U. S. Geological Survey
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UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

PEGMATITES OF THE MIDDLETOWN AREA, CONNECTICUT[1]

By

Frederick Stugard, Jr. 1919-

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

[1] This report concerns work done partly on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

OPEN FILE

1955

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PEGMATITES OF THE MIDDLETOWN AREA, CONNECTICUT

By Frederick Stugard, Jr.

ABSTRACT

The pegmatites of the Middletown area in Connecticut have been mined almost continuously for feldspar and muscovite mica since about 1865. Pegmatites in this and other areas have recently become the subject of renewed interest because pegmatites are the potential source of beryl, the ore mineral of beryllium. During 1948 to 1950, the Geological Survey studied and mapped the pegmatites in an area of about 58 square miles near Middletown. The primary objectives of the mapping were to determine beryllium resources of the Middletown area, and to ascertain relationships of beryl-bearing pegmatites to non-beryl-bearing pegmatites and to type of wall rock.

Over 330 concordant and discordant pegmatites were examined within the mapped area. The pegmatites cut the pre-Mississippian (?) metasediments of the Bolton schist and, in ascending order, mafic gneisses, the Glastonbury granite gneiss, Maromas granite gneiss, and Monson granodiorite. The position of these formations in the stratigraphic column cannot be determined with sureness; their maximum age is indicated by their relationship to the pegmatites, which have been dated by uranium- and thorium-lead ratios as about 260 million years old, presumably Mississippian.

The Bolton schist includes middle- to high-rank mica-quartz schists of various compositions interbedded with minor quantities of quartzite, diopside- and hornblende-bearing marbles, and hornblende-bearing schists and gneisses. The mafic gneisses are predominantly hornblendic gneisses and schists with subordinate mica schists and light-colored feldspathic gneisses. These metasediments are cut by the Glastonbury granite gneiss, a gray to pink, medium- to coarse-grained, porphyritic gneiss; by the Maromas granite gneiss, a gray, medium-grained, biotite granite orthogneiss; and by the Monson granodiorite, a banded to massive, medium-grained biotite granodiorite gneiss.

The metamorphic rocks in the northern part of the Middletown area dip westward, but in the southern part the Bolton schist is bowed up by the Monson granodiorite into a dome. Between these areas, the rocks show evidence of intense folding and overturning. The western part of the area is covered by fanglomerates, conglomerates, sandstones, and siltstones of Triassic age, bounded by normal faults. An east-west fault of indeterminate age probably offset the metamorphic and igneous rock units in the area near Great Hill.

The pegmatites are composed essentially of perthite, quartz, plagioclase, and muscovite. The common accessories are tourmaline, beryl, garnet, and biotite. The pegmatites have been divided into four groups based on the content of plagioclase feldspar: those with less than 40 percent plagioclase--with and without beryl--and those with more than 40 percent plagioclase--with and without beryl. About 42 percent of the pegmatites are found to have more than 40 percent plagioclase, and 58 percent of them have less than 40 percent plagioclase.

Most of the pegmatites are nearly homogeneous bodies with a grain size from about 1 to 4 inches. These have a finer-grained border zone, 1 to 6 inches thick, with a mineral composition similar to the main part of the body. This type of pegmatite is of limited economic value. About 25 percent of the pegmatites, however, show a systematic variation in mineral composition from the walls inward. Units of differing mineralogic or textural characteristics are usually richer in perthite, albite, muscovite, or quartz. The grain size increases from the walls to the center of the pegmatite. As many as five distinct units, or zones, parallel to the pegmatite-wall rock contact have been noted in an individual pegmatite. In some pegmatites fracture-filling units of quartz and perthite cut the zones. No replacement units were recognized.

The ratio of concordant to crosscutting pegmatites is almost 3 to 1. The pegmatites appear unaffected by regional metamorphism, but they have deformed their wall rocks. The wall rocks have been altered near the pegmatites by the addition of tourmaline, muscovite, albite, and beryl.

The total resources of beryl, sheet and scrap muscovite, and feldspar are incompletely known because of poor exposures and limited development. Adequate reserves of feldspar to continue mining on the present scale for many years are known. No beryl deposits capable of sustaining an operation for beryl alone have been discovered, but rock containing 0.1 percent beryl or more is available in sufficient quantities for milling if future technical developments make its use desirable. Additional sheet and scrap mica can be produced profitably only under prices much higher than those existing during World War II.

INTRODUCTION

The pegmatites of the Middletown area of central Connecticut have been mined continuously since about 1865 for feldspar, and for muscovite mica as a byproduct. Pegmatites in this and other areas have recently become the subject of renewed interest because pegmatites are the potential source of beryl, the ore mineral of beryllium.

When beryllium became of national importance for strategic uses late in World War II (Smyth, 1945, p. 23, 24, 28, 42, 43, 48, 83-84), the U. S. Geological Survey undertook a study of potential sources of beryllium ore. Accordingly, the Middletown area pegmatites were studied and mapped during 1948 to 1950. As a result of this study, it is now known that these pegmatites form a large but very low-grade source of beryllium, which may in the future be utilized. Utilization of the beryl would depend upon the existence of economic conditions making it profitable to separate the beryl from the feldspar, quartz, and mica of the rock. The average beryl content of pegmatite rock in the Middletown area is probably between 0.1 and 0.2 percent (0.02 percent BeO), although only a fraction of that quantity can be observed.

The pegmatites occur in a hilly terrain of metamorphic rocks of Paleozoic age east of a lowland developed on sedimentary rocks. These pegmatites are essentially granitic in composition and form a vast reserve of feldspars, quartz, and scrap mica. The Middletown area includes most of the Middle Haddam map quadrangle (7 1/2-minute) and 15 square miles in the southwestern part of the Glastonbury quadrangle (fig. 1).

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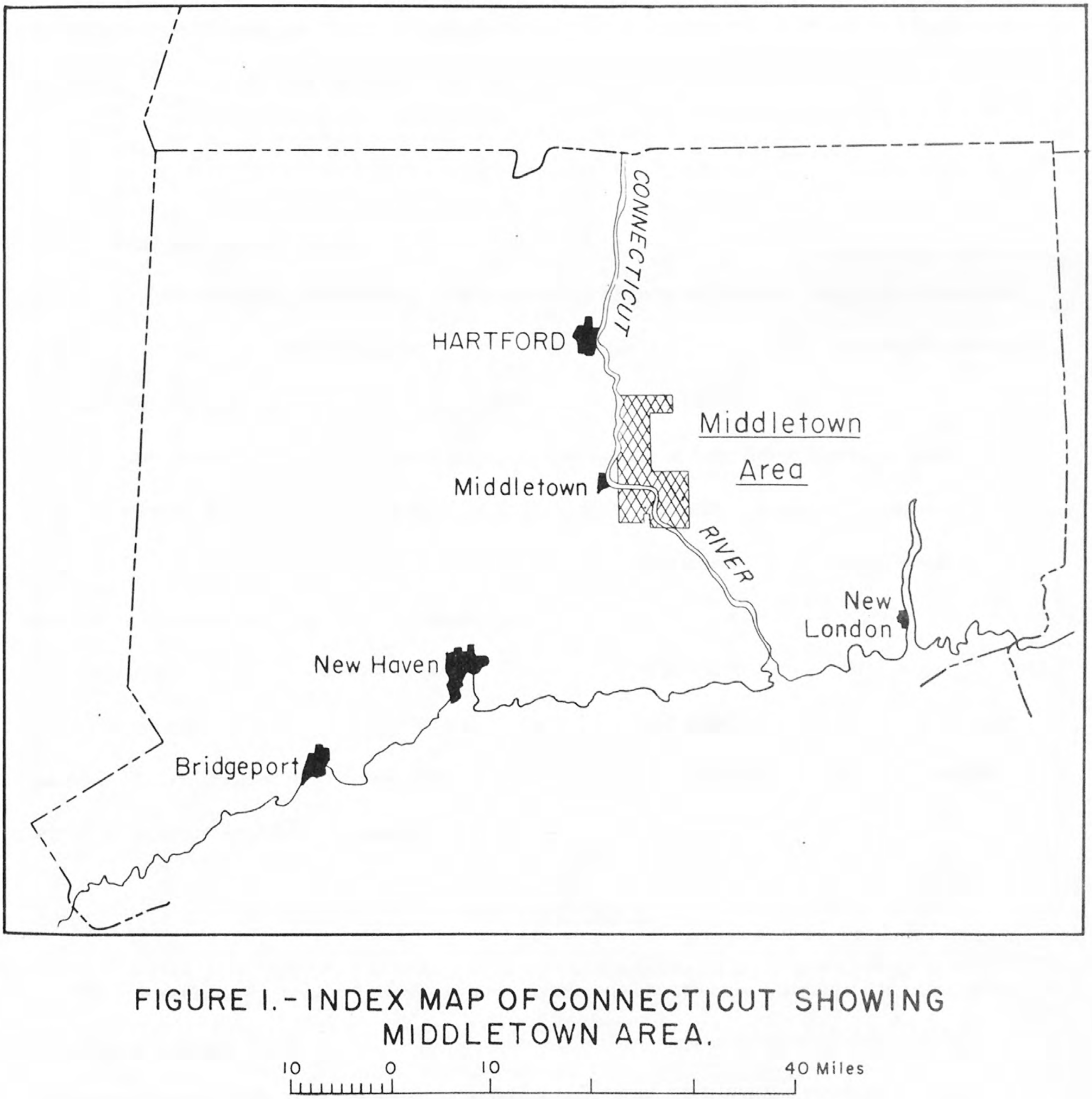

FIGURE I.- INDEX MAP OF CONNECTICUT SHOWING MIDDLETOWN AREA.

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The Middle Haddam quadrangle is immediately east of the cities of Middletown and Portland in Middlesex County; the Glastonbury quadrangle, north of the Middle Haddam quadrangle, extends into Hartford County. Access to the district is provided by a close network of hard surface roads. The major highways crossing the area are U. S. 6-A, and Connecticut routes 2, 16, 17, and 151. The Airline division of the New York, New Haven, and Hartford Railroad crosses the area from east to west.

Field work

The total area mapped is about 58 square miles and covers part of the towns of Glastonbury, Portland, Middletown, East Hampton, and Haddam. The primary objectives of the mapping were: (1) to determine beryllium resources of the Middletown area, and (2) to determine relationship of beryl-bearing pegamtites to non-beryl-bearing pegmatites and to the type of wall rock.

The areal geology of the Middletown area (fig. 2) was mapped on 1:12,000 enlargements of the 1:31,680 scale U. S. Geological Survey topographic maps of the Glastonbury and Middle Haddam quadrangles. The pegmatites on this map were grouped according to the content of plagioclase, which was determined by megascopic examination supplemented by refractive index determinations. A map of the Hale pegmatite was made on the scale of one inch to 40 feet, and the dumps of three of the largest pegmatite quarries (Hale, Howe, and Strickland-Cramer) were sampled and spectrographically analyzed for BeO. Thin sections of the most characteristic rock fabrics and compositions were studied. Specific gravity of rock hand specimens was measured on a Penfield beam balance.

Previous work

The first geological survey of Connecticut was commissioned by the state legislature and carried out in two parts. Shepard (1837) reported on the mineral wealth of the state and Percival (1842) published a state geologic map. Both Percival's map and its successor (Gregory and Robinson, 1907) show a division of the metamorphic rocks in the Middletown area.

The metamorphic rocks in the Middletown area were described by Westgate _/, Foye (1949), Digman (1950), and Mikami and Digman (In press). The sedimentary rocks of the central lowland of Connecticut, that form the western part of this area, were mapped by Davis (1898) and Krynine (1950). Longwell (1937) studied the Triassic boundary fault that transects the pegmatites and metamorphic terrain.

Pegmatite studies in Connecticut began with the discovery of rare minerals in the western part of the state (Brush and Dana, 1878, p. 33-46). Numerous early articles appeared at intervals, describing and naming unusual pegmatite minerals, but the first systematic contribution to the mineralogy of pegmatites in central Connecticut appeared in 1902 (Bowman).

Before the first World War, the U. S. Geological Survey and the Bureau of Mines made studies on the economic geology of pegmatites (Bastin, 1910; Watts, 1916), including the deposits of central Connecticut. During the nineteen-twenties and -thirties, guides for mineral collectors in the area were compiled (Shannon, 1920; Foye, 1927; Zodac, 1937; Gillette, 1937), and numerous articles described the minerals from various quarries.

Between 1926 and 1939, Schairer _/, McKnight _/, Jenks (1935), and Russell _/ studied phases of the mineralogy of pegmatites in the Middletown area. Schairer and Jenks studied the Strickland-Cramer pegmatite on Collins Hill and outlined a paragenesis of the minerals based on the theory of metasomatic replacement of an originally simple granitic pegmatite. McKnight studied several pegmatites in some detail, and Russell made an outline map showing the location of numerous pegmatites.

_/Westgate, L. G., 1902, Report on the crystalline rocks on the east side of the (Farmington) folio (Connecticut): U. S. Geol. Survey, unpublished manuscript, 42p.

_/ Schairer, J. F., 1926, The mineralogy and paragenesis of the pegmatite at Collins Hill, Portland, Conn.: unpublished report on file at Dept. Geology, Yale Univ., New Haven, Conn.

_/ McKnight, E. T., 1926, Certain phases of the natural history of pegmatites from a study of a number of Connecticut occurrences: unpublished manuscript on file at Dept. Geology, Yale Univ., New Haven, Conn.

_/ Russell, R. T., 1939, Geology of the pegmatites at Glastonbury, Conn.: unpublished report on file at Dept. Geology, Northwestern Univ., Evanston, Ill., 68 p.

Economic studies of Connecticut pegmatites, including the Middletown area, began with the descriptions of mica deposits by Sterrett (1923). Ordway_/ examined many pegmatites for their potential mica production, on behalf of the Connecticut Development Commission. During World War II, the U. S. Geological Survey investigated in this area many pegmatites containing sheet mica and beryl (Cameron and Shainin, 1947; Cameron, et al., 1953). This work consisted of detailed structural and mineralogic studies on numerous pegmatite bodies being mined at that time. At that time core drilling was done by the Bureau of Mines to explore some of the pegmatites (Boos, Maillot, and Mosier, 1949).

Acknowledgments

As part of the government program for investigation of domestic beryllium resources, geologic mapping of pegmatites in the Middletown area in central Connecticut was undertaken by the U. S. Geological Survey, partly in cooperation with the Division of Raw Materials of the U. S. Atomic Energy Commission.

Mr. Edwin W. Tooker served ably as field assistant during the field seasons of 1948 and 1949. Mr. Robert V. Cushman of the U. S. Geological Survey permitted mention of data not yet published, in connection with a short stretch of buried river channel in the Middle Haddam quadrangle. Spectrographic analyses were made by Janet Fletcher in the U. S. Geological Survey laboratories at Washington. Yale University, New Haven, Conn., furnished the writer office space and laboratory facilities during the preparation of the report. The writer is grateful to Professor Adolph Knopf for much helpful advice during the course of the work. Particular thanks are due Professor J. W. Peoples of Wesleyan University for making available numerous thin sections and other data. Dr. E. L. Troxell, Director of the Connecticut Geological and Natural History Survey, made available the unpublished manuscripts of Dr. Ralph Digman, the late Dr. W. G. Foye, and others. Professor R. F. Flint of Yale has kindly allowed full use of

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_/ Ordway, R. J., 1942, Mica-bearing pegmatites of Connecticut: unpublished report on file at Connecticut State Development Commission, Hartford, Conn., 54 p.

manuscript maps from forthcoming publications, showing the distribution of Pleistocene sediments on the northern and eastern sides of the Connecticut River, as far south as the village of Middle Haddam. The management of the Eureka Mica Mining and Milling Co. kindly allowed examination of the Hale quarry in Portland.

Physiography

The terrain of the Middletown area represents two physiographic regions: the Central Lowland, west of the Triassic boundary fault (fig. 2), and the Eastern Highlands of Connecticut, east of the Triassic boundary fault. The altitude ranges from slightly above sea level at the Connecticut River to about 730 feet at Great Hill. The cause of the abrupt deviation of the Connecticut River from the less resistant Triassic rocks of the Central Lowland into the Eastern Highlands (Davis, 1898, p. 155-156) has been a long debated problem. This change in direction occurs within the area mapped, and the river continues across the structure of all rock units encountered to its mouth at Saybrook, Conn. The wide river valley formed on the Triassic rocks changes abruptly at the Straits (fig. 2) to a steep-walled gorge, where the river enters the White Rocks area of schist and gneiss.

Rice and Foye (1927) have summarized the regional evidence on the preglacial course of the Connecticut River above the Straits and believe that it coincided with the present channel of the Mattabesset River.

The former course of the Connecticut River southward through the present site of Job's Pond is thoroughly discussed by Longwell and Dana (1932, p. 174). The area mapped as glacial outwash at this locality roughly delineates what is believed to be the position of the old river channel during glacial times. Evidence of the now-buried river channel has been found (Cushman, in preparation) by plotting the depths of bedrock from data obtained from records of the digging of water wells. The channel in the bedrock below the glacial drift extends from Gildersleeve to Job's Pond. A well on the north side of William Street (fig. 2), 1,400 feet northeast of the Eureka Mill met bedrock 100 feet below sea level. The thickness of sand above the buried channel is more than 200 feet, which contrasts with the average thickness of till and stratified drift, which is about 19 feet (Palmer, 1920: W.P.A., 1938).

The cross-axial course of the Connecticut River might be explained by the following hypotheses: (1) that the river channel through the Straits is a consequent one, formed as an outlet from a higher basin, (2) that by headward erosion the early Connecticut River cut through the ridge at the western edge of the Eastern Highlands to capture a southward flowing stream in the Central Lowland, (3) that the turning of the Connecticut River into the Highlands was localized by faulting, or (4) that the southeast reaches of the Connecticut River and other streams were superposed from an unconformable cover of sedimentary rocks. Davis (1898, p. 155-156) concluded that the most probable origin was by superposition from Cretaceous coastal plain strata similar to those on the northwest side of Long Island. Davis's conclusion has been strengthened by the finding of a log of Cretaceous age in the glacial drift several miles from the Straits (Dunbar and Flint, 1939).

GEOLOGY

The pegmatites (fig. 2) in the Middletown area intrude a sequence of metasediments of various compositons (Bolton schist and mafic gneisses), a biotite gneiss (Glastonbury granite gneiss), a granitic orthogneiss (Maromas granite gneiss), and a tonalitic orthogneiss (Monson granodiorite).

The Bolton schist is predominantly mica schist with interbedded layers of quartzite and amphibole-bearing gneiss. The Bolton schist is probably early Paleozoic in age. The group of mafic gneisses is believed to be largely tuffaceous in origin; these gneisses are characterized by the presence of hornblende. Mafic gneisses crop out in a sinuous band east of the Maromas granite gneiss, extending northward to their intersection with the Triassic boundary fault. The Glastonbury granite gneiss is an elongate body of biotite gneiss, 4 1/2 miles in maximum width, extending from Great Hill northward into Massachusetts. It is not clear whether this gneiss is actually an intrusive rock as the name implies or is a metamorphosed sedimentary formation. The geologic sections (fig. 3) could best be drawn, it was found, on the basis of an intrusive origin for the unit.

The stratigraphic thickness of the metesedimentary formations in the Middletown area cannot be measured, owing to the absence of key horizons and the intensity of folding apparent in the exposures.

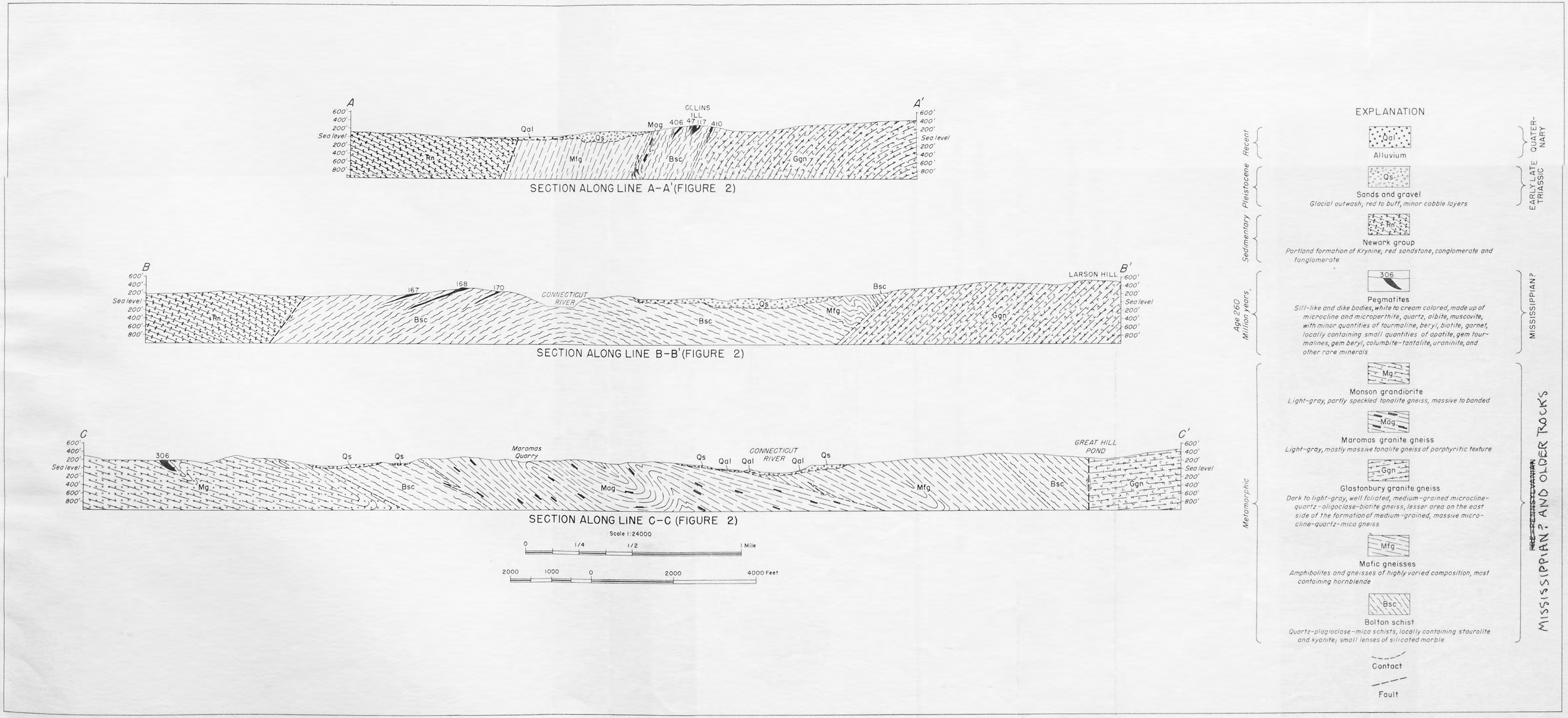

FIGURE 3.— GEOLOGIC SECTIONS, MIDDLE HADDAM QUADRANGLE, CONNECTICUT

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Geology by F. Stugard, 1953

Estimates based on the geologic sections (fig. 3) are as follows:

Bolton schist -------------------- 1,400 to 4,300 feet thick.

Mafic gneisses ------------------- 2,000 to 3,000 feet thick.

The Maromas granite gneiss intruded the Bolton schist in pre-Mississippian time and forms a small and well defined stock in the central part of the area. Another orthogneiss of tonalitic composition, called the Monson granodiorite by Emerson (1917, p. 241-243), forms the northernmost part of the Killingworth intrusive dome (Mikami and Digman, 1953) shown in part, at the lower edge of figure 2. This intrusive of pre-Mississippian age, unlike the Maromas granite gneiss, has converted the adjacent Bolton schist into a migmatite. An extension of the Monson granodiortie has been traced continuously from the east side of the Killingworth dome (i.e., the southern part of the area shown in fig. 2) to the type area in the Monson quarry in Massachusetts. East of Middle Haddam the Monson granodiorite has an indefinite contact with the Hebron gneiss.

The unmetamorphosed sedimentary rocks west of the Triassic boundary fault are the uppermost part of the Newark group of early Late Triassic age. Silty sandstone grades eastward into conglomerate and at the fault it becomes a fanglomerate. These sediments, like the crystalline rocks, are cut by dolerite dikes. Most of the Triassic formations in this area are covered by Quaternary sands, gravels, and alluvium (fig. 2).

Pegmatites cut all of these metamorphic and igneous rock units but are older than the Triassic sediments and dolerite dikes. The largest pegmatites occur in the more fissile rocks, notably the Bolton schist, within which most pegmatites are concordant intrusions. The pegmatites within the Glastonbury granite gneiss are small concordant masses and large, dike-like bodies, that in general are nearly parallel to foliation of the enclosing rocks.

The geologic history of the area is summarized below:

Geologic history of the Middletown area

Pre-Mississippian(?) time

Deposition of sediments, later metamorphosed to Bolton schist.

Deposition of tuffs and other sediments, later metamorphosed to mafic gneisses.

Mississippian(?) time

Beginning of regional metamorphism, accompanying the intrusion of Glastonbury granite gneiss(?) and decreasing in intensity during intrusion of Maromas granite gneiss and Monson granodiorite.

Intrusion of pegmatites.

Late Middle Triassic and early Late Triassic time

Normal faulting.

Deposition of Newark group.

Intrusion of dolerite dikes.

Cretaceous(?)

Deposition and erosion of sediments similar to those of coastal plain.

Pleistocene

Glaciation: deposition of ice-contact sand and gravel, and till; changes in drainage.

Deposition of river terraces and alluvium.

Bolton schist

The Bolton schist (Percival, 1842, p. 229-233 and map) crops out as a narrow band in the northern part of the Middletown area, and near the Straits in the Connecticut River (fig. 2) just east of Middletown, and it divides into two broader bands that enclose the northern end of the Killingworth dome. The west boundary of the unit is a westward dipping normal fault of Triassic age. The narrow band of Bolton schist extending northward from Collins Hill to South Glastonbury village also is cut on the north by a Triassic fault. These two areas of schist are separated by a narrow belt of mafic gneisses; the easternmost body of schist can be followed northward beyond the area mapped here, to the type locality at Bolton Notch, Conn.

The Bolton schist is dominantly mica-quartz schist of highly variable composition (table 1) that locally contains appreciable quantities of garnet, hornblende, and kyanite. Quartzite crops out at Great Hill, amphibolite at many places south of the Connecticut River, and impure marble in three observed localities. Lenses of massive quartz, conformable with the foliation, occur throughout the formation. They are from a fraction of an inch to about 2 feet thick and usually taper to thin seams at their ends. Tourmaline and beryl crystals as much as 4 inches in diameter are present in the schists near some pegmatites. Gneissic textures are locally developed in some places.

The best exposures of marble beds in the Bolton formation are in the west end of a road cut on the river road on the south bank of the Connecticut River, just east of the Triassic boundary fault; these beds are individually only a few inches thick. Other lime-rich beds are isoclinally folded for about 50 feet in the Airline railway cut 200 feet east of the Connecticut Highway 17 overpass. In the woods south of the Straits there are other lime-rich beds several inches thick. The thickest quartzite beds in the Bolton formation, about 200 feet thick, crop out as cliffs at the south end of Great Hill; the quartzite is nearly massive at the south end, but a few hundred yards farther north is a crumpled mica-quartz schist containing about 20 percent of muscovite and small quantities of kyanite, rutile, and zircon.

Table 1.—Modes of the Bolton schist 1/

Location of specimen	Rock type	Specific gravity	Quartz	Micro-cline	Plagioclase	Musco-vite	Biotite	Chlorite	Horn-blende	Accessory minerals
Roadside at south end, Collins Hill, Portland.	Fine-grained quartz-feldspar-biotite schist.	2.73	70	—	20 (An_{28-30})	3	7	—	—	x common tourmaline
Near Job's Pond, 25 feet north U. S. Highway 6-A.	Fine-grained quartz-feldspar-biotite schist.	2.68	57	10	10 (An_{28-32})	—	21	—	—	2 pyrite, x garnet
One mile northwest of Bear Hill, Middletown.	Medium-grained biotite schist.	—	40	2	25 (An_{28-32})	8	20	—	—	4 garnet, 1 pyrite, x common tourmaline, x sillimanite
	Medium-grained quartz-feldspar-biotite schist.	—	40	5	35 (An_{28-32})	—	20	—	—	x pyrite
One mile south of South Glastonbury village, 1,000 feet east of Connecticut Highway 17.	Sheared quartz-mica schist, mylonitic.	—	42	—	—	25	2	X	—	x tourmaline
Roadcut on Foote Road, Glastonbury, 1,400 feet east of Still Hill Cemetery.	Very fine-grained feldspar-biotite schist	2.67	40-45	40	—	—	15-20	X	—	x zircon
Southwest of Benvenue village, Middletown.	Medium-grained biotite-quartz schist.	—	20	10	5 (An_{25-30})	—	63	—	—	1 garnet, 1 pyrite, x apatite
Great Hill, near Portland-East Hampton boundary.	Massive quartzite.	2.65	99	—	—	1	—	—	—	—
	Crumpled quartz-muscovite schist.	—	80	—	—	20	—	—	—	x rutile, x kyanite
South-southeast of Great Hill, 0.3 mile east of road through Cobalt.	Medium-grained quartz-feldspar-biotite-epidote gneiss.	—	40	15	10 (An_{25-30})	—	20	—	—	15 epidote
Quartzite boulder southeast of Great Hill, near Pocotopaug Lake.	Sillimanite-bearing quartzite.	—	60	—	—	20	—	—	—	20 sillimanite
Outcrop near Cobalt station, East Hampton.	Fine-grained biotite gneiss.	—	63	15	X	10	10	—	—	2 pyrite
Roadcut on U. S. Highway 9, southwest of Bear Hill, Middletown.	Thin-bedded, medium-grained amphibolite schist.	—	10	10	10 (An_{45})	—	—	67	—	2 sphene, 1 pyrite
On former wagon road north of Bear Hill, just west of Hubbard Pond.	Medium-grained amphibole gneiss.	—	35	3	30 (An_{31})	—	—	10	—	20 tremolite, 2 pyrite
Road junction west of Hubbard Creek on east-west road leading to Asylum Reservoir 2.	Medium-grained amphibole gneiss.	—	45	—	2 (An_{30})	—	—	—	40	7 pyrite, 6 sericite
Two miles north of Higganum, Conn., beside railroad, just south of marsh.	Medium-grained amphibole schist.	—	45	13	25 (An_{28-32})	—	—	—	—	15 tremolite, 2 pyrite
	Fine-grained gneiss at contact with Monson tonalite.	—	25	—	60 (An_{26-30})	—	15	—	—	—
	Medium-grained actinolite gneiss.	—	30	—	60 (An_{27-29})	—	1	X	—	9 actinolite, x pyrite
Two miles east of Connecticut River, 1/2 mile north of East Hampton-Haddam boundary.	Coarse-grained amphibolite.	—	12	—	? (An_{60})	—	1	—	75	5 garnet
Lens of lime-rock in railway cut, 300 feet northeast of intersection Connecticut Highway 17 with U. S. 6-A, Portland.	Fine-grained pyroxene-bearing marble.	2.77	—	—	—	—	X	—	—	60 clinopyroxene, 35 calcite, 5 pyrite, x sphene
	Calcite rock.	—	—	—	—	—	—	—	—	50 clinopyroxene, 45 calcite, 3 pyrite, 2 tremolite, x epidote.
Reentrant of Bolton schist into Maromas granite gneiss, southeast of Benvenue village.	Medium-grained quartz-muscovite gneiss.	—	60	—	1	39	—	—	—	—
Schist inclusion in Maromas granite gneiss, northwest of Maromas Cemetery.	Medim-grained quartz-biotite-garnet schist.	—	30	—	—	—	65	—	—	7 garnet, x rutile
Contact Bolton schist and Maromas granite gneiss in brook below Benvenue quarry, Middletown.	Diopside-calcite contact rock.	—	10	—	X	—	—	—	—	80 diopside, 10 calcite.
Schist inclusion in Maromas granite gneiss north of Maromas Cemetery.	Medium-grained biotite-quartz-staurolite schist.	—	20	—	—	—	45	15	—	14 staurolite, 5 calcite, 1 pyrite, x garnet
Schist inclusion in Maromas granite gneiss near northern boundary of gneiss, at end of old railway switchback.	Medium-grained amphibolite gneiss.	—	15	—	28 (An_{32})	—	X	—	55	2 pyrite
Near contact Bolton schist with Maromas granite gneiss, old quarry-railway switchback, Benvenue quarry.	Medium-grained hornblende gneiss.	—	30	—	30	—	—	—	31	5 garnet, 4 pyrite
	Fine-grained quartz-hornblende-garnet-tremolite gneiss.	—	35	—	5 (An_{32-35})	—	—	4	25	20 garnet, 10 tremolite, 1 pyrite.
	Cataclastic quartzite.	—	80	—	1	—	—	15	—	2 apatite, 2 pyrite
Layer at contact with Glastonbury granite gneiss, Carr Brook at north end Collins Hill, Portland.	Altered diopside-hornblende-garnet gneiss.	—	8	—	4 (An_{33})	—	—	—	12	45 diopside, 25 calcite, 5 garnet, 1 sphene
	Massive medium-grained quartz-microcline rock.	—	55	40	—	—	5	—	—	—
	Medium-grained biotitic quartzite.	—	80-85	—	—	—	15-20	—	—	—
Just south of Connecticut Highway 9, near Triassic boundary fault.	Hydrothermally altered fine-grained muscovite-quartz schist.	—	45	—	—	53	—	—	—	1 garnet, 1 pyrite.

1/ Percentages of minerals based on visual estimates; "X" indicates less than 1 percent.

Most of the observed rock types of the Bolton schist (table 1) are of upper middle metamorphic rank, corresponding to the almandine garnet zone of British geologists (Tilley, 1925), but there are several outcrops of higher rank. The upper middle metamorphic rank is marked in the Bolton schist by the ubiquitous presence of garnet and brown biotite, and in a few places, such as the southeast face of Great Hill, by small staurolite crystals sparsely scattered in quartz-biotite schist. Higher rank metamorphism is noted on the western slope of Collins Hill where blades of kyanite, half an inch by 3 to 4 inches, are common in kyanite-biotite-quartz schist. The blue kyanite is confined to the 10 feet of schist immediately adjacent to the contact with a small plug of Maromas granite gneiss. Westgate (1902, p. 25-26) also reports abundant, minute staurolite crystals in the Bolton schist along State Highway 2, in a ravine at the eastern edge of the Glastonbury quadrangle. Westgate also found staurolite crystals, which reach a maximum size of half an inch by 3 inches, in a quartz-biotite-garnet-staurolite schist in the hills just west of Pocotopaug Lake, in the Middle Haddam quadrangle.

Sillimanite and its varietal form, fibrolite, occur with the quartzite at Great Hill. The presence of sillimanite, as well as the relatively coarse grain size of the rock, suggests that the entire Bolton schist may be of high metamorphic rank, and that sillimanite occurs only in the schistose parts of the quartzite because the latter is the only rock in which the Al_2O_3 content exceeds the combined CaO, K_2O, and Na_2O content.

Mylonitic or cataclastic textures were observed in thin sections of specimens from several localities, indicating that the Bolton schist has been subjected to widespread deformation. All outcrops of the Bolton schist within about 300 feet of the Triassic boundary fault have also been affected by faulting and are composed of quartz, calcite, chlorite, and sericite, with or without feldspars; similar rocks have been found near the Triassic boundary fault outside the Middletown area (Digman, 1950).

The conspicuous compositional layering of the Bolton schist is everywhere parallel to the foliation. This parallelism between foliation and an earlier S-plane probably represents a parallelism between foliation and the original sedimentary bedding. A secondary cleavage crosses the foliation of Bolton schist outcrops on Straits Hill, but elsewhere the foliation parallels bedding in exposures. An exposure of mica-quartz schists in the railway cut just west of U. S. Highway 6-A and east of Cobalt shows drag-folding and mica crenulations that indicate intense folding, but the detailed structure cannot be deciphered without subsurface information.

The Bolton schist is of metasedimentary origin and is known to be pre-pegmatite in age, i.e., older than 260 million years (pre-Pennsylvanian).

Mafic gneisses

Mafic gneisses crop out in an S-shaped band about 0.3 mile wide, extending from South Glastonbury village about 12 miles southward. The outcrops are sparse, small and weathered except for a few road cuts along Highways 17 and 6-A.

As shown by the modes in table 2, the mafic gneisses are mostly amphibolitic gneisses and schists, interbedded with subordinate layers of biotite schists and gneisses, and minor quantities of granulite, quartzite, gabbroic gneiss, microcline-bearing gneiss, and diopside-garnet-hornblende gneiss.

The mafic gneisses commonly contain either microcline, oligoclase, or andesine feldspar associated with quartz. The hornblende and biotite grains are chloritized in some samples. Pyrite is a fairly common accessory, and sillimanite was found in two thin sections.

The northern extension of the mafic gneisses have in general a moderate to steep westerly dip. It can be seen in figure 2, however, that the southern part of the formation is characterized by moderate to steep easterly dips. This reversal of dip in the southern part of the area is around the edge of a domal structure of Monson granodiorite (the Killingworth dome).

The presence of mica schist beds or lenses within the mafic gneisses suggests a pelitic sedimentary origin for the group. The mafic gneisses are pre-pegmatite in age, and consequently older than 260 million years. These gneisses are also probably older than the Maromas granite gneiss, as two small bodies of Maromas seem to be intrusive and lie within the mafic gneisses.

Table 2.—Modes of the mafic gneisses 1/

Location of specimen	Rock type	Specific gravity	Quartz	Microcline	Plagioclase	Biotite	Chlorite	Hornblende	Accessory minerals
Just south of New Haven Railroad, between Great Hill Pond and the river, Portland. (Feldspathic stringer.)	Amphibolite.	2.72	—	30	6-8 (An_{32})	—	—	60	x sphene, x garnet
	Feldspathic stringer in amphibolite.	2.72	24	—	70 (An_{32-35})	5	—	—	1 sphene
On east-west road, between Job's Pond and Collins Hill, Portland.	Amphibolite gneiss.	2.88	5	X	33 (An_{30-35})	15	—	42	5 sphene, x pyrite, x sillimanite
	Microcline-quartz rock.	2.63	10	86-88	2-4 (An_{10-12})	—	—	—	x pyrite
North of Carr Brook, on north-south road, southeast of Fogelmarks Corners, Portland.	Amphibolite-schist.	2.82	20	—	40-45 (An_{32})	5	—	20	10 calcite, x pyrite, x sillimanite
North of Carr Brook, east of Connecticut Highway 17.	Hornblende gneiss.	2.62	25	—	55 (An_{28-32})	5	—	15	x apatite
Roadcut on U. S. Highway 6-A, northeast of Paper Rock.	Hornblendic quartzite.	2.63	83	—	—	—	—	9	5 clinozoisite, 2 muscovite, x sphene, x apatite, x pyrite
Roadcut on east side Connecticut Highway 17, 0.9 mile north of Glastonbury-Portland line.	Fine-grained amphibole gneiss.	2.89	—	—	59	1	3	35	1 sphene, 1 apatite, x pyrite
Roadcut on west side Connecticut Highway 17, 0.36 mile north of Glastonbury-Portland line.	Fine-grained chloritized hornblende gneiss.	2.83	50		30-32	2-4	15	1	—
	Fine-grained hornblende gneiss.	2.76	—	—	67	25	—	6-8	x zircon
Roadcut on east side Connecticut Highway 17, 1.1 miles north of Fogelmarks Corners.	Fine-grained microcline-biotite-hornblende gneiss.	2.70	30	52-54	—	10	—	6-8	x zircon
Near second road intersection west of Haddam Neck village.	Diopside-garnet-hornblende gneiss.	—	3	5	—	—	—	15	62 diopside, 15 garnet
Beside brook in Middle Haddam village.	Medium-grained plagioclase-quartz-hornblende gneiss.	—	30	—	50 (An_{28-32})	6-8	—	10	x sphene, x apatite
	Medium-grained quartz-plagioclase lens in gneiss.	—	60	—	40 (An_{28-32})	X	—	—	—
East bank Connecticut River, 0.8 mile south of Middle Haddam village.	Gabbroic gneiss.	—	—	—	79 (An_{64})	1	—	25	x sphene, x apatite
		—	—	—	70 (An_{64})	—	—	25	5 sericite, x sphene
East bank Connecticut River, just south of Middle Haddam landing.	Hornblende gneiss.	—	17	—	45	—	7	30	x sphene, x apatite
One and one-third miles east of Connecticut River, 1/4 mile south of East Hampton-Haddam line.	Amphibole gneiss.	—	35	—	—	—	—	—	60 tremolite, 5 pyrite, x garnet
Air Line Railroad, cut north of Paper Rock, Portland.	Granulite.	—	55-57	25	15 (albite)	3-5	—	—	—
	Granulite.	—	60	20	20 (An_{9})	—	—	—	x leucoxene
South side Air Line Railroad, 1½ miles west Cobalt station.	Medium-grained biotite gneiss.	—	49	30	13 (An_{30})	6-8	—	—	x epidote, x apatite
Roadside at bottom of hill, 1 mile southeast Job's Pond.	Medium-grained biotite gneiss.	—	39	39	17 (An_{30-32})	5	—	—	—
Roadcut north side, U. S. Highway 6-A, north of Paper Rock, Portland.	Granulite.	2.59	65	25	10 (An_{25-28})	—	—	—	x muscovite, x pyrite
	Contorted, medium-grained biotite schist.	2.62	35	—	59 (An_{27})	6	—	—	—
Between Air Line Railroad and U. S. Highway 6-A, north of Paper Rock, Portland.	Fine-grained biotite gneiss.	2.65	65	5	24 (An_{28})	6	—	X	x sphene
Roadcut north side U. S. Highway 6-A, opposite entrance to St. Clement's Castle, Portland.	Medium-grained biotite gneiss.	2.73	35	5-7	48 (An_{32})	10	—	1	1 sphene, x calcite
In pasture on west side Strickland Hill, Portland.	Slightly layered microcline-quartz gneiss.	2.61	40	55	—	3	—	—	2 pyrite
Dam at Bruce's Ice Pond on Hale Brook, Portland; very close to Triassic boundary fault.	Altered microcline gneiss.	—	25	55	5 (An_{28})	5	—	—	10 pyrite
	Sericitized and chloritized gneiss.	—	—	—	55 (An_{30})	3	15	—	20 sericite, 7 leucoxene, x pyrite
	Medium-grained sheared gneiss.	—	50	46	1 (An_{30})	2	—	—	—
Old road-metal quarry on south side Roaring Brook, Glastonbury, 300 feet east of Connecticut Highway 17.	Chloritized, cataclastic, medium-grained feldspar-quartz gneiss.	2.66	30	30	—	—	30	—	8 sericite, 2 pyrite
	Sheared hornblende gneiss.	—	—	—	55	—	5	40	x pyrite
		—	—	—	75	—	10	—	10 calcite, 5 pyrite.

1/ Percentages of minerals based on visual estimates; "X" indicates less than 1 percent.

Glastonbury granite gneiss

The Glastonbury granite gneiss (Westgate, 1902, p. 9-20; Rice and Gregory, 1906, p. 114-115 and map) extends (fig. 2) from Portland northward into Glastonbury with a maximum width of about 4 1/2 miles; it is reported to extend northward into Massachusetts with an average width of about 3 miles (Westgate, 1902, p. 9; Emerson, 1917, p. 243; Keppel, 1941). Most of the outcrops of this rock in the Middletown area are small ledges in creeks and roadcuts, or dip slopes on the western sides of hills. Nearly horizontal domal outcrops of Glastonbury granite gneiss form some hilltops, such as Clark Hill and Belltown Hill. The largest exposure in the area is in the cliffs northwest of Belltown Hill. Large glacial boulders of this gneiss litter many fields.

The area of Glastonbury granite gneiss mapped (fig. 2) is almost the same as that mapped by Westgate half a century ago. Westgate proposed the name, Glastonbury granite gneiss, at that time, but his mnauscript remained unpublished and the name came into use from Rice and Gregory's report in 1906. A detailed study of this gneiss over a larger area was carried out by the Connecticut Geological and Natural History Survey in 1950 and 1951 (Herz _/), and will when published present mapped subdivisions of the formation. In general, the Glastonbury granite gneiss is a gray to pink, medium- to coarse-grained, porphyritic gneiss.

Three varieties of Glastonbury granite gneiss underlie this area: a schistose facies along the western edge of the formation, a biotitic gneiss--some with hornblende and some without--and a granitic facies. Modes of samples from each facies are shown in table 3. The essential minerals include quartz, microcline or oligoclase-andesine, and biotite. Hornblende and epidote are the most common accessory minerals.

_/ Herz, Norman, in preparation, The Glastonbury quadrangle: Connecticut Geol. and Nat. History Survey Bull., Hartford, Conn.

Table 3.—Modes of the Glastonbury granite gneiss 1/

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Location of specimen	Rock type	Specific gravity	Quartz	Micro-cline	Plagioclase	Musco-vite	Seri-cite	Biotite	Chlorite	Horn-blende	Accessory minerals
Hanging wall pegmatite (Cotta-Walden quarry), drill core.	Coarse-grained hornblende-biotite-epidote gneiss.	2.86	38	5	23 (An_{39})	—	—	10	—	15	8 epidote, x sphene, x myrmekite
	Coarse-grained gneiss.	2.82	53	5	5 (An_{31-34})	5	—	30	—	—	5 muscovite, 2 garnet, x epidote, x pyrite, x tourmaline
Northeast of Knob Hill, Glastonbury.	Medium-grained quartz-andesine-biotite-hornblende gneiss. Almost schistose.	—	40	—	35 (An_{35})	—	—	12	—	8	4 epidote, x pyrite
Bed of Roaring Brook, Glastonbury, just south of old feldspar mill site.	Coarse-grained biotite-epidote-hornblende gneiss.	—	40	—	40 (An_{32})	—	—	10	—	3	7 epidote
On Foote Road, Glastonbury.	Crushed, medium-grained hornblende epidote gneiss.	—	50	10	5 (An_{40})	—	15	—	5	7	15 sericite, 7 epidote, x zircon
Cliffs northwest of Belltown Hill, Glastonbury.	Coarse-grained quartz-microcline-biotite-epidote gneiss.	2.68	45	40	—	—	—	8	—	2	5 epidote
Roadcut east side of Connecticut Highway 2, near triangulation station A19, Glastonbury.	Medium-grained quartz-plagioclase-microcline flaser gneiss.	2.62	30	15	45 (An_{30})	—	—	6	—	—	4 epidote, x allanite, x myrmekite
Chestnut Hill Road, Glastonbury, north of Brainerd Pond.	Medium-grained quartz-microcline-plagioclase gneiss, near biotite-rich streak.	—	40	40	20 (An_{15})	—	—	—	—	—	
	Biotite-rich streak in gneiss.	—	15	—	50 (An_{38})	—	—	30	—	—	4 epidote, 1 allanite, x garnet, x pyrite
One mile north of Great Hill Pond, and east of road 1/8 mile.	Fine-grained quartz-microcline gneiss.	—	55	40	—	—	—	4	—	—	x epidote, x garnet
Just west of Portland Reservoir, south of road.	Medium-grained quartz-microcline-biotite-epidote gneiss.	—	55	35	—	—	—	5	—	—	5 epidote, x myrmekite, x tourmaline.
Roadside, 1 mile east of Portland Reservoir.	Medium-grained quartz-microcline gneiss.	—	55	44	—	X	—	X	—	1	x garnet, x pyrite
Tower Hill quarry, Glastonbury.	Medium-grained microcline-quartz-plagioclase gneiss.	2.64	31	47	21 (An_{29})	X	—	—	—	—	x muscovite, x garnet, x apatite, x pyrite, x allanite
Larson Hill, just north of Great Hill Pond, Portland.	Fine-grained biotite gneiss.	2.61	50	40	—	X	—	10	X	—	x muscovite, x garnet, x zircon, x allanite, x myrmekite
Isolated outcrop at crossroads, northwest of Penfield Hill, Portland.	Quartz-microcline-plagioclase granulite.	2.57	45	45	5–10 (An_{27})	—	—	2	—	—	x myrmekite
Overlook Road, Glastonbury.	Fine-grained crushed plagioclase-quartz-chlorite schist.	—	15	—	70	—	3	—	10	—	1 pyrite, x epidote.

1/ Percentages of minerals based on visual estimates; "X" indicates less than 1 percent.

Except for the presence of euhedral epidote, the schistose facies of the Glastonbury granite gneiss is almost indistinguishable from the adjacent Bolton schist. This facies of the Glastonbury granite gneiss is characterized by a grain size of less than 1 mm and a shredded appearance of the biotite, which is chloritized in part. Some samples show cataclastic textures. The microcline, plagioclase, and biotite grains give a "salt and pepper" appearance to weathered outcrops. There is a rather abrupt transition eastward from the schistose facies to the biotite gneiss facies. Small exposures of the schistose facies can be found near the inferred contact with the Bolton schist (fig. 2).

The biotite gneiss facies characterizes the greatest part of the Glastonbury granite gneiss: a gray to pink, medium- to coarse-grained porphyritic or porphyroblastic gneiss. Much of the exposed biotite gneiss is a flaser gneiss; that is , a gneiss containing coarse-grained, lens-shaped aggregates of microcline or quartz, about 0.3 to 0.4 inch long, wrapped about with biotite flakes. The flaser wedges out along foliation planes. The biotite gneiss facies has little "knots" of biotite plates, as do the other facies, this being the most characteristic feature distinguishing the Glastonbury granite gneiss. Biotite content is as high as 30 percent in some places but averages 5 to 10 percent. Small amounts of microcline are present in almost every sample of this and the other facies of the Glastonbury granite gneiss although this is subordinate to quartz and plagioclase. Epidote or hornblende is present in almost all samples as the most important accessory mineral. The epidote grains are unaltered and occur within hornblende, biotite, the feldspars, and as a fringe around some allanite crystals. Typical exposures of biotite gneiss are in the bed of Roaring Brook at South Glastonbury and in the cliffs northwest of Belltown Hill. A hornblendic variety of this facies was sampled in the drill cores from the hanging wall of pegmatite 386 (Gotta Walden quarry).

The last main facies of the Glastonbury granite gneiss in the Middletown area is the granitic facies. This nearly massive facies is exposed in several small quarries on Larson Hill (fig. 2) in Portland. The rock is white with black spots or "knots" of biotite and has an obscure foliation. Quartz, microcline, and biotite are the essential minerals (table 3) with less than 1 percent of any accessory. This rock represents a highly siliceous granite, the original texture of which is obscured by the later metamorphism.

Within the Middletown area, the Glastonbury granite gneiss strikes north-northeast and dips homoclinally 30° to 45° W., except at its southeastern end (fig. 2). The southeasternmost outcrops, on Larson Hill, dip southeastward; south of here the formation is not exposed and probably is cut off by an east-west fault at Great Hill Pond. The fault believed to have cut off the south end of this formation may continue beyond the Middletown area in a northeast direction (Herz, in preparation).

The dips of the foliations suggest that the Bolton schist and mafic gneisses have been cut off at depth (fig. 3, sec. B-B') by an intrusion of Glastonbury granite gneiss. Three bits of internal evidence also indicate a probably igneous origin for the Glastonbury granite gneiss: (1) inclusions of Bolton schist within the Glastonbury granite gneiss on top of Collins Hill, (2) dark colored, oval, biotite-rich patches or schlieren along foliation planes in the bed of Roaring Brook, and (3) the occurrence of diopside at the contact with Bolton schist. The inclusions of Bolton schist can no longer be observed, because since they were recorded by Westgate, the area has been covered by dumps from the Cramer pegmatite mine. The schlieren are prominent features of the Glastonbury granite gneiss in the stream bed a few hundred yards east of South Glastonbury and probably are incompletely digested remnants of Bolton schist. The contact relations of the Glastonbury granite gneiss can only be observed in this area at the site of a washed-out dam on Carr Brook on the north end of Collins Hill, Portland. Westgate (1902, p. 16-17) wrote a description of the gneiss at this contact:

"This rock differs from the normal Glastonbury hereabouts in the absence of epidote and in the small holding of biotite. Such foliation as is present is parallel to the contact with the schist, which is just west of the dam, and dips west. The foliation of the schist is also parallel to the contact. Separating the schist and gneiss at the contact is a band, about two and a half feet in width, of rock of greenish color, containing hornblende, pyroxene, garnet, small grains of titanite, and feldspars and quartz. This peculiar band is sharply marked off from both gneisses and schist."

This contact layer of rock was thought by Westgate to be a chilled, igneous contact rim, but in view of its large calcite content (table 1) it probably represents a lime-rich layer in the Bolton schist that has been altered by contact metamorphism.

Some rock flowage at elevated temperatures, or "hot working" of the Glastonbury granite gneiss has certainly occurred where schlieren are present. It is possible that some of the apparently igneous phenomena might be alternatively explained as migmatization phenomena rather than igneous intrusion phenomena, if more detailed studies of the problem were carried out. In connection with the problem of origin, it should be pointed out that the proportion of quartz in many parts of the Glastonbury granite gneiss is much higher than that in other metamorphosed igneous rocks of New England, as for example those of New Hampshire (Billings, 1937, p. 500-501); this higher percentage of quartz is accompanied by a large percentage of dark minerals.

The age of the Glastonbury granite gneiss is pre-pegmatite; that is, it is more than 260 million years old, presumably pre-Pennsylvanian. (See pegmatite 3 in table 9.)

Maromas granite gneiss

The main body of Maromas granite gneiss occupies a roughly elliptical area, 1 mile wide by 3 miles long, at the first bend in the Connecticut River east of the Straits. This body of gneiss, elongate in a northwest direction, has a foliation with a general northwest strike and a dip of 6° to 40° NE; the average dip is about 25° NE. The best exposures of the Maromas granite gneiss are in the abandoned Maromas and Benvenue quarries (fig. 2).

A careful study of the petrography and origin of the Maromas granite gneiss was published in 1899 by Westgate, 1902, who also proposed the name. The state geologic map (Rice and Gregory, 1906) presented the name as an accepted one.

The Maromas granite gneiss is a dark- to light-gray, medium-grained rock, of granitic composition (table 4), containing in places small and imperfect augen of white to pink microcline. The foliation varies from obscure to good. As exposed in the quarries, the gneiss has a main set of joints, at 2- to 6-foot intervals, parallel to the foliation; at least two other sets of joints cut the rock in the quarries. Biotite- and hornblende-rich streaks occur in the rock at irreguair intervals and are usually oval or elongate in shape. A number of tabular bodies of microcline and quartz transect the biotite-bearing

Table 4.—Modes of the Maromas granite gneiss 1/

Location of specimen	Rock type	Specific gravity	Quartz	Microcline	Plagioclase	Biotite	Chlorite	Hornblende	Accessory minerals
Maromas quarry, village of Maromas, Middletown, Conn.	Medium-grained feldspar-quartz-biotite gneiss.	2.68	45	33	10	5-7	X	—	1 calcite, 1 pyrite, x sphene
	Medium-grained aplite.	—	45	55	—	X	—	—	x pyrite
	Medium-grained quartz-feldspar-biotite gneiss.	—	55	30	4 (An_{31})	5	—	X	1 pyrite, x sphene, x apatite
	Medium-grained quartz-albite-microcline gneiss.	—	40	20	40 (An_{6-8})	X	—	—	x pyrite
	Medium-grained granodioritic gneiss.	—	45	10	30 (An_{32-35})	15	—	—	x apatite
Bonaventure quarry, Middletown.	Medium-grained quartz-feldspar-biotite gneiss.	—	45	15	30 (An_{34})	4	—	—	x muscovite, x sphene
	Medium-grained band of quartz-feldspar-hornblende-biotite gneiss.	—	40	5	40 (An_{30})	5	—	10	x allanite, x myrmekite
Benvenue quarry, Middletown.	Medium-grained feldspar-quartz-hornblende gneiss.	—	15	50	25 (An_{30-32})	X	—	10	—
	Medium-grained quartz-microcline-plagioclase gneiss.	—	30-35	35	25 (An_{28-30})	3	—	—	x garnet
	Medium-grained quartz-microcline-plagioclase gneiss.	—	35	30-35	30 (An_{38})	3	—	—	—
One and one-quarter miles west of Maromas village, near north-south road, Middletown.	Nearly massive medium-grained granitic gneiss.	—	35	25	35 (An_{35})	4	—	—	x leucoxene
In stream between Maromas village and Maromas quarry, Middletown.	Medium-grained quartz-feldspar-biotite gneiss.	—	50	25	20 (An_{26-30})	3-4	—	1	x sphene
Summit of hill northwest of Maromas quarry, Middletown.	Medium-grained granodiorite gneiss.	—	40	5	50 (An_{28})	5	—	—	x sphene, x apatite
One mile west from Maromas village, Middletown.	Medium-grained quartz-monzonite gneiss.	—	35	30	30-32 (An_{32})	3	—	—	—
East of Benvenue village, Middletown, near railroad.	Medium-grained tonalitic gneiss. Contaminated border facies.	—	55	—	30 (An_{30})	15	—	—	—
	Medium-grained garnetiferous-quartz-monzonite gneiss.	—	30	31	38 (An_{31-33})	1	—	—	x garnet
Old granite quarry west of Cobalt station, on Great Hill Pond Brook. Plug of Maromas granite gneiss within Middletown gneiss.	Medium-grained granitic augen gneiss.	2.65	41	30	20 (An_{29-31})	8	—	X	1 sphene, x pyrite, x allanite
	Medium-grained granodioritic augen gneiss.	—	45	20	35	—	—	—	—
	Medium-grained quartz-monzonitic augen gneiss.	—	30-35	35	25-30 (An_{30-32})	3-5	—	—	x sphene, x apatite
Old granite quarry on west side of Collins Hill, Portland. Plug of Maromas granite gneiss within Middletown gneiss.	Medium-grained granitic augen gneiss.	2.61	45	50	1 (An_{31-32})	4-5	—	—	—
One-third mile east from Benvenue village, south of River Road, Middletown.	Medium-grained amphibolite gneiss. Xenolith?	—	—	—	25 (An_{49})	6	—	67	1 sphene, 1 apatite
Near Bonaventure quarry, Middletown.	Quartz-microcline-plagioclase granulite.	—	40	30	30 (An_{35})	—	—	—	—

1/ Percentages of minerals based on visual estimates; "X" indicates less than 1 percent.

granite gneiss, both across and parallel to the foliation. These microcline and quartz bodies are 1 to 6 inches thick and contain less than 1 percent of dark minerals (mainly biotite and iron ores). Both the Maromas granite gneiss and the microcline-quartz bodies have a medium grain size.

The quartz in the Maromas granite gneiss has highly serrate crystal boundaries and in places contains myrmekitic intergrowths. Both the microcline and plagioclase have small, rounded inclusions of quartz. A few green hornblende grains are poikilitic. Brown biotite is the most abundant accessory mineral. A little of the biotite and part of the hornblende are chloritized. Sphene is present in most samples of the rock; allanite occurs in a few. Pyrite is the most abundant of the iron ores. The foliation is produced by a roughly planar arrangement of both biotite and feldspars.

The tabular bodies of microcline-quartz rock that cut the Maromas granite gneiss are believed to be metamorphosed aplite dikes genetically connected with the granite gneiss. The metamorphic texture and medium grain size of these dikes contrast with the texture and grain size of the pegmatites in the area. Only one large pegmatite was mapped within the Maromas granite gneiss (fig. 2), and no contacts with the country rock were observed. The paucity of pegmatites within the Maromas granite gneiss is probably the result of the massive character of the rock.

Inclusions of mica schist, from a few inches to over a hundred feet in length, occur within the Maromas granite gneiss near its contacts with the Bolton schist. Chilled borders of fine-grained, aplitoid rock an inch or two thick surround these inclusions in some places and cut across then in others. There are also several larger exposures of aplite. The aplitic rock contains small idiomorphic garnets. The Maromas granite gneiss also contains minute red garnets within 3 or 4 feet of its contact with the Bolton schist. These contact phenomena are best observed along the abandoned railroad grades leading southward from the River Road, Middletown to the now idle Benvenue quarries.

Dark streaks in the Maromas granite gneiss, containing 10 to 20 percent each of biotite and hornblende, are probably partly resorbed xenoliths of Bolton quartz-biotite-hornblende schist.

Two smaller separate bodies of Maromas granite gneiss which are exposed in the granite quarries on Collins Hill and Great Hill Pond Brook are of similar composition (table 4) to the main body of Maromas granite gneiss but have more abundant augen and are slightly lower in specific gravity. These imperfect augen are 0.2 to 0.3 inch long, pink in the center, with white rims; they are composed of microcline and show a border of feldspar and quartz grains with sieve-texture. These outcrops of granite gneiss are believed to represent two bodies of Maromas granite gneiss that were intruded along the contact between the Middletown gneiss and the Bolton schist. Like the rest of the Maromas granite gneiss, the rock from these exposures shows the effects of later straining; the quartz has strain shadows and serrate boundaries.

The mineral composition of the Maromas granite gneiss, as estimated for samples from various localities, is shown in table 4.

The foliation of the Maromas granite gneiss seem to be partly protoclastic and partly cataclastic. The relative importance of the two processes is not known. Because the rock has been recrystallized since its original formation, the degree of foliation due to flowage during the initial crystallization of the original igneous rock cannot be ascertained. As the biotite in some places is broken and is partly localized along boundaries between feldspar and quartz grains, it is probable that some of the foliation was produced by dynamic metamorphism. The foliation of the Maromas granite gneiss is not as well developed as that of other formations subjected to regional metamorphism (e.g. the Glastonbury gneiss), and therefore it is probable that the Maromas granite gneiss did not undergo the full duration of regional metamorphism. The occurrence of one large microcline grain in each augen, with smaller feldspar grains around it, suggests that phenocrysts of potassium feldspar in the original granite were crushed and that the smaller feldspar grains formed around the coarse residual cores during deformation and recrystallization. For these reasons, the Maromas granite gneiss probably was regionally metamorphosed simultaneously with intrusion, and the foliation is both protoclastic and cataclastic in origin.

The composition of the Maromas granite gneiss, like that of parts of the Glastonbury granite gneiss, includes an abnormally high percentage of quartz. Unlike the Glastonbury granite gneiss, however, the

Maromas granite gneiss shows no other suggestion of being of sedimentary origin. Evidence indicating an orthogneiss origin includes: (1) the stocklike outline, i.e., rounded, roughly elliptical; (2) the contact cuts in places across the strike of the foliation of the enclosing schists; (3) inclusions, a few inches to many feet in length, which are believed to be either pendants or xenoliths of biotite schist, occur only near the borders of the Maromas granite gneiss; (4) two bodies of similar composition are intruded along the contact of the mafic gneisses and Bolton schist at Great Hill Pond Brook and at Collins Hill; and (5) the occurrences of light-colored aplite at the contact with Bolton schist. Westgate (1899, p. 650-652) discussed this aplite and concluded that it is an endomorphic border facies of the intrusive Maromas granite gneiss. The aplite is more silicic and finer grained than the main part of the gneiss.

The Maromas granite gneiss intrudes Bolton schist and the mafic gneisses, and, therefore, is younger than those formations. Because at least one unmetamorphosed pegmatite cuts the Maromas granite gneiss, it must be older than 260 million years.

Monson granodiorite

The Monson granodiorite was named by Emerson (1917, p. 241-243 and map) for the rock occurring in the quarries at Monson, Mass. Both chemical analyses (Dale and Gregory, 1911, p. 259) and identification of all the feldspar as plagioclase (oligoclase to labradorite) indicate that at Monson the rock is a quartz diorite or tonalite rather than a granodiorite. The Monson granodiorite, as it is still called, is a banded to massive, medium-grained, biotite granodiorite gneiss. It crops out from Northfield southward through New Salem, Petersham, and Monson in Massachusetts, and across the towns of Strafford, Tolland, Vernon, Bolton, Glastonbury, Marlboro, East Hampton, Haddam, Chester, and Saybrook in Connecticut (Gregory and Robinson, 1907, map). This body of rock is about 2 miles wide, and its boundaries strike north, parallel to the near-vertical foliation. The areal extent of the formation in Connecticut has been extended from that originally mapped by Gregory and Robinson by correlation with the "Haddam granite gneiss" between the Middletown area and Long Island Sound (Mikami and Digman, 1953).

The Monson granodiorite crops out in the Middletown area (fig. 2) in two separate localities: (1) in a narrow belt along the eastern edge of the Middle Haddam quadrangle, and (2) in the Killingworth dome (Mikami and Digman, 1953) in the extreme southern part of the Middle Haddam quadrangle. These areas connect beyond the limits of the map (Mikami and Digman, 1953, map); the rock in both areas is a quartz diorite--or tonalite--gneiss, rather than a granodiorite. Exposures in the eastern belt of Monson granodiorite are meager, mostly in roadcuts. Natural outcrops are weathered to a friable white rock in which the biotite flakes show an obscure foliation.

Amphibolite crops out as a discontinuous band as much as 100 feet wide about half a mile inside of, and parallel to the contact of, the Killingworth dome. North of this amphibolite layer, the tonalite gneiss is commonly thinly layered and contains 2 to 5 percent of hornblende; south of the hornblendite layer, the rock is often quite massive and contains little or no hornblende.

The typical Monson granodiorite of the Killingworth dome segment tends to be nearly massive tonalite gneiss, with a slight foliation produced by parallel biotite flakes. Garnets, less than 0.1 inch in diameter, are present and the texture of the rock is granoblastic. The estimated mineral composition of the tonalite gneiss for various localities is given in table 5.

The tonalite gneiss exposed in the roadcut on Connecticut Highway 16 at Chestnut Hill in East Hampton is representative of the eastern belt of the formation. The rock is coarse grained, light gray in color, and is layered with dark biotite-rich bands, 2 to 4 inches thick; the dark bands wedge out within 15 or 20 feet. The foliation is fair to obscure and the texture is granoblastic. Pink garnets occur in certain layers; some of these garnets are euhedral crystals about 0.1 inch in size, and many are skeletal growths enclosing quartz. All the quartz shows strain shadows, and some of the plagioclase shows inverse compositional zoning. Microcline is relatively rare in the eastern belt of the formation.

In the Killingworth dome, the foliation of the Monson granodiorite dips outward at a low angle. The strike of the banding within the Monson granodiorite also commonly parallels the curved contact of the Killingworth dome. In the belt along the eastern edge of the Middle Haddam quadrangle, the dip of the foliation is much steeper, generally within 20 degrees of vertical. The type of folding indicated to be present in the formation is shown in figure 3 (sec. C-C').

Table 5.—Modes of the Monson granodiorite 1/

Location of specimen	Rock type	Specific gravity	Quartz	Micro-cline	Plagioclase	Biotite	Horn-blende	Accessory minerals
Roadcut on Connecticut Highway 16 at Chestnut Hill, East Hampton. (Garnetiferous layer.)	Layered gneiss.	2.72	53	—	35 (An_{30-32})	12	—	x apatite, x zircon, x pyrite
	Garnetiferous layer, medium-grained biotite gneiss.	2.75	55	—	44 (An_{28-32})	—	—	1 garnet, x apatite, x pyrite
Abandoned quarry in extreme southeast corner of Middle Haddam quadrangle.	Coarse-grained, slightly layered hornblende-biotite gneiss.	—	57	—	36 (An_{40-42})	2	5	x sericite, x pyrite
	Biotite gneiss.	—	66	—	10 (An_{38-40})	20	3	1 garnet
On road 1½ miles north of Middletown-Haddam line, west side of river.	Biotite gneiss.	—	30	—	60 (An_{32})	8	—	1 garnet, 1 pyrite
On east-west road, midway between Connecticut Highway 9 and Connecticut River.	Hornblende-biotite gneiss.	—	52	—	40 (An_{35-37})	X	7	x pyrite
East of Connecticut River, 1/4 mile north of Haddam-East Hampton boundary.	Medium-grained biotite gneiss, with minor microcline.	—	49	5	40 (An_{29-32})	5	—	1 pyrite
Railway cut, west side Connecticut River, 2 miles north of Haddam-Middletown boundary.	Thin-bedded contact facies, actinolite-bearing gneiss.	—	52	—	44 (An_{30-32})	—	—	4 actinolite, x pyrite
		—	50	—	35 (An_{25-30})	12	—	2 actinolite, x garnet, x calcite, x pyrite
On road, 1 mile north from Higganum.	Feldspathic stringer in gneiss.	—	40	—	60 (An_{10})	—	X	x apatite, x calcite
Railway cut 1 mile west from East Hampton village.	Small band of medium-grained amphibolite within biotite gneiss.	—	—	—	28 (An_{55})	10	62	x sphene, x apatite
South of Bear Hill, at southern boundary of Middle Haddam quadrangle.	Hornblende gneiss. Possibly a xenolith.	—	77	—	15 (An_{32})	—	8	x garnet, x apatite, x pyrite

1/ Percentages of minerals based on visual estimates; "X" indicates less than 1 percent.

The high quartz content and compositional layering of the tonalite gneiss in the eastern part of the Middle Haddam quadrangle suggests metamorphism of sediments or tuffs. However, because both areas of tonalite gneiss in the quadrangle are continuous with the southernmost intrusive dome of New England (Mikami and Digman, 1953, map), it is believed that this variant may be the siliceous contaminated margin of a metamorphosed tonalitic intrusion.

The tonalite gneiss must be younger than the metasediments of the Bolton schist, and both units are cut by pegmatites believed to be 260 million years in age. A Class IV age determination made on allanite from a pegmatitic phase of the Monson granodiorite at Greenwich, Mass. gave a (maximum) age of 370 million years (Marble, 1949, p. 19-20). If this determination is substantiated in the future, the Monson granodiorite must be pre-Silurian in age.

Pegmatites

Pegmatites (fig. 2) cut all of the metamorphic rocks of the Middletown area. They are described in detail in a separate section of this report.

Newark group

The western part of the Middletown area is covered by coarse conglomerates, sandstones (arkoses), and siltstones of Triassic age, separated by normal faults from the metamorphic rocks (fig. 2). The sedimentary rocks are mapped together as the Newark group.

Siltstone layers may be observed along the railroad at the extreme western edge of the Middle Haddam quadrangle (fig. 2), and adjacent to the mapped area at the abandoned brownstone quarries in the city of Portland. Red outcrops of conglomeratic sandstone may be seen on Roaring Brook in Glastonbury, along the Airline railway just north of U. S. Highway 6-A in Portland, on Duck Hill, and in the brook west of Indian Hill in Middletown. The transition from conglomeratic sandstone to giant conglomerate can be seen by going eastward along William Street, Middletown. Outcrops of crushed and bleached Triassic rock can be observed within 100 feet of the Triassic boundary fault in a road cut on the south side of U. S. Highway 6-A in Portland.

The fine-grained part of the Triassic rocks in the Middletown area is composed of quartz, feldspars, and mica, stained with red iron oxides. Rock fragments of phyllite are common in the conglomerate but cannot be correlated with any rock cropping out in the area mapped. At least 85 percent of the pebbles and cobbles in the conglomerates represent metamorphosed sediments similar to rocks in the Bolton schist. The phyllite pebbles and cobbles in the conglomerates represent metamorphosed sediments similar to rocks in the Bolton schist. The phyllite pebbles and cobbles are of a lower grade of metamorphism than the metasediments of the area to the east and may represent the upper parts of the Bolton schist that were removed during the Triassic period. This evidence suggests that a metamorphic terrain of low rank may have existed above the present medium- to high-rank metamorphic rocks, and possibly also above the present outcrop area of the Glastonbury granite gneiss.

No fossils were found in the redbeds during the present investigation, but numerous fossil fishes, dinosaur tracks, and fossil reptiles have been found elsewhere within the Newark group; the age has been established as late Middle Triassic or early Late Triassic (Lull, 1915, 1917; Colbert, 1946). The Triassic rocks in the Middletown area comprise the uppermost part of the Newark group and are, therefore, presumably Late Triassic age.

Krynine (1950, p. 30) divided the Triassic sedimentary rocks of southern Connecticut into three formations, the New Haven arkose, the Meriden formation, and the Portland formation. The Triassic rocks shown on figure 2 are part of his Portland formation.

Krynine (1950, p. 36) has shown that the heavy minerals from the lower part of the Portland formation consist of garnet (56 percent) and tourmaline (33 percent). Krynine determined that garnet comprises 72 percent and tourmaline 13 percent of the heavy mineral concentrates in the upper Portland formation (Newark group on fig. 2). The tourmaline is mostly of the black variety, schorl, but at each horizon Krynine tested, there is some indigo tourmaline; both varieties are always angular fragments of larger crystals. Outside the sedimentary rocks, schorl is found in the Bolton schist, but blue, pink, green, and colorless tourmalines are found only in pegmatites. In Krynine's samples of the Triassic sediments the colored tourmalines are accompanied by pebbles of perthite and massive "vein quartz". The present writer, therefore, believes that the Triassic rocks record the erosion of former pegmatites in higher horizons of metasediments east of the Triassic boundary fault.

Dolerite

One large dolerite dike crops out 2.3 miles northeastward from Higganum, Conn. Northeast from the outcrops shown on figure 2, dolerite float is found at several localities, and it is not improbable that the dike may continue beneath the glacial deposits. A road cut at Higganum shows the dike to be 125 feet thick and to dip 50° to 55° W. On several hillsides north of the Connecticut River, the dolerite has a chilled basaltic selvage against the Monson granodiorite and pegmatites.

The mineral composition of the dike is approximately 60 percent labradorite, 35 percent pigeonite and augite, and 5 percent magnetite and ilmenite. The texture is subophitic; the fabric, equigranular.

The dolerite is Late Triassic or post-Triassic in age, as it cuts the Newark group to the southwest (Mikami and Digman, 1953, map).

Pleistocene deposits

Surficial deposits in this area include alluvium, sand, and gravel. The sand and gravel are cross-bedded, glaciofluvial deposits containing grains and pebbles of Triassic sandstone, quartzite, Glastonbury granite gneiss, graphic granite, pegmatitic feldspars, quartz, mica, and a small quantity of some dark minerals. The sands in this area are red to light buff, a coloration inherited from the rocks of the Newark group. The larger sand and gravel deposits form elongate areas paralleling major stream valleys. The largest deposits are found along Roaring Brook.

Flint (1933, p. 966-967) has described and classified the glacial deposits of the Connecticut River valley, and the stratified sand and gravel deposits in these two quadrangles are considered by him to be dominantly ice-contact fluvial deposits.

STRUCTURE

The structure of the Middletown area is that of a homocline in the north and a concordant domal structure in the south. North of Great Hill and Collins Hill, the westward dipping homocline affects

Bolton schist, Glastonbury granite gneiss, Bolton schist, and mafic gneiss. It is not certain whether the Glastonbury granite gneiss and the Bolton schist are isoclinally folded or not. It is probable that the entire belt of Bolton schist east of the Glastonbury gneiss is overturned. At scattered locations within the Bolton schist, small drag folds indicate local overturning, so there must be considerable structural complexity that involves entire belts of rock. Locally overturned drag folds can be observed at the outcrops near U. S. Highway 6-A toward Straits Hill (fig. 2).

South of Great Hill and Collins Hill, as far as the Connecticut River, there is an area of scanty outcrops showing divergent dips. An east-west fault of indeterminate age probably offsets the metamorphic and igneous rock units in the area near Great Hill. A possible continuation of this fault has been mapped to the northeast (Herz, in preparation).

At the south end of the area mapped (fig. 2), Monson granodiorite shows parallel foliation within an orderly rock sequence. The domal structure of this sequence is clearly apparent.

The outcrops of mafic gneisses southeast of Folgelmarks Corners have oriented hornblende needles plunging 48° NW., and elongated feldspar stringers plunging 58° NW. In the vicinity of Collins Hill, drag folds and crenulations in the Bolton schist plunge 5° to 25° N. The axes of rolls on the Strickland pegmatite were noted (Cameron et al., 1954, p. 335) to plunge 5° to 25° N., but the keel of the pegmatite was found to be almost horizontal at the 125- to 140-foot levels. From these observations and from other northward plunges of drag folds within the Bolton schist, it is inferred that a low to moderate northerly plunge characterizes the fold axes (and the pegmatites) in the western part of the Middletown area.

The pegmatites commonly were emplaced parallel to strike of the schists, and less prevalently along the dip of the foliation as well. In areas where only pegmatites protrude from the overburden, the trend of their outcrops gives a fairly reliable indication of the strike of the country rock's foliation. The trend of the pegmatites changes from north-northeast to northeast as the strike of the foliation changes in the Glastonbury granite gneiss, Bolton schist, and mafic gneisses. The Triassic boundary fault also turns and trends in the same direction (fig. 2). The presence of a Triassic or pre-Triassic joint set is shown by the prominent dolerite dike that cuts sharply across both pegmatites and country rocks in East Hampton.

PEGMATITES

The Middletown area contains over 400 pegmatites of which about 300 occur in the Bolton schist, 75 in the Glastonbury granite gneiss, and 50 in the mafic gneisses. Additional pegmatites exist in the unmapped area farther south. Two types of pegmatites have been distinguished on the map (fig. 2): those in which potassium feldspar is the most abundant mineral, and those in which sodium feldspar is the most abundant. The significance of this grouping will be taken up later.

Pegmatites form a large percentage of the outcrops because they are the most resistant rocks in the Middletown area. Topographically, the pegmatites are highs, usually forming "breadloaf"-shaped outcrops. They are most abundant in the schistose rocks, where the largest pegmatites also occur.

The pegmatites range in thickness from an inch or so to several hundred feet, and in length from a few feet to several thousand feet. They are composed predominantly of microperthite, quartz, plagioclase, and muscovite. Beryl and tourmaline are widespread accessory minerals but usually total only a small fraction of 1 percent. In only one prospect, pegmatite 386 (fig. 2), does the beryl approach 1 percent of the volume of the pegmatite. Biotite occurs in about 5 percent of the pegmatite bodies, in quantities less than 0.5 percent, and shows both pseudo-hexagonal and rectangular bladed forms. Megascopically the black tourmaline in the pegmatites appears to be the same as that in the mica schist wall rocks, but under the microscope the tourmaline in the schist is found to be the common tourmaline, schorl, with a pleochroism of brown to colorless; whereas, the black tourmaline in the pegmatites invariably shows strong slate-blue to colorless pleochroism, indicating an alkali-rich tourmaline.

More than half of the pegmatites in the schistose country rocks formed sills that trend parallel to the enclosing schists. For this reason it is desirable to record the long directions of the pegmatite outcrops as a clue to the concealed wall-rock structure. In the Glastonbury granite gneiss crosscutting pegmatites are more abundant, generally have random attitudes, and are mostly less than 10 feet thick. North of South Glastonbury village, crosscutting pegmatites commonly strike northeast and are of greater size than those in the schist. Few pegmatites occur in either the massive Maromas granite gneiss or the Monson granodiorite.

Distribution - size, shape, and minerals

About 75 percent of the pegmatites are in the Bolton schist and most of the other 25 percent are in schistose parts of the mafic gneisses. The distribution of pegmatites seems to have been controlled by the fissility of the invaded formations. The parallelism of many pegmatites and the Triassic normal faults indicates preferred directions of shearing, probably ancient faults cutting pre-Cambrian basement rocks.

Some pegmatites in the Middletown area are less than 5 feet across, so small that they could not be mapped to scale, whereas others are 400 feet across and over 2,000 feet long. The small pegmatites are commonly tabular bodies; the larger pegmatites are less regular in form. The largest pegmatites lie between White Rocks and the Bear Hill area in Middletown.

The relative abundance of potassium and sodium feldspar-rich pegmatites is not related to the formation in which the pegmatite occurs, but rather shows a regional pattern in which the potassium feldspar-rich pegmatites are more numerous to the south (fig. 2).

The areal distribution of beryl-bearing pegmatites shows no significant relationship to any particular type of country rock. The even distribution of the beryl-bearing pegmatites probably indicates that beryl is an almost ubiquitous accessory but was not found in many pegmatites because of the poor exposures. The color of beryl, likewise, bears no simple relationship to the country rock intruded; beryl of all colors is found in pegmatites in any formation that has been deeply quarried.

Terminology used in describing pegmatites

Throughout this report the mineralogical composition of the granitic pegmatites, or pegmatite units, is indicated by naming the essential minerals in order of decreasing abundance. For example, "plagioclase-quartz-perthite pegmatite" indicates a rock in which the essential minerals are plagioclase, quartz, and perthite, each exceeding 5 percent, with plagioclase as the dominant mineral (Cameron et al., 1949, p. 21).

The highly variable texture and coarse grain size of many pegmatites necessitates that the textural terms in common usage for other rocks be redefined for use in pegmatite studies. The grain sizes of country rocks have been given the customary designations of "fine," "medium," or "coarse," in accordance with common usage _/. The grain sizes of pegmatite minerals are commonly many times larger than those of igneous and metamorphic rocks; therefore, these textural terms when qualified by the term pegmatitic, are classified as follows:

Pegmatitic texture	Grain size
Fine grained	Less than 1 inch in longest dimension.
Medium grained	1 to 4 inches
Coarse grained	4 to 12 inches
Very coarse	Over 12 inches

The normal texture of many pegmatites is more nearly that of a porphyritic than an equigranular rock and, therefore, it is difficult to determine average grain sizes. The limits as stated above have been applied to entire pegmatite units to indicate the size range that would be most frequently handled by quarrymen. Thus, if 20 percent of a pegmatite unit has a grain size of 1 inch, and 80 percent of the pegmatite has a grain size of 12 inches, the average grain size would be about 10 inches, or "coarse grained."

The terms "unit," zone," "fracture filling," and "replacement body" are applied to pegmatites as used by Cameron, Jahns, McNair, and Page (1949, p. 1-2): "the structural and lithologic units that differ in mineralogy, texture, or both have been designated as: (1) fracture fillings --tabular units that fill fractures in previously consolidated pegmatite, (2) replacement bodies--units formed primarily by replacement of pre-existing pegmatite, and (3) zones--successive shells, complete or incomplete, around an innermost unit or core that reflect to varying degrees the shape and structure of the pegmatite body."

_/ Coarse grained above 1 mm in diameter, medium grained between 1 and 0.5 mm, fine grained less than 0.5 mm.

Mineralogy

The pegmatites with more than 40 percent of potassium feldspar and those with more than 40 percent of sodium feldspar are separated on the map (fig. 2) on the basis of a visual estimate of the internal units of each pegmatite.

The dominant feldspar in the pegmatites of the Middletown area is a microperthite, although the more general term "perthite" is used in this report for the sake of brevity. The perthite is an intergrowth of microcline with a small amount of albite.

The plagioclase-rich group (fig. 2) is not as abundant as the potassium-feldspar-rich group but contains more of the rare minerals.

Perthite forms the largest crystals in the pegmatites, and even in pegmatites which average out to be fine grained, some potassium-feldspar cleavage faces in the graphic granite may be over 5 feet in length. Exposures in the Strickland quarry are reported to have had perthite crystals over 15 feet across. In the Hale quarry cleavage faces average about 1 foot, and faces 5 and 10 feet across are common. The feldspar is creamy colored with white albite lamellae barely visible to the eye. Some perthite always shows plaid twinning under the microscope, although no plaid-twinning was seen megascopically. The albite content of the microcline-microperthite is about 10 to 15 percent.

Large perthite crystals containing quartz lineaments are common. These intergrowths show the classical runic or cuneiform structures of graphic granite to a varying degree. It is noteworthy that the quartz lineaments lie in different directions at different places within a given perthite crystal, without any apparent regard for cleavage directions of the feldspar crystal.

The placioclase is albite in all samples tested an has a composition ranging from An_0 to An_7 _/ (table 6). Albite in many perthite-bearing pegmatites makes up almost as much of the pegmatite as does

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_/ The anorthite content was determined in this range both by determination of refractive indices of grains of feldspar, and by extinction angles measured in thin section. The anorthite content was found to be An_2 to An_7 by use of the unpublished feldspar chart compiled by Professor Adolph Knopf of Yale University.

potassium feldspar. In general, albite forms crystals less than 2 inches across, even in pegmatites where the potassium feldspar is much coarser grained. The albite crystals are whiter than the creamy-colored perthite. Visual estimates of their relative proportions were made on the basis of this color contrast, as well as the presence or absence of albite twinning. The identifications have been checked by oil immersion methods. Determination of the refractive indices is often necessary to identify the feldspar. Most parts of pegmatites with aplitoid textures have albite as the sole feldspar, but part of the aplitoid tourmaline-bearing unit in pegmatite 93 (on the west wall of Hale quarry) is microcline-rich.

Table 6.--Index of refraction of albite, Middletown area, Connecticut

Pegmatite	Quarry name	Pegmatite unit of sample	$N_X \pm 0.002$
93	Hale	Fine-grained quartz-albite tourmaline-mica	1.531
65	Griswold	Fine-grained quartz-albite	1.530
50	Howe No. 4	Fine-grained quartz-perthite	1.530
12	----	Fine-grained quartz-albite	1.530
387	----	Quartz-albite-mica	1.529
45	----	Quartz-albite	1.530
89	----	Fine-grained quartz-albite	1.530
99	----		1.531

The cleavelandite variety of albite is quite rare. Notable occurrences are in pegmatites 117, 380, and the Gillette quarry. In pegmatite 380 at the Anderson Number 1 quarry cleavelandite occurs intergrown with quartz and lepidolite in the innermost units of the pegmatite. The blades of cleavelandite are 2 to 4 inches in length, having an anorthite content of less than 2 percent.

Lepidolite and spodumene are the principal lithium-bearing minerals. The lepidolite in pegmatite 380 is in flaky intergrowths with a grain size about 0.2 inch; it is bright pink, whereas minor occurrences of lepidolite in other pegmatites, as in pegmatite 165, are pale grayish-pink.

Chemical analyses of feldspars are listed in table 7. The Howe quarry feldspar (pegmatite 73) with 2.32 percent of Na_2O is believed to be a microcline sample; the feldspars from Strickland quarry (pegmatite 117 and pegmatite 168), with 3.04 and 3.12 percent Na_2O, are believed to represent perthite samples.

Quartz occurs interstitial to the feldspars as the principal mineral in a number of pegmatite cores, and as the principal or only mineral in tabular fracture fillings. The core in part of the Gillette pegmatite is about 85 percent quartz, in crystals as much as 4 feet across, through a maximum thickness of 35 feet. Tabular quartz fracture fillings in pegmatite 118 on Collins Hill are 3 to 12 inches thick, nearly parallel, and cut across the outcrop at intervals of a few feet. The fracture fillings extend outward only to the margin of the pegmatite. External crystal faces of quartz are nowhere exposed except in a few vugs in gem-bearing pegmatites such as the Gillette.

Muscovite is the most abundant accessory mineral, in places becoming a major constituent of some pegmatite units. The usual habit is in pseudo-hexagonal "books," from less than 2 inches to more than 16 inches in diameter, and commonly with inclusions of tourmaline, garnet, and other iron-bearing minerals. The size of the inclusions ranges from less than 0.01 of an inch to an inch in diameter. Ruling, A-structure, wedged books, tied sheets, and air staining are one or all present in the micas of Middletown pegmatites.

Biotite occurs in less than 20 percent of the pegmatites but in some of these amounts to a considerable proportion of the total mica. Two habits are common: pseudo-hexagonal "books" 1 to 4 inches in diameter, and ragged, bladed forms 0.5 to 12 inches wide and of lesser thickness. The "books" of biotite seem primary forms, like those of muscovite, but the blades of biotite give the appearance of being mono-mineralic fracture fillings.

Garnet is the most ubiquitous of the accessory minerals. Salmon, pink, or red garnets are present as idiomorphic crystals 0.05 to 0.1 inch in diameter in almost every pegmatite. Somewhat flattened garnets, as much as 0.8 inch in diameter, are found in a few places included in mica "books."

Black tourmaline, called schorl, occurs in most Connecticut pegmatites, and in thin section is found to have a vivid indigo pleochroism. The size of the crystals ranges from microscopic to 6 inches

Table 7.--Chemical analyses of feldspars, Middletown area, Connecticut 1/

	Pegmatite 93, graphic granite, north and Hale quarry, Portland 2/ (percent)	Unidentified pegmatite, Haddam, Conn. 3/ (percent)	Haddam, Conn., associated with cordierite, tourmaline 1/, 4/ (percent)	Pegmatite 73, Howe No. 1 quarry Glastonbury 5/ (percent)	Pegmatite 117, Strickland quarry, Portland 5/ (percent)	Pegmatite 168, Middletown 5/ (percent)	Pegmatite 50 or 59 (?) Glastonbury 6/ (percent)
SiO_2	71.00	66.06	64.26	65.64	65.24	66.03	69.63
Al_2O_3	16.31 7/	21.57	21.90	19.10	19.74	18.99	12.30
Fe_2O_3	None	.18	?	.14	.12	.08	None
MgO	None	?	Trace	Trace	None	None	None
CaO	.22	1.80	2.16	Trace	None	None	.95
Na_2O	3.44	9.57	9.99	2.32	3.04	3.12	.79
K_2O	8.66	1.01	.50	12.58	11.84	10.96	14.96
H_2O	.12	None	.29	None	.25	?	.43
	99.75	100.19	99.00	99.78	100.23	99.18	99.06
		Spec. gravity 2.633					
Weight percent	(8/)	(8/)	(8/)				
Free quartz	18						
Or	63	2	3				
Ab	35	96	86				
An	2	2	11				

1/ All samples represent commercial feldspar except the Haddam, Conn., oligoclase, which was associated with cordierite and tourmaline in altered Bolton schist, near contact with an unidentified pegmatite.

2/ (Bastin, E. S., 1910, p. 14) Graphic granite. Specimen was "...varying in coarseness but all extremely fine grained. The quartz layers in this specimen average not more than 0.02 of an inch across and the feldspar layers not more than 0.05 inch across. Some small areas of pure feldspar were associated with the graphic granite in this specimen, so that the silica percentage shown in the analysis is lower than it would be for graphic granite alone of this fineness. The feldspars are white potash feldspar (microcline), intergrown with smaller amounts of soda feldspar (albite), containing a little lime."

3/ (Penfield, S. L., and Sperry, F. L., 1887, p. 392). Albite. Specimen 1757. Brush Collection, Yale University. (Probably from pegmatite 384 - Rock Landing quarry.)

4/ Averaged from two analyses (Smith, J. L., and Brush, G. J., 1853, p. 45) Oligoclase.

5/ (Watts, A. S., 1916, p. 126, 128, 129).

6/ (Bastin, E. S., 1907, p. 1257, in Mineral Resources U. S. 1906, pt. 2, p. 1257. Analyst: unknown.

7/ Includes trace of iron and any TiO_2 and P_2O_5 that may be present.

8/ Weight percentages from: (Mäkinen, Eero, 1917, p. 178-180).

in diameter and to a maximum length of 2 or 3 feet. The black tourmaline is most abundant in quartz, and striking subgraphic to graphic intergrowths of quartz and black tourmaline have been noted. Green and pink tourmalines occur in several pegmatites and, like the black tourmalines, these form idiomorphic crystals. Colored tourmalines of gem quality have been found in cavities in the Gillette and Strickland quarries while those quarries were active.

Beryl was identified in 62 of the 323 pegmatites studied, or approximately 20 percent. There are few published statements that permit comparison of the proportion of beryl-bearing pegmatites here to that in other areas. One such comparison is afforded by Jolliffe's statement (1944) that beryl occurs in 228 of almost 500 pegmatites he examined in the Yellowknife area of Canada; i.e., about 45 percent.

The beryl content of the pegmatites ranges from nearly zero to a maximum of 0.8 percent (pegmatite 386, Gotta Walden quarry). The beryl crystals are idiomorphic, although many crystals are skeletal and contain varying amounts of quartz and feldspar. Muscovite films have developed along fractures in some larger beryl crystals or along basal partings. The largest crystal seen by the writer (pegmatite 386) was 16 inches across, about 2 feet long, and was singly terminated. The beryl is chiefly blue, green, and aquamarine in color, though a rare golden brown beryl is found at several quarries and small fragments of pink beryl (morganite) is noted at pegmatite 381. Pale greenish-yellow to white beryl occurs at some localities, e.g., pegmatites 165 and 164, both alone and in company with blue-green beryl; such beryl is difficult to evaluate quantitatively. The fine-grained beryl impregnating the schist adjacent to pegmatite 272 is pale yellowish to white; it is also the only anhedral beryl noted. Yellowish green beryl is also found in the schists adjacent to pegmatite 386 but there the crystals are well-formed and as much as 4 inches across.

The refractive index (N_O) and BeO content of 18 representative beryl samples are given in table 8.

The mineral columbite, $(Fe, Mn)(Nb, Ta)_2O_6$, was first identified from near New London, Conn. in 1802. Columbite was identified in the nineteenth century from pegmatites in the Middletown area--in Haddam, Portland, and Middletown (Palache, Berman, and Frondel, 1944, p. 785 and 787). Two analyses of columbite believed to have come from one of the niobium-bearing pegmatites in the Middletown area are given by Wells (1937, p. 113-114). Columbite-tantalite occurs in few pegmatites in this area but only in mineral specimen quantities.

Table 8.--Index of refraction of beryl, Middletown area, Connecticut

Pegmatite	Name	Unit	$N_o \pm 0.002$	Color	BeO percent _/
	State Forest No. 1	?	1.578	Light green	13.2
93	Hale	Dump	1.580	Pale green	13.0
		Dump	1.582	Pale green	12.9
		Dump	1.582	Pale green	12.9
69	Hollister	Perthite-quartz-muscovite pod	1.584	Blue green	12.6
109	Case No. 2	Quartz-perthite core	1.583	Green, gemmy	12.8
110	Case No. 3	Dump	1.580	Green	13.0
116	Pelton	Dump	1.587	Greenish blue	12.3
83	Pratt	Dump	1.578	----	----
73	Howe No. 1	Dump	1.582	Pale green	12.9
		Dump	1.582	Pale green	12.9
		Dump	1.586	Pale green	12.4
50	Howe No. 4	Dump	1.579	----	12.1
		----	1.582	----	12.9
113	Synnott	Perthite-plagioclase-quartz-mica (unzoned?)	1.581	----	12.5
100	Bordonaro	Dump	1.581	Green	12.5
20	----	----	1.581	----	12.5
45	----	Quartz-plagioclase	1.582	----	12.9

_/ The BeO content is derived from the refractive index by use of an unpublished chart showing variation of BeO content with index of refraction by W. T. Schaller, U. S. Geological Survey.

Internal structures

Many pegmatites in central Connecticut are nearly homogeneous bodies composed of perthite, quartz, and albite, with accessory muscovite, black tourmaline, garnet, and beryl. Most are finer grained for a 1- to 6-inch thickness at the contact with the country rocks. This fine-grained selvage is the border zone as described by Cameron et al. (1945, p. 373). It outlines the shape of the pegmatite, wrapping around a central core of coarser grained pegmatite minerals. Pegmatites that are otherwise unzoned and have a more or less homogeneous fine- to medium-grained central unit rarely have been utilized commercially. Pegmatite 7, however, has a central unit of this type composed predominantly of feldspar with desirable ceramic properties; therefore, with a little sorting, almost the entire pegmatite was utilized. Pegmatites in which an intergrowth of potassium feldspar with lesser quantities of quartz extends almost to the walls are seldom commercial sources of mica or rare-element minerals.

Although over half of the pegmatites mapped are essentially homogeneous bodies, those that are characterized by two or more distinct lithologic, textural, or structural units make up the bulk of the bodies exploited for industrial pegmatite minerals. Bastin (1910, p. 44) first recognized internal mineralogic units that parallel the trend of the pegmatite in his description of pegmatite 80 (the Wiarda quarry), in 1910. During World War II, the U. S. Geological Survey (Cameron et al., 1954) made detailed plane table maps of many of the exploitable pegmatites showing the internal zoning. In some, the internal structure is not distinct; in others, it is well defined. Most of the pegmatites of the Middletown area have not been opened up by mining, so the internal zoning may not be visible in the outcrop. Pegmatite units differ from one another in texture or mineral composition. Textural changes between units are frequently found, but for the most part, the units are characterized by changes in the relative proportions of perthite and albite--a distinction difficult to make with accuracy during mapping. Units that have boundaries paralleling the contact of pegmatite with country rock are called zones. Four types of zones have been recognized and have been designated in order from the walls inward as border zone, wall zone, intermediate zone, and core. Crosscutting units within the pegmatite are called fracture fillings or replacement bodies, depending on their origin.

Most pegmatites have a thin border zone in which plagioclase is either the predominant or the only feldspar. Wall zones may be made up of perthite and quartz, as in pegmatite 164, or perthite, quartz, and plagioclase, as in pegmatite 91 (Andrews quarry). A few pegmatites have intermediate zones, as in pegmatite 117 (Strickland quarry), where an intermediate zone 1 to 22 feet thick contains about 50 percent of perthite in a matrix of quartz and plagioclase. Pegmatite cores are characteristically massive quartz containing large crystals of blocky perthite, as in pegmatites 264 and 168. If the pegmatite pinches and swells, the core may be in discontinuous segments, as in State Forest No. 2 quarry. These core segments are 90 percent quartz and 10 percent muscovite. In pegmatite 380 (Anderson No. 1 mine) a central unit is composed of more than 50 percent lepidolite, 35 to 45 percent cleavelandite, and 5 to 10 percent quartz.

Of 330 pegmatites mapped, 16 percent are zoned and 84 percent are unzoned, except for a fine-grained border zone. Of 64 beryl-bearing pegmatites, 42 percent are zoned; of the pegmatites with less than 40 percent of plagioclase, 21 percent are zoned; and of those with more than 40 percent plagioclase, 10 percent are zoned. Many unquarried pegmatites now regarded as unzoned may have internal zones either concealed by overburden or not exposed at the top of the pegmatite.

The common assemblages of essential minerals of pegmatite zones in central Connecticut and elsewhere in New England constitute only 5 of the 11 mineral assemblages noted (Cameron et al., 1949, p. 61) in the Black Hills of South Dakota. These five mineral assemblages, where present, occur in the following sequence: (1) plagioclase-quartz-muscovite, (2) plagioclase-quartz, (3) quartz-perthite-plagioclase, with or without muscovite and with or without biotite, (4) perthite-quartz, and (5) quartz. In addition to these five general assemblages, two others have been recognized in local instances: a plagioclase-quartz-spodumene unit in pegmatite 117 (Strickland quarry) may be an intermediate zone, and a lepidolite-plagioclase-quartz unit in pegmatite 380 (Anderson No. 1 quarry) may be a core.

Most fracture fillings in the Middletown area pegmatites are massive, milky to clear quartz; some are massive quartz containing idiomorphic blocky perthite. Fracture fillings also carry accessory mica or beryl, as in pegmatite 16, where the quartz contains 0.2 percent beryl. The mineral composition and the textures of fracture fillings in zoned pegmatites are often the same as those found in the inner zones, although fracture fillings are also known to cut unzoned pegmatites.

Replacement units, if present in the pegmatites of the Middletown area, are rare. Cameron et al., (1954) have described a few such units at the Hollister, Strickland, and other pegmatites.

Relations to wall rock

The pegmatites in the Middletown area cut the Bolton schist, the mafic gneisses, the Glastonbury granite gneiss, and the Monson granodiorite. Where contacts were observed, over half of the bodies were conformable to wall rock structure. The realtionships of 323 pegmatites to the enclosing rocks are listed below.

	Concordant (percent)	Crosscutting (percent)	Structural relationship uncertain (percent)
Glastonbury granite gneiss country rock -			
55 pegmatites	45	31	24
Bolton schist country rock -			
244 pegmatites	49	15	36
Mafic gneisses country rock -			
24 pegmatites	50	13	37

The ratio of concordant to crosscutting pegmatites is 1 1/2 to 1 in the Glastonbury gneiss but over 3 to 1 in Bolton and Middletown formations. The foliation in the latter two formations conforms for the most part with the shape of the pegmatite contacts, but the larger pegmatites in the Glastonbury gneiss (pegmatites 6 and 7) followed fractures that cut sharply across foliation.

Many of the concordant pegmatites have deformed the enclosing schists, presumably by the intrusive force of the pegmatite-forming fluid. The schist at the pegmatite contact in the Gotta-Walden quarry is more contorted, richer in muscovite, and better foliated than at some distance from the contact. The discordant pegmatites in some places have deformed the schistose or gneissic foliation; an excellent illustration of this bending of the country rock was published by Bastin (1911, pl. 10).

Many pegmatites, like pegmatites 1 and 2 in the Strickland-Cramer mines (Cameron et al., 1954), have a close parallelism between their irregular contacts and the foliation of the enclosing schists. Others, like pegmatites 386 (Gotta-Walden) and 100 (Bordonaro) (Boos, Maillot, and Mosier, 1949, figs. 5-14) are in part conformable and in part crosscutting.

The pegmatites in the Glastonbury gneiss have mechanically deformed the foliation of the gneiss, but pegmatites in the quartz-mica schists of the Bolton schist have both deformed and altered their wall rock. Tourmaline occurs in the schist in some places for distances up to about 3 feet from the pegmatite. This metasomatic tourmaline (schorl) is grayish or brownish green under the microscope and is less strikingly pleochroic than tourmaline from the adjacent pegmatites.

Beryl crystals occur in the border zone in pegmatites 272 and 386 and in the adjacent schist. In the hanging wall above pegmatite 272, the schist for an estimated distance of 6 inches, contains muscovite (50 to 60 percent), beryl (20 to 24 percent), and garnet (15 percent).

A study of the regional zoning of pegmatites in relation to wall rock formations would be of assistance in further prospecting for beryl or other minerals. Heinrich (1953, p. 74-75) observes that 10 of the 12 beryl-bearing pegmatites mapped by Cameron and Shainin are in the Bolton schist or very close to it. The present wirter feels this is not a significant relationship, however, since the quoted ratio of beryl-bearing pegmatites in the Bolton schist to those not within the Bolton schist (10 to 2) corresponds very closely to the ratio of pegmatites found in the Bolton schist to those found in the adjacent Glastonbury gneiss (244 to 55).

Age of the pegmatites

The Middletown area probably contains more pegmatites on which absolute age determinations have been made than any other equal area in the world. In evaluating the reliability of these age determinations, Knopf (1948, p. 664 and 666; 1949, p. 4) used the following classification:

Class I analysis .... U, Th, and Pb in minerals have been measured by quantitative chemical analysis, and isotopic composition of lead has also been determined by mass spectrograph. This method admits calculated correction for nonradiogenic lead, as well as the disintegration of Th.

Class II analysis .... U, Th, and Pb measured by quantitative chemical analysis and atomic weight of lead measured chemically. This permits allowance for disintegration of Th, but only an approximate allowance for nonradiogenic lead.

Class III analysis .... quantitative analysis of U, Th, and Pb by standard chemical methods.

Class IV analysis .... microchemical analysis of U, Th, and Pb.

Only class I analyses are considered definitive, the others being less reliable.

Successive calculations of the age of the pegmatites in central Connecticut have given lower and lower ages, starting with the original 410 million years of Boltwood in 1905 (p. 87) to the present value of 260 million years (table 9). The most recent value is probably most nearly correct, because allowance is made for the thorium present and the nonradiogenic lead (10 to 12 percent of the total lead), and more accurate determinations of the half-life periods were used.

The pegmatites of central Connecticut are about 260 million years old, indicating an Early to Middle Carboniferous age, probably Mississippian. Class I determinations made on the neighboring pegmatite area at Bedford, N. Y., and at Branchville, Conn. (table 10), give an early Paleozoic age, which indicates that the pegmatites of western and of central Connecticut (Middletown area) respectively are related to different episodes of igneous activity. Lithium-bearing pegmatites are associated with both the Taconic and Acadian episodes of intrusion.

Age determinations by the strontium method are not yet dependably accurate for minerals as young as those in central Connecticut. From Sr/Rb ratios in lepidolite, Ahrens (1949, p. 253, 255) calculated as 270 million years the ages of several unspecified pegmatites in the towns of Haddam; as 450 million years, several in Middletown; and as 540 million years, several in Portland. Because of the probably small experimental error in the age of the pegmatites at Haddam and because 270 million years agrees with the lead age, Ahrens considers this to be the only satisfactory determination. Ahrens points out that where varying ages are obtained from analyses only the lowest age can be accepted, for the analyses made without determination of the isotopic constitution are subject to error in one direction, because of the possible presence of primary, nonradiogenic strontium. The strontium method is not suitable for dating minerals less than 50 to 100 million years in age, because of the slow rate of decay, and is at its best in dating pre-Cambrian minerals, i.e., rocks more than 500 million years old.

Table 9.--Age determinations by the lead method, Middletown, Connecticut

Locality	Mineral analyzed or source of reference	Class of analysis	Latest calculation of age in millions of years (m.y.) to nearest 10, and source	Corresponding geologic age
Pegmatite 3	Samarskite, Wells 1/,	I and	260 m.y.	Early to mid-
Spinelli prospect, Glastonbury	Nier 2/, Baxter 3/	II	Holmes 4/	Carboniferous
Pegmatite 91	Uraninite, Foye and	III	280 m.y.	
Andrews quarry (formerly called	Lane 5/	and	Foye and Lane 5/	
Hale quarry), Portland		IV		
Pegmatite 91	Monazite, Fenner 6/	III	300 m.y.	
Andrews quarry, Portland			Knopf 7/	
Pegmatite 117	Uraninite, Foye and	IV	280 m.y.	
Strickland quarry, Portland	Lane 5/		Foye and Lane 5/	
Pegmatite 384	Uraninite, Ingerson 8/	IV	280 m.y.	
Rock Landing quarry, Haddam			Knopf 7/	

1/ Wells, R. C., 1937, p. 114-115.
2/ Nier, A. O., 1941, p. 113.
3/ Baxter, G. P. et al., 1937, p. 702-705.
4/ Holmes, Arthur, 1946, p. 134-137.
5/ Foye, W. G., and Lane, A. C., 1934, p. 127-138.
6/ Fenner, C. N., 1932, p. 327-333.
7/ Knopf, Adolph, oral communication.
8/ Ingerson, Earl, 1938, p. 269-276.

Table 10.--Age determinations from other localities of importance in regional considerations

Locality	Mineral analyzed or source of reference	Class of analysis	Latest calculation of age in millions of years (m. y.) to nearest 10, and source	Corresponding geologic age
Pegmatite;	Cyrtolite	I	350 m. y.	Early Paleozoic,
Bedford, N. Y.	Muench, Nier 1/		Holmes 2/	Ordovician(?)
Pegmatite;	Uraninite	III	350 m. y.	Do.
Branchville, Conn.	Boltwood 3/		Knopf 4/	
Pegmatite;	Allanite	IV	400 m. y.	Ordovician (?)
Greenwich, Mass. (now under	Marble 5/		Knopf 4/	
Quabbin Reservoir).				

1/ Muench, O. B., 1931, p. 350-357.
2/ Holmes, Arthur, 1946, p. 134-137.
3/ Boltwood, B. B., 1907, p. 253-267; 1905, pt. 2, p. 77-88.
4/ Knopf, Adolph, oral communication.
5/ Marble, J. P., 1949, p. 19-20.

Origin

The pegmatites of the Middletown area do not show a definite radial arrangement in relation to, or exclusive association with any specific rock unit, and therefore may be equally well related genetically to any of the igneous rock types. The foliated rocks, particularly the Bolton schist, contain pegmatites from the Middletown area to Long Island Sound, and it is apparent that these rocks have been the most favorable hosts for the pegmatites.

Cameron et al., (1949, p. 6; 1953) have tentatively linked the pegmatites of central Connecticut with the Glastonbury granite gneiss (which they designate as Monson gneiss). The writer does not support this interpretation because a pegmatite in Massachusetts considered to be linked with the Monson tonalite has yielded a class IV radioactivity age determination of 370 million years (maximum value) (Marble, 1949, p. 19-20), whereas the pegmatites cutting the Glastonbury granite gneiss have an age of 260 million years.

There is little evidence to show that the fluids that formed the pegmatites of the Middletown area were derived from any particular igneous rock; in fact, it is conceivable that they were the product of differential anatexis. Whatever the origin of the liquids, they moved through the metamorphic rocks as a viscous fluid and crystallized in an orderly and systematic fashion that resulted in the formation of zones and other units.

The larger size and the greater proportion of perthite-dominant pegmatites in the southern part of the Middletown area suggest that the greatest intrusive activity and the highest temperatures during pegmatite emplacement occurred from White Rocks southward to the Killingworth dome. Because the pegmatites are mostly northward plunging structures, the White Rocks-Killingworth dome area appears to represent an oblique section through the area that was the center of intrusive activity. Continued detailed mapping to the south might be expected to show an increase in the number of plagioclase-rich pegmatites.

The complex, highly irregular shapes of most of the pegmatites contrast strongly with the straight, tabular dolerite dike in East Hampton (fig. 2). The dolerite dike probably represents a relatively undifferentiated and fluid magma that came up along through-going fissures in cold rocks. The schists, on the other hand, appear to have been intruded by viscous pegmatite while more pliable and incompetent, and, therefore, presumably at a much higher temperature. The difference between the irregualr form produced by pegmatite intrusion and the tabular form of dolerite dikes is probably produced by differing temperatures of the wall rocks at the time of intrusion.

The Maromas granite gneiss shows the same type of injection into schists at its margins as the pegmatites. The larger grain size of the pegmatites, compared to the Maromas granite gneiss, must be attributed to the greater concentration of certain components in the pegmatite liquid. The water content may have been slightly greater in the pegmatite fluids, but there is no clear cut evidence of this.

In the past decades it was generally accepted that the temperature range of pegmatites had been established within close limits. A review of certain laboratory experiments shows why there is less confidence today in stating the temperatures involved. One of the first experiments on the genetic temperatures of pegmatites utilized the inversion from "high" to "low" quartz (Wright and Larson, 1909, p. 438). "High" quartz was believed distinguishable, even in the massive mineral, by etch figures on the basal pinacoid. Thus, tests by Bastin (1911, p. 39) showed that quartz in the graphic granite from Hale quarry (pegmatite 93, referred to by Bastin as the Andrews quarry) showed characteristics of "high" quartz, and it was concluded that the pegmatite had crystallized at a temperature above 573° C. The reliability of such tests was not accepted by Mugge (1907, 1932) who had first suggested that quartz might be used as a geologic thermometer.

In 1947, Ingerson (p. 375-379) tried experimentally to reproduce the genetic temperatures of pegmatites. By using data on the specific volume of water at high pressures and temperatures, Ingerson brought up to date the Sorby method of using liquid inclusions to yield calculated genetic temperatures of minerals containing such inclusions. Observing disappearance of the vapor phase at 153° C. to 165° C., Ingerson applied calculated corrections and obtained the startlingly low temperatures of 155° and 157° as the genetic temperatures for two Connecticut pegmatitic quartz masses. These determinations were made on specimens submitted by E. N. Cameron from two zones in pegmatite 109, exposed in the Case No. 2 quarry. The most probable temperature of origin for a beryl crystal obtained from the same locality was 175°. All liquid inclusions were selected as being primary ones.

In 1950 and 1951, Cameron, Rowe, and Weis (1951, p. 906-910) attempted to duplicate Ingerson's experimental results but found the vapor phase to disappear from 199° C. to 343° C. rather than 153° to 165° C. The reason for this disparity is not understood. Only fluid inclusions shaped as negative crystals in quartz or beryl, or tubular inclusions with long axes parallel to the c-axis of enclosing beryl crystals, were accepted as primary in the studies of Cameron, Rowe, and Weis (1951, p. 910) and the fluid inclusions in the Case quarry samples used by Ingerson were suspected of being secondary. Neither the current theory of origin for liquid inclusions nor the common interpretation of their behavior when heated is based upon experimental behavior of inclusions in synthetic melts. Such experimentation is needed before observance of liquid inclusions can yield valid suggestions of genetic temperatures for pegmatites.

A second recent method for obtaining genetic temperatures is used by Tuttle (1949, p. 723-730) in determining the variation in inversion temperature of quartz. Tuttle states that, " the inversion temperature of quartz believed to have grown at low temperature is higher than specimens believed to have grown at high temperatures." First tests showed pegmatite quartz from the Black Hills inverting at lower than standard inversion temperature, showing affinity to rhyolite quartz samples. The results of the fluid inclusions and those of the inversion experiments are regarded by the present writer as incompatible; the problem of genetic temperatures for pegmatites cannot be solved until additional data have been made available and the theories on which the determinations were based have been checked.

Still another method for experimental determination of genetic temperatures is the decrepitation method, based on the presence of liquid inclusions. Scott (1948) reported 165° C. temperature for one quartz specimen from the Case No. 2 quarry (pegmatite 109); this result could not be reproduced by Cameron, Rowe, and Weis (1951), and it now appears that decrepitation methods can be applied reliably to crystals which have grown on the walls of cavities or open veins, but not to pegmatites (Konta, 1951).

Study of the internal units of pegmatites gives indirect evidence that they started crystallizing at a relatively high temperature and passed through a rather wide temperature range during cooling. Fersman (1951, p. 53) infers from theoretical evidence that crystallization of pegmatites takes place in a manner analogous to magmatic differentiation; that is, in steps, with partial resolution of earlier formed minerals from time to time. Cooling steps in a magmatic fluid are delimited by physical constants such as the transformation of "high" quartz to "low" quartz and the critical point of water. Fersman names the stages of magmatic consolidation as: magmatic (900-800° C.), epimagmatic (800-700° C.), pegmatitic (700-600° C.), pegmatoide (600-500° C.), hypercritical (500-400° C.), hydrothermal (400-50° C.), and supergene (50-0°). Of these, the pegmatitic, pegmatoide, and supercritical stages are considered to be the normal temperature range of most pegmatite rock.

Other geologists (Brögger, 1894; Landes, 1925, 1928, 1933; Schaller, 1925, 1927, 1933) have stressed the importance of hydrothermal solutions replacing simple pegmatite rock to form the complex pegmatites.

Pegmatites of the Middletown area are characterized by primary intergrowths of fresh minerals. The absence of relict textures showing older pegmatite units including graphic granite, plus the absence of hydrous alteration products around feldspar and other crystals, suggest that the observed pegmatite minerals are primary. Naturally, progressive crystallization in steps changed the composition of the rest fluid, so that replacement of one mineral by another within the chamber is to be expected at the interface between solid and fluid. Pegmatite textures show such a replacement of many minerals by one another; this intergranular replacement in nearly closed systems is not to be confused with metasomatic replacement of pegmatite bodies. Pegmatites in this area show the intergranular replacement of almost every mineral present by almost every other mineral present, this replacement being the evidence for rapid changes in the pegmatite forming fluids as one mineral after another crystallizes. Metasomatic origin is considered improbable, however, for any of the pegmatite units examined by the writer in the Middletown area.

Cameron et al. (1949, p. 102-103) have shown that the general variation in composition of plagioclase in pegmatites is from more calcic at the exterior of the body to more sodic in the center. This is in accord with what would be expected from a continuous reaction series in a closed system but would not be compatible with a replacement origin by hydrothermal solutions. Many minerals increase in size inward from the walls, for example, wedge mica books and tapered beryl crystals in pegmatites 108 and 109 (Case prospects). This implies a systematic process of crystallization in which the constituents of the minerals were furnished from the center of the pegmatite. As many pegmatites show these tapered crystals in units that completely surround core units, it is difficult to understand how they could have grown in an open system such as is necessary for metasomatic replacement. In addition to the increased size of single crystals from the outer to the inner part of a pegmatite, there is generally an increase in grain size of all minerals toward the center.

Banded and mammillary structures like those shown in figures 4, 5, 6, and 7, at pegmatite 93 (Hale quarry) occur in less striking form in numerous other pegmatites, including pegmatite 95 (Wannerstrom quarry) in the Middletown area; pegmatites at Pala, Calif. (Schaller, 1925; Jahns, 1948, p. 7); pegmatites in Gunnison County, Colo.; the Suzanna Number 5 and other pegmatites in Eight Mile Park, Fremont County, Colo. (Heinrich, 1948, fig. 11, p. 448), and a number of other pegmatites. These structures have been considered to be of replacement origin by some observers, whereas others consider the banding to be the result of flowage during crystallization. That such structures can have a deformational origin is illustrated by published photographs of siltstones and shales that show similar structures as the result of flowage (Rich, 1950, p. 725, 729, 730, 734). The banded and spheroidal structures in the Middletown pegmatites are interpreted as flow structures produced during the cooling of viscous pegmatite magma.

Fracture fillings similar to those of quartz-perthite exposed in the Hale quarry (fig. 5) cut the outer parts of a large number of pegmatites in this area. In no pegmatite has the writer traced the fracture fillings into the core, but the structural and mineralogic similarity of fracture filling units to cores or zones observed in other pegmatites leads the writer to consider the quartz-perthite bodies as offshoots of the last-consolidated part of the pegmatite. It is believed that in fracture fillings in most pegmatites, the relationships are similar to those shown in the Hardesty Homestead pegmatite in South Dakota (Cameron et al., 1949, fig. 43) where the fracture filling bodies are a part of the core.

The fractures along which fracture fillings are localized are believed to be caused by contraction during cooling of the outer part of the pegmatite, while the central part was still fluid. In some poorly differentiated pegmatites the fracture fillings in the outer units may have robbed the pegmatite of material that otherwise would have formed a core. Hydrothermal alteration has not been observed around any fracture filling in this area, and it is believed that the filling of fractures took place under the same conditions that interstitial quartz formed in granite.

The deformation of the wall rocks adjacent to some pegmatites is related to the pegmatite origin. At pegmatite 117 (Strickland quarry) (Cameron et al., 1949, fig. 29, p. 38), foliation planes of the surrounding schist parallel the bulges and depressions of the irregular pipe-like pegmatite. In others, such as pegmatite 100 (Bordonaro prospect), the thinner parts of the pegmatite are concordant and the thicker parts are discordant to the wall rock. The deformation of these wall rocks, together with the absence of relict structures in the discordant parts of the pegmatite, indicates that the pegmatitic fluid was forcefully injected.

The only replacement phenomena near the pegmatites are tourmalinization and an increase of the muscovite content of the schist near the contacts. The formation of these minerals in the schist depends on the addition of potassium, aluminum, boron, and water by the pegmatite. This is but a minor border phase of the emplacement process of the pegmatites. Because transfer by fluids is much more rapid than diffusion of ions through a solid, it is probable that pneumatolitic or hydrothermal solutions were involved in this wall rock alteration.

In summary, the preponderance of evidence favors the formation of pegmatites from a magma-like fluid by a process of fractional crystalization. During some stages it appears probable that minor quantities of fluids escaped to alter slightly the surrounding wall rocks.

Descriptions of individual deposits

Over 330 pegmatites were mapped and studied during the investigation of the Middletown area. Because the main purpose of the project was economic--an evaluation of beryllium resources--particular attention was given to estimating the mineral composition, internal structure, and grain size of the observed pegmatites. Studies were also made of unusual concentrations of industrial pegmatite minerals.

Several pegmatites of special interest, either for their contained beryllium or other pegmatite commodities or for their geologic importance, are described in detail.

Hale quarry, Portland--Pegmatite 93

Introduction.--The present Hale quarry in Portland was opened in May 1902, on land owned by the Hale family. The site was leased and operated by Mr. Harry Andrews of Glastonbury, who ground the feldspar at his mill on Hale Creek, several hundred yards from the quarry. The feldspar was sold after grinding to the Bon Ami Co. After the Andrews mill burned in 1906, the feldspar was sold to the Eureka Flint and Spar Co. The quarry was closed because of high labor costs during the first World War. In 1916 the workings extended about 25 yards inside the present quarry entrance. The quarry was reopened in 1938 under a lease from the Hale brothers by the Eureka Mica Mining and Milling Co. of Portland, the producing subsidiary of the Eureka Flint and Spar Co. of Trenton, N. J. The quarry has been operated continuously since 1938, and approximately 100,000 tons of feldspar have been shipped since that time.

The present quarry operations _/ are starting on a bench 25 feet below the level of the quarry floor shown on figure 4. Dump material is being used to raise the top level of the two main dumps, rather than extending them laterally.

The Hale quarry is one of the few operating feldspar quarries in Connecticut because of the large quantities of feldspar that can be produced with little hand cobbing. The hand-sorted feldspar is shipped 7 miles by truck to the Eureka feldspar mill, on the Airline Division of the New York, New Haven & Hartford railway, where it is ground to 200-mesh and shipped to potteries throughout the United States and some foreign countries.

Mine workings.--The main open cut was 525 feet long and 45 to 100 feet deep in 1949, and an "upper level" open cut is 130 feet long and 20 feet deep. The breast of the quarry is being worked southward along the eastern two-thirds of the pegmatite, avoiding the albite-rich tourmaline-bearing rock in the west wall of the quarry (fig. 4). The quarry is being made self-draining.

The quantity of feldspar sold from this quarry is: from 1902 to 1916, probably less than 10,000 short tons; from 1938 to 1949, about 100,000 tons. No salable byproducts have ever been obtained from this quarry. Operation of a picking belt as a means of removing waste from the feldspar was abandoned after a trial.

Geology.--Pegmatite 93 (fig. 4) is zoned on the basis of essential minerals. The wall zone makes up the eastern three-quarters of the pegmatite; it is medium-grained perthite-quartz pegmatite, with subordinate albite and muscovite. On the western side a border zone of quartz-albite-mica pegmatite, from zero to 45 feet thick, has striking mammillary structures (figs. 5, 6, 7, 8) and bands of tourmaline-bearing rock. The mammillary structures contain bands rich in quartz, feldspar, and mica. Red colored bands are common and have been attributed to a high garnet content. The red coloration, however, is almost entirely due to a surface discoloration of feldspar grains. The garnets present are exceedingly small and constitute less than 0.01 percent of the rock. Feldspar reserves are large because the pegmatite gives no sign of narrowing downward, and it extends at least another 350 feet south from the present quarry.

_/ Written communication, Mr. John C. Wilkes, President, Eureka Mica Mining and Milling Co.

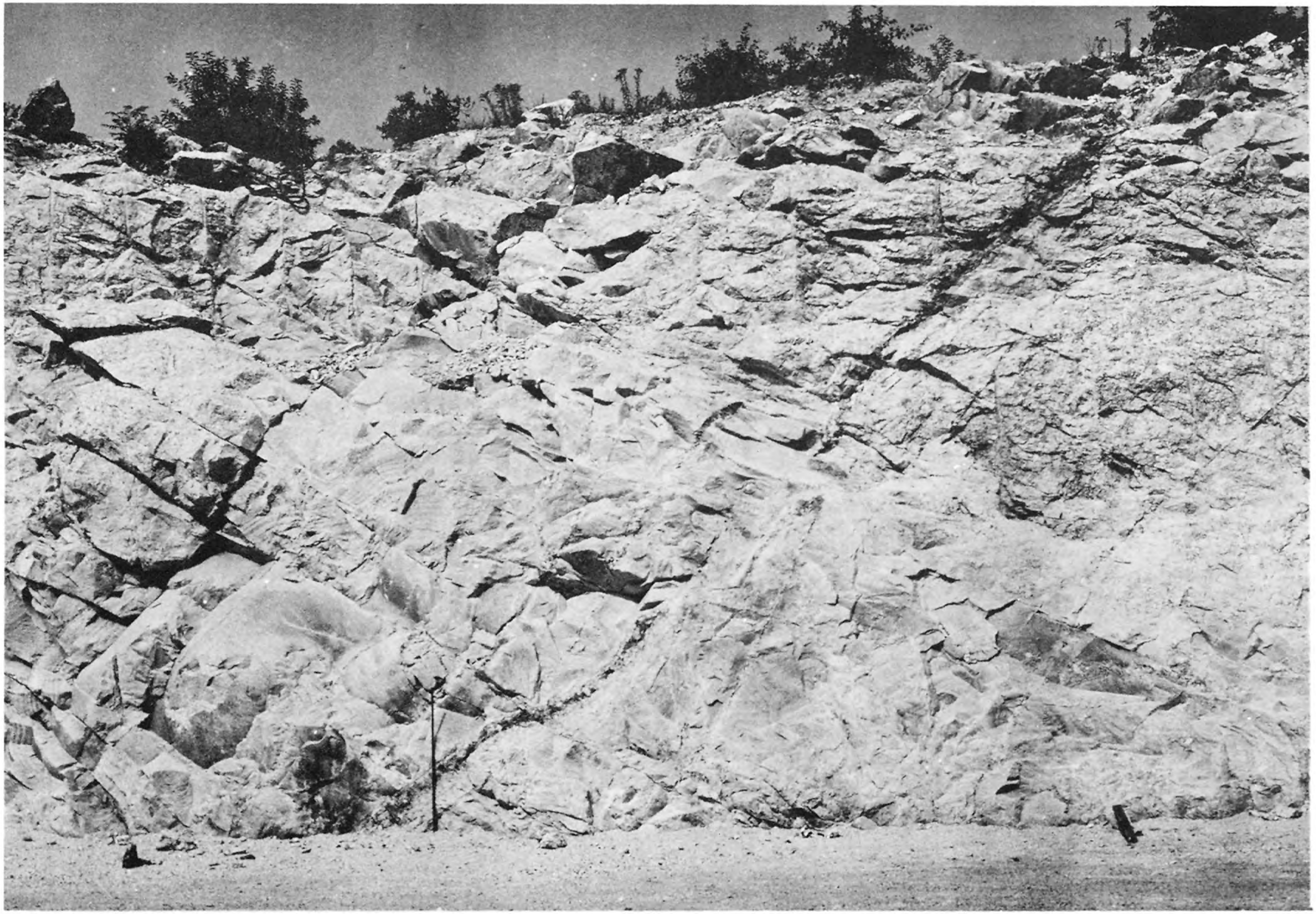

Figure 5.--Banded pegmatite cut by fracture-filling unit along the west wall of the Hale Quarry, Portland, Connecticut.

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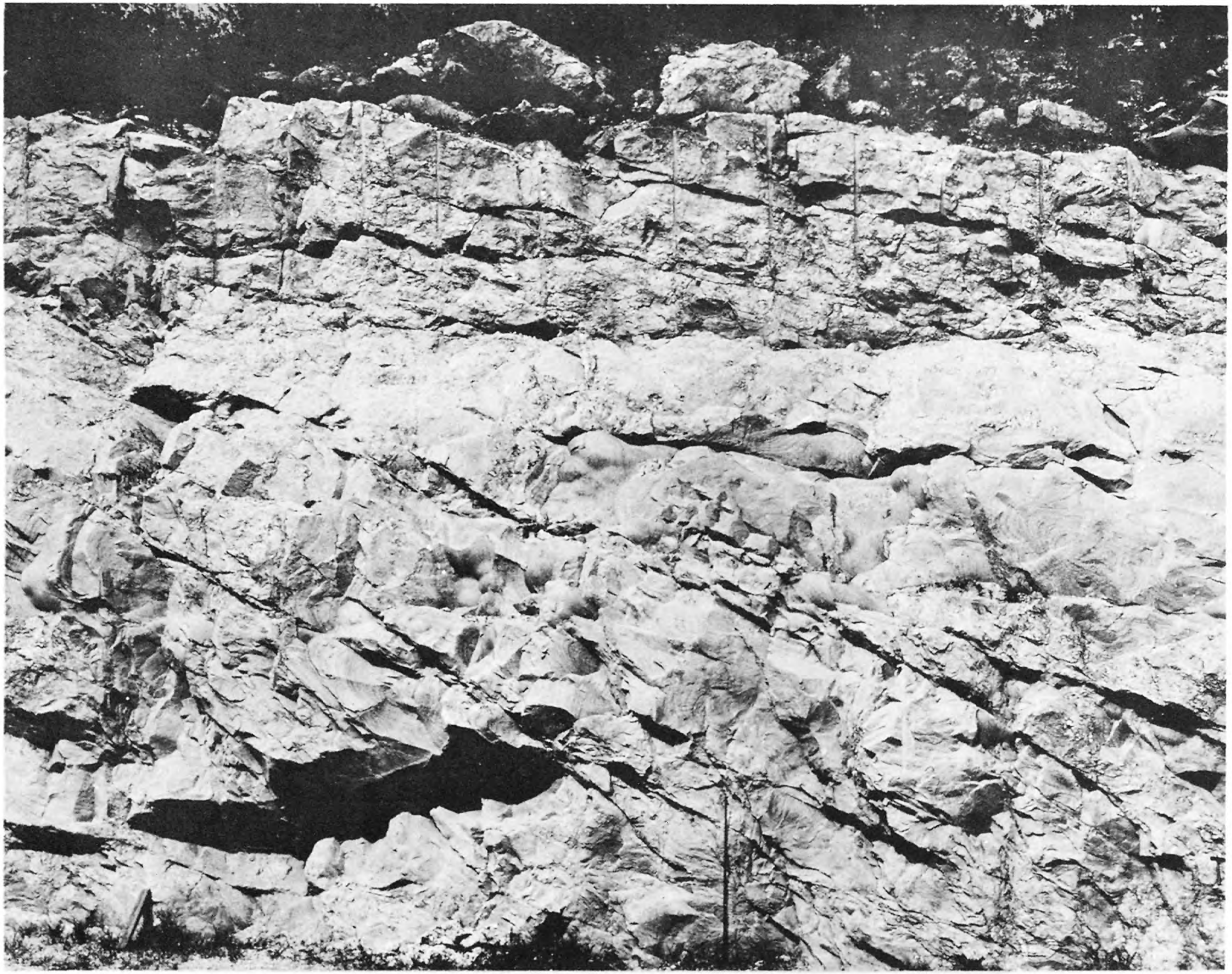

Figure 6.--Mammillary structures on the west wall of the Hale Quarry, Portland, Connecticut.

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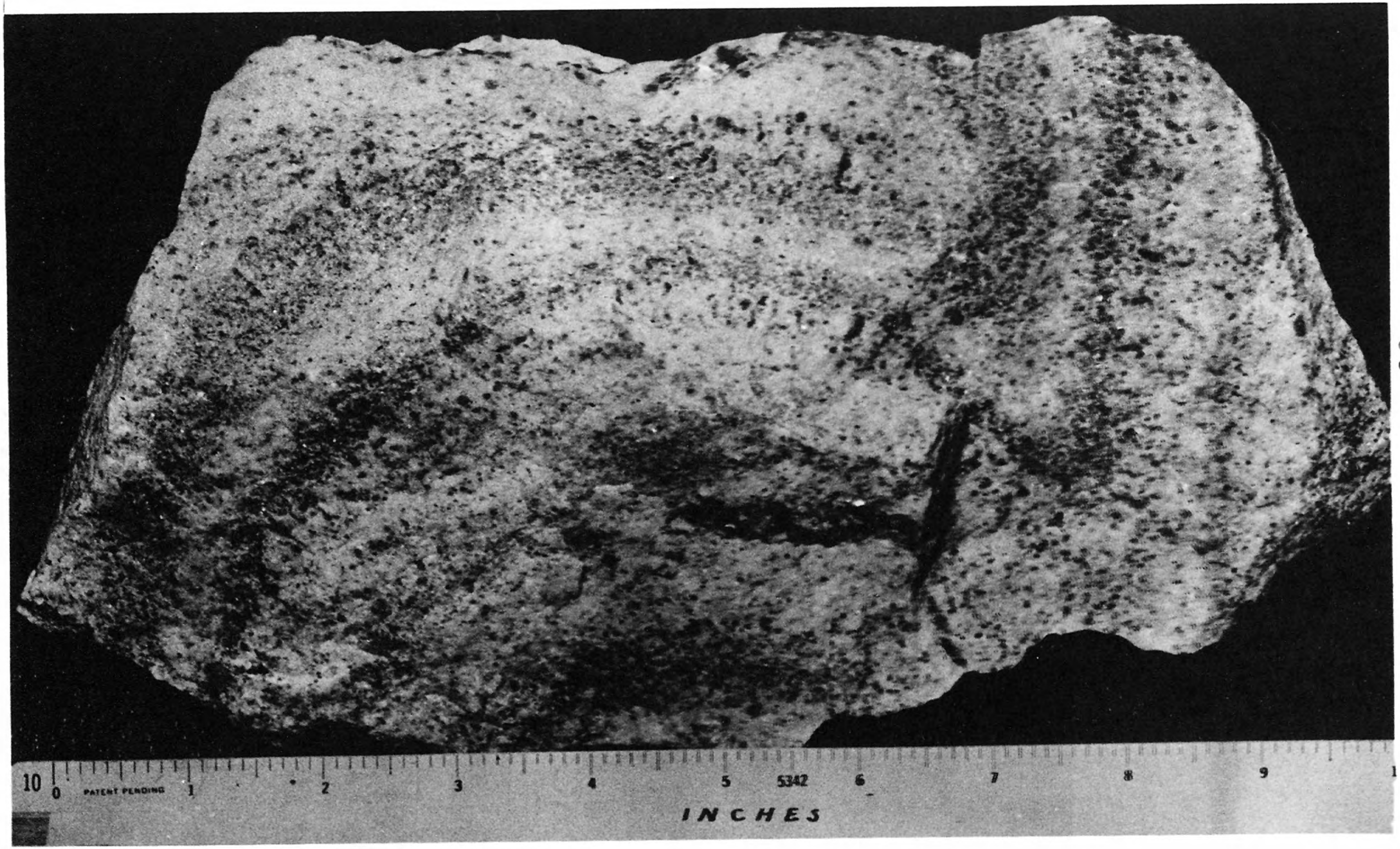

Figure 7A.--Banded albite-quartz-muscovite pegmatite from the west wall of Hale Quarry, Portland, Connecticut.

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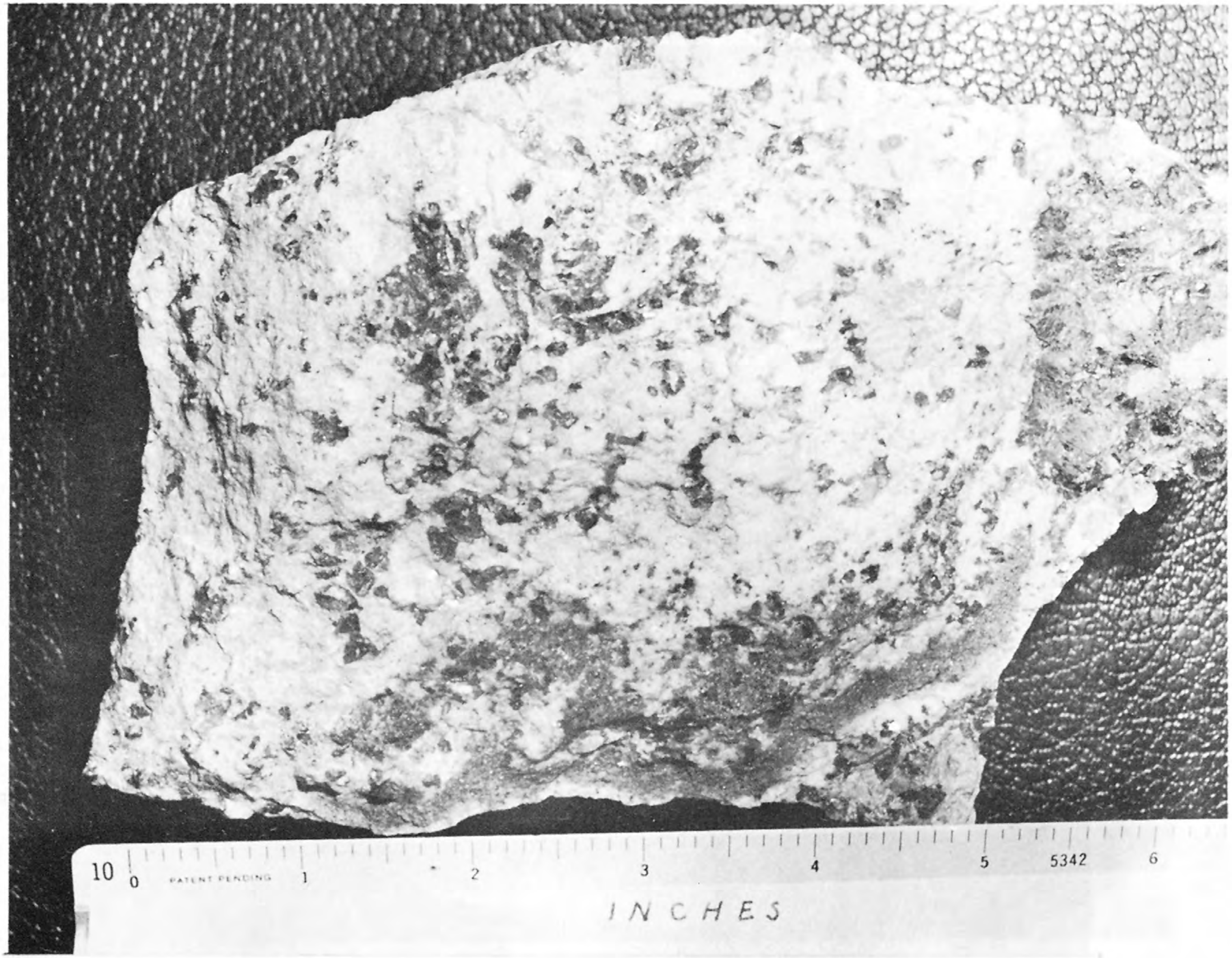

Figure 7B.--Red banded pegmatite from the west wall of Hale Quarry, Portland, Connecticut. Dark bands are red-stained feldspar.

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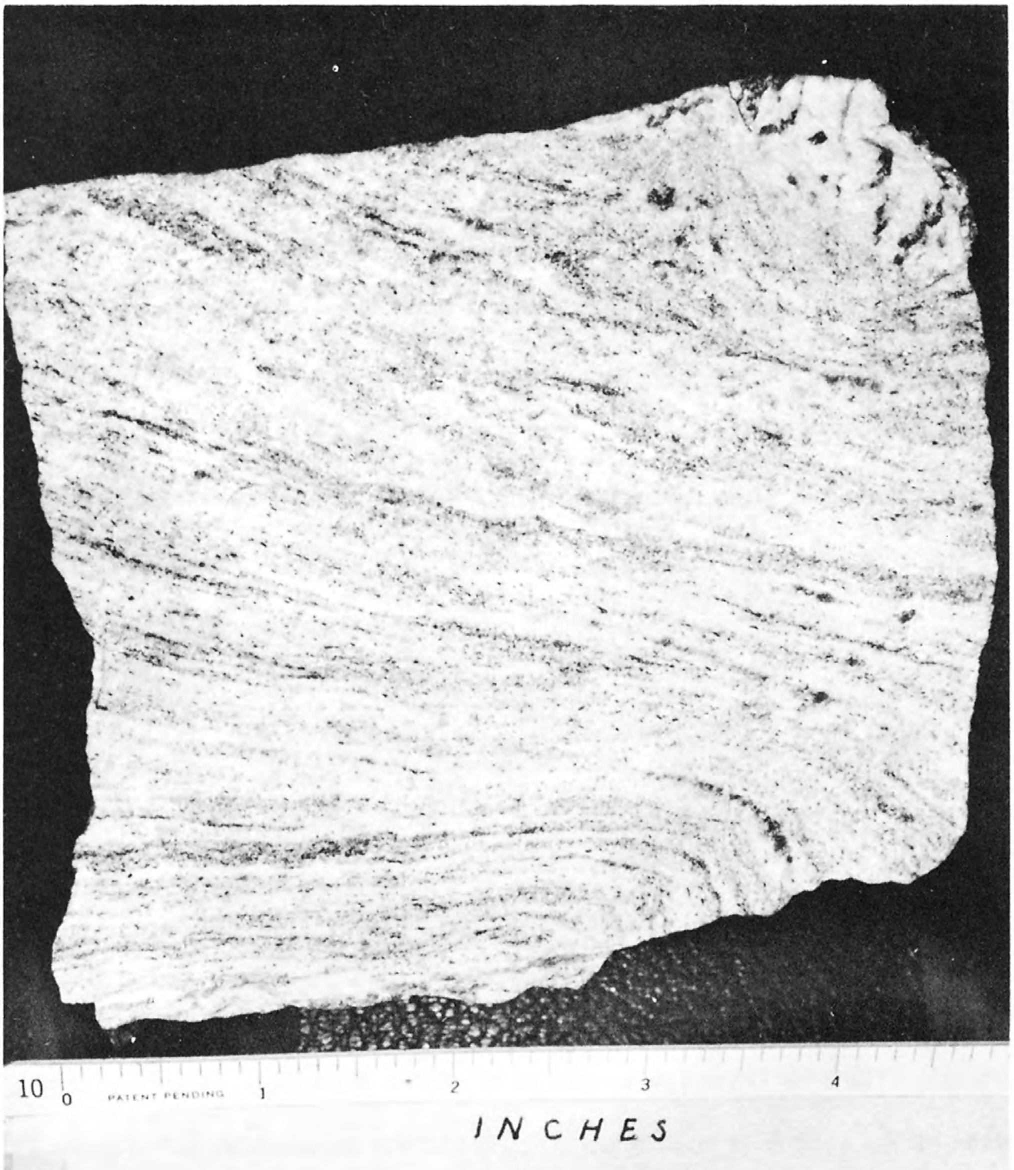

Figure 8.--Banded, aplitoid albite-quartz-tourmaline pegmatite from the west wall of Hale Quarry, Portland, Connecticut.

Beryl is not easily found. Small fracture fillings on the east side of the pegmatite contain up to 0.2 percent visible beryl, and colorless beryl has been identified in thin sections of the fracture fillings.

Apatite (fluorapatite) is distributed through the Hale pegmatite and many others in the district. Although colorless, the apatite can be easily distinguished at night by its vivid, light orange fluorescence under ultra-violet light. The apatite crystals range in size from small specks to about 10 mm across. Such fluorescent apatite is probably common in pegmatites; it is known to have been recognized in the Harding pegmatite in New Mexico. _/

Post-pegmatite fractures in the Hale quarry also display a bright fluorescence under ulta-violet light. This greenish-yellow fluorescence is emitted by a coating of hyalite which is invisible in daylight.

On the basis of contacts, now buried, between the Glastonbury granite gneiss and pegmatite 93 on the east side of the quarry, the pegmatite is believed to be crosscutting. It is probable that the pegmatite-forming fluids ascended along fractures in the Glastonbury granite gneiss and invaded the overlying Bolton schist. Emplacement was probably accomplished mostly by dilation of the wall rocks, but some assimilation took place. One partially digested xenolith was exposed in 1949 in the west wall of the upper level quarry (fig. 4).

The mammillary flow structures in the Hale pegmatite have fine-grained contact layers around them, suggesting that some cooling of the surface took place where fresh pegmatite magma erupted into a cooling and consolidating crystal mesh.

Howe No. 1 quarry--Pegmatite 73

Introduction.--Mr. George Andrews opened the Howe Number 1 quarry about 1870. Several years later the northern half of the pegmatite was sold to Joshua and William P. Husband and the southern half was leased for 20 years to Charles Hall. Operations continued for some time in the northern half, though the southern half was found to contain better feldspar for the trade. In 1905 Mr. Louis W. Howe of South Glastonbury acquired both parts of the property from which he produced 65,000 to 70,000 tons

_/ J. W. Adams, oral communication.

of feldspar between 1905 and 1928. The feldspar was recovered by hand cobbing, and the product contained as little sodium feldspar and quartz as possible; fragments with visible muscovite, beryl, or tourmaline were put on the dumps. No byproducts were sold. The ratio of recovered feldspar to waste was about 1:3. Present owner of the property is Consolidated Feldspar Co.

In 1949 the open cut was 100 feet wide, almost 800 feet long, and 100 feet deep at the south end. The north end has 25 feet of backfill and the south end is full of water. Quarrying in the north end of the pit was abandoned in 1928, partly because ground water flowed into the open cut at the rate of about 300 gallons per minute, requiring the operation of a 12-horsepower pump day and night. The quarry employed 30 to 60 men operating steam power drills and 15 to 25 men in the grinding mill. Most of the feldspar was ground to 60- or 80-mesh for use in manufacturing bath fixtures, porcelain insulators, and the remainder was ground to 200-mesh for use in scrubbing compounds. The largest amount of ground feldspar sold in any one year was 8,300 tons in 1907, and the smallest amount was 3,000 tons in 1908.

Until 1915, the feldspar was taken in ox-drawn carts to the Connecticut River, ferried across to Rocky Hill, there loaded onto 3,000-ton barges and carried by barge to the potteries in New Jersey. From 1915 to 1924 the output was carried by trolley to the Howe grinding mill. From 1924 until 1928, haulage to the mill in Glastonbury was by trucks. Since 1928, the quarry has been idle.

Geology.--Pegmatite 73 is exposed only as remnants on the walls of the Howe quarry. The body is concordant locally but, in general, dips more steeply than the enclosing Bolton schist so that it must be crosscutting at depth. The pegmatite consists of at least three units: (1) a thin wall zone of plagioclase-perthite-quartz pegmatite that contains about 0.08 percent beryl in crystals as much as a fifth of an inch in cross section, (2) a core of perthite-plagioclase-quartz pegmatite containing less than 1 percent muscovite, and (3) small fracture filling units about a foot in maximum thickness that contain as much as 1 percent beryl. Other units may be present, but the lower workings of the quarry were flooded at the time of examination. The pegmatite narrows slightly from top to bottom of the pit.

The core of perthite-plagioclase-quartz rock appears to have formed most of the pegmatite and to have been coarsely crystallized and so amenable to hand cobbing of the quarried rock. Although the beryl content was extremely small, crystals more than 6 inches in diameter have been described by former quarry workers. No rare minerals have been reported from this pegmatite. The large size of this pegmatite is its main distinguishing feature; its geologic history is typical of the numerous simple, granitic pegmatites intruded in the area during Mississippian (?) time.

Spinelli prospect--Pegmatite 3

Introduction.--The Spinelli prospect was first worked for feldspar during a part of 1912. Since that time only a few pounds of mica and samarskite have been mined; the samarskite was used for lead-uranium age determinations (table 9). The prospect is owned by Vito Spinelli of Boston, Mass. and Bovo Pezzana, who lives near the property on the north side of Hopewell Road at the intersection with Connecticut Highway 2.

Geology.--Cameron et al. (1954) give a detailed description of the geology. Pegmatite 3 (fig. 9) is a lenticular dike exposed for at least 280 feet along the strike and having a maximum width of 30 to 40 feet. This northeastwardly trending dike is cut near its middle by a steeply dipping, northwest-trending fault. The pegmatite intrudes Glastonbury granite gneiss and is chiefly made up of plagioclase-perthite-quartz pegmatite. Mica occurs as greenish, reeved and fractured muscovite, the books all being less than 4 inches across and usable only as scrap mica. The samarskite occurs only in a small pod, 14 feet long by 3 feet wide, near the western end of the pegmatite. The pod is a medium-grained perthite-quartz-mica pegmatite; the richest area of 9 by 1 1/2 feet was found by Cameron to contain 0.3 to 0.4 percent samarskite. The largest pieces of samarskite have been removed, leaving only fragments 0.1 to 2 inches long. The perthitic feldspar around the samarskite is salmon-red colored. Zonal structures have not been clearly exposed in the Spinelli pegmatite. The size of the pegmatite is insufficient to support any sustained mining.

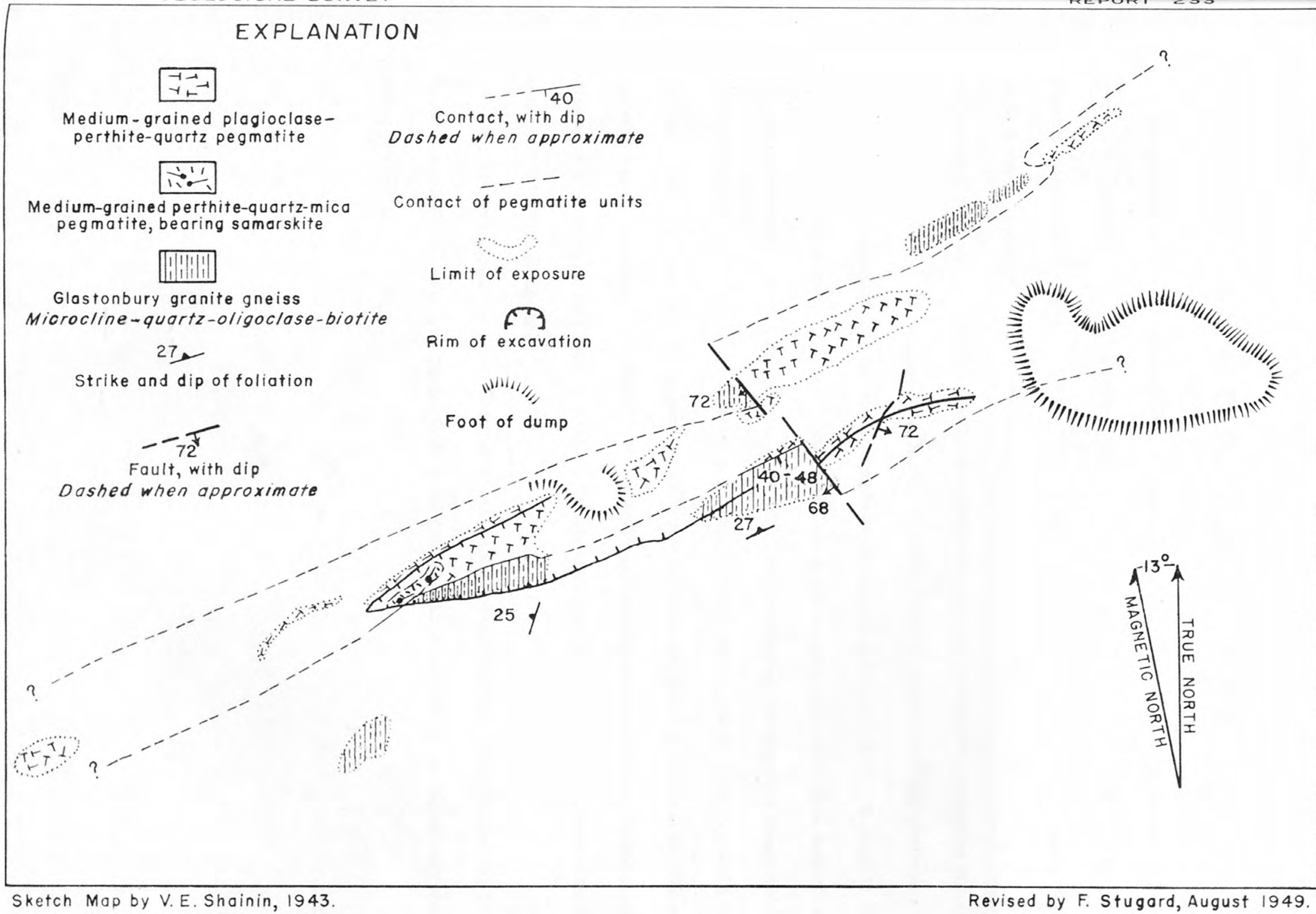

FIGURE 9.- SPINELLI PEGMATITE PROSPECT, GLASTONBURY, HARTFORD COUNTY, CONNECTICUT.

Past production of pegmatite minerals

The pegmatites of the Middletown area have been mined intermittently for feldspar and mica since about 1825, and continuously since about 1865. The recorded production of crude feldspar is 416,216 long tons and of mica is 4,131 short tons. The partial production records for Connecticut pegmatites are given in tables 11 and 12. Probably 90 percent of the Connecticut feldspar and nearly all mica production has come from the Middletown area. For those years in which Connecticut production of feldspar was reported jointly with that of New York, it may be assumed that the Middletown area produced a large part of the quantity reported, the balance coming from the quarries at Bedford, N. Y. In table 11 the production from two or more states is indicated where the producing area represented more than one state.

Mica production records in Connecticut prior to 1935 are incomplete, although it is known that in 1904 Connecticut ranked eighth of nine producing states. In 1915, 300 pounds of sheet mica and 1 ton of scrap were mined, but not sold. A small quantity of scrap mica was mined in 1924 and in 1929 mine-run mica was being sold from Strickland quarry by the Eureka Mica Mining and Milling Co. and sheet and scrap mica from the West Side mine by the Huse-Liberty Mica Co. In 1932 Connecticut ranked third among the mica-producing states.

After 1935 the production was recorded in detail in the Minerals Yearbook (table 12) and also by Cameron et al. (1954), who give a breakdown of the grades of mica produced in the Middletown area during World War II.

Table 11.--Connecticut feldspar production, 1883-1947

Source: Mineral Resources U. S. 1882-1931 and Mineral Yearbook 1932-1947

Year	No. of operating quarries in Conn.	Crude feldspar (long tons except as otherwise noted)	Value	Ground feldspar (short tons except as otherwise noted)	Value	Name or number of operating mills	Producing area represented, if other than Connecticut
1883	—	6,000	—	—	—	—	—
1884	—	6,000	—	—	—	—	—
1885	—	4,500	—	—	—	—	—
1886	—	7,500	$ 37,500 (at Trenton, N.J.)	—	—	—	—
1887-1899	—	—	—	—	—	—	—
1900	—	1,584 1/	6,800	8,006	$ 61,500	—	Connecticut and New York.
1901	—	3,514 1/	4,902	7,275	49,956	—	—
1902	—	—	—	8,742	59,642	—	Connecticut and New York.
1903	—	5,304 1/	23,561	7,435	55,628	—	Crude feldspar: Conn. and N. Y. Ground feldspar: Conn. only.
1904	—	2,163 1/	6,274	8,456	63,228	—	—
1905	—	10,501 1/	47,036	9,040	60,500	—	Connecticut, Maine, and New York.
1906	—	22,554 1/	74,036	7,500	50,500	3	Connecticut and New York.
1907	8	10,663 1/	15,825	11,500	40,500	—	—
1908	—	7,775 1/	—	9,934	—	—	—
1909	—	9,633 1/	28,522	4,011	14,491	—	—
1910	—	9,996 1/	32,903	8,743	57,071	—	—
1911	4	9,118 1/	27,450	7,379	46,107	—	—
1912	4	9,556 1/	34,943	9,519	59,154	3	-
1913	7	10,166 1/	35,867	10,122	79,903	—	—
1914	—	11,099 1/	42,965	5,414	40,326	—	—
1915	—	2,778 1/	10,715	10,732	62,409	—	—
1916	3	11,012	49,554	—	27,425	1	—
1917	—	10,455	43,160	—	34,272	Louis W. Howe	Connecticut and New Hampshire.
1918	3	5,305	29,419	—	22,708	Louis W. Howe	Connecticut and New Hampshire.
1919	—	9,715	84,050	—	49,063	—	—
1920	—	7,719	64,006	—	61,147	—	—
1921	—	9,565	65,864	—	—	—	—
1922	6	7,499	47,887	—	—	—	—

Table 11--Connecticut feldspar production, 1883-1947--Continued

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1923	8	8,780	75,379	—	—	Louis W. Howe and Tidewater Feldspar Co.	—
1924	—	6,572	51,442	2,741	$ 46,927	—	—
1925	9	10,426	71,201	—	—	—	—
1926	10	11,436	87,844	—	—	—	—
1927	9	6,123	43,319	—	—	Louis W. Howe and Tidewater Feldspar Co.	—
1928	—	6,292	48,996	2,525	36,764	Louis W. Howe, South Glastonbury; River Feldspar Co., Middletown; Tidewater Feldspar Co., Higganum.	—
1929	—	2,726	21,056	—	—	Louis W. Howe and Tidewater Feldspar Co.	—
1930-1934	—	—	—	None.	None.	None.	—
1935	—	17,103	99,770	—	—	—	—
1936	—	—	—	—	—	—	—
1937	—	—	—	—	—	—	—
1938	—	7,461	45,153	—	—	—	—
1939	—	10,033	53,120	—	—	—	—
1940	—	24,404	128,348	—	—	1	—
1941	—	13,693	92,397	—	—	1	—
1942	—	12,807	92,076	—	—	1	—
1943	—	11,618	76,463	—	—	1	—
1944	—	11,370	75,394	—	—	1	—
1945	—	11,735	74,778	—	—	1	—
1946	—	16,555	98,407	—	—	1	—
1947	—	15,408	100,152	—	—	2	—
Minimum totals for Connecticut 2/		416,216 long tons		139,074 short tons			

1/ Short tons.

2/ Includes all sure Connecticut production.

Table 12.--Mica sold or used by Connecticut producers 1935-1947 (Minerals Yearbook)

Year	Uncut punch and circle mica		Uncut mica larger than punch and circle		Total uncut sheet mica		Scrap mica		Total	
	Pounds	Value	Pounds	Value	Pounds	Value	Short tons	Value	Short tons	Value
1935	169,923	$ 5,943	95,327	$ 46,817	265,250	$ 52,760	620	$10,171	763	$ 62,931
1936	156,232	6,750	92,952	49,900	249,184	56,650	705	11,741	830	68,391
1937	311,091	12,242	90,720	31,046	401,811	43,288	561	8,616	762	51,904
1938-1940	Production not recorded.									
1941	157,816	11,135	95,009	118,761	252,825	129,896	201	3,983	327	33,879
1942	196,377	14,321	25,106	16,570	221,483	30,801	200	4,443	311	35,244
1943	165,186	26,528	36,956	38,711	202,142	65,239	304	6,795	405	72,034
1944	26,219	9,558	50,857	137,371	77,076	147,129	593	13,768	632	160,927
1945	60,823	3,246	1,009	6,879	61,832	10,125	70	1,752	101	11,877
1946	Production not recorded.									
1947	No production.									
Minimum Totals	1,243,667	$89,723	484,936	$446,255	1,731,603	$535,888	3,254	$61,269	4,131	$497,187

The quantity of mica produced in Connecticut has been a function of the current price rather than the amount available in pegmatites. The national average sales value of domestic uncut sheet mica during 1942, as computed (U. S. Bureau of Mines, 1943) was:

Size in inches, punch mica	Price per pound: Clear	Price per pound: Stained or spotted
1 1/2 x 2	$ 1.04	$ 0.88
2 x 2	1.61	.51
2 x 3	2.44	.77
3 x 3	2.98	.92
3 x 4	3.57	1.20
3 x 5	4.18	1.51
4 x 6	5.21	1.69
6 x 8	7.12	2.89
8 x 10	13.47	4.76

The maximum price for scrap mica sold from New England in 1945 (U. S. Bureau of Mines, 1946) was $25 per ton f.o.b.

Neither spodumene nor lepidolite has been produced commercially within the district. Several tons of beryl were marketed from the Strickland quarry, as a byproduct of pegmatite mining, after its reopening in 1942. During this period several tons of spodumene were put on the dump. The Anderson Number 1 quarry (fig. 2) was worked during World War I for lepidolite, but none was sold.

MINERAL RESOURCES

Pegmatite minerals

Beryl

The beryl deposits of the Middletown area have been described by Cameron and Shainin (1947). Of 120 pegmatites examined by Cameron and Shainin, only 10 were found that averaged more than 0.2 percent of beryl. The 10 highest grade pegmatites contain 0.4 percent beryl, almost all of which is too small to be separated from the rock by hand. Beryl was found disseminated through pegmatites, mostly in small, low-grade deposits. Border zones, wall zones, and intermediate zones were all found to contain beryl in some pegmatites; pods and fracture fillings also contain beryl in variable proportions ranging up to 1 percent and more of the unit, but these units are small in size.

The beryl resources in 10 pegmatites were determined by Cameron and Shainin on the basis of crystal counts and measurements on pegmatite exposures. The inferred resources of beryl totaled 859 tons in 208,000 tons of rock, an average content of 0.4 percent. Additional reserves were measured by the present writer in many other pegmatites, but the largest additional reserves were found by examination of pegmatite quarry dumps.

The beryl reserves of the Middletown area, Conn. are estimated by the author to be 2,430 tons of beryl in 2,320,000 tons of rock. These deposits, containing an average of 0.1 percent beryl, are mostly in scattered, low-grade pegmatites and are therefore economically unfavorable. The part of the reserves that might practicably be utilized as mill feed for the recovery of beryllium are the mine dumps at the Hale, Louis W. Howe No. 1, and the Strickland-Cramer quarries. Spectrographic analysis of dump samples indicates that 570,000 tons of broken rock in these dumps contain about 880 tons of beryl.

It is believed that recovery of beryl from these low-grade (0.15 percent beryl) mine dumps would be possible in a flotation process separation plant, and might become practicable at such time as it becomes of national importance to have this beryllium. Until that time, recovery of beryl is likely only as a byproduct of the feldspar industry if that industry should undertake construction and operation of a flotation process mill nearby.

In view of the regularity with which adequate search discloses beryl in well exposed pegmatites, and considering the difficulty of identifying white or colorless beryl, it is probable that many poorly exposed pegmatites actually contain between 0.1 and 0.2 percent beryl. The probable reserves, therefore, are about five times the reserves given above. Almost none of this beryl is recoverable by hand cobbing as much of it is below 0.1 inch in grain size.

The largest mine dumps in the Middletown area are at the idle Strickland-Cramer quarry and mine (pegmatites 117), the idle Howe quarry No. 1 (pegmatite 73), and the large, currently operative Hale quarry (pegmatite 93). In an effort to evaluate these dumps for beryl content, over 50 grab samples were taken from various parts of the dumps at each of these quarries. All grab samples were shoveled from about 2 feet below the weathered surface of the dump and were spaced by eye so as to include the various dumps at each quarry in amounts roughly proportional to their sizes. The samples for each quarry consisted of pegmatite fragments less than 2 inches across; these were reduced to about 10-mesh by use of jaw and gyratory crusher. The bulk samples were quartered to obtain the samples shown in table 14. These samples were quantitatively analyzed for BeO by spectrograph in the Geological Survey laboratories (table 13) after further reduction by the analyst. Semi-quantitative spectrographic analyses were made for other metals. The Spinelli prospect (pegmatite 3) dump was sampled by picking small fragments of pegmatite from the larger ones in the dump.

Because of the method of crushing, the iron content of the samples undoubtedly is several times the true iron content of the dumps. The 0.004 beryllia content of the Spinelli prospect sample is the same order of magnitude expected if the beryllium is in solid solution in the feldspar _/. The 0.04 beryllia content of the three samples from large quarry dumps indicates a beryl content of between 0.1 and 0.2 percent.

_/ Spectrographic measurement of the Be content of perthite shows about 0.001 percent, by Fletcher, Janet, 1949, written communication.

Table 13.--Spectrographic analyses of four pegmatite dump samples, Middletown area, Connecticut 1/

Analyst: Janet D. Fletcher, U. S. Geological Survey

	Sample number			
	1	2	3	4
BeO	0.02	0.02	0.02	0.004
Ba	.0X	.00X	.0X	.0X
Sr	.00X	.00X	.00X	.0X
Mn	.0X	.0X	.0X	.0X
Ti	.0X	.00X	.0X	.0X
Sn	---	---	---	.00X
Cr	.00X	.000X	.00X	.000X
V	.00X	.00X	.00X	.00X
Ni	.000X	---	.000X	.000X
Cu	.000X	.00X	.000X	.000X
Pb	.000X	.00X	.000X	.00X
Bi	---	.00X	---	---
Zr	.00X	.00X	.00X	.00X
Cb (Nb)	---	---	---	.0X
Ga	.00X	.000X	.00X	.00X
Y	.000X	.00X	.000X	.00X
B	.0X	.00X	.0X	.00X
MgO	.1-.3 percent	Below 1 percent	.3-.6 percent	Below .1 percent
Fe_2O_3	1-3 percent	.3 percent	.3 percent	.3-.6 percent
CaO	.1-.3 percent	.3-.6 percent	.3-.6 percent	.3-.6 percent
Na_2O	4-7 percent	4 percent	4 percent	2-4 percent

Looked for but not found: Co, La, Ce, Er, U, Ag, P, As, Sb, Ge, Tl, Cd, Ta, Mo, Zn.

Sample 1: Dump material Strickland-Cramer mine and quarry, Portland.
Composite of 57 grab samples totaling 280 pounds.

Sample 2: Dump material Howe No. 1 pegmatite, Glastonbury.
Composite of 50 grab samples totaling 120 pounds.

Sample 3: Dump material Hale quarry, Portland.
Composite of 77 grab samples totaling 170 pounds.

Sample 4: Dump material Spinelli prospect (samarskite-bearing).
Grab sample weighing 40 pounds.

1/ "X" indicates an undetermined digit from 1 to 9.

The constancy of beryllia content in the three large pegmatite dumps is notable, because in the Strickland-Cramer mines the beryl is believed by Cameron et al. (1954) to be confined to one unit--the quartz-cleavelandite zone--whereas in the Howe No. 1 and the Hale quarries, the beryl is disseminated through the pegmatite. Thus, it appears that the pegmatite-forming solutions had a nearly constant beryllia content, regardless of the manner in which it was localized during crystallization.

This low-grade beryllium-bearing rock is the largest beryl resource in the area. There are at present no Middletown beryl reserves, if by "reserves" is meant a deposit that can be profitably worked under present conditions. Exploitation of the low-grade resources in this area will depend upon (1) development of an economical procedure for removing beryl from quartz, feldspars, tourmaline, and other pegmatite minerals, and (2) market conditions such that beryl, feldspar, and the other pegmatite minerals recovered could sustain an economic operation.

Flotation tests (Lamb, 1947; O'Meara, 1948) on 11 tons of representative pegmatite from the Gotta-Walden prospect (pegmatite 386) showed that from a minus 20-mesh sample containing 0.14 percent BeO (about 1.3 percent beryl) a recovery of 69.3 percent of the beryllia could be obtained in a concentrate assaying 8.05 percent BeO. Since appreciable quantities of pegmatite containing as much as 1 percent beryl do not occur in this area, a successful flotation extraction must be a process capable of recovering beryl from even lower grade material, probably as low grade as 0.15 percent beryl. The percentage of recovery of the BeO must be expected to be somewhat lower than the test run by the Bureau of Mines on the higher grade beryl pegmatite.

It is clear that no "beryllium ore" exists in the Middletown area at present, if by "ore" is meant an aggregation of minerals from which beryllium could be extracted at a profit. If the quarried pegmatite already above ground were treated in a flotation plant for other minerals such as feldspar, however, it might be possible at a low additonal cost to install the cells necessary to recover a part of the beryl.

A comparison of several items in older chemical analyses, cited in table 14 (Wells, 1937, p. 24) from Howe No. 1 and the Strickland-Cramer mines, with comparable items in the spectrographic analyses of the dumps (table 14) shows a remarkable agreement between results of different samplings many years apart and between completely differing analytic methods.

Table 14.--Pegmatite analyses, Middletown area, Connecticut

Analyst: R. C. Wells; samples collected by F. J. Katz

	A (percent)	B (percent)	C (percent)	D (percent)
SiO_2	72.42	71.00	72.20	74.42
Al_2O_3	15.88	16.06	13.81	15.13
Fe_2O_3 (total Fe)	.54	.63	.86	.52
MgO	Trace	.02	None	None
CaO	.65	.32	.62	.44
Na_2O	3.74	3.75	4.05	5.40
K_2O	6.24	7.65	4.55	3.49
H_2O (total)	.46	.34	.45	.39
TiO_2	.05	.04	.17	.02
	99.98	99.81	96.71	99.81

A. Howe quarry No. 1, Glastonbury, east wall. Sample included feldspar, muscovite, and quartz.

B. Strickland quarry, Portland, across width of quarry.

C. Eureka quarries, near Middle Haddam village, East Hampton 1/.

D. Gildersleeve prospect, Portland 1/.

1/ Identity of pegmatite not known, the name being given here as it appeared in the literature.

Feldspar

Feldspars form one of the essential constituents of most pegmatites; consequently, feldspar of commercial quality occurs in many pegmatites. The size, shape, and structure of the perthite-bearing units determine whether or not feldspar with the desired characteristics can be mined profitably. Perthite occurs in larger crystals than do the other feldspars and tends to form either a hood-shaped zone above a core, or a core. Some of the largest feldspar quarries have operated entirely within the hood of a zoned pegmatite; others, such as the Hale, in a core. The enormous feldspar resources in the Middletown area are sufficient for any foreseeable production.

Mica

Mica in homogeneous pegmatites is disseminated and usually small. Some wall and intermediate zones contain sheet mica, and most of the sheet and scrap mica production has come from these zones. Fracture filling bodies and pods contain mica but seldom produce usable sheet mica.

In general, the Connecticut mica has many structural and mineralogical defects and therefore is classified as scrap mica; only an extremely small proportion can be used as sheet mica. Scrap mica comprised 1 to 3 percent of most Middletown area pegmatites.

Quartz

No recorded production of quartz has come from the Middletown area. As an intergrowth with other minerals, quartz is one of the most abundant constituents of every pegmatite. Although not a practicable product for hand cobbing, quartz could be a byproduct of every froth-flotation feldspar separation. The tonnage reserves of quartz in this area are vast.

Non-pegmatite minerals

Although determination of certain pegmatite mineral resources of the Middletown area constitute the object of this report, non-pegmatite mineral resources observed during the field work are briefly reported for the sake of completeness.

Nickel and cobalt

Nickel and cobalt were mined in the 18th and 19th centuries near the present Camp Jenkins, on the southeast slope of Great Hill (fig. 2), within what is now Meshomasic State Forest, East Hampton (formerly Chatham). The vertical and inclined shafts and the foundations of the mill can still be seen. No nickel or cobalt minerals are in sight in the old workings and no further production of metal is likely.

About 20 tons of material, intended for use in China as smalt in the manufacture of chinaware, were shipped during early operations. An assay in the mid-19th century showed run-of-the-mine ore to contain 2.2 percent of metallic minerals, and it was believed at that time that ore separators of contemporary design could derive concentrates of 20 percent metallic mineral content, about equally nickel and cobalt minerals, plus some hydrous ferric arsenate, scorodite. The history of this old mine has been given by Blake (1882). Schairer (1931, p. 109) identified arsenopyrite, scorodite, niccolite, sphalerite, galena, and smaltite-chloanthite in the overgrown mine dumps. It is reported that five attempts to work this deposit failed financially between 1762 and 1855. Further interest must depend upon finding a larger quantity of the metallic minerals reported earlier, or finding associated radioactive minerals.

Reports from the mine at Cobalt, Conn. attracted considerable early attention, first for cobalt and shortly thereafter as a possible source of nickel (Whitney, 1854, p. 496-497). Description of ores from this mine was published after the ores were exhibited at the New York Crystal Palace Exhibition of 1853-1854 (Goodrich, 1854); ores from the surface to a depth of 3 fathoms included cobalt bloom, nickeliferous mispickel (arsenopyrite), and finely-disseminated "smaltine" in gneissic rock. Analysis No. 1 is for a sample collected by J. D. Dana, and No. 2 is for a sample washed by Bradford's machine:

	No. 1 (percent)	No. 2 (percent)	
Nickel	9.44	10.17	
Cobalt	3.82	3.85	
Iron	11.85	12.92	
Sulfur	4.78	5.62	
Arsenic	70.11	67.44	(From loss by ignition)
	100.00	100.00	

Analyst: F. A. Genth.

Another analysis, made at Yale College, showed the nickel content about 3 percent lower than Genth's analyses. It was stated that the Genth analyses gave evidence of presence of the molybdenum group, but too little material was present for a determination.

It is not known whether the last mining company failed because of lack of capital, inability to separate the cobalt from the nickel, arsenic, and iron, or from exhaustion of ore. The extent reports (Francfort, 1853 _/, 1855 _/) imply that the failure may have been from the first two causes. Since the ore apparently was confined to small shear zones within the Bolton schist, the quantity of ore would at best be very small by modern standards.

_/ Francfort, E. C., 1853, Unpublished report on the mines of the Chatham Cobalt Mining Co., Middletown, Conn.

_/ ______________, July 1855, Unpublished report of Prof. Jas. C. Booth and Second annual report of Dr. E. C. Francfort to the president, trustees, and stockholders of the Chatham Cobalt Mining Co., Middletown, Conn.; map of the Chatham Cobalt Mining Co. property, Cobalt, Conn., Lith. by Robertson & Seibert Co., 120 Fulton St., New York, 1855.

After the site passed into possession of the State of Connecticut, an examination of the prospect by a mining engineer was made for the State Development Commission (Bancroft) _/. Thirteen samples from the seven available openings of the old workings were assayed and found to contain no cobalt or nickel, other than a "trace" of cobalt in two samples. Arsenopyrite was the only metalliferous mineral found to occur within 15 feet of the surface. Rock samples were included for assay, since the older reports describe disseminated ore in weathered schist.

The present writer could find no veins such as were described a century before. From the inclined shaft still open, two stopes were accessible in 1950, extending about 40 feet below the surface. No metalliferous minerals were visible there; the very small veinlets of quartz present are parallel to the foliation of the schist. No sulfide minerals were visible within the main adit--blocked about 45 feet from the portal--or within the Engine shaft--now choked with debris. The Engine shaft is known to be 120 feet deep, at which depth a crosscut was made southward for about 120 feet.

Tests with a small, portable Geiger counter showed "counts," or impulses heard per minute as follows:

The "background count" over entire hillside for several hundred yards around the workings was 24 to 43 per minute; anywhere within the stopes, 15 to 40 feet below the surface, it was 59 to 67; at the small open cut and with instrument held against the arsenopyrite flakes, the only sulfide mineral visible within the area, it was 21. At localities several miles removed from Great Hill, the "background count" was 12 to 15.

Because the increased rate of impulses could not be correlated with nearness to any body of rock, it was inferred that the increased "count" near the old workings was caused by extremely diffuse gaseous disintegration products and that the presence of uranium is not necessarily indicated. Old specimens of ore from the working face of the mine, now in the Wesleyan University Museum at Middletown, gave no reaction with the portable counter used.

_/ Bancroft, Howland, to Taylor, David, Sept. 15, 1941, in files of Connecticut State Development Commission, and Connecticut Park and Forest Commission, State Office Bldg., Hartford.

Mineral identification and radioactivity analysis in the Geological Survey laboratories gave these results on two of the Wesleyan specimens that were sawed and polished:

	Wesleyan sample 3005	Wesleyan sample 3011
U. S. Geol. Survey lab. no.:	48116	48117
Equivalent uranium:	0.006 percent	0.002 percent
Minerals:	(1) pyrite, FeS_2	(1) gersdorffite, NiAsS
	(2) chalcopyrite, $CuFeS_2$	(2) niccolite, NiAs
	(3) mineral whose composition and x-ray pattern place it midway between arsenopyrite, FeAsS, and lollingite, $FeAs_2$	(3) chlorite and quartz
	(4) staurolite, biotite, and plagioclase	

Silver and lead

Argentiferous galena was mined before the Revolutionary War at a now caved working in the Bolton schist on the south bank of the Connecticut River (fig. 2). Whitney (1854, p. 393-394) describes 120-foot-deep workings made there in 1852-1854. Whitney reports that a vein 1 1/2 to 3 feet wide contained 25 to 75 oz. silver per ton. Gangue included mostly quartz, some calcite, a very little barite, fluorspar, pyrite, and chalcopyrite. In 1949, minute quantities of fine-grained galena were found in outcrops of silicified Bolton schist near the abandoned workings. The area of the abandoned silver-lead prospect is within the crushed zone adjacent to the Triassic boundary fault.

Building stone

Stone from four of the rock units mapped in this area has been used for construction: the Monson granodiorite, Maromas granite gneiss, Glastonbury granite gneiss, and the Newark sandstones. The only active quarry in the area in 1950 was the Tower Hill Granite Co. quarry, close to Connecticut Highway 2 in the northern part of the area mapped (fig. 2). One or two workers at this quarry still cut replacements for old stone curbing from the Glastonbury granite gneiss.

Fifty years ago the cut-stone business in this area and throughout Connecticut was an important part of industry in the State. The decline of stone quarrying, as concrete and other building materials became more widely used, has resulted in a near cessation of the building stone industry. Because most of the former quarries are now abandoned and full of water, complete descriptions of the building stone and local quarries are best left to older publications (Dale and Gregory, 1911).

The Monson granodiorite was quarried in the eighteen-nineties just south of the Middle Haddam quadrangle. Westgate (1902, p. 5-6) described the rock at these quarries as a uniform, dark gray gneiss that has partings several feet apart along parallel veinlets of quartz. The stone was used for curbs and block pavement. Some care was necessary to avoid intercalated bands of dark minerals.

The description given by Dale and Gregory (1911, p. 116-117) for the Peterson quarry in the town of Bolton is thought to apply to much the same type Monson granodiorite, although the quarry was listed as being in Glastonbury granite gneiss. Dale and Gregory state that "The stone is used for underpinning, cellar stone, etc.", the use having been restricted to such uses, presumably, because the stone rusts upon exposure to weathering.

The Maromas granite gneiss was extensively quarried at the Maromas quarry, several Benvenue quarries, and many smaller openings. Railroad grades remain to show how the cut stone was shipped on railroad cars directly from the major quarries to purchasers. A smaller body of the same rock was quarried from a pit beside Great Hill Pond Brook north of the river near Cobalt. From this small quarry (fig. 2) came part of the stone used in construction of the railway bridge above the brook a few yards away, where it can be seen today.

Westgate (1899, p. 64) says of the Maromas granite gneiss "It is handsome when first quarried, but stains quickly, and so is of use only for foundations, etc." A good description of the occurrence at the Benvenue quarries is given by Dale and Gregory (1911, p. 76-78).

A description of several quarries opened in the Glastonbury granite gneiss is also given by Dale and Gregory (1911, p. 62-67). This distinctly foliated rock varies considerably from one locality to another in its appearance. In 1950 the Tower Hill quarry, 3.5 miles southeast from the Glastonbury, Conn., traffic circle, was producing a light gray, porphyritic stone for curbings, as mentioned above.

The Triassic sandstone was shipped in large quantities from the immense quarries in the city of Portland during the latter half of the nineteenth century. The finer-grained layers of sandstone are well adapted to splitting with wedges, and this rock forms a durable building material providing the bedding planes of the rock are laid horizontally in the masonry. The site for quarries in this formation had to be carefully picked to avoid the numerous areas of pebble and cobble layers that prevent easy splitting. "Brownstone" suffered an early decline from its high fashion because it was often laid with the parting surfaces vertical, in which position it was badly corroded by the weather. The dark color also became unpopular.

Sand and gravel

Areas covered by glacial outwash of sand and gravel are shown on figure 2. These areas are all covered to a depth of more than 5 feet, though most of the deposits are thicker, as at Butler's (fig. 2) and other sand pits. There is an abundance of buff-colored sand and gravel in the area, suitable for many uses after size sorting.

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