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Trip D-1

PROGRESSIVE METAMORPHISM OF PELITIC, CARBONATE, AND BASIC ROCKS IN SOUTH-CENTRAL CONNECTICUT

by

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INTRODUCTION

Throughout the New England metamorphic province few localities exhibit such a complete example of progressive regional metamorphism within a relatively small area as does south-central Connecticut. The rocks of this immediate area consist of an assortment of metamorphosed shales, graywackes, basic volcanics, and minor amounts of carbonates and sandstones. These metasedimentary and metavolcanic rocks range in age from Cambrian to Devonian and have been metamorphosed from the chlorite to the kyanite zone. Immediately to the east these metamorphic rocks are overlain unconformably by sedimentary rocks of Triassic age. To the northwest lie the Waterbury Dome and the Connecticut Valley synclinorium. The purpose of this trip is to call attention to this area of classic Barrovian metamorphism and to point out problems needing further study.

ACKNOWLEDGMENTS

The authors wish to acknowledge their heavy reliance on the excellent geologic maps of the Milford, Ansonia, and Mount Carmel quadrangles compiled by C. E. Fritts (1963, 1965a, 1965b).

STRATIGRAPHY

The stratigraphy of the metamorphic rocks exposed in the New Haven, Mount Carmel, Ansonia, and Milford quadrangles is straightforward although controversy exists concerning minor interpretations. In order to avoid misunderstandings the stratigraphic relationships as envisaged by Fritts (1962, 1965a, 1965b) and by Burger (1967) are expressed in figure 1. As this trip will avoid most of these complications, the interested reader is referred to Burger (1967) for the reasoning underlying the conflicting interpretations.

The Savin Schist is best exposed in the New Haven quadrangle. It is most likely Ordovician in age and is the oldest rock unit encountered on the field trip. The most outstanding characteristic of the Savin Schist is the pervasive homogeneity of the rocks. Although several minor rock types are present, the overall unit is an albite-muscovite-chlorite-quartz schist containing abundant lenses, pods, and veins of quartz, and thin layers of carbonate and tuffaceous material. This formation is recognized only in the chlorite zone.

The Allingtown Volcanics is considered to be a basic intrusive by Fritts (1965a, 1965b), but Burger (1967) believes this formation represents

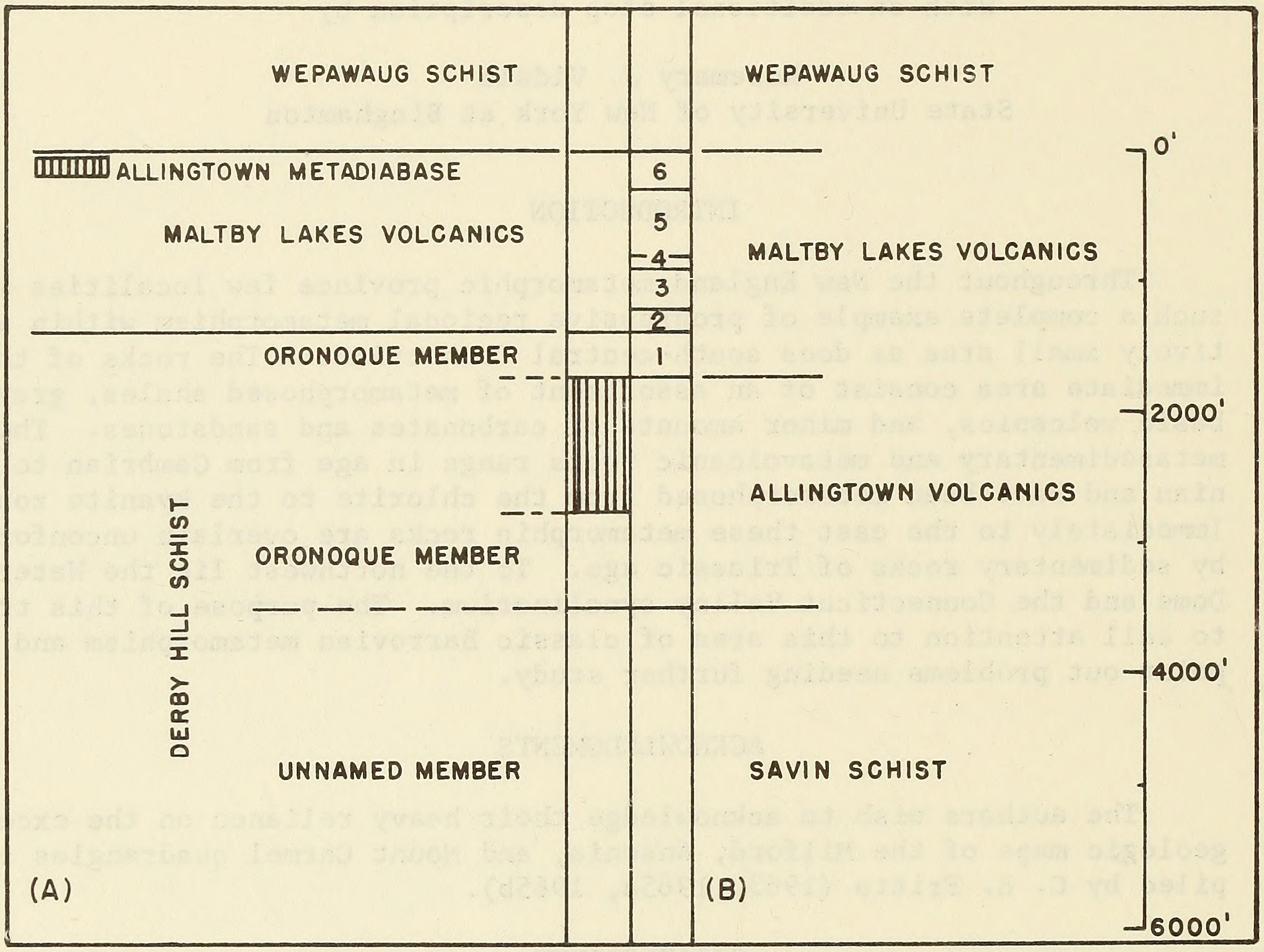

Fig. 1. The stratigraphy encountered in Trip D-1 as interpreted by (A) Fritts (1962, 1965a, 1965b) and by (B) Burger (1967).

a sequence of interbedded basic volcanics and pelitic sediments that is dominated by a thick massive flow. As in the case of the Savin Schist, this formation is recognized only in the chlorite zone. At this grade it is characteristically a porphyroblastic greenstone consisting of epidote porphyroblasts in a matrix of albite, actinolite, epidote, and chlorite.

The Ordovician formation designated as Maltby Lakes Volcanics contains a sequence of volcanic flows, pyroclastics, and tuffs that are interbedded with minor pelitic sediments and carbonates. In the chlorite zone the dominant lithologies are a fine-grained actinolitic greenschist, a quartzo-feldspathic schist, and a massive, epidote-rich actinolitic greenschist. These units can be traced through the kyanite zone.

In the chlorite zone the Wepawaug Schist is mainly a quartz-muscovite-chlorite-albite carbonaceous phyllite. With increasing metamorphic grade the grain size increases and the formation becomes a graphitic muscovite schist with bands of paragneiss (Fritts, 1962). Other lithologies present in this formation are impure limestone layers and minor thin bands of amphibolite. Mineralogic changes associated with increasing grade of metamorphism are best developed in this unit and, therefore, the majority of the stops will be in the Wepawaug Schist. The Wepawaug Schist is correlated with the Waits River and Northfield formations of Vermont and is assigned a Siluro-Devonian age by Fritts (1962, p. 36).

The so-called "Woodbridge Granite" occurs in the Wepawaug Schist as small stocks and as layers conformable to foliation. Often it is in thin layers which may represent tuffaceous acidic volcanic rocks. Whether such tuffs are water-laid or an ash fall or flow is unknown. The assemblage of this trondhjemitic unit is oligoclase, quartz, and muscovite with minor amounts of biotite and K-feldspar.

STRUCTURE

Structural relationships are apparently more complex than formerly recognized in this part of Connecticut. As a separate field trip deals with this problem (Trip D-2), the reader is referred to the portion of the Guidebook dealing with that trip for a detailed interpretation of the regional structural geology.

Structures of specific interest which will be pointed out and discussed on this trip are itemized below:

(1) Wepawaug syncline — The major structure in the New Haven, Mount Carmel, Ansonia, and Milford quadrangles is a regional syncline with a plunge to the northeast. The exact nature of the syncline is unclear due to the difficulty in correlating specific formations (Savin Schist, Allingtown Volcanics) around its hinge. This difficulty is due to structural complexities in the hinge area, lack of critical outcrop, and an increase in metamorphic grade which occurs in the hinge area (refer to fig. 2).

(2) Mixville and other minor faults — Small normal faults of post-Paleozoic age cut the Wepawaug syncline in several places. The largest of these is known as the Mixville Fault and has a displacement of at least several hundred feet (Fritts, 1965a). Fritts has postulated that this fault, which is the Triassic boundary in parts of the Southington and Mount Carmel quadrangles, extends into the Wepawaug formation

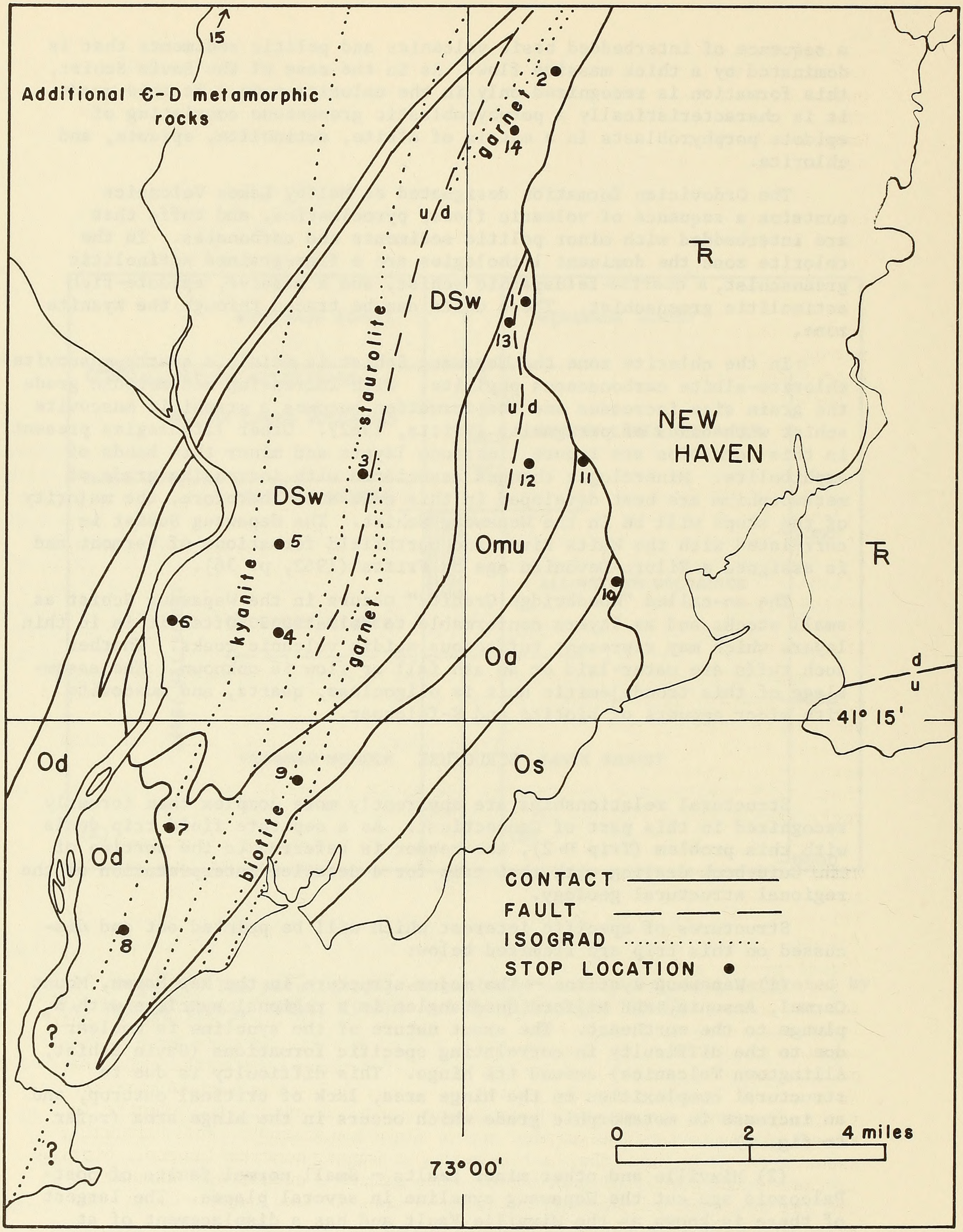

Fig. 2. Generalized geologic map of region after Fritts (1963, 1965a, 1965b) and Burger (1967). Formations shown include Savin Schist (Os), Derby Hill Schist (Od), Allingtown Volcanics (Oa), Maltby Lakes Volcanics (Omu), and Wepawaug Schist (DSw).

as far south as Orange. In the northern portion he sees some discordant foliation attitudes in the schist. In the south, however, the fault is postulated on the occurrence of truncated biotite and garnet isograds. Some evidence of discordant attitudes of foliation will be seen in the Wepawaug River gully. Neither line of evidence is substantial and the actual occurrence of the fault is problematical.

(3) Schistosity and fracture cleavage — The majority of all rock types possess a well-developed schistosity which is parallel or nearly parallel to original bedding throughout much of the area. In many outcrops this schistosity is tightly folded on a small scale and is cut by a well-defined fracture cleavage (strain-slip cleavage in rocks of appropriate composition). At a few localities, all in the Wepawaug Schist, this cleavage is further cut by kink-bands. Such relationships permit identification of at least 3 episodes of structural deformation. Recent detailed work by Dieterich has confirmed 4 distinct stages of structural evolution (see description of Trip D-2).

METAMORPHISM

The regional metamorphism of western Connecticut is similar to the classic Dalradian sequence in the Scottish Highlands, where Barrow (1912) first described metamorphic isograds. In the region of this field trip the rocks are exposed from lower greenschist through the middle amphibolite facies. As previously mentioned, the diversity of rock compositions includes pelitic schists, basic volcanics, and micaceous limestones. Each of these rock types can be seen changing in mineralogy and texture across the isograds.

The age of metamorphism here is controversial. Although throughout most of western Connecticut K-Ar dates of 320-400 m.y. have been obtained, the values from the area between Bridgeport and New Haven are 220-280 m.y. (Clark, 1966; Armstrong et al., 1968). Dieterich (1968) concludes from structural arguments that the isograds are Acadian (360-400 m.y.) and that the lower K-Ar dates are only due to reheating or uplift of warm rocks during the Allegheny orogenic period.

The isograds parallel the major northeast trending structures. Within two miles the grade rises from the chlorite zone to the kyanite zone. Only in the eastern part of the region, near the contact with the Triassic, are the lower grade rocks exposed. Fritts (1962) reports the following order of the isograds: (1) garnet, (2) biotite, (3) staurolite, (4) kyanite. The appearance of garnet before biotite is not typical of a Barrovian sequence unless the garnet is manganiferous. Compositions for the garnets in these rocks have not been determined. However, in at least one locality the reversal of isograds is not substantiated by thin section examination (on Lambert Rd., 1/3 mile north of City Rd.). The pelitic assemblage in this "chlorite zone" outcrop is biotite-chlorite. At a nearby locality in the garnet zone, but below the mapped biotite isograd, garnet occurs with both biotite and chlorite. The biotite in these specimens is fine-grained and a minor constituent, but texturally appears to be in equilibrium. Beyond the mapped biotite isograd, biotite is coarse and plentiful and occurs with garnet ± chlorite. Whether or not the reversal of isograds actually occurs in this region is an open question needing further investigation.

By taking each rock type and observing it as the metamorphic grade increases several important petrologic phenomena can be shown. Unfortunately no single layer can be followed across the isograds. The schists and volcanics are quite massive and present little problem with correlation. However, the limestone occurs as sparse discontinuous layers which can only be assumed to have had comparable original mineralogy.

At low grade the pelitic rocks in the Wepawaug Schist can be divided into two types: (1) a very mica-rich phyllite, (2) a siltstone. Both rocks have the assemblage quartz-muscovite-chlorite-plagioclase. The phyllite has 40-50% mica whereas the siltstone has 10-20% mica. This results in the phyllite having a strong crinkle texture with very well developed strain-slip cleavage. The siltstone has no crinkles or kink-bands and a relatively poorly developed strain-slip cleavage. Both rocks are fine grained. Veins of quartz and more rarely calcite are common at this grade, suggesting that fluid pressure equaled and perhaps exceeded lithostatic pressure. Texturally the rocks remain fine grained until Fritts' biotite isograd is reached. Grain size increases at this grade so that individual micas can be distinguished in hand specimen. Garnets are easily visible but are less than 1-2 millimeters in diameter. Above the biotite isograd veins are not as common as at lower grades.

In the staurolite zone grain size increases rapidly. Staurolites and garnets several millimeters in diameter are common in a coarse mica-quartz-plagioclase matrix. The differences between the two schist types are much less conspicuous. The siltstone is sandier and has a less aluminous assemblage in general. Garnets at this grade have been more noticeably rolled than at the lower grades. A lineation of included quartz grains at an angle to the foliation of the rock is the criterion used here for rolling. One staurolite from the kyanite zone shows evidence that it too has been rolled. The first staurolites to appear in the schist are anhedral and rare. Just below the kyanite isograd they occur much more commonly and as well-formed euhedral crystals.

The appearance of kyanite is not associated with a distinct textural change. Usually the assemblage in the kyanite-bearing rocks is kyanite-staurolite-garnet-biotite, which raises the question of one or more of the phases being stabilized by an extra component. No analyses of the phases have been performed so that this again is an open question.

There are similar changes in the basic rocks as the grade is increased. In the chlorite zone the assemblage is chlorite-actinolite-epidote-albite. The rocks are heterogeneous. Numerous pods of solid epidote, variations in carbonate content, and veins of calcite and of quartz occur commonly. Homogeneity has increased slightly in the garnet and biotite zones. The assemblage is similar except for an increase in actinolite relative to chlorite. At the kyanite isograd the rock is an amphibolite. Plagioclase, hornblende and quartz dominate the assemblage. Except for some local concentrations, biotite, chlorite and epidote occur as minor phases. The rock is much more homogeneous in appearance and veins are not as common as in the greenschist facies.

As noted previously the carbonates in the Wepawaug Formation are scarce and individual units cannot be traced across the isograds. All indications suggest that they are fairly homogeneous in composition. Modes from material below the staurolite isograd show the following average mineralogy: calcite 35-45%, dolomite-ankerite 25-35%, quartz 10-20%, muscovite 10-20%, opaque material 2-6%. The ratio of the two carbonates can be quite variable so that rare specimens are nearly all calcite or all dolomite-ankerite. Plagioclase and chlorite can occur in trace amounts in these low grade rocks. No mineral zoning is noticeable in the low grade carbonates. The contacts are slightly gradational with the schist, but very sharp with the tuffaceous material. Grain size increases slightly between the chlorite and biotite zone, but no other changes are evident. In the low grade staurolite zone biotite appears and plagioclase increases to approximately 1% of the rock. Chlorite also seems to increase slightly over lower grades. Muscovite and dolomite diminish rapidly. The ideal proposed reaction is muscovite + dolomite + quartz → phlogopite + anorthite + calcite + vapor, although it is difficult to reconcile the large amount of biotite produced with the relatively small amount of plagioclase. Chlorite may be involved, taking up the excess Al_2O_3.

In the higher grade staurolite zone and in the kyanite zone the reaction biotite + calcite + quartz → tremolite-actinolite + K-feldspar + vapor occurs. This reaction and the reaction forming biotite are the only consistent reactions with increasing grade. Two other important reactions occur: (1) H_2O + anorthite + calcite → clinozoisite + CO_2, (2) tremolite + calcite + quartz → vapor + diopside. However, they are commonly found in the same outcrops as the other lower grade assemblages which are in stable textural equilibrium. The explanation lies in the fluid composition. Figure 3 is a plot of several equilibrium curves which seem to be involved in these rocks. The shapes of the curves in this $T\text{-}X_{CO_2}$(fluid) plot, at constant P, are determined by the stoichiometry of the two volatile reactions (Greenwood, 1962). The diagram neither contains all the reactions possible in the system nor does it imply that the reactions shown are the stable ones or in the wholly correct relative positions. With seven components and 12 or more likely phases to occur, the correct reactions are not easily defined. However, these curves do correspond well with the best interpretations of the reactions occurring in the rocks.

The important point to notice is that at constant temperature and pressure a rock could undergo a sequence of reactions by merely changing the fluid composition. For example, take a rock at point (1) (fig. 3) with the assemblage phlogopite-calcite-quartz-plagioclase(an_{100}). As X_{CO_2} is decreased the rock will pass (if calcite and quartz are in excess) through the assemblages tremolite-K feldspar-calcite-quartz-plagioclase (which should go to tremolite-muscovite-calcite-quartz-plagioclase if the reactions are reversible), tremolite-muscovite-calcite-quartz-zoisite, tremolite-K feldspar-calcite-quartz-zoisite, diopside-K feldspar-calcite-quartz-zoisite, and wollastonite-K feldspar-diopside-zoisite-(quartz or calcite). One way to see this effect of fluid composition is to look at a gradient in CO_2/H_2O ratio produced at the contact between a limestone and a schist. Reactions in the schist evolve H_2O-rich fluids whereas reactions in a micaceous limestone generally evolve more CO_2-rich fluids. Therefore since the bulk fluid composition in general will be different, a potential gradient will exist with CO_2 being transported outward. The steepness of this will depend on the rate of diffusive mixing. At Stop #5 a qualitative example of this sequence may be seen. For the large central

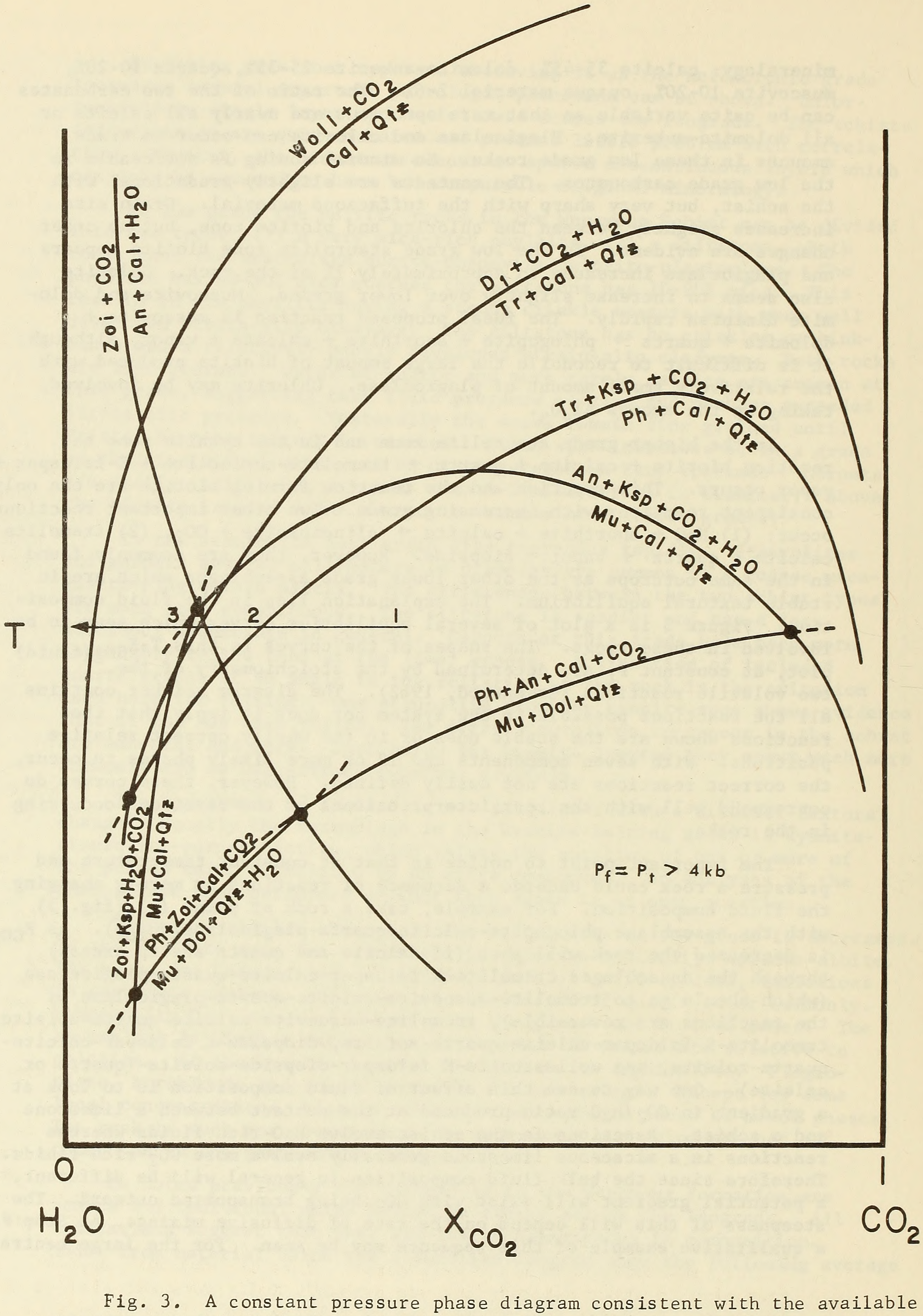

Fig. 3. A constant pressure phase diagram consistent with the available experimental data and the carbonate assemblages seen in western Connecticut. The arrow shows the gradient in X_{CO_2} suggested for the sample Wep-16c.

part of the unit the assemblage is biotite-tremolite-calcite-quartz-plagioclase(an_{43}). At the edges, where large quartz veins occur, the assemblage is diopside-clinozoisite.

Figures 4 and 5 are photographs of a sample from the kyanite zone near Stop #6. The unit is a thin limestone (≈10") in the Wepawaug Formation. The sample is of slightly greater than half the limestone plus the schist contact with 1-2 inches of the neighboring schist. The assemblages across the critical part of the sample are listed on figure 6. Some electron microprobe analytical data for the specimen are also shown. The sequence of assemblages corresponds to the path shown on figure 3 between points (2) and ≈(3). Locating point (3) is difficult because of bulk composition effects. The rest of the limestone has the same assemblage as the innermost carbonate zone shown on the diagram. A few millimeters further into the schist the stable assemblage is quartz-plagioclase-(biotite-chlorite)-muscovite with minor K-feldspar which vanishes farther on into the schist. This data implies a sharp gradient in the CO_2/H_2O ratio at the boundary with the values in the limestone and in the schist being relatively constant. If this is true, the rate of diffusive mixing is slow compared to the rates of production of the CO_2-rich fluid in the limestone and the H_2O-rich fluid in the schist. One further indication that major transport of chemical species has not occurred is that although potassium may have moved a few inches away from the limestone, the plagioclase compositions show that calcium has not been transported, in significant amounts, for more than a few millimeters.

See Figure 8 and the description of Stop #15 by Rosemary Vidale for an example of a layered calc-silicate rock in which movement of major rock components over distances of up to several centimeters can be demonstrated.

DESCRIPTIONS OF INDIVIDUAL STOPS

Refer to figure 7 for the location of all stops and consult figure 2 for their geologic position.

Stop #1 (18.39 N - 53.60 E) Amity Shopping Center, Conn. Rte. 63 at the Wilbur Cross Parkway, New Haven quadrangle.

An exposure of the Triassic unconformity is located at the north end of the outcrop. At this point the basal Triassic conglomerate overlies Ordovician Maltby Lakes Volcanics. The major portion of the outcrop exposes a volcanic unit of the Maltby Lakes Volcanics with a chlorite zone assemblage of epidote-actinolite-chlorite-albite. Numerous quartz and calcite veins are present. Note the abundance of green epidote-rich pods.

Stop #2 (20.16 N - 53.87 E) Lake Watrous on Conn. Rte. 69, Mount Carmel quadrangle.

This chlorite zone outcrop of the Wepawaug Schist exposes the three characteristic rock units of the Wepawaug: (1) a muscovite-chlorite-quartz-plagioclase phyllite with about 40% mica, (2) sandier beds with the same assemblage but with less than 20% mica, (3) brown-weathering micaceous limestone consisting mainly of calcite, dolomite, muscovite, and quartz. There are lenses of "Woodbridge Granite," which consists of plagioclase, quartz, muscovite, and minor K-feldspar. This trondhjemite appears intrusive in other outcrops but was probably tuffaceous material at this locality. Evidence for two periods of folding and a late episode of kink-banding can be seen.

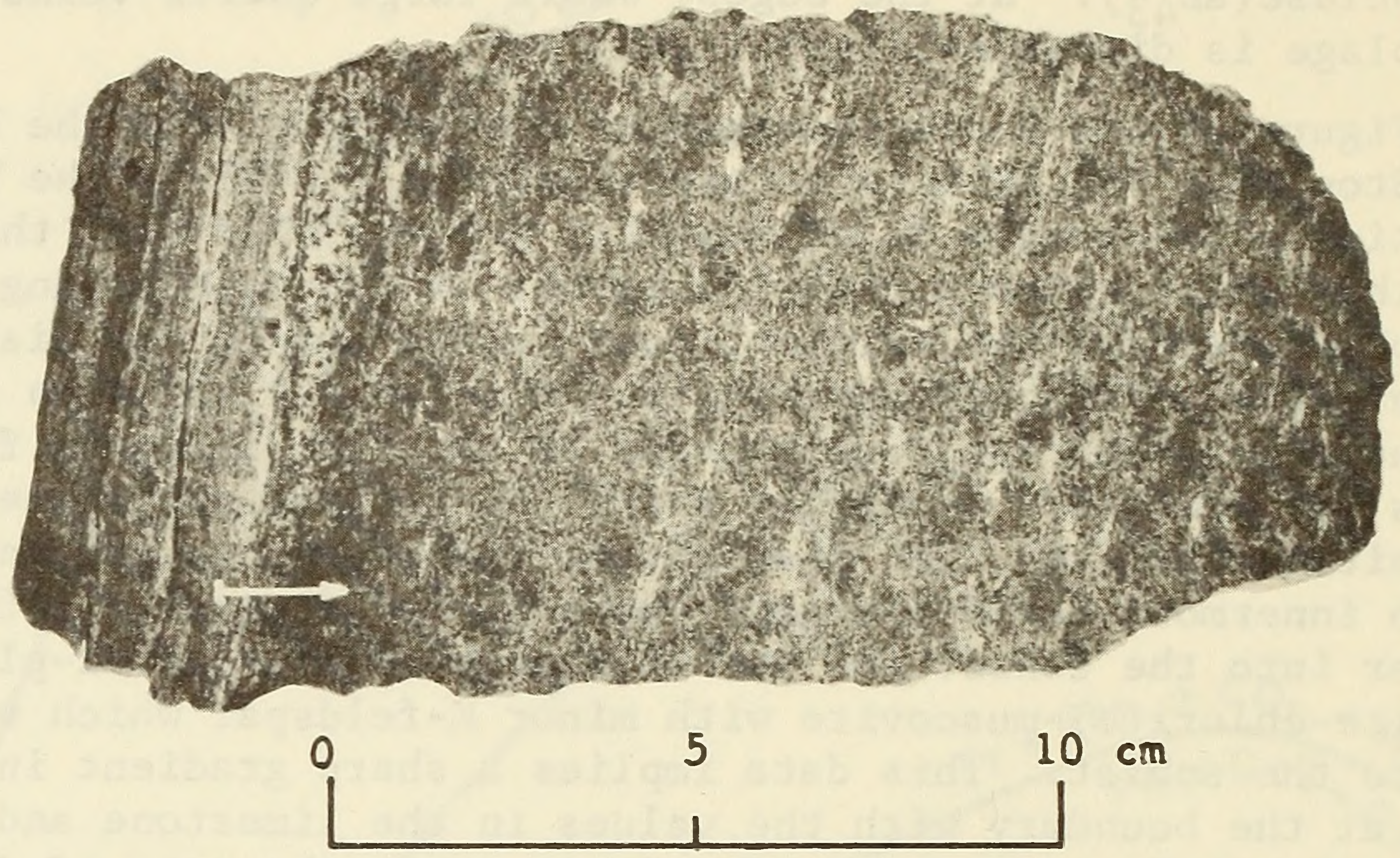

Fig. 4. Kyanite grade schist-micaceous limestone contact (Wep-16c). The arrow represents the path covered by the electron microprobe traverse.

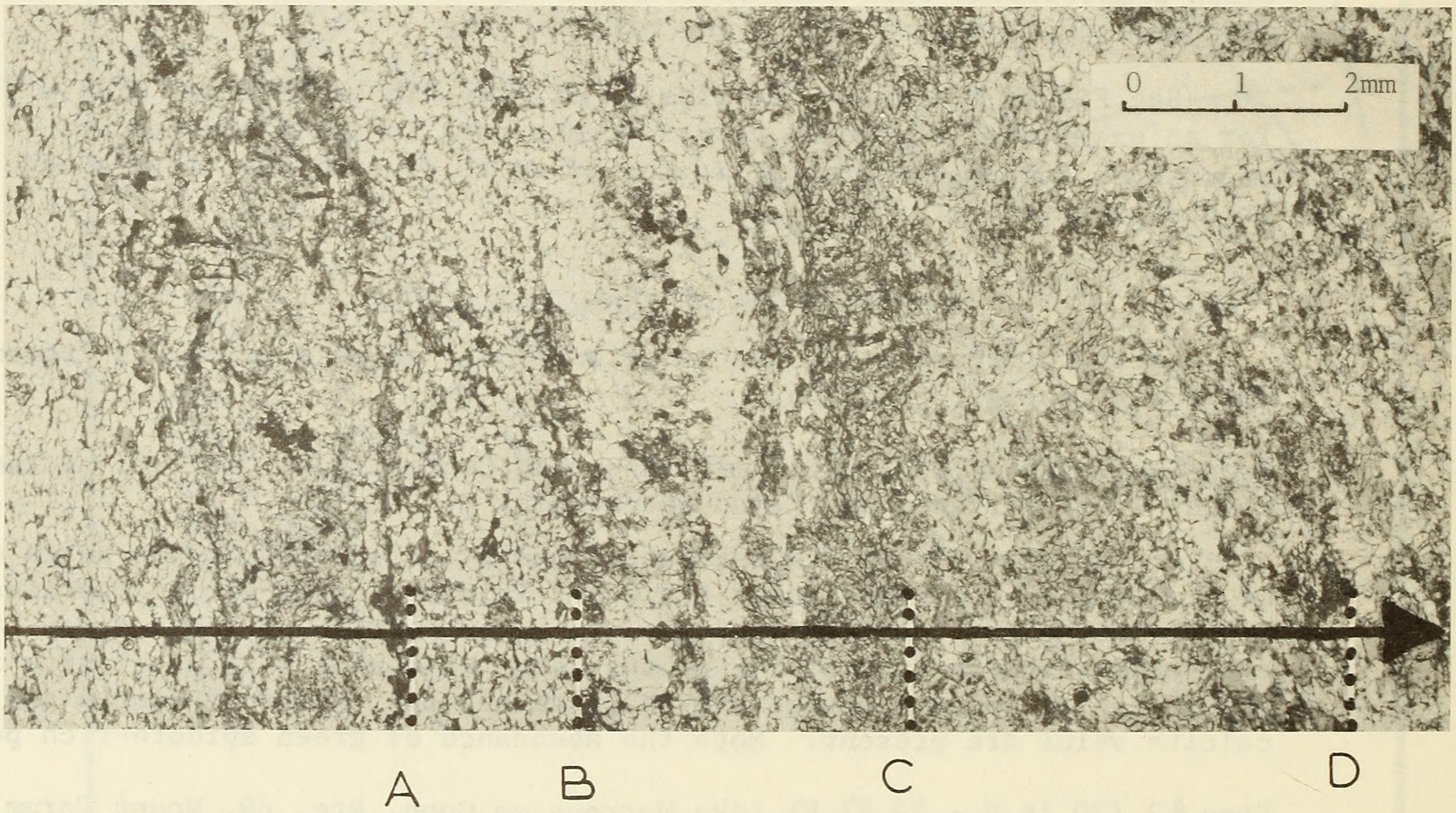

Fig. 5. Microphotograph of the polished electron microprobe section from sample Wep - 16c. The line represents the approximate microprobe traverse. The capital letters correspond to the zone boundaries shown in Fig. 6.

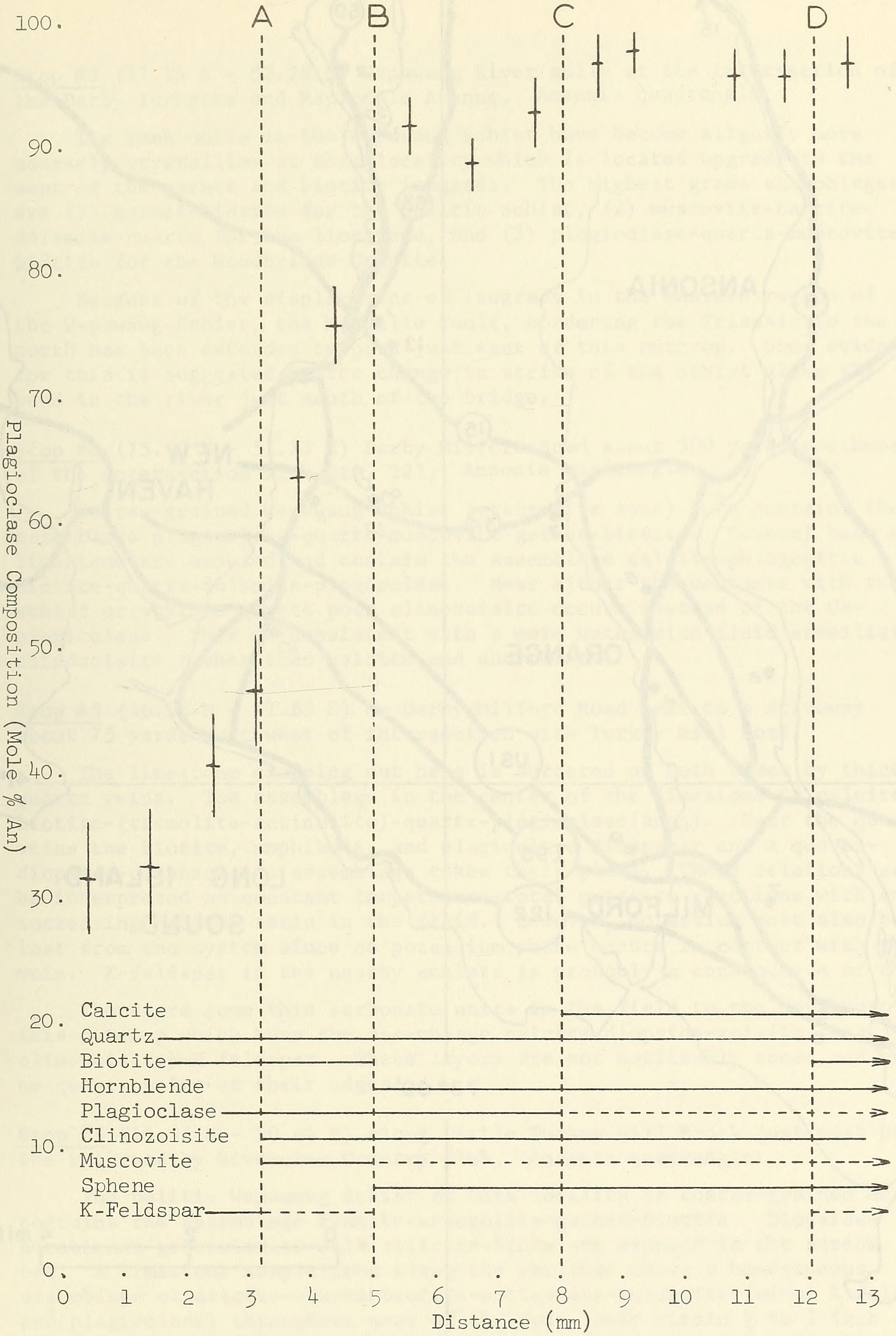

Fig. 6. Assemblages and plagioclase compositions determined in Wep-16c along the electron microprobe traverse shown in Fig. 5.

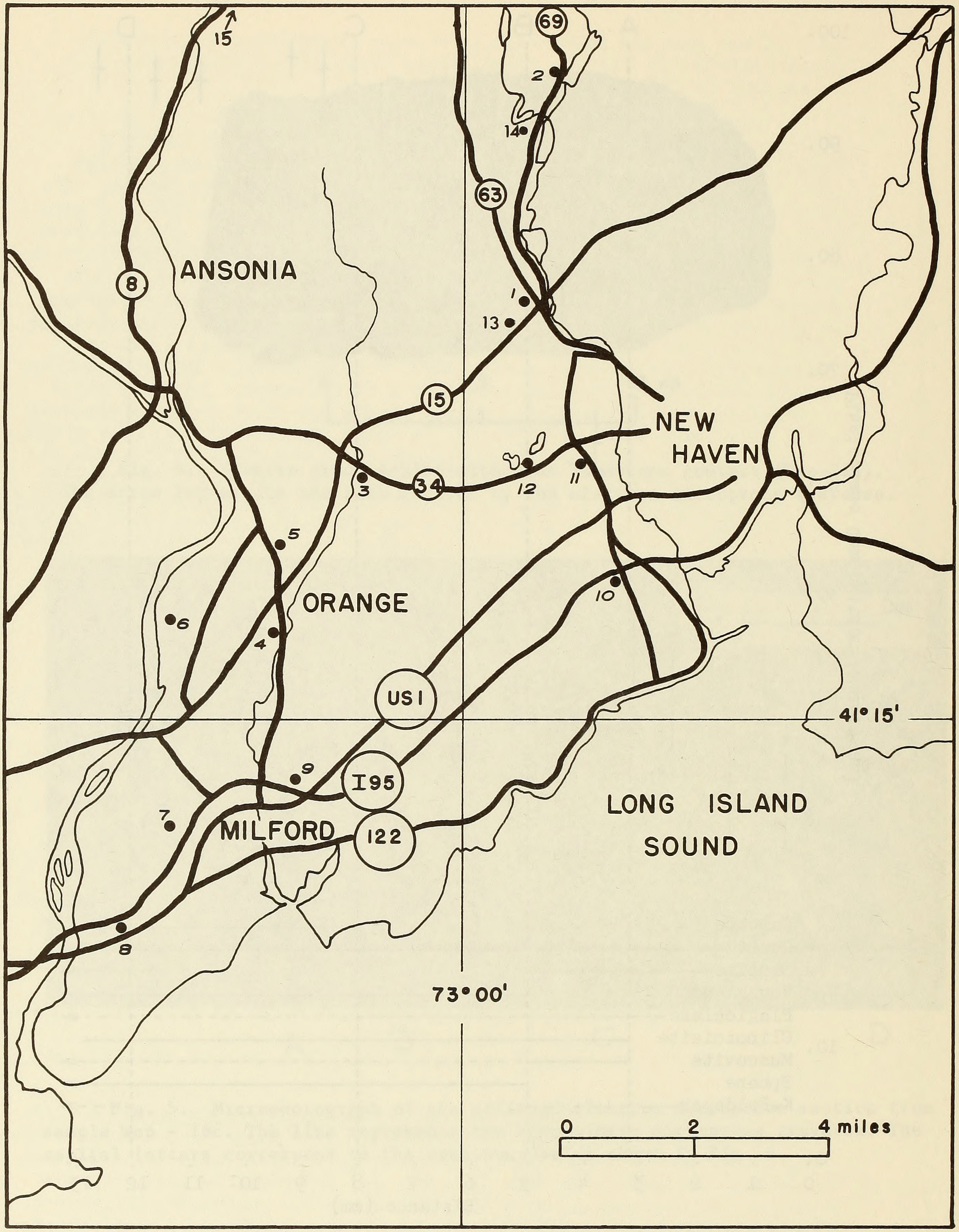

Fig. 7. Map showing location of stops.

Stop #3 (17.14 N - 52.29 E) Wepawaug River gully at the intersection of the Derby Turnpike and Mapledale Avenue, Ansonia quadrangle.

The rock units in the Wepawaug Schist have become slightly more coarsely crystalline at this locality which is located upgrade to the west of the garnet and biotite isograds. The highest grade assemblages are (1) garnet-biotite for the pelitic schist, (2) muscovite-calcite-dolomite-quartz for the limestone, and (3) plagioclase-quartz-muscovite-biotite for the Woodbridge Granite.

Because of the displacement of isograds in the eastern region of the Wepawaug Schist, the Mixville Fault, bordering the Triassic to the north has been extended to pass just east of this outcrop. Some evidence for this is suggested by the change in strike of the schist along the bend in the river just south of the bridge.

Stop #4 (15.92 N - 51.73 E) Derby Milford Road about 300 yards northwest of the intersection with Rte. 121, Ansonia quadrangle.

Coarse-grained Wepawaug Schist (staurolite zone) here contains the assemblage plagioclase-quartz-muscovite-garnet-biotite. Several beds of limestone are exposed and contain the assemblage calcite-phlogopitic biotite-quartz-dolomite-plagioclase. Near either the contacts with the schist or various quartz pods clinozoisite occurs instead of the Ca-plagioclase. This is consistent with a more water-rich fluid stabilizing clinozoisite rather than calcite and anorthite.

Stop #5 (16.52 N - 51.65 E) On Derby Milford Road next to a driveway about 75 yards northwest of intersection with Turkey Hill Road.

The limestone cropping out here is bordered on both sides by thick quartz veins. The assemblage in the center of the limestone is calcite-biotite-(tremolite-actinolite)-quartz-plagioclase(an_{44}). Near the quartz veins the biotite, amphibole, and plagioclase disappear and a quartz-diopside-clinozoisite assemblage takes their place. These relations can be interpreted as constant temperature-total pressure reactions with an increasing H_2O/CO_2 ratio in the fluid. However, potassium must also be lost from the system since no potassium phase occurs in contact with the vein. K-feldspar in the nearby schists is probably a consequence of this.

There are some thin carbonate units in the field to the northwest of this outcrop which have the assemblage calcite-diopside-zoisite (and clinozoisite)-K feldspar. These layers are not noticeably zoned and have no quartz veins at their edges.

Stop #6 (15.97 N - 50.84 E) Along Little Turkey Hill Brook just west of the railroad by Riverview Country Club, Ansonia quadrangle.

The pelitic Wepawaug Schist at this locality is coarse-grained and contains the assemblage kyanite-staurolite-garnet-biotite. Diopside-hornblende-grossularite-calc-silicate bands are exposed in the stream bed. A limestone sample from along the railroad shows a homogeneous assemblage of calcite-quartz-biotite-actinolite-muscovite-(minor K-feldspar and plagioclase) throughout most of the bed. Only within ½ to 1 inch of the sharp contact with the schist is biotite eliminated for actinolite and Ca-plagioclase for clinozoisite. Diopside does not occur. K-feldspar is concentrated in the schists near the contact. These narrow reaction zones are seen in other samples where veins do not occur at the contact. This can be interpreted as evidence for sharp gradients in the CO_2/H_2O ratio near the contact with the schist and that the rate of transport of CO_2 away from the carbonate is not significantly greater than the rate of production.

Stop #7 (14.38 N - 49.84 E) 400 yards east of the intersection of Rutland Road and Ford Street, Milford quadrangle.

This exposure on the kyanite isograd illustrates the highest-grade Maltby Lakes Volcanics observed on the trip. The dominant assemblage is hornblende-plagioclase-epidote-quartz. Streaks of epidote are common here, as they are at lower grades, but the rock as a whole is apparently much more homogenized and the distinctive and obvious pods of epidote are missing. It is believed, however, that this is the same unit of the Maltby Lakes Volcanics as seen at Stop #1.

Stop #8 (13.57 N - 50.52 E) Interchange 34 of the Connecticut Turnpike, Milford quadrangle.

Because of lack of outcrop around the southern end of the Wepawaug syncline and the change in metamorphic grade in this same general region, it is difficult to correlate the Derby Hill Schist with the Savin Schist as has been proposed. In addition the schist is difficult to differentiate from the Wepawaug Schist in many places. The generally less aluminous nature, the occurrence of quartzitic layers, and the somewhat gneissic pinstripe portions of the Derby Hill Schist are the characteristics used to differentiate it from the Wepawaug. The rock is aluminous enough for kyanite to occur in some places but normally the pelitic assemblage is garnet-biotite ± chlorite.

Stop #9 (14.69 N - 51.84 E) Burnt Plains Road overpass at the Connecticut Turnpike, Milford quadrangle.

The Maltby Lakes Volcanics are exposed here between the pelitic garnet and biotite isograds. The homogeneity is intermediate between the chlorite and kyanite zone outcrops previously described. The assemblage is chlorite-epidote-actinolite-albite.

Stop #10 (16.31 N - 54.31 E) Intersection of Campbell Avenue with exit ramp of Connecticut Turnpike Interchange 43, New Haven quadrangle.

This exposure of Savin Schist is typical for the formation and includes several of the minor lithologies found in this formation. The most common assemblage is albite-chlorite-muscovite-quartz. Massive greenstones contain albite-chlorite-epidote-calcite and are believed to represent tuffaceous layers. Light tan quartzite layers may represent thin chert beds.

Mesoscopic structures are especially prevalent at this locality. Best developed features include: tight folds of various sizes, strain-slip cleavage, refracted cleavage, and rare complexly refolded folds.

Stop #11 (17.17 N - 54.06 E) 800 yards southeast of the intersection of Derby Avenue (Conn. Rte. 34) and Forest Street, New Haven quadrangle.

This dark green, massive, porphyroblastic rock is representative of the major portion of the Allingtown Volcanics. Its typical chlorite zone assemblage is actinolite-epidote-albite-chlorite.

Stop #12 (17.11 N - 53.60 E) Along the divider strip of Derby Avenue (Conn. Rte. 34) just south of the area between the two southernmost lakes of Maltby Lakes, New Haven quadrangle.

The unit of the Maltby Lakes Volcanics exposed here in the chlorite zone is distinct from the unit seen at Stop #1. The rock type at this stop is a fine-grained, actinolitic greenschist with an assemblage of actinolite-albite-chlorite-epidote. Epidote is much less common in this unit than in the unit at Stop #1. Approximately 3000 feet further to the east along Derby Avenue one encounters a metasedimentary unit within the Maltby Lakes Volcanics. This quartzo-feldspathic schist has an abundance of quartz layers that are broken into individual pods and are parallel to a well-developed schistosity. The most common minerals are albite, quartz, muscovite, chlorite, and epidote.

Stop #13 (18.15 N - 53.51 E) Wilbur Cross Parkway about 1/4 mile west of Amity Center near the Fountain Street overpass, New Haven quadrangle.

The southwest end of the outcrop exposes a late normal fault in the greenschists of the Maltby Lakes Volcanics.

Stop #14 (19.76 N - 53.64 E) Dillon Road off Rte. 69 at Lake Dawson; about 100 yards south on the power line, Mount Carmel quadrangle.

The small lens-shaped body of tuffaceous-looking material is mapped as "Woodbridge Granite." The assemblage here is K-feldspar (50%)-chlorite-quartz-muscovite, whereas there is only minor K-feldspar in the main bodies of the "Woodbridge Granite." The rock contains inclusions of granitic material as well as pieces of phyllite, typical of the country rock.

Stop #15 (20.92 N - 51.18 E) Road cut on east side of Conn. Rte. 8, 0.6 miles north of the Seymour access road, Naugatuck quadrangle.

The calc-silicate band shown in Figure 8 is well exposed for a distance of about 50 feet. This band (Sample #RMV-9-65) is described in detail by Vidale (1968). It lies within a two-mica schist layer in the amphibolite unit between The Straits Schist and the Monroe gneiss. All three units may be seen in this road cut.

The calc-silicate band is symmetrically zoned as can be seen in Fig. 8. A 1600-count mode for each zone is given in Table 1. These modes are approximate because the zones are not homogeneous on the scale of a thin section. Table 2 and Figure 9 give the chemical composition of each zone. Cuts were taken from ground 50 gram slabs in an attempt to obtain representative samples for these analyses. Zone I was sampled several feet along strike from the rest in order to obtain a 50 gram slab. The other analyses are of one continuous sequence.

Plagioclase composition (by the method of Michel Levy) is about an_{25} in the two-mica zone (I); it ranges from about an_{25} to an_{45} going inwards across the biotite zone (II), and reaches an_{88} or higher at the center (zone VI). Garnet compositions determined from the unit cell edge and refractive index show that almandine decreases and grossularite increases from the outside toward the center of the band. Preliminary electron probe work on a kyanite grade calc-silicate band from the Hartland Formation (sample #RMV-7-65) shows similar overall trends in plagioclase and garnet

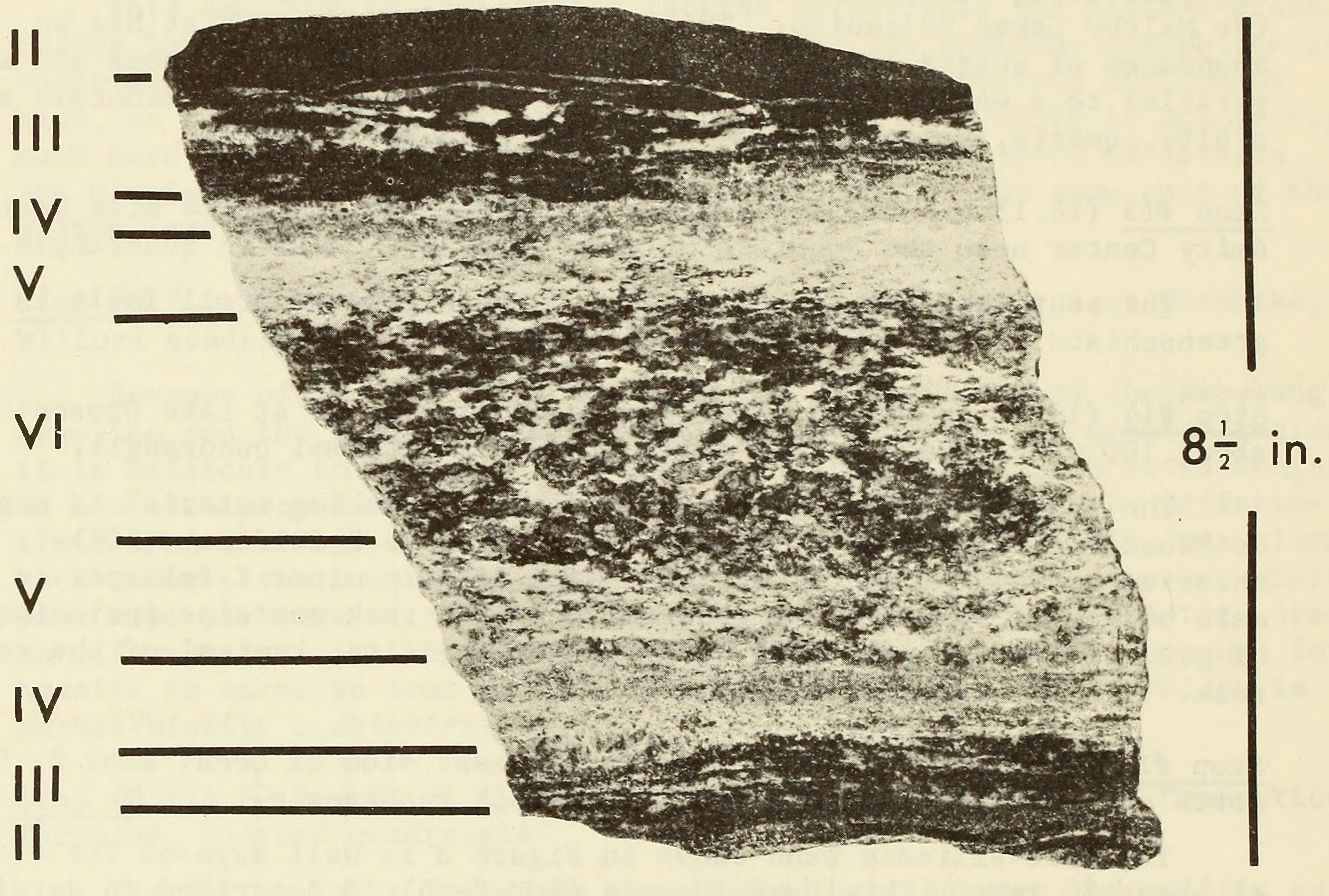

Fig. 8. Symmetrically zoned calc-silicate band at Stop 15 in road cut on Route 8, Seymour, Connecticut.

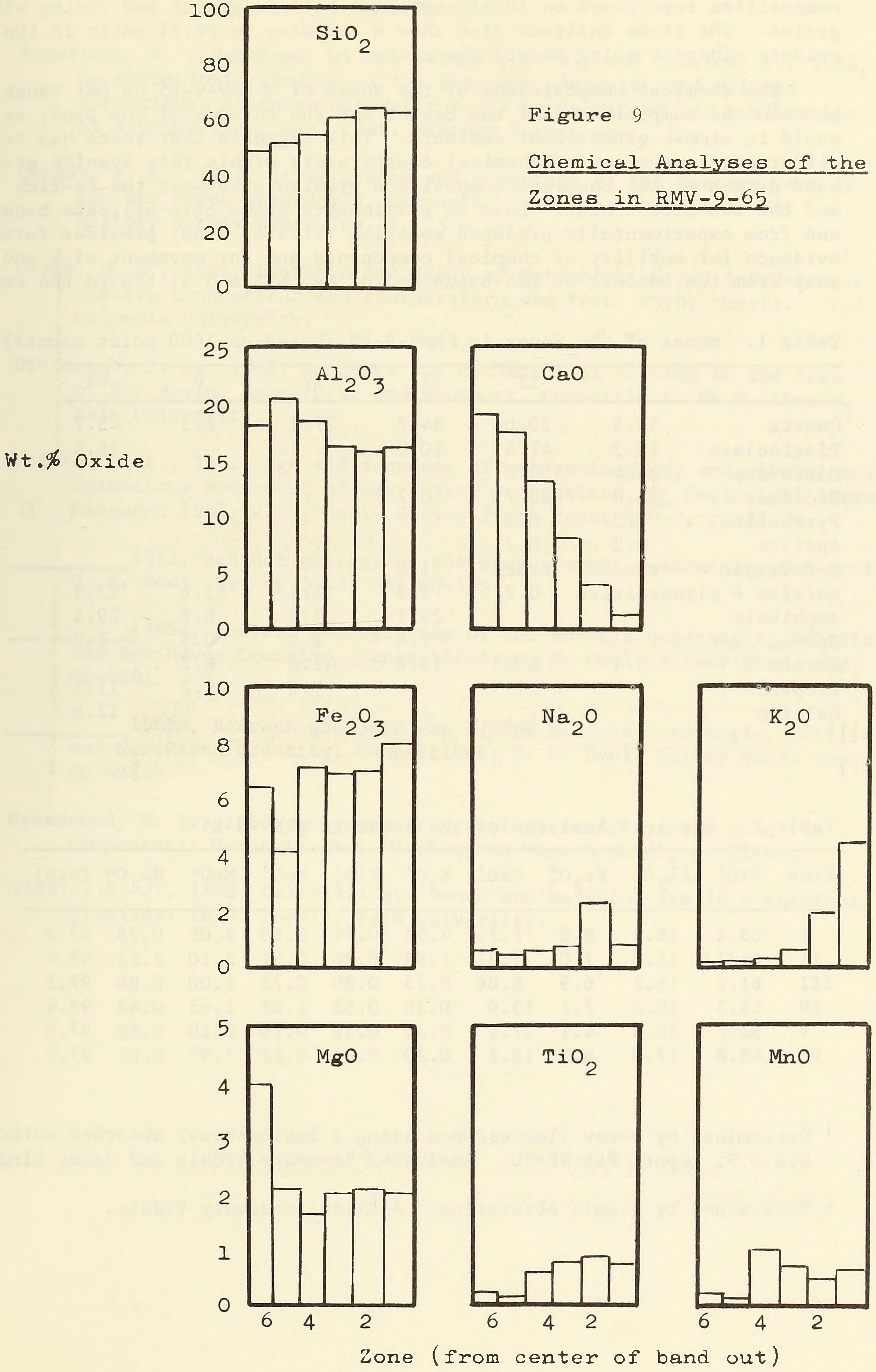

Fig. 9. Chemical analyses of the zones in RMV-9-65.

composition superposed on local variation between grains and zoning within grains. The probe analyses also show a decrease in Fe:Al ratio in the epidote minerals going toward the center of the band.

The chemical compositions of the zones of # RMV-9-65 do not range between the compositions of the center and the outside of the band, as they would in simple gradational contacts. This suggests that there has been differential movement of chemical constituents within this kyanite grade band driven by the chemical composition gradients between the Ca-rich layer and the two-mica schist. Data on sillimanite grade calc-silicate bands and from experimentally produced zonation (Vidale, 1968) provides further evidence for mobility of chemical components and for movement of K and Ca away from the centers of the bands and of Mg, Si, and Al toward the centers.

Table 1. Modes of the Zones in #RMV-9-65 (based on 1600 point counts)

	I	II	III	IV	V	VI
Quartz	33.5	20.0	34.2	27.1	7.3	5.7
Plagioclase	12.3	47.4	10.0			16.8
Muscovite	24.4	0.4				
Biotite	22.0	23.7	0.7			
Pyrrhotite	2.2	0.1				
Apatite	0.2	0.2				
K-feldspar	trace	trace	1.8			
Zoisite + Clinozoisite		0.2	1.2	11.4	65.6	23.3
Amphibole			29.1	7.2	6.2	29.4
Sphene			3.4	2.5	0.5	1.2
Garnet	5.4	8.2	19.6	42.6	8.2	
Diopside				9.2	12.2	11.1
Calcite						12.6

Table 2. Chemical Analyses of the Zones in #RMV-9-65

Zone	SiO_2'	Al_2O_3'	Fe_2O_3'	CaO'	K_2O'	TiO_2'	MnO'	MgO*	Na_2O*	Total
I	63.4	16.2	8.0	1.24	4.52	0.74	0.69	2.05	0.78	97.6
II	64.1	15.8	7.0	3.81	1.98	0.86	0.51	2.10	2.22	98.4
III	61.2	16.2	6.9	8.06	0.75	0.80	0.73	2.00	0.80	97.5
IV	55.5	18.6	7.1	13.0	0.30	0.63	1.02	1.65	0.68	98.4
V	52.2	20.5	4.1	17.5	0.25	0.19	0.16	2.10	0.58	97.6
VI	48.8	17.9	6.5	19.1	0.20	0.24	0.22	3.95	0.62	97.5

' Determined by x-ray fluorescence using a fusion-heavy absorber method, U.S.G.S. Report #66-WF-30. Analysts: Rosemary Vidale and James Lindsay.

* Determined by atomic absorption. Analyst: Rosemary Vidale.

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