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GEOCHEMISTRY OF THE NEW LONDON AREA, SOUTHEASTERN CONNECTICUT

by

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ABSTRACT

Chemical and modal analyses of Late Proterozoic metasedimentary and metaigneous rocks and Paleozoic intrusive rocks from the New London area, southeastern Connecticut, form the basis for examination of the petrology of the rocks of this part of the Hope Valley-Dedham (Avalon) terrane of southeastern New England and for their comparison with similar age rocks in other parts of the Avalon terrane in southern New England. Rocks of the Plainfield Formation are primarily silicic and calcic metasediments derived from near-shore protoliths. An admixture of metavolcanic rocks forms the transition into the Waterford Volcanic-Plutonic Complex, which consists primarily of felsic gneisses of dacitic to rhyodacitic composition and secondarily of amphibolite and hornblende gneiss of probable andesitic to basaltic composition. These metavolcanic rocks are considered to be a volcanic-arc association, but trace element analyses are insufficient to discriminate clearly paleotectonic environments. Although the calc-alkaline orthogneisses of the Sterling Plutonic Suite, the Potter Hill Granite Gneiss, and the Hope Valley Alaskite Gneiss are, on the whole, chemically distinct, they appear to belong, with the Waterford Complex, to a mafic to felsic petrogenetic sequence of volcanic and plutonic rocks.

The Paleozoic intrusions are petrologically distinct from the Late Proterozoic assemblage. The Silurian Preston Gabbro consists of an assemblage ranging from partly metamorphosed hypersthene gabbro to granodiorite. The Pennsylvanian or Permian alkalic Joshua Rock Granite is unique in this part of the Hope Valley terrane but is chemically closer to the Hope Valley Alaskite Gneiss than to the Permian Westerly and Narragansett Pier Granites, which have distinctly high barium and rare-earth element contents.

INTRODUCTION

The chemical and modal analyses of rocks from the New London area, southeastern Connecticut, that form the basis of this paper are essential data for interpreting the petrology of the crystalline rocks in this part of the Late Proterozoic, Hope Valley-Dedham (Avalon) terrane of southeastern New England. The purpose of this paper is primarily to present the data and to supplement them with comments based on field observations in the area, secondarily to present some tentative interpretations of the data, and thirdly to compare the data from the New London area with data from possibly correlative terranes elsewhere in southeast New England.

The analyses of rocks from units in the New London area (tables 1 - 7) were made in support of geologic mapping by the U.S. Geological Survey (USGS) in eastern Connecticut between 1955 and 1974 in cooperation with the Connecticut Geological and Natural History Survey. The samples were taken from rock units shown on quadrangle maps by Goldsmith (1967a, b, c, d, 1985a) and Snyder (1964) consolidated here in the bedrock geologic map (plate 1).

The tables of analyses in the appendix are of the major groups of rock, but table 4 is of rocks whose assignments are less certain. Chemical analyses of whole-rock samples were done either by conventional rock analysis at the USGS laboratories in Denver, Colorado, or by rapid rock analysis at the USGS laboratories in Reston, Virginia. Trace element abundances were determined either by delayed neutron activation or by emission spectrographic analysis. Strontium in a few samples was determined by X-ray spectroscopy. Not all samples were analyzed for trace element abundances by these methods, and some elements important to the preparation of discrimination diagrams with which to interpret the petrology were not analyzed during the mapping program. Semiquantitative spectrographic analyses are available for all samples, however, but are not given in the tables; instead, the results are summarized as histograms. Modal analyses were made by counting over 1,000 points per thin section, except for modes of most of the metasedimentary Plainfield samples, which were determined by optical estimation of percentages of minerals in thin section. Estimated modes of granitoid rocks of the area, in addition to those shown in the tables, also are summarized as histograms. Comparison of estimated modes with point counts of particular thin sections indicate that, on most samples, major minerals were estimated within a 5-percent error factor.

Setting

The New London area lies in the southwestern part of the Late Proterozoic Avalonian terrane of southeastern New England (fig. 1) in a westward projection of the terrane caused by east-west, northward tilted uplift of the coastal belt parallel to Long Island Sound (Dixon and Lundgren, 1968, p. 229; Rodgers, 1970, p. 110). This uplift brings the north- to north-northeast trending boundary of the terrane in Massachusetts (Bloody Bluff fault) and Rhode Island and eastern Connecticut (Lake Char fault) into an east-west to west-southwest trend in southeastern Connecticut (Honey Hill fault). The New London area lies entirely in what O'Hara and Gromet (1985) termed the Hope Valley terrane, which is west of their Hope Valley shear zone separating the gneissic Hope Valley terrane from the nongneissic Dedham-Esmond terrane (Hermes and Zartman, 1985). The northerly dipping Honey Hill fault passes through the northern part of the New London area. North of the Honey Hill fault is the Putnam terrane consisting of Ordovician or Late Proterozoic metasedimentary and metavolcanic gneiss and schist belonging to the Quinebaug and Tatnic Hill Formations and intruded by Silurian Preston Gabbro.

The New London area is underlain by high-grade paragneisses and orthogneisses of Late Proterozoic age that have been intruded by late Paleozoic granitic rocks. The Late Proterozoic rocks are in the upper amphibolite metamorphic facies; sillimanite is the key metamorphic index mineral, and muscovite is rare as a prograde metamorphic mineral in pelitic rocks except in the northern and eastern parts of the area. The grade of metamorphism decreases from southwest to northeast across the area. Features indicative of partial melting are common in the highest grade rocks. The metamorphism was accompanied by ductile deformation producing an interference pattern of domes and basins. The high-grade metamorphism is believed to be late Paleozoic in age (Lundgren, 1966; Hermes and Zartman, 1985; Wintsch and Aleinikoff, 1987) and has overprinted an earlier, probably Late Proterozoic, low-grade metamorphism involving isoclinally folded rocks (Goldsmith, 1985a). The ductile deformation and partial melting ceased before emplacement of undeformed dikes of Permian Westerly Granite. Retrogressive metamorphism of Permian age at greenschist facies has occurred in the Honey Hill fault zone

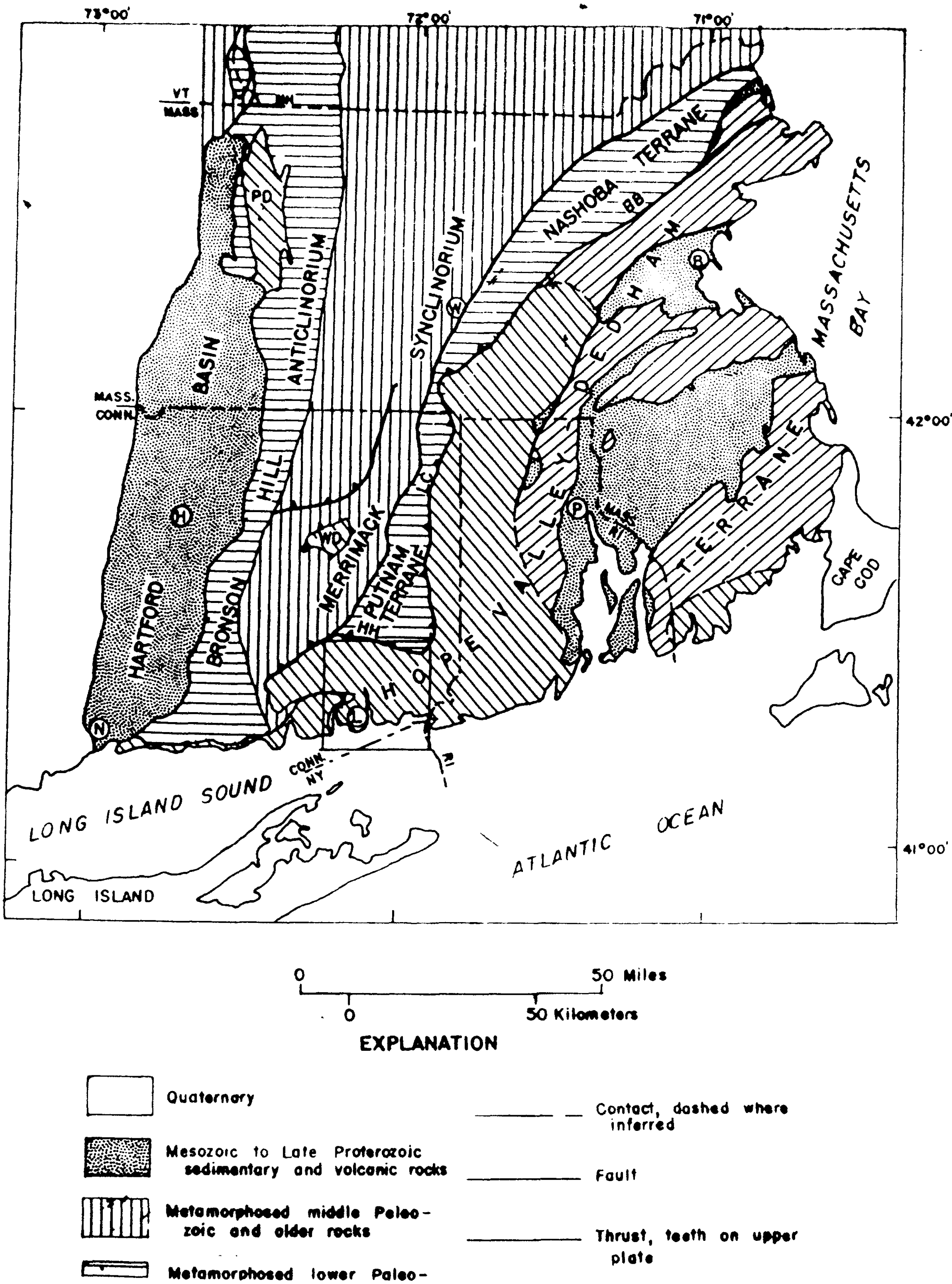

Figure 1. Location of New London area, Plate 1. B, Boston; BB, Bloody Bluff fault; H, Hartford; HH, Honey Hill fault; LC, Lake Char fault; N, New Haven; L, New London; P, Providence; PD, Pelham dome; WD, Willimantic dome; W, Worcester.

and in the upper plate rocks (Snyder, 1961, 1964; Lundgren and Ebblin, 1972; O'Hara and Gromet, 1981; Losh and Bradbury, 1984).

Stratigraphy

The Late Proterozoic rocks consist of an older, primarily metasedimentray sequence in which quartzite is conspicuous, the Plainfield Formation, and an overlying sequence consisting primarily of metavolcanic and metaintrusive rocks, the Waterford Complex (Plate 1). The Plainfield and the Waterford sequences are interlayered with granitoid gneisses belonging to the Sterling Plutonic Suite. Some of the Sterling gneisses may have had a felsic volcanic protolith. In the New London area, the predominant orthogneisses are the Hope Valley Alaskite Gneiss and the Potter Hill Granite Gneiss. Intruding the Late Proterozoic rocks are the paraconcordant Joshua Rock Granite, from which an early Permian or late Pennsylvanian zircon age has been recorded (R. E. Zartman, USGS, written commun., 1981) and the discordant Narragansett Pier and Westerly Granites of Permian age. The latter, extensive in adjacent southern Rhode Island, form only small masses and dikes in the New London area.

The rock units in the New London area (Plate 1) are those mapped and described by Goldsmith (1966; 1967a, b, c, d, 1985a) and, in part, by Feininger (1965a, b) and Lundgren (1963, 1966, 1967). The nomenclature was revised by Goldsmith (1980, and further revised on the quadrangle map of the Mystic and Old Mystic quadangles (Goldsmith, 1985a). The geologic map (Plate 1) consolidates the terminology for the map units. I have made a few additional revisions to the nomenclature in this report to conform more closely to the new North American Stratigraphic Code and to acknowledge a new age assignment based on recent radiometric dating. The unit boundaries shown on the geologic map are the same as those shown on the quadrangle maps except in one area of poorly exposed rocks near Old Mystic where I have changed a boundary to fit a more reasonable structural interpretation.

Nomenclature changes since the 1980 paper and the 1985 mapping in the Mystic and Old Mystic quadrangles are as follows:

> The Joshua Rock Granite Gneiss is changed herewith to Joshua Rock Granite in recognition of its Permian or possible Pennsylvanian age (R. B. Zartman, USGS, written commun., 1981). The age of the Joshua Rock is changed from Late Proterozoic to early Permian or late Pennsylvanian(?).
>
> The Hunts Brook schist remains an informal name, and the unit is of probable Late Proterozoic age (Goldsmith, 1985b).
>
> The Sterling Plutonic Group (Goldsmith, 1966), which includes the Late Proterozoic primarily gneissic granitoid rocks of southeastern Connecticut and adjacent Rhode Island, is renamed the Sterling Plutonic Suite. The type Scituate Granite Gneiss (Quinn, 1953), now named Scituate Granite of Devonian age (Hermes and Zartman, 1985), is no longer a part of the suite.
>
> The Waterford Group is renamed herewith the Waterford Complex to adapt to the North American Stratigraphic Code. Although interpreted to be primarily of volcanic origin (Mamacoke Gneiss, New London Gneiss), it appears to contain plutonic elements (New London Granodiorite Gneiss and probably all or part of the Rope Ferry Gneiss) and minor amounts of

metasedimentary rock (quartzite and metasediments of the Cohanzie member of the Mamacoke. The Mamacoke Gneiss of Gregory and Robinson (1906--07) and Foye (1949), changed to Mamacoke Formation by Goldsmith (1966, 1980) is changed in this report back to Mamacoke Gneiss as a name more in character with its preponderant lithology.

PETROLOGY OF THE ROCK UNITS

Plainfield Formation

Most of the analyses of rocks of the Plainfield Formation are of gneisses and schists rather than quartzite and quartz schists. Quartzite is a common rock type in the formation, but quartzite was considered not to be worth analyzing because hand-specimen and thin-section examination was felt to be sufficient to identify the mineral content (composition) and textures of the rock. Most quartzites contain small amounts of mica, mostly biotite, and feldspar. Some contain Ca-bearing minerals (epidote, diopside, scapolite, calcite) and calcic plagioclase (as in sample 3, table 1). Micas, and sillimanite where present, are concentrated primarily on parting planes between quartzite layers. However, quartzite grades into quartz schist by an increase in the amount of mica and a decrease in the amount of quartz. In some of these rocks, the quartz forms discrete lenses in a quartz-mica-feldspar matrix. Tourmaline is a common accessory mineral in the Plainfield Formation.

A comparison of the Plainfield with other metasedimentary units in eastern Connecticut (Goldsmith, 1986, repeated here as fig. 2) shows that the unit differs from the others not only in reflecting the greater amount of quartzite than other units, but in showing that the pelitic and semipelitic rocks of the Plainfield are more calcareous than pelitic units elsewhere in eastern Connecticut, such as the Tatnic Hill and Collins Hill Formations and Scotland Schist. Note, for example, the particularly high amount of CaO in gray gneiss of the middle unit of the Plainfield (samples 6-7, table 1). The Plainfield pelites and semipelites are, however, less calcareous than the metasiltstones of the Hebron Formation (fig. 2; Snyder, 1964). The gray gneisses of the middle part of the Plainfield resemble some of the gray gneisses of the Mamacoke Gneiss, but the interlayering of silicious rock and the tendency for the Plainfield gneiss to have a lower CaO content relative to SiO_2 and Al_2O_3 distinguish the Plainfield from the Mamacoke. The relatively high background amounts of the cobalt-chromium-nickel group of minerals in the semiquantitative spectrographic analyses (fig. 3) of the pelites and semipelites possibly foreshadow the volcanic paleoenvironment of the overlying Waterford Complex.

Waterford Complex

Rocks of the Waterford (Volcanic-Plutonic) Complex fall in the quartz diorite, tonalite, and granodiorite fields (Streckeisen, 1973) on a modal Q-P-K ternary diagram (fig. 4). Most of the Rope Ferry Gneiss ranges from quartz diorite to tonalite, a few light-colored layers, like sample 5 in table A-2 are granodiorite. The Mamacoke Gneiss and New London Gneiss fall in the granodiorite field; subordinate light-colored phases fall in the granite field. The Cohanzie member of the Mamacoke has a wide distribution indicating its varied compositions and partly sedimentary-volcaniclastic origin. A normative ab-an-or diagram (fig. 5) shows a similar distribution, but the New London Granodiorite Gneiss falls in and close to the trondhjemite field of

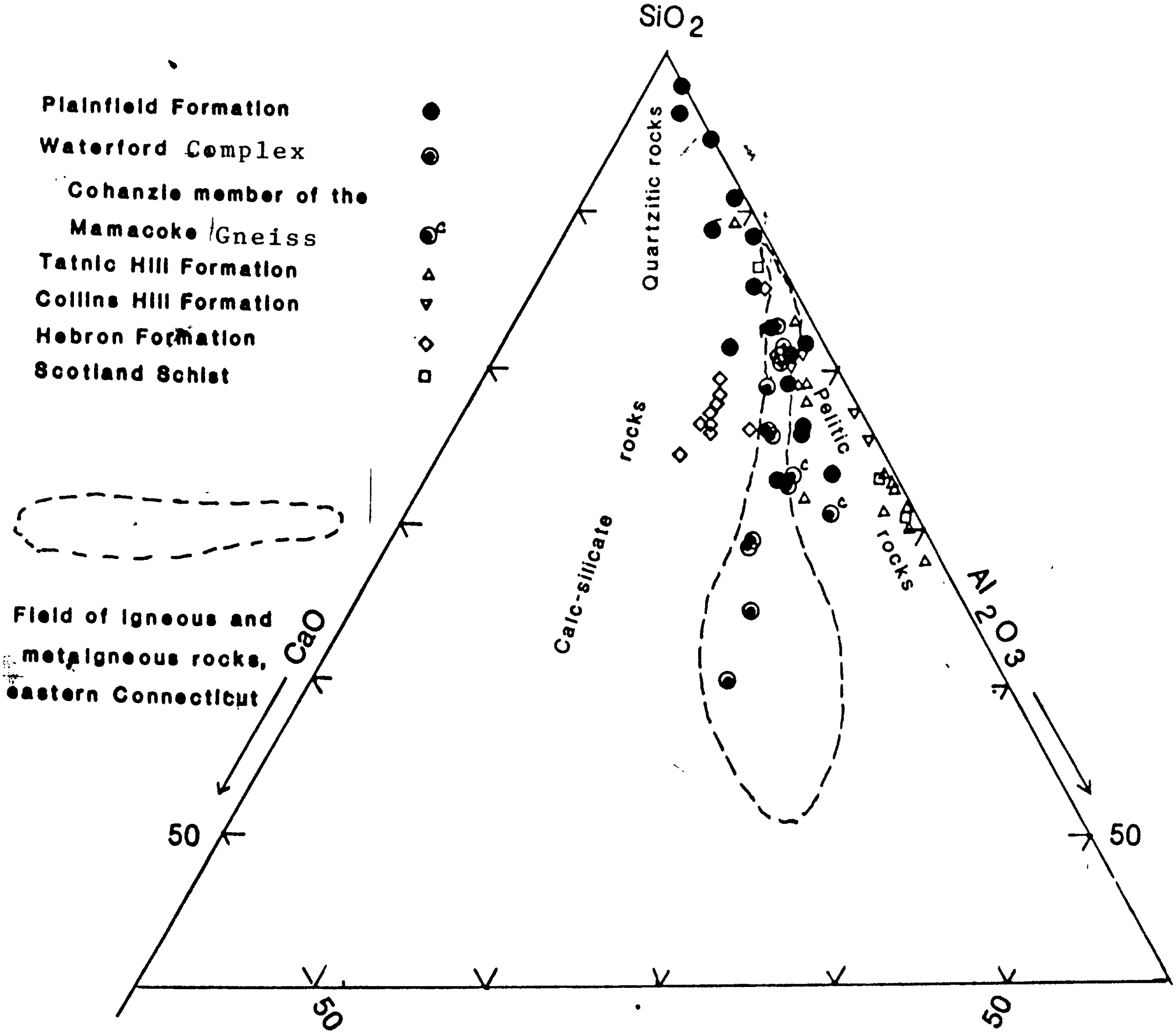

Figure 2. Chemically analyzed rocks of the Plainfield Formation and Waterford Complex compared with analyzed rocks from other formations in eastern Connecticut. Derived from the tables, and from Snyder (1964) and unpublished data of H. R. Dixon, and G. L. Snyder

(p. 4C follows)

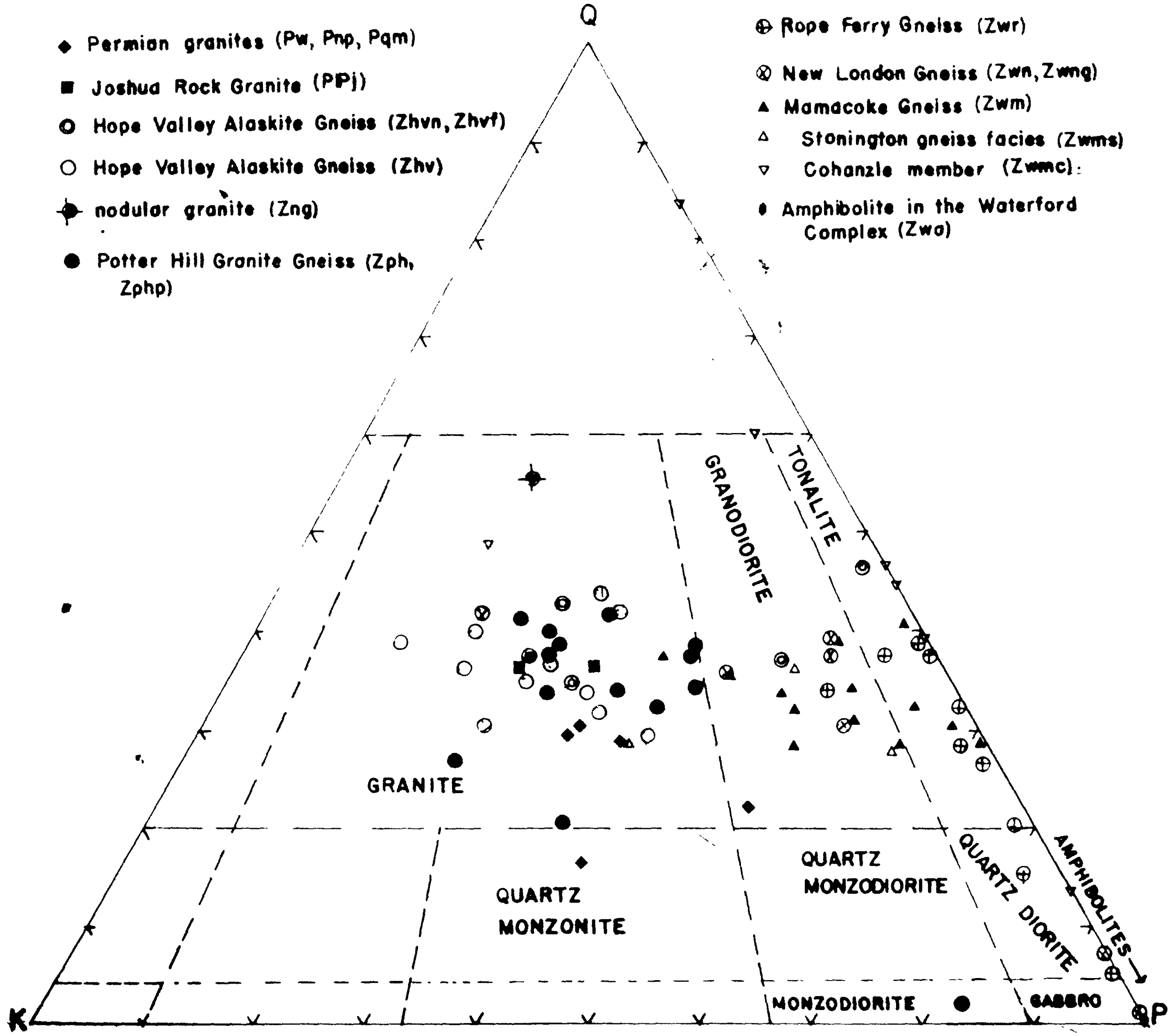

Figure 4. Modal analyses of igneous and metaigneous rocks from southeastern Connecticut. Includes modes from tables 1 and 2 of Goldsmith (1986). Fields of igneous rocks from Streckeisen (1973).

O'Connor (1965) and Barker (1979). On a plot of $K_2O + Na_2O$ against silica and CaO against silica (fig. 6), the rocks of the Waterford Complex seem to have an approximately normal distribution except, again, for the rocks of the Cohanzie member of the Mamacoke. Chondrite-normalized plots of rare-earth contents (fig. 7*A*) indicate light rare-earth enrichment and no significant europium anomaly. The Mamacoke Gneiss forms a distinct cluster above the Rope Ferry and New London Gneisses (fig. 7*A*).

The Waterford Complex appears to be relatively felsic. The bulk of the Waterford falls in the rhyodacite and dacite field when the Nb:Y is plotted against weight-percent silica (fig. 8). Amphibolites, which are primarily in the upper part of the section, fall in the sub-alkaline basalt and andesite fields. The rocks fall on the same fields when the $Zr:TiO_2$ is plotted against silica (not figured). The amphibolite (sample 12, table 2) is more mafic than the other amphibolites and could possibly be metamorphosed Preston Gabbro as mapped by Loughlin (1912) or amphibolite of the Quinebaug Formation. However, as it appears to be in the lower plate of the Honey Hill fault I have mapped it as part of the Waterford Complex.

Sterling Plutonic Suite

The Potter Hill Granite Gneiss, the Hope Valley Alaskite Gneiss, and other small masses not readily assignable fall in the granite field (figs. 4, 5). The Potter Hill is typically a uniformly gray, gneissic rock, coarser grained and lighter colored than the Mamacoke, although, in places, hard to distinguish from the Mamacoke. It is distinguished from the Hope Valley by its gray color and its greater amount of biotite and anorthite content (figs. 9, 10), although some slight overlap of the fields exists. The pattern of chondrite-normalized rare-earth content of the Potter Hill contrasts with the pattern of rare earths in the Waterford Complex in showing an europium anomaly (fig. 7) but is otherwise similar to that of the Mamacoke Gneiss. Sample 1, in table 3, taken from a poorly exposed belt mapped as Mamacoke Gneiss, but assigned to the Potter Hill on the basis of major mineral content, plots in an anomalous position in figure 7*B* and probably is Mamacoke Gneiss. The porphyritic phase of the Potter Hill (sample 9, table 3) is a somewhat more mafic rock that plots with the more felsic of the Waterford rocks in figure 10 and at the albite end of the field in figure 5. This analysis is an old one, however, and the location of the sample is not certain. Loughlin (1912) only gave a town name for its location. However, the town name plus the rock description limits the location to that of a rock similar to that which I have mapped as the porphyritic phase of the Potter Hill in the Old Mystic quadrangle.

The samples of Hope Valley Alaskite Gneiss are divided into two groups (table 5), those forming the major sills and lying primarily within the Plainfield Formation (Zhv, Zvhb, see plate 1) and those forming layers primarily within the Waterford Group, such as the northern belt of alaskite (Zhvn) and the fine-grained alaskite (Zhvf). The northern belt of alaskite and the fine-grained alaskite are possibly metavolcanic rock, but may include hypabyssal intrusive rock. The chemical difference between the two groups of Hope Valley reflects either a related, but slightly different, magma source or contamination from the mafic rocks of the Waterford. I believe it is significant that the Hope Valley, where adjacent to quartzite of the Plainfield, contains almost no biotite, and the plagioclase is albite in contrast to the Hope Valley in layers adjacent to rocks of the Waterford

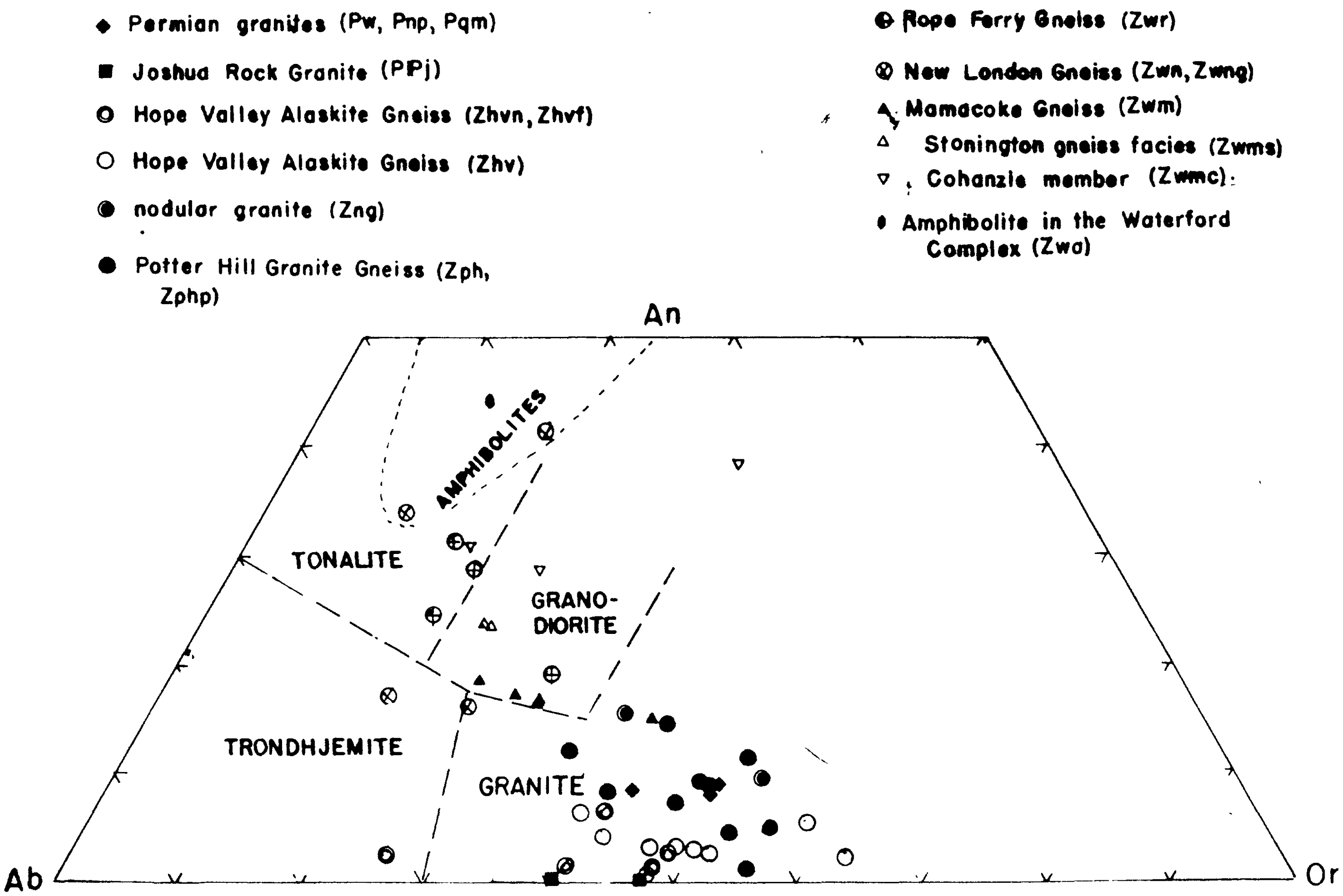

Figure 5. Normative albite, anorthite, and orthoclase of igneous and metaigneous rocks from southeastern Connecticut. Fields of silica-saturated rocks from O'Connor (1965) as modified by Barker (1979). Only amphibolites lying in the fields are shown.

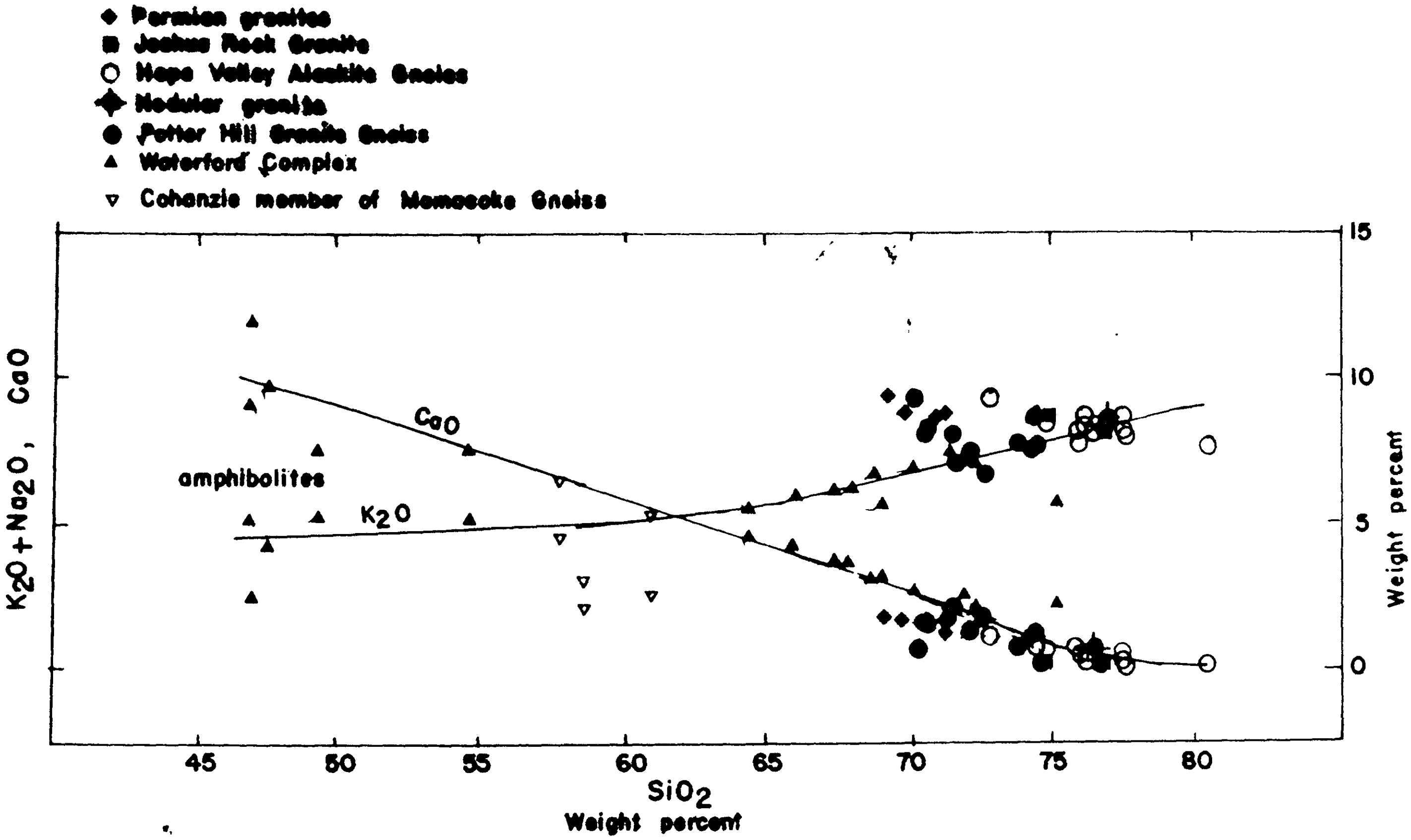

Figure 6. K_2O + Na_2O and CaO against SiO_2 for igneous and metaigneous rocks from southeastern Connecticut.

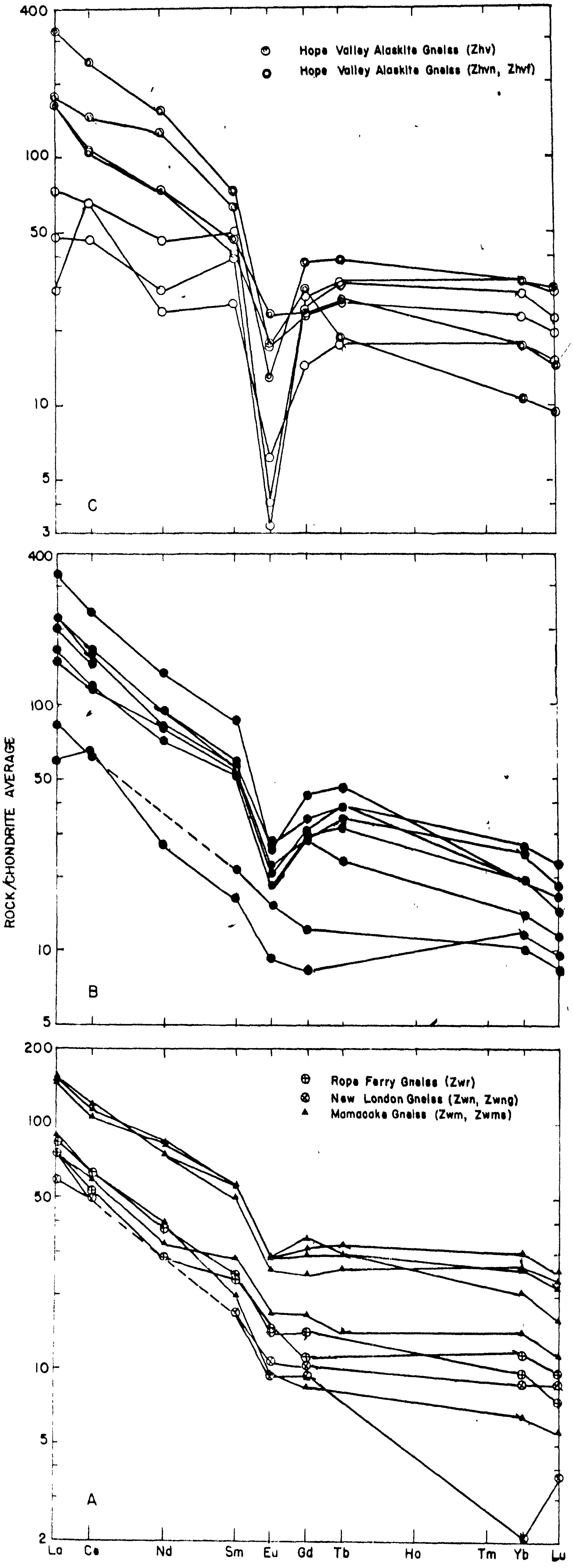

Figure 7. Rare earth elements in Late Proterozoic metaigneous rocks, southeastern Connecticut. A, Waterford Complex; B, Potter Hill Granite Gneiss; C, Hope Valley Alaskite Gneiss.

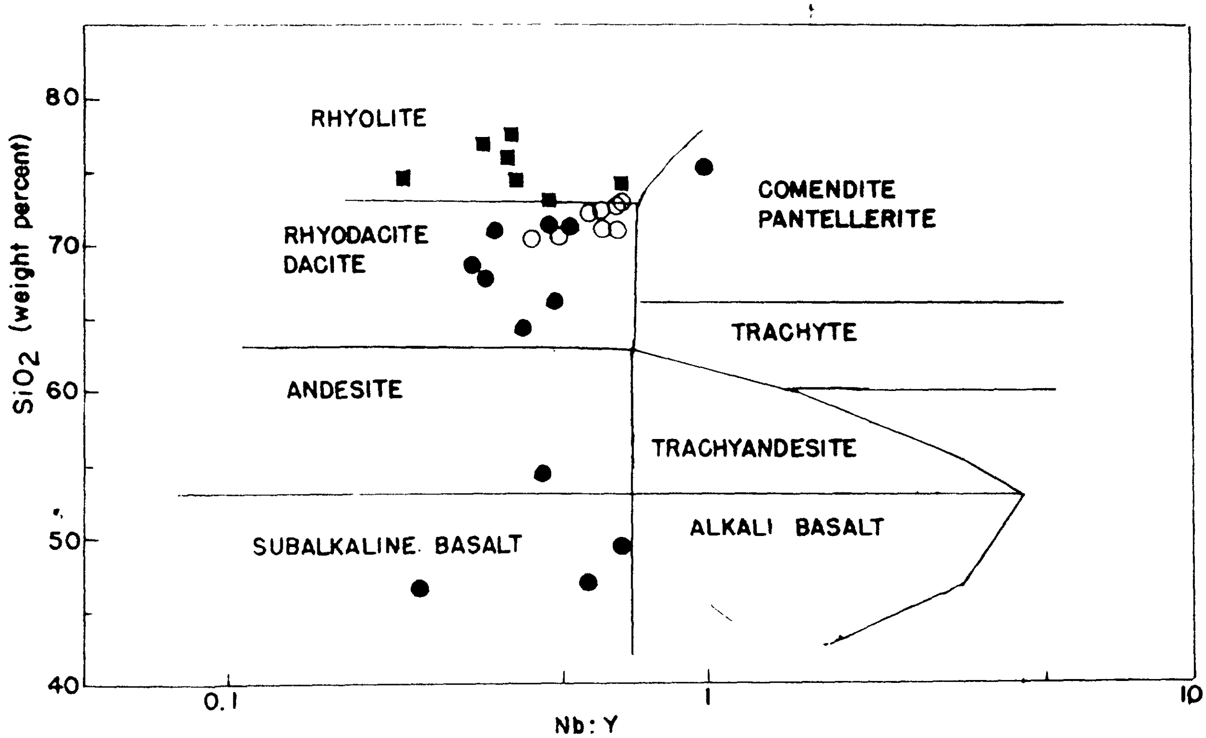

Figure 8. Nb:Y against SiO_2 for Late Proterozoic metaigneous rocks of the New London area, southeastern Connecticut and showing fields of common volcanic rocks from Winchester and Floyd (1977). Closed circles, Waterford Complex; open circles, Potter Hill Granite Gneiss; closed squares, Hope Valley Alaskite Gneiss.

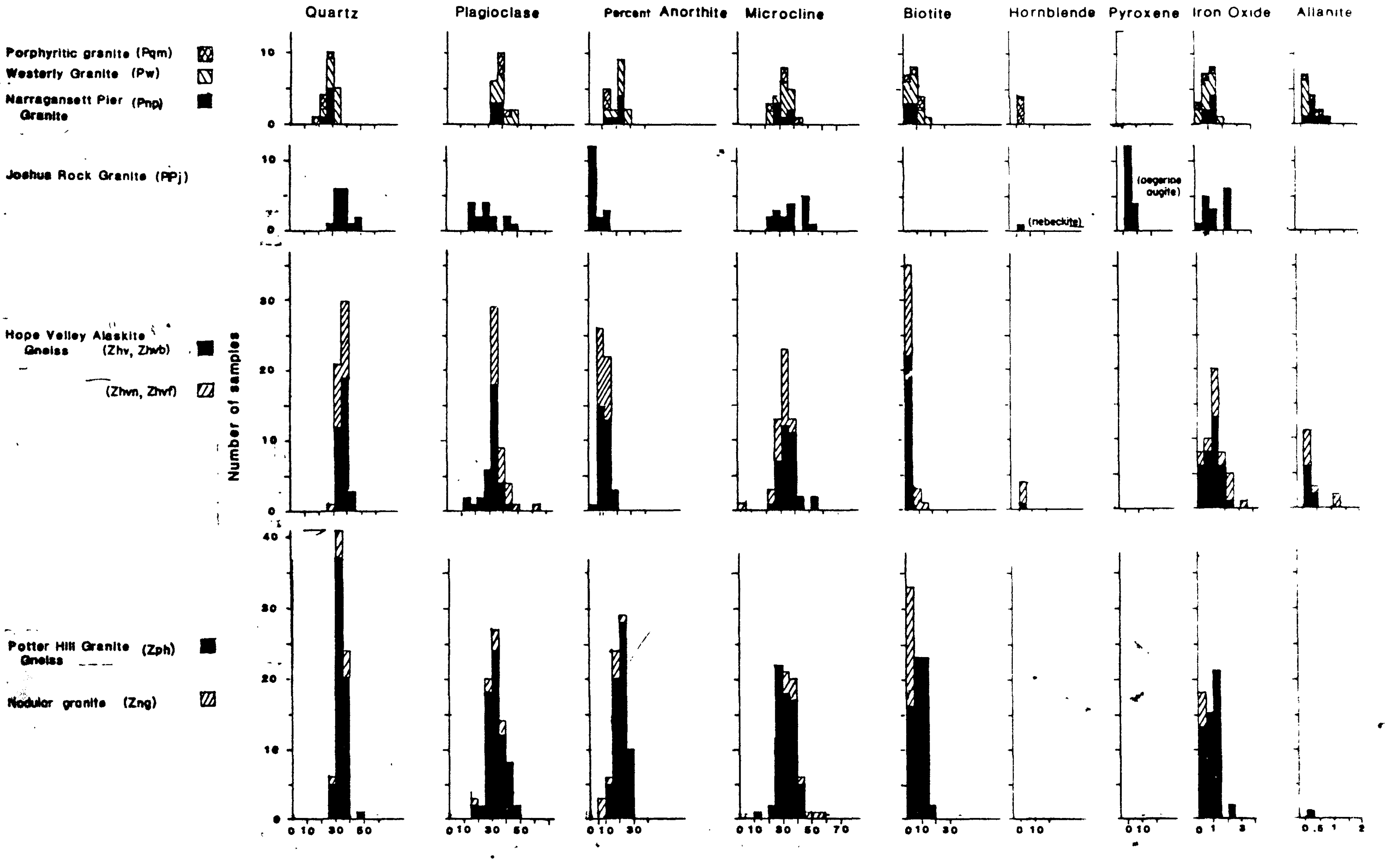

FIGURE 9. ESTIMATED MODES OF GRANITIC ROCKS IN VOLUME PERCENT, NEW LONDON AREA, SOUTHEASTERN CONNECTICUT

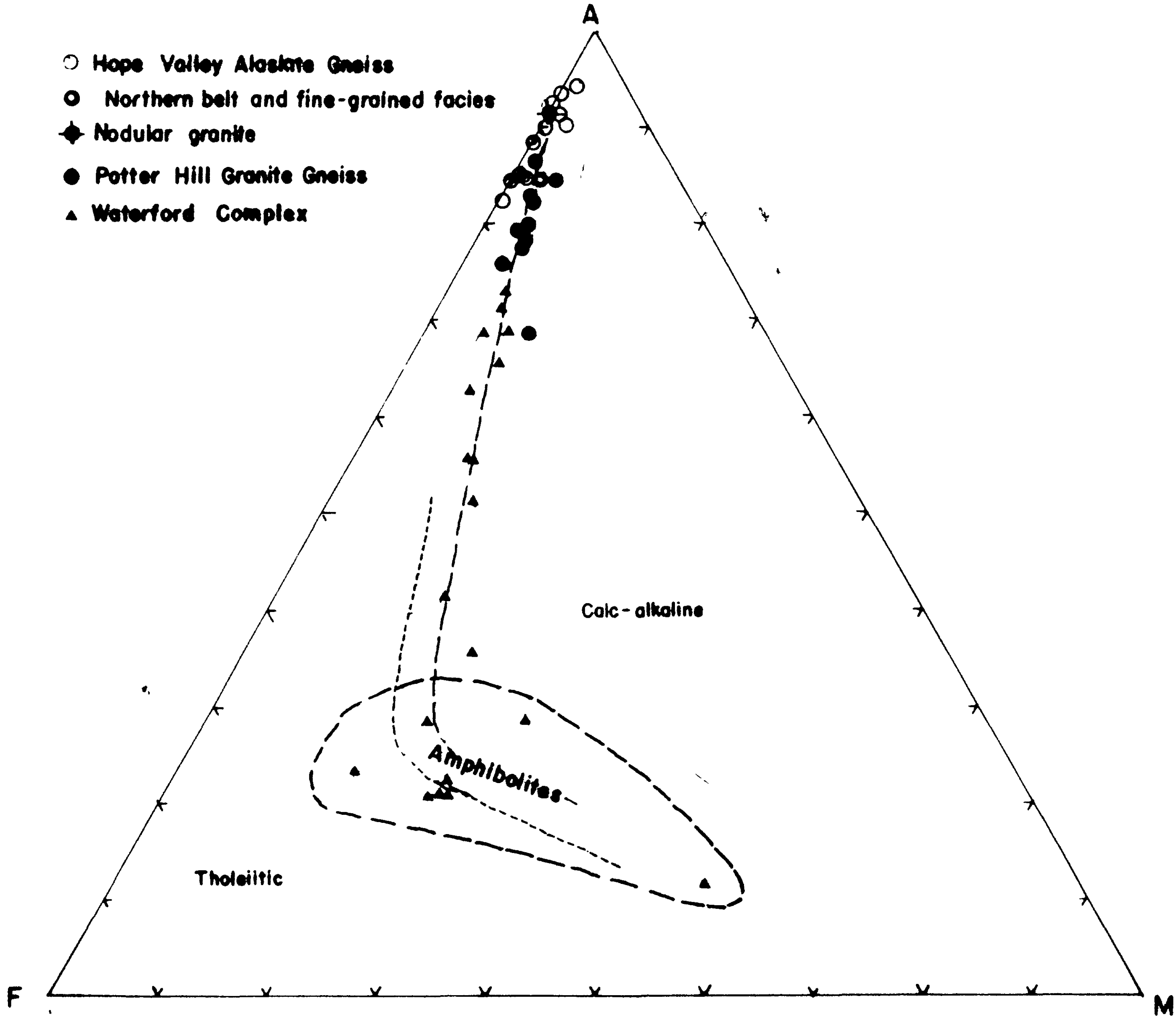

Figure 10. Late Proterozoic intrusive rocks, southeastern Connecticut, and showing field of amphibolites, heavy dashed line. Short-dashed line separates fields of tholeiitic rocks and calc-alkalic rocks (Irvine and Baragar, 1971). Long-dashed line is trend of Late Proterozoic intrusive rocks from eastern Massachusetts (Wones and Goldsmith, in press).

Group. In these, the Hope Valley contains biotite and slightly greater amounts of anorthite. The location of the samples primarily of the northern belt of Hope Valley (Zvhn) toward the albite end of the ab-or-an diagram (Ab50-73, fig. 5) possibly results from removal of potash to form biotite from hornblende in the adjacent hornblendic rocks of the Waterford Complex. The nodular granite plots consistently with the Hope Valley Alaskite Gneiss and could be considered a variant of it, although, typically, the matrix surrounding the quartz-sillimanite nodules is not gneissic even though the nodules are uniformly oriented ellipsoids. The pattern of chondrite-normalized rare-earths in the Hope Valley (fig. 7C) with its pronounced europium anomaly and light rare-earth enrichment indicates marked fractionation and conforms with the observation that the chemistry of the rock approaches that of a granite minimum melt. The samples from the northern belt of alaskite (Zhvn) have rare earth element patterns similar to those of Potter Hill samples. The Potter Hill thus appears to be similarly fractionated despite the different bulk chemistry.

The Potter Hill and Hope Valley plot along single trend lines on the alkalis and lime against silica plot (Peacock index, fig. 6), approximately on the same trend as samples from the Waterford Complex. This suggests a possible petrologic evolution from the the Waterford to the Hope Valley. The latter is, in places, clearly intrusive, the Potter Hill not clearly so. The observation that the Potter Hill is in many places flanked on one side by calc-silicate rock of the Plainfield suggests that it occupies a specific stratigraphic position. Possibly it represents a former acidic volcanic rock. Its present texture, however, gives no indication of this. Smaller masses crop out in association with a variety of rocks and in places can be seen to be intrusive. I have interpreted the Potter Hill to have been an intrusive rock.

The semiquantitative spectrographic analyses (fig. 3) of the Late Proterozoic ganitoid rocks show nothing more than background amounts of elements. The larger sills of Hope Valley Alaskite Gneiss that are bounded by rocks of the Plainfield Formation and that are assumed to have been emplaced at a deeper level than those lying in the Waterford Complex have lower amounts of trace elements than those in the Waterford Complex, except for a slightly greater background content of lead and gallium.

Border phases of the different masses of Potter Hill and Hope Valley and intermediate types such as the biotitic phases of the Hope Valley (Zhvb) contain minerals that reflect the mineralogy of the wall rocks. The pluton at Gay Hill has a mappable border phase containing quartz-sillimanite nodules, tourmaline, and garnet where in contact with sillimanite schist of the Plainfield Formation. These minerals decrease in amount inward away from the contact. Sillimanite is common in the Hope Valley and the Potter Hill where adjacent to the Plainfield Formation as, for example, in the mass near the intersection of I-95 and U.S. 1 near Flanders, Niantic quadrangle. Garnet similarly decreases in amount inwards from the contact zone in some places where Potter Hill is adjacent to garnet-mica schist of the Plainfield. A good example can be seen in a street intersection west of Connecticut College, New London, in which garnet decreases in amount inwards from the steeply dipping contact over a distance of about 10 meters. The Hope Valley Granite Gneiss contains muscovite in places in the eastern part of the map area. Where Hope Valley is flanked by the more mafic Waterford rocks, more biotite than usual and usually a more calcic plagioclase are found. The lack of mafic minerals in the Hope Valley where it is in contact with quartzite has been mentioned above. These observations coupled with the evidence for partial melting of the rocks, particularly prominent in the coastal area, suggest that burial of these rocks was deep and that time was sufficient for appreciable interaction between the granitioid rocks and the adjacent metasedimentary rocks.

Preston Gabbro

The main mass of the Silurian Preston Gabbro is in the adjacent Jewett City quadrangle to the north and has been mapped and described by Dixon and Goldsmith (1983) and Dixon and Felmlee (1986). It is primarily a clinopyroxene gabbro containing minor orthopyroxene and olivine. Trondhjemitic dikes cut the western side of the mass. The Preston in the New London area is a satellite mass in which the pyroxene largely is converted to hornblende, and the rocks range from hornblende gabbro to granodiorite. The petrology of the Preston is not discussed in this paper.

Late Palozoic Intrusive Rocks

The Narragansett Pier and Westerly Granites and the Joshua Rock Granite form distinct suites of intrusive rocks on the basis of their chemistry. The Westerly and Narragansett Pier Granites generally plot together in the granite field (figs. 4, 5). However, they lie off the trend of the Late Proterozoic granitoids on the alkalis and lime against silica plot (fig. 6). They are greatly enriched in light rare-earth elements, depleted in heavy rare earths, and show small negative europium anomalies (fig. 11). The high rare-earth content of the Westerly and particularly the Narragansett Pier also is shown clearly in the semiquantitative spectrographic analyses (fig. 3) and is reflected in the abundance of allanite in the modes of these rocks (fig. 9; table 7). The high contents of rare-earth minerals and of barium (table 7; fig. 3) are characteristic of the Permian granites in southeastern Connecticut and southern Rhode Island (O. D. Hermes, University of Rhode Island, written commun., 1985). The hornblende-bearing quartz monzonite (sample 5, table 7; Pqm) is interpreted to be a mafic phase of the Narragansett Pier Granite.

The Joshua Rock Granite, however, is an alkalic rock best shown in an alkali against alumina plot (fig. 12) in which the Joshua Rock occupies a field on the alkali-rich side, well above the 50-percent alumina line. It has a flatter rare-earth pattern (fig. 11) than do the Narragansett Pier and Westerly, has a low barium content, and, in other parameters, plots close to the Hope Valley Alaskite Gneiss, particularly the northern phase (figs. 3-6, 9). Its chondrite-normalized rare-earth pattern (fig. 11) resembles that of the northern belt of Hope Valley Alaskite Gneiss (fig. 7) in its amount of light rare-earths and moderate europium anomaly. An observation tending to support a suggestion that a genetic relation exists between the Joshua Rock and the Hope Valley is that a granitic pod at the contact of the northern belt of Hope Valley in the Fitchville quadrangle contained aegerine-augite (Snyder, 1964, table 6, sample 10). This pod contains a rare-earth-bearing sphene as does the Joshua Rock Granite (Goldsmith and others, 1961). Rare-earth-bearing sphene like that in the Joshua Rock was earlier reported from "Sterling Granite Gneiss" in Rhode Island (Young, 1938), but, although one of the samples analysed by Young that contained this sphene came from the now type Devonian Scituate Granite and might argue for a similar origin for the Joshua Rock and the Scituate, other samples came from what is now Hope Valley Alaskite Gneiss. The presence or absence of rare-earth minerals in sphene is

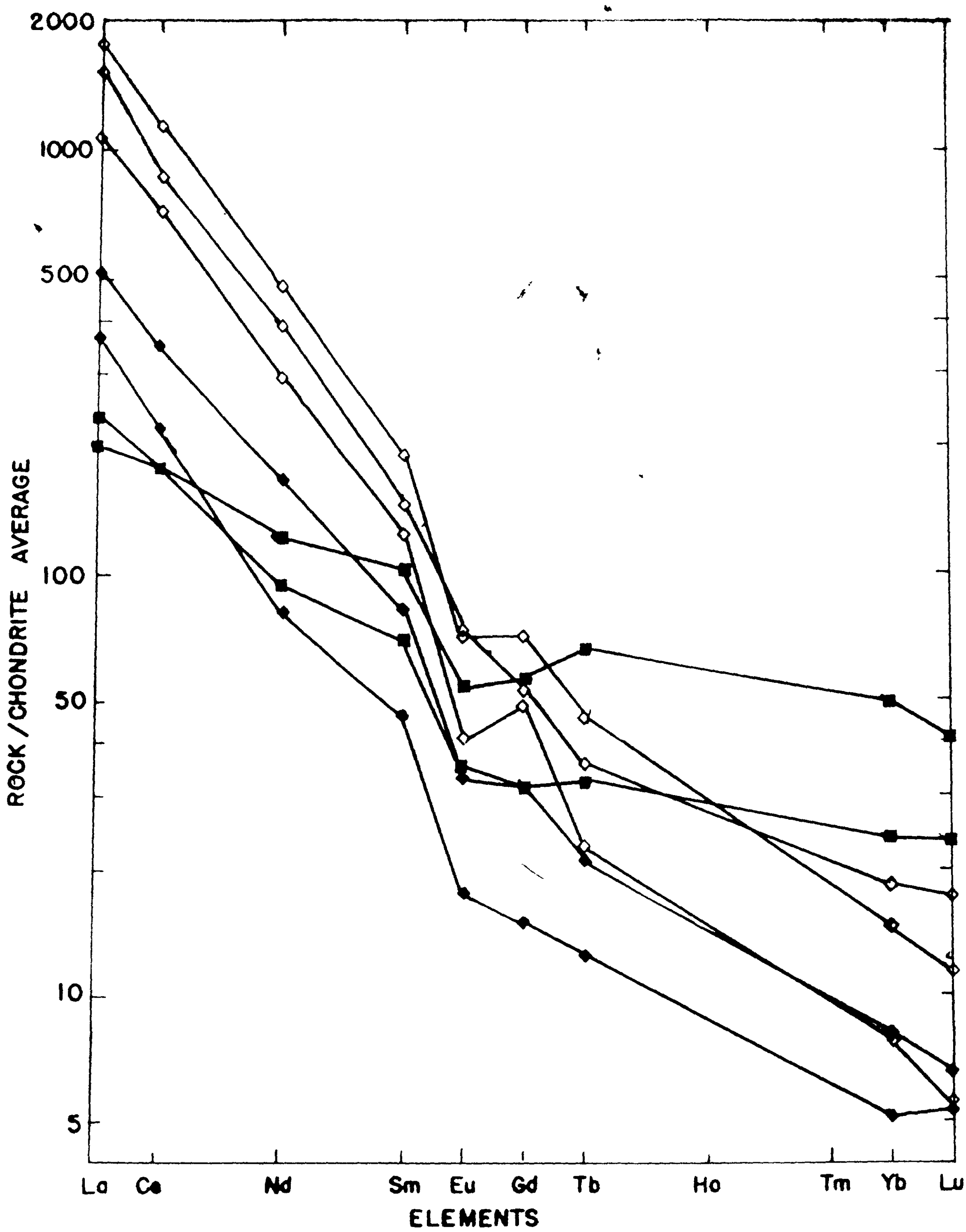

Figure 11. Rare-earth elements in late Paleozoic granites, southeastern Connecticut. Filled squares, Joshua Rock Granite; filled diamonds, Westerly Granite; open diamonds, Narragansett Pier Granite and pophyritic granite.

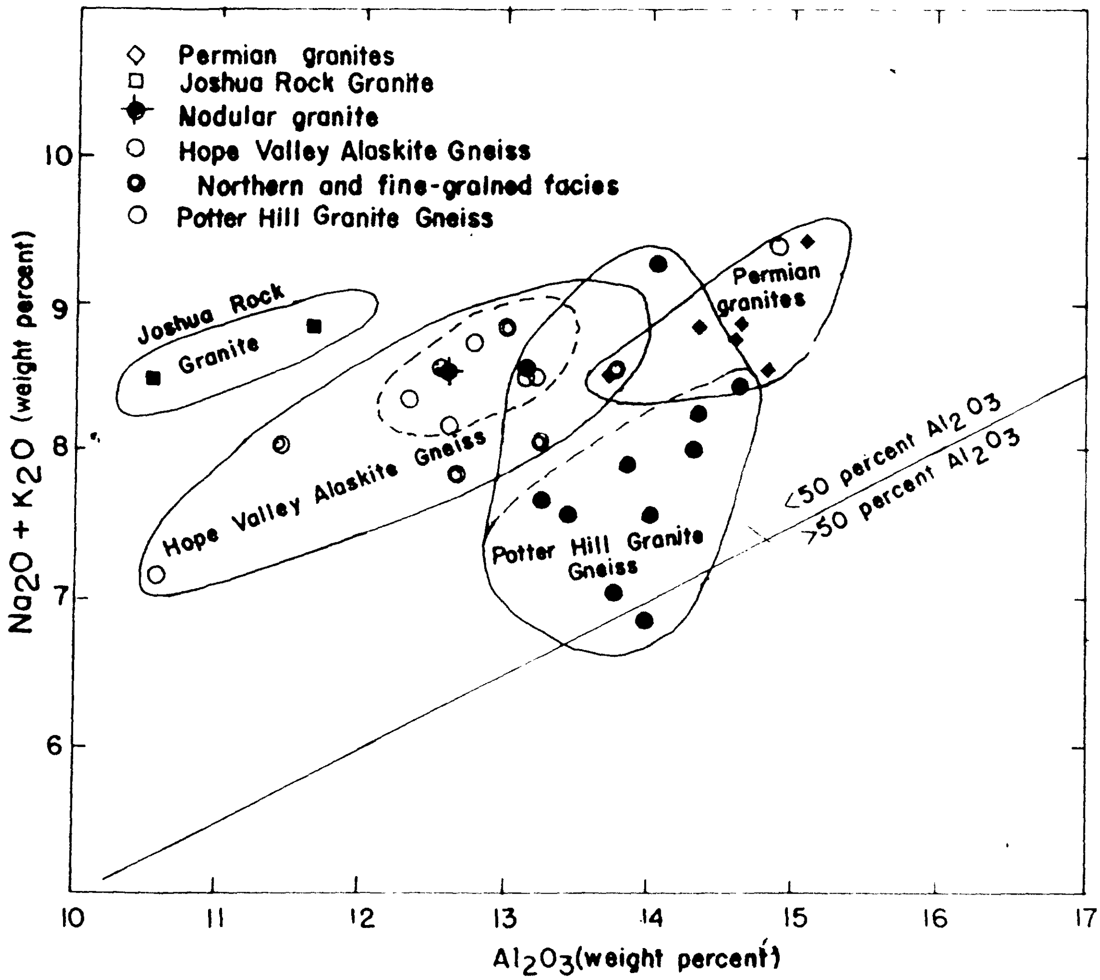

Figure 12. $Na_2O + K_2O$ against Al_2O_3 for granitic rocks of the New London area, southeastern Connecticut and general (solid lines) and restricted (dashed lines) fields of the granitic units.

influenced by the presence or absence of such accessory minerals as allanite and zircon (Staatz and others, 1977) and, thus, is not a reliable indicator of petrogenetic affinity. The suggestive chemical similarities between the Hope Valley and Joshua Rock may be only fortuitous (see below).

Comparison of the Major Units

The distinctions among the different groups of granitic rocks of the New London area are shown clearly in the plot of alkalis against alumina in figure 12 and also are indicated in the summary figures 3 and 9. In figure 12, the bulk of the samples of Hope Valley Alaskite Gneiss and Potter Hill Granite Gneiss form distinct clusters. Samples of the northern phase of the Hope Valley lie within a larger field that approaches the main field of the Potter Hill. An overlap of the fields of Potter Hill and Hope Valley, which might be suspected from field mapping and comparison of samples, does exist on this plot, but does so on the basis of two samples assigned to the Potter Hill that lie out of the field encompassing the bulk of the samples. The Permian granites occupy a distinct field, although an overlap exists with the Potter Hill and Hope Valley. The distinction between the rock groups is clear in the alkalis and lime against silica plot (fig. 6) where the Potter Hill and the Hope Valley form distinct clusters along what appears to be a single curve. On this plot, the curve accomodates most of the Late Proterozoic orthogneisses, (Sterling Plutonic Suite) and metavolcanic rocks (Waterford Complex), suggesting a single evolutionary trend.

The late Paleozoic intrusive rocks, however, clearly fall outside the trend of the Late Proterozoic orthogneisses on the lime and alkalis against silica diagram and presumably had a different origin. A few of the granitic rocks that are questionably assigned (table 4) also fall along the late Paleozoic trend. These rocks may have been misidentified during field mapping and are either rocks of a separate, heretofore unrecognized, group of uncertain age or they are Late Proterozoic but, for some reason, anomalous. Their chemistry does not match that of the Westerly and Narragansett Pier Granites, and their textures approximate those of the Proterozoic granites. Therefore, I consider these anomalous rocks to belong to the Late Proterozoic Sterling Plutonic Suite.

The Joshua Rock Granite occupies a field distinct from the field of Westerly and Narragannsett Pier Granites (figs. 12, 15) However, its chemistry, as pointed out above, is not greatly different from the Hope Valley Alaskite Gneiss. As originally mapped, it appeared to be part of the Late Proterozoic assemblage because of its stratigraphic and structural conformity within the sequence and its casual resemblance in outcrop to layers of Hope Valley Alaskite Gneiss. The late Paleozoic age determined on zircons from the rock may be in question, although the sharp terminations to the crystals, their clarity, and their tendency to cluster suggest that they are young; possibly, they are completely recrystallized old zircons in a melted rock. In support of the young age for it, however, the Joshua Rock contains perthite rather than the microcline that characterizes the Late Proterozoic granitoids.

Interpretations

The data presented in this paper are insufficient to make a thorough petrogenic anaylsis of the rocks of the New London area. Trace element chemistry is incomplete, and some of the trace elements now considered useful in preparing discrimination diagrams were not determined during the course of the project.

The Plainfield Formation appears to have been deposited in a marine near-shore environment in the vicinity of a volcanic arc. Quartzites in the upper part of the section are interlayered with and pass upward into metavolcanic rocks, amphibolite, and plagioclase gneisses. The overlying metavolcanic-metaplutonic rocks of the Waterford Complex tend to be fairly felsic (primarily dacite and rhyodacite); amphibolites, representing basaltic rocks, are subordinate in volume. The amphibolites fall in the tholeiite and calk-akaline fields on the AFM diagram (fig. 10) and subalkaline basalt field on the niobium to yttrium ratio against silica diagram (fig. 9).

The Waterford, Potter Hill, and Hope Valley rocks appear to form a petrogenetic peraluminous series from mafic to felsic. The alkali-lime index (Peacock index) is about 62 (fig. 6), which is normal for calk-alkaline rocks, and the samples plot in the calc-alkalic field (fig. 10). However, they do not have the characteristics of I-type granites. MgO content is relatively low and may be a characteristic of the Sterling Plutonic Suite. Liese (1968) observed that Sterling gneisses (Sterling Plutonic Suite) in the New London area have a higher iron to magnesium ratio than do granite gneisses to the west in the Clinton and Stony Creek domes. However, the different age granites in the latter area may not have been distinguished clearly at that time (McClellan and Stockman, 1985). The Hope Valley Alaskite Gneiss approaches the composition of a minimum melt (fig. 4) and appears to be the final product of magma generation from continental crust, as does the Potter Hill. The Potter Hill and the Hope Valley fall in the rhyodacite and rhyolite fields on the Nb:Y against SiO_2 plot (fig. 8)

The composition and habit of the late Paleozoic Narragansett Pier and Westerly Granites indicate a wholly new set of sources and conditions. Their depleted heavy and enriched light rare-earth patterns indicate a markedly fractionated source, but without much residual plagioclase. On the basis of spectrographic work on the Westerly, Liese (1968, 1979) suggested two stages of fractionation for the Westerly across southern Rhode Island and southeastern Connecticut in which a wide central belt of dikes differs in chemistry from dikes at the extreme ends. The Sterling Plutonic Suite is ductilely deformed and shows evidence of considerable interaction between granite and host rock. The latter probably resulted from mixing during initial emplacement and subsequent reheating at high temperatures during the late Paleozoic. The Westerly Granite, however, forms sharply cross-cutting dikes. Liese (1968) concluded from spectrographic evidence in feldspars and magnetite that the Westerly formed at high temperature and cooled rapidly.

The Joshua Rock Granite has a chemistry similar to the Paleozoic alkalic rocks intruding the Dedham-Esmond terrane in Massachusetts and Rhode Island and, if it is truly Paleozoic in age, is the only known alkalic rock in the gneissic Hope Valley terrane (O'Hara and Gromet, 1985) of southeastern New England. The span of time between the emplacement of the Pennsylvanian or

Permian Joshua Rock and the early Permian Westerly Granite is critical because, in that time, the high-temperature ductile deformation of the gneisses in the New London area, in which the Joshua Rock was involved, ceased, and the nondeformed, sharply bounded Westerly dikes were emplaced. The tight timespan between Permian ductile deformation and anatexis (Lundgren, 1966; Wintsch and Aleinikoff, 1987) and the early Permian Westerly dike emplacement indicate rapid uplift and cooling before emplacement of the Westerly. The Westerly is not chilled noticeably against the wall rocks, however, so that the wall rocks were not cold. The Narragansett Pier Granite probably was emplaced slightly earlier because some of the small bodies in the New London area tend to be more conformable to the map pattern of the gneisses than is the Westerly, as evident in the Old Mystic area (Goldsmith, 1985a), but the Narragansett Pier is much less conformable than the Joshua Rock. The complete structural conformity of the Joshua Rock and the indications that the chemistry of the Joshua Rock approaches that of phases of the Hope Valley Alaskite Gneiss is bothersome to me, and I reserve a question concerning the ancestry of the Joshua Rock. I have long held to the idea that the ductile deformation of the New London terrane could have begun as early as late Devonian, but recent studies do not show evidence in the terrane for a Paleozoic episode of heating other than that of the Permian (Hermes and Zartman, 1985; Wintsch and Aleinikoff, 1987).

SOME REGIONAL COMPARISONS

The Late Proterozoic rocks of the New London area, southeastern Connecticut, project beneath the Honey Hill fault to emerge in the Willimantic dome (fig. 1; Rodgers, 1985) where they are exposed in a window beneath the Willimantic thrust (Wintsch, 1979). Only the uppermost part of the sequence in the New London area is exposed in the Willimantic dome, primarily plagioclase gneiss resembling Waterford Complex rocks, and alaskitic rock, the Willimantic Gneiss, which resembles the northern facies of the Hope Valley Alaskite Gneiss. Orthogneiss and quartzite of similar age are present in the Pelham dome of central Massachusetts, although the sequences in the New London area and in the Pelham dome have not been compared in detail. Although the data are scanty, some comparisons can be made between the rocks of the New London area and those exposed in domes to the north. I do not intend to compare the rocks of the New London area with those of the Avalon terrane of western Rhode Island. Hermes and Zartman (1985) showed some of the chemical distinctions and fields of overlap between the Late Proterozoic granites (Sterling Plutonic Group) of west-central Rhode Island and the intrusive Devonian Scituate Granite. Their new radiometric data indicate that distinctions made in the past among rock units in western Rhode Island need to be reviewed. The chemistry of the Late Proterozoic rocks in the New London area is similar to that of the Late Proterozoic batholithic rocks of the Hope Valley and Esmond-Dedham terranes [Milford-Dedham zone on the State bedrock map (Zen and others, 1983)] in Massachusetts (Wones and Goldsmith, in press); for example, the samples in Massachusetts collected by Wones and others (1986) fall on an identical trend line on the AFM diagram (fig. 10). However, to discuss the petrochemistry of the whole Avalonian terrane of southeastern New England is not my intent in this paper. I only want to compare briefly the chemistry of some rocks in the Avalonian outliers, the Willimantic and Pelham domes.

The Willimantic Gneiss (Snyder, 1964) is thought to be equivalent in stratigraphic position to the northern belt of Hope Valley Alaskite Gneiss, in the northern Montville quadrangle and adjacent Fitchville quadrangle (Rodgers, 1985). Two samples of Willimantic Gneiss analyzed (G. L. Snyder, USGS, written commun., 1970) fall along the high-silica end of the Hope Valley trend in the summary plot of alkalis and CaO against SiO_2 (fig. 13). On an Ab-An-Or normative plot (fig. 14), the Willimantic falls at the edge of the Hope Valley field, as it does on the alkalis against alumina plot (fig. 15), and close to the field of Joshua Rock Granite. This apparent close chemical similarity may indicate a cogenetic relation, but is more likely a petrogenetic coincidence. The alkalic nature of the the Joshua Rock and its texture suggest that it is more akin to the Paleozoic alkalic granites elsewhere in the Avalon terrane than to the Late Proterozoic batholithic assemblages of the Dedham-Esmond and Hope Valley terranes. However, even though the two samples of Willimantic Gneiss are thought to be representative, two samples are an insufficient number on which to base comparisons.

The Dry Hill Gneiss of the Pelham dome, a Late Proterozoic gneiss resembling petrographically some of the Late Proterozoic rocks of the New London area, has a similar chemistry to the Potter Hill Granite Gneiss (fig. 13). Samples of the Dry Hill also fall, in part, in the Hope Valley field (figs. 14, 15). This is permissive, but not conclusive, evidence in support of correlation of the two terranes, which is based on the observation that the New London area and the Pelham dome have quartzite and granitoid gneiss assemblages and contain rocks of Late Proterozoic age (Ashenden, 1973; Hall and Robinson, 1982). The bits of evidence in the chemistry of the rocks of the Willimantic dome and Pelham dome support the tentative conclusion that the rocks of the Willimantic dome, and most likely the Pelham dome, may be part of the same Avalonian terrane as the rocks in the the New London area of southeastern Connecticut.

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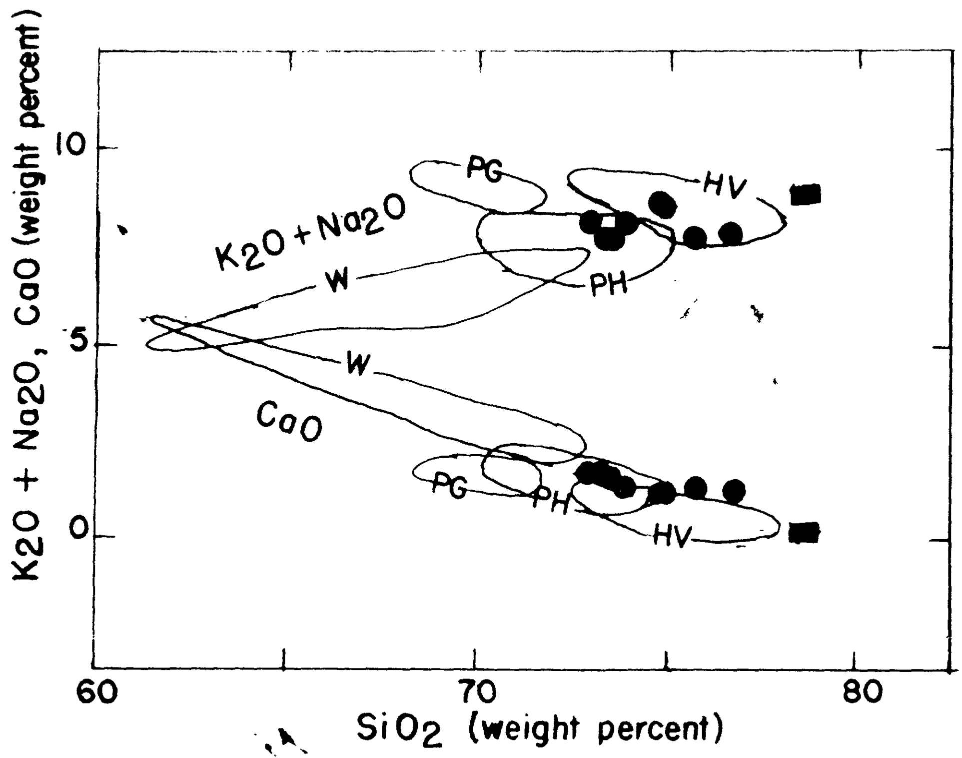

Figure 13. $K_2O + Na_2O$ and CaO against SiO_2 for Willimantic Gneiss, filled squares (G. L. Snyder, written commun. 1973), and Dry Hill Gneiss, filled circles (Peter Robinson, written commun., 1986), superimposed on fields of granitoid rocks, New London area, from figure 7. PG, Permian granites; W, Waterford Complex; PH, Potter Hill Granite Gneiss; HV, Hope Valley Granite Gneiss.

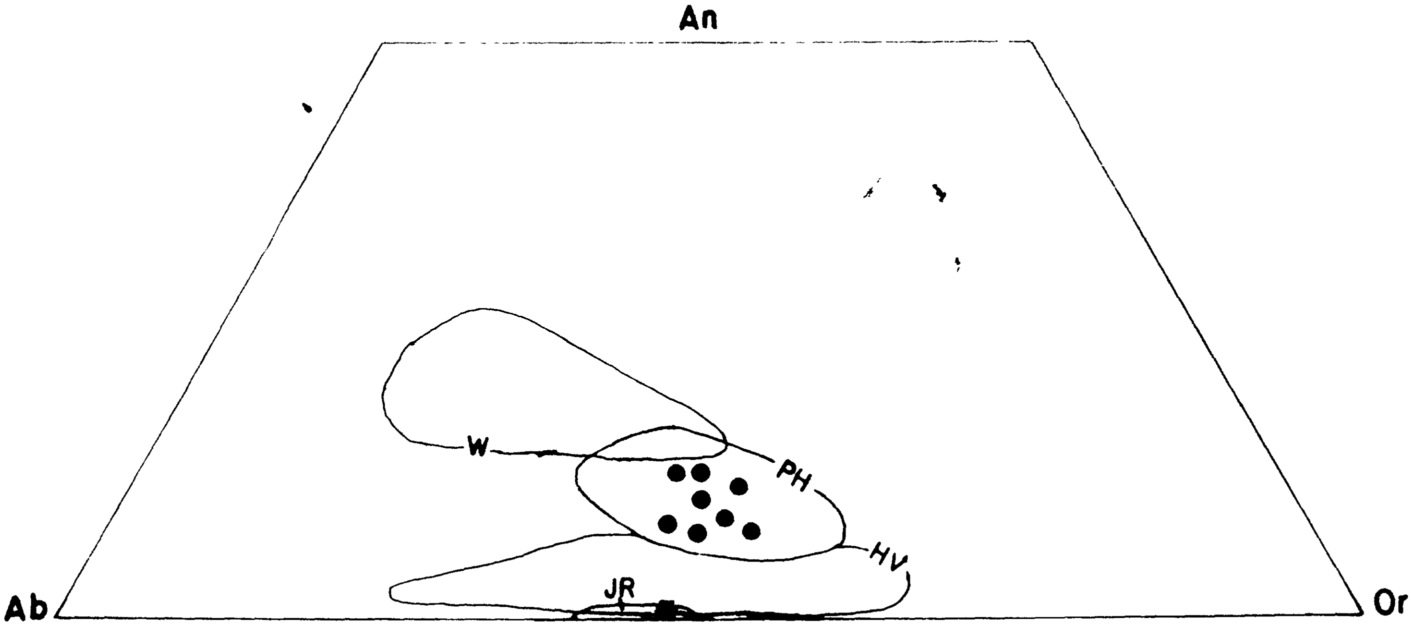

Figure 14. Normative albite, anorthite, and orthoclase of Willimantic Gneiss, filled squares (G. L. Snyder, written commun. 1973), and Dry Hill Gneiss, filled circles (Peter Robinson, written commun. 1986), superimposed on fields of Late Proterozoic granitoid rocks, New London area, from figure 6. W, Waterford Complex; PH, Potter Hill Granite Gneiss; HV, Hope Valley Granite Gneiss; JR, Joshua Rock Granite.

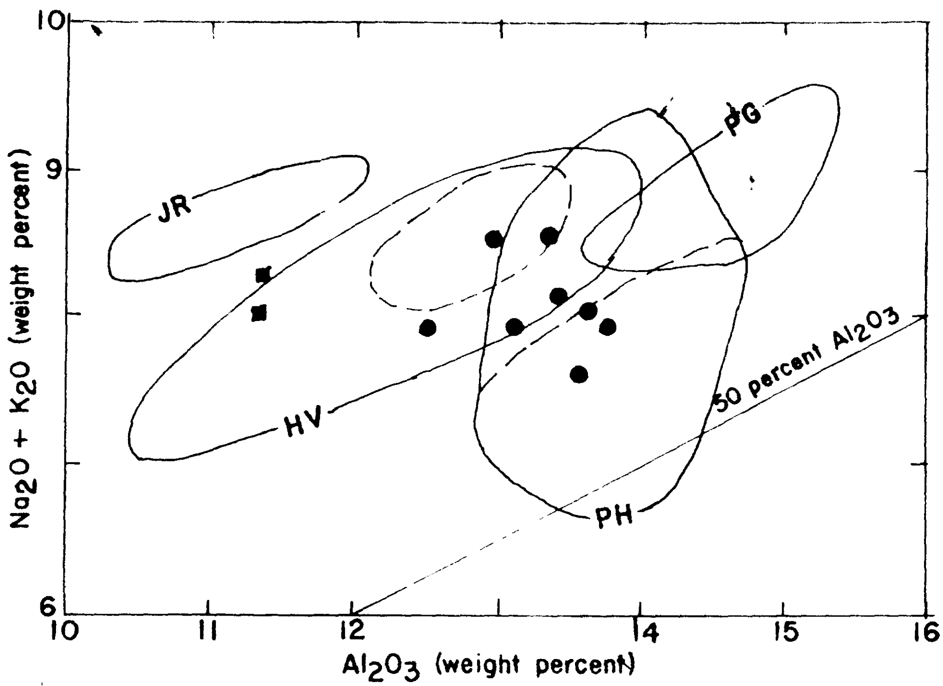

Figure 15. $Na_2O + K_2O$ against Al_2O_3 for Willimantic Gneiss, filled squares (G. L. Snyder, written commun., 1973), and Dry Hill Gneiss, filled circles (Peter Robinson, written commun., 1986), superimposed on fields of granitoid rocks, New London area, from figure 11. JR, Joshua Rock Granite; PG, Permian granites; HV, Hope Valley Granite Gneiss; PH, Potter Hill Granite Gneiss.

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APPENDIX

CHEMICAL AND MINERALOGICAL TABLES

Table 1. Chemical and modal analyses of the Plainfield Formation, south-

Major oxide composition (weight percent)

[Samples 2-3, 5-15 conventional rock analyses by J. W. Goldsmith, 1958, analysis by Floyd Brown, 1975]

sample No.	1	2	3	4	5	6	7	8
Field No.	823	C-541	C-730	C-254	C-535	C-536	C-532	C-516
SiO_2	66.9	92.97	81.42	69.10	75.83	59.28	74.55	96.02
Al_2O_3	14 9	2.53	7.73	12.52	10.96	16.26	11.92	1.90
Fe_2O_3	0.63	0.62	1.26	0.32	1.15	3.27	1.67	0.20
FeO	2.5	0.25	0.68	4.80	2.61	3.60	1.19	0.00
MnO	0.03	0.03	0.04	0.10	0.08	0.14	0.07	0.01
MgO	0.59	0.76	0.82	3.85	1.64	3.36	1.38	0.07
CaO	2.3	0.79	2.58	2.19	1.85	5.87	5.17	0.00
Na_2O	3.7	0.19	0.57	1.74	2.46	2.77	0.80	0.12
K_2O	4.9	0.60	3.81	2.93	1.70	1.75	1.62	1.11
H_2O+	0.87	0.17	0.32	0.15	0.08	0.78	0.12	0.03
H_2O-	0.06	0.46	0.08	1.08	0.84	1.59	0.75	0.08
TiO_2	0.61	0.10	0.38	0.86	0.53	1.00	0.49	0.07
P_2O_5	0.41	0.02	0.07	0.17	0.10	0.23	0.07	0.03
CO_2	0.17	0.29	0.04	0.00	0.05	0.49	0.13	0.01
Total	99	99.78	99.80	99.81	99.88	99.89	99.93	99.65

Estimated modal analyses

[a, apatite; c, calcite; ch, chlorite; o, allanite; r, rutile; t, tourma-
some muscovite are alteration products. Sample 1, 1297 points counted.
perpendicular to crystallographic a axis. [zo]Zoned feldspar; anorthite con-

Quartz	46	90	75	55	50	15	60	nd
Microcline	2	0	5	0	2	0	0	"
Plagioclase	28	3	10	20	30	60	30	"
Biotite	24	3	0	25	13	12	2	"
Muscovite	0	2	0	0	tr	0	1	"
Garnet	tr	0	0	tr	0	0	0	"
Sillimanite	0	0	0	0	0	0	0	"
Iron oxide	0.4	1	tr	tr	1	tr	1	"
Hornblende	0	0	2	0	0	10	1	"
Diopside	0	0	3	0	0	0	0	"
Epidote	0	0	3	0	0	1	1	"
Scapolite	0	tr	2	0	0	0	0	"
Sphene	0	tr	1	0	0	1	1	"
Other	a,r,z,	a,c,ch, z	a,c,ch	a,t,z	a,ch,z	a,c,ch, z	c,ch,o	" "
Percent anorthite	26	60	78	36	31	36	70	

eastern Connecticut.

1960; sample 4 by Dorothy Powers,1957; sample 1 rapid rock

9 C-521	10 C-522	11 C-530	12 C-520	13 C-529	14 C-677	15 C-671
62.19	63.11	59.10	68.30	70.29	83.90	90.26
16.35	16.35	18.44	14.58	14.61	7.76	5.14
0.78	0.89	1.20	0.92	0.84	1.25	1.04
6.30	6.02	5.58	5.83	2.42	0.63	0.68
0.15	0.17	0.15	0.13	0.06	0.04	0.01
3.16	2.79	2.66	2.20	1.07	0.82	0.44
3.39	3.15	2.77	0.75	1.99	0.39	0.00
2.84	2.90	3.72	0.83	3.18	1.33	0.13
1.92	2.34	3.68	2.88	3.98	2.72	1.14
0.41	0.07	0.10	1.65	0.05	0.40	0.58
1.09	0.86	1.21	0.39	0.55	0.17	0.15
0.89	0.96	0.93	1.11	0.54	0.27	0.28
0.19	0.17	0.20	0.07	0.11	0.03	0.01
0.25	0.08	0.11	0.14	0.11	0.02	0.01
99.91	99.86	99.85	99.78	99.80	99.73	99.87

line; z, zircon; nd, not determined. Chlorite, calcite, and
Percent anorthite determined optically in grains oriented
tent given from core to rim]

25	25	30	55	40	55	95
0	0	0	2	15	30	2
45	43	45	5	28	10	tr
25	25	25	20	17	5	1
tr	0	tr	tr	1	tr	tr
8	7	tr	5	1	0	0
0	0	0	5	0	1	1
tr	tr	0	0	tr	1	1
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
a,c,r, t,z	a,t,z	a,c,z	a,c,ch	a,c,ch, z	z	z
34	33	29	32	28	18-5[zo]	nd

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Table 1. Chemical and modal analyses of the Plainfield Formation, southeastern Connecticut, continued.

Description of samples

1. 823 Upper member? (Zp)--Gray, saccharoidal garnet biotite gneiss. Outcrop (now concealed) 0.2 km SE intersection I-95 and Conn. Rte 27, Mystic, Mystic quadrangle. UTM grid N45841 E2525.
2. C-541 Middle member (Zpg)--Gray, crystalline quartzite, weakly foliated. Road cuts I-395 0.9 km north of Raymond Hill Road, Uncasville quadrangle. UTM grid N45946, E7407.
3. C-730 Middle member (Zpc)--Light-gray-green gneissose granofels. Ledges south of power line 2 km NNE of Center Groton, Uncasville quadrangle. UTM N45875 E7490.
4. C-254 Middle Member (Zpg)--Dark-gray biotite schistose gneiss, biotite primarily in parting planes. Road cuts, Spicer Road, 0.5 km S of Church Hill Cemetary, Uncasville quadrangle. UTM grid N45930 E7499.
5. C-535 Middle member (Zpg)--Gray, slightly inequigranular, biotite feldspar quartz gneiss. Road cuts, I-395,0.8 km N of Raymond Hill Road, Uncasville quadrangle. UTM N45945 E7407.
6. C-536 Middle member (Zpg)--Dark-gray, gneissose granofels. Road cuts I-395 0.8 km north of Raymond Hill Road Uncasville quadrangle. UTM N45945 E7407.
7. C-532 Middle member (Zpg)--Light-greenish-gray, quartzose gneiss. Road cuts I-395 0.7 km N of Raymond Hill Road, Uncasville quadrangle. UTM grid N45945 E7407.
8. C-516 Lower member (Zpqq)--White, thick bedded, vitreous quartzite. Outcrop 0.6 km W of I-395, 1.5 km NW of Houghton Mountain, Uncasville quadrangle. UTM N45930 E7401.
9. C-521 Lower Member (Zps)--Gray, garnetiferous biotite gneiss, garnets porphyroblastic. S-bound entrance ramp I-395, interchange 79, Uncasville, Uncasville quadrangle. UTM N45919 E7410.
10. C-522 Lower member (Zps)--Gray, slightly inequigranular garnet-biotite gneiss. S-bound entrance ramp I-395, interchange 79, Uncasville, Uncasville quadrangle. UTM N45919 E7410.
11. C-530 Lower member (Zps)--Dark-gray biotite gneiss containing flat lenses of quartz. N-bound entance ramp, I-395, interchange 79, Uncasville, Uncasville quadrangle. UTM N45916 E7411.
12. C-520 Lower member (Zps)--Gray, inequigranular garnet-sillimanite-biotite gneiss. Road cuts I-395 near S-bound exit ramp, interchange 79, Uncasville, Uncasville quadrangle. UTM N45921 E7410.
13. C-529 Lower member (Zps)--Gray, even-grained garnet-biotite gneiss containing flat lenses of quartz and quartz and feldspar. N-bound entrance ramp I-395, interchange 79, Uncasville, Uncasville quadrangle. UTM grid N45916 E7411.
14. C-677 Lower member (Zps)--Light-gray, laminate quartz and sillimanite, thicker layers of quartz and feldspar, biotite in streaks. Road cuts I-95 at Society Road, interchange 73, Niantic quadrangle.
15. C-671 Lower member (Zpqq)--Gneiss consisting of light gray layers and lenses of quartz and flesh-colored lenses of quartz, feldspar, and sillimanite; biotite in foliation planes. Road cut I-95 0.5 km NE of Bride Brook. Niantic quadrangle. UTM N45799 E7310.

Table 2. Chemical and modal analyses of the Waterford Complex,

Major oxide composition (weight percent)
[Conventional rock analysis samples 1-2, 5-10, 13-14, and 17 by J. W. Gold-
Powers 1957. Rapid rock analysis samples 3-4, 11, and 15-16 by Floyd Brown

Sample No.	1	2	3	4	5	6	7	8	9
Field No.	C-603	C-709	843d	837d	C-711	C-710	C-716	C-692	C-718
SiO_2	69.10	66.00	67.4	67.7	71.88	49.28	46.77	54.65	72.41
Al_2O_3	14.89	15.55	14.6	14.3	14.41	14.45	16.26	16.18	14.43
Fe_2O_3	1.04	1.45	1.8	1.7	1.06	6.03	3.51	2.25	1.05
FeO	2.88	2.93	2.0	2.0	1.37	7.65	8.55	5.41	1.21
MnO	0.07	0.10	0.12	0.10	0.06	0.33	0.20	0.16	0.06
MgO	1.46	1.92	1.3	1.2	0.68	3.76	5.90	5.43	0.61
CaO	3.26	4.49	3.8	3.7	2.56	7.67	9.26	7.86	2.19
Na_2O	3.88	3.89	3.9	3.9	3.77	3.51	3.44	4.13	4.42
K_2O	1.78	2.11	2.5	2.4	3.31	1.81	1.83	1.24	2.73
H_2O+	0.60	0.42	0.30	0.46	0.13	0.77	1.09	1.05	0.29
H_2O-	0.03	0.02	0.00	0.00	0.02	0.03	0.10	0.09	0.02
TiO_2	0.55	0.60	0.56	0.62	0.35	3.00	2.43	1.03	0.31
P_2O_5	0.12	0.12	0.41	0.39	0.09	1.32	0.48	0.15	0.08
CO_2	0.15	0.09	0.06	0.05	0.02	0.07	0.01	0.08	0.02
F									
BaO									
Total	99.81	99.69	99	99	99.71	99.68	99.83	99.71	99.83
Na_2O+K_2O/Al_2O_3	0.38	0.39	0.44	0.44	0.49	0.37	0.36	0.33	0.50

Normative mineral composition (weight percent)

	1	2	3	4	5	6	7	8	9
q	29.7	22.4	26.3	27.5	30.7	4.0	0.0	1.2	30.6
c	1.3	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.5
or	10.5	12.5	15.0	14.4	19.6	0.7	10.8	7.4	16.2
ab	32.9	33.3	33.5	33.7	32.0	29.8	22.4	35.1	37.5
an	14.5	18.8	15.2	14.7	12.0	18.4	23.6	22.0	10.2
ne	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0
wo	0.0	0.9	0.4	0.5	0.0	4.5	8.0	6.5	0.0
en	3.6	4.8	3.3	3.0	1.7	9.4	4.7	13.6	1.5
fs	3.7	3.4	1.5	1.5	1.2	4.7	2.9	6.7	1.0
fo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
fa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
mt	1.5	2.1	2.6	2.5	1.5	8.8	5.1	3.3	1.5
il	1.0	1.1	1.1	1.2	0.7	5.7	4.6	2.0	0.6
ap	0.3	0.3	1.0	0.9	0.2	3.1	1.1	0.4	0.2
cc	0.3	0.2	0.1	0.1	0.0	0.2	0.0	0.2	0.0
DI	89	87	90	90	94	63	60	66	95

southeastern Connecticut

smith 1960; samples 18-19 by Marie Balazs 1956; sample 12 by Dorothy 1975]

10 C-715	11 927b	12 C-338	13 C-693	14 C-694	15 800d	16 867d	17 C-712	18 C-90	19 C-87b
75.04	47.5	46.84	71.30	64.48	70.1	68.7	60.99	57.54	58.55
13.20	17.3	18.56	14.14	15.71	13.9	14.2	17.57	16.34	20.37
0.83	3.1	3.61	0.74	1.55	1.5	1.6	0.73	2.54	0.55
1.02	7.8	7.38	2.05	3.91	1.0	1.6	6.70	5.36	7.65
0.05	0.2	0.21	0.09	0.12	0.07	0.08	0.18	0.20	0.16
0.46	5.3	6.88	1.02	2.15	0.62	0.80	3.75	3.92	3.72
2.37	9.8	11.68	1.96	4.52	2.8	3.1	5.34	4.58	3.22
4.14	3.2	1.98	3.16	3.89	4.0	4.2	0.64	3.71	1.01
1.68	1.1	0.33	4.17	1.75	3.0	2.7	1.81	2.87	2.05
0.39	0.70	1.44	0.40	0.65	0.39	0.46	1.15	0.74	0.91
0.03	0.03	0.07	0.07	0.05	0.01	0.03	0.21	0.15	0.14
0.26	1.9	0.9	0.40	0.77	0.55	0.50	0.81	1.19	0.84
0.08	0.58	0.10	0.09	0.20	0.33	0.43	0.12	0.24	0.16
0.26	0.03	0.01	0.00	0.01	0.07	0.06	0.02	0.10	0.17
								0.18	0.07
								0.05	0.04
99.81	99	99.99	99.59	99.76	99	99	100.02	99.71	99.69
0.44	0.25	0.12	0.52	0.36	0.50	0.49	0.14	0.40	0.15

39.4	0.0	0.0	30.4	20.9	30.1	27.7	28.9	8.0	28.1
1.1	0.0	0.0	1.1	0.0	0.0	0.0	5.2	0.0	11.8
9.9	6.6	1.9	24.8	10.4	18.1	16.3	10.7	17.0	12.2
35.1	27.7	16.8	26.9	33.0	34.5	36.3	5.4	31.5	8.6
9.6	30.2	40.8	9.2	20.3	11.3	12.2	25.6	19.5	13.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	6.4	6.9	0.0	0.3	0.1	0.1	0.0	0.0	0.0
1.1	6.0	13.2	2.6	5.4	1.6	2.0	9.4	9.8	9.3
0.8	4.1	7.3	2.7	4.9	0.2	1.0	10.7	6.2	12.6
0.0	5.3	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	4.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.2	4.6	5.2	1.1	2.2	2.2	2.4	1.1	3.7	0.8
0.5	3.7	1.7	0.8	1.5	1.1	1.0	1.5	2.3	1.6
0.2	1.4	0.2	0.2	0.5	0.8	1.0	0.3	0.6	0.6
0.1	0.6	0.2	0.0	0.0	0.2	0.1	0.0	0.2	0.4
								fr	0.1
95	65	59	92	85	94	92	76	76	74

Table 2. Chemical and modal analyses of the Waterford Complex, continued

Trace element abundances (parts per million)
[Delayed neutron activation analyses samples 3-4, 15-16 by L. J. Schwartz; and S. Fine, 1978-1979. [b]Emission spectrographic analysis by J. L. Harris. 1986). n.d., not determined]

Sample number	1	2	3	4	5	6	7	8	9
Field number	C-603	C-709	843d	837d	C-711	C-710	C-716	C-692	C-718
Rb	40	58	56	66	84[c]	52[c]	87[c]	30[c]	71[c]
Cs	1.4	1.7	0.7	0.6	n.d.	n.d.	n.d.	n.d.	0.8
Sr	n.d.	302[c]	358[b]	384[b]	247[c]	361[c]	552[c]	313[c]	188[c]
Ba	618	691	934	945	1301[c]	830[c]	471[c]	326[c]	834
Rb/Cs	28	34	80	110	n.d.	n.d.	n.d.	n.d.	89
Rb/Sr	n.d.	0.2	0.2	0.2	0.3	0.1	0.2	0.1	0.4
Sc	10.9	12.4	17.0	14.7	n.d.	n.d.	n.d.	n.d.	5.5
Cr	n.d.	n.d	10.0	36[a]	n.d.	n.d.	n.d.	n.d.	n.d.
Co	8.6	10.5	6.2	5.5	n.d.	n.d.	n.d.	n.d.	3.2
Zn	76	81	79	66	40[c]	139[c]	96[c]	78[c]	44
La	28	25	46	50	27[c]	42[c]	12[c]	24[c]	20
Ce	54	46	93	97	59[c]	87[c]	36[c]	48[c]	45
Nd	22	17	50	45	n.d.	n.d.	n.d.	n.d.	n.d.
Sm	4.4	4.3	10	10	n.d.	n.d.	n.d.	n.d.	3.1
Eu	0.97	1.0	2.0	1.9	n.d.	n.d.	n.d.	n.d.	0.75
Gd	3.5	2.8	7.9	7.4	n.d.	n.d.	n.d.	n.d.	2.6
Tb	n.d.	n.d	1.5	1.4	n.d.	n.d.	n.d.	n.d.	n.d.
Ho	n.d.	n.d	1.9	2.5	n.d.	n.d.	n.d.	n.d	n.d.
Tm	0.32	0.41	0.8	0.71	n.d.	n.d.	n.d.	n.d.	0.27
Yb	2.0	2.4	6.0	5.4	n.d.	n.d.	n.d.	n.d.	1.8
Lu	0.26	0.34	0.8	0.80	n.d.	n.d.	n.d.	n.d.	0.29
La/Yb	14	10.4	7.7	9.3	n.d.	n.d.	n.d.	n.d.	11.1
Hf	4.7	5.0	11.9	12.0	n.d.	n.d.	n.d.	n.d.	4.0
Zr	n.d.	130[c]	546	528	126[c]	244[c]	183[c]	169[c]	267
Th	7.2	5.3	13.2	14.4	n.d.	n.d.	n.d.	n.d.	7.0
Zr/Hf	n.d.	26	46	44	n.d.	n.d.	n.d.	n.d.	67
Nb[c]	n.d.	8	n.d.	15	9	32	6	10	8
Y[c]	n.d.	16	n.d.	44	17	46	26	23	14

samples 1-2, 9-10, 13-14 by L. J. Schwartz,
[c]Data from O. D. Hermes (written commun.,

10 C-715	11 927b	13 C-693	14 C-694	15 800b	16 867d
46[c]	15[c]	107	55[c]	76	68
n.d.	n.d.	4.7	1.2	1.3	0.6
234[c]	356[c]	n.d.	380[c]	360[b]	395[b]
528	234[c]	1982	770	857	645
n.d.	n.d.	23	46	58	113
0.2	0.04	n.d.	0.1	0.2	0.2
3.7	n.d.	5.3	15.3	7.75	17.3
n.d.	n.d.	n.d.	n.d	9.3[b]	4.5[b]
2.2	n.d.	10.3	13.5	3.3	4.4
33	107[c]	57	77	57	72
25	21[c]	29	25	55	49
44	36[c]	54	52	106	97
n.d.	n.d.	24	20	45	51
3.2	n.d.	3.6	5.1	9	10
0.65	n.d.	0.66	1.17	1.9	1.9
2.4	n.d.	2.1	4.2	6.1	8.6
n.d.	n.d.	n.d	0.68	1.2	1.4
n.d.	n.d.	n.d	0.6	1.7	1.5
0.19	n.d.	0.28	0.57	0.77	0.63
0.4	n.d.	1.3	2.8	5.2	4.2
0.13	n.d.	0.19	0.39	0.73	0.55
62.5	n.d.	22.3	8.9	10.6	11.7
3.7	n.d.	5.1	5.1	8.2	12.4
n.d.	146[c]	446	154[c]	278	540
10.1	n.d.	8.1	5.2	19.3	11.8
n.d.	n.d.	9	30	34	44
7	13	6	8	14	13
7	23	12	20	39	42

Table 2. Chemical and modal analyses of the Waterford Volcanic-Plutonic

Modal analyses

[an, andesine; ol, oligoclase; la, labradorite; c, calcite; ch, chlorite; and muscovite; si, sillimanite; tr, trace. Calcite, chlorite, epidote, and on grains oriented perpendicular to cystallographic axis a. Iron oxide is contains 4.2 percent prismatic sillimanite. n.d., not determined].

Points counted	1241	1754	1327	1178	1065	1083	1075	1054	1237
Sample No.	1	2	3	4	5	6	7	8	9
Field No.	C-603	C-709	843d	837a	C-711	C-710	C-716	C-692	C-718
Quartz	32.1	20.2	23.4	32.0	31.1	3.0	0.6	4.0	28.8
Potassium feldspar	0.8	1.1	7.8	12.0	10.4	0.0	tr	0.0	11.3
Plagioclase	50.0	55.4	53.7	44.8	50.0	49.7	39.2	48.0	55.2
Biotite	15.6	11.1	8.2	6.5	4.6	4.5	4.6	7.5	3.8
Hornblende	0.0	10.8	5.4	2.0	2.3	34.9	52.2	37.9	0.4
Garnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iron oxide	0.8	0.7	1.1	1.3	0.5	4.9	0.7	0.0	0.2
Sphene	0.0	0.2	0.3	0.2	0.0	0.0	1.8	1.3	tr
Apatite	0.2	0.4	0.2	0.4	0.2	2.9	0.8	0.3	0.1
Allanite	tr	0.0	0.0	0.1	0.0	0.0	0.0	tr	0.0
Zircon	tr	0.1	0.0	tr	tr	tr	0.0	0.0	tr
Other	0.2 ch,s	tr ch,py	0.0	0.0	0.1 ch,e	0.0	0.0	tr ch	0.1 s,ch
Percent anorthite	28	30	28	24	27	31	31	27	22

Complex, continued

e, epidote; h, hematite; i, ilmenite; o, orthoclase; py, pyrite; s, sericite;
sericite and muscovite are alteration products. Percent anorthite determined
mainly magnetite, but ilmenite and hematite also present. Sample 19

1551 10 C-715	1029 11 927b	1014 12 C-338	1085 13 C-693	1240 14 C-694	1278 15 800b	1167 16 867b	1101 17 C-712	1317 18 C-90	1087 19 C-87b
36.7	0.2	0.1	32.2	20.1	35.2	24.9	32.8	10.4	24.7
8.3	0.0	0.0	18.1	0.2	1.2	15.6	tr	0.0	0.0
48.9	42.7	44.7	37.4	49.6	50.3	46.4	33.2	65.3	30.3
4.6	11.6	0.0	11.2	12.5	12.8	9.2	22.8	9.8	20.2
0.0	42.5	52.4	0.0	15.9	0.0	2.0	0.0	12.4	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	0.0	18.5
0.3	1.5	1.3	tr	0.2	0.3	1.4	0.0	1.4	0.4
tr	1.3	1.2	tr	1.0	tr	0.2	0.0	0.2	0.0
0.1	0.3	0.3	0.3	0.2	0.0	0.1	0.1	0.4	0.2
0.1	0.0	0.0	0.6	tr	0.2	tr	0.0	0.0	0.0
tr	0.0	0.0	tr	0.0	tr	0.0	0.1	0.0	tr
0.8	0.0	0.1	tr	0.2	tr	0.3	0.0	0.1	4.7
c,ch, s		ch,e,r	ch	c,e	e	ch		c,e	c,ch,s si
24	40	59	25	28	28	n.d	71	25	44

Table 2. Chemical and modal analyses of the Waterford Volcanic-Plutonic Complex, continued

Description of samples

1. C-603 Rope Ferry Gneiss (Zwr)--Dark-gray hornblende-biotite gneiss containing thin laminae and flat lenses of quartz and feldspar, biotite in subparallel orientation, scattered clots of mafic minerals. Road cut Conn. Rte 85, 0.1 km south of I-395, Interchange 77, Montville quadrangle. UTM grid N45863 E7371.
2. C-709 Rope Ferry Gneiss (Zwr)--Gray hornblende-biotite gneiss containing thin laminae and flat lenses of quartz and feldspar, mafic minerals in streaks and as scattered individual grains or flakes. Road cut at intersection of S-bound I-395 and I-95 near Oil Mill Brook, Interchange 76, Niantic quadrangle. UTM grid N45841 E7345.
3. 843d Mamacoke Gneiss, Stonington gneiss facies (Zwms)--Gray, streaked hornblende-biotite gneiss in which mafic minerals are concentrated in streaks and small clusters. Road cuts on US Route 1, 0.5 km E of Quiambaug Cove, Mystic quadrangle. UTM grid N45808 E2550.
4. 837a Mamacoke Gneiss, Stonington gneiss facies (Zwms)--Gray, hornblende-biotite gneiss in which mafic minerals are in streaks and small clusters, elongate quartzo-feldspathic lenses mostly about 0.5 cm but as much as 1 cm in width. Road cuts U.S Route 1, 0.5 km W of Quiambaug Cove, Mystic quadrangle. UTM grid N45805 E2538.
5. C-711 Rope Ferry Gneiss, light-colored layer (Zwr)--Light-gray, inequigranular hornblende-biotite gneiss containing streaks of mafic minerals and streaks of quartz and feldspar; biotite disseminated and in clots with hornblende and magnetite as large as 5 mm, magnetite grains as large as 3 mm. Road cuts N-bound lane I-95, 0.2 km E of intersection of N bound I-395, Niantic quadrangle. UTM grid N45841 E7349.
6. C-710 Rope Ferry Gneiss (Zwr)--Dark gray, even-grained amphibolite containing quartz-feldspar streaks 2 to 3 mm wide. Road cuts N-bound lane I-95, 0.2 km E of intersection with N-bound I-395, Niantic quadrangle. UTM grid N45841 E7349.
7. C-716 New London Gneiss (Zwn)--Black, even-grained amphibolite containing a small amount of biotite, a few rusty spots, and a few larger anhedral feldspar grains. Road cuts I-95 (U.S. Route 1) 0.7 to 1 km W of intersection with Conn. Rte 85, Niantic quadrangle. UTM grid N45836 E7388.
8. C-692 New London Gneiss (?) (Zwn)--Dark-gray, gneissose amphibolite; some biotite on parting surfaces, scattered larger hornblende grains as much as 5 mm. Foliation marked by oriented hornblende and flat feldspathic lenses. Near contact with alaskite. Small abandoned quarry 0.2 km N of Conn. Rte 82, off woods road 0.5 km SW of intersection with Harris Road, Montville quadrangle. UTM grid N45970 E7302.

9. C-718 New London Gneiss, Granodiorite Gneiss facies (Zwng)--Gray, gneissose biotite granodiorite in which biotite is in streaks and disseminated, magnetite grains are scattered and lineation is more prominent than foliation. Exposures at the corner of Jefferson Avenue and Buchanan Road, southeast of High School, New London quadrangle. UTM grid N45823 E7408.

10. C-715 New London Gneiss, Granodiorite Gneiss facies (Zwng)--Light-gray, even-grained gneissose biotite granodiorite containing disseminated biotite, scattered larger magnetite grains, and a few white quartzo-feldspathic streaks. Road cuts on I-95 (U.S. Route 1) 0.7 to 1 km W of intersection with Conn. Rte 85, Niantic quadrangle. UTM grid N45836 E7388.

11. 927b Amphibolite (Zwa)--Dark-gray, thinly laminated (1-0.5 mm) amphibolite containing scattered larger (1-2 mm) feldspar grains. Outcrop on gas line, 1.2 km N. 10 W. of Wyassup Lake, Old Mystic quadrangle. UTM grid N45980 E2597.

12. C-338 Amphibolite (Zwa)--Dark-gray gneissose amphibolite; hornblende grains as much as 4 mm and feldspar as much as 3 mm in matrix containing smaller hornblende and feldspar grains (1-2 mm); weak lineation present, partly cataclastic. Small abandoned quarry on SE side of hill E of Shewville Road, 0.8 km S of Conn. Rte. 2, Old Mystic quadrangle. UTM grid N45962 E2503.

13. C-693 Mamacoke Gneiss (?) (Zwm)--Gray biotite gneiss containing disseminated flakes and clots of biotite, and flat lenses of quartz and feldspar 1 to 1.5 mm thick. Small road cut on Conn. Rte 82, 0.5 km W of intersection with Harris Road, Montville quadrangle. UTM grid N45965 E7302.

14. C-694 Mamacoke Gneiss (?) (Zwm)--Gray, hornblende-biotite gneiss, biotite disseminated and in streaks, hornblende scattered, flat quartz-feldspar lenses mostly about 1 mm wide but as much as 2 mm wide. Small road cut on Conn. Rte 82, 0.5 km W of intersection with Harris Road, Montville quadrangle. UTM grid N45965 E7302.

15. 800b Mamacoke Gneiss (Zwm)--Light-gray, even-grained biotite gneiss containing disseminated small biotite flakes and quartz-feldspar streaks as much as 2 mm wide. Outcrop contains layers of different biotite content. Outcrop on Ledyard Road, 0.8 km N of intersection with U.S. Route 1, Mystic quadrangle. UTM grid N45837 E2497.

16. 867b Mamacoke Gneiss (Zwm)--Gray, even-grained (1 to 1.5 mm) hornblende-biotite gneiss; contains quartz-feldspar streaks, disseminated biotite, and prominent scattered magnetite grains, feldspar grains rarely as much as 3 mm. Outcrop also contains subordinate coarser grained and splotchy phases. Ledges on Pellegrino Road 0.2 km W of intersection with Flanders Road, Mystic quadrangle. UTM grid N45386 E2557.

17 C-712 Mamacoke Gneiss, Cohanzie member (Zwmc)--Reddish-gray, fine-grained (about 1 mm) schistose garnet-biotite gneiss containing abundant biotite and small red garnets. Road cut just S of power line crossing Conn. Rte 85, 1.6 km SE of Douglas Lane, Montville quadrangle. UTM grid N45849 E7380.

18 C-90 Mamacoke Gneiss, Cohanzie member (Zwmc)--Dark-gray, hornblende-biotite gneiss containing a few quartz-feldspar lenticles. Abandoned quarry at N end of U.S. Naval Reservation, Groton, Uncasville quadrangle. UTM grid N45876 E7435.

19 C-87b Mamacoke Gneiss, Cohanzie member (Zwmc)--Gray, garnet-biotite gneiss containing quartz-feldspar lenticles, numerous prominent garnets as much as 8 mm in diameter, and clusters of sillimanite oriented parallel to the foliation. Abandoned quarry at N end of U.S. Naval Reservation, Groton, Uncasville quadrangle. UTM grid N45876 E7435.

Table 3. Chemical and modal analyses of Potter Hill Granite Gneiss, southeastern Connecticut

Major oxide composition (weight percent)

[Conventional rock analysis samples 1-2 by Marie Balazs, 1956, samples 3-7 by J. W. Goldsmith, 1960. Rapid rock analysis sample 8 by Hezekiah Smith, 1975. Analysis sample 9 from Laughlin (1912, table p. 123)]

Sample No.	1	2	3	4	5	6	7	8	9
Field No.	C-137	C-43b	C-678	C-697	C-702	C-703	C-723	1443	L-2
SiO_2	74.30	74.44	70.05	71.54	72.51	72.23	73.56	70.3	71.24
Al_2O_3	13.43	13.24	14.67	13.73	13.99	14.00	13.84	14.3	14.34
Fe_2O_3	0.95	0.76	1.52	0.70	0.96	1.04	1.30	1.7	0.80
FeO	0.90	1.31	1.74	2.41	1.79	1.94	1.09	0.80	1.80
MnO	0.05	0.05	0.06	0.07	0.05	0.07	0.07	0.02	0.02
MgO	0.59	0.47	0.59	0.84	0.69	0.85	0.53	0.40	0.66
CaO	1.10	1.32	1.59	2.20	1.99	1.39	0.99	1.6	2.17
Na_2O	3.51	2.54	3.29	3.24	2.88	2.64	3.26	3.1	4.25
K_2O	4.06	5.12	5.16	3.80	4.05	4.94	4.64	4.9	4.14
H_2O+	0.04	0.25	0.04	0.03	0.03	0.10	0.04	0.22	0.05
H_2O-	0.35	0.05	0.23	0.40	0.44	0.40	0.40	0.76	0.03
TiO_2	0.29	0.31	0.45	0.51	0.25	0.28	0.39	0.41	0.40
P_2O_5	0.06	0.06	0.12	0.15	0.06	0.05	0.08	0.18	nd
CO_2	0.01	0.01	0.17	0.14	0.19	0.01	0.01	0.20	0.00
F	0.03	0.07							
BaO	0.06	0.00							
Total	99.76	100.00	99.68	99.96	99.88	99.94	99.82	99	99.90
Na_2O+K_2O/Al_2O_3	0.60	0.58	0.58	0.51	0.49	0.54	0.57	0.56	0.58

Normative mineral composition (weight percent)

q	35.2	36.3	27.2	31.6	34.7	32.9	34.0	31.1	24.8
c	1.5	1.5	1.5	1.0	1.8	1.9	1.9	1.9	0.0
or	24.1	30.3	30.6	22.5	24.0	29.2	27.4	29.5	24.5
ab	29.8	21.5	27.9	27.5	24.4	22.4	27.5	26.7	35.9
an	4.9	5.6	6.0	9.1	8.3	6.5	4.3	5.6	7.8
en	1.5	1.2	1.5	2.1	1.7	2.1	1.3	1.0	1.6
fs	0.5	1.4	1.3	3.1	2.2	2.4	0.4	0.0	2.0
mt	1.4	1.1	2.2	1.0	1.4	1.5	1.9	1.5	1.2
hm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
il	0.5	0.6	0.9	1.0	0.5	0.5	0.7	0.8	0.8
ap	0.1	0.1	0.3	0.4	0.1	0.1	0.2	0.4	nd
cc	0.02	0.02	0.4	0.3	0.4	0.02	0.02	0.5	0.0
DI	89.7	88.3	84.6	81.2	82.5	84.3	89.0	87.4	85.2

Table 3. Chemical and modal analyses of Potter Hill Granite Gneiss, southeastern Connecticut, continued

Trace element abundances (parts per million)
[Delayed neutron activation analyses by L. J. Schwarz and S. Fine, 1978-1979. [b]Emission spectrographic analysis by Janet D. Fletcher. [c]Data from O. D. Hermes (written commun., 1986. n.d., not determined]

Sample Number	1	2	3	4	5	6	7	8
Field Number	C-137	C-43b	C-678	C-697	C-702	C-703	C-723	1443
Rb	71	144	223	102	114	164[c]	98	204
Cs	2.0	3.8	1.9	2.5	1.6	n.d.	1.9	1.9
Sr	n.d.	n.d.	142[c]	191[c]	228[c]	240[c]	112[c]	243[b]
Ba	802	437	642	460	849	920[c]	611	696
Rb/Cs	35	38	117	41	71	n.d.	51	107
Rb/Sr	n.d.	n.d.	1.6	0.5	0.5	0.7	0.9	0.8
Sc	4.93	6.56	7.31	10.05	5.63	n.d.	6.82	5.10
Cr	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	4.9[b]
Co	3.2	2.3	3.5	5.8	3.8	n.d.	2.9	2.8
Zn	53	43	63	51	39	23[c]	45	38
La	19	67	49	4	27	52[c]	73	109
Ce	57	126	99	145	53	93[c]	140	203
Nd	16	55	48	56	n.d.	n.d.	48	81
Sm	3.0	10.3	9.7	10.7	3.9	n.d.	10.2	16.0
Eu	0.64	1.27	1.86	1.44	1.05	n.d.	1.55	1.79
Gd	2.1	7.4	8.6	7.7	3.	n.d.	7.0	10.6
Tb	n.d.	1.61	1.81	1.81	n.d.	n.d.	1.11	2.16
Ho	n.d.	0.9	1.1	0.6	n.d.	n.d.	n.d.	2.3
Tm	0.51	0.67	0.97	0.69	n.d.	n.d.	0.62	0.63
Yb	2.3	4.0	5.0	3.9	2.1	n.d.	2.8	3.9
Lu	0.33	0.50	0.62	0.56	0.29	n.d.	0.38	0.50
La/Yb	8	17	10	19	13	n.d.	26	28
Hf	4.6	5.1	9.3	7.1	5.3	n.d.	6.8	7.8
Zr	n.d.	238	669	268	267	141[c]	252	316
Th	11.6	19.1	15.0	18.0	9.8	n.d.	14.7	44.2
Zr/Hf	n.d.	47	72	38	50	n.d.	37	40
Nb[c]	n.d.	n.d.	19	8	11	12	13	19
Y[c]	n.d.	n.d.	38	12	18	21	19	44

Table 3. Chemical and modal analyses of Potter Hill Granite Gneiss, south-eastern Connecticut, continued

Modal analyses

[c, calcite; ch, chlorite; mo, monazite; sp, sphene; tr, trace; ol, oligoclase. [z]Zoned plagioclase, hyphenated figures indicate percent anorthite in cores and in rims. [a]Sample C-122 is from same belt of rock as 43b but on the west side of the Thames River. [b]Data from Laughlin (1912, p. 120-121)]

Points counted	1278	1553	1363	1952	1183	1497	2044	2052	
Sample No.	1	2	3	4	5	6	7	8	9[b]
Field No.	C-137	C-122[a]	C-678	C-697	C-702	C-703	C-723	1443	L-2
Quartz	33	37	19	34	29	33	37	31	25
Microcline	22	20	39	20	25	35	32	28	45
Plagioclase	41	39	35	37	36	23	21	32	24
Biotite	4	3	6	6	8	8	5	6	4
Muscovite	0	0.6	0.4	0.4	1	0.1	2	2	0
Sillimanite	0	0	0	0	0.6	tr	0	0	0
Garnet	0	tr	0	tr	0.6	0.2	0	0	0
Iron oxide	0.5	0.4	1	1	0.5	0.2	2	0.6	1
Apatite	tr	tr	0.1	0.3	tr	0	tr	tr	tr
Allanite	0	0	0	0.1	tr	0	0	0	0
Zircon	0.1	tr	0.1	0	0	tr	tr	tr	tr
Other	tr	0.1	0.1	0.5	tr	tr	0.5	tr	tr
	ch,sp	mo	c,ch	c,ch,mo	mo	mo	ch	c,ch	sp,ch
Percent anorthite	12	18	23-9[z]	23	29	28	20-3[z]	25	ol

Table 3. Chemical and modal analyses of Potter Hill Granite Gneiss, southeastern Connecticut

		Description of samples
1.	C-137	Granite gneiss (in Zm)--Gray, fine-grained, even-textured gneiss. Disseminated biotite flakes in parallel orientation mark the foliation. Outcrop on Fort Shantok Road, west of Fort Shantok State Park, Uncasville quadrangle. UTM grid N45957 E7433.
2.	C-43b	Potter Hill Granite Gneiss (Zph)--Gray, medium-grained, even-grained, gneissose granite. Foliation marked by streaks of biotite and of chains of quartz and feldspars. Roadcut on Rte. 12 0.4 km N of Tom Allyn Brook, Ledyard, Uncasville quadrangle. UTM grid N45921 E7443.
3.	C-678	Potter Hill Granite Gneiss (Zph)--Gray, slightly inequigranular, medium-grained, biotite granite containing biotite both scattered and concentrated along foliation planes, feldspars locally in aggregates up to 22 mm, quartz in flat lenses, and rare scattered small garnets. Outcrops along Rocky Neck State Park Connector off I-95, East Lyme, Niantic quadrangle. UTM grid N45780 E7305.
4.	C-697	Potter Hill Ganite Gneiss (Zph)--Gray, medium-grained, even-grained, gneissose granite. Streaks of biotite alternate with streaks of gray quartz and flesh-colored and white feldspars. Ledge Route 85 0.8 km N of Chesterfield, Montville, Montville quadrangle. UTM grid N45905 E7318.
5.	C-702	Potter Hill Granite Gneiss (Zph)--Gray, medium-grained, even-grained granite gneiss. Biotite disseminated and in streaks, alternating with flat irregular lenses of quartz and feldspar. Prominent magnetite and less conspicuous small red garnets and muscovite. Road cuts U.S. Route 1 0.3 km E of Flanders at intersection with I-95. UTM grid N45830 E7337.
6.	C-703	Potter Hill Granite Gneiss (Zph)--Gray, medium-grained, even-grained granite gneiss. Biotite disseminated and in streaks, alternating with streaks of gray quartz and streaks of white and pink feldspars, prominent magnetite and small red garnets, some sillimanite on foliation planes. Ledges near contact with schist of Plainfield Formation. Road cuts U.S. Route 1 0.2 km E of Flanders near intersection with I-95, East Lyme, Niantic quadrangle. UTM grid N45830 E7336.
7.	C-723	Potter Hill Granite Gneiss (Zph)--Gray, medium-grained, slightly inequigranular granite gneiss. Foliation folded. Foliation marked by biotite in scattered flakes and in streaks and by quartz and feldspars in separate flat lenses and clusters. Ledge on Route 85, 1 km N of Four Corners, Montville, Montville quadrangle. UTM grid N45929 E7335.
8.	1443	Potter Hill Granite Gneiss (Zph)--Gray, medium-grained, even-grained, granite gneiss. Foliation marked by streaks of biotite and lenses and streaks of gray quartz, and of orange-pink and light-gray feldspars. Road cuts N-bound entrance ramp I-95 at Route 49, Voluntown Road, North Stonington, Ashaway quadrangle. UTM grid N45891 E2622.

9. L-2 Potter Hill Granite Gneiss, porphyritic facies (Zphp)--Gneissoid porphyritic granite of Loughlin (1912, p. 120); gray to pink, coarse-grained, porphyritic and gneissoid; feldspar phenocrysts mostly 0.5 to 2 in; ground mass gray, biotite in small flakes uniformly oriented and distributed. Sample probably from the mass of porphyritic gneiss east of the Preston Gabbro, Jewett City quadrangle, Griswold, Conn.

Table 4. Chemical and modal analyses of mafic-mineral-poor granite gneiss, southeastern Connecticut

Major oxide composition in weight percent

[Rapid rock analysis sample 1 by Floyd Brown, 1975, sample 2 by Hezekiah Smith, 1975; conventional rock analysis samples 3-4 by Marie Balazs, 1956; samples 5-6 by J. W. Goldsmith, 1960]

Sample No.	1	2	3	4	5	6
Field No.	845	1491	C-34	C-108b	C-719	C-698
SiO_2	74.9	72.8	77.00	76.43	74.43	70.15
Al_2O_3	13.2	14.9	12.58	13.24	13.18	14.04
Fe_2O_3	0.24	0.72	0.99	0.26	0.71	2.75
FeO	0.40	0.52	0.11	0.65	1.09	1.00
MnO	0.02	0.02	0.00	0.03	0.07	0.06
MgO	0.15	0.18	0.02	0.00	0.24	0.63
CaO	0.66	1.2	0.31	0.62	0.80	0.85
Na_2O	4.0	4.6	3.06	3.10	2.85	3.38
K_2O	4.5	4.8	5.52	4.97	5.68	5.91
H_2O-	0.32	0.42	0.02	0.09	0.01	0.26
H_2O+	0.02	0.08	0.20	0.27	0.28	0.06
TiO_2	0.12	0.22	0.08	0.05	0.27	0.46
P_2O_5	0.05	0.13	0.02	0.03	0.04	0.11
CO_2	0.02	0.02	0.11	0.18	0.10	0.07
F			0.01	0.03		
BaO			0.00	0.00		
Total	99	101	100.03	99.95	99.75	99.73
Na_2O+K_2O/Al_2O_3	0.64	0.63	0.68	0.61	0.63	0.66

Normative mineral composition (weight percent)

	1	2	3	4	5	6
q	33.4	29.2	37.8	38.3	34.0	25.7
c	0.7	0.3	1.3	2.2	1.2	1.0
or	27.1	28.3	32.6	29.4	33.6	35.0
ab	34.4	38.8	25.9	26.3	24.2	28.7
an	2.9	5.0	0.6	1.5	3.1	3.1
en	0.4	0.4	0.05	0.0	0.6	1.6
fs	0.4	0.03	0.0	0.9	1.1	0.0
mt	0.3	0.0	0.0	0.4	1.0	0.01
hm	0.0	0.0	0.01	0.0	0.0	0.01
il	0.2	0.0	0.1	0.0	0.5	0.9
ap	0.1	0.3	0.05	0.1	0.1	0.3
cc	0.05	0.04	0.0	0.4	0.2	0.2
DI	94.9	92.3	96.2	93.9	91.4	87.9

Table 4. Chemical and modal analyses of mafic-mineral-poor granite gneiss, southeastern Connecticut, continued

Trace element abundances (parts per million)
[Delayed neutron activation analyses by L. J.Schwartz and S. Fine, 1978-1979. [b]Emission spectrographic analysis by Janet D. Fletcher. [c]Data from O. D. Hermes (written commun. 1986. n.d., not determined].

Sample Number	1	2	4	5	6
Field Number	845	1491	C-108b	C-719	C-698
Rb	101[c]	232	233	163	238[c]
Cs	n.d.	2.2	1.2	2.2	n.d.
Sr	63[c]	671[b]	n.d.	92	85[c]
Ba	1043[c]	865	n.d.	520	1042
Rb/Cs	n.d.	105	194	74	n.d.
Rb/Sr	1.6	0.35	n.d.	1.8	2.8
Sc	n.d.	2.41	4.77	7.00	n.d.
Cr	n.d.	2.81[b]	n.d.	n.d.	n.d.
Co	n.d.	1.1	0.6	1.8	n.d
Zn	13[c]	24	20	37	78[c]
La	54[c]	61	24	53	83[c]
Ce	110[c]	98	58	105	154[c]
Nd	n.d.	47	27	42	n.d.
Sm	n.d.	9.7	8.3	9.2	n.d.
Eu	n.d.	1.29	0.28	1.26	n.d.
Gd	n.d	6.3	6.9	7.3	n.d.
Tb	n.d.	1.16	1.46	1.50	n.d.
Ho	n.d.	1.9	1.2	0.8	n.d.
Tm	n.d.	0.67	1.33	0.97	n.d.
Yb	n.d.	4.9	6.3	5.4	n.d.
Lu	n.d.	0.65	0.97	0.77	n.d.
La/Yb	n.d.	12	3.8	9.8	n.d.
Hf	n.d.	6.3	2.2	5.3	n.d.
Zr	139[c]	96.0[b]	209	162	337[c]
Th	n.d.	33.6	21.5	17.1	n.d.
Zr/Hf	n.d.	15	95	30.5	n.d.
Nb[c]	8	21	n.d.	13	28
Y[c]	36	44	n.d.	33	46

Table 4. Chemical and modal analyses of mafic-mineral-poor granite gneiss, southeastern Connecticut, continued

Modal analyses

[c, calcite; ch, chlorite; mo, monazite; tr, trace. [z]Plagioclase zoned, hyphenated figures indicate percent anorthite in core and in rim].

Points counted	1460	1163	743	1116	2481	1276
Sample No.	1	2	3	4	5	6
Field No.	845	1491	C-34	C-108b	C-719	C-698
Quartz	43	29	54	40	37	32
Microcline	26	29	27	26	32	35
Plagioclase	29	40	17	30	27	28
Biotite	0.8	2	tr	1	4	4
Muscovite	0.2	0.2	tr	1	1	0
Sillimanite	0	0	2	tr	0	0
Garnet	0	0	0	1	0	0
Iron Oxide	0.1	0.6	0.3	0	0.5	2
Apatite	0	0.2	0	tr	0	0.1
Allanite	0	0	0	0	tr	0
Zircon	tr	0	0	tr	tr	tr
Other	tr mo	0.4 ch	tr mo	tr mo	0.3 c,ch,mo	tr mo
Percent anorthite	11-5[z]	11-14[z]	10	14-12[z]	18-0[z]	17-10[z]

Table 4. Chemical and modal analyses of mafic-mineral-poor granite gneiss, southeastern Connecticut, continued

Description of samples:

1. 845 Hope Valley Alaskite Gneiss ? (Zhv)--Light-pink, medium-grained, even-grained, gneissose alaskite containing scattered flakes of biotite, magnetite grains, and flat aggregates of quartz. Associated aplite in the outcrop. Outcrop of shore E side of Lord's Point, Groton, Mystic quadrangle. UTM grid N45795 E2552.
2. 1491 Hope Valley Alaskite Gneiss ? (Zhv)--Light-tan, medium-grained, even-grained, gneissose alaskite. Contains flat lenses of gray quartz, alternating with flat lenses of flesh-colored and white feldspars and scattered grains of magnetite. Rock exposed in sewer line cut, outcrops near by, Iron Street, 0.45 km W of intersection of Iron Street and Spicer Hill Road, Ledyard, Uncasville quadrangle. UTM grid N45924 E7500.
3. C-34 Nodular granite (Zng)--Slightly pinkish-light-gray, sugary textured granite containing uniformally oriented ellipsoids of quartz and sillimanite. Road cut, Rte 12, 0.35 km N of intersection with Long Cove Road, Ledyard, Uncasville quadrangle. UTM grid N45881 E7445.
4. C108b Granite of the Gay Hill pluton, marginal facies (Zhvb)--Light-gray, even-grained, medium-grained, gneissose granite containing scattered small red garnets. Feldspars and quartz oriented inparallel streaks. Outcrops W side of Rte 32, 0.1 km S of Oxoboxo Brook, at Uncasville, Uncasville quadrangle, UTM grid N45919 E7415.
5. C-719 Potter Hill Granite Gneiss, light-colored phase (Zph)--Gray, medium-grained, slightly inequigranular granite gneiss. Foliation marked by parallel orientation of biotite and flat lenses of gray quartz and pinkish-orange and white feldspars. Gneiss contains scattered garnets, magnetite, and small aggregates of muscovite. Road cuts E end of New London-Groton bridge on I-95, 0.4 km W of intersection with Rte. 12, Groton, New London quadrangle. UTM grid N45829 E7447.
6. C-698 Potter Hill Granite Gneiss ? (Zph)--Red-orange-weathering, medium-grained, even-grained, weakly gneissose granite. Foliation marked by biotite flakes. A few coarser grained granitoid streaks cut across the foliation at a slight angle. Road cuts on Rte. 161, 0.7 km S of intersection with Walnut Hill Road, East Lyme, Montville quadrangle. UTM grid N45866 E7320

Table 5. Chemical and modal analyses of Hope Valley Alaskite Gneiss, south-

Major oxide composition (weight percent)

[Conventional rock analysis samples 1, 5-6 by Marie Balazs, 1956; samples 2, Goldsmith, 1960; sample 7 by Dorothy Powers, 1957. Analyses samples 3, 11 table 7, no. 5; table 6, no. 9); analysis sample 10 from Laughlin (1912, table

Sample No.	1	2	3	4	5	6	7	8	9
Field No.	C-180	C-691	1030	C-720	C-47	C-39	C-250	C-706	C-670
SiO_2	75.62	77.52	74.33	75.93	77.45	75.56	76.27	76.81	80.03
Al_2O_3	13.00	11.44	13.68	12.65	12.31	13.12	12.68	12.53	10.55
Fe_2O_3	1.07	1.28	0.66	1.83	0.85	0.58	0.93	0.83	0.64
FeO	0.58	0.73	1.30	0.20	0.27	0.56	0.38	0.50	0.36
MnO	0.03	0.05	0.05	0.04	0.01	0.02	0.02	0.02	0.01
MgO	0.00	0.02	0.44	0.17	0.01	0.09	0.10	0.03	0.07
CaO	0.27	0.32	0.37	0.67	0.45	0.83	0.47	0.42	0.33
Na_2O	3.78	3.35	5.66	3.69	3.31	2.59	3.55	3.69	2.15
K_2O	5.05	4.72	2.89	4.13	5.05	5.90	5.17	4.86	5.52
H_2O-	0.06	0.07	0.14	0.42	0.01	0.20	0.12	0.09	0.04
H_2O-	0.13	0.04	0.01	0.08	0.02	0.08	0.06	0.01	0.09
TiO_2	0.14	0.16	0.17	0.14	0.06	0.10	0.09	0.07	0.08
P_2O_5	0.02	0.00	0.01	0.00	0.00	0.01	0.04	0.02	0.01
CO_2	0.08	0.01	0.02	0.01	0.02	0.12	0.00	0.00	0.03
F	0.01				0.04	0.01			
BaO	0.03				0.00	0.00			
Total	99.87	99.71	99.73	99.66	99.86	99.77	99.88	99.88	99.91
Na_2O+K_2O/Al_2O_3	0.68	0.70	0.62	0.62	0.68	0.64	0.69	0.68	0.72

Normative mineral composition (weight percent)

	1	2	3	4	5	6	7	8	9
q	34.1	39.4	28.3	37.1	38.1	36.3	34.9	35.8	45.3
c	1.1	0.3	0.6	0.9	0.7	1.3	0.5	0.5	0.5
or	29.9	28.0	17.1	24.5	29.9	35.0	30.6	28.8	32.7
ab	32.1	28.4	48.0	31.3	28.0	22.0	30.1	31.3	18.2
an	0.6	1.5	1.6	3.3	1.8	3.2	2.1	1.9	1.4
di	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
en	0.0	0.05	1.1	0.4	0.0	0.2	0.2	0.1	0.2
fs	0.01	0.1	1.7	0.0	0.0	0.4	0.0	0.1	0.02
mt	1.6	1.9	1.0	0.4	0.7	0.8	1.0	1.2	0.9
hm	0.0	0.0	0.0	0.01	0.0	0.0	0.2	0.0	0.0
il	0.3	0.3	0.3	0.3	0.1	0.2	0.2	0.1	0.0
ap	0.05	0.0	0.0	0.0	0.0	0.02	0.1	0.05	0.0
cc	0.2	0.02	0.05	0.02	0.05	0.3	0.0	0.0	0.07
DI	95.8	95.4	93.0	92.6	95.9	92.9	95.4	95.7	97.2

eastern Connecticut.

4, 8-9 by J. W.
from Snyder (1964,
p. 123]

10 L-1	11 1121
76.94	75.71
12.59	12.15
1.37	1.04
0.14	1.01
0.00	0.07
0.25	0.17
0.01	0.57
3.56	4.28
4.62	4.35
0.22	0.02
0.00	0.07
0.08	0.17
0.00	0.03
0.00	0.22
	0.03
	0.03
100.40	99.92
0.65	0.71

38.3	33.3
1.7	0.0
27.4	25.9
30.3	36.4
0.0	0.3
0.05	1.1
0.6	0.4
0.0	0.7
0.2	1.5
1.2	0.0
0.15	0.3
0.00	0.0
0.00	0.5
96.0	95.0

Table 5. Chemical and modal analyses of Hope Valley Alaskite Gneiss, southeastern Connecticut, continued.

Trace element abundances (parts per million)
[Delayed neutron activation analyses by L. J. Schwartz and S. Fine, 1978-1979. [c]Data from O. D. Hermes (written commun. 1986). n.d., not determined].

Sample No.	2	3	4	7	8
Field No.	C-691	1030	C-720	C-250	C-706
Rb	60[c]	74	116	193	154
Cs	1.0	5.7	0.5	1.7	0.5
Sr	22.5[c]	43[c]	92	n.d.	16[c]
Ba	266[c]	533	520	426	75[c]
Rb/Cs	60	13	232	113	308
Rb/Sr	2.7	1.7	1.3	n.d.	9.6
Sc	4.07	5.57	6.32	2.13	1.25
Cr	n.d.	n.d.	n.d.	n.d.	n.d.
Co	0.3	0.5	1.1	0.4	0.3
Zn	37	58	46	32	33
La	109	59	48	10	16
Ce	215	128	91	54	41
Nd	91	75	43	14	17
Sm	12.9	11.4	8.4	4.7	7.1
Eu	1.17	0.91	1.63	0.42	0.22
Gd	7.3	9.5	6.0	3.5	6.0
Tb	0.89	1.86	1.24	0.82	1.42
Ho	n.d.	1.1	n.d.	0.7	0.6
Tm	0.85	1.11	0.71	0.63	0.89
Yb	2.2	6.6	3.4	3.5	5.6
Lu	0.32	0.99	0.48	0.51	0.76
La/Yb	49	9	14	2.8	3
Hf	10.4	11.6	6.0	5.2	5.0
Zr	506	458	257	152	87[c]
Th	5.5	12.6	14.4	18.9	24.0
Zr/Hf	49	39	43	29	17
Nb[c]	5	29	12	n.d.	15
Y[c]	13	42	30	n.d.	43

Table 5. Chemical and modal analyses of Hope Valley Alaskite Gneiss, southeastern Connecticut, continued

Modal analyses

[ab, albite; ol, oligoclase; ch, chlorite; ca, calcite; e, epidote; mo, monazite; py, pyrite; sp, sphene. [b]Data from Snyder (1964, table 7, no,. 5; table 6, no. 9). [a]C-683 substituted for C-180 is form a different outcrop about at the same horizon. [c]Data from Laughlin (1912, p. 124). [z]Zoned feldspar; hyphenated figures indicate percent in core and in rim].

Points counted	1056	1198	1636	1006	1063	1145	1203	1204	1315		2000
Sample No.	1[a]	2	3[b]	4	5	6	7	8	9	10[c]	11[b]
Field No.	C-693	C-691	1030	C-720	C-47	C-39	C-250	C-706	C-670	L-1	1121
Quartz	37	42	2	46	35	34	32	36	39	40	32
Microcline	13	30	15	2	37	32	32	43	46	40	30
Plagioclase	49	26	79	51	27	33	35	21	14	20	33
Biotite	0.1	0	3	tr	0.3	0.1	0.6	0.2	0.6	1	2
Muscovite	0	0	0	0.9	0.2	0.3	0	0	0.3	tr	0
Hornblende	0	0.4	0	0	0	0	0	0	0	0	2
Garnet	0	0	0	tr	0	0	0	0	0	0	0
Iron oxide	0.5	0.7	0.9	0.4	0.6	tr	0.9	0.2	0.1	1	0.7
Apatite	tr	tr	0	0	0	0	tr	tr	0	0	tr
Allanite	0	tr	0.1	0	0	0	tr	0	0.1	0	tr
Zircon	tr	tr	tr	tr	0	0	tr	tr	tr	tr	tr
Other	0.6 ch,sp	0.4 sp	0.4 ch,e,sp, mo	tr ch	0 tr mo	tr ca,ch	tr mo	tr mo	tr ch	tr py	1 sp, ca,ch
Percent anorthite	2	5	ab	12	8	ol	5	9-1[z]	20-7[z]	ab	2

Table 5. Chemical and modal analyses of Hope Valley Alaskite Gneiss, southeastern Connecticut, continued

Description of samples

1. C-180 Hope Valley Alaskite Gneiss, northern belt (Zhvn)--Light-gray, fine-grained, even-textured rock. Disseminated biotite flakes in parallel orientaion mark the foliation. Blastomylonitic fabric. Outcrop 0.2 km W of Fitch Hill Road overpass of I-395, Uncasville quadrangle. UTM grid N54973 E7406.
2. C-691 Hope Valley Alaskite Gneiss, northern belt (Zhvn)--Light-gray, lineated and foliated, even-grained, fine-grained alaskite containing scattered small magnetite grains and sparse hornblende. Shallow quarry 0.3 km N of Rte. 82 and 0.4 km NW of intersection with Harris Road, Montville quadrangle. UTM grid N45969 E7303.
3. 1030 Hope Valley Alaskite Gneiss?, northern belt (Zhvn)--Plagioclase gneiss (Snyder, 1964, table 7, no. 5). Gray, granular, even-grained gneiss. Outcrops N of Rte. 82, 0.6 km SW of intersection of Leffingwell Rd., Fitchville quadrangle. UTM grid N45980 E7361.
4. C-720 Hope Valley Alaskite Gneiss (Zhvf)--White, fine-grained gneissic alaskite containing scattered magnetite and a few red garnets. Streaks of white feldspar and gray quartz and scattered flakes of biotite mark the foliation. Railroad cuts 0.2 km SW of intersection of U.S. Route 1 and Meridian Road, Groton, New London quadrangle. UTM grid N45817 E7460.
5. C-47 Hope Valley Alaskite Gneiss (Zhv)--Light-grayish-orange, even-grained, homogeneous, gneissose alaskite. Foliation marked by quartz and feldspar segregated in parallel streaks and by rare biotite. Road cut on Rte. 12 on the S side of Poquetanuck Cove, Uncasville quadrangle. UTM grid N45950 E7456.
6. C-39 Hope Valley Alaskite Gneiss (Zhv)--Light-pinkish-gray, medium-grained, even-grained, gneissose alaskite containing scattered magnetite grains. Foliation marked by streaks of quartz and of feldspars. Road cuts on Rte. 12, 0.8 km N of Gales Ferry, Ledyard, Uncasville quadrangle. UTM grid N45910 E7441.
7. C-250 Hope Valley Alaskite Gneiss (Zhv)--Light-grayish-orange, even-grained, sugary textured, gneissose alaskite containing scattered biotite flakes and prominent magnetite grains. Ledges 0.2 km S of summit of Chapman Hill, Uncasville quadrangle. UTM grid N45936 E7478.
8. C-706 Hope Valley Alaskite Gneiss (Zhv)--Light-pinkish-gray, even-grained, medium-grained, gneissose alaskite containing scattered small magnetite grains. Road Cuts I-95 at intersection with U.S. Routes 1A and 1 W of Oil Mill Brook, Niantic quadrangle. UTM grid N45835 E7341.
9. C-670 Hope Valley Alaskite Gneiss (Zhvb)--Light-pinkish-gray, medium-grained, even-grained gneissose granite. Streaks of gray quartz and pink and white feldspars and scattered biotite flakes mark the foliation. Road cuts I-95 0.6 km W of Bride Brook, East Lyme, Niantic quadrangle. UTM grid N45789 E7307.

10. L-1 Hope Valley Alaskite Gneiss (Zhv?)--Gneissoid alaskite (Loughlin, 1912, p. 123-124); described as pink, gneissic, medium- to coarse grained, foliation consists of short bands of pink and white feldspars separated by shorter bands of gray quartz; magnetite and biotite thinly scattered, muscovite in places of pronounced shearing. Probably from alaskite mass east of Lantern Hill, Ledyard, Conn., Old Mystic quadrangle. No exact location.

11. 1121 Hope Valley Alaskite Gneiss (Zhvn)--Alaskite (Snyder, 1964, table 6, no. 9). Outcrop on Conn. 163, 0.5 mi lorth of Conn. 82, Montville, Conn., Fitchville quadrangle. UTM grid N45987 E7334.

Table 6 Chemical and modal analyses of Preston Gabbro, Old Mystic quadrangle, southeastern Connecticut.

Major oxide composition (weight percent) [Rapid rock analyses by Floyd Brown, 1975, except sample 5 by Hezekiah Smith, 1975].

Sample No.	1	2	3	4	5
Field No.	1114	1118	1084	1051	1469
SiO_2	48.2	43.9	54.5	71.1	72.7
Al_2O_3	18.3	17.2	16.8	13.1	13.9
Fe_2O_3	1.8	6.4	4.0	1.4	0.8
FeO	5.9	8.2	5.3	1.6	1.3
MnO	0.13	0.17	0.15	0.01	0.05
MgO	9.2	6.0	3.2	0.74	0.65
CaO	10.5	9.1	7.3	2.6	1.5
Na_2O	2.5	3.2	3.6	3.8	4.4
K_2O	0.17	0.14	0.74	2.3	2.7
H_2O	0.04	0.04	0.05	0.02	0.08
TiO_2	0.53	2.5	1.6	0.58	0.21
P_2O_5	0.04	0.46	0.75	0.22	0.08
CO_2	0.07	0.02	0.03	0.03	0.11
Total	99	99	99	99	99

Normative mineral composition (weight percent)

q	0.00	0.00	11.7	34.6	32.9
c	0.00	0.00	0.00	0.23	1.5
or	1.12	0.85	4.46	13.9	16.2
ab	12.4	27.8	31.1	32.9	37.8
an	42.7	33.0	28.0	11.5	6.32
ne	6.09	0.0	0.0	0.0	0.0
wo	6.16	4.23	1.55	0.0	0.0
en	4.13	7.65	8.13	1.89	1.64
fs	1.57	3.05	4.15	1.02	1.49
fo	15.07	5.40	0.00	0.00	0.00
fa	6.31	2.37	0.00	0.00	0.00
mt	2.92	9.53	5.91	2.08	1.18
il	1.13	4.88	3.10	1.13	0.40
ap	0.11	1.12	1.81	0.53	0.19
cc	0.18	0.05	0.07	0.07	0.25
DI	19.6	28.7	47.2	81.5	86.9

Table 6. Chemical and modal analyses of Preston Gabbro, Old Mystic quadrangle, southeastern Connecticut, continued

Trace element abundances (parts per million)
[Delayed neutron activation analyses by Louis J. Schwartz, 1978-1979. [b]Emission spectrographic analyses by Joseph L. Harris, [e] by Janet D. Fletcher. [c]Data from O. D. Hermes (written commun., 1986). [c]X-Ray spectroscopy by Harry J. Rose, Jr. n.d., not determined. -, less than]

Sample No.	1	2	3	4	5
Field No.	1114	1118	1084	1051	1469
Rb	3.2[d]	3.9[d]	16.5[d]	64	85
Cs	-2.2	-2.5	0.7	1.3	1.3
Sr	705[b]	606[b]	589[b]	150[c]	183[e]
Ba	67[d]	503[b]	208[b]	557	855
Rb/Cs	n.d.	n.d.	n.d.	49	65
Rb/Sr	0.0	0.0	0.02	0.4	0.5
Sc	25	31	24	9.6	7.8
Cr	357	110	11[b]	3.5[b]	2.7[b]
Co	44	56	24	4.3	1.6
Zn	88	128	123	68	55
La	2	3	30	28	39
Ce	5	7	68	66	70
Nd	9	-44	42	33	32
Sm	1	1.7	10.1	8.3	6.0
Eu	0.70	1.4	2.3	1.9	0.87
Gd	-2.2	1.7	8.5	7.6	5.2
Tb	-1.6	-1.8	1.6	1.5	1.6
Ho	-1.0	-1.0	2.8	2.1	1.9
Tm	-0.2	-0.2	0.8	0.9	0.7
Yb	-1.0	0.9	5.4	7.2	4.8
Lu	0.09	0.1	0.78	1.0	0.73
La/Yb	n.d.	3.3	5.5	3.9	8.1
Hf	-1.4	-1.5	6.6	9.7	3.9
Zr	11[b]	24[b]	354	478	162[b]
Th	-1.6	-1.8	4.2	10.0	33
Zr/Hf	n.d.	n.d.	54	49	41
Nb[d]	1.9	3	17	25	18
Y[d]	1.8	5	45	49	35

Table 6. Chemical and modal analyses of Preston Gabbro, Old Mystic quadrangle, southeastern Connecticut, continued

Modal analyses

[1150 to 1700 points counted per thin section. Hornblende is green. ch, chlorite; c, calcite; ep, epidote; mu, sericite-muscovite; an, anorthite content, measured perpendicular to crystallographic axis a].

Sample No.	1	2	3	4	5
Field No.	1118	1114	1084	1051	1469
Quartz	0.1	0.0	8	32	38
K-feldspar	0.0	0.0	0.0	12	12
Plagioclase	41(an45)	37(an56)	59(an38)	41(an43)	38(an31)
Hornblende[b]	52	63	19	0	0
Biotite	0	0	3	12	12
Magnetite/ilmenite	6	0.2	3	0.9	0
Sphene	0.2	0.0	0.9	0.9	0
Apatite	0.3	tr	0.4	0.2	0
Zircon	0	0	0.8	0	0
Allanite	0	0	0	0.2	0
Other	1.1 (ch,ep,c)	tr (ep)	6 (ch,ep)	2.3 (mu,ep)	11 (ch,ep,mu)

Table 6. Chemical and modal analyses of Preston Gabbro, Old Mystic quadrangle, southeastern Connecticut, continued

		Description of samples
1.	1118	Preston Gabbro (Spg)--Greenish black, gneissose, medium-grained hornblende diorite; hornblende in preferred orientation; magnetite prominent. Cataclastis evident in thin section; hornblende in aggregates enclosing plagioclase. Ledge southwest Conn. Rte. 2 above old trolley grade, 0.6 km northwest of junction Rte. 2 and Lantern Hill Road, Old Mystic quadrangle. UTM grid N45953 E2530.
2.	1114	Preston Gabbro (Spg)--Dark-gray, medium-grained, gneissose hornblende gabbro; hornblende in preferred orientation. Aggregates of hornblende 25 x 3 mm in preferred orientation. Ledge 0.35 km due north of intersection of Rte. 2 and Lantern Hill Road, Old Mystic quadrangle. UTM grid N45954 E2535.
3.	1084	Preston Gabbro (Spg)--Gray, gneissose, medium-grained, hornblende quartz diorite. Zoned subhedral tabular plagioclase oriented parallel to hornblende elongation. Ledge 1.5 km east-northeast of north tip of Lake of Isles, Old Mystic quadrangle. UTM grid N45974 E2541.
4.	1051	Preston Gabbro (Spg)--Light-gray, even-grained, medium-grained, slightly gneissic granodiorite; contains mafic inclusions 1.5 cm in diameter; lineation more prominent than foliation. Ledge south of trail 0.5 km south of summit of Prentice Mountain, Old Mystic quadrangle. UTM grid N45978 E2548.
5.	1469	Preston Gabbro (Spg)--Greenish-gray, medium-grained, but slightly inequigranular, plagioclase 1 to 4 mm in length; cataclastic appearance. Cataclasis clearly evident in thin section affecting mainly quartz and mafic minerals. Ledge at elevation 350 ft, above swamp, 0.6 km southwest of summit of Barns Hill, Old Mystic quadrangle. UTM grid N45971 E2560

Table 7. Chemical and modal analyses of Late Paleozoic intrusive rocks, southeastern Connecticut

Major oxide composition (weight percent)
[Conventional rock analyses of samples 2, 7 by J. W. Goldsmith, 1958, sample 6 by Dorothy Powers, 1957. Rapid rock analysis of sample 1 by Floyd Brown, 1975, samples 3-5 by Hezekiah Smith, 1975]

Sample No.	1	2	3	4	5	6	7
Field No.	841	C-349	1201	1203	1422	C-350	C-460
SiO_2	70.8	71.03	70.3	68.7	68.7	76.60	74.89
Al_2O_3	13.7	14.82	14.4	14.4	15.0	10.50	11.66
Fe_2O_3	2.0	1.30	1.3	1.9	1.5	2.98	2.68
FeO	1.5	0.95	1.3	1.4	1.0	0.40	0.45
MnO	0.06	0.04	0.00	0.02	0.03	0.12	0.11
MgO	1.3	0.59	0.35	0.50	0.72	0.14	0.30
CaO	2.3	1.59	1.4	1.7	1.8	0.39	0.43
Na_2O	3.9	3.40	3.3	3.2	4.2	3.80	4.62
K_2O	4.6	5.18	5.4	5.4	5.2	4.43	4.20
H_2O+	0.40	0.05	0.40	0.60	0.56	0.03	0.03
H_2O-	0.02	0.28	0.07	0.22	0.10	0.00	0.02
TiO_2	0.43	0.31	0.45	0.77	0.73	0.42	0.46
P_2O_5	0.36	0.10	0.21	0.32	0.38	0.01	0.07
CO_2	0.04	0.07	0.08	0.07	0.07	0.01	0.01
Total	99	99.71	99	99	100	99.83	99.93
Na_2O+K_2O/Al_2O_3	0.62	0.58	0.60	0.60	0.62	0.78	0.76

Normative mineral composition (weight percent)

q	25.0	27.6	27.9	26.5	20.8	37.7	31.7
c	0.0	0.01	1.3	1.1	0.3	0.0	0.0
or	27.2	30.7	32.4	32.4	30.9	26.2	24.8
ab	32.9	28.9	28.3	27.5	35.7	29.4	36.6
an	6.3	6.8	5.1	6.0	6.0	0.0	0.0
ac	0.0	0.0	0.0	0.0	0.0	2.5	2.2
wo	0.0	0.0	0.0	0.0	0.0	0.76	0.67
di	2.1	0.0	0.0	0.0	0.0	0.0	0.0
en	2.3	1.5	0.9	1.3	1.8	0.35	0.75
fs	0.4	0.23	0.58	0.0	0.0	0.0	0.0
mt	2.9	1.9	1.9	2.4	1.2	0.46	0.48
hm	0.0	0.0	0.0	0.29	0.67	1.8	1.6
il	0.8	0.59	0.87	1.5	1.4	0.80	0.87
ap	0.8	0.24	0.50	0.77	0.90	0.02	0.17
cc	0.0	0.16	0.18	0.16	0.16	0.02	0.02
DI	87	86	88	86	87	93	93

Table 7. Chemical and modal analyses of Late Paleozoic intrusive rocks, southeastern Connecticut, continued

Trace element abundances (parts per million)
[Neutron activation analyses of samples 1, 3-5 by L. J. Schwarz, 1978-1979; samples 2,6,7 by S. Fine and L. J. Schwarz, 1978-1979. Emission spectrographic analyses by [a]J. D. Fletcher and [b] J. C. Harris. [c]Data from O. D. Hermes (written commun., 1986). n.d., not determined; -, less than].

Sample No.	1	2	3	4	5	6	7
Field No.	841	C-349	1201	1203	1422	C-350	C-460
Rb	144	151	173	171	131	76	56
Cs	0.8	1.3	0.5	0.4	0.7	-3	-4
Sr	787[c]	n.d.	715[b]	1020[b]	2052[b]	n.d.	n.d.
Ba	2158	2510	1997	2998	2911	304	481
Rb/Cs	180	116	346	427	187	n.d.	n.d.
Rb/Sr	0.2		0.2	0.2	0.6	n.d.	n.d.
Sc	3.4	3.2	2.5	2.9	4.2	9.5	9.9
Cr	16	-30	6.6[b]	6.8[b]	14	-20	-30
Co	5.5	2.7	2.8	3.4	4.2	0.3	1.2
Zn	58	41	46	50	42	120	97
La	177	120	357	592	498	67	79
Ce	311	195	630	996	753	157	158
Nd	102	50	178	289	234	74	57
Sm	14.5	8.4	22.8	34.5	26.9	19.0	12.7
Eu	2.5	1.2	2.8	2.8	5.0	3.8	2.4
Gd	7.6	3.7	12.3	18.2	13.1	14.1	8.1
Tb	1.0	0.6	1.1	2.1	1.7	3.2	1.6
Ho	-2.0	-2.0	-2.2	-2.7	-2.4	2.3	1.1
Tm	0.6	0.4	0.3	0.6	0.5	2.2	1.0
Yb	1.6	1.1	1.6	2.9	3.6	10.0	4.8
Lu	0.2	0.2	0.2	0.4	0.6	1.4	0.8
La/Yb	111	109	223	204	138	6.7	16
Hf	14	6.5	14	29	22	25	17
Zr	666	365	631	1202	992	1252	889
Th	46	41	161	214	150	9	7
Zr/Hf	47	56	45	41	45	50	52
Nb[c]	32	n.d.	17	25	29	n.d.	n.d.
Y[c]	24	n.d.	26	48	44	n.d.	n.d.

Table 7. Chemical and modal analyses of Late Paleozoic intrusive rocks, southeastern Connecticut, continued

Modal analyses

[c, calcite; ch, chlorite; e, epidote; f, fluorite; m, muscovite mo, monazite; r, riebeckite. Calcite, chlorite, epidote, and muscovite are alteration products. p, perthite. [z]Zoned plagioclase; hyphenated figures indicate anorthite content of inner and outer zones].

Points counted	1209	1659	1291	1283	1117	1450	1480
Sample No.	1	2	3	4	5	6	7
Field No.	841	C-349	1201	1203	1422	C-350	C-460
Quartz	20	29	28	26	16	34	35
Microcline	22	33	35	29	40[p]	36[p]	30[p]
Plagioclase	49	32	32	35	39	24	31
Biotite	8	4	2	6	3	0	0
Hornblende	0	0	0	0	1	0	0.3[r]
Aegerine-augite	0	0	0	0	0	4	2
Magnetite/ilmenite	0.4	1	1	1	0.3	1	1
Sphene	0.4	0	0	0	0.3	0.1	0.1
Apatite	0.3	tr	0.1	0.3	0.1	0	0.1
Allanite	0.1	tr	0.4	0.4	0.4	tr	0
Zircon	0.1	0	0.2	0.1	0.0	tr	tr
Other	0.5 m,ch,c	0.5 m,ch	1 ch,c,m,f	1 ch,m,c	0.4 ch,e,f	tr mo	tr mo
Percent anorthite	25-16[z]	28	20	22	14-0[z]	1	1

Table 7. Chemical and modal analyses of Late Paleozoic intrusive rocks, southeastern Connecticut, continued

		Description of samples
1.	841	Westerly Granite (Pw)--Light-gray, even-grained, medium-grained granite. Abandoned quarry on Cove Road, Stonington, 0.2 km north of Quambaug Church at head of Quiambaug Cove, Mystic quadrangle. UTM grid N45822 E2542.
2.	C-349	Westerly Granite (Pw)--Light-gray, even-grained, medium-grained granite. Abandoned quarry 0.25 km south of Rte. 184, and 0.7 km southeast of Center Groton, Groton, Uncasville quadrangle. UTM grid N45852 E7492.
3.	1201	Narragansett Pier Granite (Pnp)--Grayish-pink, slightly seriate, medium-grained granite. Sparse spots of hematitic stain on surface. Shows flow structure in which lineation more apparent than foliation. Cuts, Rte. 2, 2.6 km south of intersection with I-95, Stonington, Ashaway quadrangle. UTM grid N45858 E2620.
4.	1203	Narragansett Pier Granite (Pnp)--Grayish-pink, medium-grained, 1.5-2 mm common grain size and pink feldspars as much as 5 mm. Flow structure apparent. Ledge, northbound entrance ramp to I-95 off of Taugwank Road, Stonington, Old Mystic quadrangle. UTM grid N45846 E2571.
5.	1422	Porphyritic granite (Pqm)--Gray, medium- to coarse-grained, seriate quartz monzonite. Mafic minerals tend to be in clots; potassium feldspars are as much as 1 cm in length. Flow structure apparent. Ledge on dead end road, west side of Long Pond at Cider Hill, 0.8 km from intersection with Lantern Hill Road, Ledyard, Old Mystic quadrangle. UTM grid N45921 E2540.
6	C-350	Joshua Rock Granite Gneiss (PPj)--Light-gray, gneissose, fine- to medium-grained granite. Hematitic stain around some mafic minerals. Abandoned quarry, now a shopping center, on west side of Route 85 0.8 to 0.9 km north of intersection with I-95, Waterford, Montville quadrangle. UTM grid N45842 E7388.
7.	C-460	Joshua Rock Granite Gneiss (PPj)--Pinkish-gray, medium-grained granite containing irregularly distributed green pyroxene and gray quartz. Cut on I-395 at Miller Pond, 0.85 km south of overpass at Old Colchester Road, Waterford, Montville quadrangle. UTM grid N45886 E7392.