BEDROCK GEOLOGY OF THE MOUNT CARMEL AND SOUTHINGTON QUADRANGLES, CONNECTICUT

by

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ABSTRACT

BEDROCK GEOLOGY OF THE MOUNT CARMEL AND SOUTHINGTON QUADRANGLES, CONNECTICUT

by Crawford E. Fritts

New data concerning the geologic structure, stratigraphy, petrography, origin, and ages of bedrock formations in an area of approximately 111 square miles in south-central Connecticut were obtained in the course of detailed geologic mapping from 1957 to 1960. Mapping was done at a scale of 1:24,000 on topographic base maps having a 10-foot contour interval.

Bedrock formations are classified in two principal categories. The first includes metasedimentary, meta-igneous, and igneous rocks of Precambrian to Devonian age, which crop out in the western parts of both quadrangles. The second includes sedimentary and igneous rocks of the Newark Group of Late Triassic age, which crop out in the eastern parts of the quadrangles. Diabase dikes, which are Late Triassic or younger in age, intruded rocks in both the western and eastern parts of the map area.

Rocks in the western part of the area underwent progressive regional metamorphism in Middle to Late Devonian time. The arrangement of the chlorite, garnet, biotite, staurolite, and kyanite zones here is approximately the mirror-image of metamorphic zones in Dutchess County, New York. However, garnet appeared before biotite in pelitic rocks in the map area, because the ratio MgO/FeO is low.

Waterbury Gneiss and the intrusive Woodtick Gneiss are parts of a basement complex of Precambrian age, which forms the core of the Waterbury dome. This structure is near the southern end of a line of

similar domes that lie along the crest of a geanticline east of the Green Mountain anticlinorium. The Waterbury Gneiss is believed to have been metamorphosed in Precambrian time as well as in Paleozoic time. The Woodtick Gneiss also may have been metamorphosed more than once.

In Paleozoic time, sediments were deposited in geosynclines during two main cycles of sedimentation. The Straits, Southington Mountain, and Derby Hill Schists, which range in age from Cambrian to Ordovician, reflect a transition from relatively clean pelitic sediments to thinly layered sediments that contained rather high percentages of fine-grained volcanic debris. Metadiabase and metabasalt extrusives above Derby Hill Schist south of the map area represent more intense volcanic activity before or during the early stages of the Taconic disturbance in Late Ordovician time. Impure argillaceous, siliceous, and minor calcareous sediments of the Wepawaug Schist, which is Silurian and Devonian in age, were deposited unconformably on older rocks during renewed subsidence of a geosyncline. The Wepawaug now occupies the trough of a tight syncline, which formed before and during progressive regional metamorphism at the time of the Acadian orogeny in middle to Late Devonian time.

Felsic igneous rocks were intruded into the metasedimentary formations of Paleozoic age before the climax of the latest progressive regional metamorphism. Intrusives that gave rise to the Prospect and Ansonia Gneisses were emplaced mainly in the Southington Mountain Schist, and the igneous rocks as well as the host rocks were metamorphosed in the staurolite zone. Although it is possible that these two intrusives were emplaced during the Taconic disturbance, the writer believes it more likely that the igneous rocks from which the Prospect and Ansonia Gneisses formed were emplaced during the Acadian orogeny. Woodbridge Granite, which intruded the Wepawaug Schist, is Devonian in age and undoubtedly was emplaced during the Acadian orogeny. In this area the granite is essentially unmetamorphosed, because it is in the chlorite, garnet, and biotite zones. Southwest of the map area, however, metamorphic equivalents of the Woodbridge are found in Wepawaug Schist in the staurolite zone. The Ansonia Gneiss, therefore, may be a metamorphic equivalent of the Woodbridge Granite.

Rocks of Late Triassic age formerly covered the entire map area, but were eroded from the western part after tilting and faulting in Late Triassic time. The New Haven Arkose of the Newark Group was deposited unconformably on an irregular surface above the metamorphic rocks, but is in fault contact with them for more than 11 miles. A sheet of West Rock Diabase at least 18 miles long and as much as 700 feet, thick intruded the arkose in Late Newark time, but changed stratigraphic position by more than 1,000 feet. Dikes of Buttress Diabase were emplaced along faults and fissures that cut across other formations in the map area. Barite and copper minerals were deposited along dikes and in fault breccias at that time.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

III. PRE-TRIASSIC ROCKS--Continued

Metasedimentary rocks--Continued

Waterbury Gneiss--Continued

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

III. PRE-TRIASSIC ROCKS--Continued

Meta-igneous and igneous rocks--Continued

Granitic to quartz dioritic gneisses, undivided--Continued

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

I. INTRODUCTION

PURPOSE AND SCOPE

Bedrock geology in and near the southeastern part of the Western Highland of Connecticut has been the subject of discussion for more than a century. Because the region is well populated, many people assume that abundant geologic information is available. Most geologic reports concerning the region, however, were based on reconnaissance rather than detailed mapping, and several major problems remained unsolved. For example, (1) the age of metasedimentary rocks in the Highland, in which no fossils have been found, was uncertain, (2) it also was uncertain whether metamorphism of the rocks was caused by known intrusives or occurred after amplacement of those bodies, (3) although some formations in southern Connecticut resemble stratigraphic units in southeastern Vermont, information about the stratigraphic positions of formations in Connecticut was inadequate for correlating rocks in both States, and (4) the western boundary of the Newark Group of Late Triassic age in central Connecticut had been interpreted as a tilted pre-Newark peneplain supposedly offset by oblique faults, which were inferred also to explain irregularities in the outline of an intrusive diabase sheet. This sheet, however, does not occupy a consistent stratigraphic position, and should not be used as a marker bed for recognizing concealed faults, unless it can be proved that the boundaries of the intrusive have been offset.

Detailed geologic mapping in the Mount Carmel and Southington quadrangles (pls. 1 and 2) permitted the study of the problems outlined above as well as several other topics of general geologic interest. These quadrangles lie along the eastern side of a large gneiss dome, here called the Waterbury dome (pl. 3), which is near the southern end of a line of similar structures of pre-Triassic age that extends from Connecticut to Vermont. The quadrangles also contain the lower part of the Newark Group of Late Triassic age and dikes of Triassic or younger age. In this report, the author discusses (1) petrography, (2) new stratigraphic units of pre-Triassic age, (3) emplacement of igneous and meta-igneous rocks, (4) age of igneous, meta-igneous, and nonfossiliferous metasedimentary rocks, (5) progressive regional metamorphism of chlorite to kyanite grade, as well as retrograde and contact metamorphism, (6) correlation of the rocks of this area with other geologic units in or near New England, (7) the boundary between the Newark Group and rocks of pre-Triassic age, (8) relief on the pre-Newark surface, (9) geologic structure, including doming in pre-Triassic time and the deformation of rocks of pre-Triassic age in ~~L~~late Newark or post-Newark time, and (10) paragenesis of deposits of barite and copper minerals of former and possible future economic interest. The relationship between texture and metamorphic history of rocks of pre-Triassic age is emphasized. By stressing lithology, origin, metamorphic history, geologic structure, and correlation, the author attempts to show that the geologic age of these nonfossiliferous rocks ranges from Precambrian to Silurian and Devonian. The geologic history of the area from Precambrian to Recent time also is summarized.

PREVIOUS WORK

The bedrock geology of parts of the map area has been studied briefly by many people, but only the more important references are cited here. Silliman (1820) described but did not name parts of the Wepawaug Schist, Prospect Gneiss, and Straits Schist. Shepard (1837) mentioned several localities of interest to mineralogists and collectors. Percival (1842) studied bedrock in the course of remarkably detailed geologic mapping of Connecticut. Credner (1866) described barite veins and underground workings at the Jinny Hill mine. Davis and Loper (1891) and Davis and Griswold (1894) discussed the western boundary of the Newark Group. Davis (1898) studied the stratigraphy and structure of the Newark Group and the form and origin of diabase bodies intruded into the Newark. Gregory (Rice and Gregory, 1906) named and redescribed several units of pre-Triassic age shown on a preliminary geologic map of Connecticut by Gregory and Robinson (1907), Schairer (1931) redescribed several mineral localities mentioned by previous authors. The western boundary of the Newark Group was discussed again by Longwell and Dana (1932), Longwell (1933a and b), Wheeler (1937), and Fritts (in press, b). Stewart (1935) studied the petrology of the Prospect Porphyritic Gneiss of Gregory. Krynine (1950) discussed the petrology and origin of the New Haven Arkose. Rodgers (Rodgers and others, 1959) suggested possible correlation of several formations of pre-Triassic age with geologic units in Massachusetts and Vermont. The history of barite mining in the nineteenth century at Cheshire, Connecticut, was discussed in an article recently prepared by the author for the Cheshire Historical Society.

CURRENT INVESTIGATIONS

Mapping of Mount Carmel and Southington quadrangles was part of a cooperative program undertaken in 1955 and financed jointly by the U. S. Geological Survey and the Connecticut Geological and Natural History Survey to provide detailed geologic maps of Connecticut at scale 1:24,000 using topographic base maps with a ten-foot contour interval. Bedrock mapping in Mount Carmel quadrangle was done in eight months during the summers of 1957 and 1958. Similar work in Southington quadrangle was carried on for two weeks in the fall of 1958 and for seven and one half months in 1959 and 1960. Geology in the southwestern corner of Mount Carmel quadrangle was revised in 1961 in the course of detailed geologic mapping by the author in Ansonia quadrangle southwest of the map area. A final field check in Southington quadrangle also was made at that time. Petrographic studies and similar investigations were conducted in offices and laboratories of the U. S. Geological Survey at Denver, Colorado, and Washington, D. C., during the period 1957 to 1962.

ACKNOWLEDGEMENTS

Mapping was facilitated by the assistance and suggestions of many people. During July and August 1957, the author was assisted by G. N. Syphers, who independently mapped much of the Wepawaug Schist and Woodbridge Granite in Mount Carmel quadrangle. For approximately two weeks in August 1959, P. S. Ely helped the author excavate the Mixville fault near Ten Mile River and Humiston Brook in Southington quadrangle. On several occasions geology of the area was discussed with R. F. Flint and A. M. LaSala, who more or less

concurrently mapped the surficial geology of Mount Carmel and Southington quadrangles, respectively. Several well drillers cooperated by permitting the author to collect samples of bedrock cuttings, by providing records of footages, and by discussing the characteristics of geologic formations penetrated in wells shown on the geologic maps. Numerous courtesies and suggestions were offered by J. W. Peoples, Chairman of the Connecticut State Geological and Natural History Survey, and his predecessor, J. B. Lucke. Both men accompanied the author on field trips in the map area.

Geologic structure, stratigraphy, and correlation of rocks of pre-Triassic age has been discussed with several people who have studied similar rocks in northern New England. The author spent two days in southeastern Vermont in June 1960 with J. L. Rosenfeld of the University of California studying rocks in and near the Chester dome, which is analogous to the Waterbury dome of the map area. Five days also were spent in northern Massachusetts and Vermont in October 1961 with L. R. Page, W. M. Cady, and A. H. Chidester of the U. S. Geological Survey studying the stratigraphic section from Hoosac Schist to Waits River Formation, which is the approximate equivalent of the section from Straits Schist to Wepawaug Schist in the map area. John Rodgers of Yale University accompanied the author in the field on several occasions and engaged in stimulating discussions numerous times. Bedrock geology of New England also was discussed with J. W. Skehan of Boston College, who has mapped in southern Vermont. The geologic age and metamorphism of Waterbury Gneiss was discussed with J. B. Thompson of Harvard University, who has studied rocks of similar metamorphic grade and stratigraphic and structural position in Vermont.

The writer is grateful for the interest, advice, and suggestions offered by Drs. E. N. Goddard, F. S. Turneaure, L. I. Briggs, D. F. Eschman, R. M. Denning, and W. C. Kelly of the Department of Geology and Mineralogy of the University of Michigan. Drs. Goddard and Eschman visited the area during the 1959 field season.

Analytical data were provided by personnel and Branches of the U. S. Geological Survey. Chemical analyses (tables 1 and 2) were made by Dorothy F. Powers, Branch of Geochemistry and Petrology. X-ray analyses mentioned in the text were made by Theodore Botinelly, Branch of Geochemistry and Petrology. Reconnaissance gravity surveys across the Mixville fault near Gaylord Mountain in Mount Carmel quadrangle and near Marion, Connecticut, in Southington quadrangle were made by Martin F. Kane and Donald L. Peterson, Branch of Geophysics. Age determinations on biotite and zircon from pre-Triassic intrusives (tables 6 and 7) were made by Herman H. Thomas and Thomas W. Stern, respectively, Branch of Isotope Geology. Nine east-west, aero-magnetic surveys at intervals of 1 mile were made across each quadrangle by personnel of the Branch of Geophysics.

II. GENERAL SETTING

LOCATION AND ACCESS

The Mount Carmel and Southington quadrangles are in south-central Connecticut at the eastern edge of the Western Highland of the State and at the western edge of the Connecticut Valley Lowland, which is underlain by the largest remnant of the Newark Group in New England (fig. 1). The map area is north of New Haven, east of Waterbury, south of Bristol, and west of Meriden, Connecticut. The area contains approximately 111square miles and includes parts of the Towns of Wolcott, Southington, Waterbury, Prospect, Cheshire, Bethany, Woodbridge, Hamden, and North Haven, Connecticut.

Access to the area, more than half of which is covered by second growth hardwood forests, is provided mainly by numerous paved roads. The most heavily-traveled route is Wilbur Cross Parkway, which crosses the southeastern corner of Mount Carmel quadrangle. Interstate Highway 84, which will cross Southington quadrangle in a nearly east-west direction just south of Larsens Pond, was under construction in 1960. Near the Farmington Canal, which was abandoned about 1848, a branch of the New York, New Haven and Hartford Railroad crosses both quadrangles in a north-south direction but is used primarily for hauling freight. An unimproved landing strip in Bethany near the western boundary of Mount Carmel quadrangle is used mainly for privately-owned light aircraft.

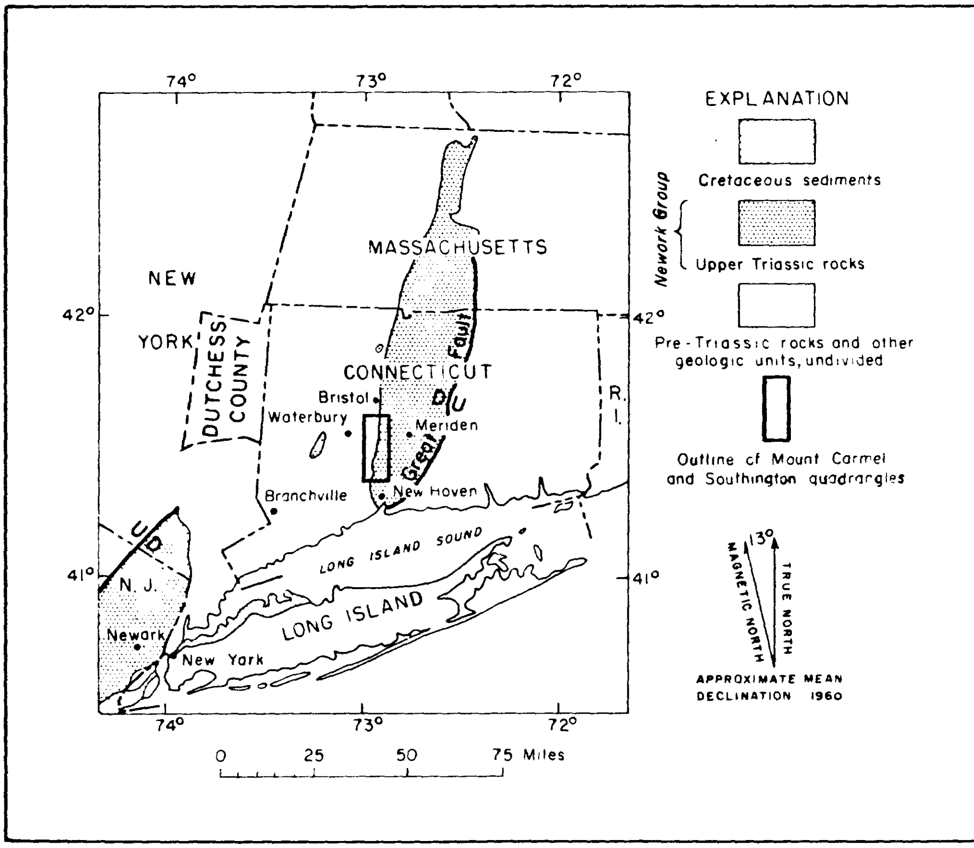


FIGURE 1. Generalized geologic map showing location of Mount Carmel and Southington quadrangles, Connecticut. Geology after Stose (1932) and Platt (1957). Also shows location of Dutche's's County, New York, and major faults of Triassic age

MAIN GEOLOGIC UNITS

Bedrock units in the map area include formations laid down during four main cycles of sedimentation and intrusives emplaced during at least three periods of geologic time. Formations originally deposited as sediments are the Waterbury Gneiss of Precambrian age, the Straits, Southington Mountain, and Derby Hill Schists ranging in age from Cambrian to Ordovician, the Wepwaug Schist of Silurian and Devonian age, and the New Haven Arkose of Late Triassic age (pl. 4). Intrusives are the Woodtick Gneiss of Precambrian age, the Prospect and Ansonia Gneisses of Ordovician or Devonian age, the Woodbridge Granite of Devonian age, the West Rock Diabase of Late Triassic age, and the Buttress Diabase of Late Triassic or younger age (pl. 3). Sediments of Cretaceous and Tertiary ages have not been found in the map area, but it is possible that they once were present (Davis, 1898, p. 165). There is no evidence to show that sediments of Mississippian to Permian age or sediments of Jurassic age ever were deposited in the map area.

TOPOGRAPHY AND DRAINAGE

Relief is moderately rugged. Local relief is a few tens to several hundreds of feet, but maximum relief is slightly more than 1,040 feet. The highest point is at Lindsley Hill (misnamed Spindle Hill on some previous topographic maps) in the northern part of Southington quadrangle. The lowest point is in the southeastern corner of Mount Carmel quadrangle, where a small oxbow lake occupies an abandoned channel in the valley of the Quinnipiac River close to sea level.

Conspicuous differences in altitude indicate marked differences in bedrock. In general, altitudes are higher in the western half of the area, which is underlain by igneous and metamorphic rocks of pre-Triassic age characteristic of the Western Highland of Connecticut. The eastern half of each quadrangle is underlain mainly by less resistant sedimentary rocks of Late Triassic age, which are characteristic of the Connecticut Valley Lowland. Some of the most prominent ridges and mountains in the area, however, such as West rock Ridge and Mount Carmel, are underlain by diabase intruded into the Triassic strata.

Drainage ultimately is southward toward Long Island Sound, although some streams flow away from the area in other directions. Most streams in the southern part of Mount Carmel quadrangle flow into the West River and Mill River, both of which empty directly into the Sound. Streams that flow northward from Mount Carmel quadrangle are tributaries of the Quinnipiac River, which crosses the northeastern part of Southington quadrangle and follows a course southward through Meriden and Wallingford quadrangles to New Haven Harbor. Streams that flow westward from the area are tributaries of the Naugatuck River, which extends southward through Waterbury, Naugatuck, and Ansonia quadrangles reaching the Housatonic River approximately at sea level.

OUTCROPS AND GLACIATION

Outcrops comprise less than two percent of the surface in the map area, but most exposed bedrock is fresh or only slightly weathered. Glaciation during the Pleistocene epoch removed any deeply weathered bedrock that may have been present, and mantled the area with deposits of unconsolidated surficial materials as much as 145 feet thick. The distribution of bedrock symbols on the maps indicates the approximate distribution of outcrops, but the outlines of individual exposures and groups of outcrops are shown by Flint (1962) and LaSala (1961). Most of the outcrops shown by Flint were mapped by Fritts in the course of bedrock mapping, but LaSala had mapped most outcrops in Southington quadrangle before bedrock mapping in that area began.

Two main directions of glacial movement are indicated by field evidence. In some places, the distribution of erratic boulders shows that the principal direction of early ice movement was from north to south. Boulders of Prospect Gneiss derived from western Cheshire and southwestern Southington, for example, rest on New Haven Arkose north and east of Bethany Mountain in Mount Carmel quadrangle, but glacial striations on outcrops in that quadrangle indicate that the general direction of the latest ice movement was from northeast to southwest. In the northwestern part of Southington quadrangle, on the other hand, striations indicate that ice moved mainly toward the south, and there is no indication of later glaciation.

RELATIONSHIP BETWEEN BEDROCK AND SURFICIAL GEOLOGY

Where poorly exposed or unexposed, bedrock has been mapped partly on the basis of topography and the distribution of angular boulders, which probably were not moved far during glaciation. The large amphibolite, for example, in the Straits Schist northeast of Scovill Reservoir is well jointed and occupies relatively low ground in many places; it is believed to be the source of numerous blocks of amphibolite, which were strewn over a broad area to the southwest during glaciation. Similarly, Scovill Reservoir is believed to be underlain by the largest body of Woodtick Gneiss in Southington quadrangle. The gneiss is exposed in only a few places near the lake, but till in that area contains numerous blocks of the rock. Some of the gneiss blocks undoubtedly were derived from joint-controlled bluffs east and north of the lake, which were formed or accentuated by plucking during glaciation, but some blocks are believed to have come from the immediate vicinity of the lake.

III. PRE-TRIASSIC ROCKS

INTRODUCTORY STATEMENTS

Pre-Triassic rocks in the map area include argillaceous, siliceous, and minor calcareous metasedimentary rocks of Precambrian to Silurian and Devonian age (Fritts, in press, a) and felsic to intermediate intrusives of Precambrian, Devonian, and Ordovician or Devonian ages (pl. 3). Most of these rocks underwent progressive regional metamorphism in Middle to Late Devonian time. Metamorphic grade increases from southeast to northwest. Pre-Triassic rocks in the Mount Carmel quadrangle are in the chlorite, garnet, biotite, staurolite and kyanite zones, whereas rocks of similar age in the Southington quadrangle are in the staurolite and kyanite zones. The possibility that some of the rocks were metamorphosed more than once is considered in the discussion of metamorphism, which follows the descriptions of the pre-Triassic rocks.

Petrographic descriptions of these rocks are based on field studies, a few chemical and X-ray analyses, and examination of about 200 thin sections from Mount Carmel quadrangle and 170 from Southington quadrangle. Except where noted, colors of fresh rocks only are recorded, using the terminology of Goddard and others (1951). Minerals are listed in order of decreasing abundance, and grain sizes are as follows: fine, less than 1 mm.; medium, 1 to 5 mm.; coarse, more than 5 mm. The percentage of anorthite (An_{0-100}) in plagioclase and the optic sign (+) or (-) of chlorite follow the appropriate mineral names. Unless indicated otherwise, the following colors and probable compositions of certain minerals apply: garnet is red almandine; tourmaline is schlorite dichroic in green; most biotite is pleochroic in brown rather than green and is of intermediate composition. White mica is reported as muscovite; paragonite was not identified in any of the rocks studied. Moderately or weakly magnetic, gray or black, opaque iron oxide is reported as ilmenite, and strongly magnetic iron oxide is reported as magnetite. Minerals formed by retrograde metamorphism are mentioned only in the discussion of metamorphism.

The complexity or simplicity of texture in metamorphic rocks in the map area depends upon lithology, structure, and metamorphic history. In general, simple textures are characteristic of rocks that parallel the regional trend of major structures and are either incompetent or lie within incompetent rocks. The texture of Straits Schist, for example, is simple; amphibolite, marble, and paragneiss within the Straits Schist also have simple textures. These rocks lie near the Waterbury Gneiss, which forms the core of a gneiss dome. Members of the Straits Schist were smeared out along the edges of the core of the dome during tectonic activity and progressive regional metamorphism. On the other hand, in many places amphibolite and paragneiss in Waterbury Gneiss have complex textures and indistinct foliation and lineation, especially where the rocks are highly contorted. Most rocks in the core of the dome not only are competent, but they also are believed to have been metamorphosed more than once. Similarly, Woodtick Gneiss, which is only moderately well foliated and lineated lies within relatively competent rocks in the core of the Waterbury dome. The Woodtick is believed to be older than the Straits Schist, and also may have undergone metamorphism more than once. On the other hand, foliation and lineation are well developed in the Prospect and Ansonia Gneisses, which lie within less competent rocks parallel to major regional structures. The foliation and lineation, which cross the boundaries of stocks and irregular intrusive bodies of the Woodtick, Prospect, and Ansonia Gneisses in some places, were imposed on these rocks during progressive regional metamorphism.

METASEDIMENTARY ROCKS

General Features

The Waterbury Gneiss and the Straits, Southington Mountain, Derby Hill, and Wepawaug Schists have the internal structure, composition, thickness, and regional distribution of metamorphosed sedimentary formations. Banding in the paragneiss of the Waterbury, for example, reflects original differences in layered sediments. Although metamorphism destroyed all evidence of original clastic grains, the gradation from quartz-rich to mica-rich parts of some bands (pl. 5, fig. A) can be interpreted as graded bedding, that is, gradation from sandy to argillaceous material, respectively, in sedimentary beds. The chemical composition of the main mica schist of Straits Schist, on the other hand, is similar to that of shale (table 1, column 5). Alternate bands of paragneiss, mica schist, and impure calcareous rocks in the Southington Mountain and Wepawaug Schists indicate alternate layers of sandy, clayey, and limey material in original sedimentary formations. Very thin banding in the Derby

Hill Schist and a rather constant thickness of 1,000 to 1,500 feet for many miles suggest that the formation is a stratigraphic unit, although it has been highly sheared in Mount Carmel quadrangle (pl. 11). Amphibolites in Waterbury Gneiss are interpreted as metasedimentary rocks, although their origin is uncertain. Amphibolites in overlying formations are believed to represent metamorphosed graywacke or fine-grained, water-laid tuff deposited in a geosynclinal environment. These rocks, therefore, are included in the descriptions of the main metasedimentary formations.

Waterbury Gneiss

General Features

The Waterbury Gneiss includes a predominant paragneiss, the Hitchcock Lake Member, minor amphibolites, and at least two unmapped bands of calc-silicate rock. The formation was named for Waterbury, Connecticut, by Gregory (Rice and Gregory, 1906, p. 100), but was redefined by Fritts (in press, a). The paragneiss underlies a semi-elliptical area of about 12 square miles in the western part of Southington quadrangle and the northwestern corner of Mount Carmel quadrangle. It is well exposed in eastern Waterbury, northern Prospect, and southeastern Wolcott, and extends into Naugatuck and Waterbury quadrangles (pl. 3). The Hitchcock Lake Member was named by Fritts (in press, a) for Hitchcock Lake in Southington quadrangle; the type locality is on a broad peninsula on the west side of the lake. This member forms a belt 250 to nearly 1,700 feet wide along the northern and eastern sides of the paragneiss, and four isolated patches surrounded by the paragneiss in Prospect and Waterbury. The contact between the two units, however, is gradational and is generalized on the geologic map of Southington quadrangle, especially south of Hitchcock Lake. Lenticular bodies of amphibolite as much as 1,700 feet long and 300 feet wide are distributed randomly through the paragneiss and Hitchcock Lake Member, but most are more or less conformable with foliation in the adjacent rock. They probably constitute less than one per cent of the Waterbury Gneiss.

Conformable bands of calc-silicate rock a few inches wide and a few feet long were found in the paragneiss near the western boundary of Southington quadrangle about 2,800 feet south of Route 70 and in the Hitchcock Lake Member about 500 feet southwest of the type locality. These rocks, however, were not mapped.

The Waterbury Gneiss, especially the paragneiss, is believed to be the lowest stratigraphic unit in the area (Fritts, in press, a) although at least one other interpretation has been offered. Gregory (Rice and Gregory, 1906, p. 100) described the formation as Hartland Schist (Straits and Southington Mountain Schists of this report) injected with granite, pegmatites, and amphibolites he believed to be meta-igneous intrusives. Rodgers (Rodgers and others, 1959, p. 41), on the other hand, believed that the Waterbury Gneiss is the lowest formation in the stratigraphic sequence exposed between Waterbury and New Haven, Connecticut. The current study has confirmed Rodgers' interpretation and has revealed that the composition, grain size, textures, and probable metamorphic history of the formation differ markedly from those of the Straits and Southington Mountain Schists. The Waterbury Gneiss is interpreted here as part of a basement complex that forms the core of the Waterbury dome (pls. 3 and 4).

Petrography

Paragneiss. Rocks mapped as paragneiss are mainly fine- to medium-grained, light- to dark-gray, well-banded gneisses with subordinate layers of mica schist. The main minerals are quartz, biotite, muscovite, oligoclase (An_{15-30}), kyanite, garnet, microcline, and magnetite, Accessory minerals are apatite, zircon, tourmaline, rutile, chlorite(+), epidote, and chalcopyrite. The thickness of bands ranges from less than 1 mm. to a few feet, but very thin banding predominates (pl. 5). In general, quartz-rich bands alternate with more micaceous layers, but pure quartzite is rare. Typical hand samples are (1) quartz-biotite-kyanite-garnet-oligoclase gneiss, (2) quartz-oligoclase-biotite-muscovite-garnet gneiss, (3) biotite-microcline-quartz-muscovite-garnet-kyanite-oligoclase gneiss, (4) biotite-quartz-muscovite-kyanite-oligoclase-chalcopyrite-garnet gneiss, (5) muscovite-quartz-garnet-oligoclase-biotite-kyanite gneiss, (6) muscovite-kyanite-quartz-biotite-magnetite-garnet-oligoclase gneiss, (7) kyanite-biotite-magnetite-oligoclase-muscovite-garnet-quartz gneiss, and (8) muscovite-biotite-quartz-garnet-oligoclase schist. The schist is most abundant in the Mount Carmel quadrangle and near the Hitchcock Lake Member in eastern Waterbury, and it is coarser than the typical gneisses. Garnets in the schist in Mount Carmel quadrangle are as much as 1 inch in diameter, but the average grain size is less than 5 mm.

Contorted banding and numerous injections and small irregular bodies of aplitic, granitic, quartz monzonitic, and quartz dioritic gneisses are characteristic of the paragneiss (pl. 6). Banding is so irregular in many outcrops that only generalized trends were mapped, especially in Prospect, eastern Waterbury, and near the Woodtick Gneiss in Wolcott. Pegmatites and intrusive gneisses in many places are too small and ill-defined to be mapped separately.

Textures in the paragneiss are more complex than in most of the other metamorphic rocks in the area. Many samples of the paragneiss are characterized by extremely irregular and intimate intergrowths of the main minerals (pl. 16) and garnet, biotite, muscovite, and kyanite each exhibit at least two crystal habits. In some specimens, nearly circular aggregates of fine-grained, anhedral garnet are thoroughly intergrown with biotite, oligoclase, and quartz (pl. 16, fig. B). In other samples, randomly distributed, euhedral to subhedral garnets have formed in or near anhedral garnet, which appears to have been crushed before the adjacent euhedral garnet crystallized (pl. 17, fig. B). Fine-grained biotite is evenly disseminated in many bands in the paragneiss, but in some bands biotite also forms randomly oriented porphyroblasts, which are characterized by ragged outlines (pl. 16, fig. A). Most muscovite formed as typical booklike crystals, but in some samples aggregates of randomly oriented, fine-grained muscovite (coarser than sericite) are strung out along narrow bands and have a shredded appearance. Nearly acicular crystals of kyanite, which resemble sillimanite, are found in many samples of the rock (pl. 16, fig. A; pl. 17, fig. A), but sillimanite has not been identified positively. Bladelike prismatic crystals of kyanite generally less than 1 mm. long are numerous.

The presence of kyanite in the paragneiss distinguishes this rock from other paragneisses of similar metamorphic grade in the map area. Fine-grained, bluish-gray kyanite is widespread and in some places abundant in the formation. Regardless of its grain size, the mineral can be recognized in many outcrops, because it stands out on weathered surfaces. It is most abundant southwest of Wolf Hill in Wolcott and east of Scott Road in northern Prospect. Kyanite was observed in 20 of 29 thin sections of rocks from this map unit in Southington quadrangle and in 3 of 6 thin sections of similar rocks from Mount Carmel quadrangle. One sample from northern Prospect is about 54 per cent kyanite. In many samples the kyanite is concentrated in thin layers parallel to banding, but in some specimens aggregates of tiny kyanite crystals form "knots" as much as 2 inches long oblique to the main foliation of the rock (pl. 18, fig. A).

Magnetite is more abundant in the paragneiss than in other rocks of pre-Triassic age in the area. In many places, especially where kyanite is abundant, octahedra and anhedral masses of magnetite as much as 3 mm. in diameter can be seen. The magnetite is disseminated through the rock, but the mineral produces strong magnetic anomalies, which are characteristic of the formation.

Chalcopyrite is found mainly as an accessory mineral in the paragneiss, but one specimen from the hill crossed by a power line west of Woodtick is approximately 5 per cent chalcopyrite.

Hitchcock Lake Member. The Hitchcock Lake Member is mainly medium- to coarse-grained, quartz-muscovite-oligoclase-biotite-garnet schist, but stringers, bands, and impregnations of granitic to quartz monzonitic gneiss are abundant. The schist also contains narrow bands of quartz-oligoclase-biotite-muscovite-garnet paragneiss, which are more numerous south of Hitchcock Lake. Some samples contain a few per cent ilmenite or magnetite and typical accessory minerals are kyanite, staurolite, microcline, tourmaline, zircon, apatite, rutile, and epidote. Bladelike crystals of kyanite as much as 1 inch long are visible in several places shown by the letter K on the geologic map of Southington quadrangle (pl. 2), but kyanite is not abundant in the Hitchcock Lake Member.

Textures in the Hitchcock Lake Member are not as complex as in the paragneiss, but several physical features distinguish the typical schist of this member from other schists in the map area. The schist contains abundant biotite, which is almost as plentiful as muscovite. Both biotite and muscovite form distinct booklike crystals which are recognized easily on foliation planes. The distribution and grain size of garnet is inconsistent. Garnet constitutes from zero to 17 per cent of the rock, and the diameter of individual crystals ranges from less than 1 mm. to about 2 inches. Many oligoclase crystals are antiperthitic, and some have numerous inclusions of quartz. Tourmaline and apatite crystals in some places are as much as 1 inch long, but most are less than 3 mm. long. Near granitic and quartz monzonitic bodies the schist also is characterized by ptygmatic folds.

Amphibolites. The amphibolite is a medium- to fine-grained, grayish- to greenish-black, foliated to unfoliated rock composed mainly of hornblende, andesine (An_{30-40}), quartz, and sphene. Garnet comprises as much as 10 per cent of rock mapped as garnetiferous amphibolite, p€wg, which otherwise is similar to the amphibolite, p€wa. Both kinds of rock contain clinozoisite, diopside, and zoisite, as well as the accessory minerals pistacite, ilmenite, chlorite(+), muscovite, zircon, and pyrite. Foliation and lineation are well developed in amphibolites that parallel relatively uncontorted banding in the adjacent rocks. For example, the large garnetiferous amphibolites west of Scovill Reservoir are foliated and lineated. In northern Prospect, on the other hand, a small amphibolite associated with contorted paragneiss lacks foliation and lineation (pl. 18, fig. B).

Textures in some of the amphibolites are complex, especially where foliation and lineation are lacking (pl. 18, fig. B). Ragged hornblende crystals contain numerous inclusions of quartz, andesine, chlorite(+), and sphene. Andesine has numerous inclusions of clinozoisite. Some garnets have ragged outlines and contain andesine, hornblende, and quartz, as well as tiny crystals of clinozoisite and sphene. One amphibolite in the Hitchcock Lake Member south of Route 70 in western Cheshire contains anhedral diopside crystals less than 1 mm. in diameter, which are arranged in aggregates as much as 10 mm. in diameter. The smaller crystals are characterized by conspicuous sieve structure and appear to be parts of larger crystals that were broken and recrystallized.

Calc-silicate rocks. Unmapped calc-silicate rocks in Waterbury Gneiss are coarse- to fine-grained, very light gray to white gneisses composed of quartz, andesine, zoisite, garnet, clinozoisite, sphene, and accessory apatite. The calc-silicate rock associated with paragneiss also contains diopside, and the calc-silicate rock in the Hitchcock Lake Member has at least one thin layer rich in hornblende. Diopside, garnet, and hornblende are characterized by sieve structure.

Origin

A metasedimentary origin for the paragneiss is indicated by the banding and composition of the rock. Gradation from quartz-rich to mica-rich parts of individual bands (pl. 5, fig. A) can be interpreted as graded bedding. The high percentages of quartz and kyanite in the rock indicate high percentages of silica and alumina, respectively, in the original material, and is not characteristic of igneous and meta-igneous rocks. The abundance of biotite and muscovite in some samples of the paragneiss also is more characteristic of meta-sedimentary than meta-igneous rocks.

The parent materials from which the paragneiss formed probably were water-laid sediments derived, at least in part, from a deeply weathered landmass, and were deposited under off-shore conditions. The percentages of alumina and iron indicated by the abundance of kyanite and magnetite, respectively, in some samples of the paragneiss are higher than those of normal sandstone and shale, but are not higher than those of rocks such as laterite and saprolite, which form as a result of deep weathering. Laterite and saprolite, however, are not characterized by graded bedding, which forms mainly by deposition in water. Furthermore, laterite generally lacks or contains very little potassium, which is moderately abundant in micas and feldspars in the paragneiss. A source area containing both fresh and deeply weathered bedrock, however, could have provided the sediments from which the paragneiss formed. Deposition in an off-shore environment is suggested mainly by the fine grain size of the paragneiss and the lack of pure quartzites, which would have formed from clean, well-sorted sands deposited in shallow water.

The Hitchcock Lake Member probably formed by metamorphism of shale, which contained moderate amounts of iron and magnesium, as well as interbedded sandy sediments. The abundance of muscovite and biotite, which together comprise more than 40 per cent of an average sample of schist from this member, is characteristic of rocks formed by metamorphism of argillaceous sediments. The rather high percentage of biotite in the schist, however, indicates that the original sediment contained moderate amounts of iron and magnesium. The abundance of feldspar is attributed partly to granitic and quartz monzonitic material, which intruded and impregnated the schist, but it is likely that the original sediment contained abundant potassium, sodium, and calcium. Except for lower alumina content, which is indicated by the lower percentage of kyanite, the paragneiss bands in this member have the composition of metamorphosed impure sandy sediments similar to the parent material from which the main paragneiss of Waterbury Gneiss formed. The higher proportion of argillaceous to siliceous sediments in the Hitchcock Lake Member, indicated by the higher ratio of schist to paragneiss, suggests that this member was deposited more slowly or in deeper and quieter water than the paragneiss.

Amphibolites in the Waterbury Gneiss are interpreted on the geologic maps of Mount Carmel and Southington quadrangles as metasediments, although their origin is uncertain. Gregory (Rice and Gregory, 1906, p. 100) believed them to be intrusives, but offered no evidence other than mafic composition to support his conclusion. The recent maps, however, show that most of the amphibolites are lenticular bodies approximately parallel to foliation and banding in the adjacent metasedimentary rocks. No clearcut examples of dikelike amphibolite bodies cutting across foliation and banding in the metasediments have been found, and no evidence such as relict igneous textures have been found in thin sections to indicate that the amphibolites originally were igneous rocks. The amphibolites could have formed by metamorphism of mafic tuffs or sediments derived from mafic igneous intrusives.

Calc-silicate rocks, which form narrow layers parallel to bands interpreted as beds in the paragneiss and Hitchcock Lake Member, are interpreted as metamorphosed, impure, calcareous, siliceous, and argillaceous sediments. They are more calcareous than typical igneous or meta-igneous rocks.

Thickness

Thickness of the Waterbury Gneiss is uncertain, because stratigraphic control at the base of the formation is lacking, the effect of tectonic activity on the original stratigraphic thickness is unknown, and the boundary between this formation and Straits Schist probably is a fault for several miles south of Larsens Pond. (The last two reasons are discussed in more detail under the heading Geologic Structure.) Furthermore, it is difficult to measure the thickness of the paragneiss and Hitchcock Lake Member, because the boundary between them is gradational, especially in eastern Waterbury. If it is assumed that foliation is approximately parallel to original bedding, and that the stratigraphic thickness has remained constant, thickness of the Hitchcock Lake member apparently varies from about 250 feet just north of section A-A' in Southington quadrangle (pl. 2) to more than 1,500 feet near the abandoned railroad in eastern Waterbury. Thickness of the paragneiss which underlies a much broader area, probably is at least several thousand feet and may be as much as 10,000 feet.

Straits Schist

General features

Straits Schist, as redefined by Fritts (in press, a), overlies Waterbury Gneiss unconformably and underlies Southington Mountain Schist. Straits Schist includes mica schist, paragneiss, amphibolites, chloritic schist, impure marble, and minor unmapped calc-silicate rocks in the lower part of The Straits Schist Member of the Hartland Formation named by Rodgers (1959, p. 40). The type locality is a narrow defile, known locally as The Straits, in northern Bethany at the western edge of Mount Carmel quadrangle about 1 mile southeast of Straitsville, Connecticut. The upper part of The Straits Schist Member of the Hartland Formation of Rodgers was mapped by the author as Southington Mountain Schist. The name Hartland is not used in this report, because it has been used in a variety of ways in previous geologic literature and is of questionable value as a formal stratigraphic name.

The Straits Schist forms a belt approximately 12 miles long and from 300 to 6,400 feet wide between Waterbury Gneiss and Southington Mountain Schist in the Towns of Wolcott, Cheshire, Prospect, and Bethany. The formation extends into Waterbury, Naugatuck, and

Ansonia quadrangles (pl. 3). The belt is narrow south of Hitchcock Lake because of tectonic thinning and faulting. The contact between Waterbury Gneiss and Straits Schist is sharp, even where not a fault, but the contact between the Southington Mountain and Straits Schists is gradational.

The predominant rock in Straits Schist is mica schist, which is characterized by uniform composition and lack of conspicuous banding (pl. 8, fig. A). Lenses and pods of quartz and pegmatite are approximately parallel to schistosity in most outcrops. Near the Southington Mountain Schist, the main minerals of the rock in some places are segregated into mica-rich and mica-poor layers as much as a few inches wide, but, in general, the rock is unbanded. The schist contains at least one minor unmapped layer of calc-silicate rock, and it is possible that it also contains unmapped amphibolite, paragneiss, and marble in covered intervals. Most of the schist in the map area is uncontorted, but near the type locality crenulations or small folds are numerous. In cross section these folds resemble waves with amplitudes and wave lengths as much as 1/2 inch.

Lenticular bodies of uncontorted paragneiss, and amphibolites as much as 600 feet wide and 2 miles long, are interlayered with the schist in Wolcott. Garnetiferous amphibolite contains feldspathic layers (pl. 8, fig. B) and a few narrow, unmapped bands of rock that resemble the paragneiss. Similarly, the paragneiss contains narrow unmapped bands of amphibolite and calc-silicate rock. Contacts between the paragneiss and garnetiferous amphibolite near Southington Reservoir No. 2 and west of Route 69 in Wolcott are generalized on the geologic map (pl. 2). The rocks probably interfinger, but are poorly exposed in the vicinity of the generalized contacts. The map units show only the dominant lithologies.

Chloritic schist and impure marble were found near the top of the Straits Schist at the northern end of the New Naugatuck Reservoir (pl. 1). The marble forms a band as much as 6 feet thick and 700 feet long. The chloritic schist underlies an area as much as 200 feet wide and at least 1,100 feet long. Chlorite also is conspicuous in several exposures of Straits Schist southwest of Larsens Pond (pl. 2), but the rocks there were mapped as part of the main mica schist.

Calc-silicate rocks were found in two places in Straits Schist but were not mapped. A podlike body about 4 feet wide and several feet long is in mica schist about 1,000 feet east of the intersection of Routes 68 and 69 in Prospect. A band of calc-silicate rock a few inches thick and a few feet long is at the eastern edge of the paragneiss just north of the Southeast Burying Ground near Southington Reservoir No. 2.

Petrography

Mica schist. The mica schist characteristic of Straits Schist is a silvery gray, medium- to coarse-grained, unbanded to poorly banded rock (pl. 8, fig. A) in which the main minerals are quartz, muscovite, biotite ($n\gamma \approx 1.634$), oligoclase (An_{15-30}), garnet, staurolite, and ilmenite. Much of the oligoclase is calcic rather than sodic, although a chemical analysis (table 1, column 5) indicates a rather low CaO content. In Southington quadrangle the schist also contains kyanite crystals as much as 1 inch long. Typical accessory minerals are chlorite(+), apatite, tourmaline, zircon, rutile, and graphite.

The texture of the schist is simple (pl. 20, fig. A). Most garnets are euhedral to subhedral, although some contain small inclusions of quartz, biotite, oligoclase, tourmaline, and chlorite. Oligoclase is slightly sericitized, but lacks other inclusions. Most biotite and muscovite crystals are booklike and do not have ragged outlines. The parallel arrangement of muscovite crystals gives the rock its schistosity. In many places, muscovite and biotite are intergrown, and individual crystals are somewhat indistinct on foliation planes. In some places, however, biotite is oblique to muscovite. Where the rock is crenulated or folded, muscovite and biotite wrap around the axes of folds as shinglelike aggregates rather than as deformed crystals. Chlorite(+) is either parallel or oblique to foliation planes; some groups of chlorite(+) crystals are fan-shaped. Kyanite forms pale blue, subhedral, prismatic crystals, which generally lack inclusions. Carr (1960, p. 8) reported kyanite to be pleochroic from pale yellow to colorless in Straits Schist in Naugatuck quadrangle, but in Southington quadrangle kyanite is colorless and nonpleochroic in thin section. Staurolite in Straits Schist, on the other hand, is euhedral to subhedral and exhibits strong pleochroism from rich yellow to nearly colorless. One staurolite crystal observed in thin section contains a small kyanite crystal, but quartz inclusions are much more numerous in staurolite.

The following characteristics distinguish this rock from the mica schist of the Hitchcock Lake Member of Waterbury Gneiss: (1) muscovite is about twice as abundant as biotite; (2) garnets are uniformly small and are evenly distributed through the schist; (3) individual mica flakes are less distinct on foliation planes;

(4) oligoclase lacks antiperthitic intergrowths of microcline; and (5) most tourmaline and apatite is uniformly small.

Paragneiss. The typical paragneiss is a medium- to fine-grained, medium-light-gray to medium-dark-gray, well-foliated and lineated rock composed of oligoclase to andesine (An_{20-40}), quartz, biotite, muscovite, garnet, and ilmenite or magnetite. Accessory minerals are chlorite(+), apatite, zircon, tourmaline, and rutile. The paragneiss is very thinly layered. Some layers a few millimeters to a few inches thick contain more mica and less plagioclase and quartz than others, but the rock is predominantly gneissic rather than schistose.

The texture of the paragneiss is simple (pl. 19, fig. A). Garnets are euhedral to subhedral, but contain small inclusions of quartz and plagioclase. Larger plagioclase crystals are poorly twinned and slightly sericitized, but lack inclusions of other minerals. Biotite and muscovite form booklike crystals, which parallel the rock foliation and lack ragged outlines.

This rock is distinguished from the paragneiss of Waterbury Gneiss by simpler texture, greater percentage of plagioclase, lack of kyanite, lack of contorted banding, and lower percentage of magnetite.

Amphibolites. Garnetiferous amphibolite, which is much more abundant than nongarnetiferous amphibolite in Straits Schist, is a tough, medium-to coarse-grained, dark-gray to greenish-black, well-foliated, and well-lineated rock. Hornblende and andesine (An_{30-40}), are abundant, and the rock also contains garnet, sphene, quartz, and ilmenite or magnetite. Accessory minerals are chlorite($\pm$), clinozoisite, biotite, zircon, apatite, and diopside. Some layers in the rock contain more feldspar and less hornblende than others (pl. 8, fig. B). Amphibolite of similar color and grain size in the Mount Carmel quadrangle lacks garnet, but contains minor amounts of calcite. The amphibolite in that area is at about the same stratigraphic position as a band of impure marble, and one band of amphibolite is in contact with the marble just north of New Naugatuck Reservoir.

The textures of the typical amphibolites in general are simple, although andesine is intergrown with garnet porphyroblasts in some places (pl. 19, fig. B). Andesine also forms thin, pale-gray to white rims around many garnets. The andesine is irregularly sericitized, but generally lacks other inclusions. Many andesine crystals show faint reverse progressive zoning, but albite twinning is inconspicuous. Some hornblende crystals are anhedral, but most are subhedral and prismatic. Simple twinning is characteristic of the prismatic crystals. Most hornblende crystals lack inclusions, but a few contain small andesine crystals.

Impure marble. The impure marble in the upper part of the Straits Schist at New Naugatuck Reservoir is a medium- to coarse-grained, white to pinkish-gray rock with thin dusky-yellow-green seams of granular silicate minerals, which give the rock conspicuous foliation and lineation (pl. 12, figs. A. and B). The marble is 60 to 90 per cent calcite. The remainder of the rock is largely a mixture of microcline, clinozoisite, diopside, and quartz, with traces of tremolite, albite or sodic oligoclase, muscovite, sphene, and apatite. A chemical analysis of a well-banded sample of the rock (table 1, column 7) indicates a rather high silica content.

Chloritic schist. The chloritic schist near the marble band at New Naugatuck Reservoir is a medium-grained, greenish-gray rock. It contains nearly 25 per cent chlorite(+), but quartz and sodic oligoclase comprise about 60 per cent of the rock. The remainder is largely biotite, staurolite, muscovite and chlorite(-). Rutile, ilmenite or magnetite, apatite, and zircon are accessory minerals. This rock contains much more chlorite(+) than the mica schist characteristic of Straits Schist, but is of comparable grain size.

Calc-silicate rock. The unmapped calc-silicate rock at Prospect is medium- to coarse-grained, medium bluish gray to grayish yellow, and contains zoisite, diopside, garnet, quartz, calcite, clinozoisite, and accessory sphene. Slender prismatic zoisite crystals are as much as 1 inch long. Most of the main minerals have inclusions of other minerals, and many crystals have ragged outlines.

The calc-silicate rock near Southington Reservoir No. 2 is a medium-grained, yellowish-gray rock composed of quartz, clinozoisite, calcic oligoclase, garnet, sphene, hornblende, diopside, and accessory apatite and zircon. Garnet is subhedral to anhedral and is intergrown with quartz, clinozoisite, and hornblende. Diopside and hornblende also are intergrown. Oligoclase is anhedral and thoroughly sericitized; many oligoclase crystals also have numerous inclusions of quartz.

Origin

The predominant mica schist of Straits Schist is chemically similar to less metamorphosed argillaceous rock, such as phyllite from the Wepwaug Schist, which is but slightly metamorphosed shale (table 1, columns 5 and 6). It is believed, therefore, that the mica schist originally was a fine-grained, argillaceous sediment. The uniform composition of the mica schist, and especially the general lack of quartz-rich bands in the rock, reflects relatively slow deposition of the original sediment in moderately deep water, presumably in a marine environment.

The chloritic schist, paragneiss, amphibolites, impure marble, and unmapped calc-silicate rocks also are believed to be of metasedimentary origin. The marble and calc-silicate rocks have the composition of impure calcareous sediments, which contained abundant silica and clay. The amphibolites and paragneiss are less calcareous, but plagioclase constitutes 28 to 33 per cent of the rocks, respectively, which indicates relatively high percentages of soda and lime. Variation in the percentage of plagioclase in layers in the paragneiss and amphibolites (pl. 8, fig. B) reflects variation in the percentage of soda and lime in layers in the original material from which the rock was formed, and can be interpreted as relict bedding. The high percentages of soda and lime also suggest that the original sediments either were of volcanic origin or were derived from volcanic material. The composition and layering of the paragneiss and amphibolite, therefore, suggest that these rocks represent metamorphosed impure sandstone and tuff (or graywacke), respectively.

Thickness

The stratigraphic thickness of Straits Schist is uncertain, because the formation has been folded in some places, and the effects of tectonic thinning and thickening are not clear. The apparent thickness of the entire formation varies from a little more than 1,000 feet near Southington Reservoir No. 2 to perhaps as much as 5,000 feet at the western edge of Southington quadrangle, and the apparent thickness of the largest garnetiferous amphibolite northeast of Scovill Reservoir is about 500 feet. These estimates were made by assuming that foliation and relict bedding are parallel, but they are not parallel everywhere. At the western end of the largest garnetiferous amphibolite, for example, foliation is not parallel to the regional trend of the body. Furthermore, the map pattern of another body of garnetiferous amphibolite near Central Avenue east of Hitchcock Lake suggests isoclinal folding. If the formation has been isoclinally folded, the true stratigraphic thickness remains in doubt.

Southington Mountain Schist

General features

Southington Mountain Schist contains banded schist, chloritic schist, porphyroblastic schist, amphibolites, impure marble, and calc-silicate rock formerly included in the upper part of The Straits Schist Member of the Hartland Formation of Rodgers (Rodgers and others, 1959, p. 40) and in the Prospect Porphyritic Gneiss and part of the Orange Phyllite of Gregory (Rice and Gregory, 1906, p. 101, 102). Southington Mountain Schist was named by Fritts (in press, a) for Southington Mountain in Southington quadrangle. The type locality is at the south end of New Britain Reservoir. The predominant rock there is banded schist, which contains alternate layers of quartz-rich paragneiss, muscovite-rich schist, and minor amphibolite. The rock is characterized by ribbonlike banding (pl.

9, fig. A) in contrast to the relatively unbanded mica schist of Straits Schist. The transition from unbanded Straits Schist to banded Southington Mountain Schist is displayed in a series of outcrops near Woodtick Road a little more than 1 mile southwest of New Britain Reservoir. The contact between the formations, which is gradational, was placed between the unbanded schist and the closest outcrops characterized by segregation into quartz-rich and mica-rich layers. Southington Mountain Schist also contains numerous unmapped quartz veins and pegmatites as much as a few feet wide and a few tens of feet long (pl. 9, fig. B).

Southington Mountain Schist occupies parts of a belt 1 to 3 miles wide and more than 10 miles long mainly east of Straits Schist in the Towns of Wolcott, Cheshire, Prospect, Bethany, and Woodbridge. The Southington Mountain Schist extends into Bristol and Thomaston quadrangles north of the map area, as well as Waterbury and Ansonia quadrangles (pl. 3). It is continuous with rocks in Naugatuck quadrangle mapped as undifferentiated Hartland formation by Carr (1960). Derby Hill Schist bounds Southington Mountain Schist on the east in the southern part of Mount Carmel quadrangle, but is not exposed north of Bethany Lake. Farther north Southington Mountain Schist is bounded on the east by the Mixville and Southington Mountain faults and by an unconformity at the base of the New Haven Arkose. South of New Britain Reservoir the belt occupied by Southington Mountain Schist also contains irregular bodies of Prospect Gneiss as much as 1½ miles wide and 6 miles long, as well as small bodies of Ansonia Gneiss. Banded rocks of probable metasedimentary origin lying near Prospect Gneiss formerly were mapped as part of the gneiss

(Rodgers and others, 1959), but the grain size, composition, and origin of Prospect Gneiss, as redefined by Fritts (in press, a) are distinct from those of Southington Mountain Schist.

Interlayered paragneiss and schist are characteristic of the predominant banded schist, but lineation, the thickness of banding, and the relation of foliation to banding are variable. In the northern part of Southington quadrangle, alternate bands of paragneiss, mica schist, and minor amphibolite commonly are 1 or 2 inches wide, but the thickness of bands varies from less than 1 inch to more than 1 foot. Mineral lineation is obscure in that area, but in many outcrops the alinement of the axes of tiny crenulations in mica-rich bands are consistent enough to map. Near Straits Schist, foliation and banding are approximately parallel (pl. 9, fig. B). In the vicinity of Lindsley Hill and New Britain Reservoir, however, the rocks in many exposures are crumpled, and foliation and banding are not parallel in every outcrop. Farther south, especially near Prospect Gneiss, the rocks also are banded (pl. 10, fig. A), and are characterized by fair to good mineral lineation. Foliation parallels banding in many exposures. In some places near Prospect Gneiss in Bethany, however, especially between Sanford and Beacon Hill Brooks, the Southington Mountain Schist is rather complexly folded, and the attitude of foliation and banding is inconsistent. In that area, mineral lineation is the most consistent mappable feature. Banding in the schist east of Larsens Pond fault in Southington quadrangle also is contorted in some places, especially in the large patches of banded schist near Darcy School in western Cheshire and near Mount Vernon Road north of Marion, Connecticut.

In the southern part of Mount Carmel quadrangle, the Southington Mountain Schist occupies a narrow belt between Prospect Gneiss and Derby Hill Schist. In that area, especially in the valley of the Sargent River, the Southington Mountain Schist in some exposures has been sheared along closely spaced planes approximately parallel to the general northeast-trending planes of shear cleavage characteristic of the Derby Hill Schist. In general, however, shear cleavage is not well developed in the Southington Mountain Schist.

Porphyroblastic schist underlies an area as much as 1,500 feet wide and 2 miles long close to Prospect Gneiss north of Marion, Connecticut. The schist is well banded, but contains numerous grayish-pink microcline crystals as much as 1 inch long. The large microcline crystals are most abundant near the adjacent porphyroblastic quartz monzonite gneiss of the Prospect Gneiss, which contains similar microcline crystals. The contact between the porphyroblastic schist of Southington Mountain Schist and the porphyroblastic gneiss is gradational, and the number of large microcline crystals decreases away from the gneiss. The porphyroblastic schist was mapped as part of Southington Mountain Schist mainly because banding is characteristic of this formation and not characteristic of Prospect Gneiss, as redefined by Fritts (in press, a). The map unit is generalized north of the South Branch of Hamlin Brook, because outcrops are scarce.

A very small body of chloritic schist was mapped in Mount Carmel quadrangle south of Rainbow Road about 1 mile north northwest of Bethany Lake. This rock is believed to be an inclusion of Southington Mountain Schist in Prospect Gneiss.

Amphibolites, calc-silicate rocks, and marble form lenticular bodies mainly in the banded schist, although some are associated with other rocks. Most are parallel to banding or foliation in the adjacent rocks. Bodies of amphibolite are as much as a few hundred feet thick and 1/2 mile long. The longest is in banded schist about 1½ miles north of Marion, Connecticut, in Southington quadrangle, but many smaller bodies form inclusions in Prospect Gneiss in Cheshire and Prospect. Biotitic amphibolite is found mainly as inclusions in Prospect Gneiss in the Town of Bethany in the Mount Carmel quadrangle. Small bodies of garnetiferous amphibolite were mapped mainly near New Briatin Reservoir in Southington quadrangle. A small band of impure marble similar to the marble in the upper part of Straits Schist was mapped in the lower part of Southington Mountain Schist south of Larsens Pond. Bands of vesuvianite-bearing calc-silicate rock as much as a few feet wide and a few tens of feet long were found only in two patches of banded schist apparently surrounded by Prospect Gneiss in western Cheshire. The large body of vesuvianite-bearing calc-silicate rock mapped south of Darcy School contains thin layers of impure marble. The rocks containing vesuvianite have unusual compositions and were mapped mainly to show their distribution. The size of most is exaggerated on the geologic map (pl. 2). Small bands of calc-silicate rocks lacking vesuvianite were found near Hitchcock Lake, Moss Avenue, Cuff Brook, Darcy School, and New Britain Reservoir, but were not mapped.

Petrography

Banded schist. Paragneiss layers in the banded schist are silvery gray or medium light gray to medium gray and contain abundant quartz and albite to oligoclase (An_{0-30}), moderate amounts of biotite, muscovite, and garnet, and small quantities of staurolite and kyanite in appropriate metamorphic zones. Pure quartzite is rare. Accessory minerals are chlorite(+), magnetite or ilmenite, tourmaline, rutile, apatite, and zircon. In the northern part of Southington quadrangle, the rocks are medium-grained and have a granular appearance, but east of the Larsens Pond fault in Southington quadrangle, and in many places in Mount Carmel quadrangle, the paragneiss bands are medium- to fine-grained and somewhat slabby. Near the Sargent River in southern Bethany the slabby characteristic is especially well developed.

Schist bands are silvery gray and are composed mainly of quartz, muscovite, biotite, oligoclase (An_{15-30}), garnet, staurolite, kyanite, and chlorite(+). Typical accessory minerals are rutile, tourmaline, graphite, apatite, ilmenite, and minor pyrite. The rocks are well foliated, but grain size varies from fine to coarse. In the northern part of Southington quadrangle, dustlike graphite is an abundant accessory mineral, and muscovite, with which the graphite commonly is associated, is fine-grained (pl. 21, fig. B). In that area the schist bands are characterized by satiny luster, and individual muscovite crystals cannot be recognized easily on foliation planes. In many places near Prospect Gneiss, however, the rocks contain less graphite, and muscovite is medium-grained. Garnets are 1 to 3 mm. in diameter in the type area, but are as much as 20 mm. in diameter near Prospect Gneiss. Kyanite crystals in the schist bands are bladelike and generally are less than 1/4 inch long, although crystals as much as 7 inches long were found in quartz pods in schist south of

Larsens Pond. Kyanite is most abundant near Straits Schist in the northern part of Southington quadrangle. Staurolite, on the other hand, is common in the schist bands, except in the biotite-garnet zone in Bethany and Woodbridge. Staurolite crystals 1/4 to 2 inches long are especially characteristic of the schist bands in the northern part of Southington quadrangle, where macroscopic staurolite was indicated by the letter S in many places on the geologic map (pl. 2).

Simple textures are characteristic of the banded schist in the type area. Garnets are euhedral to subhedral, and some show twinning and zoning (pl. 21, fig. A). Most are uniformly small and are not intimately intergrown with other minerals. Some, however, have inclusions of biotite and quartz, and a few garnets have been broken into two or three fragments, which have been "cemented" by quartz, biotite, and chlorite(+). Muscovite crystals are booklike and lack inclusions of other minerals, except perhaps where fine-grained and associated with dustlike graphite. Biotite and chlorite(+) may be parallel or oblique to muscovite. They, too, are booklike and generally lack inclusions of other minerals. Most plagioclase is clear or only slightly sericitized. Staurolite may have inclusions of quartz, but commonly is euhedral to subhedral.

Textures are slightly more complex near Prospect Gneiss. Much of the plagioclase there contains more sericite than plagioclase in the schist in the type area. Many staurolite crystals have ragged outlines and sieve structure, with numerous quartz inclusions. Many garnets have inclusions of plagioclase, biotite, and muscovite, as well as abundant quartz. Some garnets are elongate parallel to foliation. In the valley of Sargent River in Mount Carmel quadrangle, garnets are characterized by quartz-filled shear planes gently oblique to the direction of plunge of lineation formed by the parallel alinement of muscovite and biotite.

Porphyroblastic schist. The porphyroblastic schist is a layered rock similar to the banded schist, but is transitional between the banded schist and the porphyroblastic quartz monzonite gneiss of Prospect Gneiss. Near the gneiss, the percentage of biotite is greater than that of muscovite, calcic oligoclase is more abundant than sodic oligoclase or albite, and microcline is abundant. The rock is medium- to coarse-grained, and biotitic layers contain grayish pink microcline crystals as much as 1 inch long. The rocks near the gneiss are composed mainly of calcic oligoclase, quartz, microcline, and biotite. Accessory minerals are clinozoisite, zircon, apatite, ilmenite, and rutile. "Micaceous" bands contain as much as 10 per cent biotite and 15 to 25 per cent coarse microcline. Adjacent less micaceous bands contain from 1 to 5 per cent biotite and as much as 35 per cent medium-grained microcline. Near the banded schist, however, the percentage of microcline is much lower, and muscovite is more abundant than biotite. Alternate schistose and gneissic bands there have compositions much more like the schist and paragneiss, respectively, of the banded schist.

Chloritic schist. The chloritic schist mapped north northwest of Bethany Lake is a coarse-grained, greenish-gray rock composed mainly of chlorite(+) and albite to sodic oligoclase in the approximate ratio 2:1. Quartz, rutile, apatite, and zircon comprise about 5 per cent of the rock.

Amphibolites. The amphibolites in this formation are medium-grained, dark-gray to greenish-black rocks, which contain abundant hornblende and oligoclase to andesine (An_{20-40}), and smaller amounts of quartz, zoisite, clinozoisite, and sphene. Biotite and garnet are essential minerals in the biotitic amphibolite and garnetiferous amphibolite, respectively, but otherwise are similar to the typical amphibolite. Accessory minerals are apatite, ilmenite, chlorite(+), diopside, muscovite, zircon, and calcite. Most of the amphibolites are well foliated and lineated where foliation in the adjacent rocks is consistent, but where the adjacent rocks are crumpled, as near New Britain Reservoir, the amphibolites lack strong foliation and lineation. The large amphibolite body 1½ miles north of Marion, Connecticut, also lacks conspicuous foliation and lineation. In some places, the well-foliated amphibolites contain light greenish gray feldspar-rich streaks as much as a few millimeters thick, which parallel foliation. In southern Prospect a few amphibolites also contain white lenticular clots as much as 15 mm. long and 5 mm. thick, which consist mainly of intergrowths of zoisite and sericitized plagioclase. In the biotite zone west of Lake Chamberlain, an unusual band of amphibolite less than 1 foot thick contains weakly pleochroic amphibole crystals as much as 1 inch in diameter and abundant clinozoisite.

Texture in the amphibolites is variable. Where the rocks are well foliated, subhedral hornblende with few or no inclusions of other minerals are characteristic, and the texture is relatively simple like that of amphibolites in Straits Schist. Where the rocks are poorly foliated, however, hornblende crystals have ragged outlines and some have inclusions of plagioclase and quartz. The large amphibolite band north of Marion, Connecticut, is characterized by randomly oriented, subhedral to anhedral hornblende crystals several millimeters long set in a matrix composed mainly of very fine-grained, untwinned plagioclase. Some of the hornblende crystals contain tiny inclusions of plagioclase and quartz, but the texture is not as complex as that of some amphibolites in Waterbury Gneiss.

Calc-silicate rocks. Vesuvianite-bearing calc-silicate rocks of the Southington Mountain Schist are well-banded, medium-grained, and grayish yellow green to very pale orange or very light gray. They contain abundant diopside and vesuvianite and variable amounts of microcline, calcite, quartz, brown garnet (probably grossularite), wollastonite, albite, and zoisite. Accessory minerals are sphene, apatite, and zircon. The vesuvianite crystals are euhedral porphyroblasts; light-olive-gray to moderate-olive-brown, tetragonal prisms 3 to 7 mm. long and 1 to 3 mm. in diameter are characteristic. The porphyroblasts contain numerous inclusions of diopside as much as 0.1 mm. in diameter (pl. 18, fig. C) and also may contain calcite and microcline. Anhedral microcline and diopside crystals about 0.5 mm. in diameter are abundant in the matrix of many samples. Wollastonite and grossularite(?), however, were found only in the calc-silicate rock mapped near Route 70 south-southeast of Darcy School.

Unmapped calc-silicate rocks are medium-grained, well banded, and medium gray to very light gray or grayish yellow green. They contain variable amounts of andesine, quartz, diopside, biotite, zoisite, microcline, hornblende, garnet, sphene, tremolite, and muscovite. Accessory minerals are clinozoisite, apatite, ilmenite, zircon, tourmaline, chlorite(+), and calcite.

Impure marble. The marble mapped south of Larsens Pond is medium-grained, light greenish gray, and well foliated. It is composed mainly of calcite, diopside, and zoisite in the approximate ratio 5:3:2. Sphene, albite or sodic oligoclase, and microcline comprise about 5 percent of the rock. Grid twinning, which is conspicuous in most microcline in the map area, is lacking in much of the microcline in this rock.

Unmapped marble associated with the band of calc-silicate rock mapped southwest of Darcy School is medium-grained, white to grayish yellow green or medium dark gray, and well foliated. Calcite comprises 16 to 86 per cent of the rock. Diopside, zoisite, quartz, microcline, albite or sodic oligoclase, tremolite, and biotite are abundant in some layers in the rock. Accessory minerals are sphene, zircon, and muscovite. Unmapped marble associated with a body of calc-silicate rock mapped near Route 70 south-southeast of Darcy School is similar to this rock, but also contains abundant brown garnet.

Origin

The composition and thin banding of most of the rocks in Southington Mountain Schist indicate that the formation is a metamorphosed sequence of interbedded, impure, argillaceous, siliceous, and calcareous sedimentary rocks. Gradation from quartz-rich paragneiss layers to mica-rich schist layers in the banded schist reflects gradation from sandy or silty sediments to muddy or clayey sediments, or gradation from impure sandstone to shale. Bands of impure marble undoubtedly represent beds of impure limestone in the original formation. Calc-silicate rocks represent limey beds in which siliceous and argillaceous material was more abundant. Amphibolites most likely represent impure calcareous sediments, which contained moderate amounts of magnesia and iron oxide, as well as silica and alumina. They are believed to represent metamorphosed graywacke or tuff. Streaks and thin feldspathic layers in these rocks suggest bedding in original sediments, and clots of intergrown zoisite and plagioclase are interpreted as metamorphosed pebbles or pyroclastic fragments. Although the zoisite-plagioclase clots might be interpreted as metamorphosed phenocrysts of calcic plagioclase in mafic igneous intrusives, the amphibolites do not cut across banding or relict bedding in the adjacent rocks. An intrusive origin, therefore, cannot be proved. The thin bands or relict beds characteristic of Southington Mountain Schist reflect relatively rapid deposition, presumably in a eugeosynclinal environment.

Thickness

The stratigraphic thickness of Southington Mountain Schist is uncertain, because the formation is crumpled and folded in some places and is intermixed with large bodies of Prospect Gneiss. Also the Derby Hill Schist, which is believed to overlie the formation stratigraphically, is not exposed in the northern part of Southington quadrangle, where Prospect Gneiss is absent. If it is assumed that banding reflects original bedding and that the thickness of beds did not change much during folding and metamorphism, a minimum thickness of several thousand feet is required by the apparent width of the formation in the northern part of Southington quadrangle, especially southwest of New Britain Reservoir. The formation has an apparent width of about 7,000 feet in that area between Straits Schist and the eastern end of the axial plane of a major syncline, which is described in the discussion of geologic structure. Variation in the attitude of banding or relict bedding in that area, however, necessitates that the estimate of minimum stratigraphic thickness be less than 7,000 feet. Maximum thickness must be less than 3 miles, which is the greatest apparent width of Southington Mountain Schist and intermixed Prospect Gneiss in Bethany. An approximate stratigraphic thickness of 5,000 feet is believed to be more reasonable.

Derby Hill Schist

General features

Derby Hill Schist is a very thinly laminated but highly deformed muscovite-albite-chlorite-quartz schist stratigraphically above Southington Mountain Schist. Derby Hill Schist occupies a belt as much as 1,150 feet wide and a little more than 2 miles long southwest of Bethany Lake (pl. 1). The formation was named by Fritts (in press, a) for Derby Hill in Ansonia quadrangle, Connecticut, about 5 miles southwest of the map area. The unit has been mapped by the author for at least 12 miles along strike (pl. 3). Along the west side of the formation near a large reservoir at the type area, this schist is in the kyanite zone and is in contact with rocks that strongly resemble the banded schist characteristic of Southington Mountain Schist in the northern part of Southington quadrangle. In Mount Carmel quadrangle the formation also is bounded on the west by Southington Mountain Schist, but the metamorphic grade of the rocks is lower. In this area Derby Hill Schist is bounded on the east by Wepawaug Schist. Derby Hill Schist is well exposed near Lake Chamberlain, and large outcrops were visible on the floor of the lake during a drought in 1957. Here and in the northern part of Ansonia quadrangle the rock is characterized by strong cataclasis and conspicuous shear cleavage (pl. 11). Elsewhere in the map area the formation is poorly exposed or does not crop out. A block showing the characteristic shear cleavage was found in till on the west shore of Bethany Lake, but the formation was not found north or east of the lake. The schist is believed to have been cut off by the Mixville fault in the area between Lake Chamberlain and Bethany Lake.

Petrography

The characteristic rock of this formation in Mount Carmel quadrangle is a dark-gray to greenish-gray, highly sheared schist, which contains abundant very fine-grained muscovite, albite, chlorite(-), and quartz. Accessory minerals are ilmenite or rutile, tourmaline, and zircon. In general, layers composed almost entirely of muscovite alternate with layers of granulated quartz and layers composed of intergrown albite and chlorite(-). Most layers are less than 10 mm. thick, and many are less than 1 mm. thick. They have been offset along innumerable shear planes generally less than 1 inch apart, which are oblique to the main foliation of the schist (pls. 11 and 22). Albite and chlorite crystals commonly are less than 0.02 mm. long, but booklike muscovite crystals are as much as 0.15 mm. long. In some places, anhedral quartz crystals are several millimeters in diameter, but most quartz has been sheared and granulated. Numerous quartz crystals are less than 0.02 mm. in diameter. Some of the fine-grained quartz probably formed by recrystallization of silica in an original sediment, but some of the coarser quartz is in the form of veins and lenses injected between foliation planes and subsequently sheared. Some of the injected quartz contains albite crystals as much as 2 mm. in diameter, which were broken and strung out during cataclasis (pl. 11, fig. A).

Origin

The position, composition, and layering of Derby Hill Schist suggest that the formation is a stratigraphic unit. The schist is approximately parallel to banding or relict bedding in the Southington Mountain Schist. Alternate layers of muscovite, quartz, and intermixed albite and chlorite in Derby Hill Schist reflect chemically different layers in a parent material, and are interpreted as relict beds. Layers rich in muscovite reflect former clayey or muddy beds, which contained abundant potassium. Albite and chlorite, on the other hand, indicate rather high proportions of soda and ferromagnesian material, respectively. The albite-chlorite layers are believed to represent tuffaceous beds in an original sediment, and the predominant schist is interpreted as an argillaceous metatuff. In Ansonia quadrangle, this thinly layered schist also contains a large lenslike body of impure quartzite (pl. 3), which is believed to represent a sandy or silty member of the formation (or perhaps a more felsic metatuff). In Milford quadrangle, the Derby Hill Schist is overlain by several thousand feet of metavolcanic and metasedimantary rocks (Fritts, in press, a). The main metatuff of Derby Hill Schist in Mount Carmel quadrangle, therefore, represents only part of a thick sequence of material laid down during a long period of volcanic activity.

Thickness

The Derby Hill Schist is 1,000 to 3,000 feet thick, where not cut by the Mixville fault. Layering and foliation in the rock are steeply inclined or vertical in most outcrops, so that the apparent thickness on the map (pl. 3) is the approximate stratigraphic thickness, except where the formation is faulted. In Mount Carmel quadrangle and in the northern part of Ansonia quadrangle the schist is about 1,000 feet thick, but is characterized by shear cleavage and cataclasis, which undoubtedly have caused some thinning. South of the Housatonic River is Ansonia quadrangle, however, the formation contains as much as 1,000 feet of impure quartzite and 2,000 feet of the typical thinly laminated schist, but the schist is characterized by crenulations rather than shear cleavage. The crenulations undoubtedly account, in part, for some apparent thickening of the schist. Although mapping in Ansonia quadrangle is incomplete, at present it is believed that the Wepawaug Schist overlies Derby Hill Schist unconformably (Fritts, in press, a). If so, the original stratigraphic thickness of Derby Hill Schist may be more than 3,000 feet.

Wepawaug Schist

General features

Wepawaug Schist overlies Derby Hill Schist unconformably and occupies the trough of a major syncline (pls. 3 and 4). The Wepawaug includes phyllite, interlayered phyllitic schist and quartz-rich paragneiss, impure crystalline limestone, and minor amphibolite exposed in an area as much as 2½ miles long and 1½ miles wide in the Towns of Bethany and Woodbridge in Mount Carmel quadrangle. The formation also contains numerous unmapped quartz veins as much as a few inches wide and a few feet long, generally parallel to foliation. The formation was named by Fritts (in press, a) for the Wepawaug River in Ansonia quadrangle, and underlies most of the eastern half of that area (pl. 3). It also extends into the Milford, New Haven, and Naugatuck quadrangles, although in those areas it has been mapped as part of the Orange Phyllite of Gregory (Rice and Gregory, 1906; Rodgers and others, 1959; Carr, 1960).

The predominant rock in Wepawaug Schist is phyllite in the eastern part of the formation and phyllitic schist interlayered with bands of quartzitic paragneiss as much as 1 foot wide in the western part. The apparent difference between the phyllite and banded phyllitic schist is caused by an increase in metamorphic grade toward the west-northwest. Rocks in the western part of the formation have been crystallized enough to show distinct lithologic banding, but quartz-rich and muscovite-rich layers in the phyllite can be recognized in the field mainly by subtle differences in color and foliation. On weathered surfaces, quartz-rich bands commonly are lighter gray than muscovite-rich layers, although on fresh surfaces the color of the rocks generally is darkest where quartz is most abundant. Quartz-rich layers also are characterized by rather widely spaced micaceous foliation planes (pl. 23, fig. A), and many muscovite-rich layers have secondary s-planes oblique to the main foliation.

Lenticular bodies of impure crystalline limestone as much as

100 feet thick and a few hundred feet long are characteristic of the formation, but amphibolite bands are smaller and much less numerous. The limestones are most abundant near Glen Dam Reservoir and Lake Watrous. Amphibolite, on the other hand, is found only in the western part of the map unit, where the intensity of progressive regional metamorphism was high enough for amphibole minerals to form. The amphibolite bands and some of the limestone layers are only a few inches thick, but they were mapped in order to show distribution.

Banding (or relict bedding) and foliation in Wepawaug Schist are parallel or approximately parallel in many outcrops, but in some places they are almost at right angles to each other. Tight folds are visible in some exposures (pl. 13, fig. A), and near the axes of many of the folds foliation is about perpendicular to banding. In some outcrops banding is somewhat contorted and small chevron folds are numerous, especially in muscovite-rich layers. In cross section, the folds resemble waves with amplitudes and wave lengths generally less than 1 inch. Where the rocks are most contorted, only the generalized trend of banding or foliation has been mapped. The attitude of the axial planes of chevron folds also has been mapped in a few places. In some places near Derby Hill Schist, planes of shear cleavage were observed in the Wepawaug, but, in general, shear cleavage is not well developed in Wepawaug Schist.

Petrography

Phyllite and phyllitic schist. Phyllite from the eastern part of the Wepawaug Schist is very fine-grained (pl. 23, fig. A), medium gray to medium dark gray, and highly fissile. The average gain size is less than 0.1 mm. The rock tends to break along smooth foliation planes, which have a satiny luster. Quartz and muscovite in the approximate ratio 2:1 comprise about 70 per cent of the rock. Albite and chlorite(-) in nearly equal proportions are the other two essential minerals. Albite was identified in some samples by using index liquids, but generally is too fine-grained to be identified in thin section. Albite also was identified by X-ray diffraction methods (Theodore Botinelly, oral communication) in a sample of phyllite from a roadcut on Route 69 west of Lake Watrous. A chemical analysis of this rock (table 1, column 6) shows a moderate amount of soda, which presumably is combined with silica and alumina to form albite. The rock also contains porphyroblasts of chlorite(+) as much as 0.3 x 0.05 mm. in diameter. The intermediate index (nY) of chlorite from this rock ranges from about 1.628 to approximately 1.632. The chlorite(+) porphyroblasts appear to have a lower index than chlorite(-) of the rock matrix. The phyllite also contains small cubic pyrite crystals as well as accessory rutile, tourmaline, apatite, zircon, and abundant dustlike carbon.

Phyllitic schist in the western part of the formation in Mount Carmel quadrangle is characterized by larger grain size and slightly different mineral content. Wavy foliation planes reflect more complex internal structure. The rock contains garnet and biotite porphyroblasts 1 to 5 mm. in diameter, but generally lacks pyrite.

Biotite crystals are bladelike and cleavage in the mineral commonly is oblique to foliation. Alinement of elongate biotite crystals, however, gives the rock an indistinct mineral lineation. Chlorite(+) forms booklike crystals, which are either parallel or oblique to foliation, but it does not form conspicuous porphyroblasts. Chlorite(-) is present mainly where the rock has undergone retrograde metamorphism. Muscovite, quartz, and albite are abundant, and except for differences cited above, the rock contains most of the accessory minerals found in the phyllite. Toward the west, however, ilmenite becomes more abundant than rutile.

Quartzitic paragneiss bands associated with the phyllitic schist are tough, fine grained, and medium to dark gray. Quartz is abundant, and many samples of the rock also contain albite, biotite, chlorite(+), garnet, and amphibole, as well as accessory ilmenite, tourmaline, apatite, zircon, calcite, and chalcopyrite. Toward the east, pyrite is an acessory mineral in some places where biotite is absent.

<u>Impure crystalline limestones</u>. The impure crystalline limestones in the formation are tough, well-foliated and lineated, medium-dark-gray to medium-bluish-gray rocks composed mainly of fine-grained calcite, quartz, and muscovite in the approximate ratio 2:1:1. In the eastern part of the area these rocks were mapped as pyritic limestone, because they contain tiny cubic pyrite crystals barely visible to the naked eye (pl. 23, fig. B). The pyrite generally constitutes less than 1 per cent of the rock. Some samples of the pyritic limestone also contain minor amounts of very fine-grained phlogopitic biotite ($nY \approx 1.618$). Farther west similar rocks were mapped as biotitic limestone where they lack pyrite but contain phlogopitic biotite crystals as

much as 2 mm. in diameter. Chlorite(-) also is an essential mineral in the pyritic limestone and probably accounts for a small percentage of magnesia reported in a chemical analysis of the rock (table 1, column 9). The biotitic limestone of similar chemical composition (table 1, column 8) contains moderate amounts of clinozoisite and chlorite(+) as well as a little microcline and accessory sphene. Both rocks lack dolomite. On weathered surfaces, calcite has been leached from the limestones, and they are characterized by moderate-brown rinds as much as 1 inch thick, which contain most of the other minerals characteristic of the unweathered rock.

Amphibolite. The amphibolite in Wepawaug Schist is medium- to coarse-grained and dark gray to dark greenish gray. From 70 to 80 per cent of the rock is a mixture of hornblende and clinozoisite in the ratio 2:1 to 1:2. The hornblende crystals are as much as 1/2 inch long. They are characterized by weak pleochroism from pale green to nearly colorless, which suggests that they contain a moderate amount of the actinolite end member of the hornblende series. Other minerals in the rock are quartz, garnet, chlorite, calcite, sphene, and minor ilmenite or magnetite. The abundance of clinozoisite distinguishes this amphibolite from most other amphibolites in the map area.

Origin

The compositional layering of the Wepawaug Schist, like that of the Southington Mountain Schist, indicates that the formation is a metamorphosed sedimentary rock. The original sediments presumably were deposited in a eugeosynclinal environment. Metamorphism destroyed all evidence of original clastic grains, but gradation from quartz-rich to mica-rich layers, which can be seen in many outcrops of the phyllite and phyllitic schist, indicates graded bedding. The phyllite is but slightly more metamorphosed than slate or shale. Muscovite-rich parts of the phyllite undoubtedly represent original muddy sediments. Siliceous layers in the phyllite, and quartzitic paragneiss interlayered with the phyllitic schist, represent sandy or silty beds, which contained abundant silica. The impure limestones represent impure calcareous beds, and the amphibolites, which are adjacent to limestone in some places, probably represent calcareous layers that contained moderate amounts of magnesia, iron oxide, soda, and alumina. The amphibolites are interpreted as metamorphosed graywacke or tuff.

Thickness

The thickness of the Wepawaug Schist cannot be measured accurately, because the formation has been tightly folded, and the upper stratigraphic limit is unknown. However, on the basis of regional geologic structure, which is discussed under a separate heading, the limestones between Lake Watrous and Glen Dam Reservoir are believed to be some of the highest stratigraphic units in the formation in this area. The apparent width of the Wepawaug from Lake Chamberlain to Lake Watrous is about 1 mile, and foliation, which parallels bedding in many outcrops, is steeply inclined. It is likely, therefore, that the stratigraphic thickness of the formation is at least several thousand feet.

META-IGNEOUS AND IGNEOUS ROCKS

General features

The Woodtick, Prospect, and Ansonia Gneisses, and the Woodbridge Granite have the shapes of intrusive bodies and the compositions of felsic to intermediate igneous rocks. All form stocklike, dikelike, and sill-like bodies in metasedimentary rocks, and contain inclusions of the host rocks (pl. 12, fig. D; pl. 13, fig. A). The Woodtick, Prospect, and Ansonia Gneisses are foliated and lineated, quartz dioritic to granitic gneisses, which have textures characteristic of metamorphic rocks. Foliation planes in the gneisses are micaceous partings formed mainly by biotite and(or) muscovite crystals in parallel orientation. Lineation can be seen where these minerals are strung out in a consistent direction along foliation planes. Foliation and lineation both cross the boundaries of these intrusives in some places. The Woodbridge Granite, on the other hand, is characterized by randomly oriented minerals and a texture more like that of an unmetamorphosed igneous rock. Less abundant felsic gneisses and pegmatites also are interpreted as intrusive meta-igneous or igneous rocks. The gneisses and pegmatites impregnate metasedimentary rocks in many places, but form dikelike and sill-like bodies as well. Veins and lenses of quartz are discussed with pegmatites, because both probably were emplaced at about the same time. Chemical analyses of Prospect Gneiss, Ansonia Gneiss, and Woodbridge Granite are listed in columns 1 to 4 of Table 1.

Woodtick Gneiss

General features

Woodtick Gneiss is a quartz diorite gneiss, which forms tabular to irregular bodies a few feet in diameter to as much as 2¾ miles long and 1¾ miles wide in Waterbury Gneiss. It has not been found in other metasedimentary rocks in the map area. The largest body of Woodtick Gneiss mapped to date underlies Scovill Reservoir, but smaller bodies are exposed in Waterbury, Prospect, and western Cheshire. The gneiss was named by Fritts (in press, a) for Woodtick, Connecticut, near Scovill Reservoir. The type locality is a west-facing, joint-controlled bluff several tens of feet high about 1 mile southeast of the reservoir. The locality is near the eastern edge of the largest body of the gneiss.

Woodtick Gneiss is finer grained, has poorer foliation and lineation, and contains much less microcline than the Prospect and Ansonia Gneisses. It also is characterized by plagioclase of more calcic composition than the plagioclase in those gneisses. The Woodtick is interpreted as part of a basement complex overlain by Straits Schist.

Petrography

Typical Woodtick Gneiss is fine- to medium-grained, light- to medium-gray, crudely foliated, but unbanded quartz diorite gneiss. It is composed mainly of calcic oligoclase to sodic andesine (An_{20-40}), quartz, and biotite, with smaller amounts of microcline, muscovite, and garnet. Accessory minerals are hornblende, apatite, zircon, epidote, magnetite or ilmenite, rutile, and sphene. In many places the gneiss is poorly lineated, but the rock mapped as Woodtick Gneiss near Midwood Avenue west of Hitchcock Lake is well lineated.

The texture of Woodtick Gneiss is more complex than that of Ansonia Gneiss, which is of comparable grain size (pl. 25, figs. B and C), but the texture of Woodtick Gneiss is less complex than that of the paragneiss of Waterbury Gneiss. Intergrowths of minerals and sutured contacts between minerals are common in the Woodtick. Plagioclase is characterized by reverse, progressive zoning. Many plagioclase crystals also contain antiperthitic intergrowths of optically continuous microcline, as well as inclusions of muscovite, quartz, biotite, zircon, and apatite. In some places the rock also contains anhedral microcline crystals as much as 6 mm. in diameter, which have inclusions of biotite, plagioclase, quartz, and muscovite. Garnet is subhedral to anhedral; some aggregates of anhedral garnet as much as 4 mm. in diameter are thoroughly intergrown with quartz, plagioclase, biotite, muscovite, and apatite. Biotite crystals as much as 1½ mm. in diameter may have ragged outlines, but the mineral also forms small, simple, booklike crystals.

Origin

The composition, texture, and shape of bodies of Woodtick Gneiss indicate that the rock is a metamorphosed igneous intrusive. Most bodies of the gneiss are stocklike or dikelike, but some are sill-like. All resemble the common forms of igneous intrusives. In some places the gneiss not only cuts across banding in the Waterbury Gneiss but also contains inclusions of the host rock, especially near contacts with the main paragneiss of the Waterbury southeast of Scovill Reservoir.

Metamorphism is indicated by the presence of (1) garnet, (2) complex intergrowths of feldspar, quartz, mica, and accessory minerals, (3) antiperthitic intergrowths of microcline in plagioclase, and (4) reverse, progressive zoning in plagioclase. Furthermore, foliation imposed during metamorphism apparently crosses the contacts of the largest stock of Woodtick Gneiss in Southington quadrangle.

Granitic to quartz dioritic gneisses, undivided

General features

Small tabular to irregular bodies of aplitic, granitic, quartz monzonitic, and quartz dioritic gneiss as much as 1,000 feet long and 400 feet wide were mapped as granitic to quartz dioritic gneisses, undivided. All are in the area underlain by Waterbury Gneiss in Southington quadrangle, and are interpreted as part of a basement complex overlain by Straits Schist. The largest body is in northern Prospect, and three others several hundred feet long are west to northwest of Scovill Reservoir. Smaller bodies are near Hitchcock Lake and southwest of Larsens Pond.

Petrography

Aplitic to granitic gneiss south of Lymn Road northwest of Scovill Reservoir is a medium-grained, white gneiss composed mainly of albite, quartz, and microcline, but it also contains a small percentage of macroscopic muscovite and a little biotite. Accessory minerals are clinozoisite, apatite, zircon, and sphene. The albite is characterized by reverse progressive zoning and inclusions of clinozoisite and muscovite. The texture of this rock resembles that of Woodtick Gneiss, but the aplitic gneiss is more felsic.

Aplitic to granitic gneiss in the large body in northern Prospect is a medium-grained, white rock composed mainly of quartz, albite or sodic oligoclase, muscovite, and a small percentage of microcline. The plagioclase contains numerous randomly oriented muscovite crystals 0.1 to 0.2 mm. long. Microcline has much smaller inclusions of muscovite. The rock also contains numerous aggregates of small muscovite crystals and a few booklike crystals of the mineral as much as 2 mm. long.

Granitic gneiss in two bodies west of Scovill Reservoir is coarse- to medium-grained, yellowish gray to white, and is composed mainly of albite, quartz, microcline, muscovite, and garnet. Accessory minerals are biotite and apatite. The rock is crudely banded. Muscovite, albite and quartz are concentrated in layers separated by bands rich in microcline. Garnet has inclusions of quartz and muscovite.

Quartz monzonite gneiss from western Cheshire is a coarse- to medium-grained, very light gray rock composed mainly of calcic oligoclase to sodic andesine (An_{20-40}), quartz, microcline, biotite, and a little sphene. Accessory minerals are apatite, muscovite, garnet, zircon, magnetite, zoisite, and clinozoisite. Microcline crystals as much as 4 mm. in diameter have ragged outlines, and some are perthitic. Plagioclase is slightly sericitized. Anhedral garnet crystals less than 0.2 mm. in diameter are arranged in nearly circular aggregates as much a 1 mm. in diameter. One thin section contains a patch of zoisite about 7 mm. in diameter surrounded by tiny clinozoisite crystals.

Quartz diorite gneiss just north of Central Avenue at Hitchcock Lake is a medium-grained, white to very-light-gray rock composed of calcic oligoclase to sodic andesine (An_{20-40}), quartz, biotite, muscovite, and a little microcline. Garnet, clinozoisite, apatite, and zircon are accessory minerals. Plagioclase has inclusions of quartz, muscovite, microcline, and aggregates of rather coarse sericite. Some plagioclase also exhibits reverse progressive zoning. Microcline is found mainly as optically continuous, antiperthitic intergrowths in plagioclase. Anhedral garnet crystals generally less than 0.1 mm. in diameter are intergrown with biotite and plagioclase, but form nearly circular aggregates as much as 1 mm. in diameter. This rock resembles Woodtick Gneiss.

Unmapped quartz monzonite gneiss (pl. 6, fig. B) just north of a body of Woodtick Gneiss near Pierpont Road in Waterbury is a medium-grained, light gray to white rock composed of oligoclase, quartz, muscovite, and a little biotite and microcline. Accessory minerals are clinozoisite and apatite. Oligoclase contains quartz inclusions and antiperthitic intergrowths of optically continuous microcline. Garnet has inclusions of quartz and biotite.

Origin

The textures and compositions of these rocks, as well as the shapes of the bodies mapped, indicate that the gneisses are metamorphosed igneous intrusives. Stocklike, dikelike, and sill-like forms predominate, but two bodies mapped west of Scovill Reservoir and the gneiss shown in Plate 6, Figure B, impregnate Waterbury Gneiss. Metamorphism is suggested by the presence of

(1) garnet, (2) antiperthitic intergrowths of microcline in plagioclase, (3) inclusions of clinozoisite in plagioclase, (4) inclusions of muscovite in microcline and plagioclase, and (5) reverse progressive zoning in plagioclase.

Metamorphosed pegmatite

General features

Small irregular to tabular bodies of metamorphosed pegmatite were mapped only in the parts of Wolcott, Waterbury, and Prospect underlain by the Waterbury and Woodtick Gneisses in Southington quadrangle. All of these rocks are interpreted as part of a basement complex overlain by Straits Schist. The pegmatites are as much as a few feet wide and a few tens of feet long. Some can be recognized in the field by the presence of numerous garnets (pl. 7, fig. B), but others can be recognized only in thin section by textures more complex than rocks mapped as pegmatite, Dp. It is possible, therefore, that some of the rocks mapped as pegmatite, Dp, in the areas underlain by the Waterbury and Woodtick Gneisses, should have been mapped as metamorphosed pegmatite.

Petrography

The metamorphosed pegmatites are medium- to coarse-grained, and white, very light gray, pinkish gray, or light greenish gray. Quartz, microcline, and muscovite are the main minerals in the rocks. Plagioclase ranges from albite to sodic oligoclase (An_{0-15}). Accessory minerals are biotite, garnet, calcite, and apatite.

The texture of these rocks is complex. Large microcline crystals have been broken, but have been cemented by "mortar" consisting mainly of fine-grained microcline (pl. 27, fig. A). Some of the plagioclase in the rock shows similar mortar structure. Aggregates of muscovite crystals less than 1 mm. long are more abundant than large muscovite crystals; coarse crystals generally have ragged outlines. Most plagioclase contains numerous small muscovite crystals, and some plagioclase is antiperthitic. Some of the microcline crystals, on the other hand, are perthitic. In some places aggregates of anhedral garnet less than 2 mm. in diameter are intimately intergrown with biotite, muscovite, and quartz, although some garnets are euhedral to subhedral and several millimeters in diameter.

Origin

These rocks form dikelike bodies in Woodtick Gneiss as well as Waterbury Gneiss, which indicates that originally they were igneous intrusives. Metamorphism is suggested by mortar structure, antiperthitic intergrowths of plagioclase and microcline, and the presence of garnet.

Prospect Gneiss

General features

Prospect Gneiss includes granodiorite gneiss, porphyroblastic, quartz monzonite gneiss, and nonporphyroblastic, quartz monzonitic to granitic gneiss, which form small dikelike and sill-like bodies as well as stocklike bodies as much as 6 miles long and 1½ miles wide. The granodiorite gneiss predominates in this area, and is well exposed in parts of Southington, Cheshire, Prospect, and Bethany. The quartz monzonite gneiss is adjacent to the granodiorite gneiss in southern Bethany and near Marion, Connecticut, but the quartz monzonitic to granitic gneiss is found only in small stocklike bodies about 1 mile north of Marion. Prospect Gneiss also underlies large parts of Naugatuck and Ansonia quadrangles (pl. 3) and is exposed near Bridgeport, Connecticut. In Mount Carmel and Southington quadrangles, the gneiss is found mainly in Southington Mountain Schist, but it also is in contact with Straits Schist north of New Naugatuck Reservoir. The Prospect has not been found in areas underlain by Waterbury Gneiss or by the Derby Hill and Wepawaug Schists. For several miles in Southington quadrangle the gneiss is in fault contact with New Haven Arkose.

Prospect Gneiss, as redefined by Fritts (in press, a), is the meta-igneous part of the Prospect Porphyritic Gneiss named by Gregory (Rice and Gregory, 1906, p. 102) for Prospect, Connecticut. The type area described by Gregory is in the southern part of Southington quadrangle between the sites of the Prospect and Summit stations on the Meriden, Waterbury, and Connecticut River Railroad, which was abandoned in 1924. A specific type locality in the original type area is a roadcut on an abandoned trolley line about 2,000 feet southeast of the intersection of Summit and Plank Roads near the northeastern boundary of Prospect (pl. 2). The rock in the type area is uniform granodiorite gneiss, but on at least three geologic maps (Gregory and Robinson, 1907; Stewart, 1935, fold-out map; Rodgers and others, 1959) metasedimentary rocks now recognized as part of the Southington Mountain Schist were included with the granodiorite gneiss in the Prospect Porphyritic Gneiss of Gregory. Stewart (1935, p. 14, and fold-out map) subdivided the Prospect Porphyritic Gneiss of Gregory into hornblende-biotite gneiss and muscovite-biotite gneiss, which correspond in a general way to the granodiorite gneiss and quartz monzonite gneiss, respectively, described here. Both of Stewart's map units, however, contain more than one kind of gneiss as well as large areas of Southington Mountain Schist.

Contacts between Prospect Gneiss and Southington Mountain Schist are generalized in some places on the geologic maps of Mount Carmel and Southington quadrangles, especially where the contacts are not parallel to foliation. The contact between these two units near the Old Litchfield Turnpike between Routes 63 and 69, for example, is about perpendicular to foliation in some places, and is somewhat generalized on the map of Mount Carmel quadrangle. Many outcrops near the contact in that area show small dikelike and sill-like fingers of Prospect Gneiss projecting into Southington Mountain Schist, and similar relations on a smaller scale can be seen in many places in Prospect and Bethany near the edges of small patches of Southington Mountain Schist included in the gneiss (pl. 12, fig. C). In mapping the northeastern boundary of the large stocklike body near Old Litchfield Turnpike, outcrops in which Southington Mountain Schist is more abundant than Prospect Gneiss were excluded from the stocklike body. Similarly, numerous small patches, or inclusions of Southington Mountain Schist surrounded by Prospect Gneiss were mapped in Bethany, Prospect, and western Cheshire. Where the patches of Southington Mountain Schist are abundant, for example in southern Bethany, the upper boundaries of the stocklike bodies of Prospect Gneiss probably are (or were) in a general way nearly parallel to the present surface of the ground, although foliation is steeply inclined.

The contact between the granodiorite gneiss and quartz monzonite gneiss in Bethany and northwestern Cheshire is gradational and is generalized on the geologic maps. The contact was mapped mainly on the basis of the abundance of coarse, euhedral to subhedral microcline crystals, which are abundant in the quartz monzonite gneiss, (pl. 12, fig. D), but are not characteristic of the granodiorite gneiss (pl. 12, fig. C).

Petrography

Granodiorite gneiss. The granodiorite gneiss is a medium- to coarse-grained, well-lineated, light-gray rock, with conspicuous dark-gray, biotitic foliae. Grain size is smaller in the small stocklike bodies north of Marion, Connecticut, than in the large stocklike bodies in Bethany and Prospect. The rock is composed mainly of oligoclase (An_{15-30}), quartz, biotite ($nY \fallingdotseq 1.640$), microcline, sphene, and clinozoisite. Accessory minerals are muscovite, hornblende, garnet, apatite, zircon, ilmenite, rutile, chlorite(+), pistacite, and pyrite. Near the centers of the large stocklike bodies, hornblende constitutes as much as a few percent of the rock and probably should be considered an essential mineral rather than an accessory mineral. Most microcline in the rock is anhedral and less than 5 mm. in diameter, but near Southington Mountain Schist and quartz monzonite gneiss the granodiorite gneiss in some exposures contains widely separated euhedral to subhedral microcline crystals as much as 1 inch long. Where the coarse microcline crystals are present, the composition of the rock is more quartz monzonitic than granodioritic.

The gneiss is characterized by sutured crystal boundaries, and the main minerals contain numerous inclusions. At the type locality, for example, oligoclase contains numerous clinozoisite crystals generally less than 0.1 mm. long (pl. 24, fig. A). The oligoclase is twinned according to the albite and Carlsbad laws, and some crystals show faint progressive zoning. Some of the oligoclase crystals also contain biotite, garnet, muscovite, quartz, and calcite, and some have antiperthitic intergrowths of optically continuous microcline. Myrmekite, an intergrowths of oligoclase and quartz, is rather abundant. Microcline also may contain small inclusions of quartz and oligoclase. Hornblende crystals as much as 5 mm. long have irregular boundaries, and are intergrown with oligoclase in some places. Many hornblende crystals contain small, euhedral to subhedral crystals of sphene and garnet, as well as anhedral quartz and biotite.

Crenulations similar to those found in mica-rich rocks of the Straits and Southington Mountain Schists were found in the granodiorite gneiss in western Cheshire. On a hill about 750 feet northeast of Route 70 and 1,200 feet east-southeast of Larsens Pond, for example, biotitic foliae in the gneiss delineate small folds, which in cross section resemble waves with amplitudes and wave-lengths as much as 1 inch. Near the axes of the crenulations, booklike biotite crystals are arranged in shinglelike aggregates; the crystals are not bent.

Quartz monzonite gneiss. The quartz monzonite gneiss is a medium- to coarse-grained, well-foliated and lineated rock, which contains abundant oligoclase (An_{10-30}), microcline, quartz, and biotite. In some places, especially near Marion, Connecticut, epidote constitutes as much as 1 per cent of the rock, and muscovite is equally abundant in Bethany. Typical accessory minerals are sphene, garnet, zircon, apatite, pyrite, and ilmenite. Except for the presence of very coarse microcline, the grain size of the rock is comparable to that of the granodiorite gneiss. Near Marion, Connecticut, microcline crystals as much as 1 inch in diameter are pinkish gray, oligoclase is grayish yellow green, biotite is pleochroic in green, and pistacite of the epidote group forms distinct crystals in the rock matrix. In Bethany, however, microcline crystals as much as 3 inches in diameter are white, oligoclase is white to light gray, biotite is pleochroic in brown, and the rock generally contains accessory clinozoisite rather than pistacite. Most of the large microcline crystals in the gneiss in both quadrangles are twinned according to the Carlsbad law; simple and penetration twins are common. In many outcrops, the large microcline crystals are euhedral to subhedral and are randomly oriented, but in some places they have been sheared to form augen approximately parallel to the main foliation of the gneiss. The abundance of microcline in this rock reflects a higher percentage of K_2O than is found in the granodiorite gneiss (table 1, columns 1 and 2).

The texture of the quartz monzonite gneiss is comparable to that of the granodiorite gneiss. Sutured contacts between minerals are common, and the main feldspars contain numerous inclusions.

Many oligoclase crystals contain distinct booklike crystals of muscovite (pl. 25, fig. A), as well as quartz and biotite. Numerous inclusions of clinozoisite account for the grayish yellow green color of oligoclase near Marion, Connecticut. Myrmekitic intergrowths of oligoclase and quartz are common (pl. 24, fig. B). Many coarse microcline crystals contain randomly oriented, anhedral crystals of oligoclase, microcline, and quartz (pl. 24, fig. B), as well as muscovite, clinozoisite, and biotite. Tiny quartz blebs are abundant near the edges of some of the large microcline crystals (pl. 24, fig. B).

Granitic to quartz monzonitic gneiss. The granitic to quartz monzonitic gneiss is a medium-grained, light-gray, moderately well foliated and lineated rock composed mainly of albite or oligoclase (An_{5-15}), microcline, quartz, muscovite, and biotite. Accessory minerals are garnet, apatite, and zircon. This rock is distinguished from the porphyroblastic quartz monzonite gneiss by lack of coarse microcline, and by slightly more felsic composition. Furthermore, muscovite is the coarsest mineral in some samples of the rock.

The texture of the granitic to quartz monzonitic gneiss is comparable to that of the other varieties of Prospect Gneiss. Plagioclase, for example, is anhedral and contains inclusions of quartz, muscovite, biotite and apatite. Microcline contains inclusions of quartz and muscovite.

Origin

Origin of the Prospect Gneiss has been controversial for many years because (1) the rock was not mapped in detail before 1957,

(2) the meaning of certain descriptive terms has changed, and (3) interpretation of field evidence has varied. The terminology used and interpretations made by several previous authors are reviewed here, and evidence of the origin of the rock is summarized.

The use and meaning of the words phenocryst, porphyritic, bed, and interstratified has varied in geologic literature. Silliman (1820, p. 203), Percival (1842, p. 26), and Gregory (Rice and Gregory 1906, p. 102) described Prospect Gneiss as a porphyritic rock, and Gregory referred to coarse microcline crystals in the gneiss as phenocrysts. Gregory (Rice and Gregory, 1906, p. 59, 60) explained that he used the word phenocryst, which means easily-seen crystal, to describe large minerals in both igneous and metamorphic rocks, and that he described the rocks as porphyritic regardless of origin. Today, however, the words phenocryst and porphyritic are used by many geologists only in descriptions of igneous rocks. Unusually large crystals in metamorphic rocks now are referred to as porphyroblasts, and the rocks are described as porphyroblastic. Further ambiguity can be found in the report by Percival (1842, p. 29) who described "...thick beds..." of porphyritic (Prospect) gneiss "...interstratified with..." more schistose rocks. To many readers, this description would imply that the gneiss is metasedimentary in origin, but Percival (1842, p. 34) also referred to dikelike and sill-like granitic intrusives as beds.

A meta-igneous origin for Prospect Gneiss first was proposed by Gregory (Rice and Gregory, 1906, p. 103), who interpreted the rock as a metamorphosed porphyritic granite. He believed that before metamorphism the original intrusive contained large randomly oriented "phenocrysts" of orthoclase, but he admitted that the "phenocrysts" may have developed during metamorphism, perhaps by absorption and enlargement of crystals after the rocks had become foliated (Dale and Gregory, 1911, p. 20). As evidence of metamorphism he emphasized that (1) the rock is foliated, (2) some of the "phenocrysts" have been somewhat flattened, crushed at the ends, and converted to microcline, and (3) some have been squeezed, broken, and rotated so that they are parallel to foliation in the gneiss (Rice and Gregory, 1906, p. 103). He implied that some of the orthoclase crystals were not converted to microcline, but no orthoclase was found in the gneiss during the current study. Gregory (Rice and Gregory, 1906, p. 101) also believed that some of the metasedimentary rocks along the southeastern side of the large stocklike body in southern Bethany underwent contact metamorphism when the Prospect was intruded. He mentioned that narrow bands of mica schist are distributed unevenly through the gneiss (Rice and Gregory, 1906, p. 102), and he apparently interpreted them as inclusions in the gneiss. On the other hand, he interpreted patches of amphibolite in the gneiss in Southington quadrangle as mafic intrusives (Rice and Gregory, 1906, p. 103), but he offered no evidence in support of this conclusion. In fact, he stated that no contacts between the gneiss and adjacent rocks are visible.

Stewart (1935) attempted to show that the Prospect Gneiss is an unmetamorphosed, igneous rock formed, in part, by replacement, but some of his statements and conclusions contradict field evidence as well as descriptions by Gregory. For example, Stewart (1935, p. 27-29) stated that the gneiss never crosscuts the adjacent schist, and there is no evidence of strong cataclasis or of superposed foliation. The geologic maps of Mount Carmel and Southington quadrangles (pls. 1 and 2), however, show clearly that foliation crosses the boundaries of large stocklike bodies of Prospect Gneiss in Bethany and Cheshire. Furthermore, Gregory (Rice and Gregory, 1906, p. 103) had described obviously deformed microcline crystals in the gneiss, and Stewart (1935, p. 22), himself, described augen of sodic oligoclase, which are characteristic of metamorphic rocks. Stewart (1935, p. 31) also denied that there is any evidence of contact metamorphism near the gneiss, but vesuvianite and wollastonite in calc-silicate rocks in Southington quadrangle can be interpreted as contact metamorphic minerals.

Stewart (1935, p. 28-30) concluded that the Prospect Porphyritic Gneiss of Gregory was formed by injection of granitic magma, which he called Prospect Granite, into previously deformed schists. He believed that metamorphism preceded the igneous activity, and that foliation in the gneiss was inherited from the schists. Stewart (1935, p. 34,35) interpreted inclusions of muscovite in oligoclase as remnants that remained after partial assimilation or replacement of muscovite-bearing foliae in the gneiss, but he apparently did not consider the possibility that the muscovite inclusions could have formed during metamorphism of the intrusive. Stewart (1935, p. 13, 14) emphasized that the gneiss contains schistose inclusions, which resemble xenoliths in an igneous intrusive, and that foliation in the gneiss is continuous with or parallel to foliation in the schist. He also stressed mineralogical gradation between the gneiss and inclusions of "hornblende-biotite schist" (amphibolite) at locality S-13 near Route 68 in Prospect. In contrast to Gregory's interpretation, the gradation suggests that the amphibolites in Prospect Gneiss are not mafic intrusives younger than the gneiss, but it also suggests that the gneiss and the amphibolite inclusions underwent metamorphism at the same time.

Granitization of metasedimentary rocks to form Prospect Gneiss was suggested by Rodgers (Rodgers and others, 1959, p. 40) and apparently favored by Carr (1960, p. 21), who interpreted the gneiss as a "...metamorphosed derivative..." of metasedimentary rocks equivalent to Southington Mountain Schist. Carr (1960, p. 17) suggested that the gneiss is of local origin and formed by partial mobilization of the metasedimentary rocks. In the area studied by Carr, however, and in the Mount Carmel and Southington quadrangles, Prospect Gneiss is in the staurolite and kyanite zones of progressive regional metamorphism, and it is unlikely that the intensity of metamorphism was high enough to have formed the gneiss by granitization of metasedimentary rocks. Carr (1960, p. 14, 17) also stated that Prospect Gneiss occupies a consistent stratigraphic position, but the geologic maps of Mount Carmel and Southington quadrangles (pls. 1 and 2) show that the gneiss forms stocklike bodies rather than stratigraphic units.

The meta-igneous origin of Prospect Gneiss proposed by Gregory is favored by the author, although the large euhedral to subhedral microcline crystals in the rock are believed to be porphyroblasts rather than phenocrysts of igneous origin. Intrusion of an original magma, from which the gneiss formed, is suggested by the shape of the main bodies of the gneiss, and the presence of xenoliths of Southington

Mountain Schist in the gneiss. The large mass of Southington Mountain Schist near Darcy School in western Cheshire is interpreted as a pendant projecting downward into the upper part of a stock of Prospect Gneiss. Metamorphism of the rock after intrusion of the original magma is suggested by the fact that foliation crosses the boundaries of the large stocklike bodies in Bethany and western Cheshire.

The textures described and illustrated in this report also indicate recrystallization of the original intrusive. Clinozoisite crystals in oligoclase, for example, are not characteristic of igneous rocks, but suggest that calcic plagioclase has been recrystallized. Similarly, muscovite inclusions in plagioclase suggest recrystallization of potassium-bearing, sodic plagioclase, which may have undergone previous deuteric alteration to sericite. The presence of garnet in plagioclase also suggests metamorphism. Late development of the large microcline crystals characteristic of the porphyroblastic quartz monzonite gneiss is suggested by the presence of numerous inclusions of quartz, plagioclase, and anhedral microcline, and by the fact that large microcline crystals, which contain similar inclusions, also formed in the porphyroblastic schist of Southington Mountain Schist adjacent to the gneiss near Marion, Connecticut. Recrystallization of the granodiorite gneiss after foliation planes were crenulated in western Cheshire is suggested by the fact that biotite crystals near the axes of crenulations are not bent, but form shinglelike aggregates. The crenulations are near the axial plane of a major foliation syncline, which is discussed under the heading Geologic Structure. Recrystallization of plagioclase, the formation of porphyroblasts, and the possibility of contact metamorphism near Prospect Gneiss are discussed under the heading Metamorphism.

Ansonia gneiss

General features

Ansonia Gneiss is a granitic to quartz monzonitic gneiss, which forms tabular to irregular bodies a few inches to more than 1,500 feet wide and as much as 8,500 feet long. The rock crosscuts Prospect Gneiss and Southington Mountain Schist. Numerous small dikelike and sill-like bodies of the Ansonia were mapped in the Towns of Bethany and Prospect in Mount Carmel quadrangle, but the boundaries of most of the bodies mapped are generalized. The map units may contain inclusions of Prospect Gneiss and (or) Southington Mountain Schist. Ansonia Gneiss was not mapped in Southington quadrangle. The gneiss has not been found in the Derby Hill and Wepawaug Schists in the map area, but small bodies of rock similar to Ansonia Gneiss have been found in Wepawaug Schist west of the staurolite isograd in Ansonia quadrangle.

Ansonia Gneiss was named Ansonia Granite for Ansonia, Connecticut, by Carr (1960, p. 18), but was renamed by Fritts (in press, a). Carr (1960, p. 19) described the rock as a gneiss recrystallized after intrusion. The type locality is an abandoned quarry near Ansonia, Connecticut, about 4 miles west-southwest of Mount Carmel quadrangle. The quarry was described by Dale and Gregory (1911, p. 78-79). Ansonia Gneiss was referred to as Thomaston Granite by Stewart (1935, p. 27, 28), but Thomaston Granite at the type area in Thomaston, Connecticut, differs from Ansonia Gneiss in that the Thomaston lacks foliation and lineation. The Thomaston probably is younger than Ansonia Gneiss, but does not crop out in the map area.

Ansonia Gneiss is similar to the granitic to quartz monzonitic gneiss, DOpm, of Prospect Gneiss mapped in Southington quadrangle, but differs from other igneous and meta-igneous rocks in the map area. Excellent foliation and lineation and a generally high percentage of microcline in Ansonia Gneiss distinguish this rock from the Woodtick Gneiss and Woodbridge Granite, although the percentage of microcline in Woodbridge Granite varies. Plagioclase in Ansonia Gneiss is more sodic than plagioclase in the Woodtick Gneiss, and is distinguished from plagioclase in Woodbridge Granite by anhedral crystal form and lack of zoning. The Ansonia is finer grained and contains less biotite and more muscovite than the main granodiorite and quartz monzonite gneisses, of Prospect Gneiss. Ansonia Gneiss contains less iron and magnesium than Prospect Gneiss and more potassium than some samples of Woodbridge Granite (table 1, columns 1 to 4).

Petrography

Typical Ansonia Gneiss is a medium-grained, well-foliated, and well-lineated, very pale bluish-gray, quartz monzonite gneiss. Quartz, oligoclase (An_{10-15}), and microcline in nearly equal amounts comprise about 90 per cent of the rock, but muscovite and biotite in the approximate ratio 3:1 or 2:1 also are essential minerals. Accessory minerals are apatite, zircon, garnet, and a little magnetite. In some places, microcline is more abundant than oligoclase, and the gneiss is granitic, but the rock is quartz monzonitic at the type locality.

The texture of Ansonia Gneiss (pl. 25, fig. C) is comparable to those of the Woodtick and Prospect Gneisses. The main minerals in the Ansonia are anhedral, and contacts between minerals are sutured. Plagioclase crystals contain numerous irregular to nearly spherical inclusions of quartz, and micrographic intergrowths of the two minerals are common. Some of the microcline also contains inclusions of quartz, but intergrowths of microcline and plagioclase are not common. In some samples, distinct booklike crystals of muscovite are included in plagioclase. Garnet is subhedral to anhedral and may contain inclusions of quartz, mica, and feldspar. Many garnets, however, lack inclusions of other minerals.

Origin

The shape of Ansonia Gneiss bodies and the texture of the rock indicate that the gneiss is a metamorphosed intrusive. Foliation and lineation cross contacts of dikelike and stocklike bodies of the Ansonia in Prospect Gneiss and Southington Mountain Schist. This relationship indicates that the Ansonia was metamorphosed at the same time as the adjacent rocks. The Ansonia Gneiss if found only in the staurolite and kyanite zones (pl. 3). It is more felsic than the Woodtick and Prospect Gneisses, but is chemically somewhat similar to Woodbridge Granite (table 1, columns 3 and 4). The Woodbridge is found only east of the staurolite isograd in Mount Carmel quadrangle, but in Ansonia quadrangle gneissic equivalents of the Woodbridge are found west of the staurolite isograd. It is possible, therefore, that some of the rocks mapped as Ansonia Gneiss are metamorphic equivalents of some of the rocks mapped as Woodbridge Granite.

Woodbridge Granite

General features

Woodbridge Granite includes oligoclase granite and porphyritic felsite dikes intruded mainly into Wepawaug Schist in the Towns of Woodbridge and Bethany in the southwestern part of Mount Carmel quadrangle. The granite forms tabular to irregular bodies as much as 2,000 feet long and 750 feet wide, which in some places contain large xenoliths of phyllitic schist (pl. 13, fig. A). The felsite forms dikelike and sill-like bodies generally less than 40 feet in width, and contains numerous inclusions of phyllitic schist and phyllite from a fraction of an inch to several inches long. Many felsite bodies are only a few inches to a few feet wide, but they were mapped in order to show distribution. One dike of porphyritic felsite intruded the largest body of oligoclase granite in Woodbridge. A sill-like body of felsite a few inches wide, which intruded Southington Mountain Schist west of Lake Chamberlain, is the only body of Woodbridge Granite found in the area not underlain by Wepawaug Schist.

Woodbridge Granite was named by Fritts (in press, a) for Woodbridge, Connecticut. The type locality is about 1/2 mile northwest of Glen Dam Reservoir. Percival (1842, p. 20) mapped and described the rock at the type locality as "...a variety of Granite..." and referred to the porphyritic felsite as "...a peculiar Felspathic rock..." Neither the granite nor the felsite, however, was mapped by subsequent authors until 1957.

The typical Woodbridge is referred to here as oligoclase granite, but it also might be classified as quartz diorite. According to a classification of igneous rocks by Peterson (1961, p. 32), for example, a quartz-rich igneous rock in which more than 90 per cent of the feldspar is sodic plagioclase could be called quartz diorite, although normally andesine rather than sodic oligoclase is the predominant plagioclase in quartz diorite. Although oligoclase in the Woodbridge is close to albite in composition, the rock at the type locality contains very little potassium feldspar. A low percentage of potash in at least one sample of the rock is confirmed by a chemical analysis (table 1, column 4). Some of the porphyritic felsite, on the other hand, contains albite and a moderate amount of microcline. Thus the composition of at least some of the fine-grained Woodbridge is more like that of a normal granite.

Petrography

Oligoclase granite. The oligoclase granite is a medium- to coarse-grained, equigranular, very pale greenish white rock, which has a pale grayish-yellow, slightly weathered rind as much as 10 mm. thick on most outcrops. Sodic oligoclase (An_{10-15}) and quartz in the approximate ratio 2:1 comprise nearly 90 per cent of the rock. Oligoclase crystals as much as 6 mm. in diameter are the coarsest minerals in the rock. Muscovite, biotite, and microcline in the approximate ratio 5:2:1 are the other essential minerals. Accessory minerals are pyrite, apatite, and zircon. A little secondary calcite also is present in some samples.

The texture of the granite is simple, although the rock has been subjected to cataclasis. Oligoclase crystals are euhedral to subhedral and are twinned according to the albite, Carlsbad, and pericline laws (pl. 26, fig. A). Many of them also show distinct, normal, progressive zoning. The oligoclase crystals are slightly sericitized, especially in the cores, but they lack inclusions of other minerals. Some plagioclase crystals have been broken, and twin lamellae of a few have been bent. Although fragments of the broken crystals have been cemented together by quartz, the original euhedral outlines of the oligoclase crystals are clearly visible. All of the oligoclase crystals in the rock appear to be floating in a matrix composed of abundant anhedral quartz, a little anhedral microcline, and booklike crystals of muscovite and biotite. The quartz has been sheared and granulated, and much of it is characterized by extreme undulatory extinction. Many of the booklike crystals of muscovite and biotite have been bent, especially around sharp corners of oligoclase crystals.

Porphyritic felsite. The porphyritic felsite is characterized by a fine-grained groundmass and randomly oriented phenocrysts of plagioclase, quartz, microcline, and muscovite as much as 2 mm. in diameter (pl. 26, fig. B). The groundmass is composed of interlocking crystals of albite, quartz, and microcline or orthoclase, as well as small booklike crystals of muscovite and minor biotite. Accessory minerals are pyrite, apatite, and zircon. Most of the phenocrysts are plagioclase, which ranges in composition from calcic albite to sodic oligoclase (An_{5-15}). In general, they display twinning and euhedral to subhedral outlines like the plagioclase in the coarser oligoclase granite. However, in the felsite intruded into the oligoclase granite, plagioclase phenocrysts are subhedral and have sieve-like rims, which are intergrown with finer grained feldspar and quartz of the groundmass. Most of the other phenocrysts in the typical felsite are anhedral. In some places, an apparent flow structure is visible in the rock. This structure is caused by the arrangement of muscovite and biotite in the felsite parallel or nearly parallel to contacts between the felsite and adjacent rocks.

Origin

The shape of bodies of Woodbridge Granite, as well as the texture of the rock, indicate that the granite is of igneous origin. Dikes and irregular bodies of the granite crosscut relict bedding in the Wepawaug Schist and contain xenoliths of the schist. The shape of plagioclase crystals in the granite is like that of plagioclase phenocrysts in the Buttress Diabase, which is undoubtedly an igneous rock. In contrast to plagioclase in the meta-igneous Woodtick, Prospect, and Ansonia Gneisses, plagioclase in the granite is euhedral to subhedral and lacks inclusions of other minerals, except sericite. The sericite, however, can be explained as a product of deuteric alteration rather than metamorphism.

Pegmatite and related quartz

General features

Irregular to lenticular bodies of pegmatite and lenses and pods of quartz are found in most of the rocks of pre-Triassic age in the map area, but are largest and most abundant in the Southington Mountain Schist. Large bodies of pegmatite are more numerous than large bodies of quartz, but quartz veins as much as a few feet long and a few inches wide are abundant, especially in metasedimentary rocks. In general, only pegmatites and quartz veins more than 10 feet in diameter or width were mapped, but the size of some bodies was exaggerated on the geologic maps. The largest body of pegmatite mapped is about 900 feet long and 700 feet wide; it is in Southington Mountain Schist northwest of New Britain Reservoir. An unusually large body of quartz, on the other hand, in the same formation is only about 40 feet long and 15 to 20 feet wide; it is approximately 2,800 feet southwest of the intersection of Cheshire Road and Route 69 in Bethany.

Apparent gradation from pegmatite to vein quartz by decrease in feldspar content can be seen in the southwestern part of Mount Carmel quadrangle, and is consistent with a decrease in metamorphic grade of the adjacent metasedimentary rocks. Although pegmatite was not mapped in areas underlain by the Derby Hill and Wepawaug Schists, some quartz veins in those formations contain macroscopic feldspar. In general, the percentage of feldspar in quartz veins in phyllite near Glen Dam Reservoir and Lake Watrous is lower than the percentage of feldspar in quartz veins in phyllitic schist near Lake Chamberlain.

The possibility that some rocks mapped as pegmatite, Dp should have been mapped as metamorphosed pegmatite, pЄp, was mentioned in the discussion of general features of the metamorphosed pegmatite, pЄp. The possibility that some quartz veins in the Waterbury and Woodtick Gneisses were emplaced before quartz veins in the Straits Schist, for example, is considered in the distcussions of metamorphism and geologic age.

Petrography

The pegmatites are generally coarse-grained, white to pinkish gray, granitic to quartz monzonitic rocks composed mainly of albite or oligoclase (An_{0-20}), quartz, microcline, and muscovite. Accessory minerals are biotite, chlorite(+), magnetite or ilmenite, apatite, tourmaline, zircon, kyanite (in the kyanite zone only), and calcite. Some bodies of pegmatite are slightly foliated, but many are relatively unfoliated. Some bodies contain subhedral microcline crystals as much as 6 inches long, which contain graphic intergrowths of quartz, but many contain little or no microcline.

The texture of the typical pegmatite is simple (pl. 27, fig. B). Although contacts between minerals are sutured, there is no evidence of crushing and subsequent recrystallization like that characteristic of the metamorphosed pegmatite, pΘp. Some plagioclase contains sericite, which can be interpreted as a product of deuteric alteration. Some plagioclase contains small anhedral calcite crystals, which probably formed by replacement of original plagioclase.

Origin

The pegmatites and quartz veins are believed to be, for the most part, products of the latest progressive regional metamorphism, although it is possible that some bodies of these rocks were emplaced after the main metamorphism. The rocks form dikes, stocklike, and sill-like bodies in metamorphic rocks, and sutured contacts between minerals in the pegmatite resemble those of other metamorphic rocks in the area. Furthermore, foliation in some of the pegmatites is more or less continuous with, or parallel to foliation in the adjacent metamorphic rocks. The fact that in most places the pegmatites are not characterized by strong foliation suggests that emplacement occurred at about the time of the climax of the progressive regional metamorphism. The pegmatites, like most metamorphic rocks in the area, have undergone subsequent retrograde metamorphism.

METAMORPHISM

General Features

Most rocks of pre-Triassic age in the map area have undergone at least one of three kinds of metamorphism, each of which involved the formation of new minerals from constituents in pre-existing rocks. Progressive regional metamorphism caused the formation of mineral assemblages stable under conditions of increased temperature and pressure. Retrograde metamorphism, on the other hand, resulted in the transformation of certain minerals such as biotite to new minerals such as chlorite stable under conditions of temperature and pressure lower than those under which the original mineral formed. It is likely that metasedimentary rocks such as the Southington Mountain Schist adjacent to intrusives such as the Prospect Gneiss also underwent contact metamorphism, as a result of increased temperature near intrusive bodies. Each kind of metamorphism is discussed under an appropriate heading.

Progressive Regional Metamorphism

Most rocks of pre-Triassic age in the Western Highland of Connecticut have undergone progressive regional metamorphism at least once. In general, the intensity of the latest progressive regional metamorphism was low near New Haven, Connecticut (pl. 3), and increased toward the west-northwest. However, near the boundary between Connecticut and New York the intensity of metamorphism decreased. As a result, the range in metamorphic grade of rocks in Dutchess County, New York (fig. 1) is comparable to that near New Haven (Barth, 1936, pl. 1) but the arrangement of metamorphic zones is more or less reversed on opposite sides of the Highland.

Five metamorphic zones were recognized in the map area. Isograds shown on the maps (pls. 1, 2, and 3) mark the approximate eastern limits of zones in which garnet, biotite, staurolite, and kyanite are the highest grade metamorphic index minerals in pelitic rocks. East of the garnet isograd, chlorite is the highest grade metamorphic index mineral in pelitic rocks. The zones in which these five minerals first appear, generally as porphyroblasts, are referred to here as the chlorite, garnet, biotite, staurolite, and kyanite zones. Minerals characteristic of these zones are listed in Table 3. No sillimanite has been found in the map area or in Naugatuck quadrangle (Carr, 1960, p. 24), but sillimanite is abundant in some formations in the western part of Connecticut.

The main difference between the arrangement of isograds in the map area and in Dutchess County, New York, is in the sequence of zones of low grade metamorphism. In Dutchess County, for at least one mile west of the garnet isograd pelitic rocks contain biotite but lack garnet (Barth, 1936, pl. 1). In the map area, on the other hand, for several hundred feet east of the biotite isograd pelitic rocks contain garnet porphyroblasts but generally lack porphyroblasts of biotite. Garnet apparently preceded biotite in this area, because the ratio MgO/FeO in phyllite from the Wepawaug Schist (table 1, column 6) is only about 0.47, whereas the ratio in biotitic phyllite from Dutchess County is 0.64 to 0.67 (Barth, 1936, table 13, columns 4 and 5).

At least one previous author concluded that the latest progressive regional metamorphism in and near the map area was caused by emplacement of the Prospect Gneiss (Barrell, 1921, p. 14, 15). However, the distribution of isograds in the Ansonia, Naugatuck, Mount Carmel, and Southington quadrangles, in general, is unrelated to the outline of the stocks of Prospect Gneiss. The isograds do not surround the stocks. In fact, the kyanite isograd apparently crosses a large stock of Prospect Gneiss in the Ansonia and Naugatuck quadrangles (pl. 3). It is clear, therefore, that this metamorphism was superimposed on Prospect Gneiss rather than caused by emplacement of the gneiss.

The crystallization of feldspars in the metamorphic rocks is especially noteworthy, in view of the possibility that Ansonia Gneiss might be interpreted as a metamorphic equivalent of Woodbridge Granite. Although very fine-grained albite was identified in phyllite from the chlorite zone by using index liquids and X-ray diffraction methods, albite coarse enough to be identified in thin section was found only in samples of metamorphic rocks from the biotite zone and farther west. Small oligoclase crystals were identified in thin sections of phyllitic schist prepared from samples collected a few hundred feet east of the staurolite isograd near Sargent River in Bethany, and oligoclase is common in metamorphic rocks farther west. Tiny microcline crystals were identified optically in the samples of biotitic limestone from near Bethany Lake, but microcline is not abundant in metamorphic rocks east of the staurolite isograd. It is obvious, therefore, that the temperature in the chlorite, garnet, and eastern part of the biotite zones, in general, was not high enough for large amounts of oligoclase and microcline to form by recrystallization of previously formed rocks. Furthermore, it is apparent that original oligoclase and microcline in rocks such as Woodbridge Granite would be more or less stable in the chlorite, garnet, and biotite zones, but would be completely recrystallized in the staurolite and kyanite zones.

Large microcline crystals in the Prospect Gneiss are believed to be porphyroblasts, which formed during progressive regional metamorphism. The fact that small microcline crystals are abundant in metasedimentary rocks in the staurolite and kyanite zones indicates that the temperature in those zones during progressive regional metamorphism was high enough for microcline to form by recrystallization of pre-existing rock. When intrusives such as the Prospect are subjected to metamorphism, the sequence of recrystallization should be approximately the reverse of Bowen's reaction series. Thus, potassium feldspar, which forms late in the sequence of crystallization from a magma, should be the first feldspar to be recrystallized during metamorphism.

The northwestward increase in metamorphic grade of the rocks in the southeastern part of the Western Highland of Connecticut (pl.3) is accompanied by a marked increase in internal shearing and recrystallization, which obliterated pre-metamorphic textures. Except for flattened pebbles of metavolcanic rock in chloritic muscovite schist in the southeastern corner of Ansonia quadrangle, outlines of clastic fragments in metasedimentary formations in the area have been destroyed.

Where rocks have undergone more tectonic thinning, especially in zones of higher grade metamorphism, they undoubtedly have undergone more shearing and recrystallization. Thus, structures such as graded bedding are poorly preserved in the kyanite zone west of the Housatonic River (pl. 3).

In the Mount Carmel and Southington quadrangles, the northwestward increase in shearing was accompanied and followed by recrystallization. In the chlorite zone, phyllite characteristic of the Wepawaug Schist generally has smooth foliation planes, although secondary s-planes formed in some muscovite-rich layers (pl. 23, fig. A). West of the garnet isograd, however, phyllitic schist characteristic of the Wepawaug has wavy foliation planes and more secondary s-planes. In thin section, undulatory extinction in quartz is much more characteristic of rocks in the garnet and biotite zones than in the chlorite zone. In this area, extreme undulatory extinction in quartz is characteristic of Derby Hill Schist, which is entirely in the biotite zone. Within a few hundred feet of the staurolite isograd, quartz in rocks in the western part of the biotite zone lacks undulatory extinction, although biotite and garnet porphyroblasts were sheared before the rock underwent final recrystallization. In the staurolite zone, large microcline crystals in the quartz monzonite gneiss of Prospect Gneiss in Bethany were sheared to augen in some places, but recrystallization continued after shearing. Quartz in the gneiss does not show strong undulatory extinction in thin section. Furthermore, where foliation planes in the gneiss and in micaceous rocks of the Straits and Southington Mountain Schists are crenulated, undeformed mica crystals wrap around the axes of small folds as shinglelike aggregates, and must have reached their present crystalline state during recrystallization after folding.

Retrograde Metamorphism

All rocks of pre-Triassic age in the map area, except bodies of quartz, underwent slight alteration during a period of retrograde metamorphism after the climax of the latest progressive regional metamorphism. Minerals were altered as follows: kyanite to sericite, staurolite to sericite, biotite to chlorite(-), garnet to sericite and chlorite, pyrite to hematite, and rutile and ilmenite to leucoxene. The distribution of the altered minerals appears to be random.

Retrograde metamorphism of Waterbury Gneiss is believed to have occurred during the latest progressive regional metamorphism. Similar metamorphism of the Mount Holly Complex of Vermont, which occupies a structural and stratigraphic position comparable to that of the Waterbury Gneiss (Fritts, in press, a), was indicated by Doll and others (1961). Although no sillimanite was found in the Waterbury in the map area, it is believed that much of the fine-grained kyanite in the main paragneiss formed by recrystallization of sillimanite. None of the kyanite in the paragneiss is more than 0.1 mm. long, and some crystals are nearly acicular. The crystal habit is unusual, and is more like that of sillimanite than kyanite. Furthermore, the 2-inch "knots" composed almost entirely of fine-grained kyanite, which are found in the paragneiss in northern Prospect and elsewhere in Southington quadrangle, also are unusual. They are about the same size and shape as aggregates of sillimanite found in high grade metamorphic rocks in the Eastern Highland of Connecticut (Richard Goldsmith, U. S. Geological Survey, oral communication). A complex metamorphic history for Waterbury Gneiss also is suggested by the following characteristics of the formation: (1) two ages of garnet in paragneiss, (2) intimate intergrowths of garnet, biotite, and oligoclase in paragneiss, (3) extreme variation in grain size of garnet in the Hitchcock Lake Member, and (4) the abundance of feldspathic impregnations and antiperthitic intergrowths of plagioclase and microcline in the Hitchock Lake Member.

Contact Metamorphism

Contact metamorphism of Southington Mountain Schist adjacent to Prospect Gneiss is believed to have occurred before the latest progressive regional metamorphism. Although in most places evidence of early metamorphism is obscured by superimposed progressive regional metamorphism, the following facts are significant: (1) vesuvianite and wollastonite, which are typical contact metamorphic minerals, are found only in Southington Mountain Schist included in Prospect Gneiss, (2) graphite, which is fine-grained and abundant in Southington Mountain Schist away from Prospect Gneiss, is coarser and less abundant in the schist near the gneiss, and (3) muscovite and garnet in the schist near the gneiss are coarser than in the schist in the type area. Paragneiss bands in Southington Mountain Schist near Prospect Gneiss are slabby in some places, especially east of the Larsens Pond fault and in southern Bethany. The rocks in both areas are approximately parallel to the north-northeast regional trend of major structures, where the formations were subjected to more shearing during the latest progressive regional metamorphism than rocks on the northern side of the Waterbury dome. However, quartz and feldspar are slightly more abundant in some samples collected from the slabby paragneiss bands near the gneiss than in paragneiss bands in the vicinity of Southington Mountain.

AGE AND CORRELATION

Geologic ages ranging from Precambrian to Silurian and Devonian were assigned to metasedimentary formations in the western part of the map area on the basis of correlation of rocks in south-central Connecticut (pl. 3) and southeastern Vermont (Fritts, in press, a). Direct correlation between the map area and Vermont is impossible at the present time, because (1) detailed geologic mapping in the intervening area is incomplete, (2) some of the pre-Triassic rocks are covered by strata of Triassic age in central Connecticut and Massachusetts, and (3) no fossils have been found in the metasedimentary rocks in Connecticut. However, metasedimentary formations in both areas are lithologically similar and occupy comparable structural and stratigraphic positions. Possible equivalence of formations was outlined by Rodgers and others (1959, p. 14, 15), and the stratigraphic section was refined further in the course of current mapping by the author in the Ansonia, Mount Carmel, and Southington quadrangles (pl. 3). The Waterbury Gneiss in Connecticut and the Mount Holly Complex in Vermont form the cores of partly preserved domes, which are in line with other domelike structures in western Connecticut and Massachusetts (Rodgers and others, 1959; Emerson, 1917, pl. 10; Doll and others, 1961). The stratigraphic sequence from Waterbury Gneiss to Wepawaug Schist in Connecticut appears to be the approximate equivalent of the sequence from Mount Holly Complex to Waits River Formation in Vermont (table 4).

TABLE 4. Approximate equivalence of metasedimentary formations in south-central Connecticut and southeastern Vermont. (Not meant to show exact equivalence or complete stratigraphic sections)

Connecticut		Vermont		Geologic age
Interpretation of nomenclature of Rodgers and others (1959, p. 14, 15)	Nomenclature of Fritts	Nomenclature of Doll and others (1961)		
"Main body" of Orange Phyllite	Wepawaug Schist	Waits River Formation Northfield Formation		Devonian and Silurian
Milford Chlorite Schist	Metavolcanic and metasedimentary rocks, undivided	Missisquoi Formation	Barnard Volcanic Member	Ordovician
West-central part of Orange Phyllite	Derby Hill Schist		Moretown Member	
West edge of Orange Phyllite and upper part of The Straits Schist Member of the Hartland Formation	Southington Mountain Schist	Stowe Formation Ottauquechee Formation Pinney Hollow Formation		Ordovician and Cambrian
Lower part of The Straits Schist Member of the Hartland Formation	Straits Schist	Hoosac Formation		Cambrian
Waterbury Gneiss	Waterbury Gneiss	Mount Holly Complex		Precambrian

The latest progressive regional metamorphism in the map area is believed to have occurred mainly in Middle to Late Devonian time. Age determinations made on micas from several localities in southeastern New York and near Branchville, Connecticut (fig. 1) suggest that the latest progressive regional metamorphism of pre-Triassic rocks there occurred about 365 million years ago (Long and Kulp, 1958, p. 604). On the other hand, two recent potassium-argon age determinations (table 5) made on biotite from the Woodtick and Prospect Gneisses from Southington quadrangle suggest that this mineral reached its present crystalline state about 315 million years ago, presumably when the temperature of metamorphic rocks in the staurolite and kyanite zones fell below 300° C. after metamorphism. These data suggest that the latest progressive regional metamorphism in the Western Highland of Connecticut took place sometime between 315 and 365 million years ago, but most of the age determinations have given values close to 365 million years. According to a recent revision of the geologic time scale (Kulp, 1961, fig. 1) the data available suggest that the metamorphism occurred in Middle to Late Devonian time and perhaps in Mississippian time. The metamorphosed rocks, therefore, most likely are not younger than Devonian. Although rocks of Pennsylvanian age in Rhode Island have undergone similar metamorphism (Quinn, 1959), it is doubtful that this rather late metamorphism also affected the rocks of western Connecticut. The metamorphic grade of rocks in the map area increases toward the west rather than toward the east.

The age of the Woodtick Gneiss is believed to be Precambrian. The rock must have been emplaced before the climax of the latest progressive regional metamorphism. The gneiss has not been found

TABLE 5. Potassium-argon age determinations on biotite

Map unit	Laboratory number	Rock	Locality number and description	1/ K_2O (percent)	K^{40} (ppm)	2/ Ar^{40} (ppm)	$\frac{Ar^{40}}{K^{40}}$	3/ Calculated age (m.y.)
Prospect Gneiss	FPG-200 (F-1)	Granodiorite gneiss	(2) Type locality, NE Prospect, Conn.	8.54	8.56	0.173	0.0202	315
Woodtick Gneiss	FWG-250 (F-2)	Quartz diorite gneiss	(5) 1 mile NE of Woodtick, Conn.	7.84	7.86	0.159	0.0202	315

1/ Potassium determinations made with a Perkin-Elmer flame photometer using a Li internal standard by P. L. D. Elmore and I. H. Barlow, U. S. Geological Survey.

2/ Argon determinations by mass spectrometry, stable isotope dilution method, by H. H. Thomas, U. S. Geological Survey.

3/ The potassium-argon ages were calculated from the following equation:

$$t = \frac{1}{\lambda_e + \lambda_\beta} \ln \left(1 + \frac{\lambda_e + \lambda_\beta}{\lambda_e} \cdot \frac{Ar^{40}}{K^{40}} \right)$$

The following constants were used: K^{40} decay, $\lambda_e = 0.589 \times 10^{-10}/\text{yr.}$

$\lambda_\beta = 4.76 \times 10^{-10}/\text{yr.}$

$K^{40} = 1.21 \times 10^{-4}$ gm/gm K

Analytical error is approximately ±5 percent of the quoted age value.

intruding Straits Schist or younger rocks, and there is no clearcut relationship between emplacement of the Woodtick and formation of the Waterbury dome. The main body of the gneiss is at one side of the dome rather than in the center. In other words, no indisputable evidence can be cited to show that the Woodtick is younger than the Straits Schist of Cambrian age. The Straits is believed to overlie the Waterbury unconformably (see section covering geologic structure), and the possibility that the Woodtick intruded the Waterbury in pre-Straits time, that is Precambrian time, cannot be denied. If the age of the Woodtick is Precambrian and the Waterbury Gneiss has been metamorphosed more than once, it is possible that the Woodtick also underwent metamorphism more than once. Age determinations on radioactive minerals, therefore, might not be reliable. Nevertheless, age determinations on zircon from the Woodtick, especially at the type locality (table 6) suggest a possible Precambrian to Cambrian age for the rock.

The age of the Prospect Gneiss is uncertain, although the rock must have been emplaced before the climax of the latest progressive regional metamorphism. The porphyroblastic quartz monzonite gneiss exposed in Bethany is similar to the Kinsman Quartz Monzonite of New Hampshire, which is believed to be Devonian in age (Billings, 1955). The Prospect intrudes the Southington Mountain Schist of Cambrian and Ordovician age, but has not been found in rocks stratigraphically above this formation. Thus the Prospect cannot be older than Ordovician, but might be as young as Devonian. Three consistent age determinations on zircon from the Prospect Gneiss (table 6) suggest a possible Ordovician age for the rock. In view of the fact that there is an unconformity at the base of the Wepawaug Schist (see section concerning geologic structure), there is no clearcut evidence to show that the Prospect is younger than the Wepawaug Schist of Silurian and Devonian age. Nevertheless, the possibility that the Prospect was emplaced after initial folding of the Wepawaug cannot be denied. In fact, the arrangement of the main stocks of Prospect Gneiss (pl. 3) suggests that the original intrusive was emplaced during a period of regional folding that preceded and accompanied the progressive regional metamorphism in Middle to Late Devonian time. Tentatively, however, the age of the Prospect Gneiss is reported as Ordovician or Devonian, pending further investigation of the age of radioactive minerals from the rock.

The age of the Ansonia Gneiss also is reported tentatively as Ordovician or Devonian. In the Mount Carmel quadrangle, the Ansonia Gneiss intrudes Prospect Gneiss and Southington Mountain Schist, but is not known to have intruded the Derby Hill and Wepawaug Schists. In the Ansonia quadrangle, on the other hand, small bodies of rock somewhat similar to Ansonia Gneiss intrude Wepawaug Schist. The Ansonia, therefore, may be as young as Devonian, but probably is not older than Ordovician. If the age of the Prospect Gneiss is Devonian rather than Ordovician, the age of the Ansonia Gneiss must be Devonian.

The age of Woodbridge Granite probably is Devonian. The Woodbridge strongly resembles a granitic rock of probable Devonian age, which forms small plutons in the Waits River Formation near Interstate Route 91 south of Brattleboro, Vermont (see Doll and others, 1961). The Woodbridge intrudes tightly folded Wepawaug Schist, which is believed to be approximately equivalent to the Waits River Formation. In view of the fact that the age of the Wepawaug probably is Silurian and Devonian, the Woodbridge cannot be older than Devonian.

Emplacement of the Woodbridge is believed to have occurred after the Wepawaug Schist was folded, but before or during the latest progressive regional metamorphism. In Mount Carmel quadrangle the Woodbridge is found only east of the staurolite isograd, and oligoclase in the rock has not been recrystallized. However, the Woodbridge and the surrounding metasedimentary rocks it intruded were subjected to cataclasis during the latest progressive regional metamorphism. Furthermore, biotite in the granite and metasedimentary rocks was altered, in part, to chlorite during retrograde metamorphism after the climax of the latest progressive regional metamorphism. In Ansonia quadrangle the Woodbridge is found mainly east of the staurolite isograd, but small bodies of felsic meta-igneous rock intruded into Wepawaug Schist west of the isograd are believed to be metamorphic equivalents of the Woodbridge.

It is possible that some rocks mapped as Ansonia Gneiss are metamorphic equivalents of Woodbridge Granite, if the Ansonia is younger than Wepawaug Schist. In general, the Ansonia and Woodbridge are less mafic than the Woodtick and Prospect Gneisses. Some of the Ansonia, however, contains more potassium than some of the Woodbridge, making exact equivalence uncertain, even if both rocks are younger than the Wepawaug.

Only one age determination on zircon from Woodbridge Granite has been made so far (table 6). This datum suggests a Precambrian age for the rock at the type locality. However, if the granite intrudes rocks of Silurian and Devonian age, the age of the granite cannot be Precambrian. On the other hand, if the age of the Woodbridge is Precambrian, all older rocks of pre-Triassic age in the map area must be Precambrian in age. Further investigation of the age of radioactive minerals from the granite is planned.

IV. TRIASSIC AND YOUNGER(?) ROCKS

GENERAL STATEMENTS

Rocks of Triassic and Triassic or younger ages in the map area include formations of sedimentary origin, as well as igneous intrusives. Except for zones of hornfels as much as 100 feet wide near diabase, the sedimentary rocks are largely unmetamorphosed. In some places, however, the sedimentary rocks contain secondary albite and zeolite minerals, which might be interpreted as products of very low grade metamorphism. The diabase, on the other hand, is unmetamorphosed, although it probably underwent slight deuteric alteration since emplacement.

SEDIMENTARY ROCKS

General statements

The New Haven Arkose is the only relatively unmetamorphosed sedimentary formation in the map area. It is the lowest in a sequence of sedimentary and volcanic rocks in central Connecticut (table 7) recognized long ago as part of the Newark Group (Redfield, 1856, p. 357). The petrology and origin of the arkose have been discussed rather thoroughly by Krynine (1950). Although the formation was mapped in more detail during the current study, very few new petrographic data were obtained. The description of the arkose in this report, therefore, is brief.

TABLE 7. Stratigraphic sequence, Newark Group, central Connecticut

Formation	Thickness 1/ (feet)
Portland Arkose	4,000 +
Hampden Basalt (lava)	200
East Berlin Formation	500
Holyoke Basalt (lava)	350
Shuttle Meadow Formation	100
Talcott Basalt (lava)	150
New Haven Arkose (includes sheet of West Rock Diabase as much as 700 feet thick intruded near base of arkose)	10,000 +

1/ Thicknesses are approximate and are based on current detailed geologic mapping as well as on previous geologic literature.

New Haven Arkose

General features

New Haven Arkose is a sequence of interbedded conglomeratic arkose and arkosic siltstone, which underlies most of the eastern half of the map area. A lower member underlies an area of more than 50 square miles in parts of Southington, Cheshire, Hamden, Bethany, and North Haven. An upper member underlies an area of approximately 4 square miles in parts of Hamden and North Haven (pl. 1). As shown by distribution of bedding symbols on the geologic maps, outcrops of the formation are much more numerous in the eastern part of Mount Carmel quadrangle than in the central part or in Southington quadrangle.

New Haven Arkose was named by Krynine (1941, p. 1919) for New Haven, Connecticut. Krynine (1950, p. 38) recognized a lower and an upper member. He also recognized a central Connecticut and a southern Connecticut sedimentary facies, mainly on the basis of differences in heavy mineral suites. The central facies, for example, supposedly contains more blue tourmaline than the southern one, but in the map area it is impossible to distinguish between the two facies in the field. Thus, only the upper and lower members were mapped. Localities K17 and K19 (pl. 1) are type localities of the lower member in southern Connecticut, and locality K39 (pl. 2) is a type locality of the lower member in central Connecticut. Other type localities are outside the map area, but the rocks exposed on the north side of Wilbur Cross Parkway west of Old Hartford Turnpike are typical of the upper member in this area.

Petrography

The boundary between the lower and upper members of the formation in the Mount Carmel quadrangle is gradational and was mapped mainly on the basis of subtle differences in the color of the rocks. In the lower member, beds of conglomeratic arkose are grayish orange pink to very pale orange, and beds of arkosic siltstone are grayish red to dark reddish brown. In the upper member, reddish or pinkish hues predominate, and the rock is characterized by numerous grayish green, irregular to nearly spherical spots from a few millimeters to more than 1 foot in diameter. Similar spots are present in some places in the lower member, but, in general, are smaller and less numerous than in the upper member. Grayish green halos similar to the spots also surround pebbles of gray phyllitic schist, which are abundant in some places in the upper half of the lower member. Many of the spots and halos now are calcareous; calcite crystals, which surround numerous detrital mineral grains, are as much as 1 inch in diameter. The spots and halos apparently formed where primary hematite of the sediments was reduced, at least in part. The reduction must have occurred before West Rock Diabase intruded the arkose; contact metamorphic effects have been superimposed on arkose characterized by similar reduction spots. The presence of organic matter in the original sediments or sulfides in lithic fragments may have hastened reduction.

Beds in the formation are a few inches to more than 30 feet thick, and grain size is gradational both laterally and vertically. The size of detrital mineral grains and rock fragments ranges from less than 1 mm. to several inches. Typical beds consist of conglomeratic arkose that grades upward into arkosic siltstone.

Cross-bedding is ubiquitous. Cut-and-fill structures are common; places where they are most conspicuous are indicated by the letters CF on the map of Mount Carmel quadrangle. Channels as much as 2½ feet wide and 1½ feet deep have been cut in the upper, fine-grained parts of some beds, and the overlying conglomeratic arkose in many places contains fragments as much as a few inches in diameter derived from the underlying strata. These fragments originally were dried silty sediments that were incorporated in the overlying coarse material during rapid deposition.

The rocks consist mainly of angular to subangular quartz, microcline, plagioclase, muscovite, biotite, and lithic fragments. Small quantities of orthoclase, chlorite, amphiboles, pyroxenes, staurolite, and kyanite also are present in some samples. The most abundant heavy minerals are garnet, ilmenite, epidote, tourmaline, apatite, sphene, and zircon. Hematitic clay cement is abundant in many places, especially in siltstone (pl. 28, fig. B), and gives the rock its characteristic red color. Albite is a common cementing mineral in medium- to coarse-grained arkose, especially in the lower member. Calcite also is abundant as a cement in some of the conglomeratic arkose (pl. 28, fig. A), especially in the upper member. Other common cementing minerals are quartz, which forms secondary overgrowths on detrital quartz grains (pl. 28, fig. C), and laumontite, which is rather abundant in some places in Hamden (Heald, 1956, p. 1142). In general, rocks that contain albite, quartz, or laumontite as a cement are much tougher and resist erosion better than rocks in which the main cement is calcite or hematitic clay. Lithic fragments in the arkose are as much as 1 foot long, but most are only a few inches long. Quartz pebbles predominate, but fragments of phyllitic schist, which generally contain more chlorite(+) and larger garnets than phyllitic rocks of the Wepawaug Schist, are characteristic of the upper half of the lower member. Other pebbles in the arkose are various kinds of gneisses and felsic igneous or meta-igneous rocks, as well as microcline or perthite derived from pegmatites.

Thickness

The New Haven Arkose probably is 1½ to 2 miles thick in the map area, but the total thickness is greater. The outcrop width across the strike of the formation is about 32,000 feet from the unconformable contact at the southwest end of Gaylord Mountain in Mount Carmel quadrangle to the southeastern corner of the map area. The dip of bedding planesis 10° to 20° toward the east southeast. The apparent thickness, therefore, is 5,630 to 11,650 feet in this area. If the average dip is 15°, the apparent thickness is 8,580 feet. Slight repetition of the formation probably was caused by faulting, which is discussed under the heading Geologic Structure, but the arkose is believed to be 8,000 to 10,000 feet thick in this area. The total thickness undoubtedly is more than 10,000 feet, because the outcrop width of the uppermost part of the formation southeast of Mount Carmel quadrangle is approximately 15,000 feet (see Rodgers and others, 1959). Furthermore, the unit reportedly reaches maximum thickness near its eastern limit (Krynine, 1950, p. 37).

Origin

The New Haven Arkose is of continental origin. Sediments that gave rise to the formation were derived from eastern Connecticut and were deposited in a series of coalescing alluvial fans at the base of a rugged mountain range characterized by a tropical climate (Krynine, 1950, p. 193). Deposition was accompanied by recurrent elevation of the source area along a fracture known as the Great Fault, which is several miles east of the map area. Although a few fragments of quartz, pegmatite and schist in the base of the formation exposed at Roaring Brook in Southington quadrangle may have come from the underlying rocks, there is no evidence to show that large volumes of sediment in the arkose were derived from rocks of pre-Triassic age exposed in the western part of the map area. The sediments probably accumulated on a floor characterized by moderate relief (Fritts, in press, b), although some previous authors have assumed that the formation was laid down on a pre-Newark peneplain.

IGNEOUS ROCKS

General Features

The West Rock and Buttress Diabases form discordant, tabular to irregular bodies in other rocks. In general, bodies of West Rock Diabase are large and are found mainly in New Haven Arkose; they are parallel to bedding planes in some places and oblique in others. Bodies of Buttress Diabase, on the other hand, are narrow and nearly perpendicular to bedding planes in the arkose, but similar bodies of the diabase are nearly parallel to foliation planes in metamorphic rocks in some places in the western part of the map area.

The diabase bodies, in general, are well exposed, although they are covered by glacial drift in many places. The rocks are extremely tough and resistant to abrasion, but they also are well jointed. Although the diabase bodies probably were not worn down much during glaciation, numerous blocks a few feet in diameter were plucked from the southern and western sides of some exposures, and form conspicuous erratic boulders in till. Talus composed almost entirely of blocks of diabase is characteristic of the flanks of hills underlain by these rocks, and is especially abundant along the west side of West Rock Ridge and similar ridges farther north in the map area.

West Rock Diabase

General Features

West Rock Diabase forms dikes, stocks, and a large sheetlike body mainly in the lower member of the New Haven Arkose. The diabase was named by Fritts (in press, a) for West Rock, which is merely the southern end of West Rock Ridge in New Haven quadrangle. The locality is about 3 miles south of Mount Carmel quadrangle. The diabase there is near the base of the New Haven Arkose (pl. 3), but farther east in New Haven quadrangle and near the Quinnipiac River east of Mount Carmel (Rodgers and others, 1959) the diabase also is found in rocks equivalent to the upper member of the New Haven Arkose mapped in Mount Carmel quadrangle.

The diabase sheet in this area is in a position comparable to that of a large tabular body of diabase that intrudes the New Haven Arkose in northern Connecticut (Rodgers and others, 1959), but the two sheets are not known to be connected. The sheet in the map area apparently ends in the northeastern part of Southington quadrangle. The rock produces strong magnetic anomalies on numerous east-west profiles farther south, but a profile about 1 mile north of the northernmost outcrop of the diabase lacks a comparable anomaly in the appropriate position just east of the quadrangle and north-northeast of the exposure.

Interpretation of the attitude of contacts between diabase and adjacent rocks and the relationship between diabase bodies depends upon recognition of the significance of jointing in the rock, in addition to the use of magnetic profiles. Sheet joints and polygonal joint patterns characteristic of the diabase are discussed under the heading Geologic Structure.

Petrography

The West Rock Diabase is medium dark gray to dark greenish gray where fresh, but is brownish or rust-colored on weathered surfaces. The rock consists mainly of plagioclase laths and subhedral to anhedral clinopyroxene, which crystallized between and around the laths. The texture is typical of diabase. The ratio of plagioclase to clinopyroxene is about 10:7. The plagioclase is sodic labradorite (An_{50-60}), which shows faint normal progressive zoning. The clinopyroxenes are augite and pigeonite in the approximate ration 10:1. Many subhedral crystals of pigeonite are surrounded by augite, which apparently is slightly younger (pl. 29, figs. A and B). About 5 per cent of the rock, particularly where it is coarse, is a mixture, of quartz, alkalic feldspar, and micropegmatite, and approximately 3 per cent is magnetite. Biotite, chlorite, hornblende, serpentine(?), apatite, sphene, and zircon are present in much smaller amounts. The presence of olivine in the rock was reported in Rodgers and others (1959, p. 44) but was not confirmed in the current study.

Grain size in the diabase increases inward away from all contacts with adjacent rocks. The change is displayed best in a quarry at the west end of Mount Carmel east of Mill River. At that locality, diabase is fine-grained for 2 or 3 feet near New Haven Arkose at the north end of the quarry, but is medium to coarse grained along the east face of the quarry from 100 to 250 feet away from the arkose. Irregular, coarse-grained patches as much as 2 feet in diameter are widely spaced in the central parts of large diabase bodies. The patches contain clinopyroxene and amphibole(?) crystals as much as 2 inches long.

Widely spaced felsitic dikelets as much as 2 inches wide were intruded into the West Rock Diabase during a late stage of the main crystallization. Some consist mainly of micropegmatite with phenocrysts of alkalic feldspar and irregular patches of biotite. Others are composed largely of alkalic feldspar and a moderate amount of augite, with phenocrysts of albite and quartz. Dikelets of this kind were not mapped, but they can be seen near Axelshop Pond and at the summit of Mount Carmel.

Relationship Between Diabase Bodies

The largest body of West Rock Diabase is an irregular dikelike to sill-like sheet from 100 to nearly 700 feet thick and approximately 18 miles long. The sheet extends northward from the type locality and forms West Rock Ridge, High Rock, Bethany Mountain, Gaylord Mountain, Mount Sanford, and Peck Mountain, as well as smaller unnamed hills and ridges. The body reaches maximum thickness near Lake Watrous (see cross section E-E', Mount Carmel quadrangle). In that area the sheet is approximately parallel to bedding planes in the New Haven Arkose and is more or less sill-like. Farther north, especially at Bethany Gap, the diabase sheet cuts across bedding planes in the arkose and obviously is dikelike. At High Rock and Mount Sanford, and in the area between Gaylord and Bethany Mountains, the diabase is exposed or nearly exposed over broad areas, because the sheet is dikelike and, in part, nearly horizontal. West of Bethany Mountain two small patches of the diabase, which are fine grained at the bottom and medium grained above, apparently rest on Wepawaug Schist (see cross section B-B', Mount Carmel quadrangle). The patches are believed to be remnants of the main diabase sheet, which formerly extended from Bethany Mountain to Gaylord Mountain. In the area between High Rock and Gaylord Mountain the sheet probably changes stratigraphic position by as much as 1,000 feet (Fritts, in press, b). Many irregularities in the outline of the sheet elsewhere also probably reflect changes in stratigraphic position rather than offsets caused by faulting.

Narrow dikes of West Rock Diabase in southern Cheshire may be connected to the main sheet. A northeast-trending dike near Mount Sanford apparently extends outward from the eastern base of the mountain. The dike trends toward a body of similar size and composition, which forms the east-west arm of a feature known as the "cross rock" or crossed dikes of Cheshire. In the valley of Willow Brook, however, glacial drift covers bedrock almost completely over broad areas, and the presence of the diabase is questionable. A connection between the exposed dikes is inferred on the geologic map of Mount Carmel quadrangle, but is queried where outcrops are lacking for approximately 1½ miles northeast of Brooksvale. Percival (1842, p. 405) described a series of very small diabase dikes, which he observed less than 1 mile south of Brooksvale, but they were not found during the recent mapping. Presumably the dikes observed by Percival might be composed of West Rock Diabase.

The Mount Carmel Diabase mass has been interpreted in different ways by previous authors. Percival (1842, p. 399-401) recognized that the diabase is intrusive and that arkose crops out higher on the northwest than on the southeast side of the mountain. He did not classify the body specifically, but he described it as if it were a large dike related to the diabase exposed at High Rock. Davis and Loper (1891, p. 420, 421) proposed that the diabase mass at Mount Carmel is a volcanic neck that occupies a vent through which some of the lava flows of the Newark Group were extruded, but that interpretation has not been accepted by most subsequent authors. Dana (1891, p. 110) described the Mount Carmel diabase mass as a combination of dikes, but in recent geologic literature it has been referred to as a stock (Rodgers and others, 1959, p. 18).

On the geologic map of Mount Carmel (cross section C-C' and D-D'), and in this report, the stock at Mount Carmel is interpreted as an irregular part of the main diabase sheet that reached a higher stratigraphic level. A partly buried body connecting the diabase exposed at Mount Carmel and High Rock is postulated, because (1) small dikes of West Rock Diabase are exposed in the intervening area, and (2) a very large positive anomaly comparable to anomalies recorded on profiles above West Rock Ridge was recorded on a magnetic profile above the large hill southwest of Mount Carmel, where only small bodies of diabase are exposed.

The diabase body at Mount Carmel is dikelike on the northwest and sill-like on the southeast. The contacts between diabase and arkose along the northwestern and southeastern sides of the mountain dip outward at moderate angles, and the intrusive is offset vertically about 200 feet by the Mount Carmel fault, along which rocks to the west have been downdropped. Diabase at the summit west of the fault is medium to fine grained, which indicates that the original contact between the diabase and arkose there was not far above the present surface. The shape of that part of the mountain is the approximate shape of the upper part of the intrusive. East of the fault, however, the rock exposed even at the highest points is medium to coarse grained. This indicates that 100 feet or more of diabase have been eroded from the summits east of the fault. The intersections of joint planes in the diabase, which are believed to be nearly perpendicular to contacts between this rock and the adjacent arkose, plunge inward along the northwestern and southeastern sides of the mountain and are nearly vertical at the summits. This suggests that the intrusive is somewhat sheet-like but is curved about a nearly horizontal axis that trends toward the northeast. The bend visualized is a primary structure that formed at the time of intrusion; it is not a post-intrusion fold. The vertical thickness of the intrusive is unknown, but it probably is comparable to the thickness of the silllike sheet exposed on West Rock Ridge, which is as much as 700 feet thick.

Origin

The intrusive nature of West Rock Diabase is clearly established on the basis of field evidence. The texture and composition of the diabase are characteristic of mafic igneous rocks. The diabase bodies have fine-grained (chilled) margins, and cut across bedding planes in many places. Furthermore, hornfels, which is discussed under a separate heading, formed near the upper as well as the lower contacts of the main diabase sheet and near the edges of dikes and stocks in New Haven Arkose. It is obvious, therefore, that the arkose was deposited before the diabase was emplaced.

The source of the intrusive rock is uncertain, but is believed to be somewhere east of the map area, presumably near the Great Fault. No suitable conduits are known in the western part of Connecticut. Mafic dikes in the Western Highland of the State resemble Buttress Diabase rather than West Rock Diabase. No large diabase intrusives have been found in the outlier of the Newark Group west of the map area (fig. 1). Furthermore, the source of lava flows in the Newark Group most likely is somewhere near the Great Fault, because the lavas thin toward the west. It is possible that the magma from which the West Rock Diabase formed was intruded from a point or points somewhere east of Mount Sanford, which is approximately midway between the northern and southern ends of the main intrusive sheet.

Buttress Diabase

General Features

Buttress Diabase forms a system of widely spaced, nearly vertical dikes generally less than 100 feet thick, which trend toward the north-northeast across central Connecticut. The rock was named by Fritts. (in press, a) for a topographic feature known locally as The Buttress, which protrudes from the west side of West Rock Ridge in New Haven quadrangle about 800 feet northwest of the Wilbur Cross Parkway tunnel (Hawes, 1875, p. 188). A dike of Buttress Diabase there cuts across the main sheet of West Rock Diabase (pl. 3). Buttress Diabase is slightly more mafic than West Rock Diabase (table 2) and contains widely separated but distinctive phenocrysts of calcic plagioclase. Dikes of similar size, attitude, trend, and composition are found in New Haven Arkose and metamorphic rocks in and near the map area. Similar dikes also crop out in the northern part of the state east of the Newark Group (See Rodgers and others, 1959).

Grain size and jointing in Buttress Diabase are comparable to similar features in West Rock Diabase. Grain size is fine in very small dikes and near the edges of others. In the centers of the largest dikes the rock is medium grained. Irregular patches of coarse-grained diabase similar to those found in the interior of large bodies of West Rock Diabase are present near the centers of thick dikes, but are not common. Polygonal jointing is developed on a small scale in some places. Joint planes in many exposures, however, are closely spaced and are oriented rather randomly.

Petrography

The groundmass of the rock is dark gray to dark greenish gray on fresh breaks, but is brownish on weathered surfaces. It is composed mainly of plagioclase laths and subhedral to anhedral clinopyroxene in the approximate ratio 10:9. The texture of the groundmass is similar to that of West Rock Diabase. The plagioclase is calcic labradorite (An_{60-70}), which shows faint normal progressive zoning. The clinopyroxenes are augite and pigeonite in the approximate ratio 3:1. Magnetite comprises about 3 per cent of the rock. Lesser quantities of alkalic feldspar, biotite, hornblende, calcite, chlorite, serpentine(?), and apatite are present. Quartz and micropegmatite have been found in some samples of the rock, but are much less abundant than in West Rock Diabase.

Phenocrysts are grayish green plagioclase crystals or groups of crystals as much as 10 mm. in diameter. They are distributed sparsely and irregularly through the rock, and cannot be found in every outcrop. Stubby euhedral to subhedral forms are typical (pl. 29, fig. C). Simple albite and Carlsbad twinning is characteristic, but some crystals also are twinned according to the pericline law. The extinction angles and refractive indices ($n\gamma \doteq 1.574+$) indicate that the phenocrysts are slightly calcic bytownite (An_{80-85}). They are unzoned, except for thin overgrowths of more sodic plagioclase.

Two kinds of breccia have been found along dikes of Buttress Diabase in Mount Carmel quadrangle. Fragments of porphyritic diabase in a matrix of similar but finer-grained rock can be seen in an exposure in the bed of Beacon Hill Brook southwest of New Naugatuck Reservoir. Similar relationships have been found along other dikes of the rock in the map area. Breccia along the north arm of the crossed dikes of Cheshire just north of Boulder Road consists of a matrix of arkosic material that contains angular fragments of chloritized Buttress Diabase, and the breccia is traversed by dikelets of fresher Buttress Diabase as much as 2 feet wide.

Origin

Buttress Diabase is an intrusive igneous rock emplaced along faults and other fractures in pre-existing formations. The composition and texture of the diabase are characteristic of mafic igneous rocks. Dikes of the diabase cut across West Rock Diabase as well as bedding planes in New Haven Arkose, and have fine-grained (chilled) margins. Furthermore, hornfels formed in rocks adjacent to the dikes.

The breccia found along the north arm of the crossed dikes of Cheshire indicates that intrusion was accompanied by faulting, whereas the breccia at Beacon Hill Brook merely indicates that some of the magma solidified and was fractured before emplacement of the dike there was completed. The breccia with an arkosic matrix in Cheshire indicates clearly that the New Haven Arkose was unconsolidated or poorly consolidated when the Buttress Diabase was emplaced. Early dikelets were broken during faulting that accompanied intrusion, and later dikelets of the same diabase intruded the breccia.

Hornfels

Hornfels formed adjacent to the West Rock and Buttress Diabases as a result of the heat and hydrothermal activity that accompanied emplacement of these rocks. The zones of alteration are too narrow to show on the geologic maps, but hornfels can be seen in many places. It is displayed best at Roaring Brook in Chêshire, where the color of the New Haven Arkose has been changed for about 100 feet stratigraphically above the West Rock Diabase. Siltstones are grayish purple to grayish red purple, and arkose and conglomerate beds are yellowish gray to greenish gray. Red hematite of the original rock has been reduced, at least in part, and new chlorite and sericite have formed. Secondary overgrowths on quartz grains also are present. In similar hornfels near Mount Carmel, epidote has formed where the original rocks were slightly calcareous. Near dikes of Buttress Diabase that intrude New Haven Arkose, secondary calcite, chlorite, quartz, and sericite are abundant.

Age and correlation

Formations of the Newark Group in Connecticut (table 7) are believed to be generally equivalent to similar strata in comparable structural and stratigraphic positions exposed in Massachusetts and northern New Jersey, and are thought to be slightly younger than other formations in the group exposed farther south along the Atlantic coast (McKee and others, 1959, table 1). The New Haven Arkose has been correlated with part of the Brunswick formation of New Jersey and part of the Sugarloaf Formation of Massachusetts. A Late Triassic age for the strata has been established on the basis of paleontological evidence (Reeside and others, 1957, p. 1457-1461). Although no fossils were found in place in the map area, a specimen of petrified wood of probable Triassic age recently was found by by J. W. Doyle in a field on his farm east of Mount Vernon Road just south of Roaring Brook in Southington quadrangle. The specimen was identified as Araucarioxylon by Richard A. Scott, U. S. Geological Survey, in 1959.

The age of the West Rock Diabase probably is comparable to that of the Talcott Basalt (table 7). The diabase is younger than the New Haven Arkose, because it intruded the upper as well as the lower part of the formation. To the writer's knowledge, West Rock Diabase has not been found in rocks stratigraphically higher than the Talcott. Chemically, especially with regard to trace elements such as chromium and nickel (Hanshaw and Barnett, 1960) as well as zinc, the West Rock Diabase resembles the Talcott Basalt rather than younger lavas of the Newark Group. The age of West Rock Diabase, therefore, is reported as Late Triassic.

Several opinions concerning the age of the Buttress Diabase have been expressed in previous literature, although the distinctive porphyritic character of the rock was not recognized generally before the work of Hawes (1875, p. 188). Silliman (1820, p. 235) considered the dikes in the Western Highland of Connecticut near New Haven to be of pre-Triassic age, but Percival (1842, p. 399) showed that one of them, which he traced to the type locality, is younger than West Rock Diabase. Percival (1842, p. 311) believed that similar intrusives in the Western and Eastern Highlands were emplaced in fissures that diverged from the Triassic rocks of central Connecticut, which he considered to be the center of the igneous activity. Davis (1882, p. 345; 1888, p. 463; 1898, p. 80) proposed that some of the dikes in the Western Highland might represent conduits that supplied magma to the lava flows of the Newark Group. Longwell and Dana (1932,

p. 82) suggested that the dike that forms "The Buttress" at the type locality might be of the same age as the upper or youngest lava flow.

Evidence available at the present time suggests that dikes of Buttress Diabase are younger than all of the lavas of the Newark Group in Connecticut, but how much younger is not known. The dikes are lithologically unlike the lavas, which, according to available literature, do not contain phenocrysts of bytownite. Furthermore, the lavas of the Newark Group in this state thin toward the west (Rodgers and others, 1959, p. 17) and apparently came from a vent or vents along or near the Great Fault. Dikes of Buttress Diabase pinch out vertically as well as along strike in the map area, and none has been reported in contact with lavas of the Newark Group anywhere in central Connecticut. It is possible, therefore, that most, if not all, of the dikes did not intrude rocks stratigraphically above New Haven Arkose. The dike of Buttress Diabase that forms the north arm of the crossed dikes of Cheshire was emplaced along a fault, which trends toward and is believed to be continuous with a fault known to offset most, if not all, of the lavas of the Newark Group near Meriden, Connecticut, east of Southington quadrangle. Thus, it appears that Buttress Diabase was emplaced after the main volcanic activity, but it is not possible to determine how long afterward. The presence of dikes of Buttress Diabase in the Eastern Highland of Connecticut suggests that some vertical or nearly vertical displacement along the Great Fault occurred after the dikes were emplaced, but the exact time of emplacement is unknown. Tentatively, therefore, the age of the rock is reported as Triassic or younger.

V. GEOLOGIC STRUCTURE

REGIONAL SETTING

The Mount Carmel and Southington quadrangles are within a long, broad belt of highly folded rocks of Precambrian to Paleozoic age as well as tilted and faulted rocks of Late Triassic age typical of those found along the eastern side of the Appalachian Mountains and their northern counterparts in New England and eastern Canada. Formations of pre-Triassic age in and near the map area (pls. 3 and 4) have a general north-northeast trend mainly as a result of folding that occurred during the Acadian orogeny in Middle to Late Devonian time. This deformation largely obliterated any regional structural pattern that may have been imposed upon formations in Precambrian time or during the Taconic disturbance in Late Ordovician time. In this area, the Acadian orogeny apparently was followed by a long period of erosion before the New Haven Arkose of the Newark Group was deposited unconformably on rocks of pre-Triassic age. There is no evidence to show that rocks in the map area were deformed much during the Appalachian revolution in Late Paleozoic time, but tilting and faulting during and (or) after Late Triassic time resulted in further deformation of the pre-Triassic rocks as well as deformation of rocks of the Newark Group.

Remnants of the Newark Group, which are exposed in several places near the Atlantic coast from South Carolina to Nova Scotia (McKee and others, 1959, fig. 22), now are isolated partly as a result of tilting, faulting, and erosion in ~~L~~late Newark and (or) post-Newark time. The latest consensus is that the sediments accumulated in several separate basins of deposition in a region characterized by moderate to high relief (McKee and others, 1959, p. 1, 13), but some remnants, such as those in central and western Connecticut (fig. 1) formerly were connected (Krynine, 1950, p. 119). It is believed that the New Haven Arkose, for example, formerly extended across the western parts of the Mount Carmel and Southington quadrangles and was physically continuous with the South Britain Conglomerate of Hobbs (1901, p. 40). Whether or not rocks of the Newark Group in Connecticut and New Jersey (fig. 1) ever were connected continues to be the subject of much discussion among geologists working in the region.

Faulting occurred both during and after deposition of the Newark strata. The fault with the greatest regional extent and throw in Connecticut is the Great fault, which forms the eastern boundary of the Newark Group for more than 50 miles in the central part of the State east of the map area (fig. 1). Vertical or nearly vertical displacement on this fracture mainly during deposition of the Newark strata is believed to have been at least 16,000 feet and perhaps as much as 35,000 feet (Krynine, 1950, p. 5, 117, 193). Displacement of comparable magnitude occurred along a similar fault in northern New Jersey (fig. 1). The sedimentary formations of the Newark Group in New Jersey were derived mainly from uplifted pre-Triassic rocks to the west, whereas the Newark strata in Connecticut were derived mainly from uplifted pre-Triassic rocks to the east. During and (or) after lc ~~Late~~ Newark time, regional deformation resulted in block faulting and tilting of the rocks of Late Triassic age, so that now the Newark strata in Connecticut dip eastward and similar rocks in New Jersey dip westward at moderate angles. The average eastward dip in the map area is approximately 15°. Except for the Great fault, the throw on most faults that offset rocks of Triassic age in central Connecticut is only a few tens of feet to a few hundreds of feet. Nevertheless, in order to interpret correctly the structures of pre-Triassic age in the map area, it is necessary to take into consideration the effects of tilting and faulting during and (or) after Late Triassic time. Structural features of ~~Late~~ la Newark and (or) post-Newark age, therefore, are discussed first.

STRUCTURAL FEATURES OF LATE NEWARK AND (OR) POST-NEWARK AGE

In the Mount Carmel and Southington quadrangles, structural features of ~~Late~~ la Newark and (or) post-Newark age include minor flexures shown by bedding in the New Haven Arkose, as well as joints and faults. The flexures are visible mainly in Cheshire in the northeastern part of the Mount Carmel quadrangle, where the attitude of bedding planes in the arkose varies from nearly east-west to northeast and, in some places, northwest. It is likely that some of the flexures are near concealed faults. However, faults were not mapped in that area because of a lack of marker beds in the New Haven Arkose. Consequently, the flexures are not discussed in detail here. Joints are numerous in most of the rocks in the map area, including the New Haven Arkose. Many of them are slickensided, which indicates that at least slight differential movement has occurred along them. Most joints, however, were not mapped, and are not discussed. Jointing in the West Rock Diabase, on the other hand, is discussed here because of its importance in determining the attitude of diabase bodies and contacts between diabase and arkose. Four main faults were mapped where displacemant could be shown at the scale of 1:24,000 on the geologic maps (pls. 1 and 2). All of them trend northward or toward the north-northeast and were mapped for distances of several miles. Rocks are downthrown on the east along three of them, whereas rocks are downthrown toward the west along the fourth.

Two kinds of joints are characteristic of the West Rock Diabase. Sheet joints approximately parallel to contacts with other rocks formed in some of the larger tabular bodies. These joints are not shown on the geologic maps, but are displayed well in an abondoned quarry near West Cheshire. Polygonal joint patterns, which also are characteristic of tabular bodies, can be seen at the same locality (pl. 10, fig. B), and are especially well developed along the west face of West Rock Ridge, which resembles the Palisades of New Jersey. Joint columns several feet in diameter are approximately perpendicular to contacts with adjacent rocks in many places. In general, the compliment of the angle of plunge of the columns is the approximate angle of dip of the tabular body, but the relationship is not consistent everywhere. Where the diabase bodies are thin or irregular, the joints are oriented more randomly, and they tend to be more closely spaces. Double-shaft arrow symbols on the geologic maps (pls. 1 and 2) show the plunge of lines of intersections of two or more joint planes in diabase, but they do not necessarily indicate that columnar jointing is well developed or that joints are perpendicular to contacts. At Bethany Gap, for example, the symbols show that lines of intersection of some joint planes plunge toward the northwest, but columnar jointing is not well developed in that area.

The boundary between New Haven Arkose and rocks of pre-Triassic age in the map area is, in part, unconformable (pl. 14, fig. A) and, in part, formed by fractures such as the Mixville fault (pl. 14, fig. B). Contact relations and previous interpretations of geologic structure along the boundary have been discussed by Fritts (in press, b). On the basis of data presented in that article, the following conclusions are justified: (1) from Gaylord Mountain in Bethany northward almost to Roaring Brook in Southington, the Mixville fault rather than a tilted pre-Newark peneplain inferred by Davis and Loper (1891, p. 416) forms the western boundary of the Newark Group; (2) between Gaylord Mountain and Bethany Mountain the irregularity of the boundary reflects relief of approximately 1,000 feet on the pre-Newark surface rather than diagonal faults, which were inferred by Davis and Griswold (1894, fig. 1) to offset a tilted pre-Newark peneplain, (3) unless it can be proved that contacts have been offset, the West Rock Diabase cannot be used as a "marker bed" for recognizing faults, because it changes stratigraphic position by more than 1,000 feet; (4) recognition of moderately high relief on the pre-Newark surface in Connecticut affects measurement of the thickness of the New Haven Arkose, and also makes it more difficult to estimate throw where the arkose is in fault contact with rocks of pre-Triassic age.

The Mount Carmel fault in the eastern part of the Mount Carmel quadrangle is at least 4 miles long in the map area and is believed to be continuous with a fault that offsets the New Haven Arkose and overlying lavas of the Newark Group in Meriden quadrangle. The Mount Carmel fault was mapped on the basis of (1) brecciation along the north-south arm of the crossed dikes of Cheshire, (2) offsets in the boundaries of a dike of West Rock Diabase in southeastern Cheshire and the stock at Mount Carmel, and (3) the presence of a conspicuous "valley" in the diabase stock at Mount Carmel. The "valley" is believed to have formed along the fault. The attitude of the fault is unknown, but the dip is believed to be steep. If the fault dips westward, it is normal, because rocks west of this fracture have been downthrown.

Throw on the Mount Carmel fault probably is not more than 200 feet in the map area. The estimate of throw is based, in part, on the belief that the intersections of joint planes in West Rock Diabase near the fault are approximately perpendicular to contacts between the diabase and the New Haven Arkose. In Cheshire, the intersections of joint planes in the east and west arms of the crossed dikes plunge northward 35° to 45° (pl. 1), which suggests that the dike of West Rock Diabase there dips southward at about 45° to 55°. In fact, about 1 mile west of the intersection of the crossed dikes the measured dip of the west arm is about 60° S. The west arm of the crossed dikes is intersected by the dike of Buttress Diabase about 100 feet farther north than the east arm. The field relations suggest that Buttress Diabase was intruded in a fault zone along which rocks to the west were downthrown more than 100 feet, causing the apparent right lateral displacement of the east and west arms of the crossed dikes. Similarly, near the fault at Mount Carmel the intersections of joint planes in the stock of West Rock Diabase plunge inward at 45° to 55° and suggest that the contacts between diabase and arkose dip outward at 35° to 45° (pl. 1, section C-C'). This inference is confirmed by an exposed contact which dips northwestward at the west end of the mountain. Apparent offset of the contacts near the fault is about 300 to 400 feet, but at a given altitude, such as the 450-foot contour on the northwest side of the mountain, the apparent offset probably is not more than 200 feet. The contacts west of the fault in that area are closer together than those on the eastern side. Thus, the field relations suggest that the diabase west of the fault was downthrown perhaps as much as 200 feet relative to diabase east of the fault (pl. 1, section D-D').

The Mixville fault along which rocks are downthrown toward the east, forms the western boundary of the Newark Group for at least 11 miles in the central part of the map area. It also apparently offsets the Wepawaug, Derby Hill, and Southington Mountain Schists in the southwestern part of the Mount Carmel quadrangle. South of Lake Chamberlain the location of the fault is uncertain, but it apparently offsets the garnet and biotite isograds in Ansonia quadrangle (pl. 3). This fault is believed to be normal. It was excavated by the writer in 1959 at Ten Mile River near the unincorporated community of Mixville in Southington quadrangle (pl. 14, fig. B) and near Humiston Brook northwest of Marion, Connecticut. The fault is nearly vertical where exposed at Mixville, but dips toward the east at Marion. This fracture may be continuous with a fault that forms the western boundary of the Newark Group at the abandoned Bristol copper mine a few miles north of Bristol, Connecticut (fig. 1). Mine records indicate that the fault there dips eastward and has a minimum throw of about 360 feet (Bateman, 1923, fig. 26, p. 129). Reconnaissance gravity surveys by Martin F. Kane and Donald L. Peterson, U. S. Geological Survey, indicate that the throw on the Mixville fault probably is several hundred feet rather than several thousand (Fritts, in press, b).

The Larsens Pond fault was mapped for about 7½ miles in the central part of the Southington quadrangle. This fault also offsets Triassic and pre-Triassic formations and is believed to be normal. It dips about 60° E., where exposed in a new roadcut excavated in 1960 for Interstate Route 84 about 700 feet south of Larsens Pond. Rocks to the east have been downthrown. The fault forms part of the eastern boundary of the Straits Schist in western Cheshire and is believed to occupy a similar position in Prospect. The Larsens Pond fault in Prospect, however, is queried because of a lack of field evidence in support of this interpretation. The fault also is queried north of Larsens Pond, because field relations near Roaring Brook in Southington could be explained without the Larsens Pond fault. The irregularity of the western boundary of the New Haven Arkose south of locality K39 might be interpreted as evidence that the arkose was deposited on an irregular surface in that area. However, the field relations also permit the interpretation that the New Haven Arkose and Southington Mountain Schist are in fault contact for approximately 1,000 feet south of Roaring Brook, provided that throw on the Larsens Pond fault is less than 100 feet.

The Southington Mountain fault, along which rocks have been downthrown toward the east, forms part of the western boundary of the Newark Group, but also offsets at least three formations of pre-Triassic age. North of Roaring Brook in Southington, the New Haven Arkose has been downfaulted against the Southington Mountain Schist along this fault. South of the brook, erosion along the fracture has produced a fault-line scarp (Longwell, 1933b, p. 112), which forms the steep eastern face of Southington Mountain. For approximately 1½ miles north of Larsens Pond, the Southington Mountain fault probably underlies a more or less continuous depression along the eastern side of the Straits Schist. South of Larsens Pond, the Southington Mountain fault is believed to underlie a similar depression, which separates areas underlain by Waterbury Gneiss on the west and Straits Schist on the east. In the Mount Carmel quadrangle, the Southington Mountain fault also is believed to form the contact between Waterbury Gneiss and younger rocks, but the contact there could be interpreted as an unconformity rather than a fault. In that area the fault was queried, because field evidence is inconclusive. If the contact is a fault, the fracture probably is continuous with a normal fault mapped by Carr (1960) in Naugatuck quadrangle.

The throw on the Southington Mountain fault is believed to be at least several hundred feet, but field evidence is inconclusive. The estimates made here are based on the assumption that the unconformity beneath the New Haven Arkose near Roaring Brook in Southington is approximately parallel to bedding in the arkose in that area. North of Roaring Brook, the New Haven Arkose and metamorphic rocks are in fault contact for approximately 4,500 feet along the Southington Mountain fault, which strikes about N. 20° E. The arkose exposed near locality W10 strikes N. 0-5° W. and dips 20°-25° E. If the Southington Mountain fault in that area is vertical, the northeastward plunge of the line of intersection of bedding planes and the fault may be as little as 7°. These data suggest that the throw on the fault may be (4,500 ft.)$\cdot$(tan 7°), or approximately 553 feet. On the other hand, bedding in the arkose at locality W11 strikes N. 15°-25° W. and dips 10°-25° E. It it is assumed again that the fault is vertical, the plunge of the line of intersection of bedding planes and the fault is about 7° to 18°. If it is assumed further that the fault plane dips eastward at about 60°, like the Larsens Pond fault, the angle of plunge of the line of intersection of bedding and fault may be about 20°. These data suggest that the throw may be as much as (4,500 ft.)·(tan 20°), or approximately 1,638 feet. However, the estimates of throw are questionable, because (1) west of the fault arkose has been removed completely by erosion and (2) relief on the pre-Newark surface beneath the New Haven Arkose is known to vary by as much as 1,000 feet in the Mount Carmel quadrangle.

Other faults in the New Haven Arkose were mapped only where offsets could be shown at the scale of mapping or where the trend of mineralized breccia zones could be established. The breccia zones at the site of the Jinny Hill mine, for example, undoubtedly are faults, but the direction and amount of throw on the faults are unknown. Remnants of barite veins in that area dip steeply toward the south, which suggests that the main breccia zones also dip southward. The strike and dip of a mineralized fault zone at a small copper prospect north of Blacks Road in northern Cheshire was determined from a very small exposure, but the direction and amount of throw on the fault are unknown. Two faults were observed underground at the Tallman mine in Hamden (Figure 2), but displacement on them is too small to show at the scale of the geologic map of Mount Carmel quadrangle. Unusual northward dips in the New Haven Arkose at locality K17 northwest of Mount Carmel might be interpreted as evidence of faulting, but no faults with large-scale displacement were found in that area during the recent mapping.

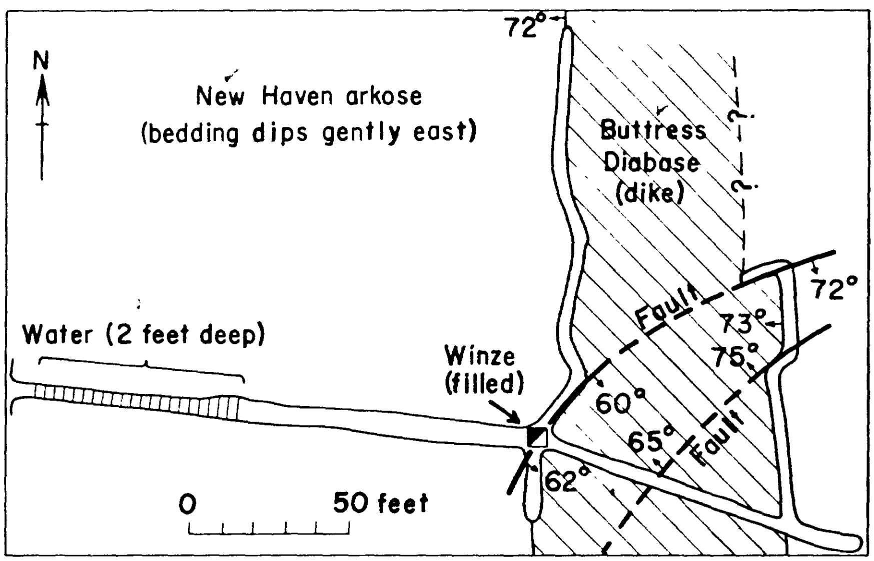


FIGURE 2. Sketch map of underground workings, Tallman Mine, Hamden, Connecticut

STRUCTURAL FEATURES OF PRE-TRIASSIC AGE

The interpretation of structure of the pre-Triassic rocks in the map area, most of which have been metamorphosed, depends, in part, upon recognition of the relationship between original characteristics and features superimposed on the rocks during metamorphism. In general, banding in metasedimentary rocks, such as the Waterbury Gneiss and the Southington Mountain Schist, is believed to reflect original differences in the composition of beds or layers of sedimentary origin. The banding is referred to as relic bedding, however, because all indication of original clastic grains in the rocks, in general, was destroyed during metamorphism. The rocks also undoubtedly underwent strong shearing as well as folding during and before the metamorphism at the time of the Acadian orogeny. Foliation, formed by the parallel arrangement of minerals during metamorphism, is oblique to banding in some places, but is parallel to banding in many others. Lineation commonly parallels the axes of folds that trend toward the north-northeast. Graded bedding mentioned in the descriptions of the pre-Triassic rocks is meant to imply gradation in composition rather than gradation in grain size of the metasedimentary rocks. In some places, features such as graded bedding provide one means of determining the tops and bottoms of original beds, but in many outcrops this kind of information suggests that the tops of layers only a few inches apart face in opposite directions. It then becomes a matter of speculation as to whether or not the rocks are complexly folded, and how much importance should be attached to the supposed sedimentary features in determining the attitude of the rocks. On the other hand, the regional distribution of formations in relation to known structures can provide reliable information concerning the sequence of metasedimentary formations and younger intrusive rocks.

The pre-Triassic rocks in and near the map area (pl. 3) lie along the east flank of a major geanticline, which underlies parts of western Connecticut and Massachusetts as well as Vermont. In Vermont the main structure is recognized as the Green Mountain anticlinorium (Thompson, 1952, p. 20), and a series of partly preserved domes is found near the eastern flank. The line of domes extends southward through western Massachusetts (Emerson, 1917, pl. 10) and along the eastern edge of the Western Highland of Connecticut (Rodgers and others, 1959, fig. 2). The pre-Triassic rocks in the western parts of the Mount Carmel and Southington quadrangles are near the southern end of this line of domes, although the main structures of pre-Triassic age here trend toward the north-northeast (pl. 3).

The predominant structure of pre-Triassic age in the map area is the partly preserved Waterbury dome. The Waterbury Gneiss forms the core of this structure (pl. 3). The Straits and Southington Mountain Schists wrap around the core, especially in the northwestern part of Southington quadrangle, but are missing from the western side of the dome. The absence of the Straits and Southington Mountain Schists there is the result of erosion after tilting and faulting, which occurred in ~~late~~ Newark and (or) post-Newark time. If this deformation is compensated for by tilting the area westward about 15°, it becomes obvious that the Straits Schist overlies Waterbury Gneiss, especially along the eastern side of the dome. It also becomes apparent that the Southington Mountain, Derby Hill, and Wepawaug Schists form a stratigraphic sequence above the Straits Schist.

A syncline at the northern end of Southington quadrangle was inferred partly on the basis of structure and stratigraphy in the adjacent Bristol quadrangle. Mapping in progress in Bristol quadrangle by H. E. Simpson, U. S. Geological Survey, has revealed that gneissic rocks in that area form the core of another dome, here called the Bristol dome. Straits Schist wraps around the core of the Bristol dome in a position comparable to that occupied by the Straits in Southington quadrangle. The Southington Mountain Schist overlies the Straits Schist in both areas and occupies the trough of a syncline (pl. 4) between the Waterbury and Bristol domes.

The largest pegmatites in the map area are on Southington Mountain near the eastern end of this syncline, where the metasedimentary rocks they intruded are characterized by crumpled banding and crenulated schist layers. The pegmatites, which were emplaced at about the time of the climax of the latest progressive regional metamorphism, apparently crystallized where compression and shearing were least intense. This suggests that the Waterbury and Bristol domes formed before the climax of the metamorphism, but how long before is uncertain. The available evidence suggests that these domes and similar ones in the line of domes mentioned above lie along the crest of a geanticline and were accentuated, if not formed, during the Acadian orogeny.

The Wepawaug Schist is believed to occupy the trough of a large tight syncline, which plunges toward the north-northeast. The axial plane of the syncline may enter Mount Carmel quadrangle near Glen Dam Reservoir. The southeastern corner of Ansonia quadrangle (pl. 3) is occupied by a sequence of metavolcanic and metasedimentary rocks formerly mapped, in part, as the Milford Chlorite Schist of Gregory (Rice and Gregory, 1906, p. 100). Bedding and foliation in this formation as well as in the adjacent Wepawaug Schist strike northeast and dip northwest at 30° to 70°. Bedding is right-side-up, and the Wepawaug clearly overlies the metavolcanic and metasedimentary rocks. Farther north along the same contact, the formations are nearly vertical, and tops of beds face west. Near the center of the Wepawaug Schist, the formation is characterized by numerous small tight folds, which plunge gently toward the north northeast. Foliation is nearly parallel to bedding along the limbs of folds, but crosses bedding near many fold axes. West of the staurolite isograd near the southern end of Ansonia quadrangle, axial plane foliation is well developed in the Wepawaug Schist and in amphibolites believed to be higher grade metamorphic equivalents of metavolcanic rocks that underlie the Wepawaug farther east. Foliation is nearly perpendicular to the contact between the amphibolites and Wepawaug Schist (pl. 4). Along the western side of the Wepawaug, foliation and bedding are nearly parallel, and both are nearly vertical. The tops of beds there are believed to face east.

An unconformity beneath Wepawaug Schist is established on the basis of field relations in the Ansonia quadrangle. Along the eastern and southern sides of the Wepawaug (pl. 3) the formation overlies the metavolcanic and metasedimentary rocks formerly mapped as Milford Chlorite Schist but along the western side of the Wepawaug, the formation overlies the Derby Hill Schist stratigraphically. Thus, it is clear that the Wepawaug overlies different rocks in different places, and the map pattern (pl. 3) suggests an unconformity beneath this formation.

An unconformity beneath Straits Schist is established mainly on the basis of field relations between this formation and Waterbury Gneiss in Southington quadrangle. Foliation wraps around the northern side of the Waterbury Gneiss, and is nearly parallel to bedding in many places near the contact between the Waterbury and Straits. The contact is nearly exposed in the bed of the Mad River in Wolcott, but a discordance in bedding is not obvious, if present. To complicate the matter further, for about 6 miles along the eastern side of the Waterbury (pl. 3), the gneiss is in probable fault contact with the Straits Schist. However, in the southwestern part of Southington quadrangle, the Waterbury trends north northwest and the Straits trends north or north-northeast. The dip of foliation and bedding in the Waterbury there is variable, but generally nearly vertical. The foliation (and presumably bedding) in the Straits nearby, on the other hand, dips predominantly eastward at moderate angles. Unless there is a very large displacement on the Southington Mountain fault, the field relations suggest that the Straits Schist overlies the Waterbury Gneiss unconformably. Additional indirect evidence of an unconformity, namely a marked difference in the probable metamorphic history of the Waterbury and Straits, is mentioned above in the discussion of metamorphism of pre-Triassic rocks. The lack of a conglomerate at the base of the Straits suggests that the formation was deposited on a surface of low relief.

East and southeast of the core of the Waterbury dome foliation synclines, which represent folded foliation rather than folded bedding, must have formed during progressive regional metamorphism, because they cross the boundaries of large stocks of Prospect Gneiss. A rather complex foliation syncline was mapped in Mount Carmel quadrangle. Near the axial plane of the fold, which is located only approximately, the attitude of foliation in the Prospect Gneiss as well as foliation and banding in Southington Mountain Schist is inconsistent. On the other hand, a relatively simple foliation syncline in Southington quadrangle is more obvious, and the axial plane is located more accurately. West of the axial plane of this fold, lineation plunges gently toward the northeast, but east of the axial plane, lineation plunges gently toward the southwest. Similar lineation is approximately parallel to fold axes elsewhere in the map area, especially in Wepawaug Schist. Field relations along the foliation syncline in Southington quadrangle, however, suggest that (1) folding there was accompanied by slight relative movement of the west limb of the syncline toward the northeast, or (2) early foliation and lineation were refolded.

Right lateral movement is shown by shear cleavage in the Derby Hill Schist. During cataclasis and shearing, the rock was crushed and partly recrystallized, especially along the planes of shear cleavage. These fractures, which are oblique to bedding and the main foliation, are generally less than 1 inch apart. Along thousands of shear planes, quartz veins and thin layers or beds in the schist have been offset a few millimeters to a few inches, so that rock northwest of each fracture has been displaced toward the northeast (pls. 11 and 22).

Tectonic thinning of formations occurred mainly where they are parallel or nearly parallel to the north-northeast trend of major structures such as the syncline occupied by the Wepawaug Schist. In the southeastern corner of Ansonia quadrangle, fragments of volcanic rock a few inches in diameter in a metamorphosed pyroclastic unit in the Milford Chlorite Schist of Gregory have been flattened and stretched parallel to foliation. The ratio of minimum to maximum diameter of the flattened rock fragments ranges from approximately 1:2 to as little as 1:5. In that area the formation is in a zone of low grade progressive regional metamorphism. In zones of higher grade metamorphism, formations in some places probably were thinned even more, as a result of shearing during metamorphism. The map pattern of an amphibolite layer in kyanite-bearing Straits Schist, for example, east of Hitchcock Lake in Southington quadrangle suggests that the layer has been isoclinally folded to form a very tight syncline, which plunges toward the north-northeast. Along the limbs of the fold, the amphibolite is much thinner than near the axis. Tectonic thinning also is suggested by the variation in width of the Straits Schist. The apparent thickness of the formation is much greater along the northern and southern sides of the Waterbury dome than along the eastern side, even where the schist is not in fault contact with adjacent formations near Southington Reservoir No. 2.

Minor folding and possible thickening of formations in the map area has occurred mainly at the northern and southern ends of the Waterbury dome and near the axial planes of large synclines. In Wolcott, especially in the trough of the syncline inferred between the Waterbury and Bristol domes (pl. 4), the Southington Mountain Schist has been crumpled. The formation there is characterized by numerous small drag folds, and crenulations are abundant in mica-rich layers of the typical banded schist. Similar crenulations are numerous in Straits Schist near the western edge of Mount Carmel quadrangle, and foliation planes in a small body of Prospect Gneiss in that area were folded to form a small foliation anticline. In some places, the

Wepawaug Schist is characterized by small chevron folds, especially near Lake Watrous, which probably lies near the axial plane of the syncline occupied by the formation. Foliation planes also have been crenulated near the axial plane of the foliation syncline in Prospect Gneiss east of Larsens Pond.

VI. ECONOMIC GEOLOGY

GENERAL STATEMENTS

Bedrock of former economic interest in the map area includes deposits of barite and copper minerals and large bodies of West Rock Diabase in both quadrangles, as well as small bodies of limestone and marble in the Mount Carmel quadrangle. Exploration for oil in the New Haven Arkose also was undertaken briefly in the southern part of the Southington quadrangle. Although large reserves of diabase remain, the rock is not quarried at the present time. The deposits of barite and copper minerals were especially important during the nineteenth century, but have not been mined in recent years. It is possible, however, that similar deposits of future economic interest still lie beneath covered intervals in the map area. Bodies of limestone and marble, on the other hand, were of relatively little importance in the past, and probably are too small and impure to be of much interest in the future.

BARITE AND COPPER

HISTORY OF MINING

The original discovery of copper minerals in southern Connecticut was made about 1710 near the intersection of the crossed dikes of Chesire, which were referred to in early land records as the "cross rock". Small quantities of chalcocite, bornite, and malachite were found in fractures in diabase dikes and as impregnations in the adjacent sedimentary rocks. Early workings at the site, which is labeled Cross Rock mine on the map of Mount Carmel quadrangle, were two trenches on the north side of the dike of West Rock Diabase (Shepard, 1837, p. 45). Other early mining activity was confined to the Copper Valley mine in the northwestern part of Wallingford quadrangle. About 1900, however, a shaft reported to be approximately 200 feet deep was sunk near the intersection of the crossed dikes, and several prospect pits were dug on the dike of Buttress Diabase north of Boulder Road. This mining activity lasted only a few years, and little is known about the quality or quantity of ore found.

Copper minerals also were found about 1 mile north of Mount Carmel at the Tallman mine, which was named for the man who first worked it in 1802. Small amounts of chalcocite, bornite, and malachite were found there along faults and as impregnations in sedimentary rocks within three feet of a dike of Buttress Diabase. The early workings consisted of a shaft about 35 feet deep, which was sunk along the western contact of the dike, and a long adit, which was driven eastward through siltstone and arkose on the hillside west of the shaft (Shepard, 1837, p. 45). More work was done in this area about 1875, but no data are available concerning the amount or value of ore found. The present extent of the underground workings, which are not connected to surface excavations, is shown in Figure 2.

Prospecting for copper also was done near Mount Carmel about 1849. and in northern Cheshire, presumably sometime during the 19th century. No data concerning production in either area have been found.

Barite was mined in the Town of Cheshire from 1838 to 1878. The Jinny Hill mine in Mount Carmel quadrangle was the first barite mine in the United States, and was the most important domestic source of barite during the 1840's and 1850's (Shepard, 1852, p. 101). Four other less important barite mines in Southington quadrangle were operated intermittently between 1864 and 1878. The total production from the Cheshire barite mines was about 160,000 tons (Beach, 1912, p. 273). Most of the ore was prepared for market at New Haven, Connecticut, but for brief periods ore also was milled at Stamford and Hamden, Connecticut. The processed barite was used mainly for the manufacture of paint in New York City.

The Jinny Hill mine was operated continuously from 1838 to about 1877. In 1866, at the height of the mining activity, 200 men were employed there (Credner, 1866, p. 144). The main or central vein at this mine was a nearly vertical mineralized breccia zone 4 to 5 feet wide, which was composed mainly of barite, quartz, and accessory copper minerals. It was known to mineralogists as early as 1812, but economic interest in it was not shown until 1829. At that time, prospecting for copper was done at the western end of the vein, but barite mining did not begin until 1838. Barite first was mined from this vein just south of Jinny Hill Road, but production was greatest in the vicinity of two shafts sunk on the eastern end of the central vein about 1,000 feet apart (Credner, 1866, p. 144). The workings there reached a total depth of 480 feet (Beach, 1912, p. 272). A third shaft reported to be 600 feet deep (Rockey, 1892, p. 687), was sunk on the same vein near Jinny Hill Road about 1871, and smaller discontinuous veins north and south of the main one were explored in shallower mine workings at that time. By 1873, the depletion of ore reserves in this area necessitated the reactivation of smaller barite mines near West Cheshire, and the Jinny Hill mine was abandoned a few years later.

Mineral Deposits

General Features

Barite and copper minerals were deposited along faults and breccia zones, as well as near contacts between the New Haven Arkose and the West Rock and Buttress Diabases. In breccia zones in New Haven Arkose at the site of the Jinny Hill mine, barite and quartz were abundant, but chalcocite, bornite, chalcopyrite, hematite, malachite, chrysocolla, and limonite comprised less than 1 per cent of the mineral deposit. Similar but smaller mineral deposits were found near the main sheet of West Rock Diabase at the sites of the four barite mines in northern Cheshire. Small quantities of chalcocite, bornite, malachite, calcite, quartz, barite, and chlorite also were deposited near dikes of Buttress Diabase at the sites of the Tallman and Cross Rock mines, and malachite and chalcocite were found at a few prospects elsewhere in the map area. Minor quantities of native copper also were deposited along a few joints in West Rock Diabase at Mount Carmel (Percival, 1842, p. 400; Blake, 1888, p. 72). A small sample of the native copper from this locality has been preserved in the Brush Mineral Collection at Yale University in New Haven, Connecticut. Schairer (1931, p. 104, 105, 111) reported galena, sphalerite, and stilpnomelane from the Tallman mine and azurite, cuprite, native copper, and stilpnomelane from the Jinny Hill mine, but these minerals were not observed during the recent mapping.

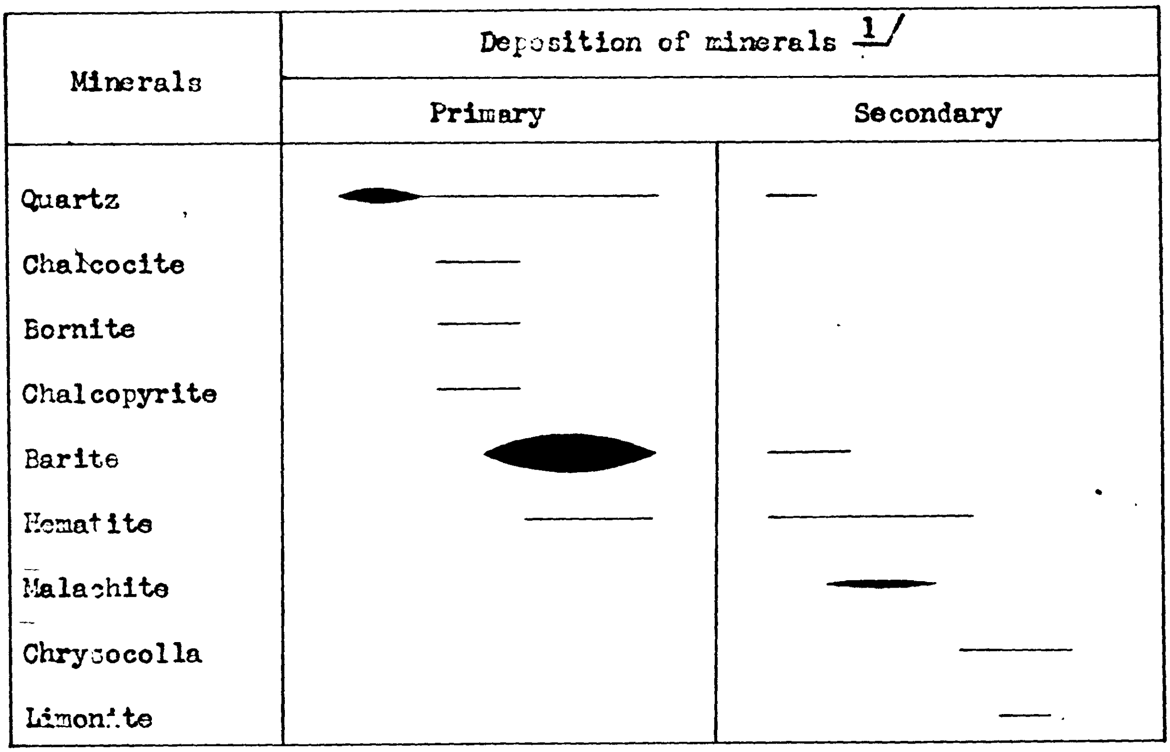
Sequence of Crystallization at Jinny Hill Mine

A paragenetic sequence (table 8) was determined by studying samples of breccia (pl. 15, fig. A) found at mine dumps near Jinny Hill, which were bulldozed in 1958 in the course of construction in that area. Formation of the mineral deposits at the site began with early silification of wall rock and rock fragments after or during initial brecciation. Brecciated siltstone and arkose are cemented by quartz, and fragments of the silicified rock are found in a matrix composed mainly of barite. Copper sulfide minerals were deposited on and between rock fragments after the first silicification. Deposition of the copper minerals was accompanied by shearing, more silicification, and the deposition of early barite. Some copper sulfide minerals were deposited after the first barite formed. Malachite, limonite, chrysocolla, and more quartz were deposited after the main period of barite mineralization. Individual minerals are described below in the approximate order of deposition.

Euhedral quartz crystals 1 or 2 mm. in diameter and 2 to 5 mm. long form linings in fractures and vugs, as well as coatings on fragments of siltstone and arkose in breccia. In thin section some of the quartz crystals exhibit twinning. Simple prisms and rhombohedral terminations are common. A smoky quartz crystal 1 inch long and about ½ inch in diameter from this locality was seen in a private collection in Cheshire. Late quartz crystals generally less than 1 mm. long formed on barite; some of the late quartz is doubly terminated.

Chalcocite forms anhedral masses less than 5 mm. in diameter as well as euhedral pseudocubic and twinned pseudohexagonal crystals as much as 2 mm. in diameter. The mineral is intergrown with bornite and rests on euhedral quartz. In some places, chalcocite and barite are intimately

TABLE 8. Paragenesis at Jinny Hill Mine, Cheshire, Connecticut



1/ Time increases toward right. Length of line indicates relative length of time during which mineral was being deposited. Thickness of line indicates relative abundance of mineral.

mixed in vein material that was sheared during and (or) after mineralization.

Bornite forms anhedral masses generally less than 2 mm. in diameter as well as euhedral cubic crystals as much as 5 mm. in diameter. The mineral is intimately intergrown with chalcocite in many specimens. Euhedral bornite (possibly intergrown with chalcocite) formed on euhedral quartz and inside some barite crystals.

Anhedral chalcopyrite is found on euhedral quartz and is intergrown with bornite and limonite in some places. Masses of chalcopyrite generally are less than 1 mm. in diameter. In some samples chalcopyrite surrounds bornite, and in others limonite surrounds chalcopyrite. Chalcopyrite also fills cavities in quartz-lined fractures in some samples of breccia as well as fractures in barite.

Barite crystals from the locality are white to colorless and range in length from a fraction of an inch to as much as 8 inches (pl. 15, fig. B). Typical tabular crystals found in samples from mine dumps are 2 to 3 inches long and 6 to 8 mm. thick. They contain tiny liquid inclusions and microcrystalline hematite. A spectrochemical analysis indicates that the ratio of barium to strontium in the barite is about 50:1. The barite forms fan-shaped aggregates in veins as much as 2 inches wide. In underground workings veins reportedly were as much as 5 feet wide, but the average width was only a few inches (Credner, 1866, p. 143). Euhedral transparent barite crystals about 2 mm. long are found in numerous cavities in breccia. Crystal faces also formed on the ends of large barite crystals that projected into cavities. Barite from this locality has been described and illustrated in mineralogical literature numerous times since 1813. A complete list of references is included in a manuscript concerning barite mining at Cheshire,Connecticut, recently prepared by the writer for the Cheshire Historical Society.

Microcrystalline hematite forms aggregates as much as a few millimeters in diameter as well as thin coatings on other minerals. Platy hexagonal crystals are as much as 0.01 mm. in diameter. The crystals are red and translucent, but aggregates have a coppery luster. In the field, the aggregates may be mistaken for native copper. The hematite was deposited on and in barite and malachite, as well as on chalcocite and chrysocolla. Microcrystalline hamatite also is found on and in late, doubly terminated quartz crystals, which formed on barite.

Chrysocolla, which is much less abundant than malachite at this locality, forms masses 1 to 3 mm. in diameter between quartz crystals. Chrysocolla also forms thin crusts on malachite, limonite, and quartz.

Malachite forms colloform masses from 1 mm. to 1 inch in diameter, as well as single crystals less than 0.1 mm. in diameter and sunburst aggregates of acicular crystals. Colloform masses resting on euhedral quartz, barite, and chalcocite are common. Acicular crystals of malachite penetrate a few crystals of late, clear barite. Malachite also formed on bornite, chalcocite, and late quartz.

Limonite forms masses as much as 1 mm. in diameter, which rest on euhedral quartz. Limonite also is found on malachite, chrysocolla, chalcopyrite, and microcrystalline hematite.

Origin

Most of the minerals in these deposits probably were precipitated from ascending hydrothermal solutions, but some of the late minerals probably were precipitated from descending or recirculated waters. Bateman (1923, p. 165) concluded that euhedral chalcocite at the Bristol copper mine several miles north of the map area was of hypogene origin. In size, form, and mode of occurrence, minerals found in the breccias at Jinny Hill strongly resemble those found at the Bristol copper mine. Chalcocite, bornite, chalcopyrite, and most of the barite, quartz, and hematite in mineral deposits in the map area are believed to be primary minerals, whereas malachite, chrysocolla, limonite, and some of the late quartz, hematite, and small, transparent barite crystals are believed to be of supergene origin.

Age

Deposits of barite and copper minerals in the map area probably are of about the same age as or slightly younger than the Buttress Diabase. The minerals found in narrow zones adjacent to dikes at the Tallman and Cross Rock mines must have been deposited during or after emplacement of the diabase. The minerals at Jinny Hill are believed to have been deposited at approximately the same time, because the breccia zones found at Jinny Hill trend toward deposits of similar minerals near dikes of Buttress Diabase at the Copper Valley mine in Wallingford quadrangle. It is possible, however, that some of the mineralization near bodies of West Rock Diabase occurred during or shortly after emplacement of the this rock.

DIABASE

West Rock Diabase was quarried in at least seven places in the map area mainly for use in construction. An excavation near Hoadley

Road north of Bethany Lake supplied blocks that were used in the construction of the dam at that reservoir about 1892. A small quarry near the southeast end of Lake Watrous provided rock for the dam there in 1914. During the period 1911 to 1933, diabase was quarried in two places near the west end of Mount Carmel. Production from the southern pit had ceased by 1928. The cessation of activity at the quarry east of Mill River was the result of action taken by the Sleeping Giant Park Association in 1930. The large quarry near the intersection of Routes 68 and 70 in western Cheshire was operated from 1914 to about 1948. Diabase also was quarried briefly several hundred feet north of Jarvis Street in Southington quadrangle, but the dates and purpose of the activity are unknown. A small excavation in coarse-grained diabase about 700 feet south of Jarvis Street probably was made sometime before 1842. Percival (1842, p. 403) mentioned that coarse diabase from the vicinity of Peck Mountain was "...formerly excavated as an iron ore."

LIMESTONE AND MARBLE

Calcareous rocks have been quarried in two places in Mount Carmel quadrangle. A small stone kiln was constructed sometime before 1842 near the band of impure marble at the north end of New Naugatuck Reservoir (Percival, 1842, p. 35). Several trenches only a few feet deep were dug in the rock, and the calcined lime probably was used by local residents to make mortar or cement. A much larger kiln was built in 1875 southeast of Glen Dam Reservoir one year after a kiln was constructed several hundred yards farther south in the New Haven quadrangle. A record book owned by the Woodbridge Historical Society indicates that both kilns were abandoned in 1876. The avowed purpose of the operation was to manufacture hydraulic cement and umber, but the impure crystalline limestone quarried nearby was unsatisfactory for that purpose. The rock contains as much as 57 per cent insoluble matter (Moore, 1935, p. 42).

OIL EXPLORATION

Cheshire Land Records indicate that exploration for oil in Southington quadrangle began in 1919, but no oil was found. According to Raymond L. Coleman (oral communication), two dry wells about 150 feet apart were drilled to depths of approximately 2,800 to 3,000 feet, respectively, on his farm southwest of the State Reformatory. These wells are shown on the map of Southington quadrangle by a single symbol, because they are so close together. If the sheet of West Rock Diabase nearby dips eastward at approximately 25° as shown on cross section B-B', Southington quadrangle, the wells probably passed through the diabase and bottomed in New Haven Arkose or rocks of pre-Triassic age.

VII. SUMMARY AND CONCLUSIONS

Waterbury Gneiss constitutes part of a basement complex of Precambrian age overlain by metasedimentary rocks of Cambrian to Silurian and Devonian age. The gneiss occupies a position comparable to that of the Mount Holly Complex of Vermont. The Waterbury was derived from an area where deep weathering or laterization supplied relatively large quantities of alumina and iron oxide to sediments that eventually formed the gneiss. The fine-grained paragneiss of the formation, which lacks clean quartzite and marble, probably was deposited rather rapidly in moderately deep water. Regardless of whether or not the Hitchcock Lake Member overlies the paragneiss unconformably, a change in the sedimentary cycle is indicated by the presence of the Hitchcock Lake Member, which contains more argillaceous rocks. The Hitchcock Lake Member must have been deposited more slowly or in deeper water than the paragneiss. The contorted banding, complex textures, and abundance of small irregular granitic to quartz dioritic intrusives characteristic of the Waterbury suggest that the formation underwent more severe metamorphism than younger formations. It is concluded that the Waterbury Gneiss underwent progressive regional metamorphism in the sillimanite zone in Precambrian time and underwent progressive regional metamorphism in the kyanite zone in Middle to Late Devonian time. The formation also probably underwent folding more than once. The lower stratigraphic limit of the formation is uncertain, but the total thickness of Waterbury Gneiss probably is at least several thousand feet.

The Woodtick Gneiss, as well as rocks mapped as granitic to quartz dioritic gneisses, undivided, and metamorphosed pegmatite also are believed to be parts of the basement complex. None of these meta-igneous rocks has been found intruding Straits Schist or younger rocks in the map area, and the textures of the meta-igneous rocks are more like that of Waterbury Gneiss than like the Straits Schist and younger rocks. In view of the probable complex metamorphic history of the Waterbury, it is concluded that the Woodtick Gneiss, the granitic to quartz dioritic gneisses, and the metamorphosed pegmatite probably intruded Waterbury Gneiss while it was deeply buried in pre-Straits time. It is possible, therefore, that the Woodtick and associated meta-igneous rocks in the basement complex also underwent metamorphism in Precambrian time as well as in Paleozoic time.

The sequence of metasedimentary rocks including the Straits Schist, Southington Mountain Schist, Derby Hill Schist, and overlying metavolcanic and metasedimentary rocks formerly mapped as part of the Milford Chlorite Schist of Gregory represents a transition from a miogeosynclinal to a eugeosynclinal environment during early Paleozoic time. This sequence is believed to be approximately equivalent to the sequence from the Hoosac Schist to the Missiquoi Formation of Doll and others (1961) mapped in southeastern Vermont. This cycle of sedimentation was preceded by a long interval of erosion, but the absence of conglomerate at the base of the Straits Schist suggests that the formation was deposited on a surface of low relief. The predominant mica schist of Straits Schist represents relatively clean argillaceous sediments deposited rather slowly in moderately deep water. Amphibolite and minor paragneiss in the formation are believed to represent tuffs or graywackes deposited during an early phase of igneous activity. The ribbonlike banding characteristic of Southington Mountain Schist reflects rapid deposition of alternate layers of impure argillaceous, siliceous, and minor calcareous sediments. Southington Mountain Schist probably was deposited during relatively rapid subsidence of a eugeosyncline. The abundance of small amphibolites in the formation indicates an increase in the amount of graywacke or tuff being deposited as subsidence continued. The extremely thin banding and relatively high percentages of albite and chlorite in Derby Hill Schist reflect a further increase in the rate of deposition and igneous activity. During the climax of igneous activity in Ordovician time, metadiabase and metabasalt as well as pyroclastic rocks were extruded above Derby Hill Schist. The total thickness of all of these geosynclinal sediments in the map area probably exceeded 15,000 feet.

The Wepawaug Schist of Silurian and Devonian age was deposited unconformably on rocks of Ordovician age during a period of renewed deposition in a eugeosynclinal environment. This formation is believed to be equivalent to the Northfield Slate and Waits River Formation of Vermont. The relatively thin banding characteristic of the Wepawaug suggests that the alternate layers of argillaceous, siliceous, and calcareous metasediments in this formation were deposited rather rapidly. The presence of numerous layers of impure limestone and marble, however, suggests that the formation accumulated a little more slowly or in slightly deeper water than the Southington Mountain Schist. Amphibolite bands are not abundant in the Wepawaug Schist in Mount Carmel quadrangle, because the formation is mainly in zones of low grade metamorphism. In Ansonia quadrangle, on the other hand, the formation contains numerous narrow bands of amphibolite in the staurolite and kyanite zones. The amphibolites are believed to represent original beds of graywacke or tuff. Although the upper stratigraphic limit of the formation is uncertain, the total thickness of the Wepawaug Schist probably is at least several thousand feet.

The unconformity at the base of the Wepawaug Schist represents a break in the sedimentary cycle at about the time of the Taconic disturbance. Although it is possible that some folding of the Straits, Southington Mountain, and Derby Hill Schists occurred at that time, there is no direct evidence of major deformation in the map area during this disturbance. The lack of conglomerate at the base of the Wepawaug Schist suggests that this formation, like the Straits Schist, was deposited on a surface of relatively low relief.

Major tectonic activity and the latest progressive regional metamorphism of rocks of pre-Triassic age in the map area probably occurred during the Acadian orogeny in Middle to Late Devonian time. The Waterbury and Bristol domes and similar structures farther north lie along the crest of a geanticline formed at that time east of the Green Mountain anticlinorium. The Wepawaug Schist occupies the trough of a large syncline formed east of the geanticline during this orogeny. The distribution of isograds in relation to stocks of Prospect Gneiss indicates that the progressive regional metamorphism was superimposed on, rather than caused by, the gneiss. Contact metamorphism, however, probably occurred adjacent to stocks of the Prospect at the time of emplacement. Slight retrograde metamorphism occurred shortly after the climax of the progressive regional metamorphism.

It is possible that the Prospect and Ansonia Gneisses, which intruded the Straits and Southington Mountain Schists, were emplaced during the Taconic disturbance in Ordovician time. In the map area, these intrusives have not been found in the Wepawaug Schist of Silurian and Devonian age, which unconformably overlie rocks of Ordovician age. Furthermore, the only available age determinations made on zircon from the Prospect Gneiss suggest an Ordovician age for the rock. These intrusives, therefore, may be members of the Highlandcroft plutonic series of Ordovician age mapped in New Hampshire and Vermont by Billings (1955) and Doll and others (1961), respectively. However, in view of the fact that age determinations made on zircon from the Woodbridge Granite are not in agreement with the age of the rock estimated on the basis of mapping, it is apparent that at the present time emphasis should not be placed on the few age determinations available. It is concluded further that, in the absence of indisputible evidence of major tectonic activity in the map area during the Taconic disturbance, it is unlikely that the Prospect and Ansonia Gneisses are Ordovician in age.

The writer believes it to be more likely that emplacement of the Prospect and Ansonia Gneisses occurred during the Acadian orogeny. If so, they may be members of the New Hampshire plutonic series of Devonian (?) age mapped in New Hampshire and Vermont by Billings (1955) and Doll and others (1961), respectively. The distribution of stocks of Prospect Gneiss suggests that this rock was emplaced after initial folding of the Wepawaug Schist of Silurian and Devonian age. The main stocks of Prospect Gneiss are more or less in line parallel to to the regional structures, which here trend toward the north-northeast, but the Prospect also intruded rocks south of the core of the Waterbury dome. The field relations suggest that the dome had formed before the Prospect Gneiss was emplaced, and it is obvious that it was easier for the Prospect Gneiss to penetrate formations stratigraphically above the Waterbury Gneiss rather than penetrate the Waterbury. Thus, the field relations suggest that the Waterbury Gneiss in the core of the Waterbury dome was a relatively competent basement mass, whereas the overlying, less competent pelitic formations were easily intruded by magmas during or after folding but before the climax of progressive regional metamorphism at the time of the Acadian orogeny. Until further age determinations are made on radioactive minerals from these rocks, however, the age of the Prospect and Ansonia Gneisses are reported as Ordovician or Devonian.

Woodbridge Granite intruded the tightly folded Wepawaug Schist of Silurian and Devonian age before the climax of the latest progressive regional metamorphism. In the chlorite, garnet, and biotite zones in the map area the granite was not strongly metamorphosed, but west of the staurolite isograd in the Ansonia quadrangle the Woodbridge was converted to a granitic gneiss. The age of the Woodbridge, therefore, must be Devonian, in spite of the fact that an age determination on zircon from this rock suggests that the granite is Precambrian in age. The rock is believed to be related to the New Hampshire plutonic series. In view of the fact that the metamorphosed equivalents of Woodbridge Granite in the Ansonia quadrangle are somewaht similar to the Ansonia Gneiss, and the age of the Prospect and Ansonia Gneisses may be Devonian, the writer believes it possible that the Ansonia Gneiss in a general way is the metamorphic equivalent of the Woodbridge Granite.

After the Acadian orogeny the next geologic events recorded in bedrock in the map area occurred in Late Triassic time. There is no record here of geologic events during Mississippian, Pennsylvanian, and Permian time. New Haven Arkose of the Newark Group was deposited in coalescing alluvial fans on an irregular surface above the folded and metamorphosed rocks of pre-Mississippian age. New Haven Arkose and younger rocks of the Newark Group probably extended across the entire map area and were continuous with similar strata in the Pomperaug valley in western Connecticut. The total thickness of Newark strata may have exceeded 20,000 feet. At about the time that the Talcott Basalt of the Newark Group was extruded above the New Haven Arkose, West Rock Diabase intruded the arkose. In Late Newark or post-Newark time, dikes of Buttress Diabase were intruded along faults that offset the New Haven Arkose and West Rock Diabase. Barite and copper minerals were deposited along dikes and faults during or after emplacement of the diabase. Tilting and faulting during and after deposition of the Newark Group was accompanied and followed by erosion, which completely removed the Newark strata from the western part of the map area. Throw on faults of Late Triassic age in the map area ranges from a few tens of feet to several hundred feet.

REFERENCES CITED

Barrell, Joseph, 1921, Relations of subjacent igneous invasion to regional metamorphism: Am. Jour. Sci., v. 1, 5th ser., p. 1-19, 174-186, 255-267.

Barth, T. F. W., 1936, Structural and petrologic studies in Dutchess County, New York; Part II, Petrology and metamorphism of the Paleozoic rocks: Geol. Soc. America Bull. v. 47, p. 775-850.

Bateman, A. M., 1923, Primary chalcocite; Bristol copper mine, Connecticut: Econ. Geology, v. 18, p. 122-166.

Beach, J. P., 1912, History of Cheshire, Connecticut, from 1694 to 1840 including Prospect, which as Columbia Parish, was a part of Cheshire until 1829: Cheshire, Lady Fenwick Chapter, D. A. R., 574 p., printed by Press of the Journal Publishing Co., Meriden, Conn.

Billings, M. P., 1955, Geologic map of New Hampshire: U. S. Geol. Survey.

Blake, W. P., 1888, History of the town of Hamden, Connecticut: New Haven, Price, Lee & Co., 350 p.

Carr, M. H., 1960, The bedrock geology of the Naugatuck quadrangle: Connecticut Geol. and Nat. History Survery Quad. Rept. 9, 25 p.

Credner, Hermann, 1866, Beschreibung von Mineralvorkommen in Nordamerika, IV. Schwerspath-Vorkommen in Connecticut: Berg- und Huettenmaennische Zeitung, Jahrg. XXV, no. 17, p. 143-144.

Dale, T. N., and Gregory H. E., 1911, The granites of Connecticut: U. S. Geol. Survey Bull. 484, 137 p.

Davis, W. M., 1882, The structural value of the trap ridges of the Connecticut Valley: Boston Soc. Nat. History Proc., v. 22, p. 116-124.

___________ 1888, The structure of the Triassic formation of the Connecticut valley: U. S. Geol. Survey, 7th Ann. Rept., 1885-1886, p. 455-490.

___________ 1898, The Triassic formation of Connecticut: U. S. Geol. Survey 18th Ann. Rept., p. 1-192.

Davis, W. M., and Griswold, L. S., 1894, Eastern boundary of the Connecticut Triassic: Geol. Soc. America Bull., v. 5, p. 515-530.

Davis, W. M., and Loper, S. W., 1891, Two belts of fossiliferous black shale in the Triassic formation of Connecticut: Geol. Soc. America Bull., v. 2, p. 415-430.

Doll, C. G., Cady, W. M., Thompson, J. B., and Billings, M. P., 1961, Centennial geologic map of Vermont: Vermont Geol. Survey.

Emerson, B. K., 1917, Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, 289 p.

Flint, R. F., 1962, The surficial geology of the Mount Carmel quadrangle: Connecticut Geol. and Nat. History Survey, Quad. Rept., no. 12, 25 p.

Fritts, C. E., in press, a, Age and sequence of metasedimentary formations northwest of New Haven, Connecticut: U. S. Geol. Survey Prof. Paper 450-D.

___________, in press, b, Late Newark fault versus pre-Newark peneplain in Connecticut: Am. Jour. Sci.

Goddard, E. N., chm., and others, 1951, Rock-color chart: New York, Geol. Soc. America, [1st printing, 1948, by Natl. Research Council].

Gregory, H. E., and Robinson, H. H., 1907, Preliminary geologic map of Connecticut: Connecticut Geol. and Nat. History Survey Bull. 7, 39 p.

Hanshaw, P. M., and Barnett, P. R., 1960, Possible use of boron, chromium, and nickel content in correlating Triassic igneous rocks in Connecticut, in Short papers in the geological sciences: U. S. Geol. Survey, Prof. Paper 400-B, p. B170-B172.

Hawes, G. W., 1875, The trap rocks of the Connecticut valley: Am. Jour. Sci., 3d ser., v. 9, p. 185-192.

Heald, M. T., 1956, Cementation of Triassic arkoses in Connecticut and Massachusetts: Geol. Soc. America Bull. v. 67, no. 9, p. 1133-1154.

Hobbs, W. H., 1901, The Newark system of the Pomeraug valley, Connecticut: U. S. Geol. Survey 21st Ann. Rept., pt. 3, p. 7-160.

Krynine, P. D., 1941, Triassic sediments of Connecticut: Geol. Soc. America Bull., v. 52, no. 12, pt. 2, p. 1919.

____________, 1950, Petrology, stratigraphy, and origin of the Triassic sedimentary rocks of Connecticut: Connecticut Geol. and Nat. Hist. Survey, Bull. 73, 247 p.

Kulp, J. L., 1961, Geologic time scale: Science, v. 133, no. 3459, p. 1105-1114.

LaSala, A. M., Jr., 1961, Surficial geology of the Southington quadrangle, Connecticut: U. S. Geol. Survey Geol. Quad. Map GQ-146.

Long, L. E., and Kulp, J. L., 1958, Age of the metamorphism of the rocks of the Manhattan prong: Geol. Soc. America Bull. 69, no. 5, p. 603-606.

Longwell, C. R., 1933a, The Triassic belt of Massachusetts and Connecticut in Longwell, C. R., and others, Eastern New York and western New England: Internat. Geol. Cong., 16th, United States 1933, Guidebook 1, Excursion A-1, p. 93-103.

____________, 1933b, Hartford to New Haven, Connecticut in Longwell, C. R., and others, Eastern New York and western New England: Internat. Geol. Cong., 16th, United States 1933, Guidebook 1, Excursion A-1, p. 111-116.

Longwell, C. R., and Dana, E. S., 1932, Walks and rides in central Connecticut and Massachusetts: New Haven, Tuttle, Morehouse & Taylor Co., 229 p.

McKee, E. D., and others, 1959, Paleotectonic maps of the Triassic system: U. S. Geol. Survey, Misc. Geol. Inv. Map I-300, 33 p.

Moore, F. H., 1935, Marbles and limestones of Connecticut: Connecticut Geol. and Nat. History Survey Bull. 56, 56 p.

Percival, J. G., 1842, Report on the geology of the State of Connecticut: New Haven, Osborn & Baldwin, 495 p.

Peterson, D. W., 1961, AGI data sheet 23; descriptive modal classification of igneous rocks: Geotimes, v. 5, no. 6, p. 31-36.

Platt, J. N., Jr., 1957, Sedimentary rocks of the Newark Group in the Cherry Brook Valley, Canton Center, Connecticut: Am. Jour. Sci., v. 255, no. 7, p. 517-522.

Quinn, A. W., 1959, Bedrock geology of the Providence quadrangle, Rhode Island: U. S. Geol. Survey Geol. Quad. Map GQ-118.

Redfield, W. C., 1856, On the relations of the fossil fishes of the sandstone of Connecticut and other Atlantic States to the Liassic and Oolitic periods: Am. Jour. Sci. and Arts, 2d ser., v. 22, no. 66, p. 357-363.

Reeside, J. B., Jr., and others, 1957, Correlation of the Triassic formations of North America exclusive of Canada: Geol. Soc. America Bull., v. 68, no. 11, p. 1451-1513.

Rice, W. N., and Gregory, H. E., 1906, Manual of the geology of Connecticut: Connecticut Geol. and Nat. History Survey Bull. 6, 273 p.

Rockey, J. L., 1892, History of New Haven County, Connecticut: New York, W. W. Preston & Co., v. 1, 740 p.; v. 2, 827 p.

Rodgers, John, Gates, R. M., and Rosenfeld, J. L., 1959, Explanatory text for preliminary geological map of Connecticut, 1956: Connecticut Geol. and Nat. History Survey Bull. 84, 64 p.

Schairer, J. F., 1931, The minerals of Connecticut: Connecticut Geol. and Nat. History Survey Bull. 51, 121 p.

Shepard, C. U., 1837, A report on the geological survey of Connecticut: New Haven, B. L. Hamlen, 188 p.

____________1852, A treatise on mineralogy: New Haven, B. L. Hamlen, 3d ed., v. 1, 245 p.

Silliman, Benjamin, 1820, Sketches of a tour in the counties of New Haven and Litchfield, Connecticut, with notices of the geology, mineralogy and scenery, etc.: Am. Jour. Sci. and Arts, 1st ser., v. 2, p. 201-235.

Stewart, Lincoln, 1935, The petrology of the Prospect porphyritic gneiss of Connecticut: Connecticut Geol. and Nat. History Survey Bull. 55, 40 p.

Stose, G. W., 1932, Geologic map of the United States: U. S. Geol. Survey

Thompson, J. B., Jr., 1952, Southern Vermont, *in* Guidebook for field trips in New England: Geol. Soc. America, 65th Ann. Mtg., Nov. 10-12, 1952, 142 p.

Wheeler, Girard, 1937, The west wall of the New England Triassic lowland: Connecticut Geol. and Nat. History Survey Bull. 58, 73 p.

APPENDIX I. PHOTOGRAPHS OF ROCKS

PLATE 5.

FIGURE A. Uncontorted, banded paragneiss of Waterbury Gneiss a few hundred feet southwest of junction of County and Ranson Hall Roads, Town of Wolcott, Southington quadrangle. Light gray layers are quartz-rich; dark gray layers are more micaceous. If gradation from quartz-rich to micaceous parts of individual bands to right of one-foot rule is interpreted as graded bedding, tops of original beds face right (east). White pods and lenses are quartz.

FIGURE B. Contorted, thinly banded paragneiss of Waterbury Gneiss just west of highest point on power line right-of-way northwest of Hitchcock Lake, Town of Wolcott, Southington quadrangle. Dark layers rich in biotite stand out on weathered surface and probably contain fine-grained kyanite. Light gray layers contain abundant quartz and feldspar. Aplitic veins at upper left cut across banding. Hammer has six inches marked off on handle for scale.

PLATE 5.

FIGURE A.

FIGURE B.

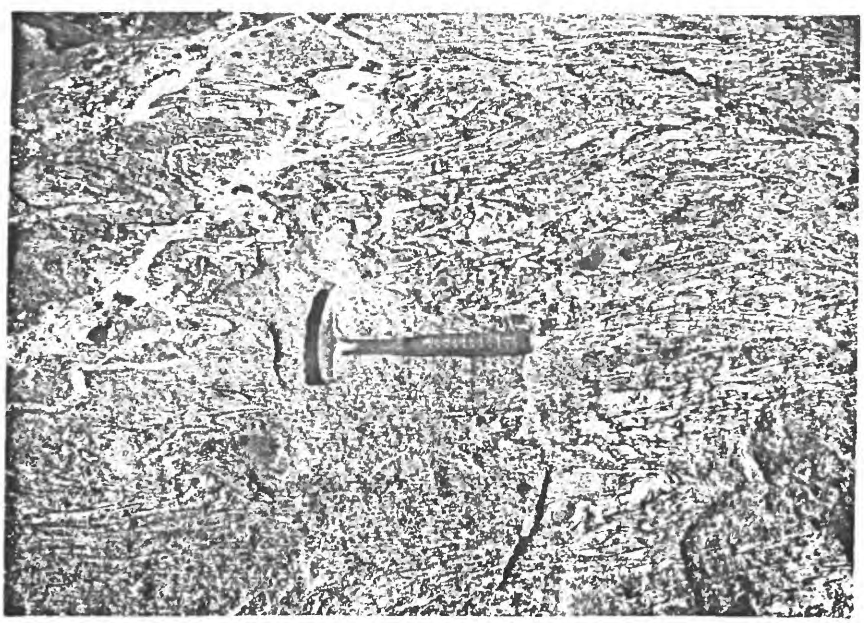


PLATE 6.

FIGURE A. Pegmatite swarm in contorted paragneiss of Waterbury Gneiss about 1,000 feet north of where Straitsville Road crosses Marks Brook, Town of Prospect, Mount Carmel quadrangle. These pegmatites were mapped as pegmatite, Dp, but they may be equivalent to the metamorphosed pegmatite, p6p, mapped in Southington quadrangle.

FIGURE B. Medium-grained granitoid gneiss impregnating contorted paragneiss of Waterbury Gneiss on west side of Pierpont Road, Town of Waterbury, Southington quadrangle. Pen knife is three inches long. Light gray lines that cross foliation are scars made by bulldozer. The granitic gneiss at this locality is near the northern end of a body of Woodtick Gneiss. but the relationship between the two meta-igneous gneisses is uncertain. The granitoid gneiss shown here was not mapped separately, but it is similar to rocks mapped as meta-igneous gneisses, undivided.

PLATE 6.

FIGURE A.

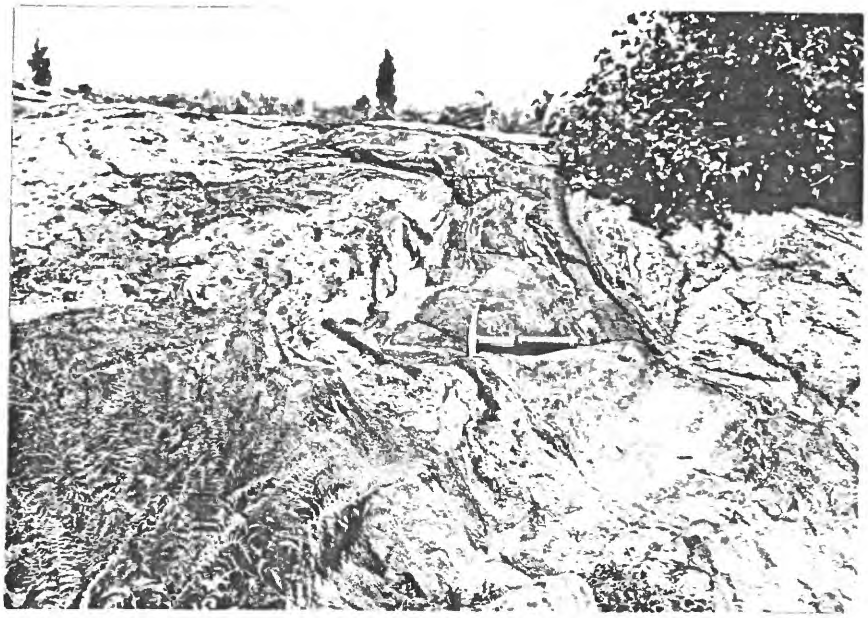


FIGURE B.

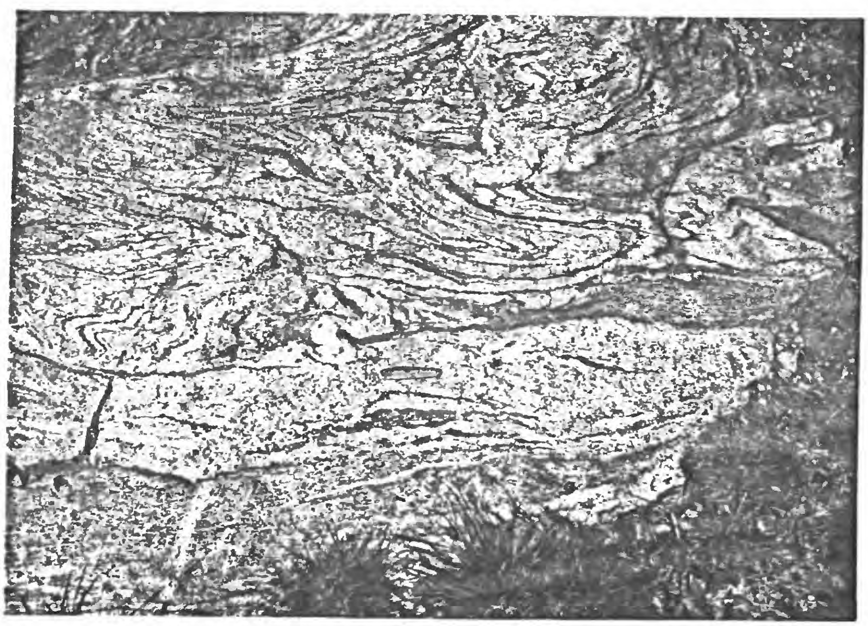


PLATE 7.

FIGURE A. Feldspathic mica schist in Hitchcock Lake Member of Waterbury Gneiss on west side of County Road about 2,000 feet south southwest of Ranson Hall Road intersection, Town of Wolcott, Southington quadrangle. Light colored bands contain abundant feldspar and quartz. Darker bands contain abundant biotite and muscovite in nearly equal quantities. Note coarse garnets in tree shadow below and to right of one-foot rule.

FIGURE B. Metamorphosed pegmatite on power line right-of-way northwest of Hitchcock Lake, Southington quadrangle. Note small garnets near pen knife, which is three inches long. Note also variation in grain size of rock.

PLATE 7.

FIGURE A.

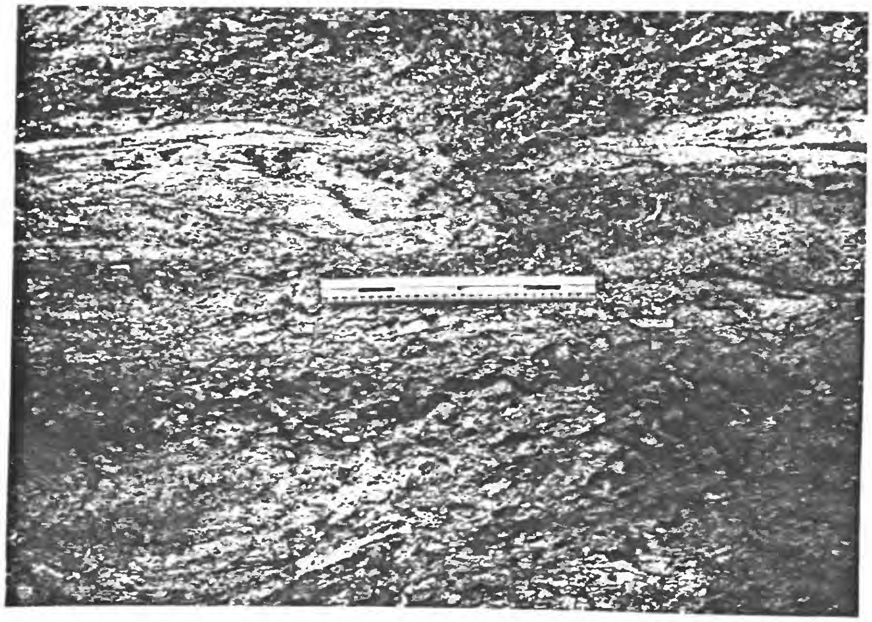


FIGURE B.

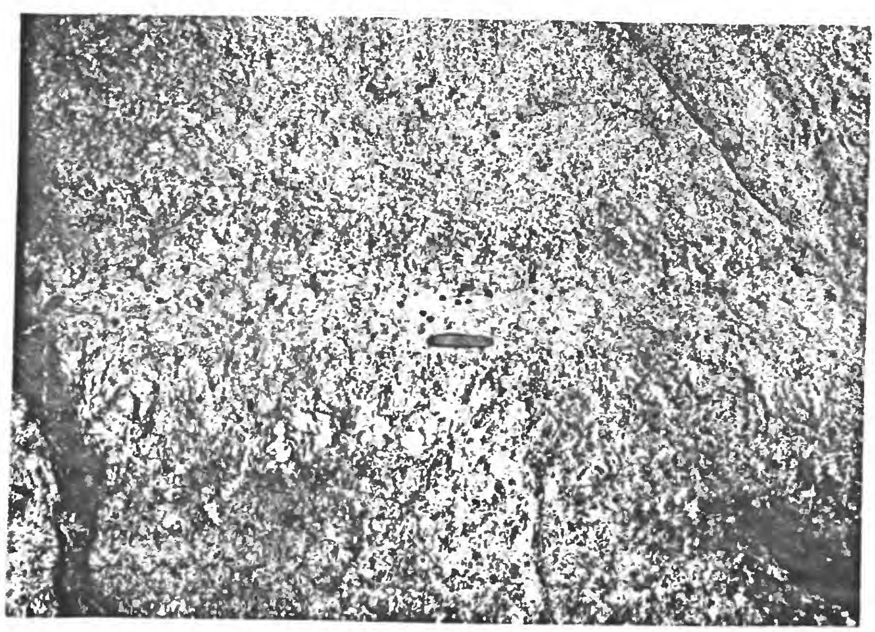


PLATE 8.

FIGURE A. Broad outcrop showing uniform composition of medium- to coarse-grained mica schist characteristic of Straits Schist, on hill (altitude 900+) approximately 4,500 feet south-southwest of Becar Hill, Town of Wolcott, Southington quadrangle. White lenses and pods are pegmatite and quartz. Note general lack of banding. Compare with Plate 9 and Plate 10, Figure A.

FIGURE B. Banded, garnetiferous amphibolite in Straits Schist west of Spindle Hill Road, Town of Wolcott, Southington quadrangle. Garnets stand out on weathered surface. Light colored layers above hammer contain abundant plagioclase, but little or no hornblende. Note pinch-and-swell structure in layer below hammer.

PLATE 8.

FIGURE A.

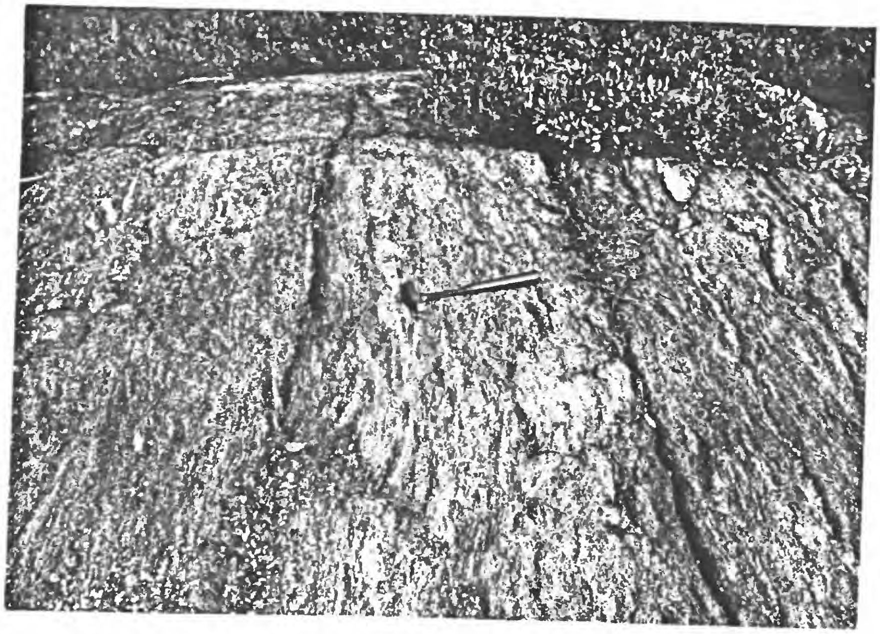


FIGURE B.

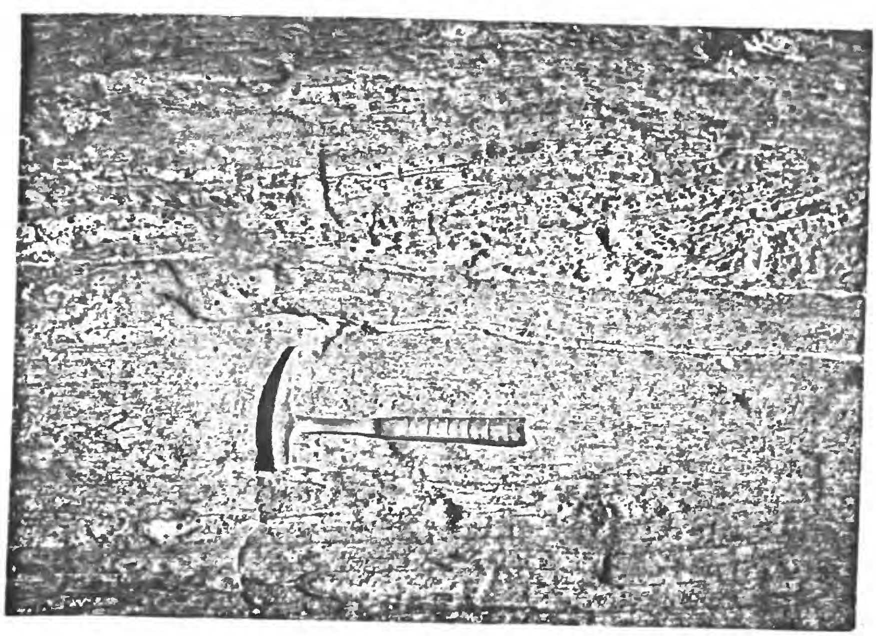


PLATE 9.

FIGURE A. Ribbon-like banding characteristic of Southington Mountain Schist at type locality southwest of New Britain Reservoir, Southington quadrangle. Two dark bands near one-foot rule are medium-grained amphibolite. Rule parallels latest glacial striations, which trend toward southwest away from viewer. Light-gray bands are medium-grained paragneiss; medium-gray bands are fine-grained, crenulated muscovite schist containing abundant dust-like graphite and numerous macroscopic staurolite crystals. Drag folds in amphibolite, which here indicate apparent relative movement of west side toward north (right), are characteristic of the formation at Southington Mountain, but do not indicate movement in the same direction in every outcrop.

FIGURE B. Southington Mountain Schist containing unmapped nearly white lenses and pods of pegmatite and quartz, about 800 feet east southeast of the intersection of Route 69 and Bound Line Road, Town of Wolcott, Southington quadrangle. Hammer handle points south (right) parallel to glacial striations. Rock is generally similar to banded formation shown in Figure A, but amphibolites are rare here. Drag folds are less conspicuous in outcrops like this near Straits Schist, but rocks become more contorted near northern boundary of map area, where they occupy the trough of a large syncline.

PLATE 9.

FIGURE A.

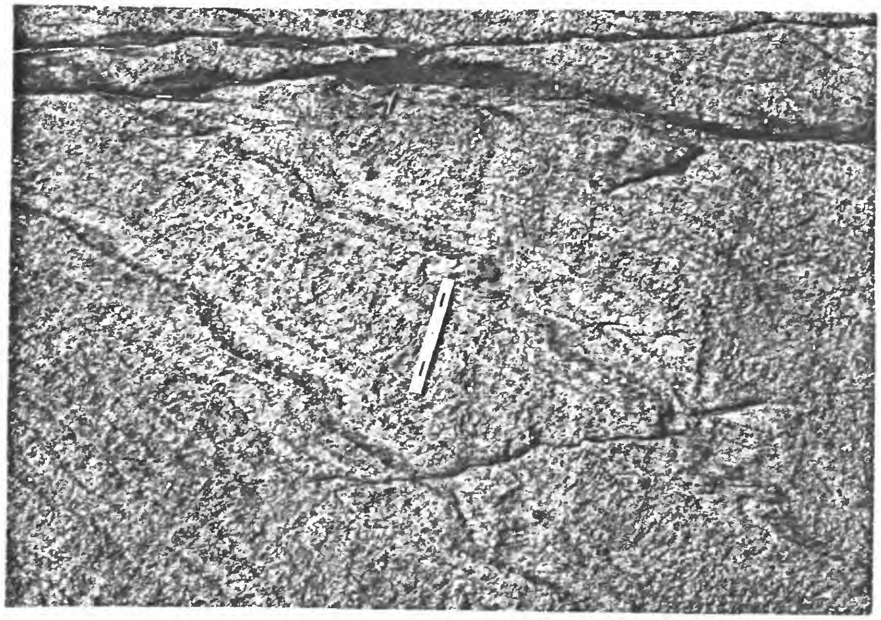


FIGURE B.

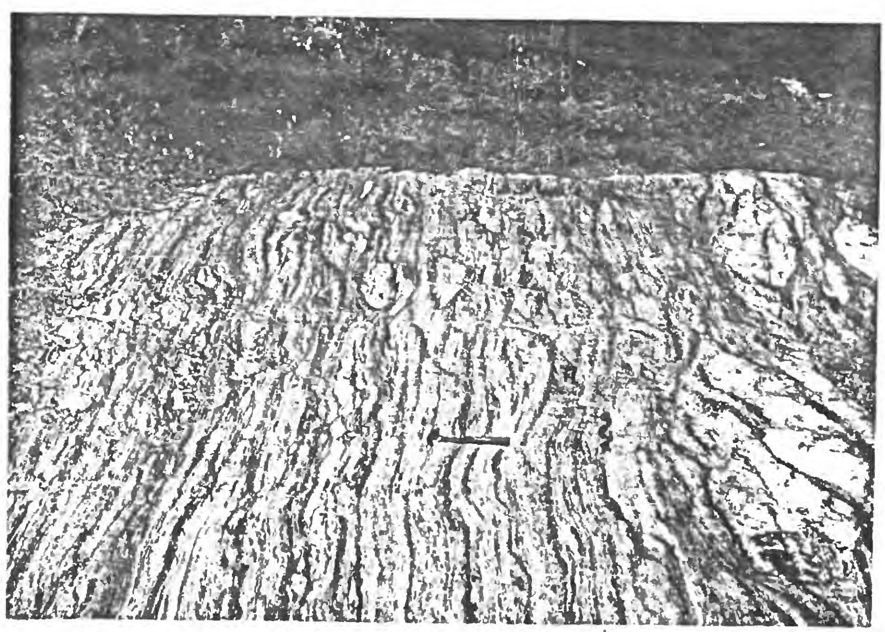


PLATE 10.

FIGURE A. Southington Mountain Schist, spillway of New Naugatuck Reservoir, Mount Carmel quadrangle. Rocks shown here are characteristic of formation near Prospect Gneiss. Width of bands less uniform and rocks less graphitic than in type area, but lithologies otherwise similar. Dark bands are medium-grained schist composed mainly of quartz, muscovite, biotite, oligoclase (An_{15-30}), garnet, and staurolite. Light bands are medium-grained paragneiss composed mainly of quartz, oligoclase (An_{15-30}), biotite, muscovite, and garnet.

FIGURE B. Jointing in West Rock Diabase at abandoned quarry near intersection of Routes 68 and 70, West Cheshire, Southington quadrangle. Polygonal joint columns plunge steeply toward northwest (left). Sheet jointing and diabase body dip gently toward southeast (right). Diabase on dip slope at upper right is fine-grained. Rock at base of quarry face near automobile is medium- to coarse-grained.

PLATE 10.

FIGURE A.

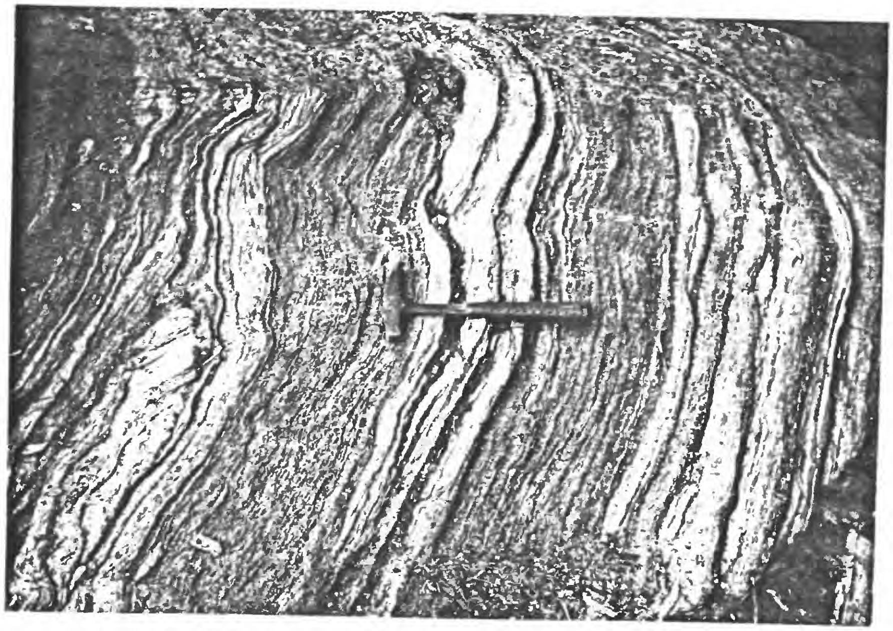


FIGURE B.

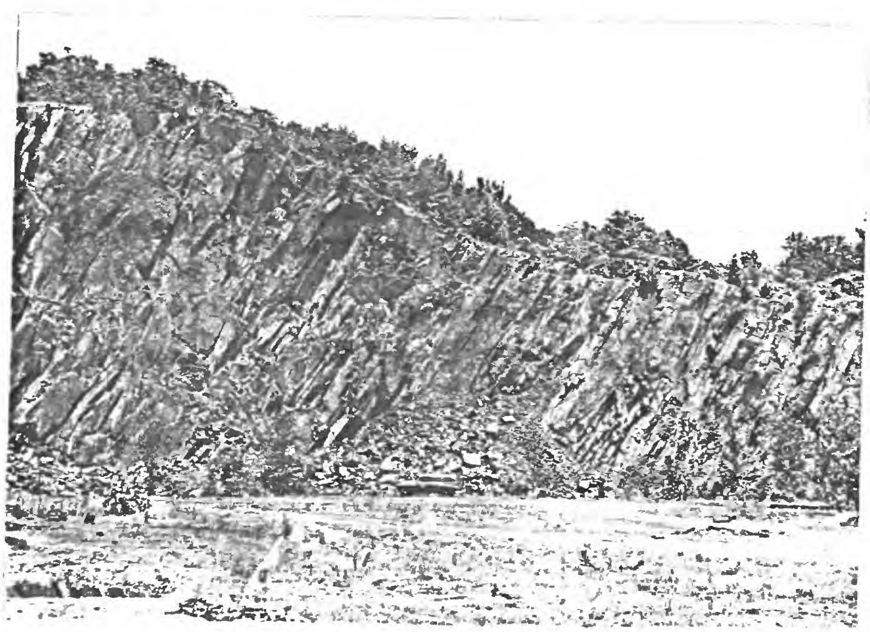


PLATE 11.

FIGURE A. Polished hand sample of Derby Hill Schist from northern part of Ansonia quadrangle, showing thin layering and typical shear cleavage. Main foliation nearly horizontal in photograph. Shear cleavage inclined from upper left to lower right. Dark layers are composed mainly of very fine-grained muscovite. Light layers are composed mainly of intergrown, very fine-grained albite and chlorite, but some are composed of very fine-grained granulated quartz. Light gray lens about 1 inch long and 1/2 inch wide at lower right is medium-grained quartz injected into schist before rock was sheared. Small white spots at upper right are medium-grained albite associated with quartz injected into schist.

FIGURE B. Close-up view of Derby Hill Schist on bottom of Lake Chamberlain Reservoir, Mount Carmel quadrangle, visible during drought in 1957. Compass points north (right). Note pervasive shear cleavage, along which movement was right lateral (northwest side moved northeastward). Large white areas are quartz, which has undergone strong cataclasis. See Plate 22.

PLATE 11.

FIGURE A.

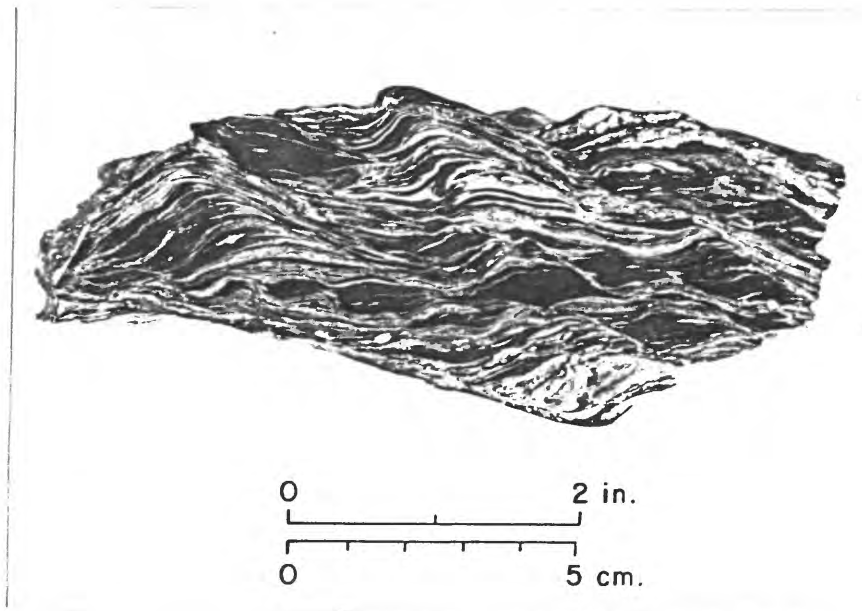


FIGURE B.

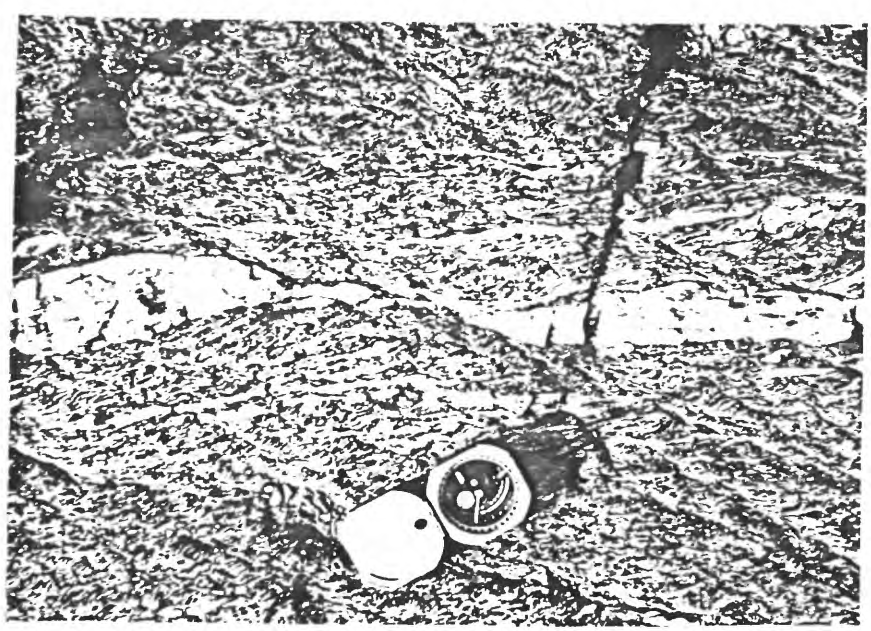


PLATE 12.

FIGURE A. Impure marble, north shore of New Naugatuck Reservoir, Mount Carmel quadrangle. White bands are mainly calcite; dark bands contain abundant clinozoisite, quartz, and microcline.

FIGURE B. Dip slope of impure marble, north shore of New Naugatuck Reservoir, Mount Carmel quadrangle. Note excellent lineation (parallel to hammer handle) formed by alinement of silicate minerals.

FIGURE C. Contact between granodiorite gneiss of Prospect Gneiss (light gray) and an unmapped inclusion of biotitic paragneiss (dark gray) near locality S13, Route 68, Town of Prospect, Mount Carmel quadrangle.

FIGURE D. Quartz monzonite gneiss of Prospect Gneiss containing numerous large white microcline porphyroblasts and two inclusions of metasedimentary biotite-quartz-feldspar gneiss (dark gray), about 750 feet south of Old Bethany Cemetary, Mount Carmel quadrangle. Foliation is slightly oblique to face of outcrop.

PLATE 12.

FIGURE A.

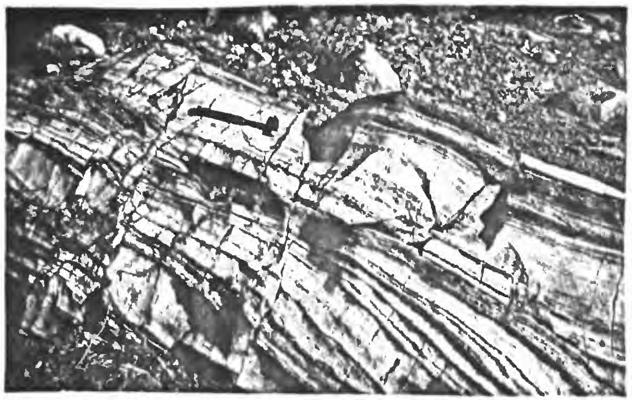


FIGURE B.

FIGURE C.

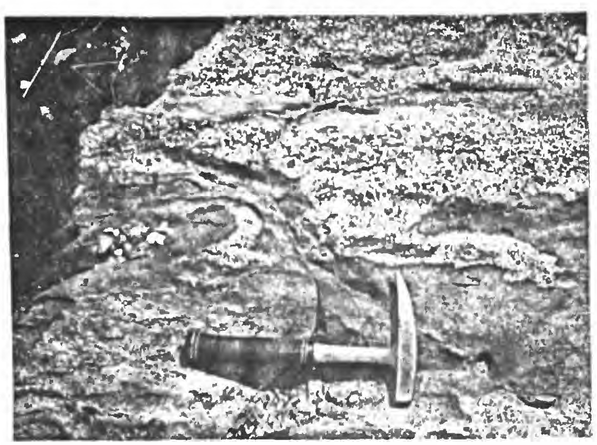


FIGURE D.

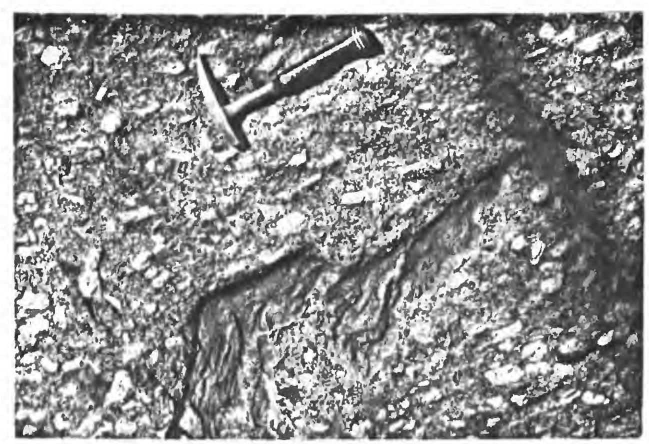


PLATE 13.

FIGURE A. Small anticlinal drag fold along east side of impure crystalline limestone, spillway of Glen Dam Reservoir, Mount Carmel quadrangle. Thinly layered rock at lower right is phyllite characteristic of Wepawaug Schist in chlorite zone.

FIGURE B. Boulder of Woodbridge Granite containing inclusion of garnetiferous, phyllitic schist, in Sargent River at gas line south of Lake Chamberlain, Mount Carmel quadrangle.

PLATE 13.

FIGURE A.

FIGURE B.

PLATE 14.

FIGURE A. Unconformity, north bank of Roaring Brook, Southington quadrangle. New Haven Arkose dipping gently eastward overlies fresh nearly vertical Southington Mountain Schist. Hammer at contact shows scale.

FIGURE B. Fault contact between hydrothermally altered Prospect Gneiss on left and fresh New Haven Arkose on right, excavated on north bank of Ten Mile River, Southington quadrangle. Contact is nearly vertical, but seems to dip steeply westward in photograph because of slope of stream bank. Notice altered gneiss (light gray, above trenching shovel) slumped over well-indurated arkose. Nearly vertical striations on slickensided joint in arkose can be seen east of pail. Hunting knife and prospecting pick have been driven into thoroughly altered gneiss. One-foot rule below and to right of pick handle rests on altered gneiss near gouge.

PLATE 14.

FIGURE A.

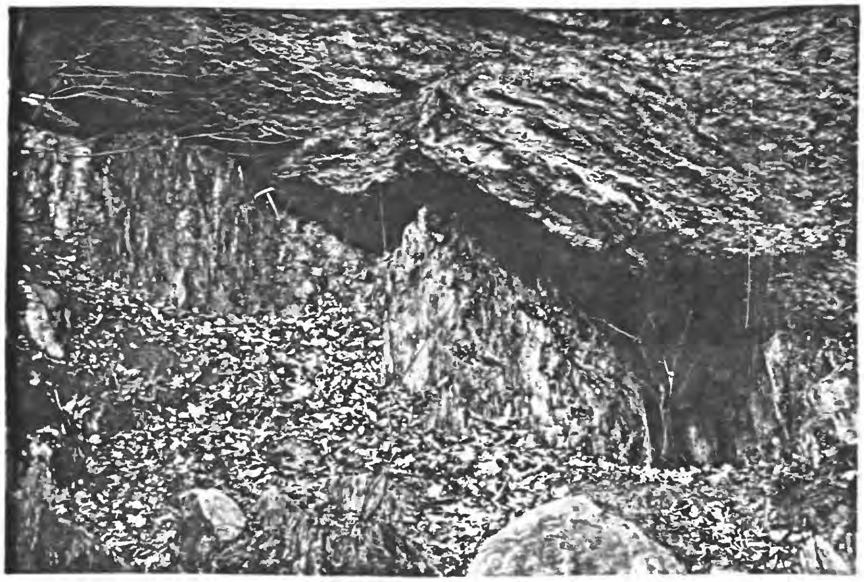


FIGURE B.

PLATE 15.

FIGURE A. Fault breccia from Jinny Hill mine dump, Town of Cheshire, Mount Carmel quadrangle. Fragments of New Haven Arkose are cemented by quartz and barite. One-foot rule shows scale.

FIGURE B. Barite crystals from Jinny Hill mine, Town of Cheshire, Mount Carmel quadrangle. Crystals now on display at Peabody Museum, Yale University, New Haven, Connecticut. Six-inch rule shows scale.

PLATE 15.

FIGURE A.

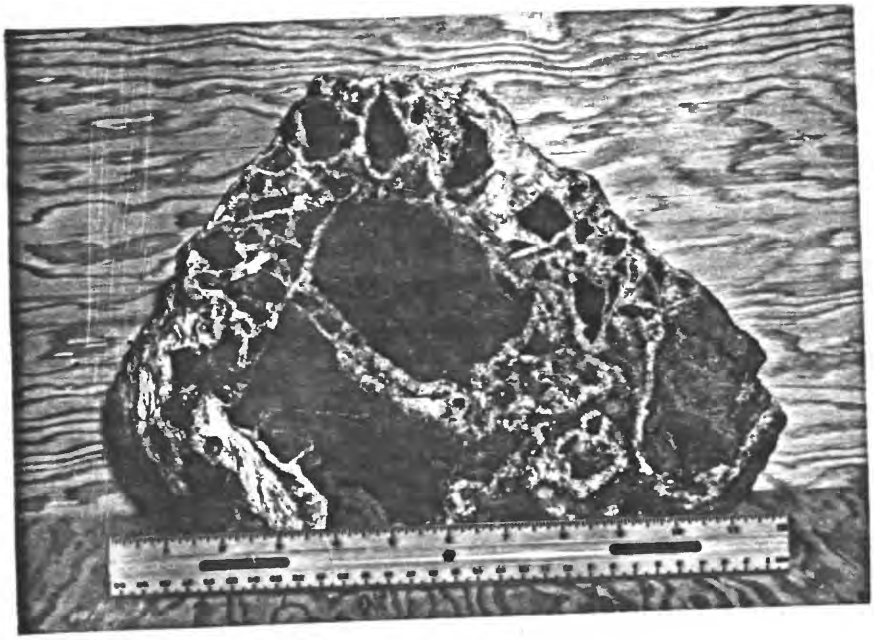
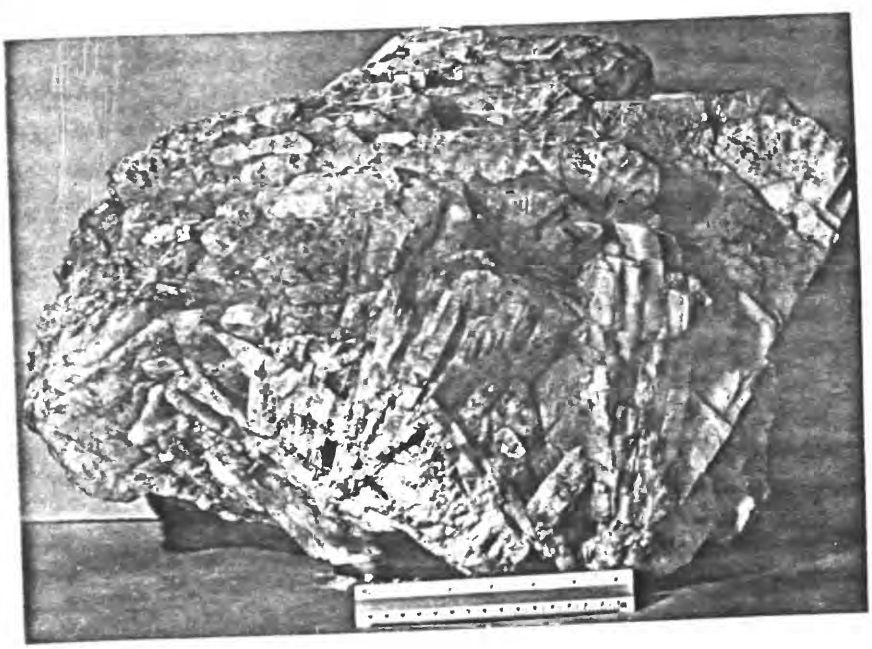


FIGURE B.



APPENDIX II. PHOTOMICROGRAPHS OF ROCKS

PLATE 16.

FIGURE A. Paragneiss of Waterbury Gneiss, west shore of Hitchcock Lake, about 300 feet north of Central Avenue, Southington quadrangle. Crossed nicols; 18X. B, biotite; Mc, microcline; Q, quartz; M, muscovite; G, garnet; K, kyanite; O, oligoclase. Crude lineation and foliation inclined gently to right. Note complex texture and variation in grain size. Biotite porphyroblast containing tiny inclusions of muscovite and quartz is intergrown with anhedral garnet (dark). Microcline contains tiny crystals of quartz and muscovite, and a little oligoclase. Kyanite crystals are blade-like, but appear to be acicular above and to right of biotite porphyroblast where minimum diameters of kyanite crystals are visible. Dark spot at lower right is hole in thin section.

FIGURE B. Relict garnet porphyroblast in paragneiss of Waterbury Gneiss, about 400 feet east of Old Naugatuck Reservoir, Mount Carmel quadrangle. Crossed nicols; 15X. Q, quartz; O, oligoclase; B, biotite; M, muscovite; G, garnet. Note abundance of oligoclase and biotite intergrown with aggregate of anhedral garnet that represents single original garnet porphyroblast rotated oblique to foliation, which is nearly horizontal in photomicrograph.

PLATE 16.

FIGURE A.

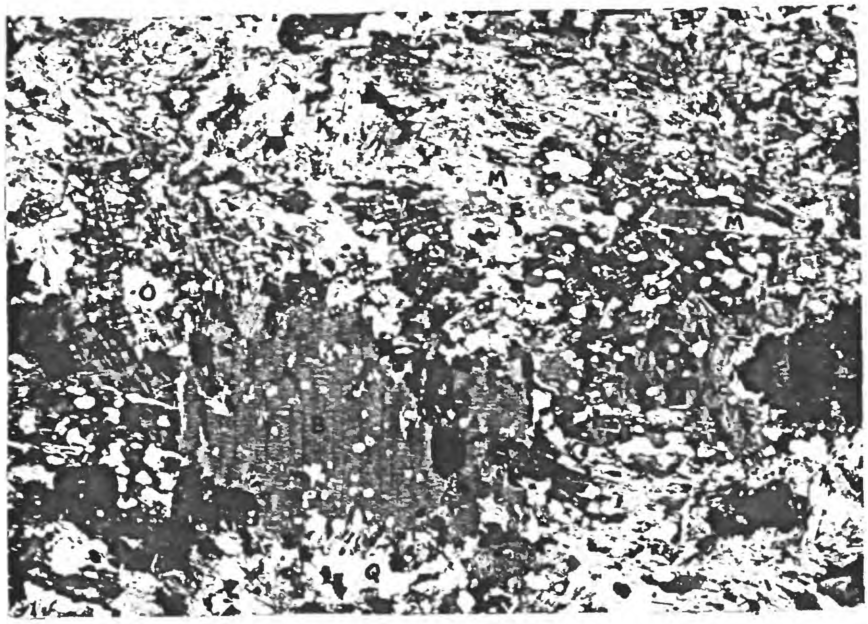


FIGURE B.

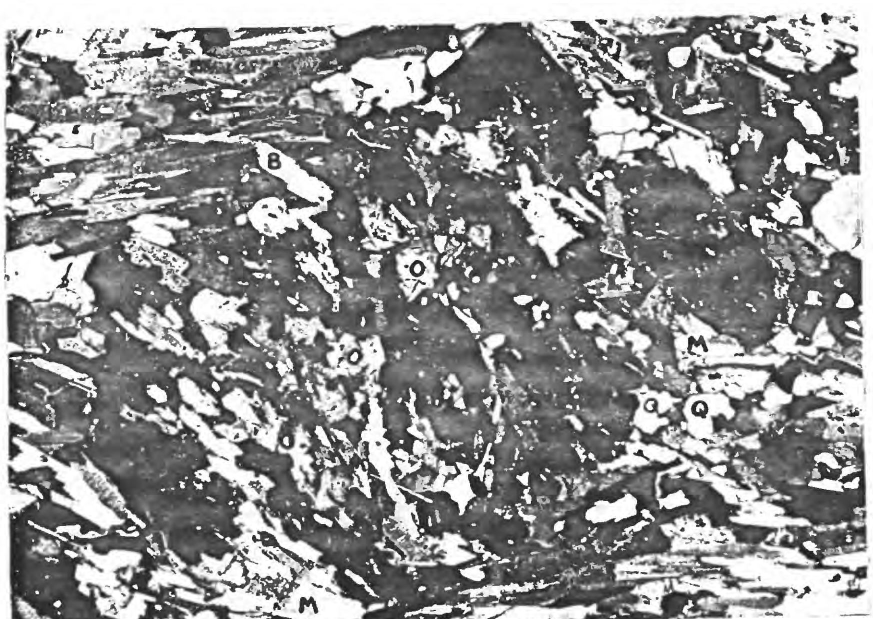


PLATE 17.

FIGURE A. Paragneiss of Waterbury Gneiss, about 1,350 feet east of western quadrangle boundary 1,900 feet south of Route 70, Town of Waterbury, Southington quadrangle. Crossed nicols; 15X. Q, quartz; B, biotite; K, kyanite; G, garnet; O, oligoclase. Texture unusual. Quartz-rich layers appear to have been injected between finer-grained layers, which contain abundant biotite, aggregates of rod-like kyanite crystals less than 0.5 x 0.1 mm., and garnet. Most kyanite is intergrown with tiny crystals of quartz and oligoclase, but some kyanite is included in garnet. Note small oligoclase crystals in biotitic layer near bottom of photomicrograph and coarser oligoclase in quartz-rich layer to right.

FIGURE B. Paragneiss of Waterbury Gneiss, east side of Wolf Hill, Town of Wolcott, Southington quadrangle. Plain light; 15X. M, muscovite; Q, quartz; G, garnet; O, oligoclase; B, biotite, K, kyanite. Texture and metamorphic history complex. Note euhedral to subhedral garnet surrounded by older, finer-grained, anhedral garnet. Sericite (not distinguishable in photomicrograph) surrounds some kyanite crystals, but in many places is associated with coarser, ragged crystals of muscovite. Kyanite generally less than 0.3 mm. long; tiny muscovite crystals fill fractures in kyanite and are intergrown with kyanite at ends of some crystals.

PLATE 17.

FIGURE A.

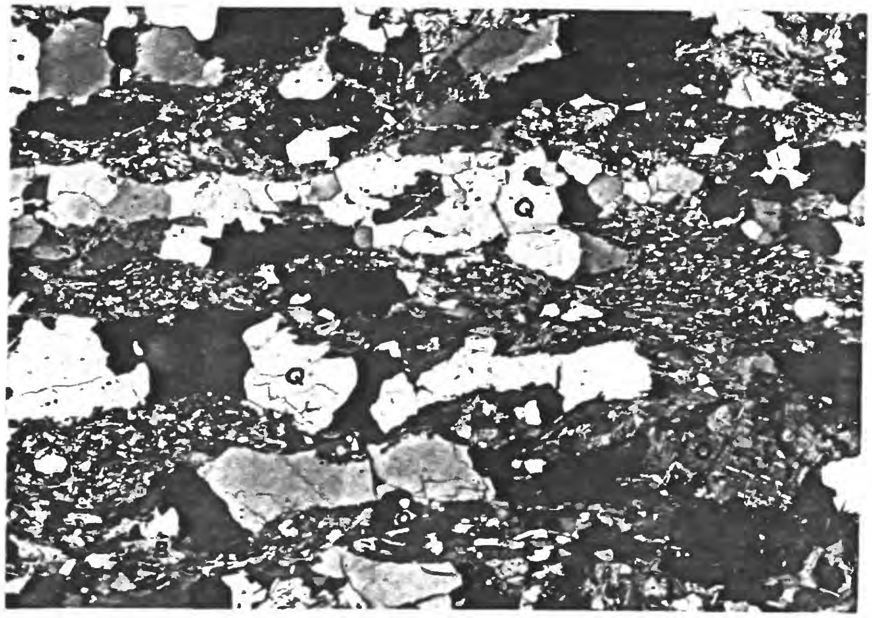


FIGURE B.

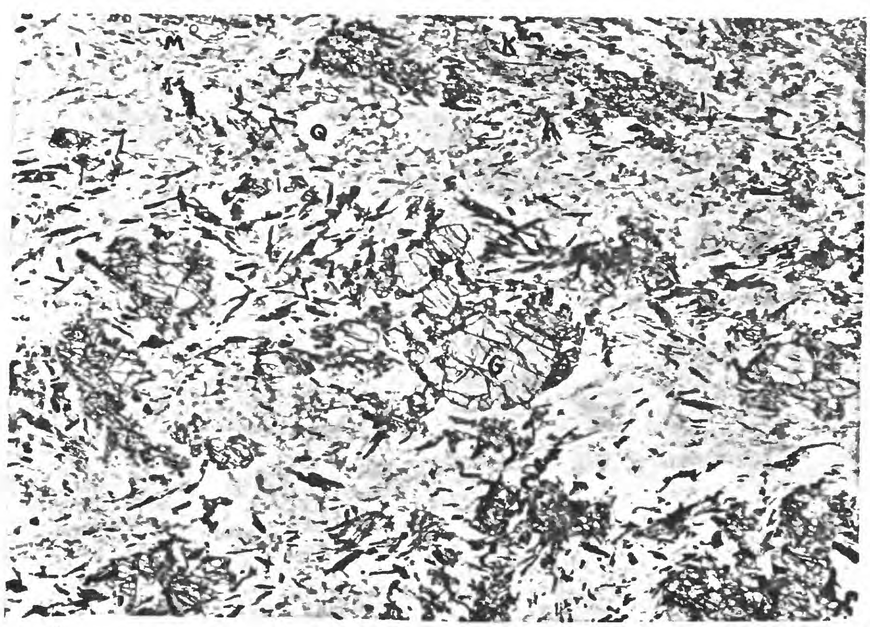


PLATE 18.

FIGURE A. Kyanite "knot" in schistose layer in paragneiss of Waterbury Gneiss, east shore of pond near intersection of County and Ranson Hall Roads, Town of Wolcott, Southington quadrangle. Crossed nicols; 15X. M, muscovite; K, kyanite; B, biotite; Q, quartz; C, chlorite (+). Aggregates of fan-shaped groups of kyanite crystals in upper half and near lower edge of photomicrograph are approximately perpendicular to foliation, which is nearly vertical in photomicrograph.

FIGURE B. Amphibolite in Waterbury Gneiss north of diabase dike in northern Prospect, Southington quadrangle. Crossed nicols; 15X. H, hornblende; A, andesine; Q, quartz; Z, zoisite. Note complex texture and lack of lineation and foliation. Hornblende has numerous tiny inclusions of quartz, andesine, and chlorite (+). Andesine has tiny inclusions of clinozoisite.

FIGURE C. Vesuvianite-bearing calc-silicate rock in Southington Mountain Schist near Prospect Gneiss south of Darcy School, western Cheshire, Southington quadrangle. Crossed nicols; 15X. D, diopside; M, microcline; V, vesuvianite; A, albite; Q, quartz. Vesuvianite porphyroblasts contain numerous tiny crystals of diopside; some also contain crystals of calcite and microcline(?) generally less than 0.1 mm. in diameter. Matrix mainly diopside and microcline, with a small amount of plagioclase (probably calcic albite).

PLATE 18.

FIGURE A.

FIGURE B.

FIGURE C.

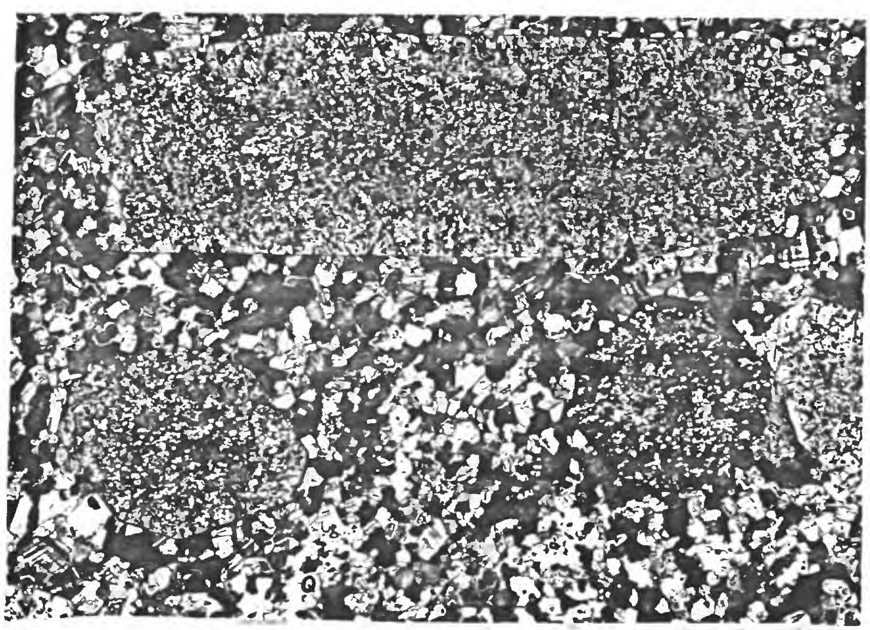


PLATE 19.

FIGURE A. Subhedral garnet porphyroblasts in paragneiss of Straits Schist near north end of Southington Reservoir No. 2, Southington quadrangle. Crossed nicols; 15X. P, plagioclase (calcic oligoclase or sodic andesine); B, biotite; Q, quartz; G, garnet. Lineation and foliation nearly horizontal in photomicrograph. Albite twinning inconspicuous in plagioclase. Garnet contains small inclusions of quartz and plagioclase, but note simple texture. Compare with Plate 16, Figure B.

FIGURE B. Garnet porphyroblasts intergrown with plagioclase in largest body of amphibolite in Straits Schist northeast of intersection of Woodtick and County Roads, Town of Wolcott, Southington quadrangle. Crossed nicols; 15X. H, hornblende; A, andesine; G, garnet. Lineation and foliation approximately horizontal in photomicrograph. Plagioclase slightly sericitized; albite twinning rarely visible. Rock texture relatively simple. Compare with Plate 18, Figure B.

PLATE 19.

FIGURE A.

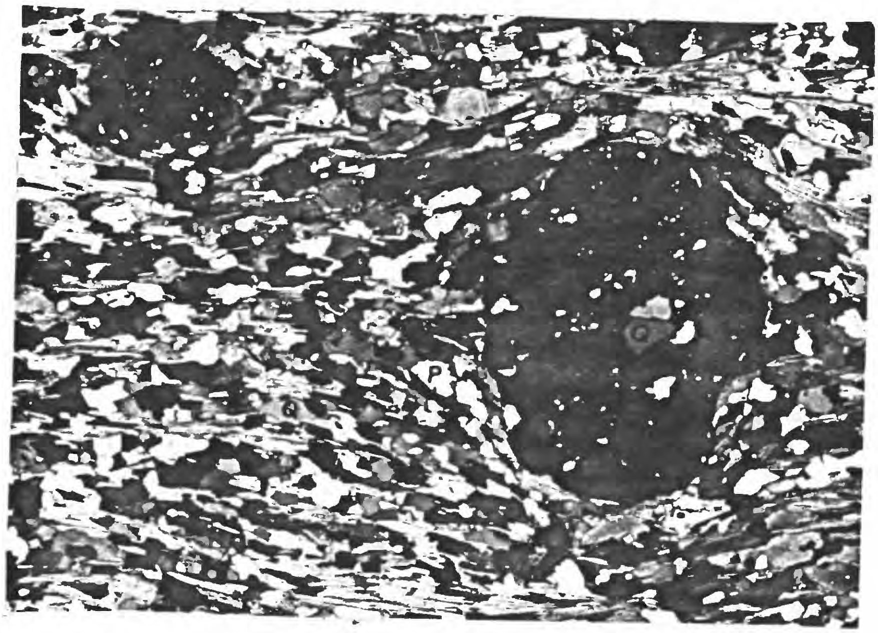


FIGURE B.

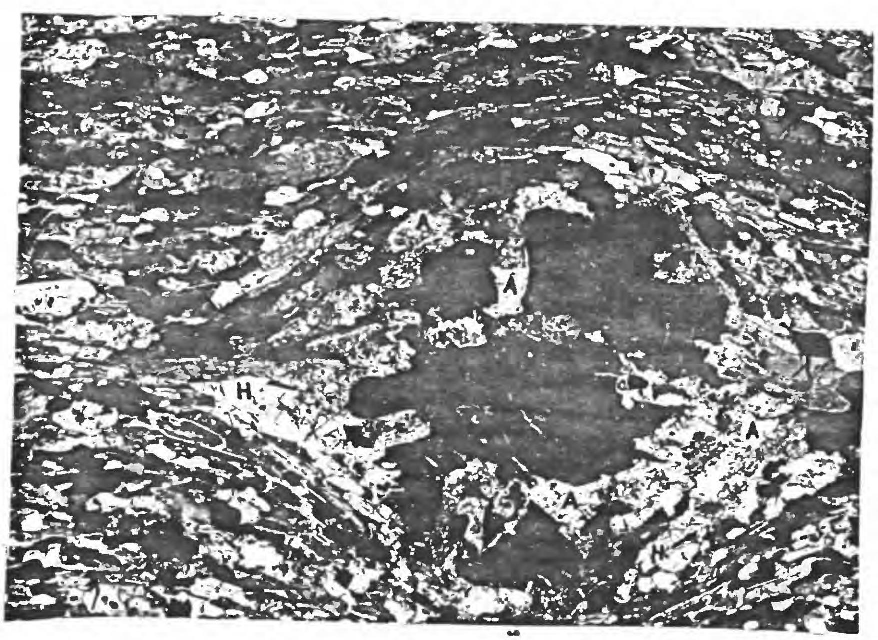


PLATE 20.

FIGURE A. Fresh, medium- to coarse-grained, staurolite-bearing mica schist characteristic of Straits Schist, west side of Route 69 about 700 feet north of Coer Road intersection, Town of Prospect, Mount Carmel quadrangle. Plain light, 15X. M, muscovite; B, biotite; Q, quartz; G, garnet; S, staurolite; C, chlorite (+). Rock also contains sodic oligoclase, which is not visible in photomicrograph. Note that biotite and chlorite (+) are oblique to muscovite in some places and parallel in others. Garnets contain numerous small inclusions of quartz and biotite, but rock is characterized by simple texture. Compare with Plate 16, Figure B.

FIGURE B. Mica schist of Straits Schist at type locality, Route 63, northern Bethany, Mount Carmel quadrangle. Crossed nicols, 15X. Q, quartz; M, muscovite; B, biotite; G, garnet; ST, staurolite; C, chlorite(+); S, sericite. Note that garnet and staurolite porphyroblasts are partly altered to sericite, as a result of retrograde metamorphism.

PLATE 20.

FIGURE A.

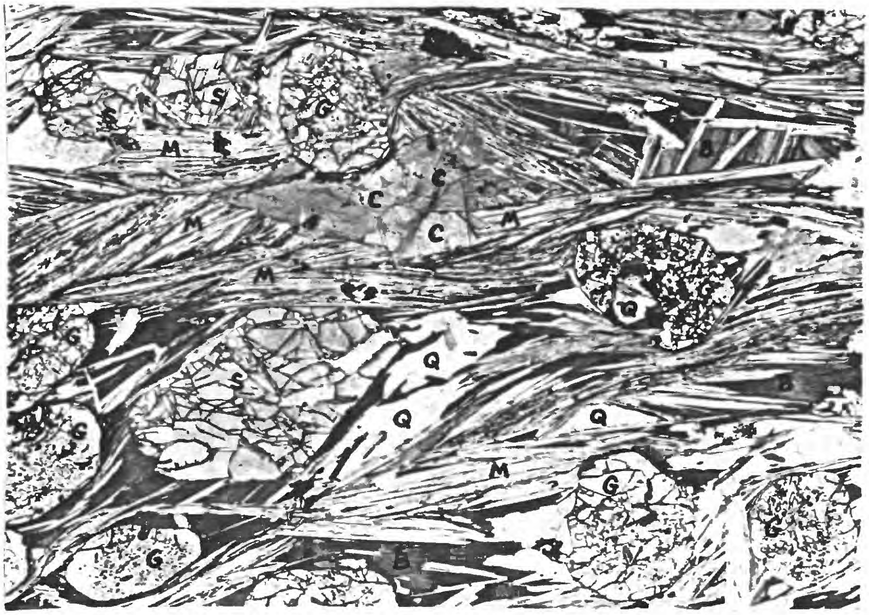


FIGURE B.

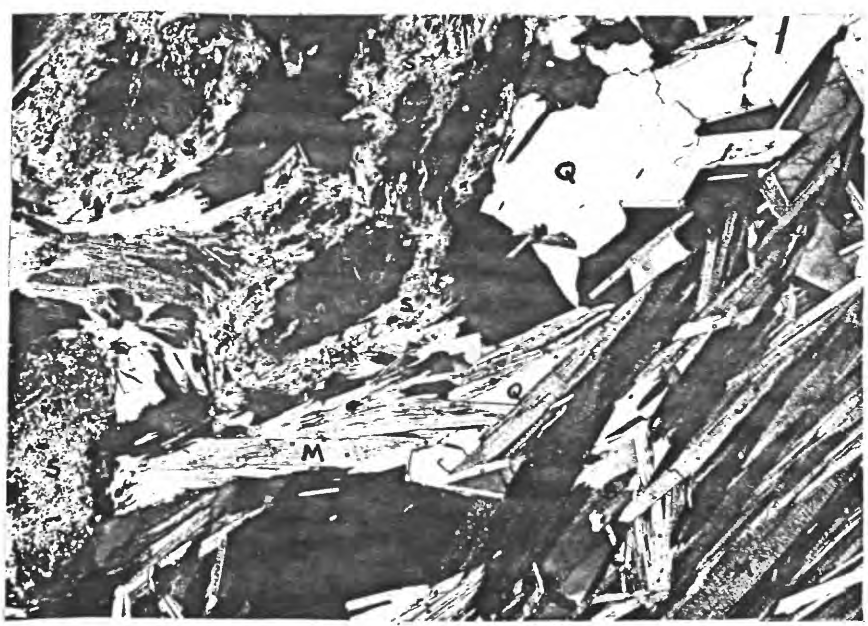


PLATE 21.

FIGURE A. Kyanite-bearing paragneiss band in Southington Mountain Schist, Spindle Hill Road, west southwest of Becar Hill, Town of Wolcott, Southington quadrangle. Plain light, 10X. Q, quartz; M, muscovite; G, garnet; B, biotite; K, kyanite. Rock also contains oligoclase and staurolite, which are not visible in photomicrograph. Thin dark layer at upper left is fine-grained, graphitic, muscovite schist. Note that muscovite is much coarser where graphite is lacking and quartz abundant. Note also six parts in twinned core of zoned garnet at lower right. Some garnets contain inclusions of biotite and quartz, but general texture is simple. Compare with Plate 16, Figure B.

FIGURE B. Crenulated, staurolite-bearing, graphitic, muscovite schist band in Southington Mountain Schist, Route 69, about 1,250 feet south of northern boundary of Southington quadrangle. Plain light, 15X. Q, quartz; M, muscovite; S, staurolite; B, biotite; O, oligoclase; C, chlorite(+). Abundant dust-like graphite is associated with fine-grained muscovite. Note booklike chlorite (+) oblique to muscovite at top of photomicrograph. Large, black, anhedral crystal at bottom of photomicrograph is ilmenite or magnetite.

PLATE 21.

FIGURE A.

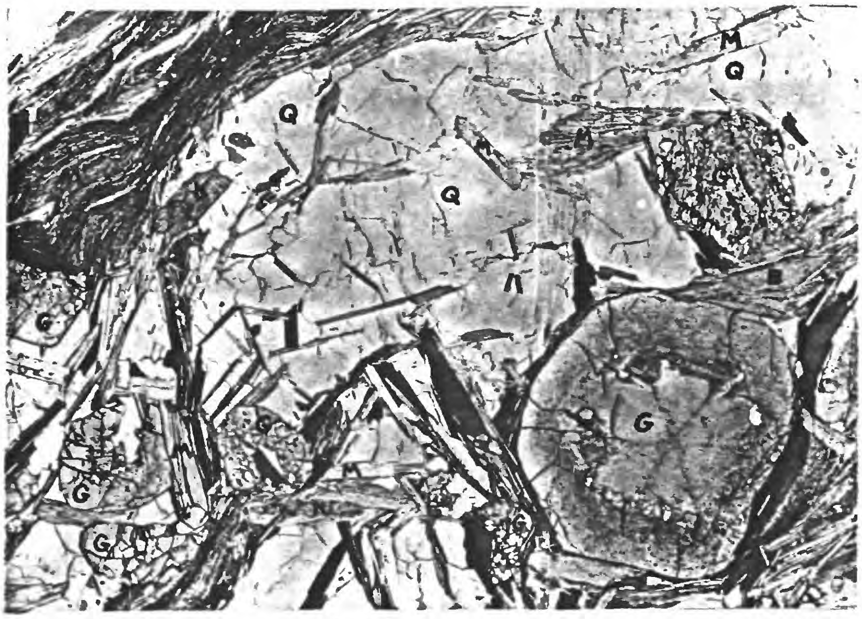


FIGURE B.

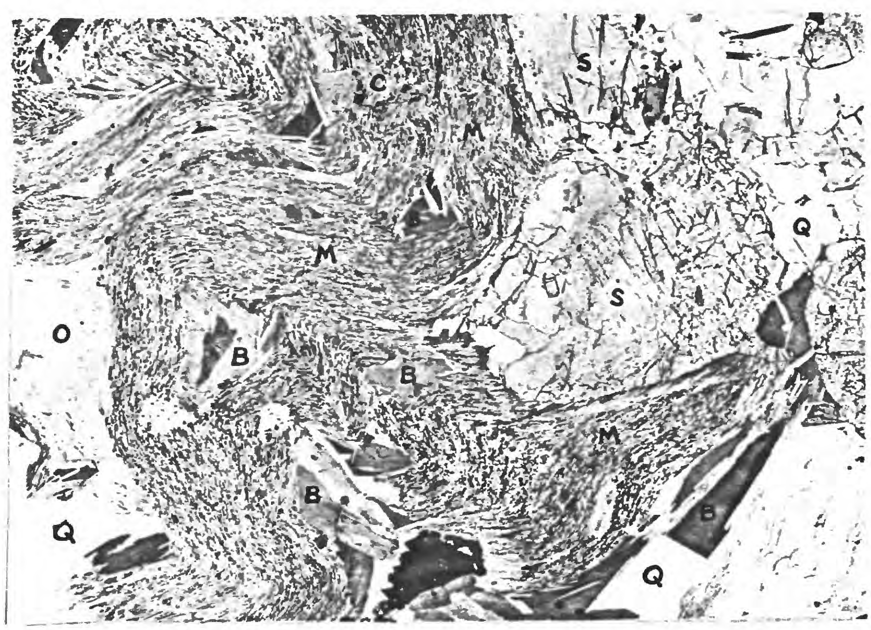


PLATE 22.

FIGURE A. Sheared schist characteristic of Derby Hill Schist in biotite-garnet zone, east shore of Lake Chamberlain, Mount Carmel quadrangle. Plain light, 15X. M, muscovite; Q, quartz; C, chlorite (-) intergrown with albite and quartz. Small black lenses are ilmenite. Main foliation approximately horizontal in photomicrograph. Shear cleavage trends from lower left to upper right; thin section reversed (left to right) with respect to orientation of shear cleavage in the field. Note small folds and numerous thin quartz lenses, which should not be confused with cracks in thin section.

FIGURE B. Same as Figure A above, except that nicols crossed. Note that quartz has been sheared and granulated during strong cataclasis. Thin black streaks are cracks in thin section. Compare with Figure A above.

PLATE 22.

FIGURE A.

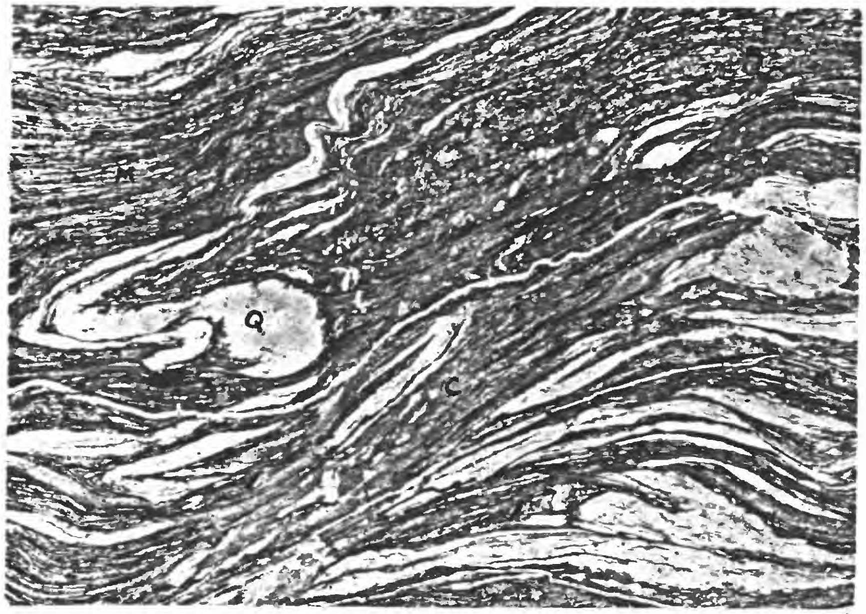


FIGURE B.

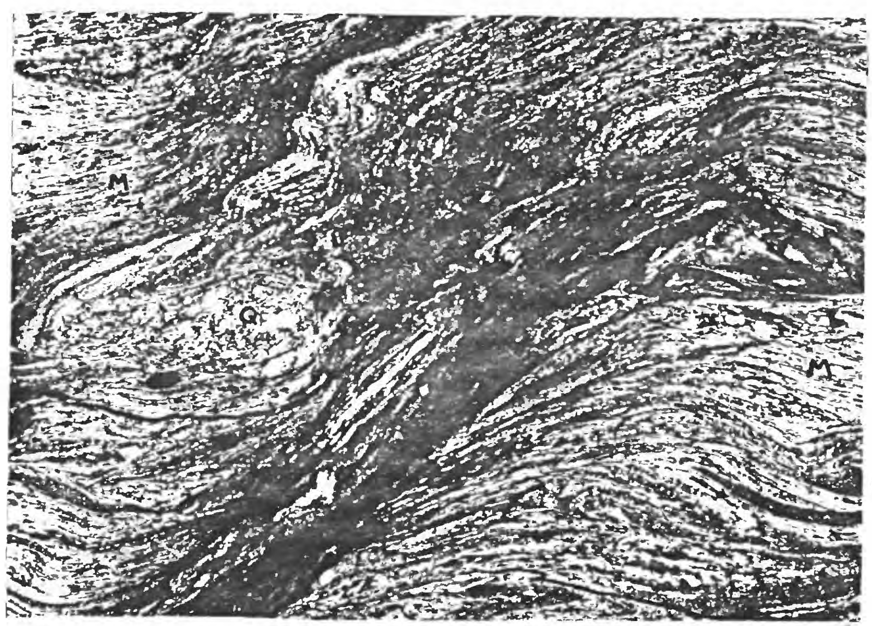


PLATE 23.

FIGURE A. Phyllite of Wepawaug Schist from new roadcut on Route 69 west of sharp bend near Lake Watrous, Town of Woodbridge, Mount Carmel quadrangle, Connecticut. Crossed nicols, 15X. Rock in lower half of photomicrograph is quartz-rich; rock in upper half is muscovite-rich. Main foliation is nearly horizontal in photomicrograph and is approximately parallel to relict bedding. Secondary s-planes in micaceous layer are oblique to main foliation. The s-planes resemble cross bedding, but are not sedimentary features. They formed during metamorphism. Outlines of all original clastic grains in the rock were destroyed during metamorphism.

FIGURE B. Impure, pyritic, crystalline limestone from Wepawaug Schist, Route 69 south of Lake Watrous, Town of Woodbridge, Mount Carmel quadrangle, Connecticut. Crossed nicols, 15X. Foliation and lineation are approximately horizontal in photomicrograph. Rock is composed mainly of calcite, quartz, muscovite, and chlorite. Dark squares are cubic porphyroblasts of pyrite.

PLATE 23.

FIGURE A.

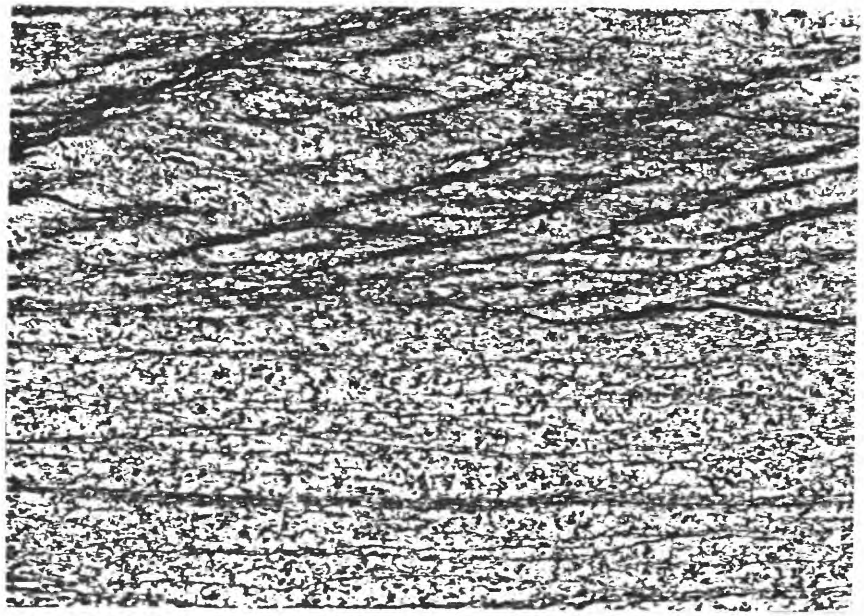


FIGURE B.

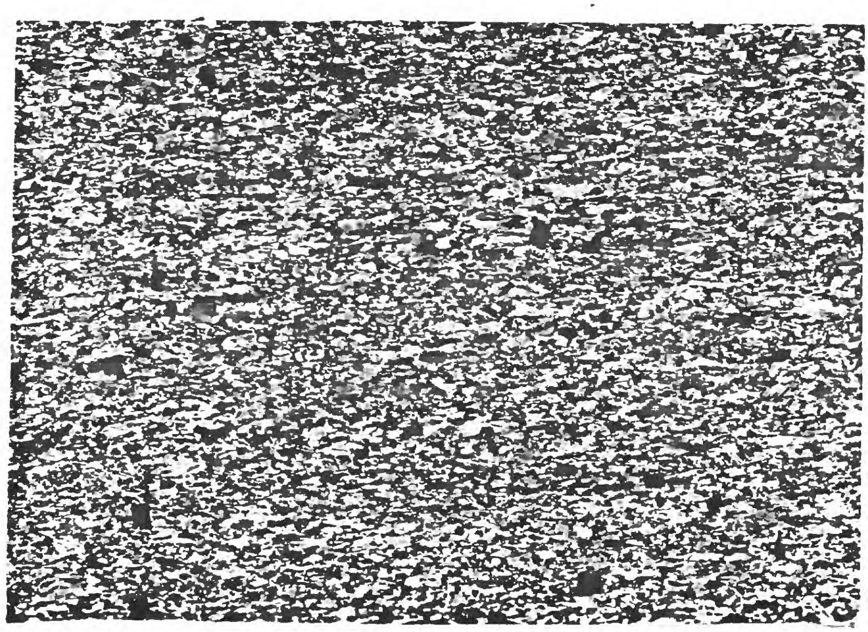


PLATE 24.

FIGURE A. Prospect Gneiss from type locality, abandoned trolley line near boundary between Prospect and Cheshire, Southington quadrangle. Crossed nicols, 15X. O, oligoclase; Q, quartz; B, biotite; H, hornblende; Mc, microcline; S, sphene. Large crystal of oligoclase (An_{25-30}) is twinned according to Carlsbad law; contains numerous clinozoisite crystals less than 0.1 mm. long, a few small biotite crystals, and one small garnet (dark). Lineation and foliation nearly vertical in photomicrograph.

FIGURE B. Large, pink microcline crystal in Prospect Gneiss, low roadcut on Old Mountain Road, 1,400 feet northeast of Route 6A intersection west of Marion, Southington quadrangle. Crossed nicols, 15X. Mc, microcline; O, oligoclase; Q, quartz; B, biotite. Note small randomly oriented inclusions of oligoclase, microcline, and quartz in larger microcline crystal, which is twinned according to Carlsbad law. Note also numerous tiny quartz inclusions in oligoclase and microcline near edges of large microcline crystal.

PLATE 24.

FIGURE A.

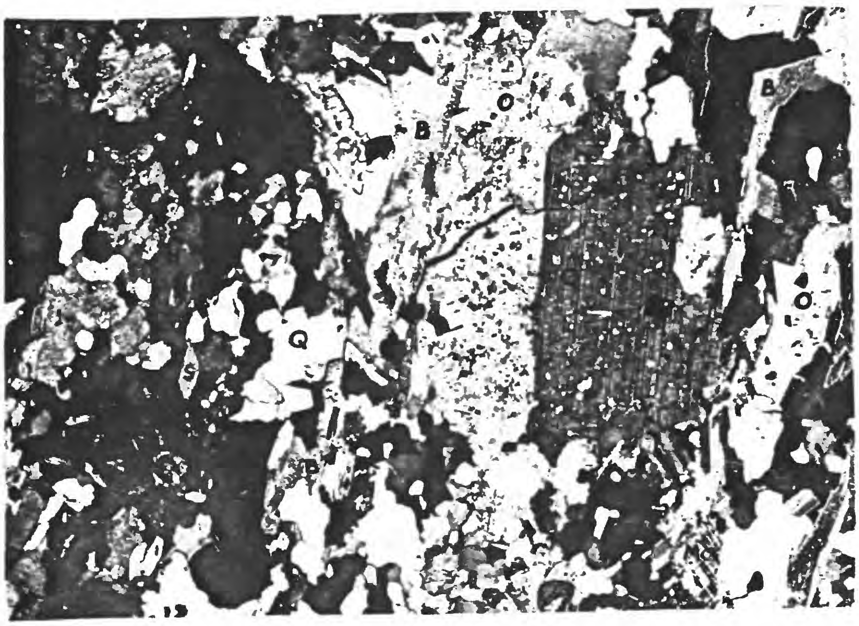


FIGURE B.

PLATE 25.

FIGURE A. Plagioclase containing distinct muscovite crystals, in dikelike body of Prospect Gneiss, west side Route 69 about 1,250 feet north of Gaylord Mountain Road intersection, Town of Bethany, Mount Carmel quadrangle. Crossed nicols, 15X. O, oligoclase; Q, quartz; B, biotite; Mc, microcline; M, muscovite. Rock also contains numerous white microcline crystals as much as 3 inches long, which are not shown in photomicrograph.

FIGURE B. Woodtick Gneiss about 1,300 feet southwest of type locality northwest of Hitchcock Lake, Southington quadrangle. Crossed nicols, 15X. A, andesine; Q, quartz; B, biotite; Mc, microcline. Crude lineation and foliation approximately horizontal in photomicrograph. Note lack of muscovite and small quantity of microcline. Andesine crystal at bottom of photomicrograph has small, optically continuous, antiperthitic intergrowths of microcline characteristic of Woodtick Gneiss. Many andesine crystals in this rock also have sodic cores and calcic rims. Many biotite crystals have ragged outlines, not shown here.

FIGURE C. Ansonia Gneiss from type locality in Ansonia quadrangle about 4 miles west southwest of Mount Carmel quadrangle. Crossed nicols, 15X. Q, quartz; O, oligoclase; Mc, microcline; M, muscovite; B, biotite. Excellent lineation and foliation approximately horizontal in photomicrograph. Note abundance of microcline and muscovite. Compare with Woodtick Gneiss in Figure B.

PLATE 25.

FIGURE A.

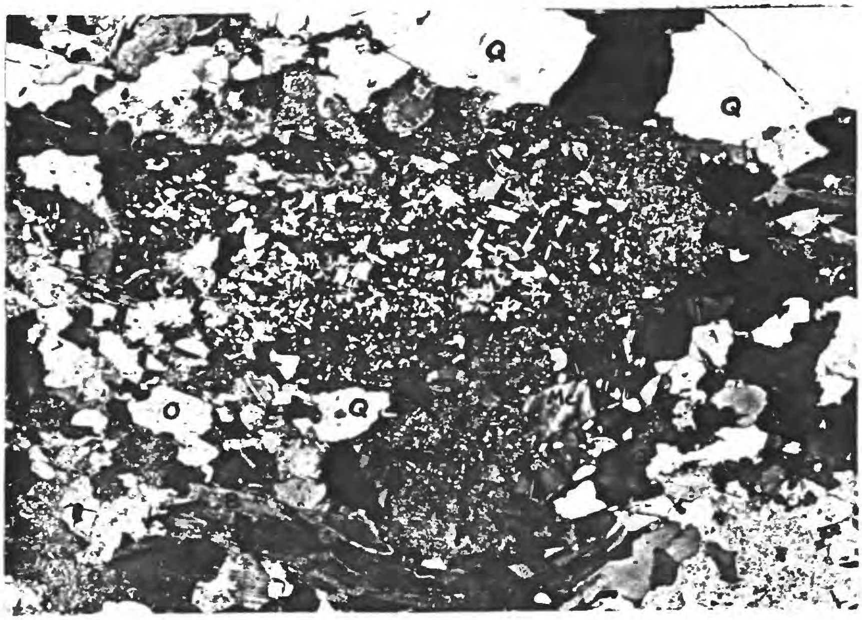


FIGURE B.

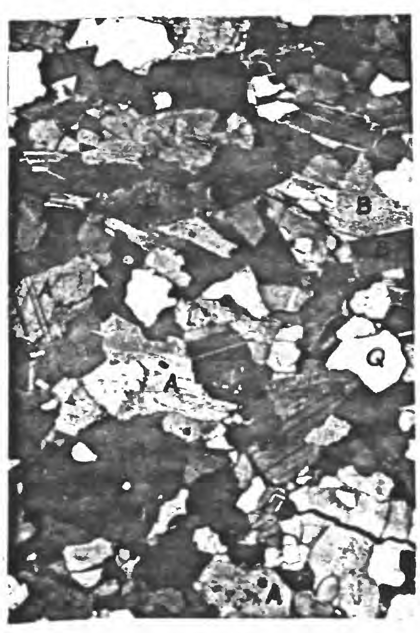


FIGURE C.

PLATE 26.

FIGURE A. Woodbridge Granite, type locality, southwest corner of Mount Carmel quadrangle. Crossed nicols, 15X. O, sodic oligoclase, Q, quartz; M, muscovite. Euhedral to subhedral, zoned oligoclase crystals are twinned according to albite, Carlsbad, and pericline laws and are surrounded by bent muscovite and abundant sheared quartz. Note bent twin lamellae in oligoclase at top of photomicrograph. Microcline rare. Compare with Prospect, Woodtick, and Ansonia Gneisses, Plates 24 and 25.

FIGURE B. Porphyritic felsite related to Woodbridge Granite, southwest corner of Mount Carmel quadrangle. Crossed nicols, 15X. O, sodic oligoclase; M, muscovite; Q, quartz. Similar to dike that intruded Woodbridge Granite near type locality. Oligoclase phenocrysts resemble main feldspar of Woodbridge Granite shown in Figure A. Muscovite and quartz are found as small phenocrysts and as tiny crystals in groundmass, which also contains abundant albite and a little microcline and biotite.

PLATE 26.

FIGURE A.

FIGURE B.

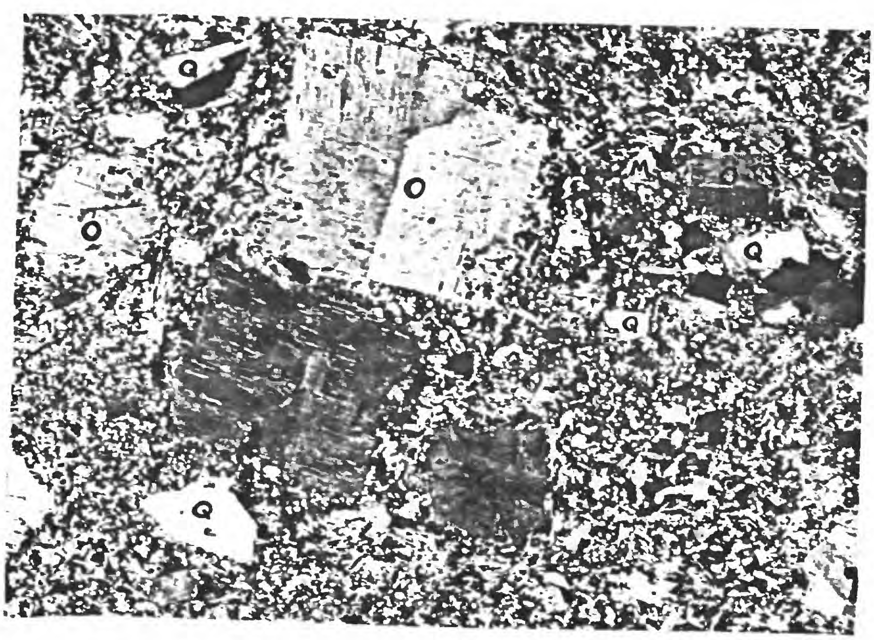


PLATE 27.

FIGURE A. Metamorphosed pegmatite intruded into Woodtick Gneiss, southwest corner of Southington quadrangle. Crossed nicols, 15X. Q, quartz; Mc, microcline; M, muscovite, A, albite, B, biotite. Note large broken microcline crystal healed by "mortar" composed mainly of much smaller microcline crystals. Broken albite crystal to left exhibits similar mortar structure. Note also aggregates of small muscovite crystals, which are much more numerous than larger single crystals of muscovite. Some coarse microcline in this rock is perthitic.

FIGURE B. Pegmatite intruded into schist between Waterbury and Prospect Gneisses, south side of Route 70, near Larsens Pond, Southington quadrangle. Crossed nicols, 10X. A, albite; Q, quartz; M, muscovite. Albite slightly sericitized; crystal at upper right also contains numerous tiny anhedral crystals of calcite. Note simple texture; compare with metamorphosed pegmatite in Figure A.

PLATE 27.

FIGURE A.

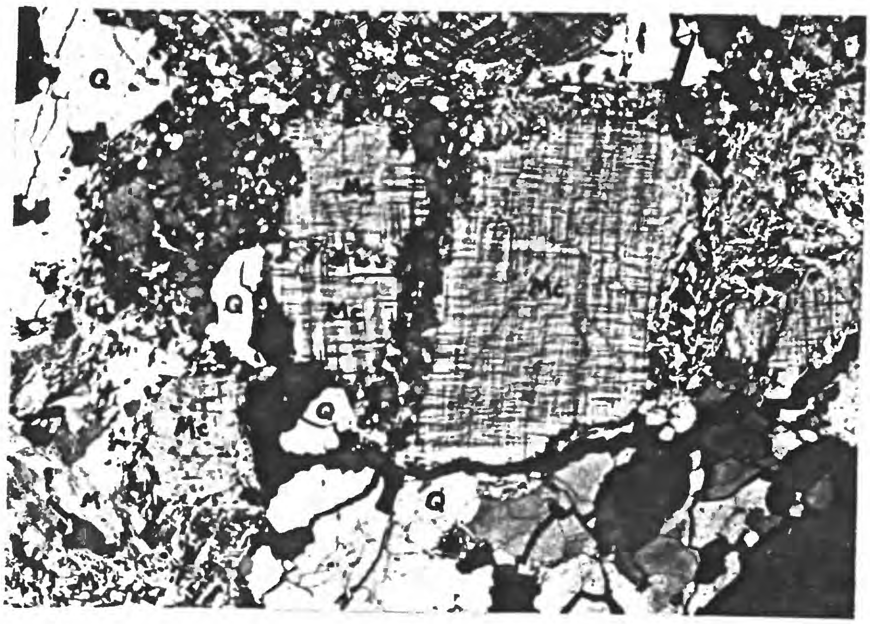


FIGURE B.

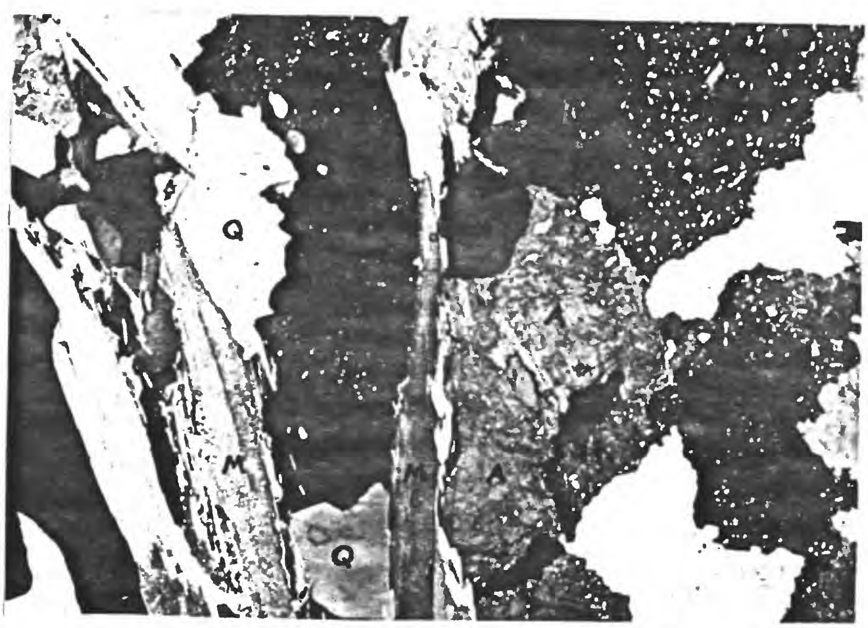


PLATE 28.

FIGURE A. Conglomeratic arkose with calcite cement, New Haven Arkose, Jinny Hill mine dump, Town of Cheshire, Mount Carmel quadrangle. Crossed nicols, 15X. C, calcite; Q, quartz; P, plagioclase; B, biotite. Large fragment at top of photomicrograph is fine-grained quartzite. Righthand third of photomicrograph is pebble of phyllitic schist, which contains much more chlorite and tourmaline than phyllitic schist of Wepawaug Schist.

FIGURE B. Arkosic siltstone characteristic of lower member of New Haven Arkose, west side of Carmel Road, south of West Rock Diabase at Bethany Gap, Mount Carmel quadrangle. Plain light, 15X. Q, quartz; P, plagioclase. Dark matrix is hematitic clay cement. Note angularity, random orientation, and range of size of detrital grains.

FIGURE C. New Haven Arkose showing three modes of occurrence of quartz, west end of central barite vein, Jinny Hill mine, Town of Cheshire, Mount Carmel quadrangle. Crossed nicols, 15X. Q, detrital quartz; OQ, quartz overgrowth on detrital grain; VQ, vein quartz; P, plagioclase; R, detrital rock fragment. Crack at left side is approximate boundary between quartz-barite vein and arkose.

PLATE 28.

FIGURE A.

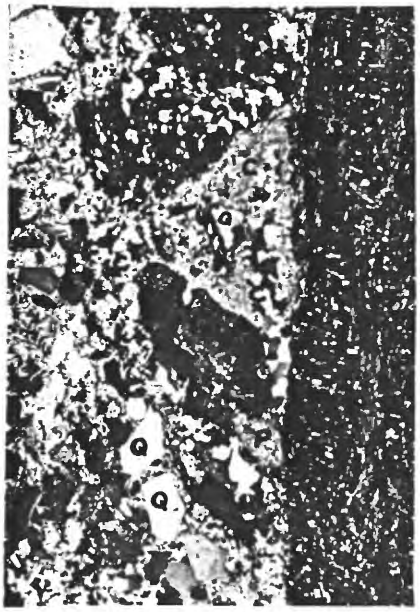


FIGURE B.

FIGURE C.

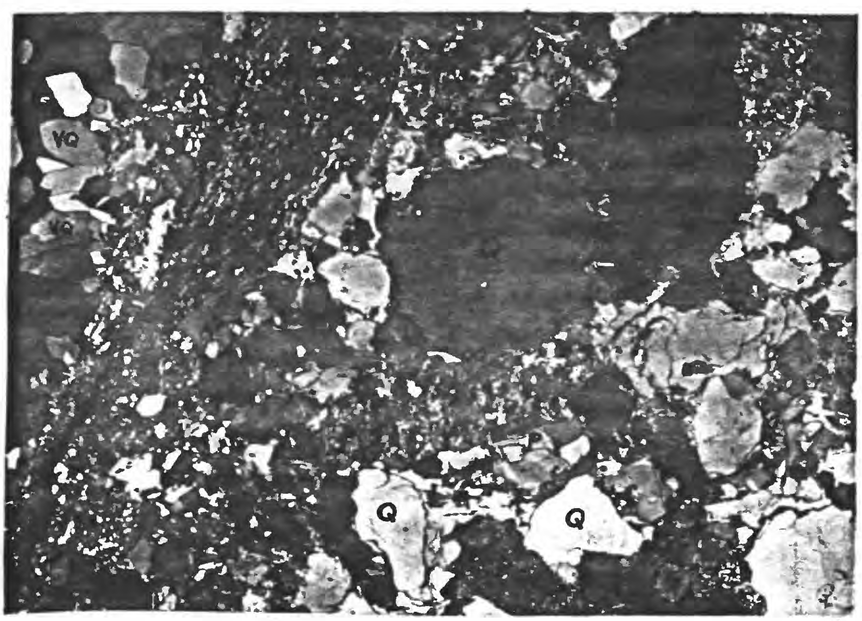


PLATE 29.

FIGURE A. West Rock Diabase from abandoned quarry east of Mill River at Mount Carmel, Mount Carmel quadrangle. Plain light, 15X. L, labradorite (An_{60-70}); A, augite; P, pigeonite; M, micropegmatite. Black anhedral crystal at lower left is magnetite. Pigeonite is partly altered to serpentine(?) and is surrounded by or intergrown with augite. Note difference in relief of pigeonite and augite.

FIGURE B. Same as Figure A, except that nicols crossed. Note twinning in augite at left and slight difference in interference colors of pigeonite and augite. Pigeonite easily mistaken for olivine unless small optic angle is confirmed under crossed nicols.

FIGURE C. Bytownite (An_{80-85}) phenocryst in Buttress Diabase, north side of West Wood Road about 1,400 feet west of Route 10, Town of Hamden, Mount Carmel quadrangle. Crossed nicols; 15X. Bytownite is twinned according to albite, Carlsbad, and pericline laws and is slightly sericitized; also contains rows of tiny unidentified elliptical inclusions. Note narrow zones of labradorite(?) at edges of bytownite crystals.

PLATE 29.

FIGURE A.

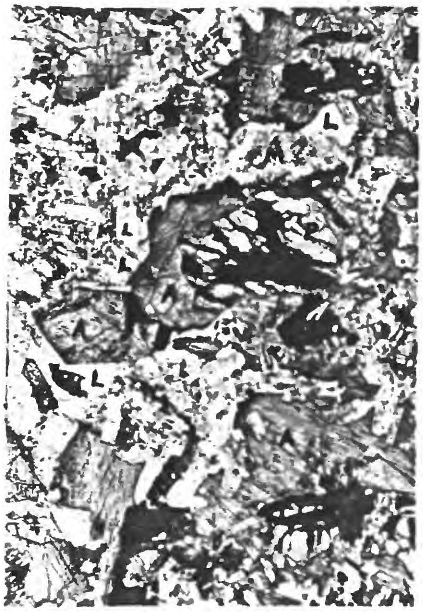


FIGURE B.

FIGURE C.