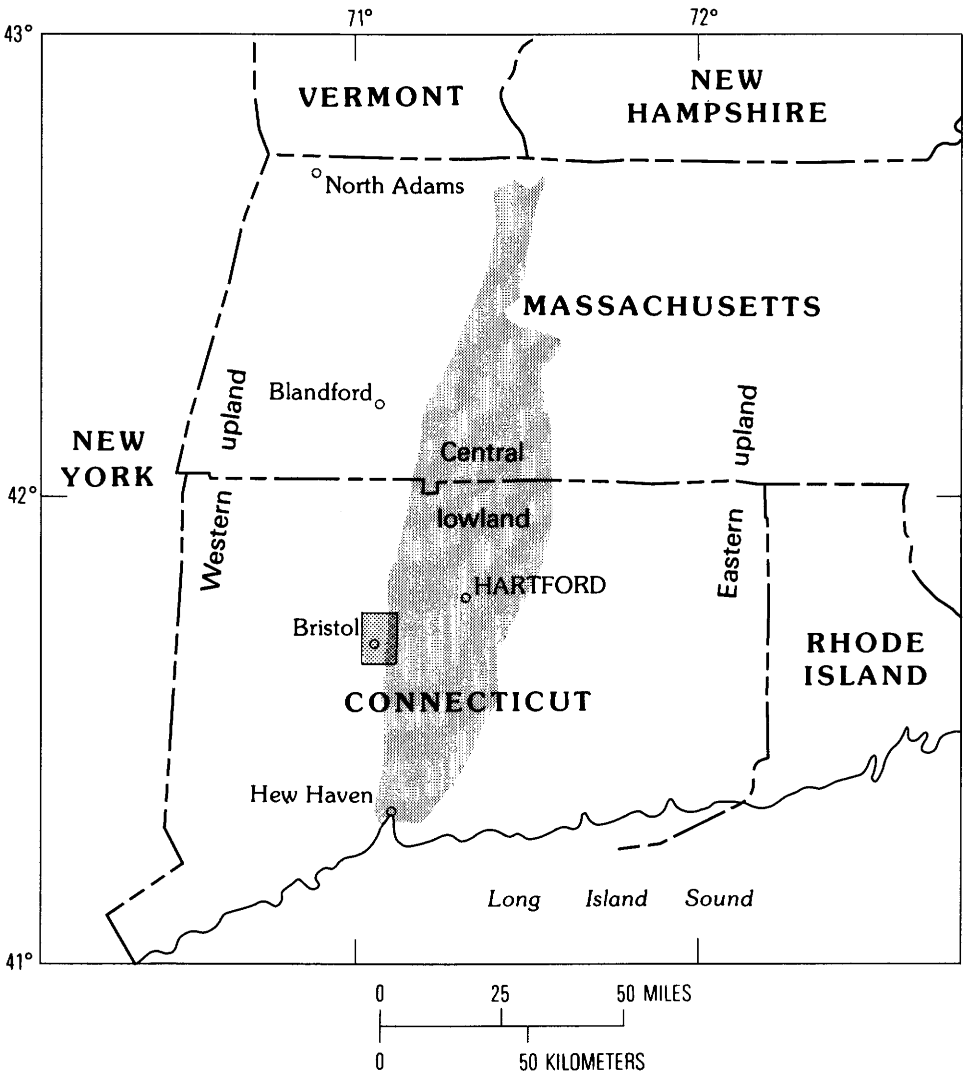


Figure 1. Index map of southwestern New England showing location of the Bristol quadrangle, the central lowland (also known as the Hartford Mesozoic basin), and the eastern and western uplands of Connecticut and Massachusetts.

in the correlation chart (fig. 2) in the present report. In this chart the stratigraphic names used are those of the author cited, but all units are correlated in the manner used by Hatch and Stanley (1973), and not necessarily in the manner chosen by the authors of the reports cited. To those correlation columns is added, as inferred by this author, a column containing the names of rock units of pre-Triassic age in the Bristol quadrangle, Connecticut, arranged to correlate with the chart of Hatch and Stanley (1973). These correlations are discussed briefly.

Taine Mountain Formation

In 1898, Emerson (p. 156–163) gave the name Savoy Schist to metasedimentary strata of inferred (p. 18) Early Silurian (now replaced by Ordovician) age in western Massachusetts that underlay his Hawley Schist and that overlay other units named by him. He described the Savoy Schist as in part a "chloritic sericite-schist * * *; flat, thin-fissile into plates 10–15 mm thick, with the micaceous minerals concentrated mostly on the lamination planes; * * *." Subsequently, in central Vermont, Richardson (1919, p. 138) gave the name Missisquoi Schists to sericite schist that he considered to be of Late Cambrian age; later (1924) he modified the name to Missisquoi Group.

The name Moretown Formation was introduced by Cady (1956) in north-central Vermont for quartz-albite-sericite-chlorite granulite characterized by fine, distinct, closely spaced stripes he called "pinstriping"—suggestive of the "thin-fissile * * * plates" described by Emerson. The granulite was correlated by Cady with the Missisquoi

Group of Richardson (1924) and was inferred to be of Ordovician age. Doll and others (1961) reduced the Missisquoi Group to formational status, the Moretown Formation to member status, and defined the member as the basal unit of three in the Missisquoi Formation. They also concluded that the member is of Middle Ordovician age; their reasoning was outlined and evaluated by Hatch and Stanley in 1973 (p. 16). Chidester and others (1967) subsequently returned the Moretown Member to formational status. The name Moretown Formation generally has been accepted since then for pinstriped metamorphic strata of inferred Middle Ordovician age in northern New England.

The name Hartland Schist was introduced by Gregory (1906, p. 96–100) for micaceous schist of inferred possible Late Ordovician age in western Connecticut. Since its introduction, the name has been used by various geologists in western Connecticut with some variation in opinion as to the geologic age of the rock. Five subunits are now recognized (Gates and Martin, 1976) and designated from the base upward by Roman numerals. They (Gates and Martin, p. 316) correlated Hartland unit I with the Taine Mountain Formation of Stanley (1964), a correlation agreed to by Stanley and Hatch (1976, p. 355).

Stanley (1964) and Simpson (this report), while mapping independently in the Collinsville quadrangle and the adjacent Bristol quadrangle, respectively, each identified within the Bristol Dome a sequence of three similar but distinctly separable stratigraphic units that are pinstriped. Logically the units belong to a single formation, but the lack of detailed field studies did not permit direct correlation with existing formations in southeastern Vermont (Doll and others, 1961) or in south-central Vermont (Skehan, 1961) where the name Moretown had been used. Stanley (1964, p. 17) therefore designated the three subunits as members of his Taine Mountain Formation of possible Precambrian(?) to Cambrian age (p. 43–48). The name Taine Mountain Formation is adopted formally here. Stanley (1964, p. 17) and Simpson agreed in the field upon names for each of the three members: Wildcat Member (basal), Scranton Mountain Member (middle)—whose type localities are in the Collinsville quadrangle—and Whigville Member (upper), whose type locality is in the Bristol quadrangle. These three names also are adopted here. Because of the pinstriping the Taine Mountain Formation is tentatively correlated with the Moretown Formation; thus, the inferred age of the Taine Mountain is Middle Ordovician.

Wildcat Member.—The name Wildcat Member of the Taine Mountain Formation, of possible Precambrian (Proterozoic) to Cambrian(?) age, originally was assigned by Stanley (1964, p. 17–20) to a basal pinstriped gneiss subunit in the southern part of the Collinsville quadrangle; it was named for exposures on Wildcat Mountain. The member as mapped in the Bristol quadrangle is directly traceable into, and is equal to, Stanley's member. The type locality of the member, its boundaries, and its lithologic characteristics remain the same as those described by Stanley.

Scranton Mountain Member.—The name Scranton Mountain Member of the Taine Mountain Formation, of possible Precambrian (Proterozoic) to Cambrian(?) age, originally was used by Stanley (1964, p. 17–21) to designate a middle pinstriped gneiss subunit overlying his Wildcat Member of the Taine Mountain Formation in the southern part of the Collinsville quadrangle, where this member's name is taken from exposures on Scranton Mountain. As it is mapped in the Bristol quadrangle, the member is directly traceable into, and is equal to, Stanley's member. The type locality of the member, its boundaries, and its lithologic characteristics remain the same as those described by Stanley.

Whigville Member.—The name Whigville Member of the Taine Mountain Formation, of possible Precambrian (Proterozoic) to Cambrian(?) age, was published first by Stanley (1964, p. 17, 21), for a pinstriped gneiss subunit overlying his Scranton Mountain Member of the Taine Mountain Formation. He designated no type locality for the member, as better exposures are located in the Bristol quadrangle.

The unit is a plagioclase-quartz gneiss marked by distinctive thin layering (pinstriping) of muscovite and biotite. It is well exposed in the type section, located on a hillside about 530 ft high and situated 2,000 ft south-southwest of the road junction in the village of Whigville, for which it is named, in the north-central part of the Bristol quadrangle. The type locality is identified on the geologic map. Apparent variation of thickness of the formation probably was caused by intense folding; an average thickness is estimated at 3,000 ft. The Whigville Member, as mapped by Stanley in the adjacent Collinsville quadrangle, is directly traceable into, and is equal to, the member as mapped in the present report.

Bristol Gneiss

The name "Bristol Granite-gneiss" was given by Rice and Gregory (1906, p. 104) to metamorphic rocks that they believed to be of granitic origin and that are exposed in the vicinity of Bristol, Conn. The name may have been modified from Percival's (1842) use of the name "Bristol granitic basin" for that area. In 1956, Rodgers and others modified the rock name to Bristol Gneiss.

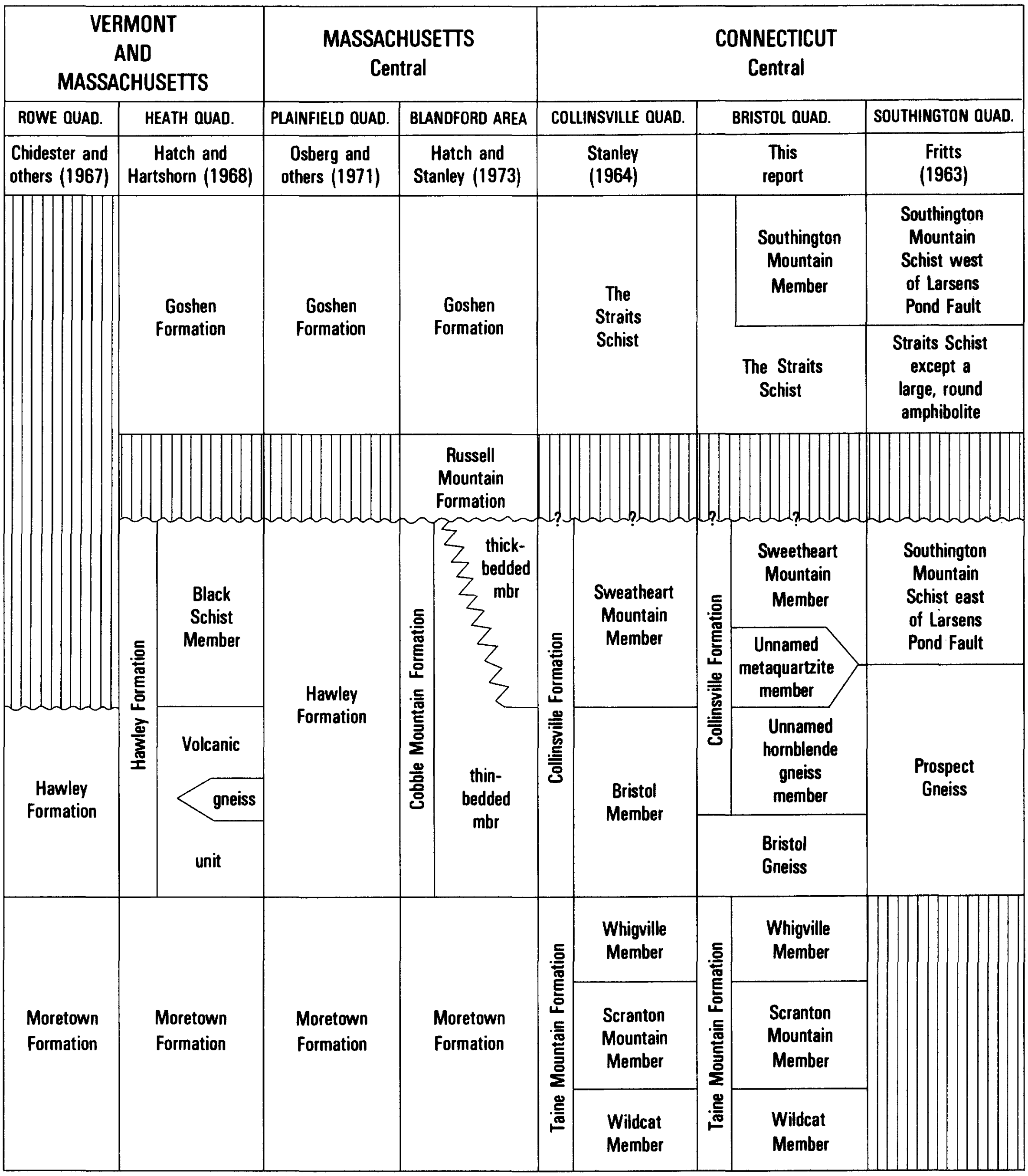
Stanley (1964) concluded that the "Collinsville Formation consisted of two named members; with the prior concurrence of this author he informally called (p. 23) the lower subunit the Bristol Member because of its lithologic similarity to gneiss exposed in the vicinity of Bristol. Stanley described his Bristol Member as marked by "alternating layers rich in light or in dark minerals" or by "thin,

AREA AND REFERENCE / SYSTEM AND SERIES		MASSACHUSETTS Central-Western	VERMONT Central		VERMONT North-central	VERMONT South-central	VERMONT South-central
		Emerson (1898)	Richardson (1919, 1924)	Currier and Jahns (1941)	Cady (1956)	Doll and others (1961)	Skehan (1961)
DEVONIAN ? SILURIAN	Lower ? Upper	Goshen Schist	Memphramagog Slates	Northfield Formation	Northfield Slate	Northfield Formation	Northfield Slate
SILURIAN	Middle			Shaw Mountain Formation	Shaw Mountain Formation	Shaw Mountain Formation	
ORDOVICIAN	Middle	Hawley Schist	Missisquoi Schists (1919) or Group (1924)	Cram Hill Formation		Missisquoi Formation: Carbonaceous Schist Member	Cram Hill Formation
ORDOVICIAN	Middle	Hawley Schist	Missisquoi Schists (1919) or Group (1924)	(unnamed schists)		Missisquoi Formation: Barnard Volcanic Member	Barnard Gneiss Member
ORDOVICIAN	Middle	Savoy Schist	Missisquoi Schists (1919) or Group (1924)	(unnamed schists)	Missisquoi Group: Moretown Formation	Missisquoi Formation: Moretown Member	Moretown Formation

Figure 2. Correlation chart for selected metamorphosed stratified rock units in western and southern New England. Formal and descriptive names used are those of the authors cited, but they are arranged in

discontinuous folia [sic] rich in dark minerals evenly distributed through the rock." He included (p. 23–24) in his Bristol Member as its upper part a zone characterized by garnet-rich coticule, epidote-bearing amphibolite lenses and layers enclosed by hornblende-plagioclase, or by biotite-plagioclase gneiss. He made no reference by name to Moretown-like pinstriping; but from the lithology described the unit may be correlated with the Taine Mountain Formation.

Stanley's name Bristol Member of the Collinsville Formation is here raised in rank, revised, and adopted as the Bristol Gneiss of inferred Middle Ordovician age. The name is restricted to rock composed mainly of foliae of plagioclase and quartz that alternate with foliae of muscovite, biotite, and chlorite. The garnet- and epidote-bearing amphibolite and hornblende gneiss that constitute the upper part of Stanley's Bristol member are here



the sequence of the present report. Thus, the geologic age correlations shown in this chart may differ from the geologic age correlations made by the various authors. Chart mainly from Hatch and Stanley (1973, pl. 2).

excluded and are reassigned to the overlying unnamed hornblende gneiss member of the Collinsville Formation.

The Bristol Gneiss as stratigraphically restricted here is composed of plagioclase-quartz gneiss characterized by foliae of muscovite or biotite, or locally chlorite, and contains scattered small garnets and large pods of amphibolite. It is exposed in and near the city of Bristol and is particularly well displayed in the type locality, which is the Penn Central Railroad (formerly the New York, New Haven, and Hartford R.R.) cut on the south side of St. Thomas Cemetery near the center of the quadrangle. This locality is identified on the geologic map. Apparent variation in the thickness of the member is thought to be due to locally intense folding; available data suggest that the average thickness may be about 2,000 ft. The lower part of the unit as mapped by Stanley in the adjacent Collinsville quadrangle is directly traceable into, and is equal to, the member as it is mapped in the Bristol quadrangle.

The Bristol Gneiss locally is marked strikingly by pinstriping that generally consists of laminae of biotite, muscovite, and some chlorite interlayered with granitoid plagioclase and quartz. The micaceous foliae are as much as 2 mm (millimeter) thick, and the plagioclase-quartz laminae are as much as 5 mm thick. Elsewhere, as on the west edge of urban Bristol, granitoid rock of plagioclase and quartz is more massive and laminae are fewer, thinner, and discontinuous. Because of the laminae the rock-stratigraphic unit may be correlated with the Moretown Formation of inferred Middle Ordovician age in central Massachusetts. If the correlation is correct, the Bristol Gneiss would constitute a fourth member of Stanley's Taine Mountain Formation. However, the Bristol Gneiss is so different lithologically and texturally that its use as a key bed in mapping the metamorphic sequence in the Bristol area warrants its formational status.

Collinsville Formation

In 1898 Emerson (p. 163–175) assigned the name Hawley Schist to metamorphic rock of sedimentary and volcanic origin and inferred a middle Ordovician age for it in western Massachusetts. Emerson distinguished this unit by its "general distribution of hornblende" from his Savoy Schist below and fιom his Goshen Schist above. In central Vermont, Richardson (1919, p. 138) gave the name Missisquoi Schists to certain sericite schists (then a possible correlative of the Savoy Schist of Emerson, 1898); in 1924 Richardson modified that name to Missisquoi Group, and in 1927 (p. 143) identified an unnamed hornblende schist as the uppermost formation of the group. Subsequently, Currier and Jahns (1941), also in central Vermont, defined the Cram Hill Formation of probable Middle Ordovician age as the equivalent of the upper part of Richardson's "Missisquoi." A middle unit of that group later was identified by Doll and others (1961) as their "Barnard volcanic member" of Richardson's "Missisquoi." Since then, the "Barnard volcanic member" and the overlying Cram Hill unit or their equivalents have constituted, either individually or together, the Hawley Formation of probable Middle Ordovician age for most authors (Chidester and others, 1967; Hatch, 1967; Hatch and Hartshorn, 1968; Osberg and others, 1971). Hatch (1967) redefined the Hawley as all rocks between the Moretown Formation and the Goshen Formation.

Stanley in 1964 (p. 22), with the concurrence of Simpson (Stanley, 1964, p. 23), took the name Collinsville Granite-gneiss as used by Rice and Gregory (1906, p. 105–107) and modified it to the Collinsville Formation for certain rocks of inferred Cambrian age (Stanley, 1964, fig. 6) "cropping out on the southern face of Sweetheart Mountain" (p. 22) in the Collinsville quadrangle. These rocks constitute metamorphic strata that are younger than those of Stanley's Taine Mountain Formation and older than those of The Straits Schist. The rocks are exposed in both the Bristol and Collinsville Domes. Stanley used the name of Collinsville in part because the lack of detailed field studies did not permit direct correlation of these strata with existing mapping in northern New England, and in part because the formation contains subunits that lithologically differ markedly from the rocks commonly associated with the older name of Bristol Granite-gneiss of Rice and Gregory (1906, p. 104).

In 1967 Stanley, working in the Blandford area of west-central Massachusetts, mapped a sequence of two units to which he assigned the temporary field names "4TB" and "5." The units subsequently were designated by Hatch and Stanley (1973, p. 9) as the unnamed lower, or thin-bedded member and the unnamed upper, or thick-bedded member, respectively, of their new Cobble Mountain Formation of inferred Middle Ordovician age. They concluded (p. 15) that the Cobble Mountain Formation "is, at least in large part, a facies equivalent of the Hawley Formation." They also stated (p. 25) that the unnamed upper member of the Cobble Mountain Formation is correlated with the uppermost unit, the Sweetheart Mountain Schist Member, of the Collinsville Formation.

Metamorphic strata in the Bristol quadrangle that lie between the Bristol Gneiss and The Straits Schist of this report are assigned to the Collinsville Formation as agreed upon earlier with Stanley (1964, p. 23). However, because of the work of Stanley (1967) and of Hatch and Stanley (1973), the formation is no longer considered to be of Precambrian or of pre-Triassic age but is now inferred to be of Middle Ordovician age and, at least in part, a correlative of the Hawley Formation in Massachusetts. Assignment to the Collinsville Formation is based in part on the similarity of lithologies and in part on the sequence of those lithologies. Together the strata constitute three members of distinctive character. The lowermost member is an unnamed amphibolite and hornblende gneiss overlain locally by an unnamed metaquartzite and by the Sweetheart Mountain Member.

Unnamed hornblende gneiss member.—Garnet-rich coticule, epidote-bearing lenses and layers of amphibolite, and hornblende gneiss formerly constituted the uppermost part of Stanley's (1964, p. 23) Bristol Member of the Collinsville Formation, of possible Precambrian or Cambrian(?) age. In the present report the amphibolite and hornblende gneiss are excluded from the Bristol Gneiss because they differ markedly in mineral composition and lack the characteristic foliae. The strata are reassigned here to constitute an unnamed hornblende gneiss member that directly overlies the Bristol Gneiss of this report. The member is best exposed on the ridge south of Hurley Hill at the east end of a roadcut just south of and approximately parallel to the Pequabuck River. The thickness of the member near the roadcut may be about 400 ft. The upper part of Stanley's (1964) Bristol Member of the Collinsville Formation is directly traceable into, and is equal to, this member of the Collinsville Formation in the Bristol quadrangle.

Unnamed metaquartzite member.—Locally, a thin metaquartzite unit directly overlies the unnamed hornblende gneiss member of the Collinsville Formation of inferred Middle Ordovician age. The unit is best exposed in the same roadcut as the hornblende gneiss member (see preceding discussion) and is mappable for a distance of about 2 mi along strike; its thickness probably averages about 100 ft. This informal member may be of little value in regional correlation because similar local metaquartzite units are found at various localities and in scattered horizons in the metamorphic sequence of southern New England. In the Bristol quadrangle it is tentatively assigned to constitute an unnamed middle member of the Collinsville Formation of inferred Middle Ordovician age.

Sweetheart Mountain Member.—The name Sweetheart Mountain Member of the Collinsville Formation, of possible Precambrian to Cambrian(?) age, was given by Stanley (1964, p. 27) to metamorphic strata that overlie his Bristol Member of the Collinsville Formation. The name of the unit was taken from a type locality on Sweetheart Mountain, in central Collinsville quadrangle. Stanley's name is adopted here as Sweetheart Mountain Member of the Collinsville Formation of inferred Middle Ordovician age. The stratigraphic unit to which the name is assigned constitutes the uppermost member of three belonging to that formation in the Bristol quadrangle and overlies the unnamed hornblende gneiss member or the unnamed metaquartzite member, whichever is locally present. The type locality and its lithologic characteristics remain the same as those described by Stanley (1964).

The correlation of the Sweetheart Mountain Member with the Hawley Formation of Hatch and Hartshorn (1968) depends upon (1) direct tracing of the member from the Bristol quadrangle into Stanley's member in the adjacent Collinsville quadrangle, (2) correlation of Stanley's member with the unnamed thick-bedded (upper) member of the Cobble Mountain Formation of Hatch and Stanley (1973, p. 25), and (3) whether or not that thick-bedded part of the Cobble Mountain Formation is a time-equivalent of the Hawley Formation in northern and central Massachusetts or at least that part of the Hawley presently exposed near Blandford, Mass. If the thick-bedded member is not time-equivalent to the Hawley, the member is younger and so is a correlative of the Goshen Formation. The two possibilities were proposed by Hatch and Stanley (1973, p. 15).

Perhaps the best time marker so far identified in rocks of the Hawley and Goshen Formations of western Massachusetts is an unconformity described by Hatch (1967, p. D14) and by Hatch and Stanley (1973, p. 13–14) and recognized at least as far south as the Blandford quadrangle. From their description, one can infer that it might mark a widespread erosion surface and that evidence of it might be found elsewhere in southern New England.

In the Bristol quadrangle no unconformity between the Sweetheart Mountain Member and the overlying strata of The Straits Schist has been identified. However, a basal facies of The Straits Schist that was observed locally suggests the possibility of such an erosion surface. The facies is described as part of that unit. Stanley (1964) did not recognize an unconformity at the same stratigraphic position in the Collinsville quadrangle, but did map "calc-silicate gneiss or granulite" in a position comparable to the basal facies in the Bristol quadrangle. Hatch and Stanley (1973, p. 24–25) considered it "lithically identical with and at the same stratigraphic horizon as the Russell Mountain Formation in the Blandford" area. In the Southington quadrangle Fritts (1963) drew an unconformity at the base of his Straits Schist.

If the inference of an erosion surface at the top of the Sweetheart Mountain Member in the Bristol quadrangle is valid, the surface could be presumed to correlate with the unconformity described by Hatch (1967) and Hatch and Stanley (1973). In that event, the unnamed thick-bedded (upper) member of the Cobble Mountain Formation is logically correlative in age with the upper part of the Hawley Formation and with the Sweetheart Mountain Member of the Collinsville Formation. If the presumption of correlation is not valid, then the thick-bedded member of the Cobble Mountain Formation must be younger than the Hawley or at least that part of the Hawley exposed near Blandford, Mass.

The Straits Schist

In 1898, Emerson (p. 177) gave the name Goshen Schist to metamorphic strata of inferred Late Silurian age in central western Massachusetts. In northern Vermont, Richardson (1908, p. 276–279) applied the name "Memphramagog slates" to a loosely constituted unit of inferred Ordovician age that included slate bodies known commercially as Montpelier and Northfield slates. In 1941, Currier and Jahns redefined Richardson's unit, renamed it the Northfield Slate, and tentatively considered it to be of Middle Ordovician age. Cady, in 1956, believed the Northfield Slate to be of possible Silurian age; Skehan, however, in 1961 considered the unit to be Silurian or Devonian in age from the work of Boucot and others (1958), but Doll and others (1961), although they accepted Skehan's age assignment, used the name Northfield Formation.

Subsequently, geologists (Hatch, 1967; Hatch and Hartshorn, 1968; Osberg and others, 1971; Hatch and

Stanley, 1973) working in and near Emerson's original area in Massachusetts readopted Emerson's original name, modifying it to Goshen Formation (Hatch, 1967) of Silurian and Devonian age. The formation is described (Hatch and Stanley, 1973, p. 16) as a mainly "thinly bedded, graded bedded unit of carbonaceous pelitic schist and micaceous quartzite." An unconformity marks the base of the formation (Hatch, 1967, p. D14; Hatch and Stanley, 1973, p. 13–14).

The work in northern New England summarized here was in progress when the metamorphic stratigraphy of western Connecticut began to attract significant interest among geologists in the late 1940's and early 1950's. The work in Connecticut was hampered by the lack of detailed studies in the area between Connecticut and northern New England, for dependable correlations between those localities were not feasible. Correlations mainly were attempted with the work of others nearby, and a proliferation of proposals resulted. Commonly the proposals were tentative as the stratigraphy was complicated, the structure complex, and the geologic age of field units was consistently indefinite and at best inferred. Undoubtedly the most significant advance in unraveling the geology of western Connecticut was the recognition by Rodgers and others (1959) of a lithologically distinctive stratigraphic unit of wide lateral extent.

The name "The Straits Schist Member of the Hartland Formation" and an age of possible Middle Ordovician or older was given by Rodgers and others (1959, p. 40) to metamorphic strata that are well exposed in a gorge that was formerly known as The Straits, and that is on Connecticut Route 63 just north of Bethany, Conn. They characterized the rock as a coarse to very coarse, commonly crumpled, muscovite schist with various minor minerals; "locally quartz (and feldspar) and mica dominate alternate layers" causing a more gneissic character in them. The Straits Schist was recognized by various geologists in western Connecticut, but inferences as to its correlation and age have differed greatly. Rodgers and others (1959, p. 33) correlated the Hartland Formation with Emerson's (1898) Hoosac Schist that Emerson considered to be of Early Silurian age. Subsequent authors (Cady, 1960; Doll and others, 1961) considered the Hoosac Formation to be of Early Cambrian(?) age. The Hartland Formation has been divided recently by various geologists (see Gates and Martin, 1976) into five Hartland units designated by Roman numerals from the basal unit upward. Gates and Martin (1976, p. 322) correlated Hartland unit II with The Straits Schist, but this is not agreed to by Stanley and Hatch (1976, p. 355).

Fritts (1963) raised The Straits Schist Member to formational rank, modified the name to "Straits Schist," and thought it to be of Cambrian(?) age. Stanley (1964, p. 28) preferred the original form of the name, "The Straits Schist," retained the formational rank, and reassigned it to the Hartland Group, a name both revived and raised in rank. He inferred the age of the group to be Cambrian following the reasoning of Rodgers and others (1959). In 1968, however, Stanley concluded, that "The Straits Schist" was in part equivalent to the Hawley Formation and in part to the Goshen Formation in central western Massachusetts. That conclusion implies his acceptance of a Late Silurian and Early Devonian age (Hatch, 1967; Hatch and Hartshorn, 1968).

In the Bristol quadrangle, a distinctive sequence of metamorphic strata younger than the Sweetheart Mountain Member of the Collinsville Formation is correlated with the Straits Schist of Fritts (1963) in the adjacent Southington quadrangle. The strata in the Bristol quadrangle consist mainly of rusty-weathering, medium- to coarse-grained, commonly crenulated, garnet-bearing, graphitic, muscovite-rich, plagioclase-quartz schist characterized by graded bedding. The unit is differentiated from the underlying Sweetheart Mountain Member of the Collinsville Formation by the smaller size of the garnets present, the presence of graded bedding, the lesser amounts of both biotite and plagioclase, the common presence of crenulation, and, most obviously, the presence of graphite dusting the muscovite flakes in The Straits Schist. The correlation with Fritts' (1963) unit is based on those same characteristics. His name, Straits Schist, is modified here to include the capitalized article "The" originally used by Rodgers and others (1959). Fritts (1963) inferred a Cambrian(?) age for his unit, but here the age is tentatively inferred to be Silurian or Devonian, and the unit is tentatively correlated with the Goshen Formation of Hatch and Hartshorn (1968) and of Hatch and Stanley (1973). This correlation is based on the lithologic similarity and the relation to a possible unconformity at the base of the two units.

The basal contact of The Straits Schist in that part of the Bristol quadrangle south of the Pequabuck River and just west of Lake Avenue is marked by a lithologic facies that has a greater feldspar content than does the remainder of the unit. Much of the feldspar appears as rounded clots. This basal part may represent a coarser, probably more feldspar-rich, facies of the original sediment; the clots may represent feldspathic pebbles. Such a facies may represent a basal sandstone on an unconformity; if so, it supports the correlation of The Straits Schist as a correlative of the Goshen Formation, for Hatch (1967, p. D14) referred to "a major regional unconformity" at the base of the Goshen, and Hatch and Stanley (1973, p. 13) stated that in the Blandford quadrangle, central western Massachusetts, Goshen strata "rest on successively older units." In the Collinsville quadrangle Stanley locally mapped (1964) calc-silicate-quartzite lenses in the upper part of the Collinsville Formation (1968); they have been correlated (Hatch and Stanley, 1973) with the Russell Mountain Formation in western Massachusetts (Hatch and others 1970; Hatch and Stanley, 1973). Fritts (1963) showed an unconformity at the base of the Straits Schist in the Southington quadrangle.

Southington Mountain Member.—In 1963, Fritts gave the name Southington Mountain Schist to metamorphosed strata of Cambrian(?) and Ordovician(?) age in the northern part of the adjacent Southington quadrangle, where they are well exposed on Southington Mountain. The strata, which were described as the upper part of The Straits Schist Member of the Hartland Formation by Rodgers and others (1959), consist of alternating bands of quartz-feldspar granulite and of graphitic, muscovite-biotite schist that are characterized by distinct, widespread, graded bedding and locally by much staurolite.

These rocks are directly traceable into the southern part of the Bristol quadrangle, where strata that are lithologically the same are widely exposed. These rocks are therefore assigned to the same unit, which is here revised as the Southington Mountain Member of The Straits Schist and may correlate with the Goshen Formation (Hatch and Hartshorn, 1968) of the Heath quadrangle, Massachusetts-Vermont, of Middle Silurian to Early Devonian age. The correlation is based on the graded bedding and the stratigraphic sequence, including the possible unconformity at the base of the underlying Straits Schist. Gates and Martin (1976, p. 325) correlated the Southington Mountain Schist with their Hartland unit III, but this was not agreed to by Stanley and Hatch (1976, p. 355).

New Haven Arkose

The eastern one-third of the Bristol quadrangle lies within the central lowland of Connecticut, known geologically as the Hartford Mesozoic basin (see fig. 1). Bedrock consists of the New Haven Arkose of the Newark Supergroup (Upper Triassic), which was named and defined by Krynine in 1950 for exposures in New Haven County, Conn. In the Bristol quadrangle the strata are poorly exposed. They probably consist mainly of massive- to well-bedded, coarse- to fine-grained reddish-brown arkosic sandstone and conglomerate with iron-oxide cement. The beds dip downward to the east and southeast at angles as great as 20 degrees.

The western margin of the lowland is marked by a prominent fault-line scarp, with the fault downthrown on the east. In places along the fault the normal rock color has been altered by ground water leaching the iron-oxide cement. This alteration turns the rock to a distinctive pink to light-orange. Leaching is best exposed on the west side of Jerome Avenue about 0.5 mi north-northeast of Hurley Hill.

INTRUSIVE ROCK UNITS

Minor amounts of six intrusive rock units are present in the Bristol quadrangle. Two kinds of pegmatites are exposed at many localities in the metamorphic rocks of the upland; serpentinite and granite are each found at two places, and an amphibolite at one. In addition basalt, which may be intrusive, is present at one locality within the Triassic rocks of the lowland.

Pegmatite is widely distributed and is present in all metamorphic rock units except the unnamed metaquartzite. However, pegmatite is noted predominantly in rocks of inferred Middle Ordovician age. Most pegmatite bodies constitute pods or dikes. The pods are as much as 20 ft across and 75 ft long; the dikes are generally less than 12 ft across and are of indeterminate length. Pegmatite pods are composed mainly of quartz and twinned, white plagioclase feldspar. Several small pegmatite dikes are composed chiefly of quartz and pink orthoclase feldspar. At one locality, a tabular orthoclase pegmatite about 8 inches thick was observed to crosscut diagonally another dike of similar composition about 1.5 feet thick.

Crystals of black tourmaline as much as 2 mm in diameter and about 1.2 cm (centimeter) long are present in a few pods. In rare cases the number of crystals increases as the pod margin is approached.

Two serpentinite bodies in the Bristol quadrangle are enclosed by the Sweetheart Mountain Member of the Collinsville Formation. The body near the northwest corner of the map area (pl. 1) must postdate the original sedimentary structures that enclose it and may have been intruded no later than the metamorphism that altered those sediments. If the internal gneissic structure of the body was caused by flowage during emplacement, then it may be younger than the metamorphism. No definitive information was observed in the other serpentinite.

Amphibolite constitutes a single dike about 500 ft east of Bristol Reservoir No. 1. The rock may represent a mafic intrusive nearly as old as the enclosing sediments that became the Bristol Gneiss, or as young as pre-late metamorphic age.

Gray granite forms two narrow dikes. The rock in both bears a striking resemblance to the intrusive Thomaston Granite (Cassie, 1965), exposed in the adjacent Thomaston quadrangle. Both dikes are nonmetamorphosed and thus are presumed to postdate the regional metamorphism. The maximum observed thickness of the granite dikes is 90 cm.

Three small closely spaced exposures of basalt at a single locality on the southwest flank of Campground Hill in the east-central part of the Bristol quadrangle lack visible contacts with the surrounding New Haven Arkose. The rock is composed of massive basalt and might represent a large boulder nearly covered by glacial deposits; it also might represent a basalt dike. If the rock is a dike, it may correlate with rock mapped as Buttress Diabase in the adjacent Southington quadrangle (Fritts, 1963), as dolerite in the adjacent Collinsville quadrangle (Stanley, 1964), as Buttress Diabase in the contiguous Avon quadrangle (Schnabel, 1960), and as Buttress Dolerite on the bedrock geological map of Connecticut (Rodgers, 1985). The age of the Buttress Diabase is Early Jurassic based on potassium-argon age deterninations by Sutter (1985).

METAMORPHISM AND DEFORMATION

Most rocks of the Bristol Dome owe their present character to metamorphism that altered original rocks, minerals, and textures to those now apparent. Because the existing rocks contain evidence of both graded bedding and cross-bedding and constitute a sequence of stratigraphic units, the original rocks probably were mainly of sedimentary origin, perhaps derived in part from reworked volcanic material and possibly in part from some interlayered volcanic deposits.

Little evidence has been obtained from the rocks of the Bristol quadrangle regarding the geologic age or ages of the metamorphism and crustal deformation that affected them. The deformation and metamorphism must postdate deposition of the youngest domed and metamorphosed unit, the Southington Mountain Member of The Straits Schist. If the inferred correlation of that schist with the Goshen Formation of Silurian and Devonian age is correct, then the doming and perhaps the regional metamorphism could have occurred during the Acadian orogeny at or near the end of Early Devonian time. Evidence of deformation or metamorphism during the Taconic orogeny in Late Ordovician time was not observed.

The grade of metamorphism attained by rocks of the Bristol quadrangle is indicated by the presence of kyanite and staurolite, mainly in the Southington Mountain Member of The Straits Schist and locally in the Whigville Member of the Taine Mountain Formation.

In Late Triassic and Jurassic time, normal faulting broke the younger sedimentary rocks into great blocks that were tilted downward to the east.

STRUCTURAL GEOLOGY

Faults.—The prominent topographic boundary between the metamorphic rocks of the Bristol Dome and the sedimentary New Haven Arkose of the adjacent lowland is a faultline scarp that reflects a normal fault. The fault formerly was exposed in a long-abandoned copper mine at the southern end of Mine Mountain. This exposure was described by early geologists, whose works were summarized by Bateman (1923), as a normal fault dipping 70° east, with a vertical displacement of 360 ft; adjacent to the fault the sedimentary strata show drag. No other exposure of the fault is known in the Bristol quadrangle.

In 1960, Martin F. Kane (U.S. Geological Survey, written commun.) made two east-west reconnaissance traverses with a gravimeter across the quadrangle—one along and at the latitude of Shrub and Stevens Streets, and another adjacent to the Pequabuck River. Stations were spaced at about 1,000- to 3,000-ft intervals on both traverses. On the basis of assumed average rock densities of 2.70 for crystalline rocks and 2.55 for arkosic strata, and a profile difference of about 1 milligal where each of the traverses crosses the inferred location of the boundary fault, Kane calculated vertical displacement along the boundary fault to be about 500 ft.

The position of the boundary fault on the geologic map is inferred mainly from the topography, from the two gravimeter profiles, and from its inferred position in the adjacent Southington and Collinsville quadrangles. Southward from the Pequabuck River the fault may follow the foot of the topographic scarp more closely than is shown.

Two other faults of significant observable displacement are known or inferred in the quadrangle. One trends north-northeast between Hurley Hill and Federal Hill and is clearly indicated by the stratigraphic displacement it caused. The other trends north from Cedar Swamp Pond; it is inferred from the pattern of lithologies in available exposures, but the evidence is not clear.

Several faults of indeterminate throw and without topographic expression were observed in manmade exposures. The faults are marked by characteristics that include slickensides, clayey fault gouge, drag of foliation, and both fine and coarse brecciation. Together, they suggest two sets of faults—one trending northwestward, the other north-northeastward. On the west flank of Hurley Hill, brecciated rock recemented by quartz veinlets and containing flecks of copper minerals is additional evidence of faulting.

Bristol Dome.—Martin F. Kane (written commun., 1960) measured a drop of 3.5 milligals on the gravimeter traverse he made in Bristol along the Pequabuck River. On the basis of an assumed average rock density of 2.70 for the metamorphic rocks, he concluded that a mass of lower density rock underlies the structural dome at a depth of 1,500–2,000 ft.

Lineaments.—Northeast-trending topographic lineaments along the east side of the quadrangle are in part extrapolated from faults mapped in the adjacent New Britain quadrangle (Simpson, 1966) and in part inferred from the topography of the Bristol quadrangle. The lineaments may extend southwestward to the north-trending boundary fault, but, if so, that extension is hidden beneath the thick glacial deposits that lie west of Redstone Hill. The lineaments shown may represent faults of small displacement; others of the set that are not recognized may lie to the north.

The offset of the amphibolite rock unit mapped at the south end of Mine Mountain may be due to faulting. Extension of an inferred fault to the northwest is suggested by the topographic lineament of the northwest branch of

Wildcat Brook; this valley extends into the adjacent Collinsville quadrangle, where it is buried beneath thick surficial deposits.

Distinct topographic lineaments that constitute three major sets plus a minor set are apparent on aerial photographs of the southwest part of the quadrangle, and are almost as distinct on the topographic base map. From their orientation relative to the mapped syncline separating the Bristol Dome from the Waterbury Dome to the south-southwest (Fritts, 1963), and from foliation attitudes, these lineaments are thought to represent faults of small displacement, or joints. Three major sets of lineaments are also distinct in the northwest part of the quadrangle, but they are less clear on the topographic base.

ECONOMIC GEOLOGY

An abandoned copper mine is at the south end of Mine Mountain. Reportedly (Norton, 1907), this mine was opened sometime in the early 1800's and closed in 1895, having yielded a profit as great as $2,000 a month at the time of a temporary closing in 1857. The orebody (Bateman, 1923) followed a normal-fault contact between the metamorphic rocks and the younger sedimentary strata. The principal ore minerals were chalcocite and bornite, with subordinate chalcopyrite and small amounts of covellite, pyrite, sphalerite, galena, and barite; quartz and calcite were also present in considerable amounts. The ore minerals occurred in veins as much as 8 in. thick and as disseminated veinlets and blebs in the sedimentary strata. Bateman stated that the minerals were deposited by solutions at slightly less than 91 °C that bleached the strata by leaching from them the ferrous oxide that causes their red color. Bateman also inferred that the solutions were derived from basaltic magmas that formed the nearby dikes and lava flows. An alternative source may have been the granitic magma that yielded either the gray granite or the pink pegmatite in the quadrangle.

Two other apparently unsuccessful attempts to mine copper ore were located farther south. One (Peck, 1932, p. 140–141) included the construction of one or more shafts and some lateral drifts about 1850 "between Bradley Street and Belridge Road, near Brewster Road." The other (W. R. Roseen, oral commun., June 1961) was located across the Pequabuck River from the south end of Hurley Hill but on the north side of Mountain Road and about 500 ft west of King Street, behind the Roseen home. He described "a shaft, now filled," and showed ore samples containing wolframite, pyromorphite, galena, sphalerite, and wulfenite.

Pegmatite.—No pegmatite has been quarried for production of feldspar, quartz, or mica. The size of the pegmatite pods and lenses, none more than about 400 ft long, suggests that such an operation is not presently economic.

Cut stone.—Widely scattered small quarries have been opened in each of the principal types of metamorphic rock exposed in the Bristol quadrangle; generally, only one quarry has been opened in each type. Some of the rock quarried appears to have been used as foundation stone for farm buildings in the vicinity. Most of the quarries, however, apparently were opened to supply trimmed foundation blocks used in the construction of the former Fuller Barnes residence.

Other resources.—No other rock or mineral resources of present economic character were observed in the bedrock.

ENGINEERING GEOLOGY

All bedrock units in the Bristol quadrangle are composed of strong rocks capable of in-place support of great loads. Their support can fail by rocksliding (landsliding) in some circumstances. The potential for such failure is relative, and varies from moderate to negligible. It depends mainly on the orientation of faults, fractures, mineral layering, and the land surface in relation to the orientation and design of excavations.

Slope Stability

Excavations with vertical faces or slopes cut more or less perpendicular to the trend (strike) of the layering (foliation) of minerals will be most stable and probably will present only minor raveling of freshly blasted faces. Those faces or slopes cut nearly parallel to the strike of mineral layering can be subject to rocksliding along fractures or mineral-layering planes that slope downward into an excavation. If the fractures or mineral layering are oriented downward, away from a cut face or slope, there is no hazard other than minor raveling.

Fractures and mineral layering are most likely to be a cause of rocksliding in The Straits Schist and its Southington Mountain Member, less so in the Sweetheart Mountain Member of the Collinsville Formation and the Wildcat and Scranton Mountain Members of the Taine Mountain Formation—and even less so in the Bristol Gneiss, and least so in the hornblende gneiss and metaquartzite member of the Collinsville.

Excavatability

New Haven Arkose.—Thin beds of sandstone and, rarely, of conglomerate may be rippable locally with heavy equipment, especially where near the ground surface. Rare thin beds of siltstone and shale are rippable but do not constitute thick-enough parts of the geologic sequence, or occur sufficiently frequently in interlayered sequences, to be of much benefit. Massive beds of sandstone and conglomerate undoubtedly will require blasting and should be shielded with blasting mats. Debris will tend to be irregular and angular in form. Bleached sandstone and conglomerate like that exposed in Page Park may occur elsewhere along the boundary fault. This sandstone is somewhat weaker than rock of normal red color and so may be more easily ripped and may yield slightly larger quantities of debris per blast.

Wildcat, Scranton Mountain, and Whigville Members of the Taine Mountain Formation and the Sweetheart Mountain Member of the Collinsville Formation.—These rock units probably will require blasting and will yield somewhat slabby debris; the use of blasting mats is advised.

Bristol Gneiss, and the hornblende gneiss and metaquartzite members of the Collinsville Formation.—These rocks are relatively massive as compared with the other rock units and cannot be ripped. Blasting will be necessary, and the debris will be somewhat irregular in form and angular; the use of blasting mats is advised. Some unstemmed shotholes in the hornblende gneiss member are reported to have "rifled out" without rock displacement.

Drillability

No major problem should be presented by any of the bedrock units; however, The Straits Schist and its Southington Mountain Member tend to clog drill bits.

A fault may constitute a construction problem if it slopes downward into an excavation in such a manner that the rock above the fault can slide along the fault surface into the excavation.

No seismic activity along any of the mapped faults is know to have occurred in so long a time that all faults in the quadrangle are considered to be inactive.

Zones of broken and pulverized rock along a fault may yield small to moderate flows of ground water when the fault is intersected by an excavation. The presence of ground water increases the potential for rocksliding into an excavation.

Faults and Faulting

Faults are mapped on the basis of visible geologic evidence of relative displacement of rock on the two sides of the fault trace; other faults may be present for which geologic evidence was not visible at the ground surface. Unknown faults will be similar in character to known faults.

The attitudes of significant faults are unknown, with the exception of the fault along the east side of Mine Mountain, which is known from subsurface information to dip 70° east in the vicinity of the abandoned copper mine.

That fault is represented by a wide zone of broken and pulverized rock that is known to be more or less cemented by subsequent mineralization at that locality. Other mapped faults may be marked by similar zones that are 1–5 ft thick, but they are not known to be mineralized. Minor faults of indeterminate displacement visible in some roadcuts are marked by similar zones less than 4 in. wide that lack mineralization.

None of the faults is known to show evidence at or near the ground surface of movement at least once within the past 35,000 years or movement of recurring nature within the past 5,000,000 years.

REFERENCES CITED

Bateman, A.M., 1923, Primary chalcocite; Bristol copper mine, Connecticut: Economic Geology, v. 18, no. 2, p. 122–166.

Boucot, A.J., MacDonald, G.J.F., Milton, C., and Thompson, J.B., Jr., 1958, Metamorphosed middle Paleozoic fossils from central Massachusetts, eastern Vermont, and western New Hampshire: Geological Society of America Bulletin, v. 69, p. 855–864.

Cady, W.M., 1956, Bedrock geology of the Montpelier quadrangle, Vermont: U.S. Geological Survey Geologic Quadrangle Map GQ–79, scale 1:62,500.

______1960, Stratigraphic and geotectonic relationships in northern Vermont and southern Quebec: Geological Society of America Bulletin, v. 57, p. 125–159.

Cassie, R.M., 1965, The evolution of a domal granitic gneiss and its relation to the geology of the Thomaston quadrangle, Connecticut: Wisconsin University Ph. D. thesis, 109 p., scale 1:24,000.

Chidester, A.H., Hatch, N.L., Jr., Osberg, P.H., Norton, S.A., and Hartshorn, J.H., 1967, Geologic map of the Rowe quadrangle, Franklin and Berkshire Counties, Massachusetts, and Bennington and Windham Counties, Vermont: U.S. Geological Survey Geologic Quadrangle Map GQ–642, scale 1:24,000.

Cornet, Bruce, 1977, The palynostratigraphy and age of the Newark Supergroup: University Park, Pa., Pennsylvania State University Ph.D. Thesis, 504 p.

Currier, L.W., and Jahns, R.H., 1941, Ordovician stratigraphy of central Vermont: Geological Society of America Bulletin, v. 52, p. 1487–1512.

Doll, C.G., Cady, W.M., Thompson, J.B., Jr., and Billings, M.P., 1961, Centennial geologic map of Vermont: Vermont Geological Survey, scale 1:250,000.

Emerson, B.K., 1898, Geology of old Hampshire County, Massachusetts, comprising Franklin, Hampshire, and Hampden Counties: U.S. Geological Survey Monograph 29, 790 p.

Fritts, C.E., 1963, Bedrock geology of the Southington quadrangle, Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ–200, scale 1:24,000.

Gates, R.M., and Martin, C.W., 1976, Pre-Devonian stratigraphy of the central section of the western Connecticut highland, *in* Page, L.R., ed., Contributions to the stratigraphy of New England: Geological Society of America Memoir 148, p. 301–336.

Gregory, H.E., 1906, The crystalline rocks [of Connecticut], *in* Rice, W. N., and Gregory, H.N., Manual of the geology of Connecticut: Connecticut Geological and Natural History Survey Bulletin 6, p. 39–156.
Hatch, N.L., Jr., 1967, Redefinition of the Hawley and Goshen Schists in western Massachusetts: U.S. Geological Survey Bulletin 1254–D, 16 p.
Hatch, N.L., Jr., and Hartshorn, J.H., 1968, Geologic map of the Heath quadrangle, Massachusetts and Vermont: U.S. Geological Survey Geologic Quadrangle Map GQ–735, scale 1:24,000.
Hatch, N.L., Jr., and Stanley, R.S., 1973, Some suggested stratigraphic relations in part of southwestern New England: U.S. Geological Survey Bulletin 1380, 83 p. [1974]
Hatch, N.L., Jr., Stanley, R.S., and Clark, S.F., Jr., 1970, The Russell Mountain Formation, a new stratigraphic unit in western Massachusetts: U.S. Geological Survey Bulletin 1324–B, 10 p.
Krynine, P.D., 1950, Petrology, stratigraphy, and origin of the Triassic sedimentary rocks of Connecticut: Connecticut Geological and Natural History Survey Bulletin 73, 247 p.
Norton, M.L., 1907, Copper mines in Bristol, *in* Bristol, Connecticut, which includes Forestville: Hartford, Conn., Smith, Smith, and Dates, p. 440–442. [Sterling Memorial Library, Yale University, Catalog No. Ci 71.308]
Osberg, P.H., Hatch, N.L., Jr., and Norton, S.A., 1971, Geologic map of the Plainfield quadrangle, Franklin, Hampshire, and Berkshire Counties, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–877, scale 1:24,000.
Peck, Epaphroditus, 1932, A history of Bristol, Connecticut: Hartford, Conn., Lewis Street Bookshop. [Available at the community library, Bristol, Conn.]
Percival, J.G., 1842, Report on the geology of the State of Connecticut: New Haven, Conn., Osborn and Baldwin, 495 p.
Rice, W.N., and Gregory, H.N., 1906, Manual of the geology of Connecticut: Connecticut Geological and Natural History Survey Bulletin 6, 273 p.
Richardson, C.H., 1908, The geology of Newport, Troy, and Coventry: Report of the State Geologist on the Mineral Industries and Geology of Certain Areas of Vermont, 1907–1908, 6th, p. 265–291.
______1919, The terranes of Roxbury, Vermont: Report of the State Geologist on the Mineral Industries and Geology of Vermont, 1917–1918, 11th, p. 120–140.
______[1924], The terranes of Bethel, Vermont: Report of the State Geologist on the Mineral Industries and Geology of Vermont, 1923–1924, 14th, p. 77–103.
______1927, Geology and petrography of Barnard, Pomfret, and Woodstock, Vermont: Report of the State Geologist on the Mineral Industries and Geology of Vermont, 1925–1926, 15th, p. 127–159.
Rodgers, John, 1985, Bedrock geological map of Connecticut: Connecticut Geological and Natural History Survey, scale 1:125,000.
Rodgers, John, Gates, R.M., Cameron, E.N., and Ross, R.J., Jr., 1956, A preliminary geological map of Connecticut, 1956: Connecticut Geological and Natural History Survey Bulletin 84, 64 p.
Rodgers, John, Gates, R.M., and Rosenfeld, J.L., 1959, Explanatory text for preliminary geological map of Connecticut, 1956: Connecticut Geological and Natural History Survey Bulletin 84, 64 p.
Schnabel, R.W., 1960, Bedrock geology of the Avon quadrangle, Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ–134.
Simpson, H.E., 1961, Surficial geology of the Bristol quadrangle, Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ–145, scale 1:24,000.
______1966, Bedrock geologic map of the New Britain quadrangle, Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ–494, scale 1:24,000.
Skehan, J.W., 1961, The Green Mountain anticlinorium in the vicinity of Wilmington and Woodford, Vermont: Vermont Geological Survey Bulletin 17, 159 p.
Stanley, R.S., 1964, The bedrock geology of the Collinsville quadrangle: Connecticut Geological and Natural History Survey Quadrangle Report 16, 99 p.
______1967, Geometry and age relations of some minor folds and their relation to the Woronoco nappe, Blandford and Woronoco quadrangles, Massachusetts, *in* Guidebook for field trips in the Connecticut valley of Massachusetts: New England Intercollegiate Geologic Conference, 59th Annual Meeting, Amherst, Mass., Oct. 13–15, 1967, p. 48–60.
______1968, Metamorphic geology of the Collinsville area, trip D–4, *in* Guidebook for field trips in Connecticut—New England Intercollegiate Geologic Conference, 60th Annual Meeting, New Haven, Conn., Oct 25–27, 1968: Connecticut Geological and Natural History Survey Guidebook 2, 17 p. [Paged separately]
Stanley, R.S., and Hatch, N.L., Jr., 1976, Discussion—Early Paleozoic stratigraphy of western Massachusetts and Connecticut and southeastern New York, *in* Page, L.R., ed., Contributions to the stratigraphy of New England: Geological Society of America Memoir 148, p. 351–356.
Sutter, J.F., 1985, Progress on geochronology of Mesozoic diabases and basalts, *in* Robinson, G.R., Jr., and Froelich, A.J., eds., Proceedings of the second U.S. Geological Survey workshop on the early Mesozoic basins of the eastern United States: U.S. Geological Survey Circular 946, p. 110–114.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1990—573-049/26,069 REGION NO. 8