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ORIGIN OF THE MOUNT MERINO CHERT AND SHALE, MIDDLE ORDOVICIAN, EASTERN NEW YORK STATE

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ORIGIN OF THE MOUNT MERINO CHERT AND SHALE, MIDDLE ORDOVICIAN, EASTERN NEW YORK STATE

A thesis presented to the Faculty
of the State University of New York
at Albany
in partial fulfillment of the requirements
for the degree of Master of Science

Dorothy M. Lang
1969

Acknowledgements

This study was undertaken at the suggestion of J. M. Bird, who recognized long before the writer the significance of the Mount Merino units, and who foresaw their relationship with New England vulcanism prior to recent stratigraphic and paleontologic studies. G. Putnam, W. Means, and, most intensively, J. M. Bird, reviewed the manuscript and made many helpful suggestions. The petrographic data and conclusions, however, are the writer's alone.

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ORIGIN OF THE MOUNT MERINO CHERT AND SHALE, MIDDLE ORDOVICIAN, EASTERN NEW YORK STATE

Abstract

Mount Merino Chert and Shale, Middle Ordovician, is one of the most siliceous units of the Taconic sequence (eastern New York and western Vermont); it is composed of interbedded shale, siliceous shale, argillite and chert. Non-clastic quartz - aggregates of quartz having a mosaic or felted texture - predominates in all beds, except shale. All siliceous beds are finely laminated; most laminae are distinguished from adjacent laminae by the texture of the quartz groundmass, and the amount of clastics, carbonates, chlorite and sulphides. Statistical comparison of the textures of the quartz aggregates which occur with the other mineral components suggests that the components of each lamina represent a stable mineralogic assemblage; the assemblages probably formed during silica precipitation and early diagenesis. These assemblages are compositionally-consistent with experimental data regarding the formation of authigenic minerals in the presence of colloidal silica.

Mount Merino rocks comprise a minor part of the Giddings Brook slice of the Taconic allochthon; the Mount Merino fauna is the youngest of the Giddings Brook slice rock sequence. Mount Merino rocks also occur as boulders and blocks in Forbes Hill Conglomerate, an autochthonous wildflysch-like terrain underlying the Giddings Brook slice.

Petrographic aspects of Mount Merino rocks indicate a "starved" depositional environment distant from an extensive land area. The predominant source of silica for the rocks was probably vulcanism (the Ammonoosuc volcanics) which became relatively intense during Mount Merino time, just preceeding emplacement of the Taconic allochthon.

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ORIGIN OF THE MOUNT MERINO CHERT AND SHALE, MIDDLE ORDOVICIAN, EASTERN NEW YORK STATE

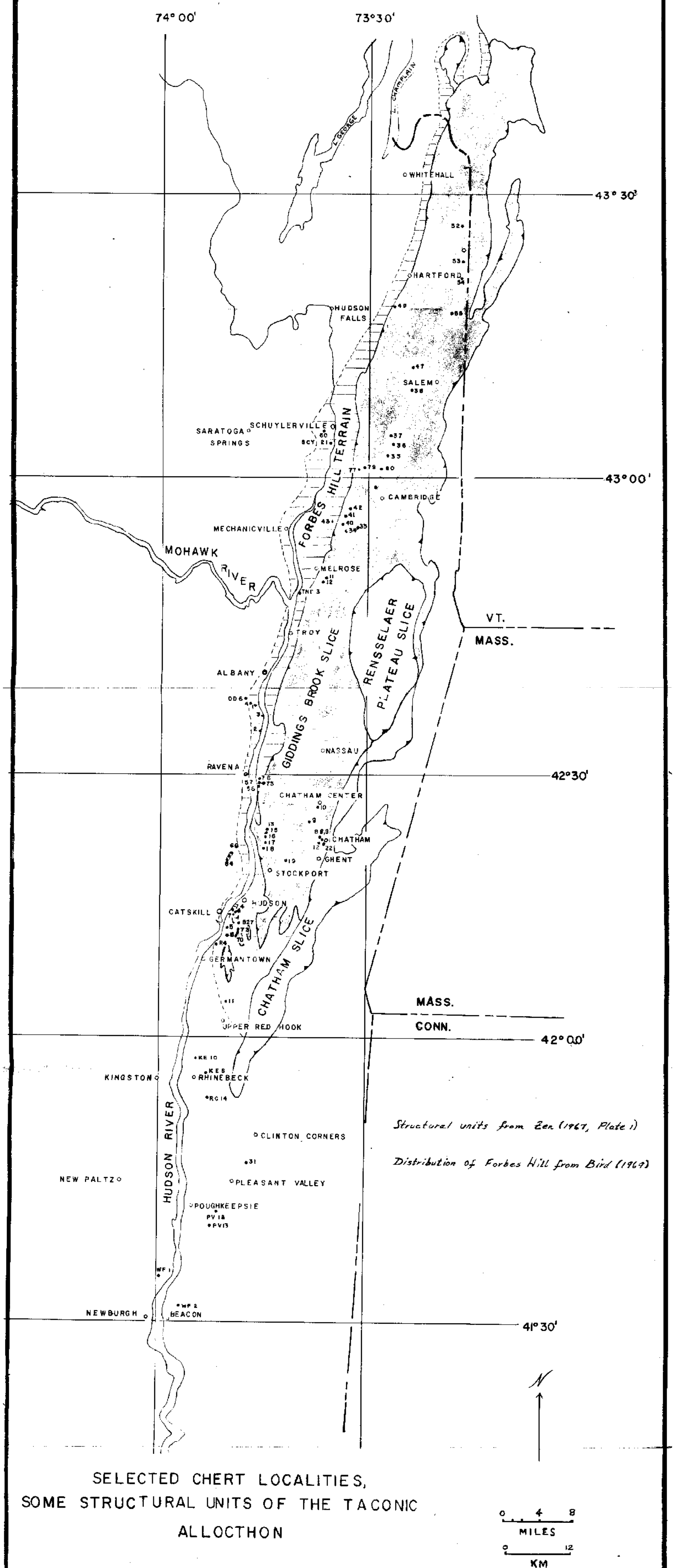
INTRODUCTION

Mount Merino Chert and Shale, one of the most siliceous units of the Taconic sequence (Zen, 1967, p. 8, 14-31) of eastern New York and western Vermont (Map 1), is made up of shale, siliceous shale, argillite and chert.

Taconic sequence rocks are predominantly shale, with interbeds of sandstone, limestone, and greywacke. This sequence overlies autochthonous (locally parautochthonous) shallow marine deposits - predominantly carbonate, with some quartzite (see Zen, 1967, p. 10 and Plate 2); the carbonate sequence ranges in age from Lower Cambrian into Middle Ordovician (see Zen, 1967, Appendix I). Taconic sequence rocks are both autochthonous and allochthonous (Zen, 1967). The autochthonous sequence - most of the Normanskill Shale with interbeds of Austin Glen greywacke - are entirely Middle Ordovician (see Zen, 1964, p. 12). Allochthonous Taconic sequence rocks - several formations (see Zen, 1967; Fig. 4, and text) - constitute the Taconic allochthon; these rocks range in age from pre-*Olenellus*, Cambrian? of Zen (1961), into Middle Ordovician.

The Taconic allochthon is made up of six or seven structural units, called slices (Zen, 1967; Fig. 4). Rocks comprising the allochthon were probably deposited in a region now at least partially occupied by the Green Mountain anticlinorium complex; at least the two earliest-formed slices - the Giddings Brook and Sunset Lake - were emplaced into the "Normanskill basin" (site of deposition of much of the autochthonous Taconic sequence) by gravity sliding (Zen, 1967). Giddings Brook slice

TACONIC REGION - EASTERN NEW YORK



SELECTED CHERT LOCALITIES,
SOME STRUCTURAL UNITS OF THE TACONIC
ALLOCTHON

MAP 1.

figure in thesis is a fold-out at larger scale - see separate pdf file linked on abstract page for this larger-scale map rocks have the longest age-span of sediments of the pre-"Taconic orogeny" phase of "off-shelf" sedimentation (Cambrian? into Middle Ordovician) (Zen, 1967, p. 16).

Zen (1961, 1967) and Bird (1969) concluded that stratigraphic and structural relationships of the "Normanskill" indicate that some of the Normanskill is genetically related to the emplacement of at least the Giddings Brook slice of the Taconic allochthon. Bird (1969) suggested that Austin Glen Graywacke, in the Normanskill, was deposited prior to, during, and after emplacement of the Giddings Brook slice, and some was deposited on the Giddings Brook slice during its movement. Wildflysch-like conglomerate and "slide-blocks" up to 5 miles long (Bird, 1969) characterize the Forbes Hill Conglomerate (Zen, 1961, p. 311) terrain (Bird, 1969). These "conglomerates" apparently formed during emplacement of the Giddings Brook slice, when boulders and blocks derived from both the Giddings Brook slice and (underlying) Normanskill-Austin Glen (Zen, 1967, p. 35) were deposited and/or intermixed at the "toe" of the slice (Zen, 1967, p. 68).

Mount Merino rocks comprise a minor part of the Giddings Brook slice (and its probably extension to south of Poughkeepsie; J. M. Bird, _pers. comm._); boulders and large slide-blocks of Mount Merino are fairly common in the Forbes Hill Conglomerate terrain. Shale of the Mount Merino contains graptolite assemblages characteristic of Zone 12 (_Climacograptus bicornis_) age (Berry, 1962), the youngest of the Giddings Brook slice (Bird, 1969); they are probably the youngest rocks deposited prior to tectonism which resulted in Giddings Brook-Sunset Lake gravity sliding (Bird, 1969).

Although the distinctive lithic aspects of the Mount Merino units have been recognized by many Taconic geologists, very little petrologic attention has been given these rocks. Therefore, the significance of these "anomalous" rocks has not been fully appreciated. The primary purpose of this thesis is to describe and interpret petrologic aspects of the Mount Merino rocks. The results suggest that many of the laminae represent hydrous silicate precipitates, deposited in a marine environment during a period when little clastic material was transported to the site of deposition. The petrologic aspects substantiate Bird's (1969) suggestion that the anomalous lithic character of the Mount Merino may be related to specific geologic events that just preceeded the Taconic gravity sliding.

Previous Studies

The name Mount Merino Chert and Shale was first used formally by Ruedemann (1942, p. 90). Rocks of Ruedemann's Mount Merino had previously been described by Mather (1843), Dale (1899, 1904), Ruedemann (1904, 1908, 1919, 1930), and Cushing and Ruedemann (1914); Dale (1899) first described petrographic characteristics of the rocks - the "Hudson red and green slate" and the "Hudson white beds".

Ruedemann and Wilson (1936) examined both "Normanskill cherts" and older "Deepkill cherts"; they concluded that the rocks were abyssal deposits, formed by the accumulation of colloidal silica derived from submarine or continental volcanic activity. Ruedemann and Wilson (1936) and Ruedemann (1942) described radiolarian forms observed in the cherts.

Ruedemann and Wilson (1936) and Ruedemann (1942) recognized that most Mount Merino rocks occur within a belt which trends NNE, and that typical Austin Glen rocks occur west of the belt. Ruedemann (1901, 1942) observed that shales of both units contain faunas characteristic of the "Lower Dicellograptus Zone". However, as pointed out by Ruedemann and Wilson (1936) and Ruedemann (1942), Austin Glen and Mount Merino rocks are not interbedded. In fact, Ruedemann's (1942) only evidence that a contact between them might exist are the few exposures of black siliceous shale containing thin sandy interbeds, that occur in the Mount Merino belt. These exposures, in addition to the faunal evidence, probably led Ruedemann (1942, p. 88) to designate the Normanskill Formation as being made up of Austin Glen and Mount Merino.

Goldring (1943), Craddock (1957) and Warthin (1949, 1953) described new Mount Merino localities and their stratigraphic relations. Berry (1962) studied graptolite faunal assemblages of Reudemann's Normanskill Shale; he found graptolite assemblages in Taconic rocks which correspond with his zones of the Mariavillas Chert and Shale of the Marathon region (Berry, 1960). Berry's (1962) study made possible the correlation of several units of the Taconic sequence.

Berry (1962) also found that many of Ruedemann's "Deepkill chert" exposures are correlative with parts of the Poultney Slate of the northern Taconic region, which contains some siliceous and arenaceous rocks (Theokritoff, 1964). The Poultney ranges in age from Early to Middle Ordovician (Berry, 1961); the youngest Poultney is Zone 12 in age, correlative with the Mount Merino (W. B. Berry, pers. comm. to E-an Zen, in Zen, 1964).

The Indian River (Keith, 1932, p. 403) red and green slate overlies the Poultney. It also is Zone 12 in age, and is lithically equivalent to red and green Mount Merino rocks (Bird, 1969).

Bird (1969) pointed out that the lithic characteristics of the upper Poultney and Mount Merino (including Indian River) suggest they are of the same facies - distinct from the younger, synorogenic Austin Glen facies. Bird (1969) suggested that the Mount Merino be assigned to the Poultney Formation.

Methods of Study

Samples of cherty rocks, including cherts, argillites and siliceous shales*, were collected from seventy-five relatively undeformed outcrops in areas mapped as "Normanskill" on the Geologic Map of New York (Fisher, et al, 1961) (Map 1); on this map, "Normanskill" includes the Mount Merino Chert and Shale, and the Austin Glen Greywacke. Precise locations of all sampled outcrops are listed in Appendix I, Table I. Gross bedding and lithologic characteristics were noted for each outcrop and an average of 5 hand specimens considered representative of each exposure, were collected for thin-section and x-ray diffraction analysis.

The outline of the structural units of the Taconic allochthon, determined by Zen (1967) and Bird (1969), were superimposed on the sampling map to determine the gross structural position of the Mount Merino rocks. Gross characteristics (bedding and lithology) of sampled exposures were compared to determine the extent of mineralogic and internal bedding variation between similar rocks which occur throughout the Taconic region.

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* The lithologic distinctions between chert, argillite, and siliceous shale discussed in this paper are as follows. The cherts have a hardness of about 7 (measured normal to bedding), conchoidal to sub-conchoidal fracture, and relatively smooth cleavage surfaces; some have a resinous lustre. The argillites have a hardness of about 6, sub-conchoidal fracture, slaty cleavage, and a slightly gritty cleavage surface. The siliceous shales have a hardness of 4-5, occasionally have sub-conchoidal fracture, but commonly have slaty cleavage, and generally appear slightly gritty on cleavage surfaces. The nomenclature of these rocks can be somewhat arbitrary because some beds are intermediate according to the above definitions.

PETROLOGY OF THE MOUNT MERINO CHERT AND SHALE

Most exposures of Mount Merino rocks are either red and green (hereafter, referred to as red-green), or green, grey and black (hereafter, referred to as green-black). The red-green units weather to red, green, and, rarely, brown; the green-black units weather to green, white, gold, black, tan and rust-brown.

Berry (1962) designated the red-green units Member 1 of the Normanskill Shale, and the green-black units Member 3 of the Normanskill Shale. Berry's Member 2 is black shale with interbeds of mudstone; it apparently is absent in the northern Taconic region. Lenses of black shale occur in the upper portions of the red-green units (Berry, 1962).

A conformable contact between red-green and green-black units was observed at only one exposure - Fly Summit, Washington County (80)*. However, both types of Mount Merino rocks are commonly exposed within small areas.

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* The number in parenthesis is the locality number used in this study. Locations of all locality numbers are listed in Appendix I, Table I.

Gross Bedding Characteristics

Contacts between beds of shale, siliceous shale, argillite and chert are sharp and planar; shale partings occur between some cherty* beds. Convolution, when present, usually only affects a single lamina within a bed. Although many outcrops are tightly folded, very little recrystallization or shear related to folding has occurred.

Three bedding assemblages have been observed:

1. Cherty beds 2 inches to 8 feet thick, but mostly thicker than two feet (Plate 1). Cherts and argillites predominate; shale partings (less than 1/8 inch thick) occur rarely. The red-green exposure at Fly Summit (80), Washington County, and the green-black exposure at Flint Mine Hill (67), Greene County, are typical of this assemblage. This assemblage is rare.

2. Cherty beds usually less than 2 feet thick, more commonly less than 6 inches thick; thicknesses vary less than 2 inches throughout most exposures (Plate 2). Cherts and argillites predominate; shale partings, or beds up to 2 inches thick, are common in some exposures, particularly those in the southern Taconic region. This assemblage is typical of black-green exposures, including that at the eastern approach to the Rip Van Winkle Bridge (7), Columbia County. One of the few thin-bedded, red-green exposures observed is in a road-cut on NY Route 9G about 1.1 miles northwest of Weys Corners (KE 10), Dutchess County.

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* The term cherty is used hereafter to collectively refer to all of the siliceous rocks - siliceous shales, argillites, and cherts.

3. Exposures comprised predominantly of siliceous shale, or shale (locally altered to slate) with subordinate or sporadic interbeds of argillite, chert, or mudstone, commonly less than 6 inches thick, and rarely up to 1½ feet thick (Plate 3). This assemblage is typical of most red-green exposures, including those 2 1/8 miles N8W of Granville (52), Washington County*, and 1 3/4 miles S30W of Chatham Center (9), Columbia County*.

A continuous stratigraphic section containing more than one of these assemblages was not observed during this study.

Most Mount Merino exposures observed in this study have less than 25 feet of strata. The thickest stratigraphic section observed is at Fly Summit (80), Washington County, and is approximately 125 feet thick. Berry (1962) estimated the total thickness of the Mount Merino units as 500-750 feet.

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* Graptolites collected from these localities by Berry (1962) are listed in Appendix I, Table 2.

Internal Bedding Structures

Each bed of cherty Mount Merino examined is comprised of thin, mineralogically distinct laminae and lenses. Although most laminae are less than an inch thick, thicknesses vary markedly with no apparent regularity. Also, although the laminae are discernible in some hand specimens, more obvious, relatively thick "color bands" (shades of red-brown, green and black) parallel bedding (Figure 1, Plate 4) and obscure the scale of lamination; the color bands are commonly 1 to 5 inches thick.

Contacts between laminae are either planar or slightly undulatory, and knife-sharp (Plate 6). In the few exposures where laminae could be traced laterally, even some less than 1/10 inch thick are regular and continuous throughout a distance of at least 30 feet (e.g. on the southwest side of Willard Mountain, 77, Washington County). Mineralogic variations between laminae are marked in thin-sections; however, there is no tendency for the rocks to break along laminae contacts. Plate 5 illustrates the typical configuration and scale of lamination, and several types of mineralogic and textural variation which commonly occur.

Mineralogically distinct lenses occur within most laminae (Figure 2, Plate 4; Plate 5); most lenses are less than 1/2 inch thick and 1½ inches long (rarely, up to 1 foot long in the thick-bedded units). Some, comprised solely of non-clastic quartz, appear to have resulted from post-depositional mineral segregation. However, some lenses contain distinctive clastic fragments and, less commonly, authigenic minerals, that are not present in the rest of the thin-section; these include radiolarian-like forms, silicate clasts, carbonaceous shreds, and euhedral carbonates (Plate 7). Each lense observed is completely within a lamina - none occur at the contact between laminae. Many lenses appear to have slumped, depressing the adjacent parts of the groundmass; this movement is implied by the alignment of clastic strings beneath the lenses, and the optical discontinuity of the adjacent groundmass. Also, localized disruption of the groundmass occurred when laminae ruptured or slumped (Plates 8 and 9).

A unique lamina was observed in an exposure of thin-bedded, red-green units northwest of Weys Corners (KE 10), Dutchess County. An irregularly bounded area less than 3 inches thick, which occurs within a 1½ foot thick chert bed, is comprised of subparallel, erratically convoluted, pink-weathering elongate lenses, within a green matrix (Figure 1, Plate 10). The lenses are composed chiefly of rhombs of ferroan domite (hereafter, referred to as ankerite) and mosaic quartz (Figure 2, Plate 10); the matrix is composed of granular clay, mosaic quartz, and subsidiary ankeritic rhombs.

Rarely, a rounded chert fragment was found in thin-sections of chert and argillite (Plate 11). The texture of each fragment observed is uniform; none contained organic material. The roundness of the fragments suggest they were easily abraded, though at least partially crystalline, prior to deposition.

Nodules of calcium phosphate (XPDF card # 11-232, diffraction peaks) up to 1 inch in diameter were observed at one locality (7).

Mineralogy

Most of the laminae are composed chiefly of non-clastic quartz - i.e. aggregates of quartz crystals of various shapes. These crystalline aggregates exhibit several textures (Plates 12-15):

(1) quartz crystallites less than .02 mm in length, interspersed in pale brown, granular, isotropic material (refractive index approximately 1.55)

(2) fine-size mosaic quartz, less than .02 mm in diameter

(3) coarse-size mosaic quartz, greater than .03 mm in diameter

(4) sparse, irregularly bounded, interlocking crystals less than .02 mm long, all elongate parallel to bedding, forming a "shredded quartz network"

(5) numerous, irregularly bounded, interlocking crystals, less than .02 mm long, all elongate parallel to bedding, forming a "spongey quartz network"

(6) felted masses of quartz which form a "semi-continuous quartz network".

The latter three textures exhibit mass extinction. Laminae characterized by each of the quartz textures listed above (and other mineralogic variations) are interbedded with each other within a single bed.

Most of the green-black beds are brown in thin-section; the color intensity, however, does not correspond with intensity variations in the hand specimen - some of the blackest laminae are colorless in thin-section. Often the mosaic quartz laminae are darker in thin-section than the quartz network laminae. Some laminae, which are green in hand specimen and exhibit mass extinction, are pleochroic from pale brown to dark brown; some of the red laminae are pleochroic from red to black (KE 10).

Most lenses are comprised of mosaic quartz, or quartz crystallites and isotropic material, but a few are comprised of the spongey and semi-continuous quartz networks; these latter occur within laminae of shredded quartz. This is a significant aspect for the interpretation of the origin of these rocks.

Subangular grains of quartz and feldspar less than .02 mm in diameter are present in most units. The grain boundaries of most are corroded. Twinned sodic plagioclase is common; microcline and zoned plagioclase are rare. These definitely clastic silicates constitute less than 5 percent of most siliceous laminae. Most commonly they are dispersed randomly throughout a lamina; some form single-grain stringers (Plate 5) which parallel bedding.

Clastic laminae less than 0.9 mm thick are common in the cherty beds (Plate 17). The constituent grains are larger - up to .04 mm - and more pervasively altered than the grains dispersed throughout the siliceous groundmasses. Most of the clastic grains are quartz and feldspar. Other clastic grains observed include chlorite, augite (40), hypersthene (9,13), garnet (13), biotite (green → brown → pale brown pleochroism), schorlite (blue → yellow pleochroism), microcline (13,17), apatite (9,13), rutile (1,33), and barite (3); these accessories constitute less than 5 percent of any of the clastic laminae. Many clastic laminae also contain angular carbonate grains up to .04 mm in diameter (Plate 17); in most laminae, the carbonate fraction is less than 15 percent, less commonly up to 50 percent (5,13), and rarely up to 90 percent (16,72).

Some laminae and lenses contain euhedral, subhedral and severely corroded carbonate grains less than .02 mm in diameter; within a single lamina, calcitic, dolomitic, and ankeritic carbonate crystals occur in each form*. These carbonate grains appear to float within the quartz groundmasses (Plate 18). The carbonate content commonly varies markedly between laminae; in a few laminae the percentage of carbonate changes gradually, normal to bedding**. It is not readily apparent whether these grains are clastic or authigenic; further, since both definitely clastic carbonate laminae and definitely authigenic laminae do occur, little information about the origin of these fine-size carbonates can be inferred from these other occurrences. It seems possible that some grains are authigenic, and some clastic; this may account for their chemical heterogeneity.

In several thin-sections, lenses with abundant fine-size carbonates occur in laminae which do not contain any carbonates (Plate 7, Figure 2). Fine-size carbonates occur in many laminae characterized by abundant spherules and rods of chlorite (chamosite?)*** (Plate 20); the groundmasses of these laminae are mosaic quartz.

A few laminae and lenses are comprised of large, euhedral carbonate

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* In most samples with carbonates, at least two carbonate minerals were sufficiently abundant to be identified by x-ray diffraction analysis.

** The relative proportions of each carbonate appear to vary between laminae, but no quantitative estimates could be made because of the fine particle size.

*** These "chlorites" have a shape commonly characteristic of chamosite. The relief is high, the refractive index about 1.64. X-ray diffraction peaks correspond with that of "chamosite", XPDF 7-315.

crystals - 0.2 mm to 0.9 mm in diameter - and mosaic quartz (Plate 16, Figure 1). Most are less than 1.5 mm thick.

Siderite (refractive indices 1.6-1.8) was conclusively identified optically only in the few thin-sections where it had a spherulitic form and comprised nodules. The nodules were surrounded by aggregates of euhedral pyrite and euhedral carbonate in a quartz matrix (Plate 19).

Pyrite occurs in most laminae either as euhedral crystals or irregularly shaped granules; granular aggregates are particularly abundant within some laminae (Plate 21). Pyrite selectively replaces the larger euhedral carbonates which characterize some laminae, and some spherulitic forms (discussed on the following pages).

Shredded carbonaceous material (identified by its dark brown color in reflected light) is commonly concentrated in thin, sharply delimitted laminae. A few shreds occur throughout most units.

Cryptocrystalline clay (identified by its matted texture and white color in reflected light, sometimes with red color where stained by hematite) is relatively abundant in the less siliceous units, but a minor constituent of the cherty rocks.

Laminae characterized by each of the minerals described above, occur in all of the cherty rocks. Apparently the tenacity of the bed is not affected by large amounts of clastic material or carbonate minerals. The rocks do not cleave along laminae contacts. No regional variation of any of the mineralogic components was recognized.

Organic Forms in the Cherty Mount Merino Rocks

Several types of organic forms were observed in the cherty Mount Merino rocks; they include - in order of decreasing abundance - (a) spine-like forms, (b) radiolarian-like forms, (c) spherules with smooth edges and (d) lenticular forms. Many of these forms were described in detail by Ruedemann and Wilson (1936) and Ruedemann (1942)*. In 1967, Robert Goll (Lamont-Doherty Geological Observatory) re-examined Ruedemann's collections and stated (pers. comm. to J. M. Bird) that few of the specimens could positively be identified as organic forms, because of their poor state of preservation. However, these forms occur within lenses in beds which do not otherwise contain the forms, and within distinct laminae. This distribution is similar to that of many of the mineralogic variables. Therefore, these forms are described briefly below.

The spine-like forms (Figures 1-7; Plate 22) are less than .03 mm in length and are comprised of coarse mosaic chalcedony (refractive index slightly less than quartz); they commonly occur in laminae and lenses with radiolarian-like forms. However, in one sample, a "spiculite" lens completely devoid of radiolarian (Figure 8; Plate 22), occurred adjacent to a lamina with radiolarian and spicules.

Most of the radiolarian-like forms are less than 0.2 mm in diameter (Plates 23-25). These are either substantially altered from mosaic quartz or chalcedony to granular isotropic material and chlorite, or partially replaced by pyrite; forms in several states of alteration were observed

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* Several faunas, including those reported by Ruedemann and Wilson (1936) and Ruedemann (1942), are listed in Appendix II, Table 2A.

within each lamina (Plate 23, Figure 1). Although small percentages of these forms are fairly common, "radiolarites" (units composed of more than 20 percent of these forms) (Plate 6) are relatively rare.

A few spheroids with strikingly smooth edges, 0.2 mm to 0.3 mm in diameter (Figures 1-3, Plate 26), are composed of coarse mosaic quartz, and have a core of pyrite. Some have a few granules of quartz in the core; others a smooth pyritic rim. They occur most commonly in pyritic units containing a large percentage of granular clay - units which only rarely contain radiolarian. Some of these forms, however, were observed in "radiolarian"-bearing units.

The smallest forms are all nearly perfect spherules (Plate 25; Figures 4-7, Plate 26). Most are composed of a single radial aggregate of chalcedony; less commonly, they are composed of two concentric shells, although still essentially a single radial aggregate. They are almost perfectly preserved in those units which contain severely altered radiolarian forms. They commonly occur with radiolarian but were observed in several laminae without radiolarian. They resemble (photographs of) spores reported from the Bigfork Chert (Ordovician) of the Marathon region of Texas, by Goldstein (1959).

Small lenticular forms with smooth sharp edges (Figures 8-10; Plate 27), composed of spherules of chalcedony, fibrous radial chalcedony, or isotropic material with quartz crystallites, occur in units with and without spherulitic or radiolarian-like forms. Long axes of these forms are usually not parallel to bedding. In several of these forms, composed of fibrous chalcedony, very small bifurcate joints truncate the crystal fibers.

Forms composed of pale brown, isotropic material with moderate positive relief are present in small amounts in nearly all thin-sections (Plate 28); the material is tentatively identified as collophane. Although present in many of the siliceous units, these forms appear to be more common in units which contain relatively abundant clastic material. The shapes of the forms are suggestive of plant fragments; their delicacy indicates that they probably were not severely agitated during transport.

Mineralogic Assemblages

In thin-sections of cherty Mount Merino rocks, each lamina is distinguishable from adjacent laminae by groundmass texture and constituent minerals. Study of these distinguishing features of the laminae indicate, additionally, that particular textures of the quartz groundmass are commonly associated with particular authigenic minerals and the amount and kind of clastic grains. Because of these relationships, more detailed interpretation of the origin of the rocks is possible, than would be on the basis of the distinguishing features alone.

Most of the laminae as well as their contained lenses are comprised of two to four "mineralogic components", i.e., authigenic and/or detrital minerals, and the quartz groundmass texture. Two hundred and eleven (211) compositionally distinct laminae and lenses were studied in fifty-seven (57) thin-sections*; for each of these laminae and lenses, the percentage of all mineralogic components of each was estimated optically. In order to determine the most common associations of the principle mineralogic components (those equal to or greater than 10 percent**), the following comparison was made:

(a) the number of times a mineralogic component occurred together with each of the other components, to

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* Within each thin-section, there are commonly several laminae and lenses of the same composition. However, since the purpose of studying the laminae was primarily to recognize the mineralogic variation which occurs between laminae, only each compositionally distinct lamina and lens was intensively studied. The number of mineralogically similar laminae within each thin-section was not recorded.

** Indicated hereafter as ($\geqslant$10%).

(b) the total number of occurrences of the component.

This comparison is expressed as a percent.

For example, 82 of the 211 analyzed laminae and lenses have a quartz network, or felted quartz groundmass. Forty-five (45), or 55 percent of these 82 samples, were comprised of both a quartz network groundmass and mosaic quartz; fourteen (14) of the 82, or 17 percent, were comprised of both clastic grains and a felted quartz groundmass. No laminae or lenses with a felted quartz groundmass (mineralogic component, ⩾10%) contained isotropic material or chlorite (chamosite?).

The results of this statistical comparison are summarized in Chart 1. Two types of data are included:

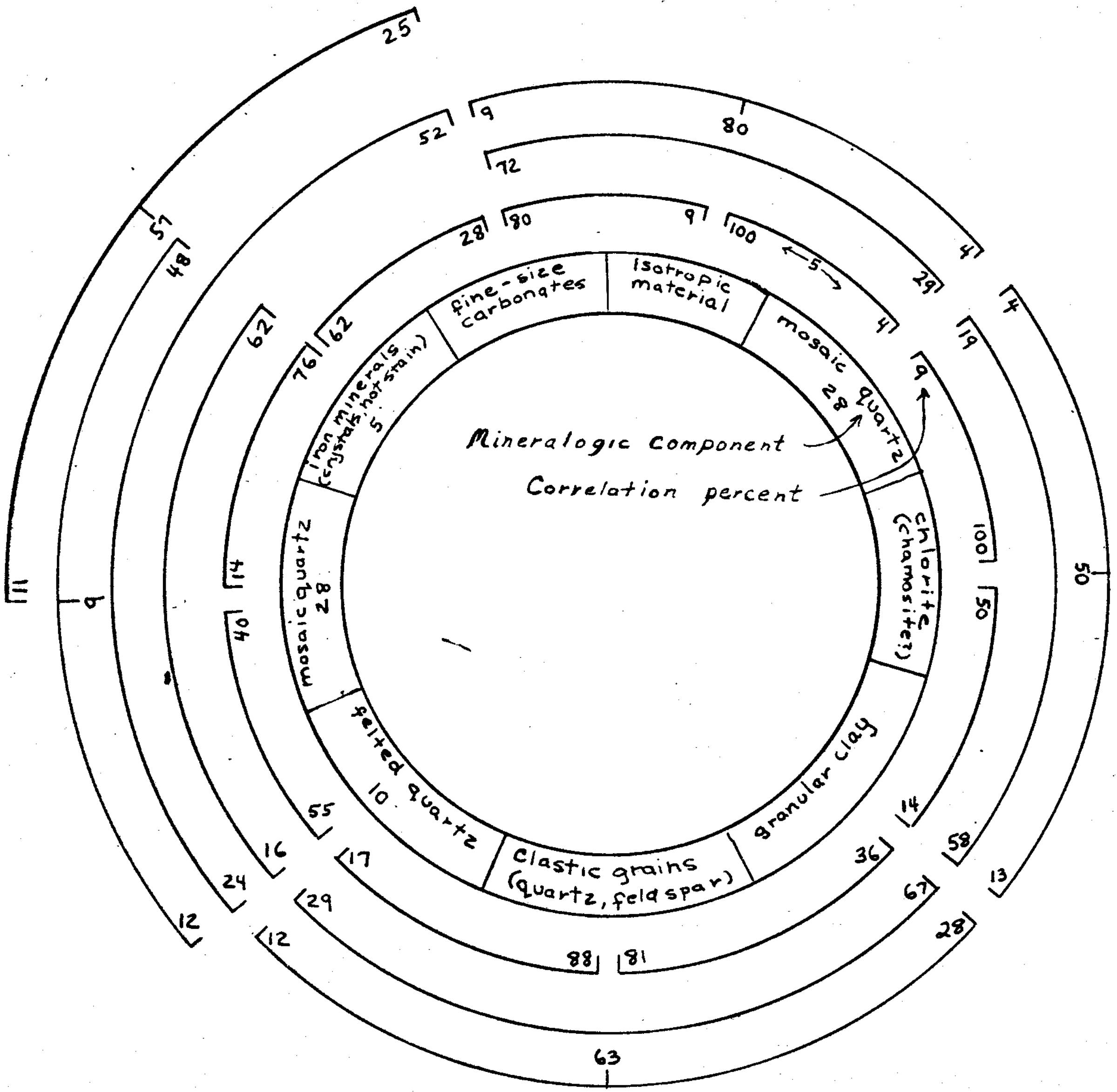
(1) The mineralogic component most commonly associated with a selected mineralogic component. The mineralogic component most commonly associated with a selected mineral component has the highest correlation percent. The number adjacent to each barb on the arcs of the correlation diagram is the correlation percent; the barbs and correlation percents are directly opposite the selected mineralogic component. Relatively high correlation percentages indicate the following:

(a) most laminae or lenses having granular clay (⩾10%) have a felted quartz groundmass (⩾10%) - this is indicated by the 67% barb which points towards "granular clay".

(b) most laminae or lenses containing clastic grains (quartz, feldspar) (⩾10%) have granular clay and a felted quartz groundmass (⩾10%) - this is indicated by the 88% and 81% barbs which point towards "clastic grains".

MINERAL ASSEMBLAGES :

Mineral components (≥10%) with correlation percentages greater than thirty percent: analysis of 211 lenses and laminae



See text for explanation of the chart.

CHART I.

(c) when chlorite (mineralogic component) makes up at least 10 percent of a lamina or lens, the groundmass is always mosaic quartz - this is indicated by the 100% barb on the chlorite-mosaic quartz arc.

(d) when isotropic material (mineralogic component) comprises at least 10 percent of a lamina or lens, the groundmass is always mosaic quartz - the 100% barb on the isotropic material-mosaic quartz arc.

(e) most fine-size carbonates occur with isotropic material - the 80% barb on the isotropic material-fine-size carbonate arc.

(f) most iron minerals occur in laminae of mosaic quartz - 76% barb on the iron minerals-mosaic quartz arc.

(g) most laminae are comprised of felted quartz with interstitial mosaic quartz - 40% to 55% barb on mosaic quartz-felted quartz arc. However, twenty-eight percent (28%) of the mosaic quartz laminae are comprised predominantly of mosaic quartz ($\geqslant$90%, because a principle mineralogic component is at least 10%, by definition); only ten percent (10%) of the felted quartz laminae are comprised predominantly of felted quartz ($\geqslant$90%).

(2) <u>The mineralogic associations of each component</u>. Several "mineral assemblages" occur in the Mount Merino cherty rocks. The associated mineralogic components, shown by arcs connecting barbs, are:

(a) fine-size carbonates-isotropic material-mosaic quartz

(b) mosaic quartz-chlorite (chamosite?)-granular clay

(c) granular clay-clastic grains (quartz and feldspar)-felted quartz

(d) felted quartz-mosaic quartz-iron minerals

(e) mosaic quartz-iron minerals-fine-size carbonates.

Similar mineralogic associations occur in both lenses and laminae; however, lenses are more commonly comprised of mosaic quartz, rather than felted quartz.

Plate 1: Thick-bedded Mount Merino units. Darker “laminae” are color bands; these occur sporadically throughout most beds.
(80, Cambridge 7½'Q.).

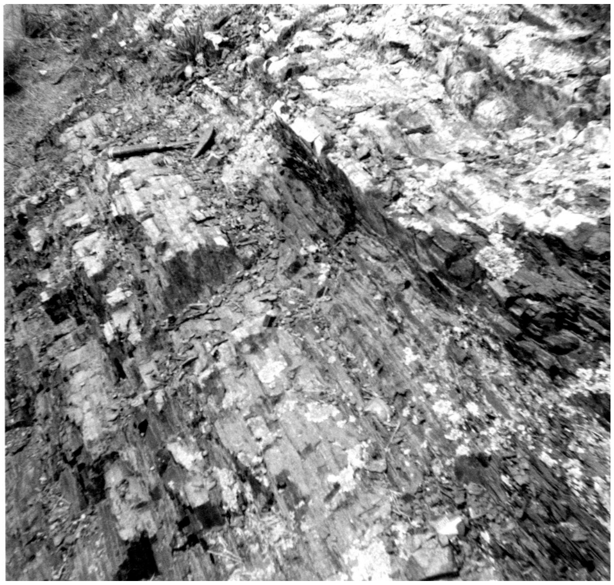


Plate 2: Thin-bedded Mount Merino units. The thicknesses of most beds are consistent throughout the exposure.
(17, Stottville 7½'Q.).

Plate 3: Mount Merino siliceous shale.
(9, Kinderhook 7½'Q.).

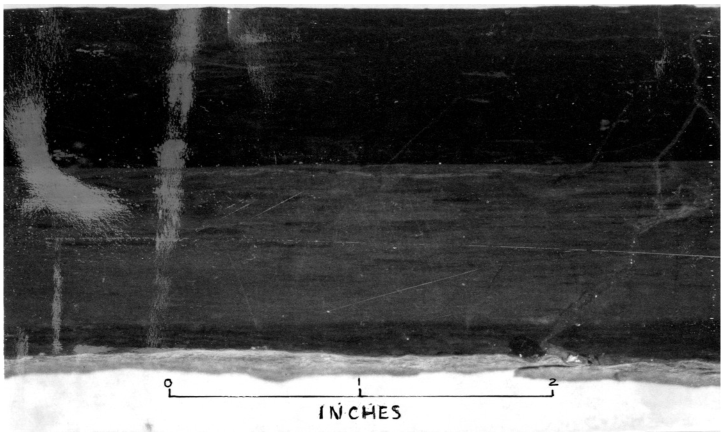


Plate 4, Figure 1: Broad "color bands" (see text) in a thinly laminated chert bed. The laminae are only distinguishable microscopically, and (in this bed) are less than 0.5 inch thick.
(12, Chatham 7½'Q.).

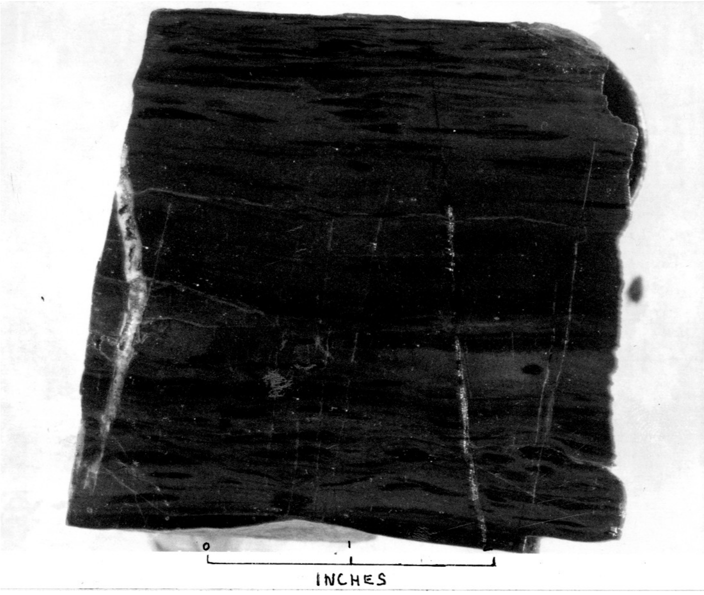
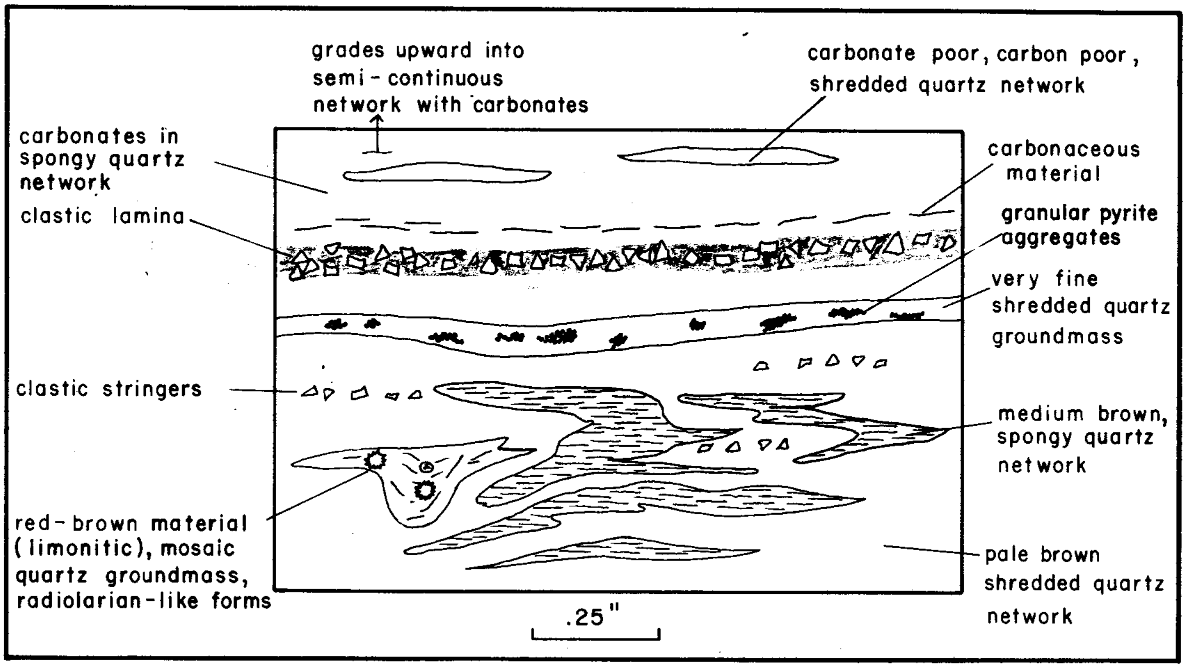


Plate 4, Figure 2: Lenses in chert. The lenses are readily visible only in the upper and lower portions of this hand specimen, though prominent microscopically, especially in the middle portion.
(64, Hudson North 7½'Q.).



Sketch of a thin-section of argillite (16C). The configuration and scale of mineralogic and textural variations is typical of cherty Mount Merino rocks.

PLATE 5

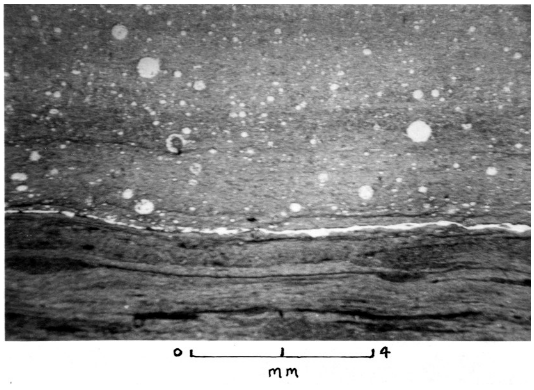


Plate 6: Smooth, sharp contact between a radiolarian-rich lamina (A) and another chert lamina (B). At the contact, there is a thin lamina of coarse mosaic quartz. Plane-polarized transmitted light (hereafter, PPTL).
(12, Chatham 7½'Q.).

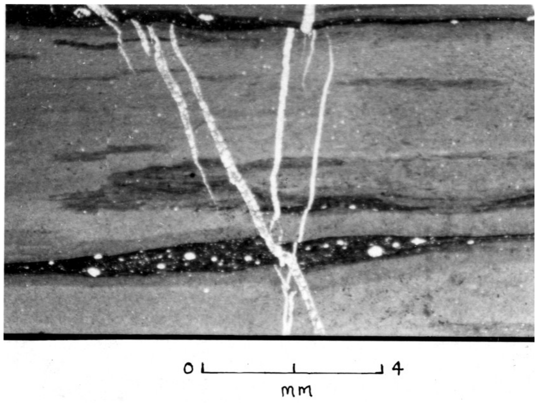


Plate 7, Figure 1: Radiolarian-bearing, carbonaceous lenses in laminae without radiolaria. PPTL.
(34E, Schaghticoke 7½'Q.).

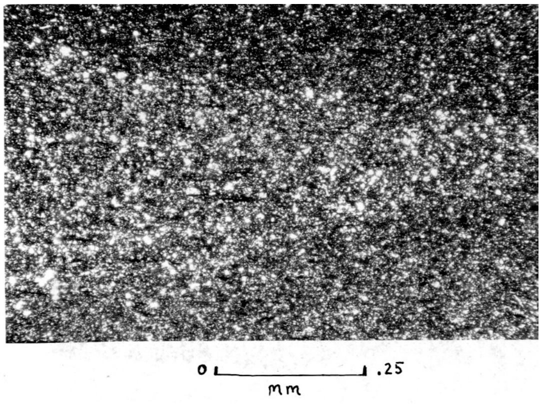


Plate 7, Figure 2: Carbonate-rich lens, indistinguishable in plane-polarized transmitted light from the surrounding quartzose groundmass. Crossed nicols (hereafter XN).
(33D, Schaghticoke 7½'Q.).

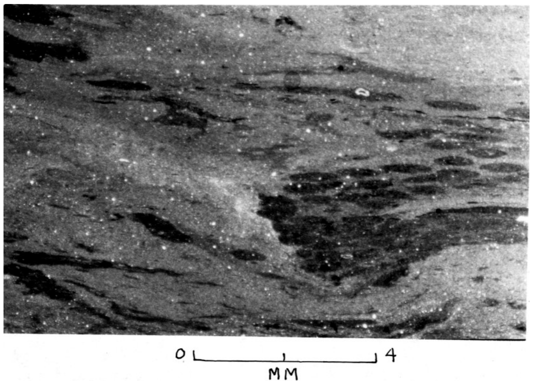


Plate 8, Figure 1: slumped lamina, underlying lenses of the same composition. The dark shadow is the area of the former position of the bed. PPTL.
(80A, Cambridge 7½'Q.).

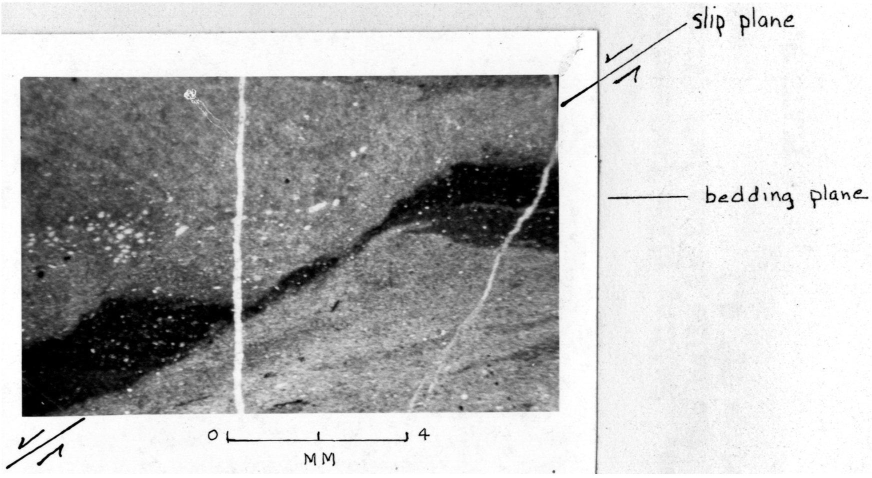


Plate 8, Figure 2: Pre-consolidation rupture and flow. The lower part of the dark lamina ruptrued; the upper part stretched. PPTL.
(71, Catskill 15' Q.).

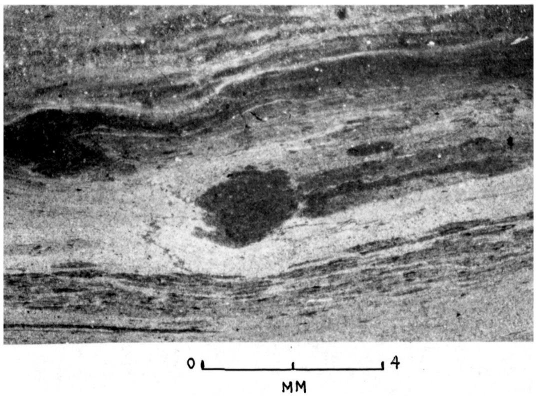


Plate 9, Figure 1:
(80A, Cambridge 7½'Q.).

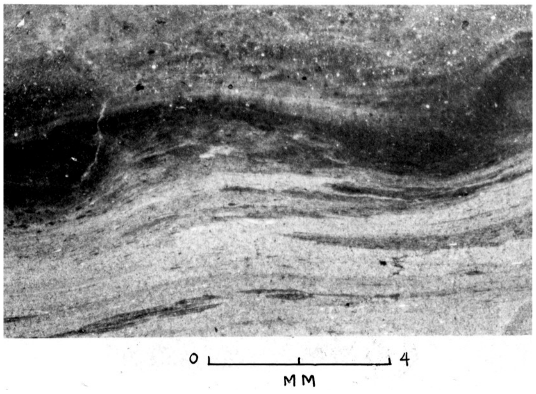


Plate 9, Figure 2:
(80A, Cambridge 7½'Q.).

Ball and swirl structures. Bedding plane (determined from adjacent, relatively undisrupted laminae) is horizontal. The balls in the upper photograph (Figure 1) appear to have been pulled from each other. PPTL.

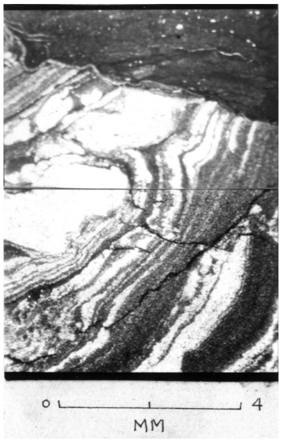


Plate 10, Figure 1: Convoluted laminae and lenses abut against a typical chert matrix. Bedding lineations in the chert laminae are horizontal. PPTL.
(KE10, Kingston East 7½'Q.).

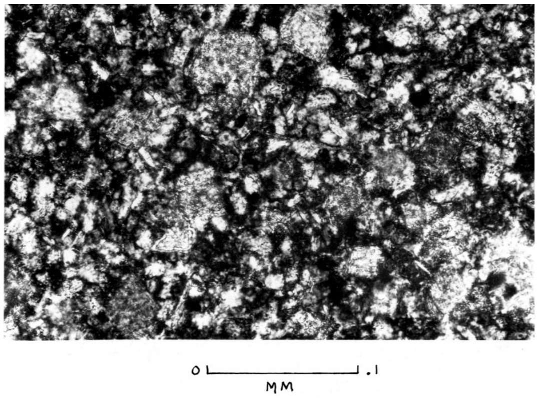


Plate 10, Figure 2: Mosaic quartz and rhombs of ferroan dolomite ("ankerite") which comprise the colorless, convoluted laminae and lenses in Figure 1. XN.

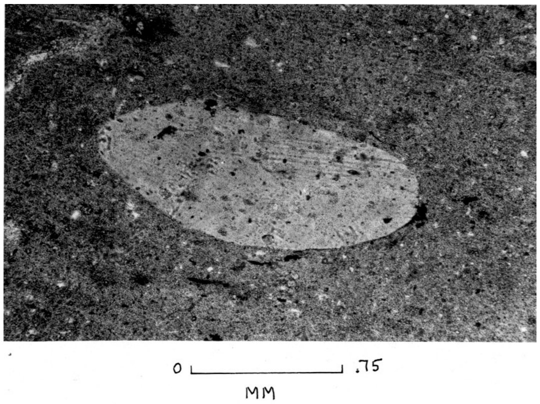


Plate 11, Figure 1: A chert fragment, with spongy quartz network groundmass, in a lamina composed of shredded quartz, and fine-size carbonate grains. PPTL. (7K, Catskill 7½'Q.).

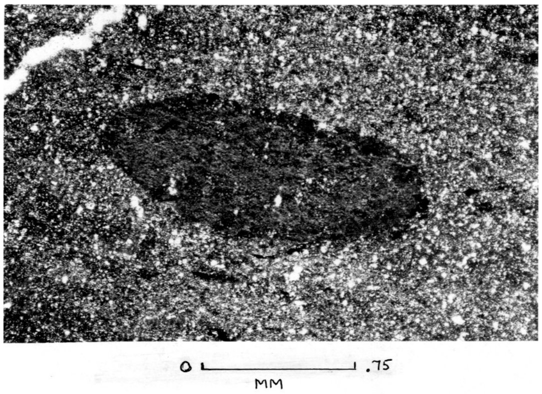


Plate 11, Figure 2: Chert fragment in Figure 1. XN.

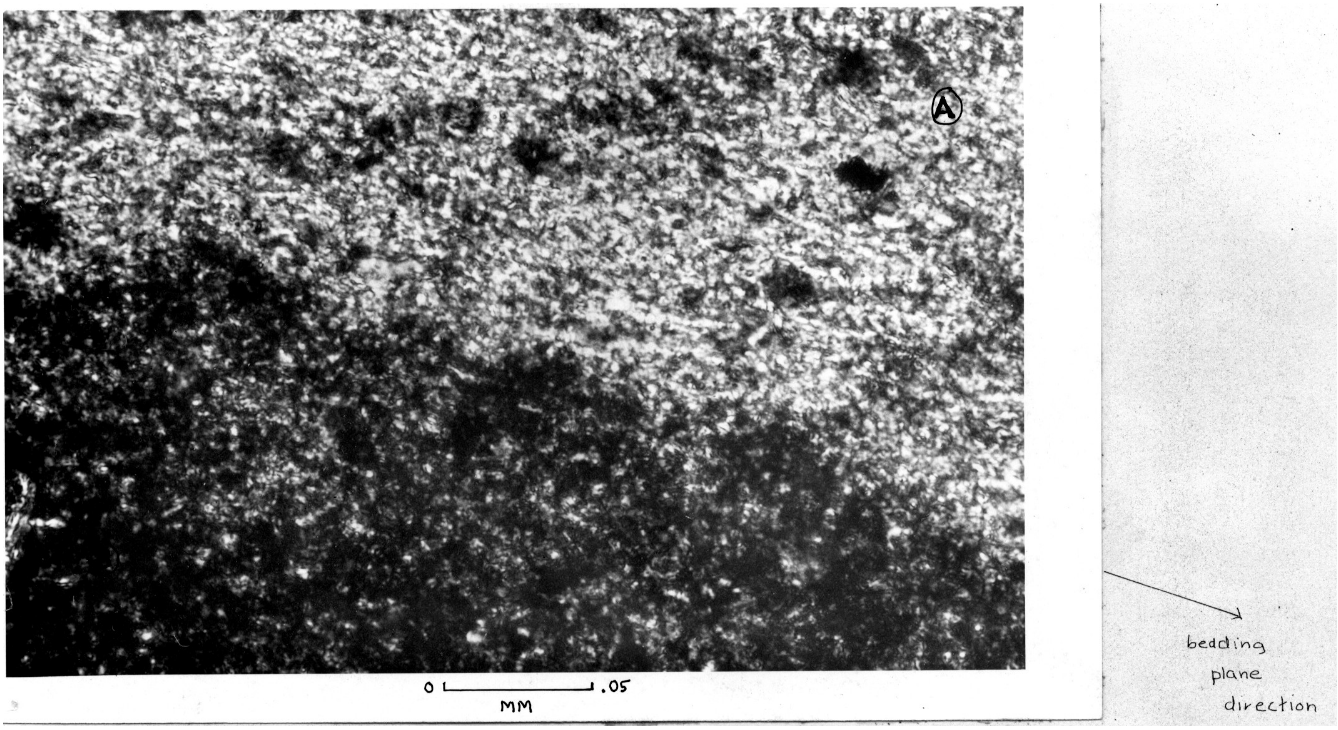


Plate 12: Lamina with a semi-continuous quartz network groundmass (A) in contact with a lamina of mosaic crystallites and granular isotropic material (B). XN.
(16C, Stottville 7½'Q.).

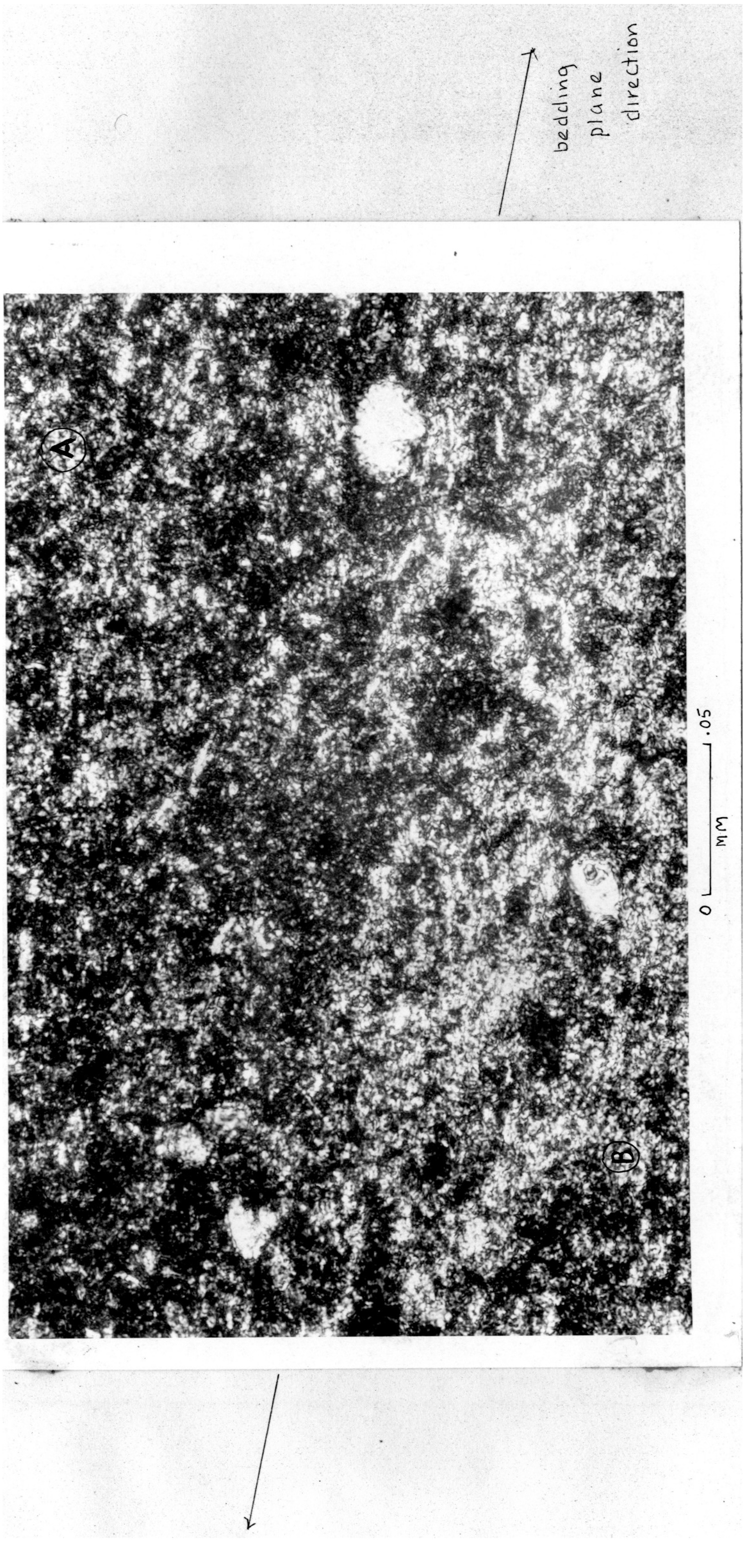


Plate 13: Lamina with a shredded quartz network groundmass (A) in contact with a lamina with a spongy quartz network groundmass (B). XN.
(1A, Delmar 7½'Q.).

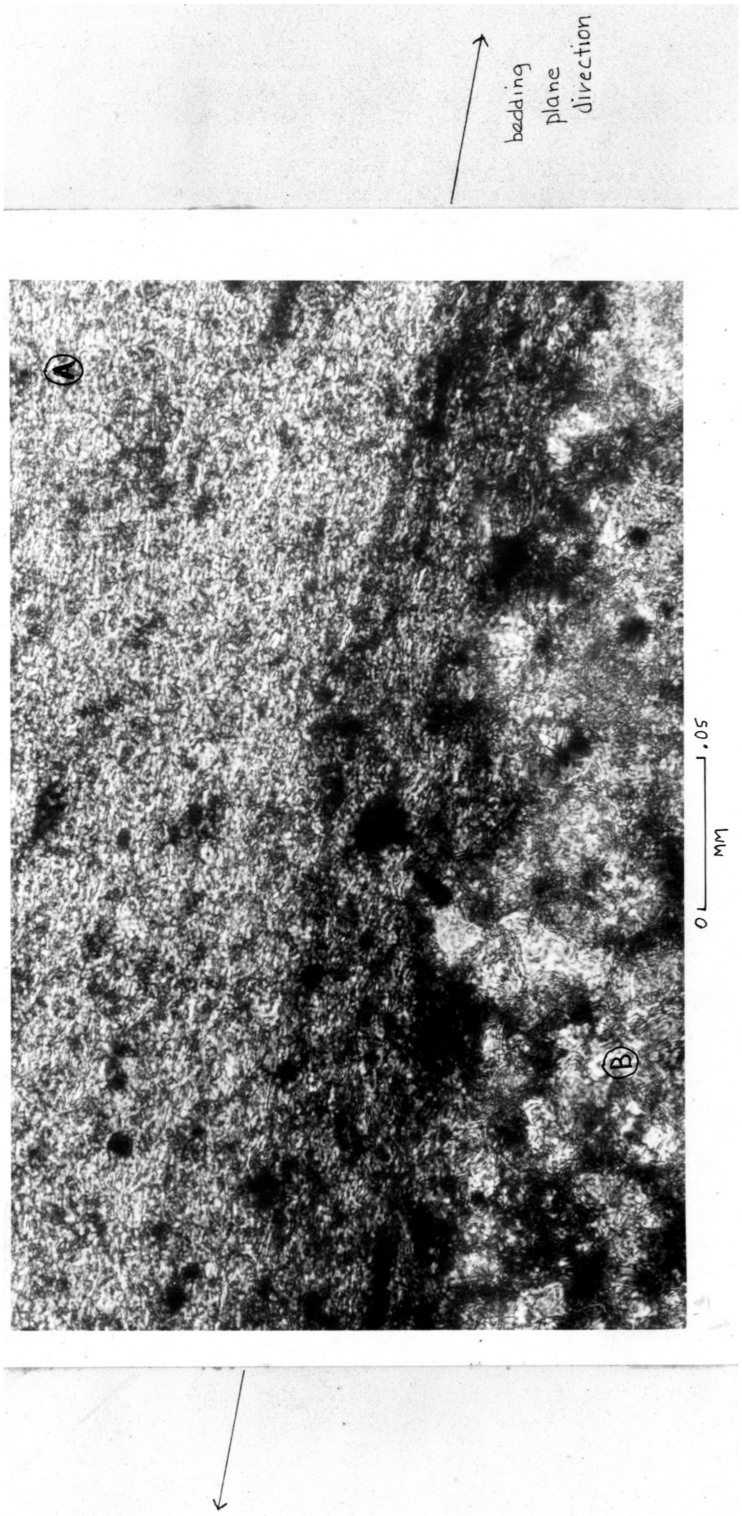


Plate 14: Lamina with a semi-continuous quartz network groundmass (A) in contact with a carbonate-rich lamina with a fine mosaic quartz groundmass (B). XN. (13C, Kinderhook 7½'Q.).

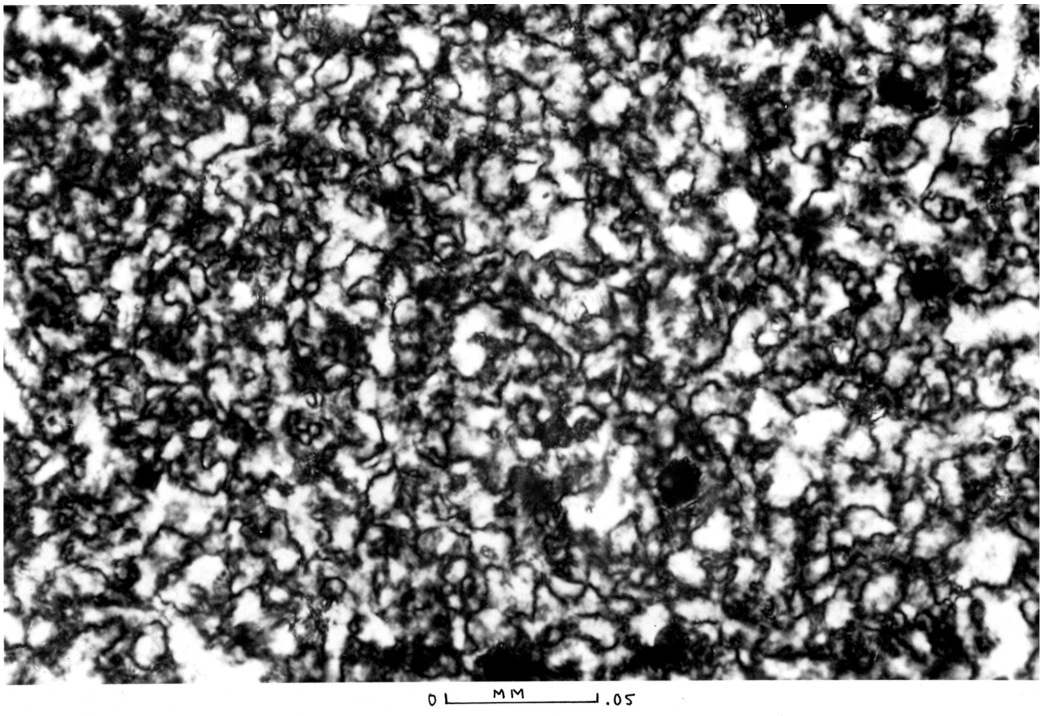


Plate 15: Coarse mosaic quartz groundmass. XN.
(12, Chatham 7½'Q.).

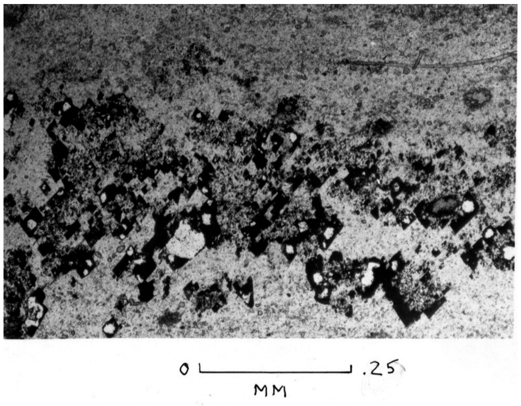


Plate 16, Figure 1:
(67B, Hudson North 7½'Q.).

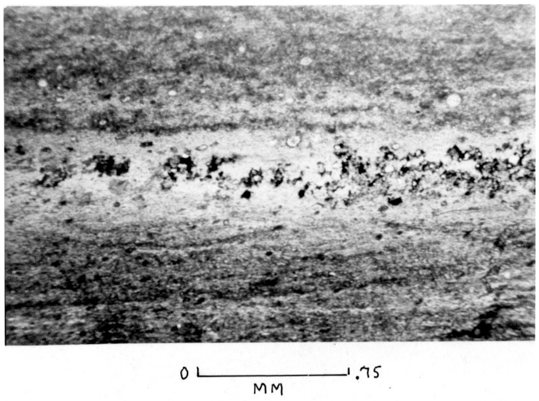


Plate 16, Figure 2:
(67B, Hudson North 7½'Q.).

A lamina composed of euhedral carbonate rhombs and mosaic quartz (A). Contacts with adjacent laminae are sharp and regular. PPTL.

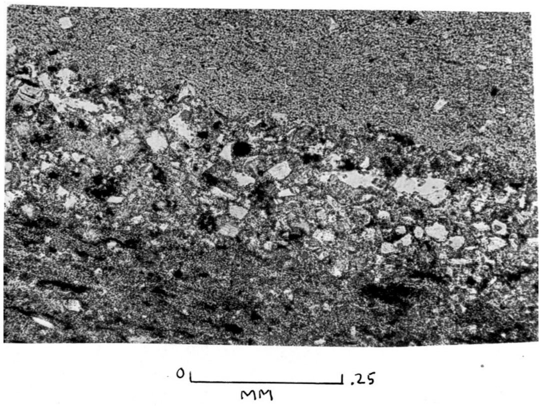


Plate 17, Figure 1: A thin, clastic lamina separating a carbon- and carbonate-rich lamina having a groundmass of mosaic crystallites from a lamina with a spongy quartz network groundmass. PPTL
(16C, Stottville 7½'Q.).

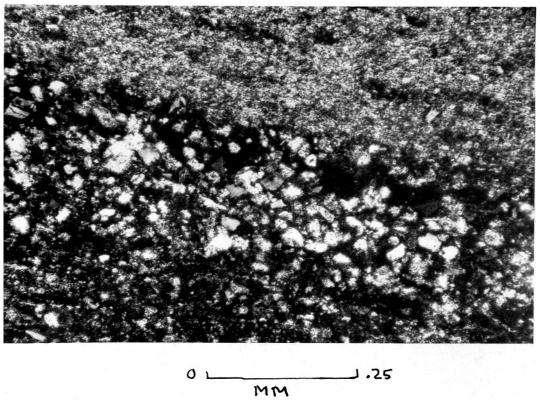


Plate 17, Figure 2: Laminae in Figure 1. XN.

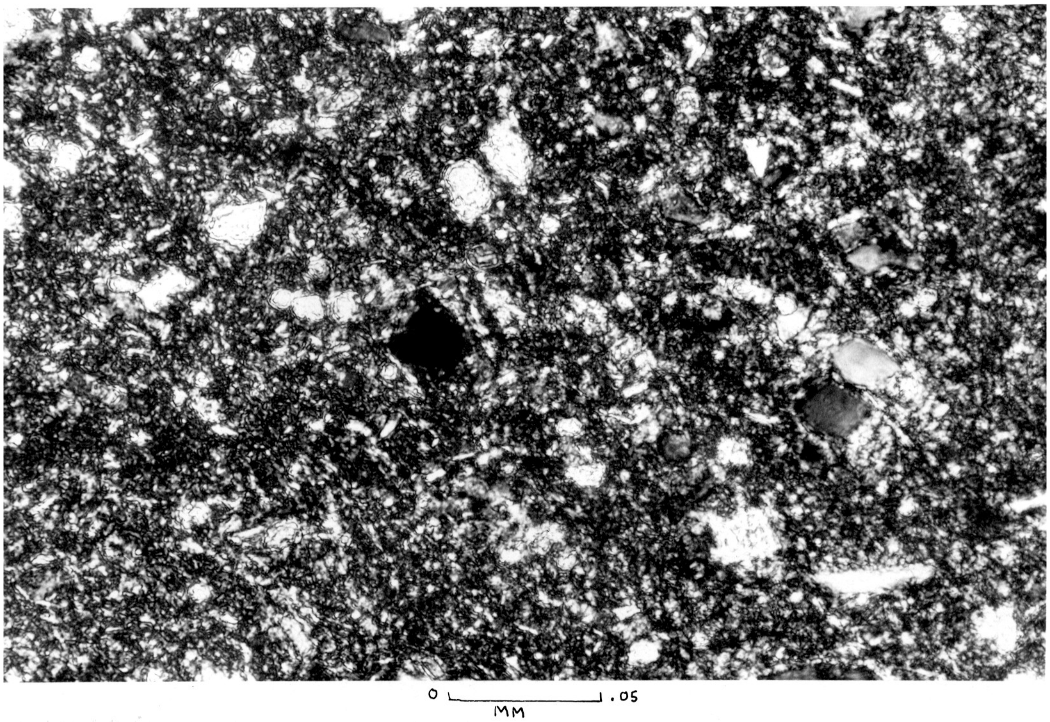


Plate 18: Euhedral and corroded carbonate grains in a fine mosaic quartz groundmass. XN.
(72F, Catskill 15' Q.).

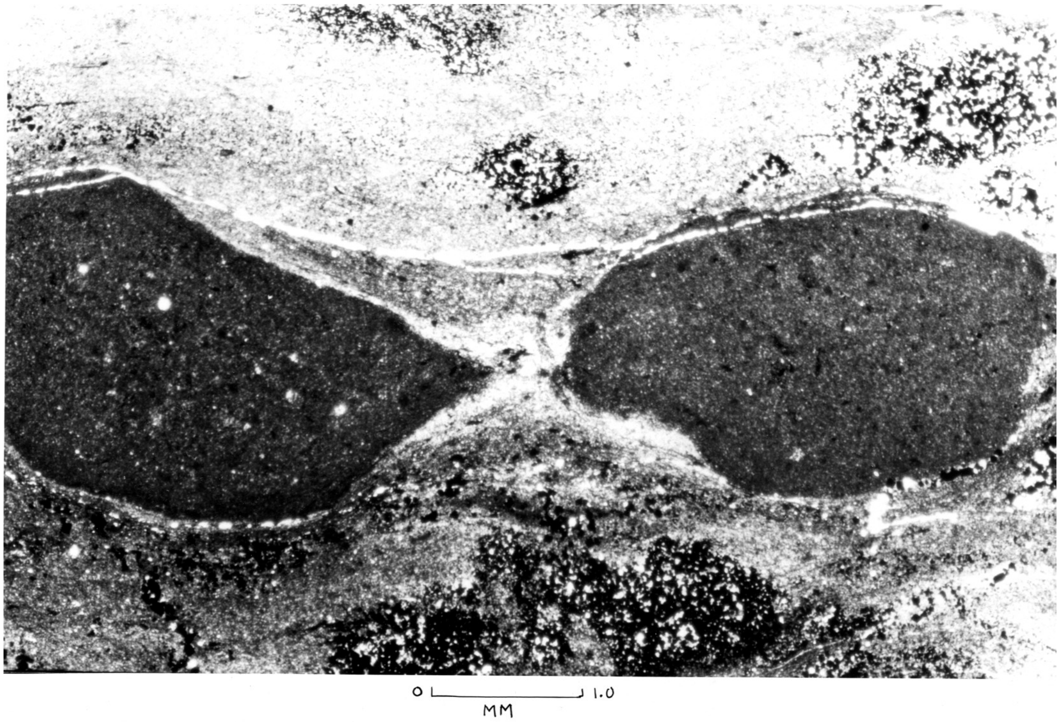


Plate 19: Nodules composed of spherulitic siderite. These occur in laminae of mosaic quartz, together with numerous aggregates of euhedral pyrite and euhedral carbonate. PPTL..
(7J, Catskill 15' Q.).

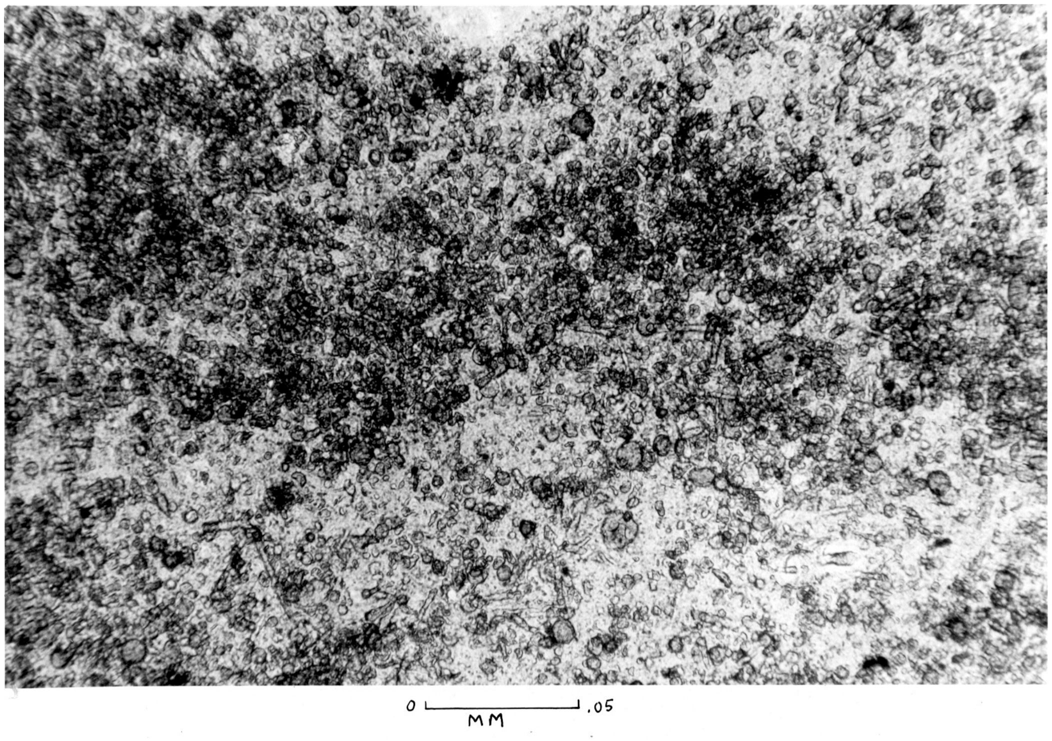


Plate 20: Rods and spherules of chamosite? In a mosaic quartz groundmass.
PPTL.
(67B, Hudson North 7½' Q.).

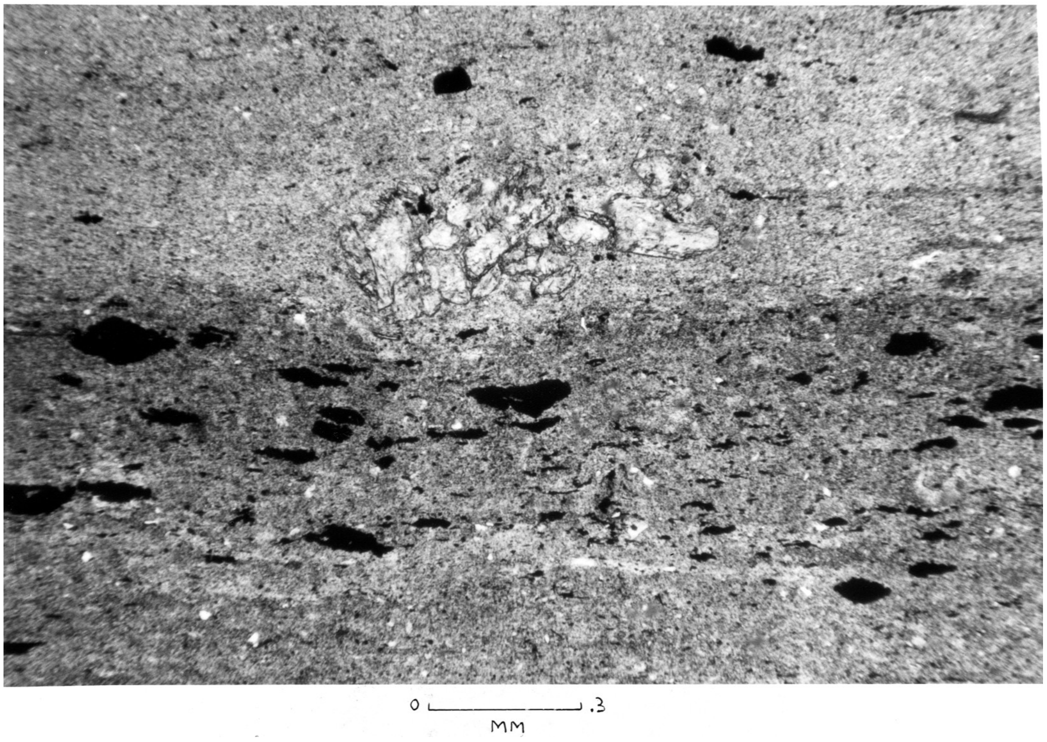


Plate 21: A lamina containing numerous aggregates of pyrite granules (A). Fragments of a chloritized mineral occur in the adjacent groundmass. PPTL. (16C, Stottville 7½' Q.).

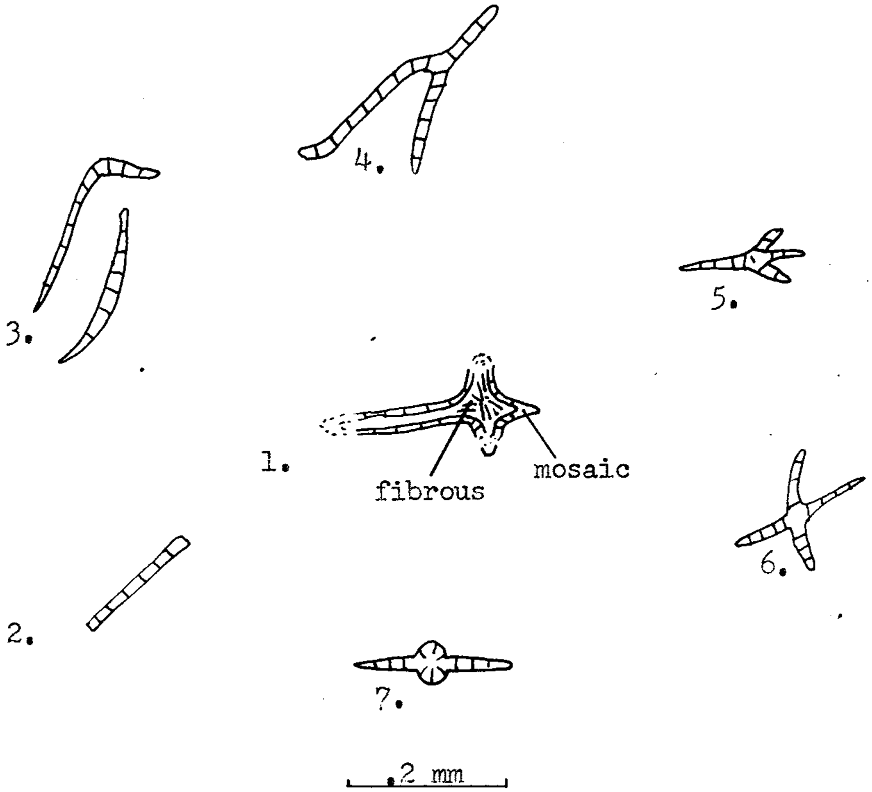


Plate 22, Figures 1-7: Sketches of some spine-like forms; most are comprised of coarse mosaic chalcedony.

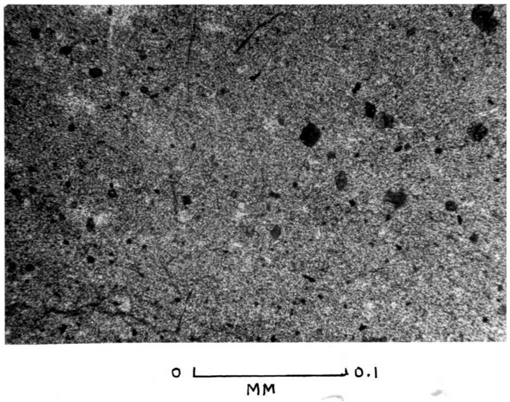


Plate 22, Figure 8: Spiculite lens (adjacent to a lamina with radiolarian and spicules, not shown). PPTL.
(80E, Cambridge 7½'Q.).

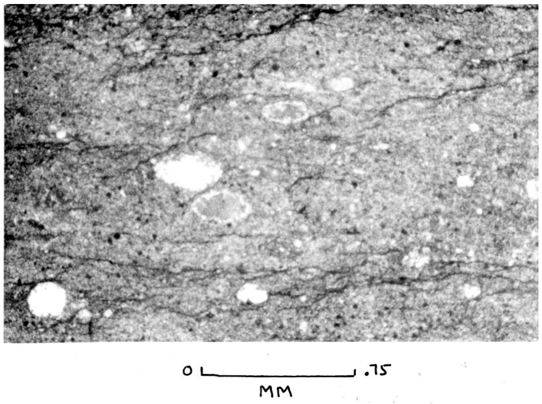


Plate 23, Figures 1: Some spherulitic forms of organic origin illustrating several typical degrees of preservation. Argillite. PPTL.
(79D, Schuylerville 15' Q.).

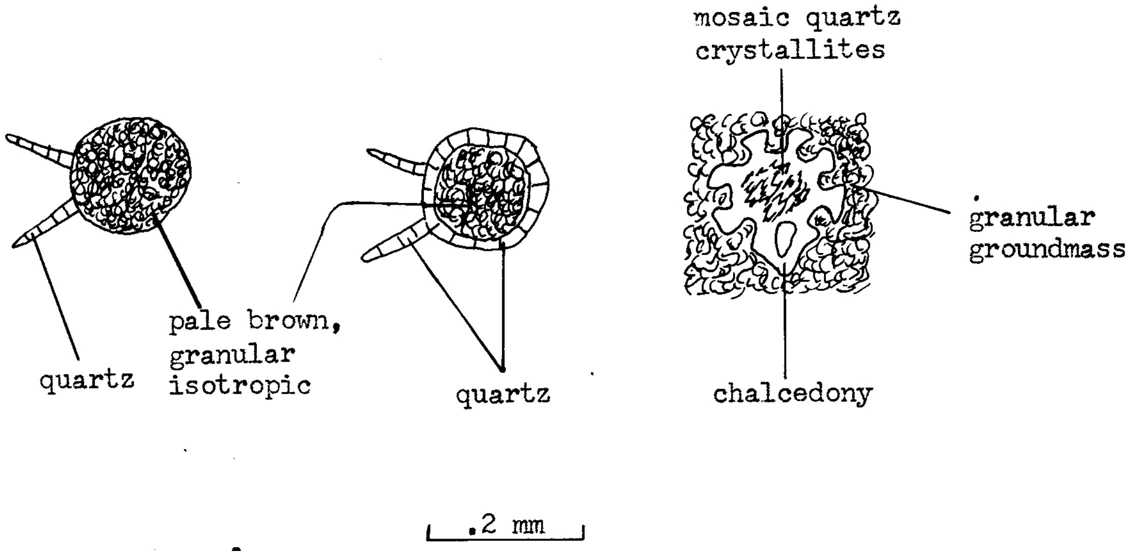


Plate 23, Figures 2-4. Sketches of some radiolarian-like forms observed in thin-sections of the cherty Mount Merino rocks.

1.

mosaic crystals, chalcedony or quartz

2.

granular, isotropic core;
mosaic rim, quartz or chalcedony

3.

core or inclusions of pyrite;
mosaic chalcedony rim

4.

pale brown, granular, isotropic (RI 1.54-1.55)
± pyrite rim

5.

two concentric shells
pale brown, granular, isotropic (RI 1.54-1.55)
± quartz crystallites

.2 mm

Sketches of some spherulitic forms, with irregular edges, observed in the cherty Mount Merino units.

PLATE 24.

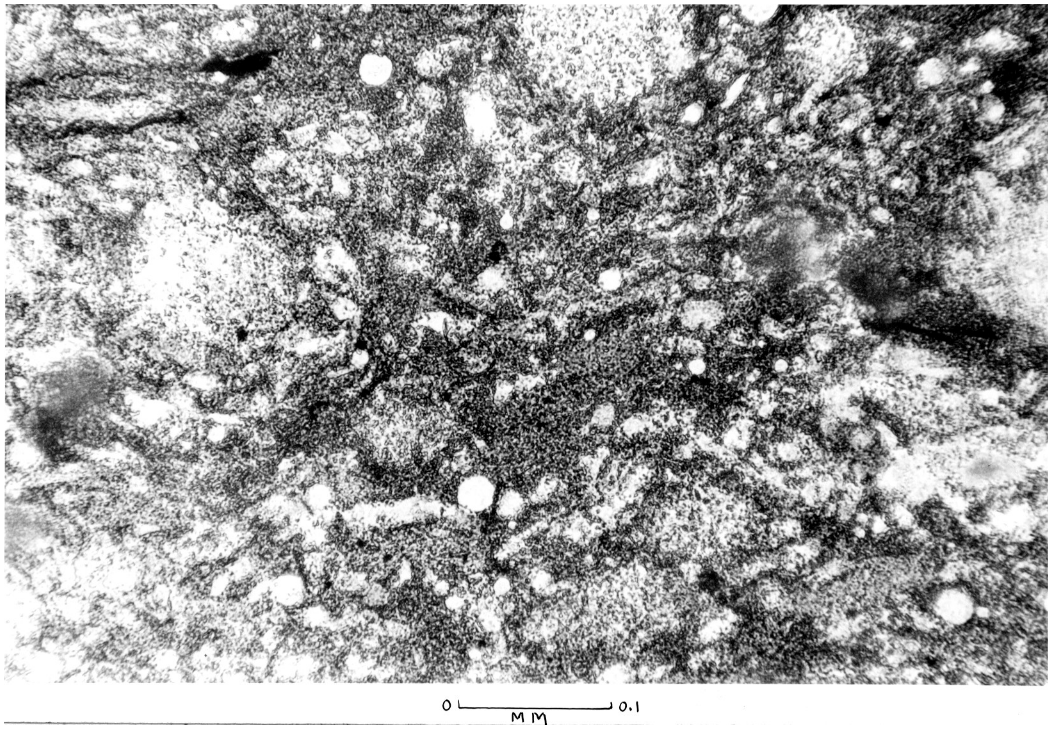
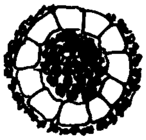
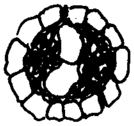


Plate 25: Small spherules and larger, radiolarian-like forms. The groundmass is fine mosaic quartz. XN.
(12, Chatham 7½' Q.).

1.



2.



pyrite core ± rim
radial coarse mosaic quartz

pale brown,
granular,
isotropic

3.

radial coarse
mosaic quartz

4.

5.

radial chalcedony - simple aggregate, or two concentric shells

fine mosaic
aggregates

granular, isotropic
material

6.

coarse, radial
mosaic quartz

7.

radial chalcedony

.2 mm

Sketches of some spherulitic forms, with smooth edges, observed in thin-sections of the cherty Mount Merino units.

PLATE 26.

granular, isotropic
material
(RI 1.54-155)

1.

fibrous, radial
chalcedony -
bifurcate joints cut
across crystals

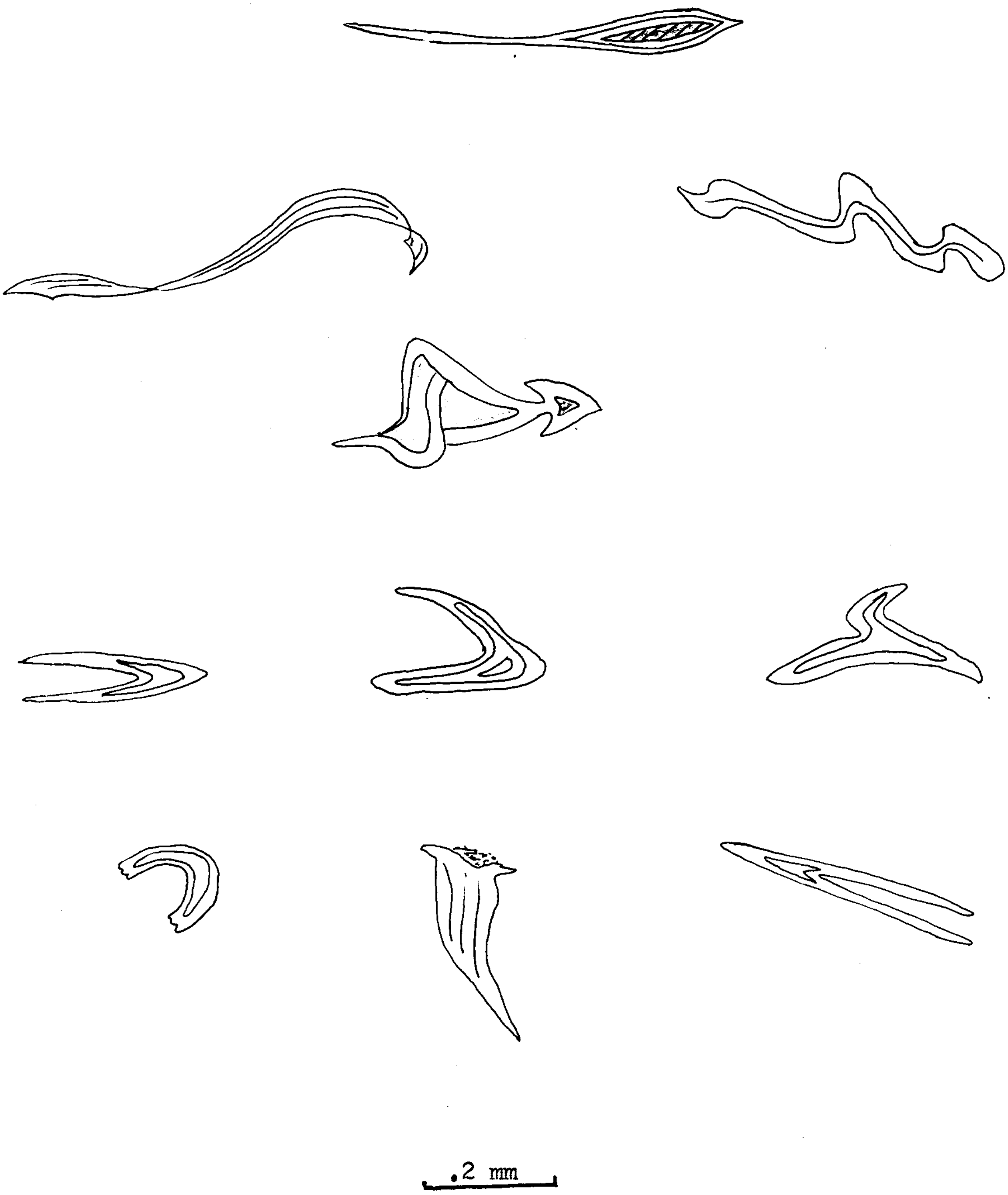
2.

spherules of chalcedony,
surrounded by optical discontinuity in groundmass

3.

Lenticular forms observed in thin-sections of the cherty Mount Merino units.

PLATE 27.



Collophane forms observed in thin-sections
of the cherty Mount Merino units.

PLATE 28.

CONCLUSIONS

The structure and composition of the lenses and laminae of the Mount Merino rocks studied suggest several aspects of deposition. The lenses containing organic material (radiolarian-like forms and carbonaceous material), clay, and grains of quartz and feldspar, which occur within laminae which contain considerably less or none of this material, suggest these "lenses" agglomerated in a place other than where they were finally incorporated into the laminae. The place of origin was probably on the sea-floor, but could even have been at or near the ocean surface.

The lamination of the units is certainly a primary sedimentary structure. At, or soon after formation, each lamina was coherent but pliable; a crystalline framework did not exist until just prior to, or soon after, the deposition of the next lamina. However, during formation, the "lamina" was an open system, as clastics (clays, quartz and feldspar, radiolarian, etc.) were also deposited within the "lamina", without disrupting the groundmass.

The mineralogic aspects of the Mount Merino rocks indicate that colloidal silica was abundant during deposition. Interpretation of many of the mineralogic variations and internal bedding structures observed are consistent with experimental data of Krauskopf (1956) regarding the tolerance of a system in which silica may precipitate, to chemical and physical variations.

For example, in slightly supersaturated solutions*, silica forms

---

* The theoretic solubility of amorphous silica is 50-80 ppm at 0°C, 100-140 ppm at 25°C and 360-420 ppm at 100°C (Alexander, et al, 1954).

a colloid which is very stable, particularly in acid solutions (Krauskopf, 1956). The stability of the colloid is relatively unaffected by several, generally significant, geochemical variables - pH, metallic cations except aluminum, and most solids, including carbonates and clay minerals (Krauskopf, 1956). However, the rate of polymerization, and eventually the formation of silica gel is notably increased by the addition of gelatinous siliceous seeding masses (Krauskopf, 1956), and by Al^{+3} when the Si:Al is approximately 45:1 (Gotto, 1956).

Several petrographic aspects of the cherty Mount Merino rocks suggest some laminae formed by aggregation of colloidal particles that eventually formed gelatinous laminae. In addition, the chemical variations which occurred during formation of a bed - e.g., those which effected the formation of laminae with abundant pyrite (either as euhedral crystals, or irregularly shaped aggregates), carbonates (alternately? calcitic, dolomitic or ankeritic), and chlorite (chamosite?) - are those which have been shown by Krauskopf (1956) to have little affect on the precipitation of silica.

Origin of the Mosaic Quartz and Felted Quartz Groundmasses

The "purest" laminae of cherty Mount Merino beds are those in which mosaic quartz comprises at least 80 percent of a lamina; these are relatively rare. Most commonly, various proportions of clay, carbonates, clastic quartz and feldspar, and/or organic fragments, together comprise up to 50 percent of a mosaic quartz lamina. The mosaic quartz groundmasses are almost certainly the crystalline equivalent of gelatinous laminae formed by precipitation of colloidal silica, directly from sea water. The relatively pure mosaic laminae were probably deposited more rapidly than those with other minerals; some clastic material apparently was "suspended" by polymers of silica in the water just overlying the ocean floor, until conditions suitable for precipitation existed.

During the formation of colloids, the clay minerals which settled to the sea floor probably adsorbed large amounts of silica; this facility of the clays has been demonstrated by MacKenzie, et al, (1967). When the concentration of silica became sufficiently high, a lamina of silica would precipitate; this precipitate would then overlay a lamina of silica-rich clay. During diagenesis, water would be expelled, and the groundmass of the clay lamina would crystallize. The felted quartz networks probably formed by this process - the "diagenetic silicification" of clayey sediments due to retarded diffusion resulting mainly from precipitation of silica. This process accounts for the orientation of the quartz network groundmasses, and the way in which laminae characterized by the quartz networks are interbedded with laminae of mosaic quartz. The common association of felted quartz with clay minerals (see Chart 1) also supports this hypothesis.

The petrographic character of the laminae which comprise the Mount Merino beds indicates that these laminae are the basic sedimentologic units of these bedded cherty rocks, rather than the bedding units. In addition, the regularity of bedding in stratigraphic sections which commonly contain shale partings or beds, suggests that a bed is a secondary structure, related perhaps to

(1) the tolerable "compaction" a "sequence of laminae" may undergo prior to substantial de-watering, and

(2) the thickness of (siliceous) sediment through which ionic diffusion may take place.

The mechanical aspects of siliceous sediments undergoing compaction may be analagous to rocks undergoing stress. Instead of minute variations in the degree of compaction between laminae, stress may build to a "yield stress", at which time a "sequence of laminae" which represent the thickness through which the stress may be tolerated, will undergo compaction.

A density variation would then exist between adjacent "beds". As the sediments and interstitial water equilibrate, a "chemical barrier" which would retard diffusion of ions might occur, in addition to the barrier of the silica precipitates. These conditions might trap most of the silica within a "bed". The relative proportions of silica and clay might determine the lithology of the bed - siliceous shale, argillite or chert. Since silica in solution would diffuse upward, if the upper laminae of a "bed" could absorb much of the silica, a "clayey" zone might form near the base of a bed.

Site of Deposition

The small size and amount of clastic grains other than "clay" in the Mount Merino rocks suggest that the sediments were deposited either (1) in a region far from, or isolated from a source of detritus, or (2) at a time when "clastics" were not being supplied to the basin. The fine lamination of the units indicates a quiescent environment. Ruedemann (1942) concluded that the Mount Merino radiolarian species indicate that the rocks were probably deposited in an abyssal environment at a depth of approximately 12,000 feet. This depth is comparable with that postulated by Zen (1967, p. 47), based on stratigraphic considerations; he suggested that the rocks of the Taconic allochthon were deposited in an area similar to that of the Timor Trough, adjacent to the Sahoel shelf northwest of Australia.

The results of this study of Mount Merino rocks support Zen's (1967) reconstruction of the site of deposition for the allochthonous Taconic sequence, a "deep-water" environment east of the Cambrian-Ordovician carbonate shelf region. This depositional region is now the region at least partially occupied by the Green Mountain anticlinorium complex (Zen, 1967).

Origin of Silica in the Mount Merino Rocks

Petrographic study of the Mount Merino rocks clearly indicates that silica was abundant within the site of deposition at the same time when clastic detritus (excepting "clay") was sparse and very fine-sized. Possible sources of abundant silica include:

(1) siliceous organisms

(2) volcanic ash (Bramlette, 1946; Bissell, 1959), or emanations (Davis, 1918; Sampson, 1923; Bissell, 1959)

(3) river water draining chemically-weathering terrain (Clarke, 1924; Tarr, 1926).

Most geologists who have studied bedded cherts have discussed the possibility that these rocks originated from radiolarian ooze; however, most have concluded that the radiolarian are "secondary" - that they became prolific in silica-rich water and therefore, occur in most bedded cherts.

Presently, most radiolarian ooze is accumulating within a narrow region of the eastern Pacific Ocean, between the lattitudes 5°N and 15°N; to the north the sediment is principally red clay, and to the south, calcareous ooze (Sverdrup, et al, 1942). In this radiolarian-ooze forming region, frictional effects caused by the opposing motions of the Counter Equatorial Current and the North and South Equatorial Currents result in two spiral convective cells within which the silica content is relatively high (Sverdrup, et al, 1942). The North and South Equatorial Currents are the westward continuations of currents which flow parallel to the coasts of North and South America from the direction of the poles

(Sverdrup, et al, 1942). Vulcanism along these coasts probably contributes significantly to the silica content of these water masses.

Strakhov (1962) and Bullard, et al, (1965) concluded that during the Ordovician (which includes Mount Merino time), the equatorial plane was nearly parallel to and in the region of the Appalachian geosyncline, analogous to its present position which is approximately 5° south of the radiolarian belt. Although the relative scarcity of radiolarian in the Mount Merino rocks suggests the sediments did not accumulate as "radiolarian ooze", it might be expected that radiolarian modified the distribution of silica in the sea water, since the tests would dissolve as they sank. The petrologic character of the Mount Merino rocks suggest the sediments were deposited relatively rapidly, compared with the computed rate of deposition of radiolarian ooze - 0.5-1.0 cm/1000 years (= .17-.33 cm of dry sediment)(Strakhov, 1962). However, the relatively common occurrence in the Mount Merino rocks of lenses with radiolarian, in radiolarian-free beds suggests radiolarian may have been abundant near the ocean surface or at moderate depths and that some lenses which eventually were incorporated into the siliceous laminae agglomerated near the ocean surface.

Another source of silica may have been emanations from submarine volcanoes. High concentrations of silica in sea water would be associated with submarine vulcanism; super-saturation of silica would occur readily as the water temperature lowered during transport or by mixing. Evidence of this vulcanism is found in central and eastern Vermont, where there is a thick section of (metamorphosed) shales with interbeds of clastic volcanic material and lava flows - the Ammonoosuc volcanics (Currier and

Jahns, 1941; Hall, 1959). Cady (1960) assigned these rocks to the Middle Ordovician; Harwood and Berry (1968) found Zone 12 graptolites in equivalent beds in Maine.

The paucity and fine-size of clastics in the cherty Mount Merino beds suggest that the units were deposited at a time when possible sources of clastic material - the Adirondack region of New York or "Appalachia" - either had low relief or were submerged. Some silica may have been derived from these masses; however, the critical implication of this petrographic aspect is that: (1) bedded cherts are not formed when clastics other than clay are abundant, and (2) low relief of land masses existed just prior to extensive vulcanism.

On the basis of graptolite chronology (Harwood and Berry, 1968), the Mount Merino units are lateral equivalents of the Ammonoosuc "spillite" facies (Bird, 1969); this vulcanism was apparently an event which immediately followed a period of sublevation and subsidence, just preceeding tectonic movement (Bird and Dewey, <u>in prep</u>) that led to the emplacement of the Taconic allochthon (Zen, 1967; Bird, 1969).

Summary

The cherty rocks of the Mount Merino Chert and Shale are comprised of thin laminae characterized by various amounts of fine-grained clastics (clay, and quartz and feldspar), carbonates, and sulphides, within texturally distinct "groundmasses" of quartz aggregates (either mosaic or felted). The laminae are primary deposits; the mosaic quartz laminae probably formed by precipitation of colloidal silica, while the felted networks probably formed beneath or between mosaic quartz laminae, primarily as a result of retarded diffusion of silica during early diagenesis; the silica had probably been adsorbed by the clay minerals in these laminae during deposition. The authigenic minerals represent stable mineral assemblages formed as a result of mineralogic equilibration at the time of deposition.

The rocks were deposited in an abyssal environment at a time when possible source areas (the Adirondacks or "Appalachia") either had very low relief or were submerged. These conditions existed at the same time submarine vulcanism became relatively intense in eastern Massachussetts, New Hampshire and western Maine. The predominant source of silica for the units was probably this vulcanism. The Mount Merino rocks, however, are distinct from cherts interbedded with spillites; they probably represent a lateral facies of the "spillite" facies and formed in an environment in which other basin sediments could interact with, and be incorporated into siliceous laminae. The ammonoosuc vulcanism was an early precursor of the episode of tectonism which ultimately led to the emplacement of the Taconic allochthon (Zen, 1967; Bird, 1969).

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*This publication is referred to only in Appendix I.

APPENDIX

Contents:

Table I: Selected Mount Merino Localities

Table I summarizes information about selected field localities. Explanations of column headings follows:

Co-ordinates. The (x, y) values are the distances in millimeters from the margins of the indicated quadrangle (either 7½ or 15 minute) to the location of the exposure. Positive 'x' values indicate the distance from the western margin, negative 'x' from the eastern margin; positive 'y' values indicate the distance from the southern margin, negative 'y' from the northern margin. A star adjacent to the co-ordinates indicates a position only approximately located due to either (a) extensive outcrops in a particular area, or (b) inability to precisely locate in the field localities described in literature.

Members. While collecting field data, exposures were catalogued according to Berry's (1962) subdivision of the Normanskill Shale:

Member 4 = Austin Glen Graywacke

Member 3 = White-weathering black and green chert and siliceous argillite

Member 2 = Gray mudstone and black shale

Member 1 = Red and green chert and shale.

This notation is used in Table I. Member numbers enclosed in parentheses occur near the specified locality, but are not in contact with the member. A slash between member numbers indicates a fault contact exists between the members.

Investigators. Most Mount Merino exposures reported in the publications listed below are included in Table I, in addition to new localities found during this study. Some exposures have been described by several investigators; the location of the exposure, as described by the earliest investigator, has been included under the heading *general location*, except where the original designation is particularly unclear. Some locations listed were not examined in this study; however, based on the description of some of these, Berry's (1962) member number has been included. The number preceeding the publications is used in Table I:

1. Gurley, 1896
2. Dale, 1899
3. Dale, 1904
4. Dwight, 1900
5. Ruedemann, 1908
6. Ruedemann, 1914
7. Ruedemann, 1930
8. Ruedemann, 1934
9. Ruedemann and Wilson, 1936
10. Ruedemann, 1942
11. Goldring, 1943
12. Warthin, 1949
13. Warthin, 1953
14. Craddock, 1957
15. Berry, 1959
16. Berry, 1962

Collection Number. Numbers used in this paper. Those which are prefixed by letters were found while mapping Austin Glen rocks with J. M. Bird (NSF grant GP-3563).

Fossil Locality Number. Number used in Table IIB.

TABLE I

SELECTED MOUNT MERINO LOCALITIES

County, Quadrangle	Co-ordinates (x, y)	General Location	Investigators	Members	Collection Number	Fossil Locality Number
WASHINGTON COUNTY						
Thorn Hill 7½' Q.		1 mi N Hampton on road to Fair Haven	2	3		
		.9 mi S Hampton	15	1		
Granville 7½' Q.	(-52,-296)	2 1/8 mi N8W Granville	16	1(2)	52	1
	(115,-145)	6 1/8 mi N45W Granville	15,16	1(2)		2
Hartford 7½' Q.	(-08,30)	Salem School		2(3)	48	
	(205,170)	.3 mi N of The Hook		2	49	
West Pawlet 7½' Q.	(-37,-05)	Rt 22, E of South Granville		2	53	
	(-52,-170)	Rt 22, E of Green Pond		3,4	54	
	(-122,128)	Rt 22, .8 mi SSW School No 8		3,4	55	

WASHINGTON COUNTY (CON.)

Schuylerville 15' Q.	(-36,28)	Willard Mt	6,9	2,3,4	77	
	(-138,148)	.85 mi SW of Victory Mills	9	2,3	60	3
	(-125,142)	Road-cut 2.5 mi S15W Schuylerville		3		
	(-14,32)	.8 mi E of Willard Mt		3	78,79	
	(-119,110)*	.3 mi NE of Coveville			Scy 21	
Cossayuna $7\frac{1}{2}$' Q.		9 3/4 mi N62E Schuylerville	16	2		5
	(-38,116)	Fitch Point		3?	38	
	(-46,-261)	1.9 mi NE Cossayuna		1?	47	
Cambridge $7\frac{1}{2}$' Q.	(183,248)	Road-cut 2.4 mi N of N Cambridge		3	37	
	(177,188)	Road-cut 1.2 mi N of N Cambridge		3?	36	
	(168,84)*	$\frac{1}{2}$ mi S of N Cambridge		3,4	35	
	(115,55)	Fly Summit	9	1,3	80	6
Schaghticoke $7\frac{1}{2}$' Q.	(-88,170)	.7 mi W of Johnsonville		3	33	

TABLE I (Continued)

WASHINGTON COUNTY (CON.)						
	(-178,136)	.6 mi E of Valley Falls		3	34	
	(-207,198)	1.1 mi N of Valley Falls		1	40	
	(-167,-290)	Rural cemetary, 2.3 mi N10E of Valley Falls		1?	41	
	(-143,-226)	2.3 mi SW of S Easton		2	42	
	(139,225)*	Rt.40, 1.4 mi S County Line		3?	43	
Eagle Bridge 7½' Q.	(48,-60)*	7 mi S33E Schuylerville	16	3		7
RENSSELAER COUNTY						
Troy North 7½' Q.	(-32,-286)*	2 1/8 mi S13W Melrose	16	2?		8
	(-146,229)	E bank Hudson R at Pleasantdale			TND 3	
Tomhannock 7½' Q.	not found	Mt Rafinesque	7,9	1,2,3,4		
	not found	Rice Mt	9	3		
	(52,-235)*	Tributary of Deepkill 1½ mi S30E Melrose	16	1/3	81,82	9

TABLE I (Continued)

RENSSELAER COUNTY (CON.)						
		bed of Deepkill 1 3/4 mi S25E Melrose	16	2		10
East Greenbush 7½' Q.	not found	Grandview Hill	3	3		
ALBANY COUNTY						
Delmar 7½' Q.		Kenwood	5			11
	(-28,245)	Paarda Hook		3	2	
	(-26,-199)	Van Wie's Point	9,10	3	3	
	(-83,-113)	Feura Bush Rd, S of Glenmont	5,9,10, 16	3	4	12,13
	(-66,-115)	2 mi S Albany, Glenmont Station	8,10,16	3	1	
		bed of Vloekie Kill, W of highway	16	2?		14
	(-80,-10)	E bank of Normans Kill			DD6	
Ravena 7½' Q.	(-78,-210)	RR cut .7 mi S County Line			57	

TABLE I (Continued)

ALBANY COUNTY (CON.)						
	(-74,-220)	5 1/8 mi S14W of Castleton	16	3,4	56	15
		Castleton Cut-off, NY Central RR = 4 7/8 mi S8W of Castleton	9,16	3,4	75?,76?	16
COLUMBIA COUNTY						
Kinderhook 7½' Q.	(65,03)	Along US9 at Sunnyside	14	3	13	
	(-22,235)*	1¼ mi N59W Chatham Center	16	2		17
	(-18,96)	1 3/4 mi S30W of Chatham Center	16	1/3	9	18
	(-75,60)*	2 5/8 mi S39W of Chatham Center	16	2		19
East Chatham 7½' Q.	(65,15)*	1 mi NW Chatham	9,14	1,3		20
	(38,180)	¼ mi S Chatham Center	14,16	3,4	10	21
	(38,196)*	Kinderhook Creek at Chatham Center	14			22
	(12,137)	1 mi SW Chatham Center, S bank Kinderhook Creek	14			23

TABLE I (Continued)

COLUMBIA COUNTY (CON.)						
Hudson North 7½' Q.	(-156,135)*	1½ mi N of Athens on W shore Hudson R	9	3		
	(-153,45)*	W of Hudson on RR	10	3		
	(154,-212)	Flint Mine Hill	9,11	3(4)	64	
	(160,-183)	"			65	
	(149,-215)	"			66	
	(147,-213)	"			67	
	(150,-212)	"			68	
	(151,-208)	"			69	
Stottville 7½' Q.	(67,-01)	1 1/8 mi N of Stuyvesant Falls	14,16	3	14	26
	(58,-09)	"			15	
	(58,-19)	"			16	
	(57,-57)	.4 mi N Stuyvesant Falls		3	17	
	(21,-196)	Chittenden Falls = Rossman Falls	9,14	3/4	18	
	(165,-283)	West Ghent	9	3	19	27
	(25,-295)	Stockport Area	5			24

TABLE I (Continued)

COLUMBIA COUNTY (CON.)

	not found	1 3/4 mi S76W of Chatham	16	2		
		½ mi NW Mellenville	14			28
	not found	Brick Tavern, NY 66	14			29
	not found	2 1/8 mi S17E of Stockport	16	3		
	(51,-82)*	Stuyvesant Falls	9,10,14	3		30,31
	(73,196)*	½ mi E of Stottville	14			32
	(14,-260)*	Creek bank, ½ mi N of Stockport	1,9,14, 16			
		1 mi NW of Ghent	9,14			
	not found	1 mi E of Omi	14	3		33
	(-22,-204)*	1 mi W of Ghent	9	3		34
		2 mi N of Mellenville	14			35
Chatham 7½' Q.	(40,-45)*	1 mi S75W of Chatham (Samples Nms 6,7,8,9 of Berry, 1962)	14,16	1/3	12	36
	(48,-70)*	RR cut 1 mi S75W Chatham (Samples Nms 22 of Berry, 1962)	16	1,2		

TABLE I (Continued)

COLUMBIA COUNTY (CON.)						
Catskill 15' Q.	(-114,-76)	NY 9G, .9 mi S Rip Van Winkle Bridge	10	3	5	
	(-108,-110)	1.1 mi E of Burden Dock		3	6	
	(-101,-48)	3 mi S53W Hudson	16	2,3	7	
	(-95,-42)	Mount Merino	8,9,10, 11	3	8	37,38, 39,40
	(-101,-34)	"			74	
	(-86,-122)	Blue Hill		1	70	
	(-81,-114)	"		1	71	
	(-76,-111)	Blue Hill = 4 5/8 mi S18W Hudson (Nms 27 of Berry, 1962)	9,10,16	1	72	41
	(-76,-98)	Old Albany Post Rd at Town Line		3	73	
	(-08,195)	3 mi E of Blue Store	10	3		
	(-164,178)*	Viewmonte	10	3		
	(70,21)*	2 mi S Glasco	9,10			42
	(-142,-136)	bank of Roeliff Jansen Kill, near Hudson R	9	2	R4	

TABLE I (Continued)

Table IIA: Some Reported Fossils in the Mount Merino Chert and Shale: Explanatory Notes

Because of the importance of the chronology of these rocks to regional geology, fossils from Mount Merino rocks are listed in this table. The information is from Dale (1899), Ruedemann (1901, 1908, 1934, 1942), Cushing and Ruedemann (1914), Ruedemann and Wilson (1936), Goldring (1943), Warthin (1953), Craddock (1957) and Berry (1962). As pointed out by Berry, assemblages of graptolites rather than individuals are required for zonal determination; only at a few localities have such sufficiently large graptolite assemblages been found. The graptolite zones in which particular species occur are listed in the following table. The fossil number is used in Table IIB (which lists the fauna reported at each locality).

TABLE IIA

SOME REPORTED FOSSILS IN THE MOUNT MERINO CHERT AND SHALE

Fossil Number	Name	Zone
	GRAPTOLITES	
1	*Amphigraptus divergens* (Hall)	
2	*A. multifasciatus* (Hall)	
3	*Azygograptus? simplex* Ruedemann	
4	*A. walcotti* Lapworth	
5	*Climacograptus* n. sp.	
6	*C. bicornis* (Hall)	12
7	*C. bicornis* var. *peltifer* Lapworth	12
8	*C. eximius* Ruedemann	11,12
9	*C. modestus* Ruedemann	12
10	*C. parvus* Hall	11,12
11	*Climacograptus phyllophorous* Gurley	
12	*C..putillus* mut. *eximius* Ruedemann	11,12
13	*C. scharenbergi* Lapworth	13
14	*C. scharenbergi* var. *stenostoma* Bulman	11,12
15	*Corynoides calicularis* Nicholson	11,12
16	*C. curtis* Lapworth	
17	*C. gracilis* Ruedemann (=*C. calicularis* Nicholson; Berry, 1960)	(11,12)
18	*C. gracilis perungulatus* Ruedemann (=*C. calicularis* Nicholson; Berry, 1960)	(11,12)

TABLE IIA (Continued)

19	*C.* *incurvus* Hadding	11,12
20	*Cryptograptus* *tricornis* (Carruthers)	11,12
21	*Desmograptus* *tenuiramosus* Ruedemann	
22	*Dicellograptus* sp.	
23	*D.* *divaricatus* var. *bicurvatus* Ruedemann	
24	*D.* *divaricatus* var. *rectus* Ruedemann	
25	*D.* *divaricatus* var. *salopiensis* Elles and Wood	12
26	*D.* *gurleyi* Lapworth	11,12
27	*D.* *gurleyi* var. *exilis* Ruedemann	11
28	*D.* *intortus* Lapworth	11,12
29	*D.* *mensurans* Ruedemann	
30	*D.* cf. *D.* *moffatensis* var. *alabamensis* Ruedemann	11
31	*D.* *sextans* (Hall)	11,12
32	*D.* *sextans* var. *exilis* Elles and Wood	11,12
33	*D.* *sextans* var. *perexilis* Ruedemann	
34	*D.* *sextans* var. *tortus* Ruedemann	
35	*D.* cf. *D.* *smithi* Ruedemann	11,12
36	*Dicranograptus* *contortus* Ruedemann	11
37	*D.* *furcatus* (Hall)	
38	*D.* *furcatus* var. *exilis* Ruedemann	
39	*D.* *nicholsoni* Hopkinson	13
40	*D.* *nicholsoni* var. *diapason* Gurley	
41	*D.* *nicholsoni* var. *parvangulus* Gurley	
42	*D.* *ramosus* (Hall)	
43	*D.* *ramosus* var. *longicaulis* Elles and Wood	

TABLE IIA (Continued)

44	*D. spinifer* Elles and Wood	
45	*D. spinifer* var. *geniculatus* Ruedemann	
46	*Dictyonema spiniferuna* Ruedemann	
47	*Didymograptus* sp.	
48	*D. sagittarius*	
49	*D. sagitticaulis* Gurley	12
50	*D. serratulus* (Hall)	11,12
51	*D. subtenuis* (Hall)	11
52	*Diplograptus* sp.	
53	*D. angustifolius* Hall	
54	*D. calcaratus acutus*	
55	*D. euglyphus* Lapworth	
56	*D. foliaceus* var. *acutus* Lapworth	
57	*D. foliaceus* var. *incisus*	
58	*D. incisus*	
59	*D. multidens* Elles and Wood	12
60	*D. multidens* var. *diminutus* Ruedemann	12
61	*Dolichopterus antiquus*	
62	*Glossograptus ciliatus* Emmons	11,12
63	*G. ciliatus* var. *debilis* Ruedemann	11,12
64	*G. hincksii* (Hopkinson)	11
65	*G. whitfieldi* (Hall)	
66	*Glyptograptus euglyphus* (Lapworth)	11,12
67	*G. euglyphus* var. *pysmaeus* (Ruedemann)	12
68	*G. teretiusculus* (Hisinger)	10,11,12

TABLE IIA (Continued)

69	*Hallograptus mucronatus* (Hall)	12
70	*H. bimucronatus* (Nicholson)	11,12
71	*Lasiograptus bimucronatus* Ruedemann	11,12
72	*L. mucronatus* Ruedemann	11,12
73	*L. pusillus*	
74	*Leptograptus* sp.	
75	*L. flaccidus*	
76	*L. flaccidus spinifer trifidus* Ruedemann	
77	*L. flaccidus* mut. *trentonensis* Ruedemann	11
78	*Medusae graptus wilsoni*	
79	*Nemagraptus* sp.	
80	*N. exilis* Lapworth	
81	*N. exilis* var. *linearis* Ruedemann	11,12
82	*N. gracilis* (Hall)	11
83	*N. gracilis* var. *approximatus* Ruedemann	
84	*N. gracilis* var. *crassicaulis* Gurley	
85	*N. gracilis* var. *distans*	
86	*N. gracilis linearis* Ruedemann	
87	*N. gracilis* var. *surcularis* (Hall)	11
88	*N. nitidulus*	
89	*Odontocaulis hepaticus* Ruedemann	
90	*Orthograptus* sp.	
91	*O. angustifolius* (Hall)	
92	*O. calcaratus* var. *acutus* (Lapworth)	12
93	*O. calcaratus* var. *incisus* (Lapworth)	13

TABLE IIA (Continued)

94	*O. foliaceus* var. *acutus* Lapworth	
95	*O. foliaceus* var. *incisus* Lapworth	
96	*O. whitfieldi* (Hall)	12
97	*Pterygotus priscus*	
98	*Ptylograptus poctai* Ruedemann	
99	*Retiograptus geinitzianus* (Hall)	11,12
100	*Syndyograptus pecten* Ruedemann	
101	*Thamnograptus* sp.	
102	*T. capillaris*	
150	*Dicellograptus divaricatus* (Hall)	11,12
151	*Amplexograptus* cf. *A. perex cavatus* (Lapworth)	12
152	*Leptobolus walcotti* (Ruedemann)	
	RADIOLARIAN	
106	*Acanthosphaera minuta*	
107	*A. robusta*	
108	*A. perspinosa*	
109	*Cenosphaera antiqua*	
110	*C. pachyderma*	
111	*Choenicosphaera brevispina*	
112	*Dorydictyum minutum*	
113	*D. magnum*	
114	*Doryplegma armatum*	
115	*D. nux*	
116	*D. priscum*	

TABLE IIA (Continued)

117	*Druppula simplex*
118	*Halicalyptra ambulans*
119	*H. similis*
120	*Haliemma antiquum*
121	*H. penrosei*
122	*Heliosphaera heeckeli*
123	*H. micropora*
124	*H. rusti*
125	*H. venusta*
126	*Lithocampe* (?) *spinosa*
127	*Sethocapsa pytine*
128	*Siphonosphaera streptosiphonia*
129	*Sphaerozoum minutum*
130	*Spongoprunum oligoporum*
131	*Spongotrochus primaevus*
132	*Staurosphaera sancta*
133	*S. crassispina*
134	*Stylostaurus hindei*
135	*Triposphaera maxima*
136	*Xiphosphaera parva*
137	*X. brachyacantha*
138	*X. macracantha*

TABLE IIA (Continued)

	OTHER FOSSILS
141	*Choenicosphaera multispinosa*
142	*Hughmilleria priscus*
143	*Paterula amii* (Schuchert) (brachiopod)
144	cf. *Protovirgulia dichotoma* Hall
145	*Pyritonema rigidum* (Ruedemann) (sponge)
146	*Schizotreta pupilliformis* (Ruedemann) (brachiopod)
147	*Teganium merino* (sponge)

TABLE II B.

SOME REPORTED FOSSILS IN THE MOUNT MERINO CHERT AND SHALE, LISTED BY LOCALITY

FOSSIL NUMBER (SEE TABLE II A): zone in parenthesis

FOSSIL LOCALITY NUMBERS (SEE TABLE I)	1	2	3	4	5	6 (12)	7 (12)	8 (11,12)	9 (12)	10 (11,12)	11	12 (11,12)	13 (13)	14 (11,12)	15 (11,12)	16	17 (11,12)	18 (11,12)	19 (11,12)	20 (11,12)	21	22	23	24	25 (12)	26 (11,12)	27 (11)	28 (11,12)	29	30 (11)
1	·	·	·	·	·	X	·	X	X	·	X	·	·	·	·				·	·	·	·	·	·				·	·	·
2	·	·	·	·	·	X	·	X	X	·	X	·	·	·	X				·	X	·	·	X	·				·	·	X
3	·	·	·	·	X	·	·	·	·	·	·	·	·	·	·				·	·	·	·	·	·				·	·	·
4	·	·	·	·	·	·	·	·	X	·	·	·	·	·	X				X	·	·	·	·	·				·	·	·
5	·	·	X	·	·	X	·	X	X	·	X	·	·	·	X				X	X	·	·	·	·				X	·	·
6	X	X	·	·	X	·	·	·	·	·	·	·							·	·	·				·	·	·	·	·	·
7	·	·	·	·	·	·	·	·	X	·	X	·							·	·	·				·	·	X	·	·	·
8	X	X	·	·	X	X	·	X	·	X	X	·			·				·	X	·				·	·	·	·	·	·
9	X	X	·	·	·	·	·	X	X	·	·	·							·	X	·				X	·	·	·	·	·
10	·	·	·	·	·	X	·	·	X	·	·	·							·	·	·				·	·	·	X	·	·
11	X	X	·	·	·	X	·	·	·	X	·	·	·	·	·	X	·	·	·	X	·	·	X	X	X	·	X	·	·	·
12	X	·	X	·	·	X	·	·	·	X	·	X	·	·	·	·	·	X	·	X	X	·	X	·	·	X	·	·	·	·
13	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
14	·	·	·	·	·	·	·	X	X	·	·	·	·	·	X	·	·	·	·	X	·	·	·	·	·	X	·	X	·	·
15	·	·	·	·	·	X	·	X	·	·	X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	·	X	·	·
16	·	·	·	·	·	X	·	X	X	X	X	·	·	X	·				X	X	·	·	·	·	X	X	X	·	·	·
17	·	·	·	·	·	X	·	X	X	·	X	·	·	·	·				·	X	·	·	·	·	X	X	·	X	·	·
18	·	·	·	·	·	X	·	X	X	X	·	·	·	·	X				·	X	·	·	X	·	X	X	·	X	·	·
19	X	·	·	·	·	X	·	X	X	·	·	·	·	·	X				·	X	·	·	X	·	·	X	·	·	·	·
20	·	·	·	·	X	·	·	·	·	·	·	·	·	·	·				·	·	·	·	·	·	·	X	·	·	·	·
21				·	·	X	·	X	X	·	X	·							·	X	·	·	X	·	·	X	·	X	·	·
22				·	·	X	·	·	·	·	·	·							·	·	·	·	·	·	·	X	·	·	·	·
23				·	·	·	·	·	·	·	·	·							·	·	·	·	·	·	·	·	·	·	·	·
24				X	·	X	·	·	·	X	·	·							·	·	·	·	·	X	·	X	·	X	·	·
25				·	·	·	·	·	·	·	·	·							·	·	·	·	·	·	·	·	·	·	·	·
26				·	·	X				·	·	·										X	·	·						
27				·	·	·				·	·	·										·	·	·						
28				·	·	X				X	·	·										X	·	·						
29				·	X	·				·	·	X										X	·	·						
30				·	·	·				·	·	·										·	·	·						
31				·	·	·				·	·	·										·	·	·				·	·	·
32				·	·	X				X	·	·										·	·	·				·	·	·
33				·	·	X				·	·	·										X	·	·				·	·	·
34				·	·	·				·	·	·										·	·	·				·	·	·
35				·	X	X				·	·	X										X	·	·				·	X	·
36	·	·	·	·	X	·	·	·	·	X	·	·	·	·	·	X	·	·	·	·	·	X	·	·	·	·	·			
37	·	·	X	·	·	X	·	·	X	·	·	·	X	·	·	·	·	·	·	X	·	·	·	·	·	X	·			
38	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·			
39	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·			
40	·	·	X	·	·	X	·	·	X	·	·	·	X	·	·	·	·	X	·	X	·	·	·	·	·	X	·			
41										·	·	·				·	·	X												
42										·	·	·				·	·	·												
43										·	·	·				·	·	·												
44										X	·	·				·	X	·												
45										·	·	·				·	·	·												

TABLE II B. (con.)

	FOSSIL NUMBER (SEE TABLE II A): zone in parenthesis																													
FOSSIL LOCALITY NUMBER (SEE TABLE I)	31 (11,12)	32 (11,12)	33	34	35 (11,12)	36 (11)	37	38	39 (13)	40	41	42	43	44	45	46	47	48	49 (12)	50 (11,12)	51	52	53	54	55	56	57	58	59 (12)	60 (12)
1	·	·	·	·	·	·	·	·	·	·	X	·							X	X	·							·	·	·
2	X	X	·	·	·	·	X	X	·	X	X	X							X	X	·							·	·	X
3	·	·	·	·	·	·	·	·	·	·	·	·							·	·	·							·	·	·
4	·	·	·	·	·	·	·	·	·	·	·	·							·	·	·							·	·	·
5	X	X	X	·	·	X	X	·	·	·	X	X							X	·	·							·	·	·
6	·	·	·	·	·	·	·	·	·	·	·	·							·	·	·									
7	X	·	·	·	·	·	·	·	·	·	·	·							·	·	·									
8	X	·	·	·	X	·	X	·	·	·	·	X							X	·	·									
9	·	·	·	·	·	·	·	·	·	·	X	X							·	·	·									
10	·	·	·	·	·	·	X	·	·	·	·	·							·	·	·									
11	X	·	·	·	·	X	X	X	·	·	·	X	·	·	·	·	·	·	X	X	X	·	X	·	·	X	·			
12	X	X	·	X	·	·	X	·	·	X	X	X	·	X	X	X	·	·	·	·	·	·	X	·	·	X	X			
13	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·			
14	X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·			
15	X	X	·	·	·	·	X	·	·	·	·	X	·	·	·	·	·	·	X	X	·	·	·	·	·	·	·			
16	X	X	·	·	X	·	X	·	·	·	·	X	X	·	·				X	X	X							·	·	X
17	X	X	·	·	·	·	·	·	·	·	·	·	·	·	·				·	·	·							·	·	·
18	X	X	·	·	·	X	X	·	·	·	·	X	·	·	·				X	·	·							·	·	·
19	X	X	·	·	·	·	X	·	·	·	·	X	·	·	·				X	X	·							·	X	·
20	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·				·	·	·							·	·	·
21	X	X	·				X	·	·	·	X	X	·	X	·	·	·	·	X	·	·	·	·	·	·	·	·			
22	·	·	·				·	·	X	·	·	·	·	·	X	·	·	·	·	·	·	·	·	·	·	·	·			
23	·	·	·				X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·			
24	X	·	·				X	·	·	X	X	X	·	·	·	·	·	·	X	X	X	·	X	X	·	X	X			
25	·	·	·				·	·	·	·	·	·	·	·	·	·	X	·	·	·	·	·	·	·	·	·	·			
26	X	·	·				X	·	·	·	·	·				·	·	·	·	·	·	·	·	X				X	·	·
27	·	·	·				·	·	·	·	·	·				·	·	·	·	·	·	·	·	·				·	·	·
28	X	·	·				X	·	·	·	·	·				·	·	·	X	·	·	·	·	X				·	·	·
29	X	·	·				·	·	·	·	·	X				·	X	·	·	·	·	X	·	·				·	·	·
30	·	·	·				·	·	·	·	·	·				·	·	·	·	·	·	·	·	·				·	·	·
31	X	·	·				·	·	·	·	·	·	·	·	·				·	·	·	X	·	·						
32	X	·	·				X	·	·	·	·	X	·	·	·				·	·	·	X	·	·						
33	·	·	·				·	·	·	·	·	·	·	·	·				X	·	·	·	·	·						
34	·	·	·				·	·	·	·	·	·	·	·	·				·	·	·	·	·	·						
35	X	·	·				·	·	·	·	·	·	X	·	·				·	·	·	·	·	·						
36	X	·	·							·	·	·		·	·	·	X	·	X	·	·	X	·	X						
37	X	X	X							X	X	X		X	X	·	·	·	X	X	X	·	·	·						
38	·	·	·							·	·	·		·	·	·	·	·	·	·	·	·	·	·						
39	·	·	·							·	·	·		·	·	·	·	·	·	·	·	·	·	·						
40	X	X	X							·	X	X		X	X	·	·	·	X	·	X	·	·	·						
41																·	·	·										·	·	·
42																·	·	·										·	·	·
43																·	·	·										·	·	·
44																·	·	X										X	·	·
45																·	·	·										·	·	·

TABLE II B. (con.)

FOSSIL LOCALITY NUMBER (SEE TABLE I)	FOSSIL NUMBER (SEE TABLE II A.)																													
	61	62 (11,12)	63	64 (11)	65	66 (11,12)	67 (12)	68 (10,11,12)	69 (12)	70 (11,12)	71 (11,12)	72 (11,12)	73	74	75	76	77 (11)	78	79	80	81 (11,12)	82 (11)	83	84	85	86	87	88	89	90
1				·	·	X	·	·	X	·	·	·				·	·	·	·	·	·	·	·	·	·	X	·			
2				·	·	·	X	X	·	·	·	·				·	·	·	·	X	·	X	·	·	·	·	·			
3				·	·	·	·	·	·	·	·	·				·	·	·	·	·	·	·	·	·	·	·	·			
4				·	·	·	·	·	·	·	·	·				·	·	·	·	X	·	·	·	·	·	·	·			
5				X	·	·	·	X	X	X	·	·				·	X	·	·	X	·	X	·	·	·	X	X			
6	·	·	·	·	·	·	·	·	·																·	·	·			
7	·	·	·	·	·	·	·	X	·																·	X	·			
8	·	X	·	·	·	X	X	X	X																·	X	·			
9	·	·	·	·	·	X	·	X	·																·	·	·			
10	·	X	·	·	·	·	·	·	·																·	·	·			
11	·	X	·	·	X	·	·	·	·	·	X	X				·	·	·	·	·	·	X	X	·	·	·	X	·	·	·
12	·	X	·	·	X	·	·	·	·	·	X	X				X	X	·	·	X	·	X	X	·	X	·	X	·	X	·
13	·	·	·	·	·	·	·	·	·	·	·	·				·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
14	·	X	·	·	·	·	·	X	X	·	·	·				·	·	·	·	·	·	X	·	·	·	·	·	·	·	·
15	·	·	·	·	·	X	X	·	X	X	·	·				·	·	·	·	X	·	·	·	·	·	X	·	·	·	·
16				·	X	X	X	X	X	X	·	·				·	X	·	·	X	·	X	·	·	·	X	X			
17				·	·	·	·	·	·	·	·	·				·	·	·	·	·	·	·	·	·	·	·	·			
18				·	X	X	·	X	X	X	·	·				·	·	·	·	X	·	X	·	·	·	X	X			
19				·	·	·	X	X	X	X	·	·				·	·	·	·	X	·	·	·	·	·	·	X			
20				·	·	·	·	·	·	·	·	·				·	·	·	·	·	·	·	·	·	·	·	·			
21	·	·	·	·	·	·	·	X	X	X	·	·							·	X	·	X	·	·	·	·	·			
22	·	X	X	·	·	·	·	·	·	·	·	·							·	·	·	·	·	·	·	·	·			
23	·	·	·	·	X	·	·	·	·	·	·	·							·	·	·	·	·	·	·	·	·			
24	·	X	·	·	·	·	·	·	·	·	·	X							·	X	X	X	·	X	·	·	X			
25	·	·	·	·	·	·	·	·	·	·	·	·							·	·	·	·	·	·	·	·	·			
26													·	·	·	·	·	·	X	·	·									
27													·	·	·	·	·	·	·	·	·									
28													·	·	·	·	·	·	·	·	·									
29													·	·	X	·	·	·	·	·	·									
30													·	·	·	·	·	X	·	·	·									
31		·												·																
32		·												X																
33		·												·																
34		·												·																
35		X												·																
36	·	X	·	·	·	·	·	·	·	·	·	·	·	X	·	·	·	·	·	·	·	·	·	·				·	·	·
37	·	X	X	·	·	X	X	·	·	·	·	·	·	·	X	·	·	·	·	·	·	X	·	·				·	·	·
38	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·				·	·	·
39	·	·	·	·	·	·	·	·	·	·	·	·	X	·	·	·	·	·	·	·	·	·	·	·				·	·	·
40	X	X	X	·	X	X	·	·	·	·	X	X	·	·	X	X	·	·	·	·	X	X	·	·				X	·	·
41				·	X	·				·	X	·	X	·	·	X	·	·							·	X	·			
42				·	·	·				·	·	·	·	·	·	·	·	·							·	·	·			
43				X	·	·				·	·	·	·	·	·	·	·	·							·	·	·			
44				·	·	·				·	·	·	·	·	·	·	·	·							·	·	·			
45				·	·	·				·	·	·	·	·	·	·	·	·							·	·	·			

TABLE II B. (con.)

FOSSIL LOCALITY NUMBER (SEE TABLES)	FOSSIL NUMBER (SEE TABLE II A.)																													
	91	92 (12)	93 (13)	94	95	96 (12)	97	98	99 (11,12)	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
1	·	X	X	·	·	·																								
2	·	X	X	·	·	·																								
3	·	·	·	·	·	·																								
4	·	X	X	·	·	·																								
5	·	X	X	·	·	X																								
6	·	·	·																·	X	·	·	X	X				X	X	X
7	·	·	·																·	·	·	·	·	·				·	·	·
8	·	X	·																·	·	·	·	·	·				·	·	·
9	·	·	·																·	·	·	·	·	·				·	·	·
10	·	·	X																·	·	·	·	·	·				·	·	·
11	·	·	·	·	·	·	·	·	X	·	·	X				·	·	·	·	·	·	·	·	·						
12	·	·	·	·	·	·	·	X	·	X	·	X				·	·	·	·	·	·	·	·	·						
13	·	·	·	·	·	·	·	·	·	·	·	·				·	·	X	·	·	X	·	X	·						
14	·	X	·	·	·	X	·	·	·	·	·	·				·	·	·	·	·	·	·	·	·						
15	·	X	X	·	·	·	·	·	·	·	·	·				·	·	·	·	·	·	·	·	·						
16	·	X	X	·	·	·	·	·	X																					
17	·	·	·	·	·	·	·	·	·																					
18	·	X	X	·	·	·	·	·	X																					
19	·	X	X	·	·	X	·	·	·																					
20	·	·	·	·	·	·	·	·	·																					
21	·	X	X	·	·	X				·	·	·													·	·	·			
22	·	·	·	·	·	·				·	X	·													·	·	·			
23	·	·	·	·	·	·				·	·	·													·	·	·			
24	·	·	·	·	·	·				·	·	X													·	·	·			
25	·	·	·	·	·	·				·	·	·													·	·	X			
26										·	·	·																		
27										·	·	·																		
28										·	·	·																		
29										·	X	·																		
30										·	·	·																		
31																·	·	·				·	·	·	·	·	·			
32																·	·	·				·	·	·	·	·	·			
33																·	·	·				·	·	·	·	·	·			
34																X	·	·				·	X	·	X	·	·			
35																·	·	·				·	·	·	·	·	·			
36	·	·	·				·	·	X	·	X	·				·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
37	·	·	·				·	·	·	·	·	·				·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
38	·	·	·				·	·	·	·	·	·				·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
39	·	·	·				·	·	·	·	·	·				X	·	·	X	·	·	X	·	·	·	X	·	·	·	X
40	X	X	X				·	·	·	·	·	X				·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
41	·	·	·	X	X	·				·	·	X							·	·	·									
42	·	·	·	·	·	·				·	·	·							·	X	X									
43	·	·	X	·	·	·				·	·	·							·	·	·									
44	·	·	·	·	·	·				·	·	·							·	·	·									
45	·	·	·	·	·	·				·	·	·							·	·	·									

TABLE II B. (con.)

	FOSSIL NUMBER (SEE TABLE II A.)																													
FOSSIL LOCALITY NUMBER (SEE TABLE I)	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	150	151	152
1																														
2																												X		
3																														
4				X																										
5																												X		
6	X	X		X		X		X	X	X		X	X	X		X		X												
7																														
8																												X		
9																														
10																														
11																												X		
12																												X		
13																														
14																														
15																												X		
16																												X		
17																												X		
18																												X		
19																												X	X	
20																												X		
21																												X		
22																														
23																														
24																								X				X		
25																														
26																														
27				X																										
28																														
29																														
30																														
31																														
32																														
33																														
34		X	X																											
35																														
36																														
37																												X		
38																														
39					X						X					X	X		X	X			X		X	X				X
40																											X			
41																														X
42														X																
43																														
44																						X								
45																														

SUMMARY, TABLE II B.

Fossil Locality Number	Member	Zone of reported fossils according to Berry, 1960 (the total number of various species of each zone is in parenthesis)
1	1(2)	11-12 (4) ; 12(4) ; 13(1)
2	1(2)	11 (2) ; 11-12 (9); 12(6) ; 13(1)
3	2,3	NO DETERMINATION (N. D.)
4	2	11-12(2) ; 12(2) ; 13(1)
5	2	11(5); 11-12(10) ; 12(6) ; 13(1)
6	1,3	N. D.
7	3	11(1) ; 11-12 (2) ; 12(1)
8	2?	11 - 12 (9); 12 (4)
9	2?	11-12 (4); 12 (2)
10	2	11-12 (2) ; 12 (2) ; 13(1)
11	3	11(5); 11-12 (9) ; 12 (3)
12	3	11 (3) ; 11-12 (11) ; 12(1)
13	3	N D
14	2 ?	11(1) ; 11-12 (8) ; 12 (4)
15	3,4	11-12(9) ; 12(4) ; 13(1)
16	3,4	11 (6) ; 11-12 (15) ; 12 (8)
17	2	11-12(7) ; 12(3)
18	1,2.	11(4) ; 11- 12 (3) ; 12(6); 13(1)
19	2	11(1) ; 11-12 (10) ; 12 (9) ; 13(1)
20	1,3	11-12 (2)
21	3,4	11(1) ; 11-12 (8) ; 12(6) ; 13(1)
22	?	11-12 (2); 12(1) ; 13(1)
23	?	N D
24	3	11 (3); 11, 12 (8) ; 12 (2)
25	3,4	N D
26	2,3?	11-12(1) ; 12(1)
27	3	N D
28	3	11-12(2) ; 12(2)
29	3	11-12 (1)
30	3	N D
31	3	11-12(1)
32	3	11-12 (2) ; 12(1)
33	3	12 (2)
34	3	N D
35	3	11-12(2) ; 12(1)
36	3	11-12(4) ; 12(1)
37	3	11 (2) ; 11-12 (8) ; 12(4) ; 13(1)
38	3	N D
39	3	N D
40	3	11-12(7) ; 12(1) ; 13(1)
41	1	11-12 (2)
42	3	N D
43	3	N D
44	?	11 - 12 (2)
45	?	N D