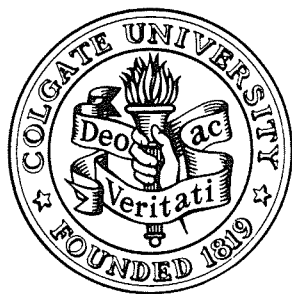


THE NEW YORK STATE GEOLOGICAL ASSOCIATION



CO-HOSTED by
COLGATE UNIVERSITY
and
UTICA COLLEGE



44th Annual Meeting

SEPTEMBER 15, 16, 17, 1972
HAMILTON and UTICA, NEW YORK

NEW YORK STATE GEOLOGICAL ASSOCIATION

44th Annual Meeting

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FIELD TRIP GUIDEBOOK

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and

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DEDICATION

The Guidebook for the
44th Annual Meeting of
The New York State Geological Association
is dedicated to
G. Arthur Cooper
Colgate Alumnus
and
Eminent Contributor to
North American Paleontology

PREFACE

This year's guidebook reflects the preponderance of sedimentary and glacial geology in the Utica-Hamilton area. It is a geologically classical region, first made famous by James Hall. It is also the area in which G. Arthur Cooper began his paleontological studies while an undergraduate at Colgate University. It is with great pride that we dedicate this year's guidebook to Dr. Cooper.

In the past the New York State Geological Association Meeting has been convened in the spring. This year we are holding it in the fall for several reasons. Amongst these is the rededication of Lathrop Hall at Colgate University. Lathrop Hall has long been the combined home of both the Geology and the Physics Department. In 1970-1971 the old edifice (1909) was renovated, and a new link was added between McGregory and Lathrop Halls. The current facility is both spacious, attractive and functional.

We are honored to have as guest speakers and panelists for the rededication G. Arthur Cooper, M. King Hubbert, and J. Tuzo Wilson. They will be joined by two Colgate physics alumni: Guyford Stever, Director of the National Science Foundation; and Harvey Picker, Dean of the School of International Relations of Columbia University.

We welcome these men, and we welcome all of you to the rededication ceremonies and to the other functions of this weekend.

- James McLelland, Editor

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THE CLINTON GROUP OF EAST-CENTRAL NEW YORK

by

H. S. Muskatt

Utica College

INTRODUCTION

The only completely conformable, exposed sequence of the Clinton Group (Middle Silurian) of New York State is located in its type area in the east-central part of the state. The Group is characterized by a heterogeneous lithology that includes pebbly sandstones, impure and clean sandstones, shaly, green and gray mudstones, carbonates and ironstones. Except for the Medina Group of upper Lower Silurian age, the Clinton Group, at its type locality, contains the only major sequence of detrital clastics in the Silurian of central and western New York.

The materials that comprise most of the Clinton Group of east-central New York probably were deposited in a near-shore, shallow water environment, the shifting strand generally being located in the vicinity of the Joslin Hill area (long. $75^{\circ}07'$). Paleocurrent data obtained chiefly from cross beds and ripple marks, and the general coarsening of units eastward, indicate a northwesterly paleoslope and a probable eastern provenance.

Detrital albite rarely forms 1 percent of the Clinton rocks; only a trace of orthoclase was seen in two thin sections. The heavy mineral assemblage consists predominantly of rounded zircon, tourmaline, and rutile. Angular grains of epidote, diopside, and garnet are common. Provenance was chiefly a meta-sedimentary terrane.

The Shawangunk Conglomerate of southeastern New York consists chiefly of orthoquartzite, and subarkose. Orthoclase, which may form 24 percent of the rock becomes more abundant upward. Albite is absent. Chert is more common and of larger size than that found in Clinton. The heavy mineral assemblage is

basically similar to that of the Clinton but there are significant varietal differences. The mineral content and evidence of an easterly transgressive Clinton sea indicate that the Shawangunk, at least from Otisville, New York, northward, is younger than the Clinton Group of central New York.

For this study (Muskatt, 1969) more than 1200 oriented samples were collected from 51 localities in central New York, and 67 samples were collected from 6 selected localities in the Shawangunk Mountains. All samples were studied under the binocular microscope. One hundred and fourteen samples from the east-central New York area and 24 from the Shawangunk Mountains were chosen for thin-section and heavy-mineral analyses.

STRATIGRAPHY

The following rock units, in ascending stratigraphic order, comprise the Clinton Group (fig. 1) of east-central New York: Oneida Conglomerate, Sauquoit Formation and its eastern facies, the Otsquago Sandstone, Westmoreland Iron Ore, Willowvale Shale, Dawes Dolostone, Kirkland Iron Ore, and the Joslin Hill and Jordanville, respectively the western and eastern members of the Herkimer Formation.

This predominantly clastic sequence grades westward into shales and limestone, except for the Sauquoit which has no western equivalent. The middle Clinton is not present in western New York (Gillette, 1947, fig. 2). North and east of its outcrop belt the Clinton has been removed by erosion, to the south it is covered by younger rocks. It dips southeast about 40 to 100 feet to the mile.

An excellent account of the history of Clinton Group terminology is given by Gillette (1940, 1947). He also gives a fairly comprehensive list of the fauna found in the Clinton of New York and their zonation. Gillette's (1947) correlations are most comprehensive and are generally adhered to today (Fisher, 1959). He placed the lower boundary of the group at the base of the Thorold Sandstone in

western New York and at the base of the Oneida Conglomerate in central New York. The upper boundary of the group he placed above both the Rochester Shale in western New York and its eastern equivalent, the Herkimer Sandstone in central New York. Vanuxem, who introduced the term "Clinton" as a group name in 1842, used the same upper and lower limits.

Recent studies concerning the Clinton Group of central New York, in varying degrees of comprehensiveness, include: Alling (1947), Dale (1953), Grossman (1953), Hunter (1960), Muskatt (1969), Rickard and Zenger (1964), Schoen (1962), Yeakel (1962), and Zenger (1967, 1971).

Oneida Conglomerate

The Oneida Formation was named by Vanuxem (1842, p.75) and was designated then, as now, as the basal unit of the Clinton Group in east-central New York. Wherever exposed, the unit forms prominent breaks in slope, or rapids and waterfalls in streams. This hard, light-gray, pebbly sandstone is made up of almost pure quartz sand and gravel tightly cemented with silica and are submature to supermature orthoquartzites. It is disconformable with the Frankfort Formation of the Middle Ordovician below but is conformable with the formations above. (pl. 1) with which it is occasionally interbedded.

The thickness of the Oneida decreases, along its outcrop belt, from a maximum of 34 feet at station 8b eastward to a feather edge at station 38 and westward, to about 11 feet at station 1. (See table A, fig. 2, and pl. 1). The Oneida ranges upward from very thick-bedded sandy pebble conglomerate near the base through the more common medium - to thick - bedded pebbly to slightly pebbly, medium to coarse sandstone. Thin - and very thin - bedded sandstones are present in places. Laminated siltstones and mudstones are rare. Near the base of the formation the modal pebble size is about 25 mm. The average maximum diameter of the ten largest vein-quartz pebbles at several different localities has a range of

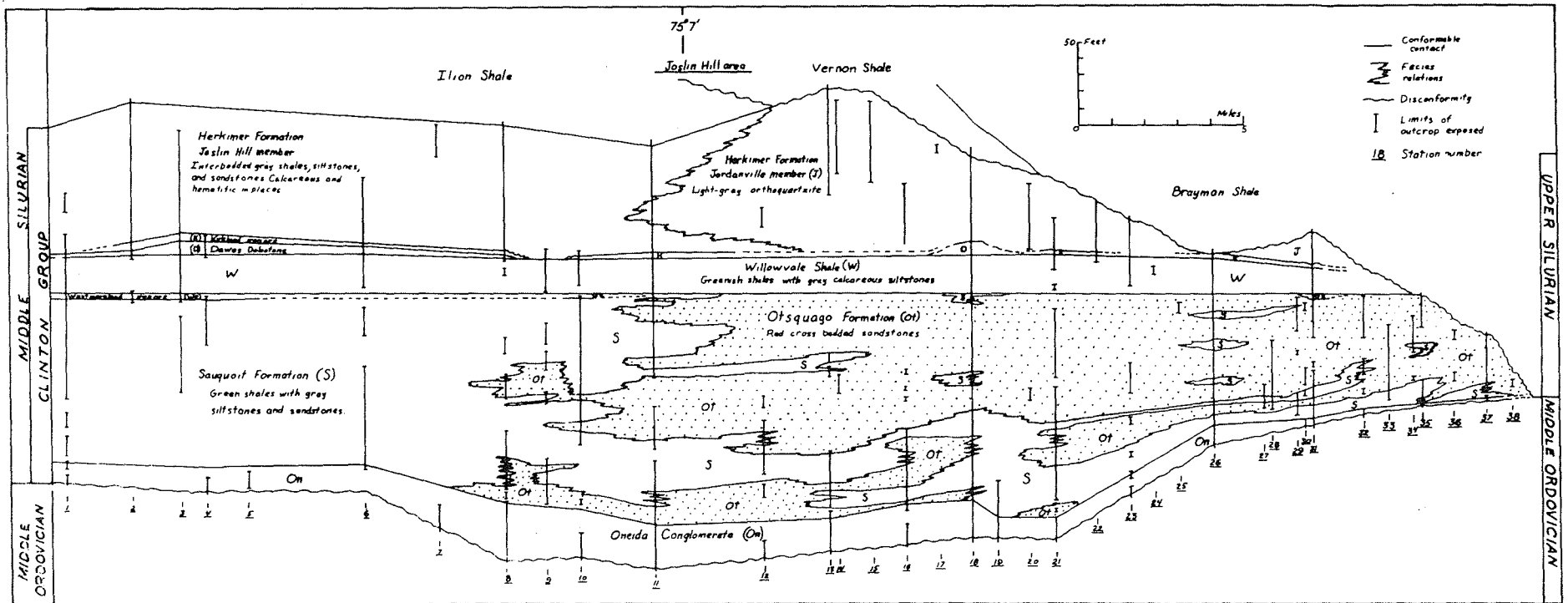


Plate 1.— Generalized east-west cross-section of the Clinton Group outcrop belt of east-central New York. Base of Willowvale is arbitrary datum. See figure 2 for station locations.

43-56 mm. with a maximum size of 63mm. Pebbles above the basal 5 feet usually have a modal diameter of about 10 mm. Most pebbles are rounded to well rounded; subangular pebbles are rare.

Pebbles of dark gray shale, which resemble the underlying Franfort, occur in the lower part of the Oneida. Greenish-gray clay galls up to 4 inches in diameter are present in places. The basal 2 to 5 inches of the unit is invariably impregnated with finely disseminated pyrite; several specimens yielded more than 50 percent pyrite by weight.

Fossils in the Oneida are scarce. The most common forms seen are Arthropycus and fragments of Lingula. Scolithus (?) tubes and meandering trails are rare. When found Arthropycus is generally about 5 feet above the base.

Sediments of the Oneida were probably laid down near shore. Beds accumulated under variable supply of detritus and wave or current energy. Near shore origin is suggested by a combination of the following features:

1. presence of Arthropycus thought to be a "strand line" type of fossil whose habitat is the zone between terrestrial and marine environments (Amsden, 1955, p. 68; Pelletier, 1958, p. 1057; Yeakel, 1962, p. 1526).
2. deep and vertical burrows (Scolithus?) believed to have been formed by organisms in littoral or very shallow water environments (Lochman, 1957, p. 124, 134; Seilacher, 1964, p. 313; 1967, p. 418; McAlester and Rhodes, 1967, p. 386).
3. broken and scattered fragments of linguloid brachiopods suggesting energy such as may be obtained in a near shore zone. Modern species of Lingula are most commonly found where the water is shallower than 60 feet (Craig, 1952, p. 115).
4. alternation of rock types and maturity of beds. Presence of clay and silt sized material in beds which alternate with beds of orthoquartzite lacking this fine material suggests a near-shore or beach environment where winnowing varied considerably thereby yielding different rock types from initially

mineralogically similar sediment.

5. interfingering of the Oneida with marine formations several miles west of the area studied (Gillette, 1947, fig. 2).

Cut-and-fill structures, commonly encountered in recent non-marine deposits (Twenhöfel, 1950, p. 312; Dunbar and Rodgers, 1957, p.64), suggest part of the Oneida may be non-marine. Variance of the Oneida cross beds ($3894 = \text{standard deviation of } 62.4$) is close to the lower limit for recent and ancient fluvial-deltaic deposits (Potter and Pettijohn, 1963, p. 89).

Sauquoit Formation

Chadwick (1918, p.341) proposed the name Sauquoit for the shale and sandstone beds between the Oneida Conglomerate and the Westmoreland Iron Ore in the Oriskany and Sauquoit Valleys. The Sauquoit is conformable with the underlying Oneida and in places appears to be gradational. Light colored sandstones, similar to those of the Oneida, are present in places in the lower part of the Sauquoit, but they contain pebbles of shale and phosphate which are very rare in the Oneida. The upper contact is well defined in the western part of the area studied where it is overlain by the Westmoreland ironstone. Hematite oolites of the Westmoreland are often embedded in the upper surface of the Sauquoit. Eastward the contact is less definitive because of the absence of the ironstone and more limited exposures (pl. 1). There the contact is placed at the top of a sequence of thin-bedded, grayish-green, very fine-to medium-grained calcareous sandstones that is followed by a sequence of greenish and grayish shales assigned to the Willowvale. In places the contacts are gradational.

No complete section of the Sauquoit Formation is exposed, even in the type locality of the Sauquoit Valley. The maximum outcrop thickness of about 115 feet is found in the westernmost part of the area studied. Thickness decreases eastward

by grading into and interfingering with the equivalent Otsquago red beds (pl. 1). The absence of the unit from western New York is due to its removal by erosion (Gillette, 1947, p. 77).

The formation varies from greenish-gray shaly mudstones, through grayish, fine-grained sandstones to green shale and phosphate pebble conglomerate. A few beds are calcareous; ferruginous beds are rare. Sandy dolostones are also sparsely represented. In the western part of the area studied shaly mudstones are most common with occasional interbeds of siltstones and well-sorted, very fine-grained to medium-grained sandstones some of which are calcareous. Also present are occasional thin-to medium-bedded, poorly sorted medium to coarse sandstones containing pebbles of green shale, phosphate and quartz. Conglomerates and sandy dolostones are uncommon. Occasionally some of the thicker beds wedge out. Thicker beds and coarser grains are more common in the lower part of the unit. Eastward the shale apparently grades into coarser and thicker beds of siltstone and sandstone and the number of carbonate beds decrease; however, the sandstones are more commonly calcareous.

Some clay shales contain, on the upper bedding plane surface, small clusters or clots of round to well-rounded, frosted, fine-grained quartz. Black, rounded, ellipsoidal to disc-shaped phosphatic nodules or pebbles and greenish-gray flat shale pebbles are abundant in some of the sandstones. The pebbles are usually concentrated on the top or bottom bedding plane of a given bed and are generally aligned subparallel to the bedding. Some beds contain more than 10 percent pebbles and warrant the terms clayey, sandy phosphate pebble or flat shale pebble conglomerate. Quartz pebbles are sometimes associated with them. These conglomeratic beds, although infrequent, become more common eastward and often in beds with large scale ripples.

Fossils are present in some of the mudstones and siltstones. They are rare in the sandstones. The following fossils are common in places, according to Gillette (1947, Table 3).

pelecypods

Ctenodonta macriformis (Hall)

Cyrtodonta alata (Hall)

Leptodesma subplana (Hall)

Pterinea emacerta (Conrad)

brachiopods

Chonetes cornutus (Hall)

Coelospira hemispherica (Sowerby)

Leptaena rhomboidalis (Wilckens)

Ostracods are also present. Gastropods and trilobites are rare. Minute, laminated, fragments of Lingula are frequently scattered in some of the sandstones. Rare worm (?) borings penetrate some mudstones in places. Tracks of some arthropod, and organically disturbed bedding are infrequent. Interlacing, meandering feeding trails, probably of some worm, are common in some mudstones.

Sediments of the Sauquoit probably were deposited under near-shore, shallow water conditions. From west to east the environment changed as indicated by the decrease in shale and concomitant increase in calcareous siltstones and sandstones. Cross-bedding and ripple marks are also more common eastward.

Most likely the western part of the formation formed as shallow water fore-set beds of a delta. This is suggested by low sand content, laminated mudstones, rare mottling of strata by organisms, upward coarsening of the unit, occasional winnowed beds of siltstones, and rare ripple marks. The fauna present, although sparse, suggests a soft substrate in a shallow-water, near-shore environment.

Leptodesma and Pterinea are pectinids which tend to be most abundant in relatively

shallow waters (McAlester and Rhoads, 1967, p. 386). Pterinea presumably lived in an environment such as oysters do today (Ladd, 1957, p.35). Oysters thrive in shallow water, from approximately halfway between high and low tide levels to a depth of about 100 feet (Galtsoff, 1964, p.1). Cyrtodonta live mostly in shallow water (Moore and others, 1952, p. 418). Ziegler and others (1968, p. 12-17), in a study of Silurian marine communities, suggest that Eocoelia (= Coelospira) inhabited near-shore environments. Lingula is most commonly a shallow water fauna (Craig, 1952, p. 115).

Meandering feeding tracks and trails, numerous in the finer clastics in places, are frequently seen in the intertidal zone (McKee, 1957, p. 1739; van Straaten, 1959, p. 200). Winding, relatively horizontal, non-patterned feeding burrows and trails are generally found in shallow-water environments (Seilacher, 1967, p. 418, 421).

Sandstones are more common eastward as are cross-bedding and ripple marks. Some sandstones are better sorted than others and only rarely are the grains well rounded thereby indicating variable current velocities and rates of sedimentation.

Ripple marks of various types (wave and current, linguloid, interference, truncated, and large and small scale ripples) are present in the central and eastern part of the Sauquoit. Abundant ripple marks of different sizes and types are characteristic of intertidal primary structures (Kindle, 1917; McKee, 1957, p. 1742; van Straaten, 1959, p. 200; Klein, 1964, p. 195; Evans, 1965, p. 224). Flat-topped ripple marks have been described from the intertidal zone by McKee (1957, p. 1742), Tanner (1958), Trefethen and Dow (1960, p. 589), and Klein (1964, p. 195). Such ripple marks have not been reported from any other depositional environment. Isolated sand ripples and flat-shale pebble conglomerates, seen in places, is suggestive of sheltered strands (Allen, 1967, p. 435). They are also often formed in the intertidal zone (McKee, 1957, p. 1739; van Straaten, 1961, p. 206).

Except for the flat-topped ripple marks, none of the features seen in the central and eastern part of the Sauquoit are individually diagnostic of any one environment. Together, however, they suggest that deposition of these coarser sediments was in shallow water near-shore and on tidal flats. Meandering tracks and trails, abundant ripple marks of various types and sizes, flat-shale pebble conglomerates, and laminations of sand and mud are described from such depositional environments by van Straaten (1954, 1959, 1961), van Straaten and Kuenen (1957), McKee (1957, p. 1738), and Evans (1965). These writers also include channel floor deposits represented by large and small scale cross bedding, cut-and-fill structures, and scour marks in this environmental range; all these structures are seen in the Sauquoit. Several of these writers also state that mud cracks, also present in the Sauquoit, are occasionally associated with such deposits.

Further indication that the eastern part of the Sauquoit is a near-shore deposit is the interfingering of this part of the formation with the non-marine Otsquago red beds to the east (pl. 1) suggesting both regression and transgression of the sea.

Otsquago Formation

The name Otsquago was introduced by Chadwick (1918) for the red, frequently cross-bedded sandstones typically exposed along Otsquago Creek (sta. 31) which flows through the town of Van Hornesville. The unit forms the major part of the middle Clinton from the Joslin Hill area eastward (pl. 1) and attains a maximum exposed thickness of approximately 100 feet at station 21. Thickness is variable because of the interfingering nature of the unit as well as the effects of erosion in the east. Muskatt (1969, p. 72) considers the Otsquago to be a formation because of its extent and distinctive characteristics. The Otsquago crops out in practically every stream bed examined from the Joslin Hill area eastward, often forming rapids and small waterfalls. Extensive hillside ledges of Otsquago are also present.

The bottom contact of the Otsquago red beds with the underlying light gray Oneida is readily discernable by color and the presence of phosphate and shale pebbles in the Otsquago. In several places the unit is separated from the Oneida by the Sauquoit (pl. 1). In all cases the contacts of these units appear to be conformable.

The sharp upper contact of the red sandstone of the Otsquago with the overlying olive-gray shales of the Willowvale was seen only at station 26. At station 31 the Otsquago appears to grade into the overlying Westmoreland Iron Ore as hematite oolites are present in the uppermost part of the Otsquago. At station 35 the upper Clinton is missing and the Otsquago is disconformably overlain by grayish thin-bedded shales and carbonates of the Upper Silurian Brayman Shale. The Otsquago, due to erosion, thins rapidly to the east of station 35, and pinches out just west of Dugway Gorge approximately 0.8 miles southwest of Salt Springvale. West of station 35 the contact seems to be conformable.

The Otsquago varies from claystone in partings, through sandstone, to slightly pebbly sandstone. Typical Otsquago is poorly sorted, to moderately sorted, medium-grained, hematitic and chloritic orthoquartzite. Usually it is submature but rarely is it sorted and mature or very poorly sorted and immature. Grains are subangular to subround as a rule, but angular, round, and well rounded grains are not uncommon.

The great majority of beds in the Otsquago are very thin-bedded to thin-bedded; these are normally fine-to medium-grained, occasionally coarse-grained ferruginous sandstones. In places they are slightly calcareous. Siltstones are less frequent. Medium beds are composed of medium to very coarse, ferruginous sandstone often containing abundant flat shale pebbles and phosphate nodules; quartz pebbles are less common. Cross bedding, predominantly of the planar type, is commonplace in the Otsquago (table 1) and is a major structural characteristic of the formation. Cross-bedded units range in thickness from 7 inches to 11 feet. Current ripple marked surfaces are often found within a few feet above the cross-bedded units.

A few fossils are present in some of the darker beds (dark grayish red, 5 R 3/2 and 10 R 3/2) of the Otsquago. These include a pelmatazoan columnal, several badly worn valves of some articulate brachiopod, and fragments of Lingula. Also present in some of these darker beds and some of the shaly interbeds are arthropod walking tracks (Diplichnites) and probable feeding trails of meandering worms (?). Casts of resting burrows (Rusophycus) and elongate crawling trails (Cruziana) are not uncommon in some of the shaly interbeds. Dr. Richard Osgood of Wooster College is presently studying these trace fossils.

The Otsquago Formation was probably formed mostly by fluvial deposition, possibly in deltaic distributary channels, under oxidizing conditions as is indicated by the red color, the essentially unidirectional dispersal pattern, interfingering with the western marine facies, the Sauquoit, and is consistent with the paucity of fauna.

Otsquago cross-bedding measurements (Table 1) have a variance of 3,484 (standard deviation of 59) thereby indicating a fairly constant direction of flow and suggests fluvial deposition (Potter and Pettijohn, 1963, p. 89). Small scale cross-stratification and asymmetrical ripple marks are common in point-bar sands where large scale cross-stratification is the dominant sedimentary structure (Allen, 1965 b, p. 140, 142, and Table IV). The Otsquago sandstone is composed of very fine sand to pebbly sand with rare silt. Stratification is mostly regular but some lenticular masses and irregular layers are present. This and the large and small scale cross-bedding, the large and small scale asymmetrical ripples, and the cut-and-fill structures indicate that the formation accumulated by lateral accretion through point bar growth in meandering streams. Allen (1964 b, p. 166; 1965b, p. 138) has found similar characteristics in stream deposits and Coleman and others (1964, p. 246) report similar features from deltaic distributary deposits.

Structures similar to those in the Otsquago are found in channel floor

deposits in intertidal flat areas (van Straaten, 1961, p. 206), and in deposits in an estuary (Land and Hoyt, 1966). It is difficult to differentiate fluvial from estuarine point-bar deposits except by the presence of marine fossils (Land and Hoyt, 1966, p. 206). A very few marine fossils are present in the blacker beds and interbedded shales of the Otsquago.

The red color of the beds suggests an environment in which the sediments were exposed to the atmosphere. The red beds owe their color to the presence of hematite, which forms as much as 30 percent of the rock but generally ranges from 5 to 15 percent, whereas the blacker beds have lower hematite content but more abundant chlorite and finely disseminated pyrite. The relationship between the red and black beds suggests reduction during the temporary encroachment of the sea into the area of red bed deposition.

Phosphate nodules in some of the blacker beds of the Otsquago are similar to those found in some beds of the Sauquoit and Herkimer formations. Pevear (1966, p. 252) found that dissolved inorganic phosphate concentrations in estuaries are commonly high enough to cause phosphatization of calcium carbonate. This may account for the presence of the nodules in the very shallow near-shore deposits of these rock units. Some may be fecal pellets.

In view of the above, the Otsquago Formation is considered to be a river or distributary channel deposit that occasionally was partly drowned by a shallow sea or encroached into the sea. The blacker sandstones are probably brackish, possibly estuarine.

Westmoreland Iron Ore

The term "Westmoreland" was introduced by Gillette (1947, p. 90) as a designation for the oolite iron ore of Smyth (1892, p. 104). Wherever exposed the Westmoreland rests on the Sauquoit or Otsquago and is overlain by the Willowvale Shale. All contacts are sharp but appear to be conformable and occasionally transitional.

Maximum thickness of the unit is about 3 feet, seen at Clinton, New York (station 3), but diminishes both eastward and westward. The easternmost exposure, at station 31, is only one inch of ferruginous, calcareous sandstone that contains hematite oolites; it may be part of the Otsquago.

The Westmoreland is a calcareous, oolitic-hematitic iron-ore. Oolites are generally layered, showing alternating bands of hematite and chamosite. They are subspherical to slightly flattened; about 80 percent are approximately 1 mm. in diameter. Nuclei are usually subround to well rounded quartz grains; some are either an aggregate of chlorite, calcite, or of hematite. Some oolites are composed entirely of hematite. Space between the oolites is filled with hematite, sparry calcite, and euhedral dolomite grains. Small subangular grains of quartz are scattered about. Hematite occurs as an earthy red cement for oolites as well as other grains. Hematite, as oolites and cement, averages about 55 percent and carbonate forms about 20 percent of a given specimen.

Gillette (1947, p. 94, and Table 3) found, along with some trilobites and ostracods, the following brachiopod fauna in the intercalated shales:

Chonetes cornutus (Hall)

Coelospira sulcata (Prouty)

Dalmanella elegantula (Dalman)

Eospirifer radiatus (Sowerby)

Leptaena rhomboidalis (Wilckens)

Sowerbyella transversalis (Wahlenberg)

The Westmoreland probably is a shallow water near-shore deposit that probably formed in relatively warm water. The highly irregular bedding in the ironstone suggests agitated waters in the area of deposition. Most areas of oolite formation are thought to be in shallow, agitated waters. James (1966) believes warm and humid conditions would be most reasonable for the formation of this type of ironstone.

Willowvale Shale

Gillette (1947, p.94) applied this name to those rocks which occupy a position between the Westmoreland and the Kirkland iron ores. Thickness is relatively constant across the outcrop belt, ranging from 23 feet at station 3 to 21 feet at station 26, but decreases to 16 feet at station 21. The contact of the Willowvale with underlying rock units is sharp and seems to be conformable. The unit appears to be transitional upward into the Dawes, the Kirkland, and the Joslin Hill member of the Herkimer Formation. Contact with the overlying Jordanville member of the Herkimer is disconformable.

The Willowvale Shale may be divided into an upper and lower part with a transition zone about 4 feet thick approximately 10 feet from the base of the unit. The lower part is predominantly greenish shaly claystone with only a few beds of silty claystone and calcareous siltstone, and rare very fine - to fine grained, calcareous sandstone. This grades upward into mainly grayish silty shale; thicker and coarser interbeds are more common and sandy dolostone beds are present.

Fossils are more common and abundant in the Willowvale than in any other rock unit of the Clinton group in east-central New York. The fossils in the upper part of the Willowvale commonly are fragmentary. Among the more common fossils found are the following:

brachiopods

Atrypa reticularis (Linnaeus)

Camarotoechia neglecta (Hall)

Chonetes cornutus (Hall)

Coelospira sulcata (Prouty)

Dalmanella elegantula (Dalman)

Eospirifer radiatus (Sowerby)

Leptaena rhomboidalis (Wilckens)

Lingula lamellata (Hall)

Schuchertella subplana (Conrad)

Sowerbyella transversalis (Wahlenberg)

pelecypods

Ctenodonta mactriiformis (Hall)

Leptodesma rhomboidea (Hall)

Pterinea emacerta (Conrad)

The Willowvale appears to represent a near-shore, deltaic transgressive clastic wedge with a regressive sea and concomitant shallowing of water as the sea filled with sediment. This is suggested by the upward coarsening and thickening of the beds of the Willowvale as well as the fragmented fauna found in the upper part of the unit. Most of the fauna listed for the Willowvale, as with the Sauquoit and Westmoreland, suggest a soft substrate in a shallow-water, near-shore environment.

Dawes Dolostone

This unit was named Dawes Sandstone by Gillette (1947, P. 99) for the "... light gray, slightly calcareous sandstone which underlies the Kirkland Iron Ore and overlies the Willowvale Shale". Dawes Quarry Creek, station 3, is the type locality. Muskatt (1969, p. 122) suggests that the name Dawes Sandstone be dropped and replaced by Dawes Dolostone. On cursory examination the unit appears to be sandstone with shale interbeds but microscopic examination shows the Dawes consists predominantly of sandy dolomitic limestone and dolostone. Thickness of the unit varies and has a maximum of 7 feet 8 inches at its type locality. Both the upper and lower contacts appear to be gradational in the type locality. Because of the transitional nature of the contact between the Willowvale and Dawes, Muskatt (1969, p. 126) considers the Dawes as a local member of the Willowvale. Although the Dawes also grades upward into the Kirkland Iron Ore the distinctive

characteristics of the ironstone make it easy to recognize.

The Dawes consists predominantly of medium-gray or medium dark-gray (N5 or N4) sandy dolostone and dolostone with some interbeds of dark-gray (N3) shales, and N4 or N5 siltstone and calcareous, very fine to fine sandstone. The several sandstones examined are on the borderline between sandstone and limestone because their carbonate content ranges from 40 to 50 percent. With decrease in quartz carbonate, particularly dolomite, increases. Quartz content in the carbonate rocks ranges from less than 1 percent to 50 percent. Most of the Dawes contains less than 10 percent quartz, chiefly in angular grains. Quartz content decreases and dolomite content increases upward in the Dawes. Most, if not all of the thicker, beds are dolostones.

Fragments of thin-shelled articulate brachiopods, pelecypods, gastropods, cephalopods, bryozoa, and palmatazoan columnals are present in the Dawes. Recognizable were Atrypa, Leptaena, Lingula, Hormotoma, and Dawsonoceras.

Sediments of the Dawes probably were deposited in a shallow near-shore zone with relatively strong currents. This is suggested by the irregular bedding, cross stratification and lamination, general absence of clays from the moderate to well-sorted siltstones, sandstones, and carbonates, and the presence of carbonate clasts and sparse broken and rounded marine fossils. Considering variations in thickness of the Dawes, regular to irregular bedding planes, and the above mentioned characteristics the Dawes may have formed as part of an offshore bar.

Kirkland Iron Ore

Chadwick (1918, p. 349) proposed the name Kirkland Iron Ore for the "red flux iron ore" of Smyth (1892, p. 104). Zenger (1971, p. 9) has introduced "Kirkland Dolostone" for the unit because the dominant lithology is dolostone. Although the unit is a highly fossiliferous, hematitic dolostone, hematite, which is not uniformly distributed, is rarely less than 10 percent and occasionally

more than 40 percent thus making the grayish red unit easily recognizable as an iron ore. It is recommended that the term "Kirkland Iron Ore" be retained.

The Kirkland attains its maximum thickness of $5\frac{1}{2}$ feet at Dawes Quarry (station 3). From there it pinches out 3 miles to the west and thins erratically eastward to Otsquago Creek (station 31). The lower contact is conformable and it is also gradational with the Dawes Member of the Willowvale. Contact with the overlying Herkimer is gradational from the Joslin Hill area westward, eastward the contact appears to be unconformable except at station 22, where it appears to be gradational.

The irregular, discontinuous beds of the Kirkland is composed of fossils replaced by hematite. Occasionally the non-uniformly distributed hematite gives the beds a patchy appearance. Thin interbeds of greenish shale are present in places. Poorly sorted quartz forms from 1 to 15 percent of the unit and chlorite content ranges from 1 to 10 percent.

Some of the more common fossils found in the Kirkland are:

brachiopods

Leptaena rhomboidalis (Hall)

Sowerbyella transversalis (Wahlenberg)

bryozoans

Acanthoclema asperum (Hall)

Eridotrypa solida (Hall)

Fistulipora crustula (Bassler)

coelenterata

Palaeocyclus rotuloides (Hall)

The Kirkland was probably deposited in waters similar to those in which the Westmoreland formed. Why the Kirkland is fossiliferous and the Westmoreland is much less so is not known. Perhaps the oolitic ironstone formed in shallower water and was subjected to greater continuous agitation than the fossiliferous ironstone.

Herkimer Formation

Zenger (1966) changed the "Herkimer Sandstone" (Chadwick, 1918, p. 351) to "Herkimer Formation" and introduced the "Joslin Hill" and "Jordanville" as members of the formation, representing the western and eastern lithofacies respectively. Interfingering of the two facies occurs in the Joslin Hill area (pl. 1). West and east of this area the change in facies is abrupt. Thickness of the Herkimer in the western part of the area is about 80 feet. East of the Joslin Hill area the thickness is about 100 feet, the unit thinning rapidly to the east because of post-Clinton pre-Cayugan erosion. Both the top and bottom contacts of the Joslin Hill member seem to be gradational. Basal contact of the Jordanville with both the Willowvale and Kirkland is sharp and probably is disconformable except for the contact at station 22 where the Kirkland appears to grade into the overlying Jordanville. The upper contact is disconformable (pl. 1).

The Joslin Hill member consists of interbedded grayish mudstone, calcareous siltstone and very fine-to coarse-grained sandstone, and sandy dolostone. Mudstone decreases and calcareous sandstone increases eastward. Sandstones are generally moderately sorted to well-sorted, mature, dolomitic, medium-grained orthoquartzites. Flat shale pebbles and phosphate nodules are present in some of the coarser sandstone beds. The Jordanville Member is chiefly light-gray, mature, medium-grained orthoquartzite; supermature orthoquartzite is not uncommon. Quartz content is rarely less than 99 percent.

Small and large scale ripple marks are common in the dolostones and sandstones of the Joslin Hill Member (Table 1). Also present are cross beds, channels, and mud cracks.

Only three individual fossils have been found in the Jordanville. Scolithus (?) tubes have been observed in places. Fossils in the Joslin Hill Member are abundant in places. A listing is given by Gillette (1947, Table 3) and Zenger (1971, Table 2). Brachiopods and pelecypods are the fossil groups best represented,

cephalopods, trilobites, bryozoans, ostracods, and plants are less common. Pelmatozoan columnals are abundant in many dolostones. Worm (?) trails and borings are seen in some mudstones. Rusophycus is common in some of the calcareous sandstones, particularly at Dawes Creek (station 3). Among the more common fossils listed by Zenger (1971, Table 2) are the following:

brachiopods

Coolina subplana (Conrad)

Leptaena rhomboidalis (Wilckens)

Stegerhynchus neglectus (Hall)

pelecypods

Cornellites emaceratus (Conrad)

Modiolopsis subcarinata (Hall)

Mytilarca mytiliformis (Hall)

The well sorted white sands of the Jordanville Member probably represents beach and shallow parts of the infralittoral environment. Sediments of the Joslin Hill sequence probably accumulated further offshore in a moderately to strongly agitated environment. This is suggested by the presence of abundant and rounded fossil fragments, large- and small-scale ripple marks, and cross-beds. That the western facies accumulated in shallow water is shown by the presence of mud cracks and small channels indicating that, at times, the shallow sea retreated leaving the area of deposition exposed at times to the atmosphere. Flat-shale pebbles are often formed in the intertidal zone. Most of the fauna found also suggests a shallow-water, near-shore environment.

PALEOCURRENT ANALYSIS

Although the several rock units that comprise the Clinton Group in east-central New York were deposited under different environmental conditions, similar in some cases, they are interrelated and in most cases transitional. Paleocurrent examination of each rock unit has shown similar trends (Table 1).

Cross-bedding

The Clinton cross-bedding is dominantly of the torrential or planar type and appears to be typically of fluviatile nature. Trough-like cross-laminated units form only 5-6 percent of all the cross-bedding. Cross-bedded units of the Clinton Group range in thickness from 2 inches to 12 feet. Cosets range from an accumulated thickness of 16 inches to as much as 35 feet.

Figure 2 depicts the moving average of the flow directions of the grouped sections and is the best estimate of the regional paleocurrent pattern for the Clinton Group of central New York. Uniformity of transport to the northwest is evident from the map pattern. Current directions were generally consistent through Clinton time in central New York (Table 1).

The resultant mean vector of the foreset dip azimuths is 284° with a variance of 4038 (standard deviation, 63.6). The most common variance of fluvial-deltaic deposits is in the range 4,000 to 6,000, and for marine deposits in the range 6,000 to 8,000 (Potter and Pettijohn, 1963, p. 89). All the rock units in the Clinton Group fall below 6,000 the suggested upper limit for fluvial-deltaic deposits. The high variance for the Sauquoit (5839) is close to the lower limit for marine deposits (6,000).

Ripple Marks

All of the rock units studied, except the ironstones, contain ripple marks (Table 1). Many ripple marks seen in cross-section were not measured. Seventy percent of the ripple mark current directions recorded show a preferred westward direction. The calculated mean ripple trend is 358° (fig. 2) with a standard deviation of 43.9 (variance = 1925). As shown by Table 1, trends in the various rock units are relatively similar and the variances relatively close. It is generally assumed that ripple marks define depositional strike.

Seventy-two percent of the ripple marks measured fall in the range from $\frac{1}{2}$ inch to 7 inch wave length whereas the remaining 28 percent range from 14 to 52 inch wave length. There is no apparent preferred orientation of trend by any given ripple mark wave length or by the grouped small-or large-scale ripple marks.

MINERALOGY

Although the proportions of mineral constituents may vary considerably from one rock unit to another, as well as one bed to another within an individual rock unit, generally the same mineral species are present. Because of controversy regarding the age of the Shawangunk Formation of southeastern New York, some data from the Shawangunk is included. See Muskatt, 1969.

Transported detritus, which forms the framework of most of the rocks, is relatively similar among the various rock units but even here differences are seen. For example, the Clinton contains a small percentage of detrital plagioclase and only a rare trace of orthoclase whereas the Shawangunk contains abundant orthoclase but no plagioclase.

Quartz is the most common mineral species. In places, in some units, carbonate and hematite are very abundant. Micaceous minerals such as illite or sericite, muscovite, sparse biotite, and in places abundant chlorite are present in most thin sections. A number of species and varieties of heavy minerals are common in almost all units, and there are only minor differences from one unit to another as shown by tables 2 and 3. In almost all cases zircon and tourmaline are most abundant.

Light Minerals

Quartz

Quartz is ubiquitous in the Clinton Group of central New York, and, except for the Oneida Formation, generally increases in abundance and modal size to the east thereby indicating an eastern source. The Shawangunk is relatively similar

to the Clinton in quartz types and their relative proportions.

The quartz grains are colorless and transparent, occasionally turbid. Most contain minute liquid and vapor inclusions and also mineral inclusions. Extinction is highly variable. All six quartz extinction types described by Folk (1968, p. 71) are present. About 90 percent of the quartz pebbles are vein quartz. "Deformation" lamellae are present in some quartz grains.

Quartz grain shape varies from angular to well rounded. Angularity increases with decrease in grain size. In places, alternating beds show variations in rounding of grains in the same grain size suggesting varying rates of deposition and reworking by currents.

Clear secondary quartz overgrowths are present in optical continuity with the detrital sand grains and usually distinguishable by "dust" rings of clay, chlorite, or hematite. Authigenic quartz crystals are present in the carbonate rich rocks. Replacement of quartz by dolomite, pyrite, hematite, and calcite is not uncommon.

The average maximum diameter (a.m.d.) of the ten largest quartz pebbles at each locality was calculated. The a.m.d. range in the Shawangunk was 52-65 mm, the maximum pebble measurement being 75 mm. The a.m.d. of the Oneida Conglomerate has a range of 43-56 mm with a maximum size of 63 mm. Chert grains in the Clinton are sparse and rarely larger than medium sand; in the Shawangunk chert is more common and occasionally is of pebble size.

Feldspar

Albite, absent from the Shawangunk, is present in all rock units of the Clinton Group but the ironstones. The mineral is scarce, only a few slides contain as much as 1 percent by volume.

Potash feldspar is very rare in the Clinton. Orthoclase in trace amounts was found in only two thin sections after staining. Two grains of microcline were noted, prior to staining, one in each of two different thin sections than contained

the orthoclase. All these grains are of silt size.

Orthoclase is common in the Shawangunk, in places forming as much as 24 percent by volume of the sample. The grains are angular to subangular and vary from fresh to almost completely altered. They are frequently as large, if not occasionally larger than the associated quartz.

Mica

Sericite (illite ?) occurs in varying amounts. It forms as much as 30 percent of the siltstones and larger amounts of the shales. Muscovite rarely forms more than a few percent of a given sample. Normally only a trace of muscovite exists; biotite is rare.

Clay Minerals

Illite (?), chlorite, and chamosite are present. Illite (?) content generally decreases with increase of quartz grain size.

Chamosite, absent from the Shawangunk, is confined to the ironstone beds. It is present as chamositic oolites with concentric sheaths composed entirely of golden yellow or green chamosite, or as pale-yellow sheaths alternating with hematite.

Chlorite is not restricted to a particular lithology among the rocks studied, and ranges from either a trace or total absence to 30 percent by volume as determined from thin sections. Where hematite is present, chlorite is often associated in lesser amounts. Where chlorite is abundant hematite is generally absent.

Carbonate Minerals

Calcite and dolomite are the only carbonate minerals observed. Calcite is present in all of the rock units and lithologic types studied. Dolomite is absent only from the Shawangunk. Schoen (1962, p. 46 and 47) in his study of the ironstones of the Clinton Group, found calcite to be rare and most of the carbonate to be dolomite. Zenger (1971, p. 29) found a similar relationship for the Joslin

Hill Member.

Heavy Minerals

The average heavy mineral content, excluding pyrite and hematite, of the samples examined from both the central New York and Shawangunk areas is about 0.1 percent by weight, with a range from slightly less than 0.01 percent found in the dolostones and shaly mudstones to as much as 0.3 percent in some of the coarser, cleaner sandstones.

Twenty different detrital and five different authigenic heavy minerals were found; their relative frequencies, excluding pyrite and hematite, are shown in tables 2 and 3. The average heavy-mineral content of the formations studied in the central New York area does not vary enough to be of diagnostic stratigraphic value. Slight variation in heavy-minerals between the Clinton and Shawangunk exists.

Grain size measurements of zircon, tourmaline, rutile, and garnet show that the largest grains are present in the Clinton. Only the relatively uncommon pink zircons from the Shawangunk are of greater size than those in the Clinton. Rounded zircon grains with inclusions are much more common in the Clinton Group. Also absent from the Shawangunk are large, well-rounded black tourmaline grains and rare pink to red tourmaline seen in the Clinton. Other significant frequency differences just mentioned, may be seen in table 2.

Zircon

Zircon is the most abundant of the heavy minerals and was found in all samples studied. The zircon is predominantly colorless, but some is pink and some brownish. A few have a yellowish tinge. Mineral inclusions are common. Zoned zircons are not uncommon, particularly in the brownish variety. The grains show a considerable variation in form, from idiomorphic to well-rounded. Most are rounded to well-rounded. Euhedral and round zircons may contain round or euhedral inclusions.

Tourmaline

Tourmaline was found in almost all the samples studied. Numerous varieties are present. Shapes range from a few which are idiomorphic to perfectly rounded. Over 90 percent are rounded. Colors are very variable but were grouped into six categories: colorless-orange, brown, brown-green, green, blue, and black.

Inclusions are common. All of the first four major varieties include grains that may or may not have inclusions. Inclusions were not seen in the blue variety.

Rutile

Rutile is relatively common. The grains are red, reddish-brown, or yellow. In the central New York area, the frequency of rutile by color is: red = 28 percent, reddish brown = 45 percent, and yellow = 27 percent, whereas the Shawangunk showed red = 46 percent, reddish brown = 30 percent, and yellow = 24 percent. Rutile grains range from a few slightly worn crystals to generally well rounded. Most are rounded to well-rounded. Most grains show very weak pleochroism, a few are distinct brown to yellow. Some grains show striations and some show well developed geniculated twinning. Several grains had inclusions.

Garnet

Light pink to colorless, subangular to subrounded, irregular grains of garnet are found in both areas studied. A few pale yellow grains and a few reddish grains are also present in the Clinton. Some grains contain small mineral and liquid inclusions as well as cavities. No euhedral crystals of garnet or rounded to well-rounded forms nor any degree of alteration was observed.

Pyrite

Pyrite is common in all the rock units and in most of the samples. In the Shawangunk it rarely forms as much as 10 percent of a sample, normally it is considerably less than 5 percent. Rock units in the Clinton Group contain variable amounts of pyrite. Most samples from the basal 2 inches of the Oneida contain as

much as 50 percent pyrite by weight. The mineral occurs most commonly as isolated euhedral cubic or pryrithedral crystals, rarely octahedral. It is also found in spongy masses composed of minute cubes or spheres. Most of the pyrite is closely associated with organic material. Pyrite has replaced quartz, dolomite, chlorite, fossil debris, and hematitic oolites.

Hematite

Hematite is present, in varying amounts, in all of the rock units studied, but is most abundant in the Westmoreland and Kirkland ironstones which contain up to 55 percent hematite by volume. Schoen (1962, table 2) reports up to 85 percent hematite in the Westmoreland. The Otsquago contains, in places, up to 30 percent hematite chiefly as films and stains on grains, or as interstitial cement. Often the hematite is concentrated with fossil debris.

The hematite occurs chiefly as an earthy light-red cement. Where abundant it apparently has replaced quartz, dolomite, and fossil debris. In several thin sections thin scales or plates of authigenic specular hematite, blood red in color by transmitted light, were seen under high magnification. These crystals have replaced parts of fossils and grains of quartz, dolomite, and other pre-existing minerals, and may possibly be one of the last diagenetic minerals to form in the rocks of the Clinton Group.

Other heavy minerals

Leucoxene is fairly common but how much of it is of detrital origin and how much, if any, is of diagenetic origin is uncertain. Other detrital heavy minerals listed in table 2 are present in lesser amounts and are generally angular to subangular. Barite occurs as a cement in some rocks.

PROVENANCE

The heavy minerals in the Clinton Group of central New York and the Shawangunk Formation of southeastern New York indicates that these strata were derived chiefly from the erosion of low grade metasediments with some contributions

from clastic sedimentary rocks, gneiss, granite (?), pegmatite, and possibly basalt. In view of the abundant pebbles of vein quartz present in both areas, the source area may have contained an abundance of pegmatitic or hydrothermal veins. Abundant potash feldspar in the Shawangunk indicates that "granitic" rocks were present in the source area.

Paleocurrent data and an eastward coarsening of rock units suggests an eastern or southeastern source for the Clinton Group or, at the very least, a western or northwestern paleoslope in the vicinity of the area of deposition. Yeakel's work (1959, 1962) suggests a similar interpretation for the Shawangunk Formation. Although both areas received their detritus from the east it does not indicate that one source area supplied both the Clinton and the Shawangunk.

CLINTON-SHAWANGUNK RELATIONSHIP

Relationship of the Clinton and its source of supply with that of the Shawangunk is not clear. Grain size measurements and mineral differences suggest either different source areas or that the Clinton received additional material from some closer source, possibly some part of the southern extension of the Adirondack arch. At least the lower part of the Clinton, if not all of the Clinton is probably older than the Shawangunk (Muskatt, 1969, p. 287). Drill hole data brings the two units to within 40 miles of each other; however, both units are readily identifiable with no evidence of transition between them. There is no evidence that the units are continuous.

DEPOSITIONAL HISTORY

Sedimentary structures, petrology, and the fossils examined in the Clinton Group suggest that the type Clinton was deposited chiefly in shallow-water infralittoral to transitional environments which were at or near the eastern margin of the New York Clinton sea. The Clinton rock units in New York that formed west of that margin were deposited for the most part in a shallow marine sea.

The Clinton Group of east-central New York, for the most part, shows a history of shifting environments about a fluctuating strand. The Joslin Hill area acted as the general strand line which marks the eastern marine edge throughout most of Clinton Group deposition in central New York. Its importance was probably also felt during post-Clintonian time. That such a strand existed is shown by the following features seen in the vicinity of the Joslin Hill area (see plate 1).

1. Interfingering of the near-shore shallow water and tidal flat deposits of the Sauquoit with its eastern facies, the Otsquago, which formed under fluvial and estuarine conditions.
2. Interfingering of the near-shore shallow water deposits of the Joslin Hill Member of the Herkimer Formation with the white beach sands of its eastern facies, the Jordanville Member.
3. All but one of the Dawes outcrops are located west of the area.
4. In the Joslin Hill area, and westward the Ilion Shale conformably overlies the Herkimer. Eastward the Ilion has been removed by erosion and the Vernon Shale disconformably overlies the Herkimer.

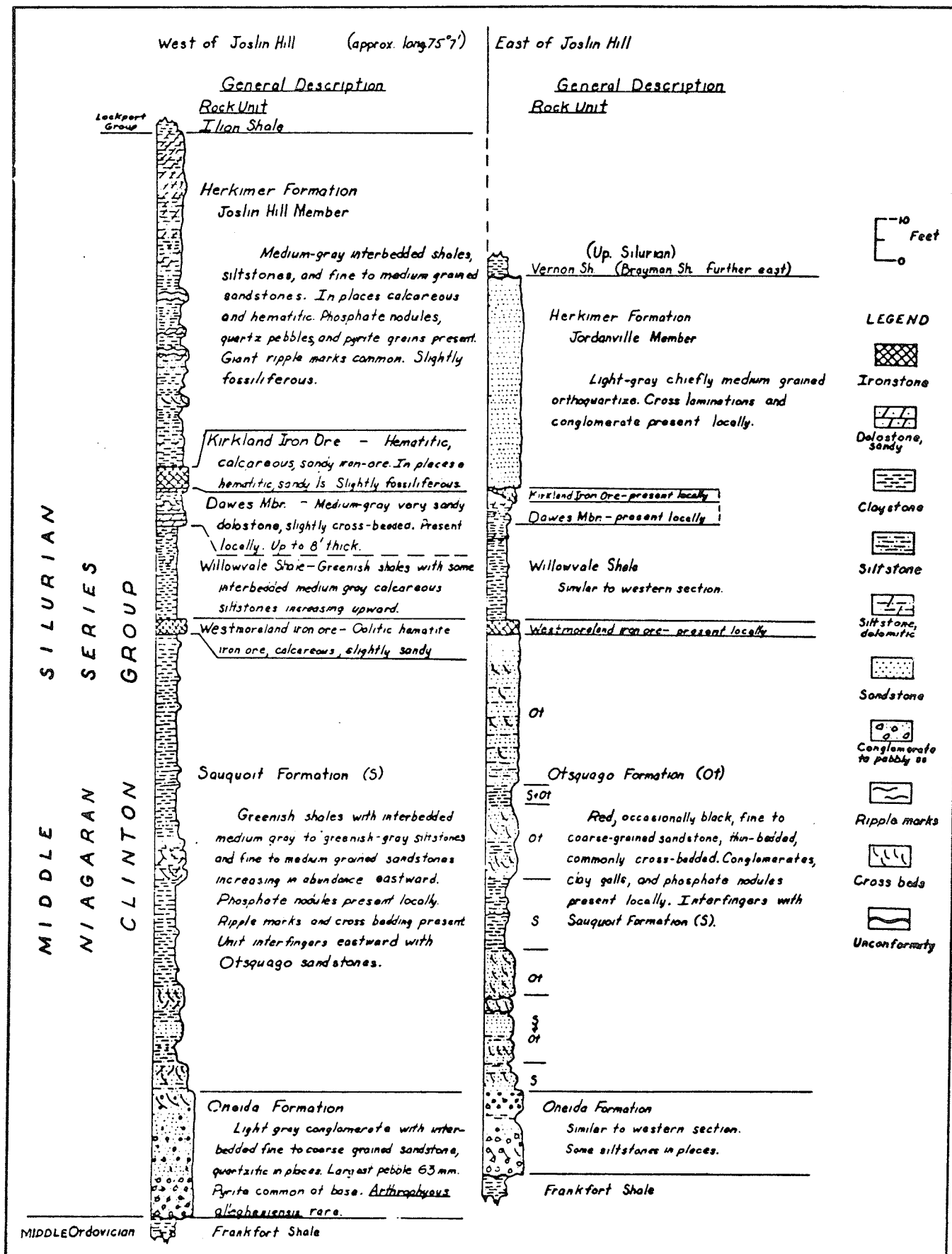


Fig. 1. - Generalized Stratigraphic Columns of the Clinton Group in East Central New York.

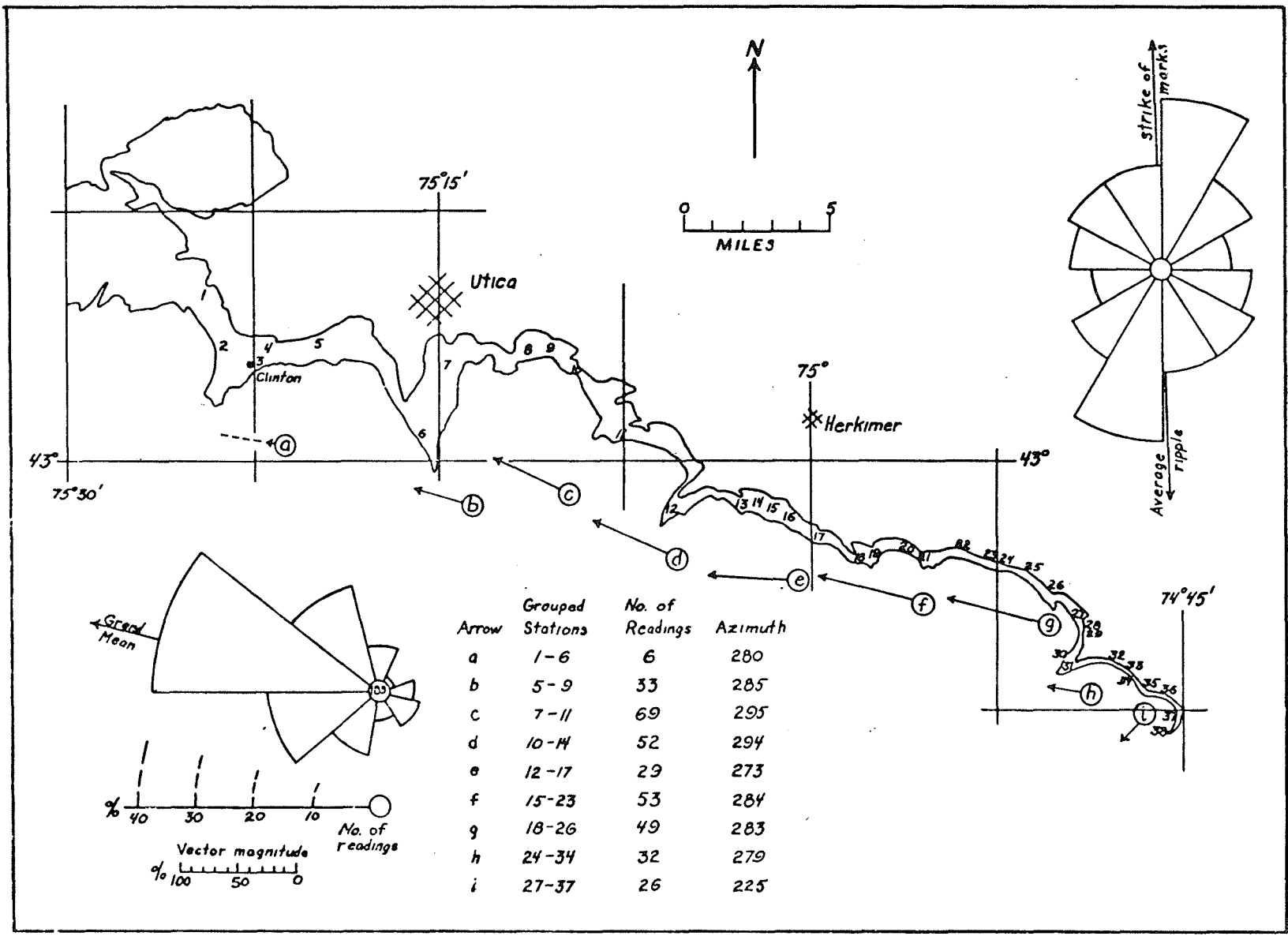


Figure 2.— Moving average of east-central New York Clinton Group cross-bedding vector means and composite current rose. Outcrop outline shows station locations. Histogram, upper right, shows trend of ripple marks in area. (See Table A for geographic locations.)

Table 1
Paleocurrent trend relationships in the Clinton Group
of central New York

	Mean Cross-bedding dip azimuth (from north)	n	S	V	Variance	Mean Ripple Mark Trend	n	S	V	Variance
Composite	284 ^o	183	63.6	22.4	4038	358 ^o	79 ^a	43.9	12.3	1925
Oneida	254 ^o	39	62.4	24.6	3894					
Sauquoit	295 ^o	16	76.4	25.9	5839	0 ^o	32	36.0	10.0	1292
Otsquago	289 ^o	119	59.0	20.4	3484	344 ^o	22	55.3	16.1	3057
Joslin Hill	318 ^o	6	37.6	11.8	1414	16 ^o	22	35.6	9.5	1270
Jordanville	301 ^o	3	38.6	12.8	1489					

n = Number of readings. S = Standard deviation. V = Coefficient of variation.

^aIncludes one set of ripple marks from the Oneida, Willowvale, and Dawes.

Table 2

Stratigraphic variation of detrital heavy-mineral frequencies in percent of total heavy minerals

	Oneida	Sauquoit	Otsquago	Willow- vale	Dawes	Herkimer	Central N.Y. average	a.	Shawan- gunk	b.
Zircon (range) (average)	76-87	74-88	72-83	76-85	70-90	71-82	70-90 82	100%	87-95 93	100%
Tourmaline	9-24	4-18	5-20	1-8	3-15	15-23	1-24 13	100	0-5 4	96
Rutile	2-8	3-7	3-6	0-7	2-10	2-10	0-10 4	79	0-6 2	79
Leucoxene	3-9	4-10	2-8	1-5	5-10	2-7	1-10 4	76	1-7 3	70
Garnet	0-2	0-T ^c	0-T	0-4	0-2	0-4	0-4 2	40	0-T	14
Sphene	0-1	0-1	0-1		T-2	T-1	0-2 T	37	0-1 T	25
Diopside	0-2	0-1	0-T		0-T	0-2	0-2 T	29	0-1 T	37
Hornblende	0-T	0-T		0-T	0-T	0-2	0-2 T	29	0-T	29

Table 2—Continued

	Oneida	Sauquoit	Otsquago	Willow- vale	Dawes	Herkimer	Central N.Y. average	a.	Shawan- gunk	b.
Epidote	0-1	0-2	0-1	0-T		0-1	0-2 T	26	0-2	42
Apatite	0-T	0-T	0-T	0-T	0-T	0-T	0-T	21	0-T	17
Topaz	0-T	0-T	0-T	0-T		0-T	0-T	18	0-T	4
Andalusite	0-T	0-T				0-T	0-T	13	0-T	17
Augite	0-T	0-T	0-T				0-T	10	0-1 T	37
Corundum	0-T	0-T		0-T	0-T		0-T	10	0-T	8
Staurolite					0-T	0-T	0-T	10		0
Zoisite	0-T	0-T				0-T	0-T	8	0-T	4
Monazite				0-T		0-T	0-T	5	0-T	4

Table 2—Continued

	Oneida	Sauquoit	Otsquago	Willow- vale	Dawes	Herkimer	Central N.Y. average	a.	Shawan- gunk	b.
Clinozoisite		0-T					0-T	3	0-T	4
Tremolite								0	0-T	8
Kyanite								0	0-T	4

Table 3
Stratigraphic variation of authigenic
heavy-mineral frequencies in percent

	Oneida	Sauquoit	Otsquago	Willow- vale	Dawes	Herkimer	Central N.Y. average	a.	Shawan- gunk	b.
Anatase	0-T	0-T	0-1	0-T	0-T	0-1	0-1 T	26	0-T	17
Brookite	0-T	0-T				0-T	0-T	13	0-T	37
Barite	0-T	0-T	0-T			0-T	0-T	5	0-T	4

- a. Percent of heavy-mineral mounts from central New York containing this mineral.
b. Percent of heavy-mineral mounts from the Shawangunk mountains containing this mineral.
c. T indicates less than 1 percent present.

Table A
 Location of outcrops examined
 in east-central New York

Station	Map ^a	Coordinates ^b	Geographic Location
1	Clinton	810.8-125.0	Lairdsville Gulch
2	do.	815.0-116.9	College Hill Creek
3	Utica W.	825.1-113.0	Dawes Creek
4a	do.	828.4-114.8	Mud Creek
4b	do.	827.1-117.5	Utica Rd.
5	do.	834-118	Girl Scout Camp "Stone Ledge"
6	do.	849.8-107.5	The Glen
7a	Utica E	259.5-117	S. Reservoir
7b	do.	259.7-112.5	Tilden Ave.
8a	do.	269.3-114.3	Wilson Rd.
8a ¹	do.	269.3-116.9	N. Minden Turnpike
8b	do.	269.1-113.8	Wilson Rd.
8bl	do.	268.7-110.7	Wilson Rd.
8c	do.	271-118	Cliff N. of Brookway Rd.
9	do.	276.0-115.3	Stream N. of Brookway Rd.
10	do.	280.3-111.0	Stream N. of Camp HiHo
10a	do.	282.2-110.1	Stream S. of Frankfort Center
10b	do.	284.0-109.2	Road S. of Frankfort Center

Table A—Continued

Station	Map	Coordinates	Geographic Location
10b1	do.	284.2-108.8	Road S. of Frankfort Center
11	do.	287.6-100.6	S. Moyer Creek
11a	Ilion	293.0-99.0	Stream S. of Joslin Hill Rd.
11b	do.	(296-297) - (95.7-98)	Joslin Hill Rd.- Clemons Rd.
11c	Millers Mills	302.7-92.2	Barringer Rd.
11c1	do.	299.8-90.2	do.
12	do.	(294-299.5) - (82.4-88)	Ilion Gorge
13	do.	308.8-88.0	Spinnerville Gulf
14	do.	(310-88)	NW Bell Hill
15	do.	314.5-85.0	Warren Rd.
		between 1020-1240 contours	
16	do.	(317-321) - (80-87)	Vickerman Hill and Rte. 28
17	Jordanville	324.8-78.8	N.E. of Brown School
18	do.	329.4-74.7	Flat Creek
19	do.	332.3-77.0	Day Creek
20	do.	(338-77)	Rock Hill Rd.
21	do.	342-77	Stream E. of Rock Hill Rd.
22	do.	348.0-76.0	Aney-Tri Town Rds.
23	do.	353.4-75.5	Stream at Deck

Table A—Continued

Station	Map	Coordinates	Geographic Location
24	Van Horns- ville	357.5-73.2	Upper Deck Road (Spring)
25	do.	360.3-71.6	Rd. S. of Smith Corners
26	do.	365-68	Ohisa Creek
27	do.	370.7-62.5	Travers-Cramers Corner Rds.
28	do.	370.5-60.8	Travis Rd.
29	do.	369.2-57.8	Travis Rd.
30	do.	368.3-56.7	Stream N. of Van Hornsville
31	do.	368.0-55.5	Otsquago Creek
32	do.	375.0-55.0	Stream N. of Wiltse Hill Rd.
33	do.	378.8-55.0	Wagner Hill Rd.
34	do.	380.0-52.0	Stream N. of Willse Four Corners
35	Van Horns- ville	381.3-51.0	Stream N. of Willse Four Corners
36	do.	(385-386)- (49.5)	3 Streams E. of Gros Rd.
37	E. Spring- field	386.8-44.0	Stream N. of Salt Springville
38	do.	383.8-41.5	Stream .7 mi. SW Salt Springville N of Dugway Gorge

a. All maps refer to U.S.G.S. Topographic Maps,
Scale 1:24,000

b. N. Y. State coordinate system

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TRIP I: EAST-WEST FACIES CHANGES IN THE CLINTON GROUP
(MIDDLE SILURIAN) OF EAST-CENTRAL NEW YORK

H. S. Muskatt

Total Miles	Miles from last point	Route Description
0.0	0.0	<u>Assembly point:</u> Treadway Inn parking lot on New Hartford Street, .4 mi. north of Utica North-South Arterial (rtes. 5 & 12). Use N. Y. Mills exit.
		<u>Departure time:</u> 7:45 SHARP! One hour to STOP 1.
		Leave parking lot and turn left (S) onto New Hartford Street.
.3	.3	Cross North-South Arterial (rtes. 5 & 12) you are now on rte. 8 traveling south through Sauquoit Valley, a glacial trough.
10.7	10.4	Cassville (Oneida Street = rte. 8). Outwash plain with kettle holes
15.7	5.0	Rte. 20, Bridgewater, turn left (W) onto Rte. 20.
13.9	3.2	West Winfield, intersection with rte. 51.
30.2	11.3	Richfield Springs, intersection with rte. 167
33.4	3.2	Warren
35.1	1.7	Petrified Creatures on right.
36.2	1.1	Springfield Four Corners, intersection with rte. 80.
39.1	2.9	East Springfield, turn left (N) onto Otsego Co. rte. 30 (Clinton Rd). Right turn (S) off rte. 20 goes to Glimmer Glass State Park located on the northern end of Otsego Lake. Cooperstown and the Baseball Hall of Fame is located on the southern end of the lake.
40.1	1.0	Wiltse Hill Rd. "T-inters.", turn left (W)
40.5	0.4	"T-inters.", turn right (N) and continue on Wiltse Hill Rd.
43.5	3.0	Wiltse Four Corners inters., continue N on Wiltse Hill Rd.
44.7	1.2	Wagner Hill Rd. inters., turn right (N). Nice view of Mohawk Valley in middle distance and Adirondacks in far distance.
45.0	0.3	<u>STOP 1</u> (30 min.) Wagner Hill Rd., Sta 33 (Van Hornesville 7½' Quad)

Otsquago Formation (Picture Stop)

Nine feet of cross-bedded, ripple marked Otsquago red beds are exposed on the east side of the road. Another 35 feet of the unit is exposed in the woods across the road, northwest of the stop.

The outcrop is small but spectacular. Please stand back to allow others to take photographs first. This is a picture stop.

Continue down hill along Wagner Hill Rd. to intersection

- 45.1 0.1 Beebe Hill Rd. inters., turn left (W).
 46.3 1.2 Rte. 80 inters., turn left (SW).
 47.6 1.3 Travis Rd. inters., turn SHARP right (N), Van Hornesville
 47.8 0.2 Outcrops of Otsquago ss on left (W) side of road station 29
 48.4 0.6 STOP 2 (45 min.) Travis Rd., Sta. 28 (Van Hornesville 7½' Quad.)

Otsquago Formation

Forty-two feet of the Otsquago is exposed. The first 15 feet, on the east side of the road, shows medium-to coarse-grained, cross-bedded red sandstones with some interbeds of green and gray shales which may be part of the Sauquoit. The remainder of the section is found on the west side of the road. Tracks and trails are common in this exposure, particularly Cruziana.

Continue north on Travis Rd.

- 48.8 0.4 STOP 3 (30 min.) Travis Rd. at intersection with Cramers Corner Rd, sta. 27 (Van Hornesville 7½' Quad.)

Otsquago Formation

Fifteen feet of cross-bedded, pebbly, coarse-grained sandstones are exposed. Three cross-bedded units are present. Lenses of conglomerate and some phosphate pebbles are also seen. Graded beds, fining upward, is evident.

Continue west on Travis Rd.

- 51.2 2.4 Bush Rd. inters., turn left (W)
 52.3 1.1 Aney Hill Rd. inters., turn right (N)
 54.6 2.3 STOP 4 (1 hr.) Aney Hill Rd at intersection with Tri-Town Rd., station 22 (Jordanville 7½' Quad.)

Willowvale Shale, Kirkland Iron Ore, and

Jordanville Member of Herkimer Formation.

This outcrop was recently exposed by a new road cut and has not been previously reported. It is one of the very few readily accessible exposures where contact of the Kirkland with the underlying Willowvale and overlying Jordanville may be seen. The contacts are located at the northern end of the exposure, downhill. A little digging and weeding may be required.

The Kirkland is approximately 11 inches thick and is fossiliferous. Palaeocycclus is common. (PLEASE DO NOT STRIP THE EXPOSURE. ABUNDANT SAMPLES OF THE KIRKLAND MAY BE TAKEN AT THE LAST STOP). Digging exposed about 2 feet of Willowvale below the Kirkland.

About 40 feet of Jordanville is exposed above the Kirkland; the uppermost 5 feet is in the field to the east. The lower 8 feet of the Jordanville is a "transition" zone showing alternating beds of reddish, blackish, and greenish sandstones with some thin grayish shale interbeds. Above this zone is the "typical" white ortho-quartzite of the member. A 2 inch thick layer of gray shale is seen about 8 feet above the "transition" zone. No fossils were seen in the shale. Cross bedding, channeling, ripple marks, shale pebbles, and lenses of pebbly sandstone and conglomerate are present. A few trails were found. Glacial strial and chatter marks on the Jordanville in the field strike N85W.

LUNCH (45 min.) Mr. Aney has kindly offered the use of his front lawn for our use. PLEASE KEEP IT CLEAN.

Continue north on Aney Hill Rd.

- | | | |
|------|-----|---|
| 55.3 | 0.7 | Rte. 167 inters., turn right (N). |
| 55.4 | 0.1 | Rte. 168 inters., Paines Hollow, turn left (W). <u>CAUTION</u> - There are a number of one lane bridges along this route. |
| 58.4 | 3.0 | Frankfort Shale (Middle Ordovician) exposed on both sides of road. |
| 62.0 | 3.6 | Rte. 28 inters., turn right (N). |
| 62.6 | 0.6 | Rte. 5S inters., Mohawk, turn left (W). |
| 64.3 | 1.7 | Ilion, inters. rte. 51 (Home of Remington Arms) |
| 66.8 | 2.5 | Frankfort, inters., rte. 171, turn left (S) at light onto to rte. 171. |
| 67.6 | 0.8 | Cross on overpass above new rte. 5S |
| 68.5 | 0.9 | Frankfort Gorge, rte. 171, Exposures of Frankfort Shale (Middle Ordovician) along the route. |
| 70.6 | 2.1 | <u>STOP 5</u> (1 hr.) Rte. 171, Frankfort Gorge, Moyer Creek, station 11 (Utica East 7½' Quad.). |

CAUTION

This road is fairly well traveled and is one of several in the area considered as the racers delight.

Frankfort Shale, Oneida Conglomerate,
Otsquago Sandstone

Exposures are seen on both sides of the road. The Oneida disconformably overlies the Frankfort Formation (upper Middle Ordovician). A minor amount of channeling may be seen at the contact.

Pebbles of Frankfort Shale are incorporated in the lower part of the Oneida. The basal 5 feet of the Oneida is conglomeratic with the lowermost few inches containing abundant pyrite. The remaining 22 feet of Oneida is mostly medium-to coarse-grained white sandstones with some interbeds of pebbly sandstone and conglomerate. On the south side of the road some thin greenish shale lenses and clay galls to 4 inches are present.

Twenty-seven feet above the Oneida-Frankfort contact the Oneida grades into the reddish to blackish Otsquago. Cross bedding is very common. A few unidentifiable brachiopods are present in some beds.

The well known South Moyer Creek section (Grossman, 1953) starts about 300 yards south of the junction of that tributary with Moyer Creek about 100 yards west of the bridge over Moyer Creek.

Continue west along rte. 171

- | | | |
|------|-----|---|
| 72.5 | 1.9 | Gulf Rd. inters., turn right (N) |
| 73.5 | 1.0 | Highland Airfield on right (N) |
| 73.7 | 0.2 | Albany St. (Minden Turnpike) inters., continue north on Albany |
| 74.7 | 1.0 | Higby Rd. inters. (Stewart Corners), turn left (W) onto Higby |
| 75.8 | 1.1 | Graffenburg Rd. inters., continue on Higby |
| 77.5 | 1.7 | Sessions Rd - Tilden Ave. inters., continue on Higby |
| 77.9 | 0.4 | Mohawk St. inters., continue on Higby |
| 78.4 | 0.5 | Chapman Rd. - Valley View Rd. inters., turn left (West) onto Chapman |
| | | Chapman - Valley View Inters., w/ Higby Rd. Turn onto Chapman Rd. down hill, west. Heading down east wall of Sauquoit Valley, a glacial trough. |
| 79.7 | 1.3 | Cross Oneida St. and continue on Kellogg Rd. (Washington Mills) |
| 80.1 | 0.4 | Turn left onto Tibbitts Rd. |
| 80.3 | 0.2 | Cross Oxford Rd and continue west on Tibbitts Rd. Climbing west wall of Sauquoit Valley, look behind to east for a view of the glacial trough. |
| 82.2 | 1.9 | Rte. 12 inters., turn right (N) |
| 82.3 | 0.1 | Brimfield St. inters., turn left (W) |
| 84.4 | 2.1 | Building foundation at left is that of the last operating iron mine in the central New York area which closed in the early 1960's. |

- 84.5 0.1 Dawes Ave. inters., continue along Brimfield
- 84.9 0.4 New St. intersection, turn left (S)
- 85.2 0.3 STOP 6 (3 hrs.) New Rd, Dawes Creek, station 3 (Utica West 7½' Quad).

Sauquoit Formation, Westmoreland Iron Ore, Willowvale Shale, Dawes Dolostone, Kirkland Iron Ore, Joslin Hill Member of the Herkimer Formation.

This section starts below the bridge on New Rd. that crosses Sherman Brook but locally referred to as Dawes Creek.

WE WILL REBOARD BUSES UPSTREAM WHERE IT CROSSES DAWES AVE.

Going upstream, 46 feet of the Sauquoit is exposed. The unit consists of greenish shales with discontinuous interbeds of calcareous sandstones and very-fine grained sandstones. Some of the interbeds show cross lamination on a fresh surface.

About 15 feet above the last exposure of Sauquoit turn left (N) up a normally dry tributary valley.

At the foot of the tributary 3 feet 3 inches of the oolitic Westmoreland Iron Ore is exposed. (Abundant ore for samples may be taken at the top of the tributary.) Above the Westmoreland 23 feet of the Willowvale Shale is exposed. The lower part of the Willowvale is predominantly greenish shale with a few beds of calcareous siltstone and sandstone. The upper part is mainly grayish silty shale with some interbeds of calcareous siltstone, sandstone and sandy dolostone. Between the upper and lower parts of the unit is a 4 foot transition zone which starts approximately 10 feet from the base of the unit. Fossils are present.

At the top of the tributary turn left (W) about 25 feet.

Dawes Dolostone

Contact of the Dawes with the underlying Willowvale is not seen here. Across the valley the contact is visible and the Dawes, there, as well as upstream, is cross-bedded. Here 7 feet 8 inches of the Dawes is exposed. The unit consists predominantly of sandy dolomitic limestone and dolostone with some interbeds of shale, siltstone, and calcareous sandstone. Some fossils are present.

The Dawes grades into the overlying fossiliferous Kirkland Iron Ore. Only 3 feet 2 inches of the ironstone is exposed here. Further upstream the Kirkland (5 feet thick) is seen to grade from the Dawes and into the overlying Joslin Hill.

Turn around and follow the path east along the valley top to Dawes Picnic Grove. Go past the buildings and follow the road to the parking lot.

The floor of the parking area is on the Joslin Hill. Abundant Rusophycus is scattered about. North of the parking area is an abandoned quarry. The Joslin Hill is composed chiefly of gray intercalated shale, siltstone, dolomitic sandstones, and sandy dolostone. Ripple marks and fossils are present.

(IF TIME PERMITS RETURN TO PICNIC TABLES FOR OPEN DISCUSSION)

Continue upstream along the Joslin Hill. A total of 36 feet of Joslin Hill is exposed along the stream. Ripple marks are fairly common and mud cracks rare. Go directly upstream until you reach the first waterfall east of the bridge that is on Dawes Ave. Several ripple marked beds are present as you continue upstream. The wave length of some reach 44 inches.

Climb up the slope to Dawes Ave., board the buses and return to start.

Continue south on New St.

85.3	0.1	Kellogg St. inters., turn left (E) onto Kellogg
85.8	0.5	Dawes Ave. inters., turn left (N) onto Dawes
85.9	0.1	Bridge on Dawes. Ripple mark sets beneath bridge and continuing upstream. Wave lengths to 44 inches.
86.0	0.1	Dawes Grove entrance on left (W) dirt road.
86.3	0.3	Brimfield St. "T-inters.", turn left (W) onto Brimfield
86.7	0.4	New St. inters. on left. Continue on Brimfield
86.8	0.1	Clinton Rd - Rte. 12b "T-inters." Clinton N.Y. to left. Turn right (N)
88.4	1.6	Inters. with rte. 5b, continue on 12b
90.4	2.0	Genesee St. (rtes. 5 & 12) inters. Cross inters. and continue on rte. 5 (E), 12 (N), Utica North-South Arterial
91.3	0.9	New York Mills exit to New Hartford St., North on New Hartford
91.7	0.4	Treadway Inn on New Hartford St.

END OF TRIP

Sedimentology and Stratigraphy of the Salina
Group (Upper Silurian) in East-central New York

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Abstract

The available evidence from outcrops suggests that the Salina Group of east-central New York was deposited in peritidal environments of a transgressing epeiric sea. Sedimentologic criteria suggest that the depositional environments were hypersaline with evaporites including halite deposited. The lithofacies of the Salina Group and the restricted fauna are characteristic of hypersaline conditions. The units underlying and overlying the Salina Group are "normal" marine carbonates.

Evidence from outcrops and subsurface studies indicates that the evaporites were deposited in environments which may have ranged from shallow water to supratidal. Thick accumulations of Salina Group rocks resulted from structural activity within the depositional area rather than from infilling of a deep topographic basin.

Introduction

The Salina Group of New York State is one of the major salt producing units in the United States. The production of salt from mines or brine wells has been quite important in the history and industrial development of central New York State. The salt was a major factor in the building of the Erie Canal and in the history of the city of Syracuse. During the War of 1812, salt production began at Syracuse as the result of the high prices for imported salt. During the Civil War, Syracuse salt production freed the North of salt worries while a lack of salt in the South influenced the duration of the war. Production from the Salina Group at Retsof, New York, began nearly one hundred years ago, and today the Retsof mine is reported to be the largest producer of rock salt in the world (King, 1966).

In spite of the economic and historic importance of the Salina Group relatively little is known about the depositional history of this unit. Several important studies have been made of the Salina Group (Clarke, 1903; Leutze, 1956; 1959; Rickard, 1969), but most of these have emphasized stratigraphy rather than its sedimentologic history. Alling (1928) discussed, in detail, the sedimentology of the Salina Group, but his study is now dated even though it contains much useful information. Alling and Briggs (1961) and Rickard (1969) have summarized regional

relationships of the Salina Group in the Appalachian and Michigan Basins, but do not treat the sedimentology in a detailed manner.

Recent controversies over the origin of sedimentary evaporites have spurred interest in carbonate-evaporite sequences throughout the world (Shearman, 1966; Buzzalini et al, 1969; Kudryavtsev, 1971; Friedman, 1972). Therefore, a study of the sedimentology of the Salina Group takes on additional interest. In studying the sedimentology of the outcropping Salina Group, limits can be placed upon the environments of evaporite deposition by interpreting the environments of deposition of the interbedded non-evaporite sedimentary rocks.

The purposes of this field trip are 1) to observe the stratigraphy of the Salina Group especially as it relates to sedimentology, 2) to interpret depositional environments, and 3) to gain some insight into the conditions which might have contributed to evaporite formation.

This paper first presents the stratigraphy of the Salina Group. Stratigraphy is essential in ascertaining the lateral relationships of the units and their bearing on the sedimentology. Following the stratigraphy is a section dealing with environmental reconstruction. These environmental interpretations are based on the sedimentologic and stratigraphic relationships of the various units of the Salina Group. Localities at which the Salina Group will be examined are shown in Figure 1.

Stratigraphy

The Salina Group of New York State was deposited during the Late Silurian (Cayugan Epoch) in the northern portion of the

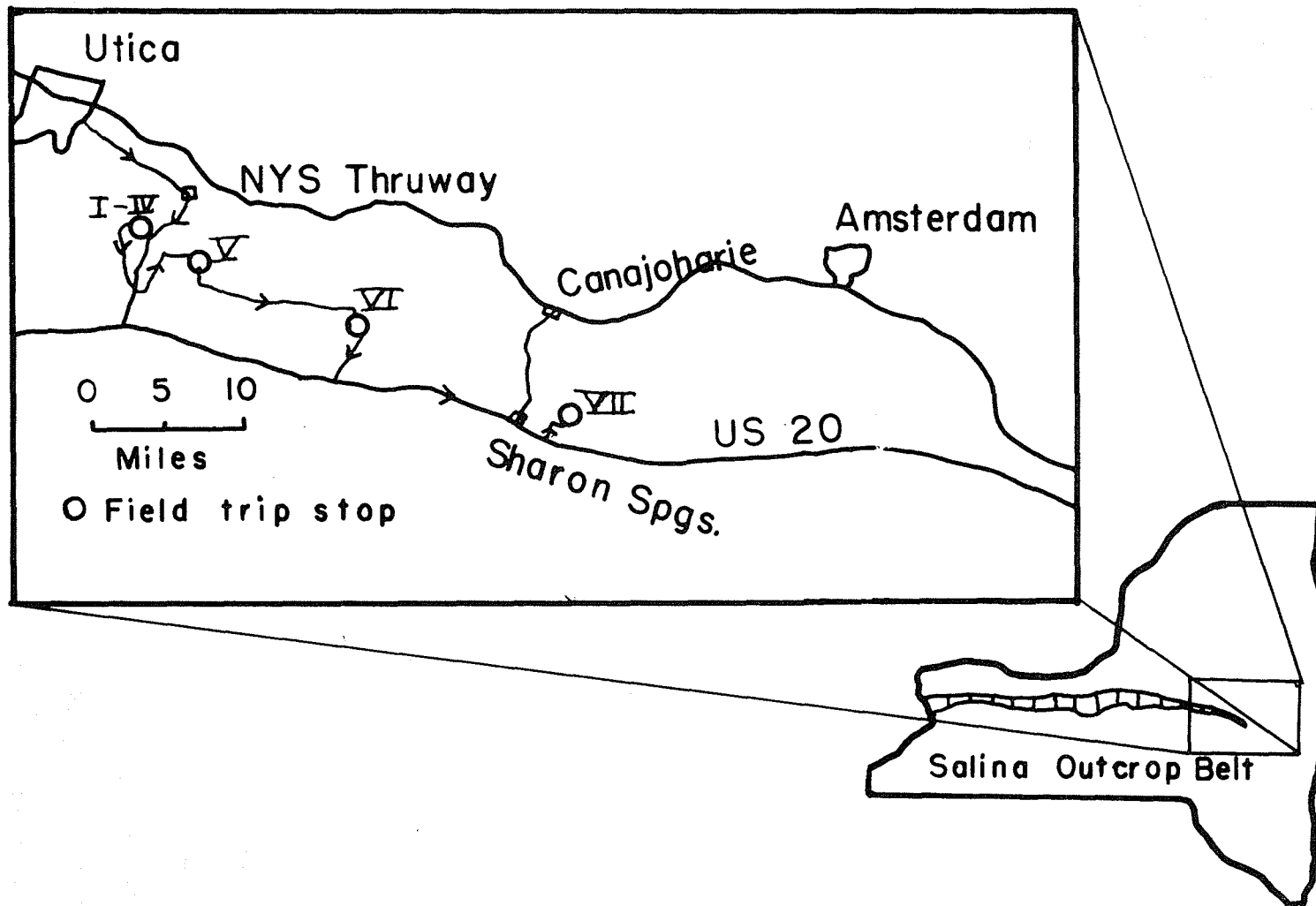


Fig. 1. Sketch map of field trip area showing location of stops and of the Salina Group outcrop belt.

Appalachian Basin. It is underlain in most of the outcrop belt by the Lockport Group (Niagaran Series - Middle Silurian); toward the east the group lies on progressively older rocks (fig. 2). The outcrop belt of the Salina in New York is an east-west trending belt up to ten miles wide (fig. 1). This outcrop belt lies along the boundary of the plateau front to the south and the lake plain to the north. The eastern limit of the outcrop belt is in the vicinity of Schoharie. To the west, exposures extend through the Buffalo region into Ontario; outcrops west of Auburn, however, are quite poor and widely scattered. The best area for outcrop study is an area bounded on the north by the New York State Thruway, on the south by highway U.S. 20, on the west by Auburn, and on the east by Schoharie (fig. 1).

Detailed stratigraphic studies of the Salina Group on outcrop have been made by Leutze (1956, 1959). These studies have solved many problems of outcrop terminology and relationships. Rickard (1969) has clarified subsurface relationships and established correlations with the outcrops. The Salina Group as recognized by Leutze and Rickard consists of four formations - the Vernon, Syracuse, Camillus, and Bertie (fig. 3).

The Vernon Shale, the oldest of the Salina formations, is typically bright red shale with local beds or lenses of green shale, dolomite, sandstone, or gypsum. The Vernon reaches its maximum thickness of 500 to 600 feet in the vicinity of Syracuse. The thickness of the Vernon decreases both east and west. To the west, the formation disappears southwest of Rochester. To the east the Vernon is 120 to 160 feet thick at Ilion gorge

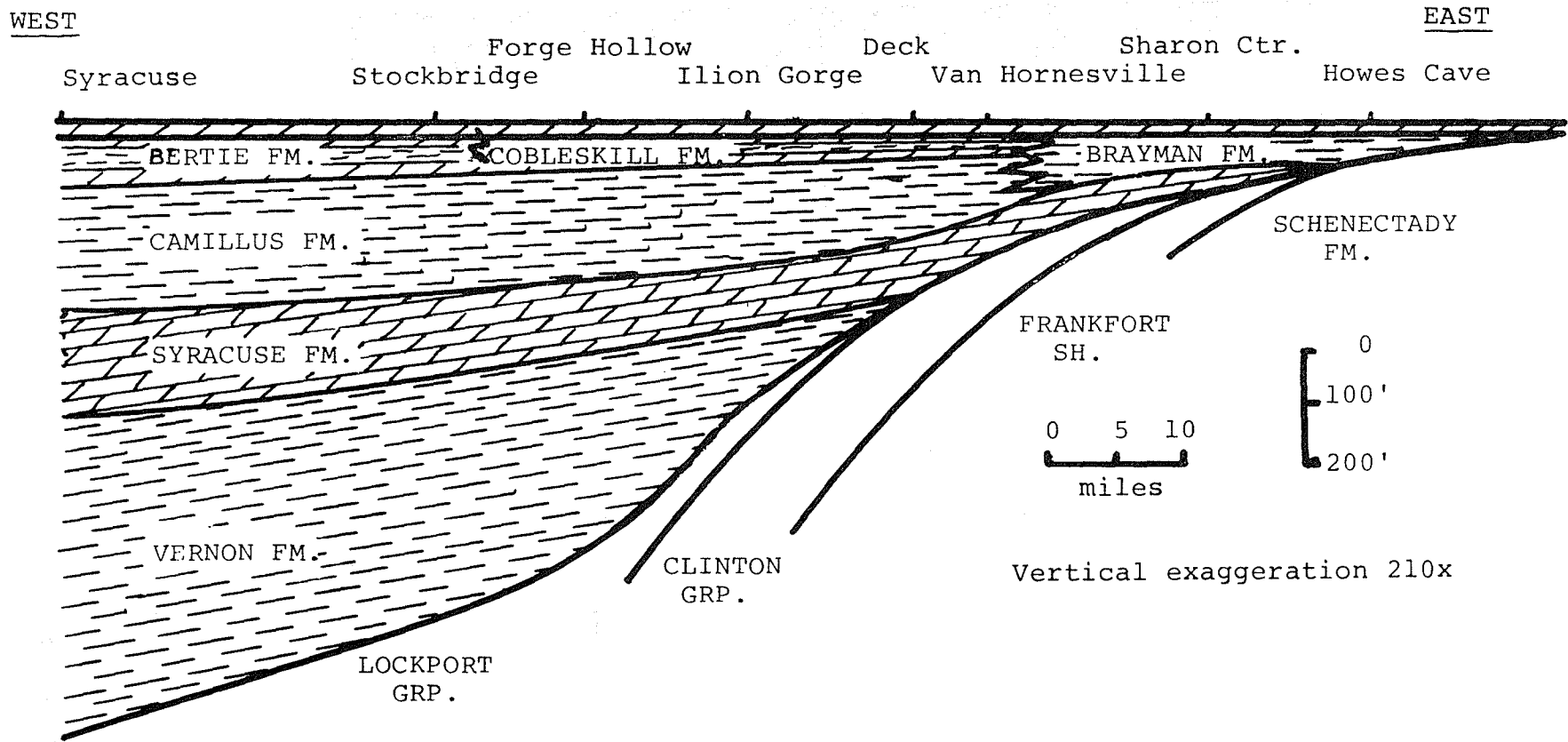


Fig. 2. Schematic east-west section showing transgressive nature of the Salina Group.

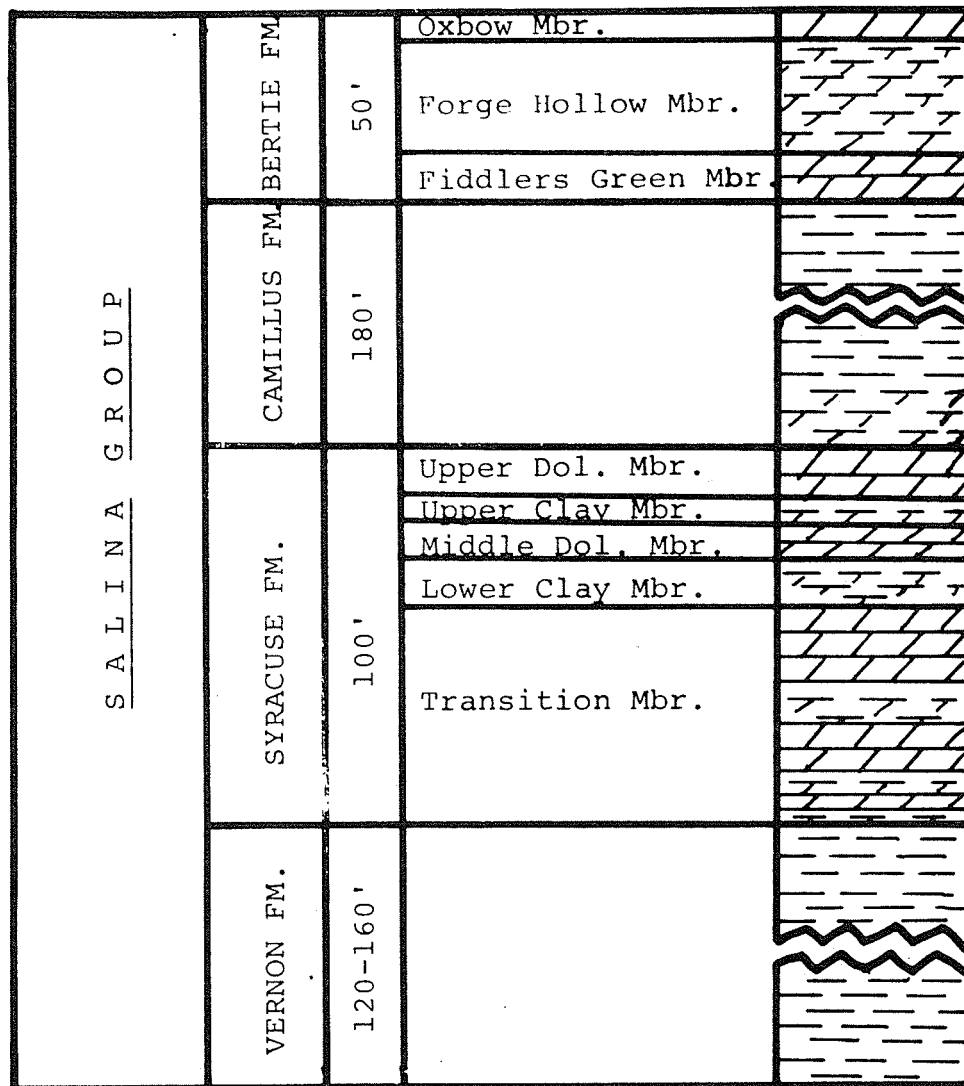


Fig. 3. Stratigraphy of the Salina Group (Cayugan Series - Upper Silurian).

(Stop I) but is not present 11 miles east at Deck where the Syracuse Formation unconformably overlies the Herkimer Sandstone. At Ilion gorge the Vernon consists of at least 95 percent red shale. This red shale decreases in abundance to the west; near Syracuse the red shales make up about 70 percent of the formation. West of the Genesee River red shales make up less than half of the formation (Leutze, 1964).

Overlying the Vernon Shale is the Syracuse Formation. The Syracuse Formation was originally defined as the salt and interbedded sediments known only in the subsurface (Clarke, 1903). At the outcrop, only the overlying Camillus Shale was recognized. Leutze (1956) redefined the Camillus Shale and applied the term "Syracuse Formation" to the dolomites, shales, and evaporites correlative with the subsurface salt sequence. The Syracuse Formation from Ilion gorge west consists of five members. East of Ilion gorge, division of the Syracuse Formation into members is difficult. The members are, in ascending order: the Transition Member, Lower Clay Member, Middle Dolomite Member, Upper Clay Member, and Upper Dolomite Member.

The Transition Member, the lowest member of the Syracuse Formation, consists of thin gray-to-green dolomite beds alternating ^{with} green shales. Some gypsum is present in the Transition Member at Ilion gorge (Stop II). Where exposed, the contact with the Vernon Shale is disconformable. The thickness of the Transition Member in Ilion gorge (Stop II) is at least 60 feet. In the central part of the state, the Transition Member reaches 100 feet

in thickness. As the name implies, the lithology of this member is transitional between the underlying Vernon and typical Syracuse lithologies.

Overlying the Transition Member of the Syracuse Formation is the Lower Clay Member. Typically, in the Syracuse region, this member consists of structureless, unbedded, gray clay averaging 12 feet in thickness. This member is found at approximately the same horizon as thick subsurface salt beds and is thought to be the insoluble residue of the salt beds (Leutze, 1956, 1959, 1964). This interpretation is supported by the presence, near Syracuse, of blocks of bedded gypsum encased in the clay. In Ilion gorge (Stop II) the Lower Clay Member shows some bedding, but characteristically is a highly weathered clay with some interbedded fine-grained gypsum and dolomite. Relationships of the Lower Clay Member at Ilion gorge to the subsurface Syracuse Formation are unknown. The thickness of this Member is about 11 feet. This member is difficult to distinguish from the Transition Member.

Thick bedded, resistant, ripple marked light gray dolomite characterizes the Middle Dolomite Member. Ostracodes, small pelecypods, and graptolites are present in this member but are poorly preserved. The Middle Dolomite Member is only seven feet thick at Ilion gorge; this compares with a thickness of 37 to 44 feet at Syracuse.

Above the Middle Dolomite Member another clay bed occurs. This has been designated the Upper Clay Member and is about seven feet thick in Ilion gorge. The Upper Clay Member seems to be

identical to the Lower Clay Member in all aspects except stratigraphic position.

The uppermost unit of the Syracuse Formation is the Upper Dolomite Member. This member consists of thin-to thick-bedded grey dolomite which internally is finely laminated. Abundant mudcracks and some ripple marks are found throughout the member. Fossils include algal mounds and ostracodes. The contact with the overlying Camillus shale is gradational. Approximately 15 feet of dolomite have been assigned to this member in Ilion gorge.

The Camillus Shale is conformable with the Syracuse Formation. The dominant lithologies of the Camillus Shale are red and olive-green shales; these shales occur as massive beds up to 35 feet thick or as one to three foot interbeds. Some dolomites and brown shales are present in the lower portion of the unit; mudcracks and ripple marks are common in the dolomite sediments. Many of these dolomites are finely interbedded with gypsum. Quartz sand-rich zones are present throughout the Camillus. The sand content seems to decrease westward. No fossils have been found in the Camillus. The thickness of the Camillus at Ilion gorge (Stop III) is about 180 feet.

The youngest unit of the Salina Group is the Bertie Formation. In central New York the Bertie contains three members - the Fiddlers Green Dolomite, Forge Hollow Shale, and Oxbow Dolomite, in ascending order. The Bertie Formation is overlain by the Cobleskill Dolomite.

The Fiddlers Green Member is exposed at the top of the Ilion

gorge section (Stop IV) and at Passage Gulf (Stop V). In these sections, the Fiddlers Green Member consists of medium- to thick-bedded, grey to brown, laminated dolomite. Mudcracks and fossils are found at some horizons in this unit. A massive bed at the top of the member contains abundant fragments and a few whole specimens of Eurypterus remipes and, also, abundant mudcracks. Both contacts of this member are sharp but appear to be conformable. The Fiddlers Green Member is about 15 feet thick at Passage Gulf (Stop V).

The Forge Hollow Member is also exposed at Stops IV and V. This member consists of thin-bedded, finely laminated, brown shaly dolomites. Gypsum crystal molds and interbedded gypsum are common. Mudcracks are abundant on some bedding surfaces. Thickness of this member at Stops IV and V is about 30 feet.

The Oxbow Member is not exposed at any of the field trip stops, but at its type section, about 15 miles west of Ilion gorge, it consists of thin-to medium-bedded, light grey dolomite. This unit is about four feet thick at Forge Hollow, the type section, and thins toward the east. Rickard (1962) has identified the Oxbow Member as far east as Deck.

East of Van Hornesville (Stop VI) the Camillus Formation and Bertie Formation are not distinctive units. The equivalent interval, the Brayman Formation, is represented by argillaceous, greenish-grey dolomites with shaly bedding and a high pyrite content. Well-rounded quartz sand and silt particles occur throughout the unit. Due to confusion in the stratigraphic nomenclature of the Salina Group, the relationship of the Brayman Formation

with the Syracuse Formation has been unclear. The Brayman was correlated with the "upper Camillus" and Bertie by Fisher and Rickard (1953), but this correlation preceded Leutze's redefinition of the Camillus and addition of the Syracuse Formation to outcrop terminology; therefore, the interval represented by the Brayman is unclear. It is apparent from several exposures east of Deck that the Brayman is equivalent to the Camillus and Bertie Formations but not to any portion of the Syracuse, as defined by Leutze (1956, 1959). This relationship is clear at Sharon Center (Stop VII) where Syracuse Formation dolomites, with characteristic fossils, are overlain by a typical Brayman lithology. The Brayman Formation, therefore, is the eastern equivalent of the Camillus and Bertie Formations, but not of the Syracuse. The Syracuse like the Vernon thins to zero thickness eastward through overlap and does not grade into the Brayman.

Environmental Reconstruction

The depositional environments of the Salina Group can be reconstructed through the use of sedimentology and stratigraphy. Sedimentary structures are particularly important in this reconstruction as, in the absence of fauna, they are the only reliable indicators of environments of deposition. Those sparse and poorly preserved fossil assemblages that are occasionally found in the Salina Group are indicative of restricted, hypersaline marine conditions.

The Vernon Shale has been the subject of extensive debate. Grabau (1913, p. 569) considered the Vernon a windblown loess

deposit, and Newland (1928) postulated that it was a residual soil. These hypotheses are discredited by the presence of the marine fauna described by Fisher (1957) at the type section in Vernon township.

Alling (1928) proposed that the Vernon Formation was deposited as "an initial shoreward phase of deltaic sedimentation". Fisher (1957) points out that the fossils of the Vernon are characteristic of a hypersaline environment; he suggests deposition in a large restricted multiple lagoon or a series of small restricted lagoons. The stratigraphic relationships of the Vernon indicate that the Vernon Sea transgressed eastward. This transgression was apparently onto a featureless low land which supplied fine grained sediments through long meandering streams. Apparently the eastward limit of transgression was somewhere between Ilion gorge and Deck.

The sedimentary structures and fossils in the Syracuse Formation collectively suggest deposition in a peritidal (near tidal) hypersaline environment. Very abundant mudcracks are found throughout the Syracuse; these mudcracks and associated flat-pebble conglomerates indicate at least intermittent subaerial exposure. Oscillation ripple marks are found in a few places indicating moderate bidirectional currents. Numerous erosional surfaces are also indicative of water movements. Nodular gypsum is present in the Syracuse Formation. This nodular gypsum is quite similar in appearance to nodular anhydrite which Shearman (1966) reported from sabkhas along the Persian Gulf. Friedman and Sanders (1967) report other occurrences of gypsum and anhydrite

associated with sabkha dolomites. In addition, the sediments of the Syracuse Formation are typically finely laminated dolomites, quite similar to the stromatolitic sediments of modern peritidal environments; algal heads are found in few places throughout the unit. None of these sedimentary structures alone is indicative of a peritidal environment, but collectively they present valid evidence for such an interpretation.

The fossils of the Syracuse Formation are typical of a hypersaline, restricted environment. Ostracodes are the most abundant fossils. Brachiopods, pelecypods, gastropods, eurypterid fragments, and graptolites have also been reported from the Syracuse Formation. Some horizontal burrows have been identified in the Upper Dolomite Member.

There seems to be little vertical change in the Syracuse Formation other than fluctuation in the amount of argillaceous material. Laterally, however, changes in depositional environments are apparent. The Sharon Center exposure (Stop VII) contains very abundant mudcracks and displays a nodular fabric throughout. The rocks here are representative of much more frequent subaerial exposure - possibly representing supratidal deposition. West of Sharon Center the sedimentary structures indicate less frequent exposure. The Sharon Center locality probably lies near the eastern depositional edge of the overlapping Syracuse Sea.

Although no halite is apparent in the outcrops, the Syracuse Formation is the major salt producer of New York State. The

environment of deposition of this salt has been quite controversial. Dellwig and Evans (1969) suggest that the salt was deposited in a shallow sea marked by turbulent water. Rickard (1969), on the other hand, proposes that "most of the Salina evaporites were deposited in waters 100 to 400 feet deep and possibly as much as 600 feet deep". A study in progress by this writer of a core from the Morton Salt Company mine near Penn Yan shows mudcracks, flat-pebble conglomerates, erosion surfaces, nodular anhydrite, and stromatolites in dolomites interbedded with salt beds of the Syracuse Formation. This writer has also observed mudcracks and flat-pebble conglomerates in the base of a dolomite bed immediately overlying one of the major salt beds of the Syracuse Formation in the Cayuga Rock Salt mine north of Ithaca. The sedimentary structures of dolomites from these two localities suggest similar environments of deposition to the peritidal environments of the dolomites along the outcrop belt. The peritidal origin of the dolomites intercalated with the salt beds, therefor, limits the probable environment of deposition of the salt beds to the shallow water or supratidal environments.

If the environment of deposition of the salt beds is limited to shallow water or supratidal environments, a mechanism must be proposed to explain the thickening of the Salina Group to the south. Traditionally, this southward thickening has been explained by the depositional filling of a deep topographic basin which deepens southward. The presence of peritidal dolomites interbedded with the salt beds in the Syracuse Formation, however, makes this

deep topographic basin hypothesis difficult to support. The alternative to a deep topographic basin is a structural basin. In the structural basin hypothesis, the basin subsides at approximately the same rate as the rate at which sediments are deposited. The depositional interface is never in "deep water", and an actual topographic basin need never exist. Instead, a broad tidal flat or peritidal area persists. A faster rate of subsidence near the center of the flat accounts for the increased thickness of sediments to the south. This hypothesis is in agreement with the lithology and sedimentary structures of the rocks and is the one proposed to explain the southward thickening of the Salina Group. This structural subsidence may also explain the apparently contradictory conditions of a restricted hypersaline sea which is transgressive. Subsidence of the basin margins of the Salina Sea might result in transgressions in spite of the restricted condition of the waters.

The depositional environments of the Camillus Formation are more obscure. No fossils have been found in the Camillus; a few mudcracks are the only sedimentary structures present. Lithologically the Camillus is a dolomitic shale with the dolomite content decreasing upward. Well-rounded sand grains are found throughout the Camillus. Nodular gypsum and gypsum interbedded with dolomite are found in the lower portion of the Camillus. The association, both above and below, with marine units and the presence of dolomite and gypsum suggest the Camillus is a marginal marine deposit although conclusive fossil evidence is lacking. The sedimentary

structures indicate at least intermittent subaerial exposures. Rounded quartz grains may be eolian in origin. East of Van Hornesville (Stop VI), the Camillus along with the Bertie grade into the Brayman Shale.

The Bertie Formation was probably deposited in an environment similar to that of the Syracuse Formation. Mudcracks, flat-pebble conglomerates, small erosional channels, burrows, possible molds of evaporite crystals, and nodular fabrics have been found in the Fiddlers Green and Oxbow Members of the Bertie. The Forge Hollow Member, found between these dolomites, is a mudcracked, finely laminated, argillaceous dolomite with shaly bedding. Fossils of the Bertie are typical of a restricted, hypersaline environment, and the sedimentary structures are compatible with a peritidal origin.

The Brayman Shale which is the eastern equivalent of the Bertie and Camillus Formations is probably quite similar to the Camillus in origin. The presence of abundant pyrite indicates reducing conditions at some time in the history of the Brayman Shale.

Summary

The Salina Group represents a complete cycle of sedimentation. It is underlain and overlain by relatively "normal" marine carbonates, the Lockport and Cobleskill Formations respectively. This cycle of sedimentation is especially interesting in that it is a transgressive hypersaline sequence. Classically hypersaline sequences were thought to be regressive in nature. Not enough

evidence is yet available to explain this apparently contradictory relationship. One possible explanation is that the transgressions are the result of structural activity within the Salina Basin. The sedimentology, however, clearly shows that the Salina Group rocks of the eastern portion of the outcrop belt represent deposition in a hypersaline, peritidal environment. The rocks are characterized by mudcracks, other peritidal sedimentary structures, and restricted hypersaline fossil assemblages.

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ROAD LOG

<u>Total</u>	<u>From last Stop</u>
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Stop I - Vernon Shale

0.0	0.0
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Start at Junction N.Y. 51 & Jerusalem Hill Road. The exposures on the south side of Jerusalem Hill along the creek are near the bottom of the Vernon Formation. The Vernon here is a massive red shale. A few green spots can be seen in the red shale. These apparently result from reduction around particles of organic matter; dark carbonaceous debris occasionally can be found in the center of these green spots. Green color is also present along joints indicating color change due to ground water action.

The contact of the Vernon with the underlying Lockport Formation is exposed along the west side of Steele Creek about 1000 feet north of this exposure. The Lockport is a medium-bedded dolomite with mudcracks and current ripples. The contact of the Lockport with the Vernon is sharp but may be conformable. The thickness of the Vernon in Ilion gorge is 120 to 160 feet.

Proceed west on Jerusalem Hill Road.

Stop II - Syracuse Formation

0.5	0.5
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Pull off just west of Bridge where creek crosses road. Outcrop is 0.1 miles further west.

This stop exposes a nearly complete section of the Syracuse Formation. The lower contact of the Syracuse with the Vernon is not exposed. The contact with the overlying Camillus is gradational. The section is as follows:

Camillus Fm.

Syracuse Fm. (94 ft.)

Upper Dolomite Mbr. (14 ft.)

Upper Clay Mbr. (7 1/2 ft.)

Middle Dolomite Mbr. (7 1/2 ft.)

Lower Clay Mbr. (11 ft.)

Transition Mbr. (54 ft.)

Ripple marks and mudcracks can be found throughout the Syracuse and Camillus Formations at this locality. Ostracodes and other fossils are present in the Middle and Upper Dolomite Members, and algal heads in the Upper Dolomite Member. Note also the finely laminated nature of the dolomites and dolomitic sediments; these laminations are characteristic of peritidal deposits.

Continue west on Jerusalem Hill Road.

<u>Total</u>	<u>From last Stop</u>
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Stop III - Camillus Formation

0.9	0.4	Quarry on left (S) side of road.
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The section to be examined is in the quarry on the south side of Jerusalem Hill Road. About 80 feet of Camillus are exposed in this quarry. The total Camillus thickness in this area is about 180 feet. The section in this quarry is typical of the middle and upper Camillus. The lower portion of the Camillus, however, is more dolomitic. With the exception of a few mudcracks, sedimentary structures and fossils are generally absent.

Continue west.

Stop IV - Bertie Formation

1.5	0.6	Junction of Jerusalem Hill Road and Cedarville Road, Town of Litchfield Maintenance Building on left (S) side of road. Outcrop is across Cedarville road from building.
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This is a brief stop to examine the Fiddlers Green and Forge Hollow Members of the Bertie Formation. These units will be examined in more detail at the next stop. Mudcracks and eurypterids are common in the massive bed at the top of the Fiddlers Green. Poor outcrops in the field above the roadcut may be in the Cobleskill Formation. About 13 feet of the Fiddlers Green Member and 25 feet of the Forge Hollow Member are exposed here. The composite thickness of the Salina Group along the Jerusalem Hill Road in Ilion gorge is about 450 feet.

4.2	2.7	Turn left (S) onto Cedarville Road. Junction Cedarville road and N.Y. 51.
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Proceed onto N.Y. 51 heading East and pass general store on route (S) and then Fire Hall on left (N).

4.3	0.1	Junction of N.Y. 51 and Elizabethtown Road. Turn left (N) on Elizabethtown Road.
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7.3	3.0	Junction Brewer Road and Elizabethtown Rd. in Elizabethtown. Turn right (E) onto Brewer Road.
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8.4	1.1	Junction Spohn Road and Brewer Road. Turn right (S) onto Spohn Road.
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Stop V - Camillus and Bertie Formations

8.7	0.3	Outcrop on left (E) side of road in passage gulf.
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The section in this roadcut is as follows:

Bertie Fm. (40 ft.)
 Forge Hollow Mbr. (23 ft.)
 Fiddlers Green Mbr. (17 ft.)
 Camillus Fm. (25 ft.)

<u>Total</u>	<u>From last Stop</u>
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The Camillus-Bertie contact can be examined at this stop. This contact is quite sharp. Below the contact, the Camillus consists of gray and green dolomitic shales with mudcracks. The overlying Fiddlers Green Mbr. of the Bertie Formation is medium- to thick-bedded dolomite. Mudcracks are present throughout, especially in the two foot massive bed at the top of the Fiddlers Green Member; this bed also contains eurypterids. The Forge Hollow Member is a shaly dolomite with some mudcracks and is exposed in the gentle slope just above the massive bed.

Continue southeast on Spohn Road.

- | | | |
|------|-----|--|
| 10.8 | 2.1 | Junction Spohn Road and N.Y. 472. Petrie Brown Memorial on route.

Turn right (S) onto New York 472. |
| 11.0 | 0.2 | Proceed into Columbia Center to Junction N.Y. 472 and Jordanville Road.

Turn left (E) onto Jordanville Road.

Proceed east. |
| 13.0 | 2.0 | Junction Jordanville Road and N.Y. 28.

Proceed east (straight across) on Jordanville Road. |
| 15.5 | 2.5 | Junction Jordanville Road and N.Y. 167.

Remain on Jordanville Road East and N.Y. 167, going through town of Jordanville. N.Y. 167 forks off to north (cemetery). Stay on Jordanville Road East. |
| 21.4 | 5.9 | Turn right (S). Jordanville Road takes a 90° turn here.

Proceed south on Jordanville Road. |
| 22.4 | 1.0 | Stop VI - Syracuse and Camillus Formations |

Road cut on east side of road. Another exposure about 0.1 mile south on west side.

The Salina Group in this area has thinned to less than 150 feet from the 450 feet measured in Ilion gorge. The Vernon Formation is not present as the result of depositional onlap. The easternmost exposure of Vernon shale is about eight miles to the west, north of Jordanville.

About 45 feet of Clinton sandstones, shales, and hematite beds are exposed below the Syracuse Formation. The contact with the Syracuse is at the top of a poorly consolidated conglomeratic sandstone (Herkimer). This contact is disconformable.

<u>Total</u>	<u>From last Stop</u>
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The Syracuse at Van Hornesville is about 80 feet thick. Although member designations are difficult, the lower 55 feet appears to consist of the transition and Lower Clay Members. The Middle Dolomite Member is about 10 feet thick; the Upper Clay Member, eight feet; and the Upper Dolomite Member, 15 feet. Mudcracks are present throughout the Syracuse Formation. Halite crystal casts associated with mudcracks have been found on some talus slabs. Algal heads and burrow trails are present in the Upper Dolomite Member. Some lenses of fine-grained non-laminated dolomite are present in the well-laminated Upper Dolomite Member. Eurypterid fragments are also found in this member.

The Syracuse Formation grades upward into the Camillus Formation. The Camillus is a grayish-green to dull red dolomitic shale. In places, fragments of the grayish-green sediment can be found contained in a red matrix. This is the easternmost exposure of the Camillus Formation; the correlative interval to the east is designated Brayman Shale.

Proceed south on Jordanville Road.

22.5	0.1	Junction Jordanville Road and N.Y. 80.
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Turn right onto N.Y. 80. Proceed south.

24.2	1.7	Herkimer and Otsego Co. Line.
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27.1	2.9	Junction N.Y. 80 and U.S. 20.
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Turn left (E) onto U.S. 20.

Proceed east on U.S. 20, passing through Cherry Valley, east Springfield, and Sharon Springs to Sharon Center.

42.6	15.5	Junction Gilbertville Road in Sharon Center.
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Turn left (N) onto Gilbertville Road.

43.6	1.0	Sharp right (E) turn in - Gilbertville Road.
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43.9	0.3	Junction Gilbertville Road and Dirt Road.
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Turn left (N).

44.2	0.3	Stop VII - Syracuse and Brayman Formations
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Quarry set off road (on east side) about 100 feet.

The Syracuse Formation has thinned to less than 30 feet at this quarry from nearly 100 feet in Ilion gorge 25 miles to the west. In addition to thinning eastward through overlap, the sedimentology of the Syracuse Formation at Stop VII is quite different from Ilion gorge (Stop II). The Syracuse consists of thin-bedded laminated shaly dolomites with very

abundant nodules throughout. The nodules are now filled with calcite which probably is secondary after gypsum or anhydrite. Around these nodules the dolomite has been brecciated. In addition to the nodular fabric, mudcracks are quite abundant in the Syracuse Formation. Some ripple marks, cross laminations, and fossils (ostracodes, gastropods, and brachiopods) are also present. The exposure is probably quite near the eastern depositional limit of the Syracuse Formation and more frequent subaerial exposure should be expected. The abundance and types of sedimentary structures and the nodular fabric suggest a supratidal or near supratidal environment of deposition.

The overlying Brayman Formation is a massive greenish gray shaly dolomite and dolomitic shale. Well-rounded sand grains can be found in this unit; these sand grains may be eolian. A 12 inch dolomite bed near the top of the quarry may represent the influence of Fiddlers Green sedimentation even though the Bertie Formation is not recognizable this far east. The thickness of the exposed Brayman at this locality is about 20 feet.

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STRATIGRAPHY OF THE MARINE LIMESTONES AND SHALES OF THE
ORDOVICIAN TRENTON GROUP IN CENTRAL NEW YORK

by

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INTRODUCTION

For about 150 years the Ordovician rocks of the Mohawk Valley region have been under study. Many geologists and paleontologists of the 19th and 20th centuries have studied the limestones, shales, and fossils of the Black River Group and the Trenton Group in the Black River, West Canada Creek, and Mohawk River valleys (see Kay, 1937, for an historical review of early work). As a result, these rocks have become well-known as part of the medial (middle time of a three-fold subdivision) Ordovician standard section of North America.

However, the geology of the Trenton Group, as well as the Black River Group, still poses several relatively complex and interesting stratigraphic problems. Exposures are occasionally complete, but many are not. The repetitious nature of the sedimentary layers of the Trenton Group often mask significant variations critical to correct lithostratigraphic, biostratigraphic, and paleoecologic interpretations. The modern approaches to the study of paleoenvironments of carbonate rocks have just recently been applied with emphasis to parts of the medial Ordovician sequence in central and northwestern New York. Many previous investigators who have studied these formations have been, by necessity, primarily concerned with lithostratigraphy, such as statistical analysis of rock types (especially Chenoweth, 1952, and Lippitt, 1959), biostratigraphy and correlation, and mapping. Present and future work depends and will depend heavily on that of earlier workers who prepared the way by determining the basic lithostratigraphic and biostratigraphic frameworks which will be examined and evaluated on this field trip.

The interests of this author center around establishing a detailed time and lithic microstratigraphic framework for the Trenton Group in central and northwestern New York. This would form the basis and provide the confidence for reconstructing the environments of deposition and determining the paleogeography. At present, special emphasis is being placed on statistical analysis of the rock types from both detailed field measurements and carbonate petrography, small scale physical and biological correlation, primary sedimentary structures, trace fossils, fossilization, and fossil community analysis. This information should better document the initial and subsequent wider transgressions and regressions of the Trentonian sea.

The purposes of this field trip to the Trenton Group limestones of central New York are to:

- 1) Demonstrate the stratigraphic succession and lateral facies changes.
- 2) Discuss and evaluate the age relationships and time correlations.
- 3) Examine and evaluate the criteria for determining the conditions and environments of deposition and paleogeography.

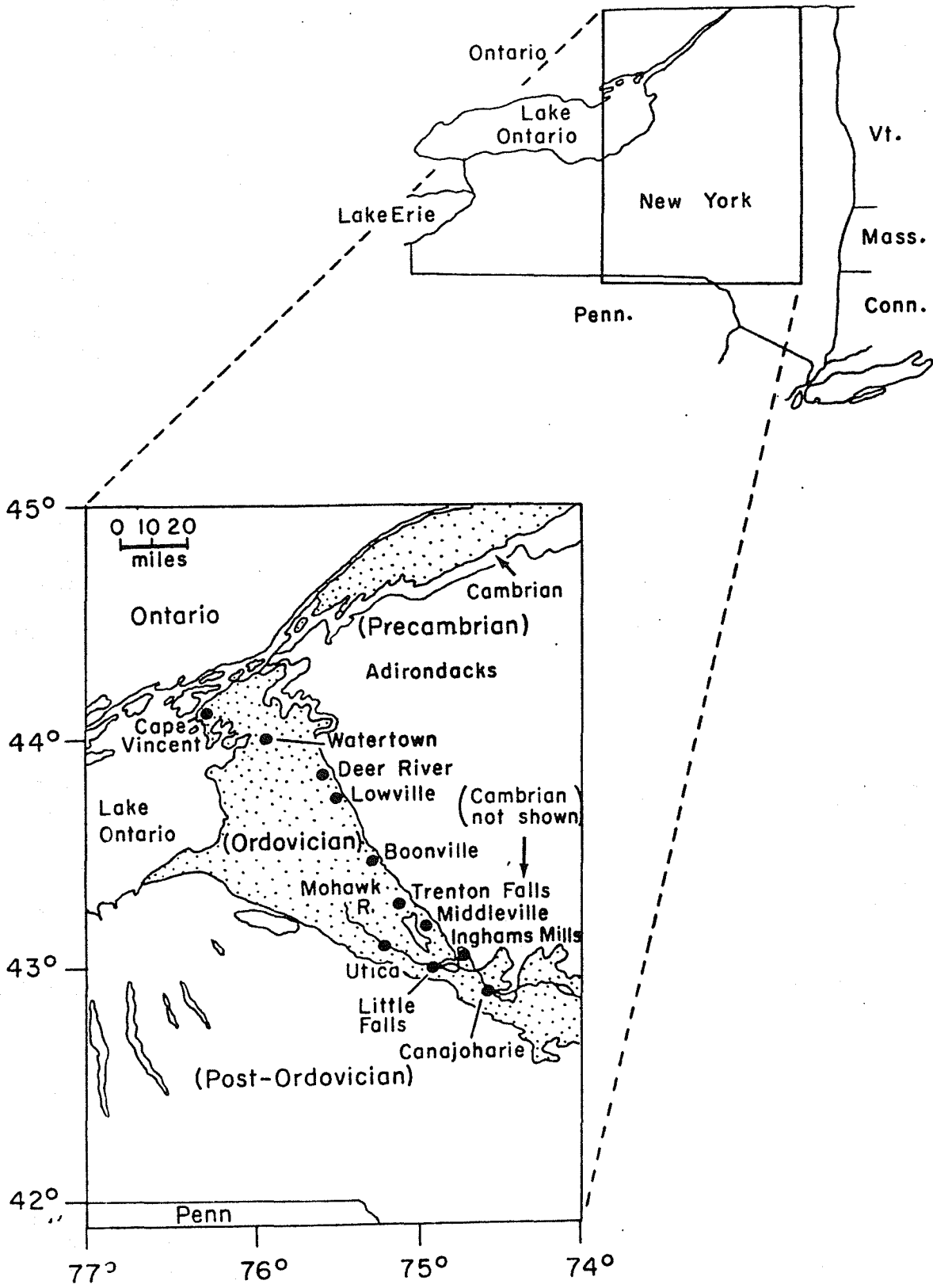


Figure 1. Geologic outline map of study area.

This field trip guide will summarize previous work on the Trenton Group in central and northwestern New York. The order of localities has been chosen to be as conveniently as possible for economy of travel along a southeast to northwest traverse that also essentially climbs up the stratigraphic succession.

REGIONAL GEOLOGIC SETTING

Lower Paleozoic rocks nearly surround the Adirondack Dome, a complex of Precambrian igneous and metamorphic rocks, of northern New York which forms with the Frontenac Arch in southeastern Ontario on the northwest the northern boundary of the Allegheny Synclinorium (Kay, 1948). In northwestern New York and southeastern Ontario, medial Ordovician Bolarian and Trentonian strata comprise most of these bordering sedimentary rocks (figs. 1-2). Subsurface contours drawn on the base of the combined Black River-Trenton sequence indicate a gentle (about $\frac{1}{2}$ to $1\frac{1}{2}$ degrees) regional dip southwestward (Flagler, 1966, pl. 5). A few north-east-southwest trending normal faults cut Paleozoic and Precambrian rocks (Cushing, 1905a; Kay, 1937).

Along the margin of the Adirondacks from central to northwestern New York, Cambrian rocks occur only in the Mohawk Valley (Little Falls Dolomite) and in the St. Lawrence Lowland (Potsdam Sandstone). Early Ordovician (Canadian) limestones and dolostones occur in the Mohawk Valley, but disappear immediately to the northwest (Tribes Hill and Chuctanuda formations, Fisher, 1954). Thus, the limestones of the Black River Group progressively overlap the late Cambrian and early Ordovician strata in central New York and part of the late Cambrian strata of northwesternmost New York. Along the west-central margin of the Adirondacks, they lie nonconformably on the Precambrian.

In northwestern New York, the Black River and Trenton groups are complete. However, to the southeast in central New York the lowest Black River, upper Black River, and lowest Trenton limestones progressively disappear and a disconformity representing at least two stages appears to exist along the Black River-Trenton boundary (fig. 2) (Cameron, 1968, 1969a, 1969b). Eastward in the Mohawk River valley south of the Adirondacks, the Black River Group and the Trenton Group limestones pinch out across the Adirondack Arch east of Canajoharie (figs. 1-2), reappearing farther to the east in the Mohawk and Champlain valleys. In addition, the middle and upper Trenton Group changes facies in central New York from interbedded shelly limestones and shales to non-shelly limestones and shales and finally to black, graptolite-bearing shales over a few miles from east of the type section at Trenton Falls to west of Canajoharie (figs. 1-2).

THE TRENTON GROUP

Significance:

The Ordovician rocks of New York State have customarily served as the North American standard for the early and medial Ordovician (Kay, 1937; Fisher, 1962), of which the Trenton Group has comprised the top. A standard section (or group of sections) is important because it is generally used to supplement a type section and is used for comparison and correlation. It is chosen "...to serve as a standard of reference for a certain part of the geologic column in a certain geologic province" (Dunbar and Rodgers, 1957, p. 301). In North America, standard sections are necessary because the type sections for the geologic periods are in Europe where the geologic column was first established.

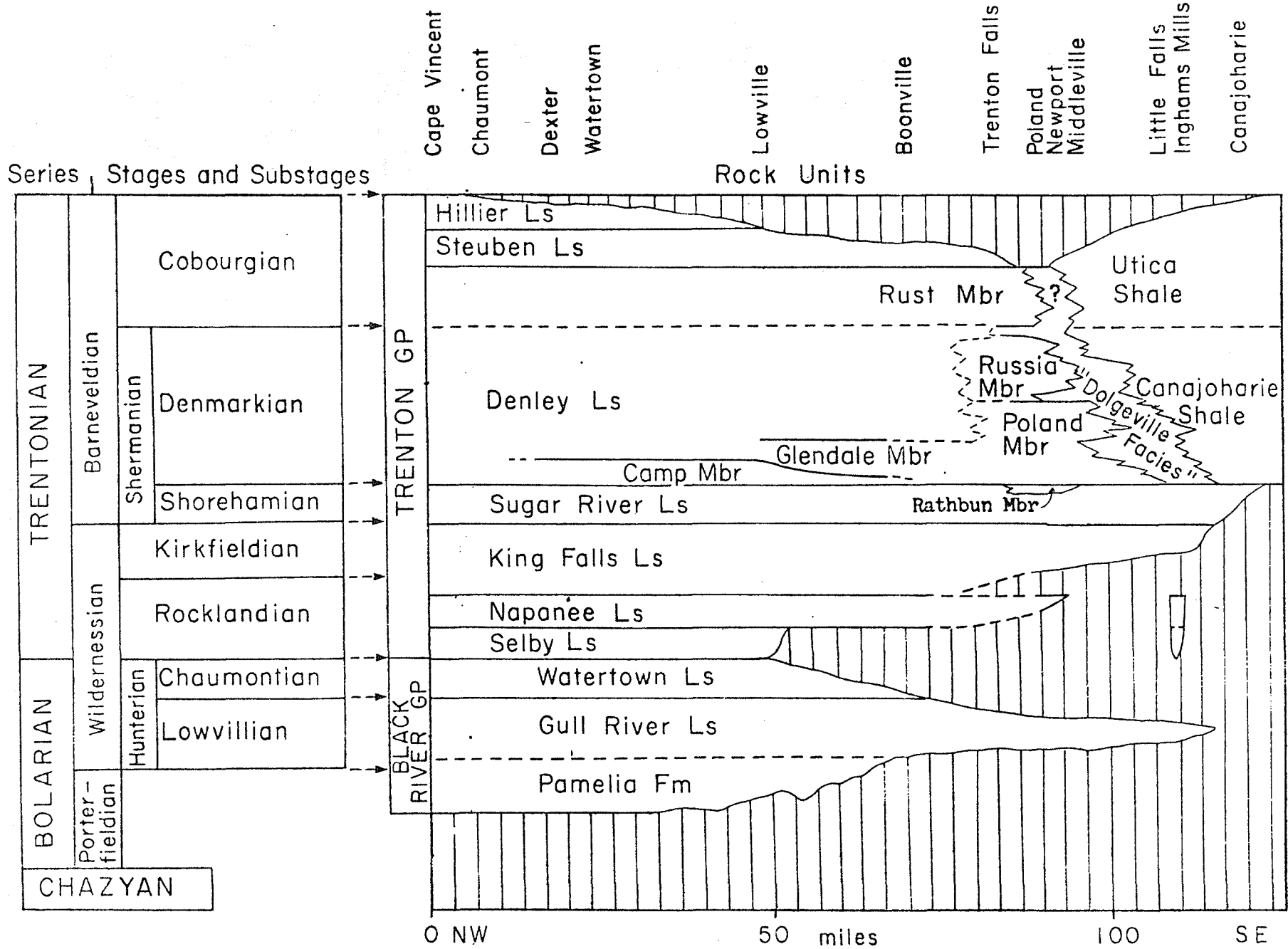


Figure 2. Medial Ordovician stratigraphic classification and nomenclature for central and northwestern New York.

Formations:

Introduction - Seven vertically successive Trenton limestone formations occur in northwestern New York (fig. 2). Southward to central New York, however, the Hillier at the top disappears due to an erosional unconformity (disconformity). In addition, the Selby at the base is also absent to the south because the early Trentonian transgression was not completed until later during the third (Shorehamian) stage, marking the end of the early Trentonian (fig. 2). The middle Trenton Group is dominated by the relatively thick Denley Limestone (250 feet) which is subdivided into 5 members. Three of these comprise the whole formation in central New York where the lower and middle Denley grades into the Dolgeville Facies which, with the upper Denley, in turn grades, by facies change, into the Canajoharie and Utica black shales.

Selby Limestone - The Selby Limestone, defined by Kay (1937) and raised to formational rank by Cameron (1967), is a somewhat massive unit averaging about 10 feet thick and composed of burrow-reworked, calcisiltites and fine-grained calcarenites. The Selby extends from southeastern Ontario where the type section is located southeastward to disappearance in the Black River valley west of the Adirondacks between Lowville and Boonville (figs. 1-2) (Cameron, 1968). It will not be seen on this field trip.

Napanee Limestone - The 20- to 40-foot thick Napanee Limestone, defined by Kay (1937) and raised to formational rank by Cameron (1967), is characterized by fine- to medium-grained calcisiltites interbedded with calcareous shales (Cameron, 1968). Its type section is in southeastern Ontario from which it extends southeastward to disappearance in central New York where two unnamed members illustrate complicated early Trentonian paleogeography (fig. 2). Although the Napanee will not be seen on this field trip, it will be studied in detail on another trip at this meeting (see the field trip guide by Cameron, Mangion, and Titus elsewhere in this book).

Kings Falls Limestone - The fairly widespread Kings Falls Limestone was defined by Kay (1968b) and is composed of interbedded medium- to thick-bedded, coarse-grained, very fossiliferous limestones and thin calcareous shales. It disappears west of Canajoharie (fig. 2). The limestones are dominantly horizontally and cross-laminated calcarenites, being shelly throughout central New York, but less shelly in the upper half in northwestern New York. See the field trip guide by Cameron, Mangion, and Titus elsewhere in this book for a description of this formation.

Sugar River Limestone - The fairly widespread Sugar River Limestone was defined by Kay (1968b). This formation, which disappears east of Canajoharie across the Adirondack Arch (fig. 2), is composed of interbedded burrow-reworked, thin- to medium-bedded, fine- to medium-grained calcarenites and thin, calcareous shales. (For a detailed description, see the field trip guide by Cameron, Mangion, and Titus elsewhere in this book.) The Rathbun Member has been recognized in the valley of West Canada Creek as comprising the topmost 6 to 10 feet of the Sugar River Limestone (Chenoweth, 1952). At the type section at Rathbun Brook, Kay (1943) described "...6 feet of brachiopod coquina, calcilutite and calcareous shale..." directly underlying the Trocholites subzone of the Poland Member of the Denley Limestone.

Denley Limestone - In central and northwestern New York, the Denley Limestone has been subdivided into 5 members. The basal Camp and Glendale members, defined by Chenoweth (1952), comprise the lowest Denley Limestone to the north where they are succeeded by a very thick unnamed member. The Camp member

forms the base and is composed of about one to 12 feet of burrow-reworked, rubbly, nodular, argillaceous, calcisiltites and fine-grained calcarenites interbedded with thin calcareous shales. It will not be seen on this field trip, but it resembles, to some degree, the limestones of the Trocholites subzone (Stop #4) that are also at the base of the Denley Limestone in central New York where the Camp is absent.

The Glendale Member is composed of "...35 feet of even-bedded, hard blue-gray barren calcilutites, calcareous shales, and coquinal calcarenites..." (Chenoweth, 1952, p. 530) located west of the Adirondacks from Boonville to Lowville. The calcilutites and calcisiltites contrast strongly with the underlying Camp Member and the undifferentiated overlying Denley limestones. Because of the similarity between the Glendale to the north and the Poland Member to the south, the Glendale is considered a northward tongue of the lower Poland Member exposed at Trenton Falls (Chenoweth, 1952). The interval immediately south of Sugar River (Boonville) to Trenton Falls (about 16 miles) is concealed.

The Denley has not been further subdivided in northwestern New York, except for local unnamed members (Chenoweth, 1952). However, along West Canada Creek at Trenton Falls three members are recognized and comprise the whole formation which is fully exposed except for the extreme base. In ascending order, the Poland, Russia, and Rust shaly limestones possess a thickness of about 250 feet.

The Poland Member, defined by Kay (1943), is about 60 feet thick (including about 10 feet covered at the base) at the type section at Trenton Falls. It is composed of argillaceous, bituminous, fine-grained calcisiltites and calcareous shales (Kay, 1943). At Trenton Falls it is overlain by the Russia Member, but southeastward, e. g., at Middleville, it is overlain by a tongue of the Dolgeville Facies (fig. 2).

The Russia Member, defined by Kay (1943), is about 75 feet thick at the type section at Trenton Falls. It is composed of rubbly, burrow-reworked, shaly limestones that nearly lack shelly calcarenites. Southward, e. g., south of Poland and Middleville, fine-grained calcisiltites become more abundant and eventually this member, like the Poland Member, is replaced laterally by the Dolgeville Facies (Kay, 1937, 1943, 1953). The top of the type section contains beds that resemble the Dolgeville, thus indicating another tongue of the Dolgeville Facies (fig. 2).

The Rust Member, defined by Kay (1943), "...comprises 115 feet of argillaceous and Rafinesquina deltoidea (Conrad)-bearing coquinal limestone to the base of the coarse-textured Steuben limestones..." (Kay, 1943, p. 602). The famous slumb breccias at Trenton Falls occur near the top of this member. To the south, in western Herkimer County, the Rust apparently changes to the black shale facies of the lower Utica; It is more argillaceous in the poorly exposed intervening area around Poland, New York. The undivided upper Denley of northwestern New York resembles to some degree the Rust Member of central New York.

Steuben Limestone - The Steuben Limestone, defined by Kay (1943), is composed of horizontally and cross-laminated, heavy-ledged, medium- to coarse-textured, massive, encrinitic calcarenite with little interbedded shale. It forms a scarp at the top of the Denley Limestone (Lippitt, 1959) in northwestern New York where it is less encrinitic, more shaly, well-burrowed, and resembles the overlying Hillier Limestone. In the vicinity of Trenton Falls it appears to be only up to about 26 feet thick, but to the north it reaches about 50 feet.

Hillier Limestone - The Hillier Limestone, defined by Kay (1937), is about 60 to 70 feet thick in northwestern New York. Because it thins southward to disappearance in southern Lewis County, it will not be seen on this field trip. It is less massive than the subjacent Steuben Limestone, being composed of argillaceous, fine-grained calcarenitic and calcisiltitic limestones and interbedded thin, calcareous shales. Above this unit are the Collingwoodian (late Ordovician, i. e., Cincinnati) shales which are time-equivalent with the upper Utica shales of central New York (Kay, 1937).

Dolgeville Facies - The term Dolgeville beds (Cushing, in Miller, 1909, p. 21) was applied to the interbedded, limestones and shales transitional between the Denley (Poland and Russia members) and Canajoharie-lower Utica black shales. The limestones are relatively thick, black, fine-grained, argillaceous, and sparsely fossiliferous. The shales are also relatively thick, black, and sparsely fossiliferous. This 50- to 100-foot thick facies has a limited distribution from southeast of Trenton Falls to west of Canajoharie. Insufficient exposure makes detailed evaluation of its stratigraphic relationships difficult, but tongues into the Denley Limestone are known. See the description of the Poland and Russia members of the Denley Limestone in the text above for further details. Its fauna is characterized by some graptolites, inarticulate brachiopods, and the trilobite Triarthrus becki (Green). Occasionally, thin beds with typical Trenton shelly faunas dominated by the articulate brachiopod Dalmanella can be found (Stop #2).

Canajoharie and Utica Shales - The Canajoharie Shale, which is at least 50 feet thick, is Denmarkian in age and is the time-equivalent of the Dolgeville Facies and the Poland and Russia members of the Denley Limestone (Kay, 1937, 1943, 1953, 1968). The Utica Shale, which is up to 750 feet thick, overlies the Canajoharie Shale to the southeast and the Cobourgian limestones to the northwest. It is Cobourgian and younger in age (fig. 2). Essentially, both formations are a monotonous sequence of graptolite-bearing, black shales (Kay, 1937, p. 268-271, 282-283; Kay, 1953, p. 57-58, 62-64). The Utica shales will not be seen on this field trip, but the lower Canajoharie will be examined at Stop #1.

TIME-STRATIGRAPHIC UNITS

The Trentonian Series refers to the time during which the Trenton Group was deposited. Five stages are recognized as subdivisions of the Trentonian Series (fig. 2). These are, in ascending order, the Rocklandian, Kirkfieldian, Shorehamian, Denmarkian, and Cobourgian. Kay (1960, p. 30) thought that "Probably the term stage is too high an order for the named divisions of the Trentonian..." and proposed larger subdivisions which have not been generally accepted, except possibly for Shermanian which includes the Shorehamian and Denmarkian (Sweet and Bergstrom, 1971). The formations (described above) deposited during these stages are indicated by figure 2.

TRANSGRESSIVE AND REGRESSIVE SEQUENCES

Most of the limestone formations of the Trenton Group represent sediments deposited from relatively shallow epicontinental seas. The lower Trenton limestones resulted from an early Trentonian sea transgressing from about west to east according to the northwest-southeast outcrop belt. This transgression, which reached the Adirondack Arch near Canajoharie, was completed by Shorehamian time with the relatively deep water Sugar River Limestone (fig. 2). For a more detailed discussion of this transgression, see the field trip guide by Cameron, Mangion,

and Titus elsewhere in this book.

The early Trentonian transgression was followed in Denmarkian time by subsidence of the Adirondack Arch into a deep water region that accumulated the Canajoharie and Utica black shales. This resulted in the formation of a shallow marine bank to the northwest whose margin accumulated the Poland, Russia, and Rust members of the Denley Limestone. These three members grade into the northern relatively undifferentiated main body of the relatively shallow marine Denley limestones. Possibly, along the slope of this bank the Dolgeville Facies accumulated.

During the late Trentonian, a regression occurred in the Trenton Falls area with the deposition of the coarse-grained, cross-laminated Steuben Limestone which is followed by an erosional unconformity. Finally, a post-Hillier, Cincinnati (late Ordovician) sea accumulating black shales retransgressed the whole area.

TIME CONTROL AND CORRELATION

to
Due to the belief that many rock units of the Trenton Group are diachronous (e. g., Fisher, 1962; Barnes, 1965, 1967) rather than being time-parallel (Kay, 1968), the criteria used for determining time will be briefly summarized. Age and time-correlations within the Trenton Group are established by means of both fossils and certain lithic criteria. Lithic criteria can supply useful evidence for accurate local correlating and dating, especially if a general temporal framework is available from paleontological evidence. These include metabentonites (Kay, 1935, 1943, 1953), marker beds, tongues, persistence of contrasting lithologies (Chenoweth, 1952; Cameron, 1968), lithic similarity, and stratigraphic position and sequence.

In the medial Ordovician rocks of northwestern New York, assemblage zones, range zones, epiboles, overlapping ranges, first occurrences, last occurrences, and so forth, are used in correlation. Many of these criteria are limited in large part to intrabasinal correlation in New York, Ontario, and surrounding areas, such as the trilobite Cryptolithus which has a much larger stratigraphic range in the southern Appalachians. Two zones mark the Rocklandian Stage at the base of the Trentonian Series (Cameron, 1969a): the Doleroides ottawanus and Triplisia cuspidata assemblage zones. No named zone has yet been defined for the fossil assemblages of the Kirkfieldian aged Kings Falls limestones. The Shorehamian Sugar River limestones contain the Cryptolithus tessellatus assemblage zone which includes a characteristically unusual abundance of the bryozoan Prasopora. The differentiation of the Denmarkian limestones "...is arbitrary and difficult, for although the..." Shorehamian and lower Cobourgian "...have persistent guide fossils, none that are both distinctive and abundant have been discerned in..." most of "...the intermediate beds..." (Kay, 1937, p. 263), i. e., much of the lower Denley Limestone. Some local zones and subzones have been recognized: (1) the Trocholites subzone occurs in the lower Poland in the vicinity of Trenton Falls (Kay, 1943, 1953), (2) the zone of abundant Sinuities and Ctenodonta in the Camp Member of northwestern New York (Chenoweth, 1952), and (3) the Diplograptus amplexicaulis (Hall) zone occurs in the lower Canajoharie Shale, Poland Member, and the top of the Glendale Member (Chenoweth, 1952). Stratigraphically above, the Rust and Steuben contain the Rafinesquina deltoidea zone. The zone of Hormotoma and Fusispira occurs in the Hillier Limestone at the top of the Trenton Group.

STRATIGRAPHIC CLASSIFICATION AND PROBLEMS

Geologists have applied several contradictory working hypotheses to interpretations of the stratigraphic relationships of the medial Ordovician sedimentary rocks in New York and Ontario: (1) that the formations are time parallel (Kay, 1937, 1942, 1968b; Young, 1943; Chenoweth, 1952; Cameron, 1968, 1969a, 1969b), (2) that the formations gradually transgress time (Winder, 1960; Barnes, 1965, 1967), (3) that some formations are miscorrelated (Sinclair, 1954; Kay, 1968a), and (4) that some formations radically transgress time and are time-equivalent facies of each other over relatively short distances (Fisher, 1962). While some workers have almost failed to apply the facies concept (Twenhofel, *et. al.*, 1954; Fisher, 1962), others have over-applied it to the point of confusion and produced misleading and incorrect correlations.

As a result of these varying viewpoints, several terminological difficulties arose: (1) Since the formations were thought to be time-parallel, some stratigraphers and paleontologists applied the same name to biological zones, rock units, and time-parallel units (Fisher, 1962). (2) As a corollary of the above, formations were often recognized by certain so-called characteristic fossils (Kay, 1937, p. 251), rather than lithic criteria because some geologists were only interested in time (Kay, 1968b). (3) Because of this confusion, because some faunas were thought to be ecologically restricted, and because there are gaps in the New York sequence, new reference sections in other regions were proposed by G.A. Cooper (1956).

Early workers applied a single term for the rock units and the time-rock units (stages) because they were principally interested "...in distinguishing rocks of an age rather than of one kind" (Kay, 1968b, p. 1373). These time-rock units were called stages by Clarke and Schuchert (1899), Cushing (1905b), and Kay (1937, 1947), but others (Grabau, 1913; Willis, 1901) generally called them formations, relying upon context for distinction between the two concepts (Kay, 1968b). "Formations formed divisions of the 'standard time-scale' (Williams, 1901, p. 573)" (Kay, 1968b, p. 1373).

Fisher (1962) stated that "...misunderstanding persists, owing to mixed usage of lithostratigraphic, biostratigraphic, and chronostratigraphic units all termed 'formations'. Furthermore, some geographic names are used in a dual or even triad sense (*viz.*, Rockland Limestone, Rocklandian Stage, Rocklandian-Dalmanella zone), and one is never quite certain of the writer's intention." According to standard usage, Rockland Limestone ought to be a lithic unit, Rocklandian stage a time-stratigraphic unit, and Dalmanella zone a biostratigraphic unit. To remedy the dual usage of nomenclature, some paleontologists and stratigraphers have been adding the suffix "-ian" or "-an" to the formation names to clearly indicate whether a stage, i.e., a time-rock unit is being discussed. Rocklandian and Kirkfieldian (Figure. 2) were used as stages by Kay in 1935, although not with the "-ian" ending until 1948 when he used the name Trentonian, as did Grabau (1909).

Raymond (1914, 1921) named the "Rockland" and succeeding Trenton formations and "...applied the names to units recognized by a succession of faunal zones; these were chronostratigraphic" (Kay, 1968a, p. 167.) Wilson (1946) correctly regarded the subdivisions as biostratigraphic. Thus, biostratigraphic units came to be used as lithostratigraphic units which seem to parallel time lines independently drawn from studies of the faunas and the lithologies, including metabentonites (Kay, 1937, 1942, 1943, 1953; Young, 1943; Chenoweth, 1952; Lippitt, 1959; Cameron, 1968, 1969a, 1969b). These lithic units are not completely uniform throughout their geographic distribution, but contain lithofacies changes (Cameron, 1968) or change systematically along the outcrop belt and contrast with overlying and underlying units in a constant way (Chenoweth, 1952; Cameron, 1968). Actually, the outcrop belt in northwestern New York may follow approximately the original shoreline, so as to expose the axis of linear lithosomes that once paralleled the medial Ordovician coast (Cameron, 1968; Walker, 1969). In this case, then, the lithic units are most probably both lithic and time-stratigraphic. A cross-section cut perpendicular to the present outcrop belt, i. e., perpendicular to the ancient shoreline, might show them to be time-equivalent facies of each other, as suggested by Fisher (1962) in his correlation chart of the Ordovician rocks of New York State.

There has been much controversy over the usefulness and limits of the divisions of the North American medial Ordovician standard. Systematic paleontologists working independently on many different fossil invertebrate groups have independently concluded that the New York Ordovician sequence is incomplete and that, for some portions, other areas should be sought to serve as a standard (Fisher, 1962), e.g. B.N. Cooper (in G.A. Cooper, 1956) working on trilobites, G.A. Cooper (1956) working on brachiopods, Flower (1957) working on nautiloids, Whittington (in Kindle and Whittington, 1958) working on trilobites, Berry (1962) and Sweet and Bergstrom (1971) working on conodonts. Many workers now [working on graptolites] follow G.A. Cooper's (1956) scheme of six stages for the medial Ordovician, which are (in ascending order): Whiterock of Nevada, Marmor and Ashby of Tennessee, Porterfield and Wilderness of Virginia, and Trenton of New York.

The original standard sections for the medial Ordovician were defined from New York, but not from completely contiguous sections. Fisher (1962) correctly states that "...widely separated successive stages of the time scale are accepted in some cases, but this practice should not be encouraged." Also, "...widely separable locales are chosen for a supposed continuum, thereby increasing the chance of omission or duplication of time..."

Cooper (1956) believed the Black River faunas to be closely related to those of the lower Trentonian Rocklandian Stage. He proposed the "wilderness" as a stage term for the upper Bolarian and lower Trentonian interval and restricted the "Trenton" to the medial and late Trentonian of Kay's (1937) usage. Fisher (1962) substituted "Barneveld" for this restricted "Trenton" Stage and kept the terms Trenton and Black River for rock-stratigraphic units. Cooper overlooked the Kirkfieldian Stage which Fisher (1962) added to the top of the "Wilderness".

In addition, much evidence gathered recently indicates there is an overlap of the medial Ordovician Trentonian Series and the late Ordovician Cincinnati Series which are both part of the North American Ordovician Standard. Conodont research suggests that the Edenian Stage of the early late Ordovician (Cincinnati Series) is time-equivalent to the later Trentonian Cobourgian Stage (Fisher, 1962; Schopf, 1966; Sweet and Bergstrom, 1971). Because of this overlap, Sweet and Bergstrom (1971) suggested leaving the Cincinnati Series in tact and further modifying the Trentonian part of the North American Standard for the medial Ordovician.

In central New York west of the Adirondack Arch complex facies relationships compound time-correlations and additional stratigraphic and paleontologic studies are needed (Fig. 2). Exposures are not often complete and the seemingly repetitious nature of the complex sedimentary rock types make study difficult. Lack of ecological understanding of the macrofossils has lead many to doubt their usefulness in correlation.

At the present time, some disagreement exists as to whether one should follow Cooper's terminology or that of Kay and his predecessors. In either classification, the "Trenton" (restricted) or "Barneveld" and Trentonian are still taken from the New York section whose upper part is believed by many investigators to be equivalent to the lower Cincinnati Series of Ohio. Kay (1968b) proposed a classification of the Ordovician of northwestern New York in which he attempted to clarify the terminology by usage of completely separate and unambiguous time and rock nomenclature, as did Liberty (1955, 1963, 1969) in southern Ontario. The stratigraphic classification used herein (Fig. 2) for the Trentonian of northwestern New York follows that of Kay (1968) with modification for the lower Trenton Group from Cameron (1967, 1968, 1969a, 1969b). A thorough historical review of the early classification of these limestones can be found in Kay (1937, p. 237-249); for a review of some later work, see Cameron (1968).

DESCRIPTIONS OF INDIVIDUAL STOPS

Stop #1. Canajoharie Creek:

Three formations will be seen along Canajoharie Creek at the southern edge of the village of Canajoharie: Chuctanunda Creek Dolostone, Sugar River Limestone, and Canajoharie Shale. The Chuctanunda Creek is a stromatolite-bearing, otherwise unfossiliferous, early Ordovician (Canadian) dolostone disconformably underlying 17 feet of Sugar River Limestone. The later is succeeded conformably by the Canajoharie graptolite-bearing black shales. At this locality the Sugar River probably represents more shallower water conditions than the relatively deeper water, more-burrow reworked, Sugar River lithologies to the northwest. The base contains atypical shelly calcarenite and a pararippled bed, followed by a concentration of calcisiltites. The middle contains more typical burrow-reworked non-shelly calcarenite. Near the top, along the macadam path, several thick, shelly calcarenitic lenses occur that probably represent channels.

Stop #2. Route 55 South of Little Falls:

Along the west-facing hillside, a quarry and roadside exposures may be found. The quarry contains about $2\frac{1}{2}$ feet of Gull River Limestone (middle Black River Group) succeeded by about 18 feet of very fossiliferous Kings Falls Limestone. The latter contains shelly and non-shelly calcarenites with current laminations alternating with thin shales and burrow-reworked horizons. Along the roadside, there are 15 feet of Sugar River non-shelly, somewhat burrowed calcarenites with horizontal and cross-laminations visible. This is succeeded by about 10 feet of Dolgeville Facies which is composed of 6 feet of alternating thick black shales and black, argillaceous calcisiltites followed by about 4 feet of shale.

Stop #3. City Brook (locality #C1):

The Gull River Limestone of the Black River Group lies disconformably on the quartz arenite-rich late Cambrian Little Falls Dolomite below the bridge. The lower falls is supported by the upper Gull River Limestone, and the upper falls (Craig, 1941, fig. 5; Kay, 1953, fig. 11) is supported by the middle Kings Falls Limestone. The Rathbun member at the top of the Sugar River Limestone and the superjacent Denley Limestone will not be examined because we will have to respect the NO TRESPASSING signs.

Gull River Limestone. The lower 8 feet are tan weathering, gray, quartz arenite-rich, ostracod-bearing, impure, thick-bedded, medium-textured, argillaceous limestones interbedded with a few calcareous shales up to 3 inches thick. Vertical burrows are abundant. A 3-inch thick metabentonite occurs at 6' 9" (Kay, 1943, 1953).

The upper $19\frac{1}{2}$ feet of the Gull River is composed of relatively pure, light gray weathering, dove gray, conchoidally fracturing calcilutite (sublithographic) and some calcisiltites. Stylolites are abundant from 11 to 16 feet. Thin shales are frequent between 13 and 16 feet, at the 18th foot, and especially between $19\frac{1}{2}$ and $21\frac{1}{2}$ feet where the limestones are very argillaceous (Fig. 3). Vertical burrows (Phytopsis) are abundant between 11 and 16 feet and in the top foot. Mudcracks occur above and below the 25th foot. An intertidal to lagoonal origin is probable for these limestones.

Kings Falls Limestone. Sediment from a coquinal calcarenite bed at the base of the Kings Falls fills some of the burrows in the highly burrow-reworked calcilutite bed at the top of the Gull River. The Kings Falls is characterized by coquinal calcarenites, as at the previous locality, in contrast with the non-coquinal calcarenites of the superjacent Sugar River Limestone. Cross-laminated and pararippled beds are frequent.

At 7 feet a deep reentrant marks where a metabentonite is weathering out. Less than a mile north, at Buttermilk Creek, this clay is 9 feet above the base of the Kings Falls (Kay, 1953). If this altered volcanic ash near the base of the Kings Falls between Stony Creek and Buttermilk Creek is part of a single bed, then it represents a synchronous

tine surface indicating that this formation is overlapping the Gull River eastward. Therefore, the base of the Kings Falls becomes progressively younger eastward, increasing the gap in time marked by the black River-Trenton boundary in that direction.

Sugar River Limestone. The contact between the Kings Falls and Sugar River limestones is drawn where shale becomes more abundant. This coincides with a contact drawn where non-coquinal calcarenites become persistently abundant and coquinal calcarenites almost disappear. The Sugar River at this exposure is mainly composed of interbedded coarse-grained calcarenites and calcareous shales. These calcarenites are encrinitic and rich in bryozoa, especially cryptostomes. The shales are especially abundant in the lower 10 feet, thus further accentuating lithic contrast with the upper Kings Falls below. The Sugar River Limestone contains the Cryptolithus tessellatus Zone which is characterized by C. tessellatus and the relative abundance of Prasopora. Unusually large Prasopora occur near the top.

Stop #4. Rathbun Brook:

The upper Sugar River and lower Denley limestone will be seen on Rathbun Brook. The $2\frac{1}{2}$ feet of very fossiliferous, burrow-reworked, argillaceous, black, hard Trocholites subzone beds of the base of the Denley form the top of the waterfall. Immediately succeeding these, one can see the typical fine-grained calcisiltite beds of the lower Poland Member in the stream bed. About 50 feet of Poland and about 52 of Russia are incompletely exposed over a long distance upstream. About 55-60 feet of Utica shale outcrops farther upstream after about 30 feet of covered interval. Beneath the Trocholites subzone in a stepwise fashion the Sugar River Limestone is fully exposed with the 9 foot thick Rathbun Member at the top. Note the shelly calcarenites of the Rathbun contrasting with the non-shelly calcarenites of the lower member of the Sugar River below and the Poland above. Also note the relatively thick calcisiltite beds of the Rathbun which contrast with the lower Sugar River and show similarities with the Poland above.

Stop #5. Bridge at Trenton Falls Gorge:

About 13 feet of Middle Poland limestone and thin shales are exposed upstream from the bridge on West Canada Creek. Note that the middle Poland is coarser grained and more fossiliferous than the lower Poland at Rathbun Brook (Stop #4). Burrowed fine-grained limestones are still characteristic of this member, however.

Stop #6. Lower Trenton Falls Gorge:

Poland (about 50 feet thick) and Russia (about 75 feet thick) members of Denley limestone can be seen on the opposite bank from the road at the powerhouse. Two reentrants 9 feet apart in the upper Poland represent metabentonites. At the powerhouse gate, the Poland-Russia contact is about 12 feet above the road. The coarser-grained, more rubbly, burrow-reworked, more fossiliferous Russia Member can be examined along the hillside exposures

on the walk back to the cars.

Stop #7. Dam at Trenton Falls Gorge:

The lower Steuben Limestone and much of the Rust Member of the Denley Limestone can be seen after crossing the dam. By the spillway, the 26 feet of massively bedded, horizontally and cross-laminated, encrinitic Steuben Limestone can be examined from the top of the dam. The contact with the Rust is clearly visible from the reservoir and in the spillway wall. In the spillway, the slump structures in the upper Rust can be examined. Below the spillway the very fossiliferous calcarenites of the upper part of the 115 feet of Rust are excellently exposed. See text above for a detailed description of the Rust at this exposure.

ACKNOWLEDGEMENTS

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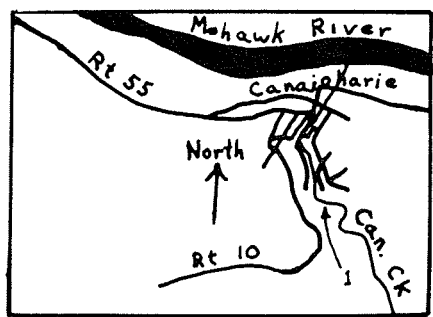
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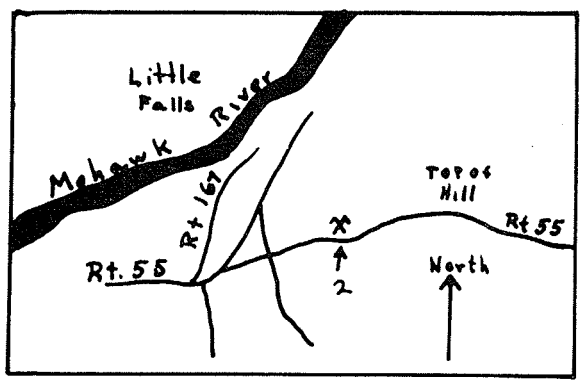
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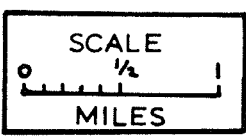
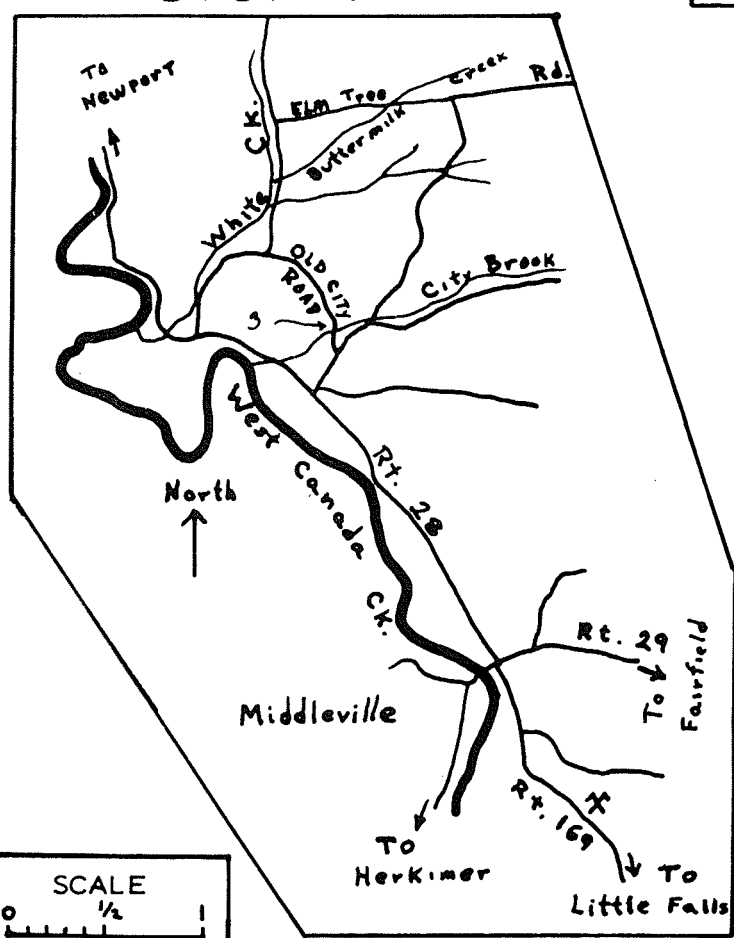
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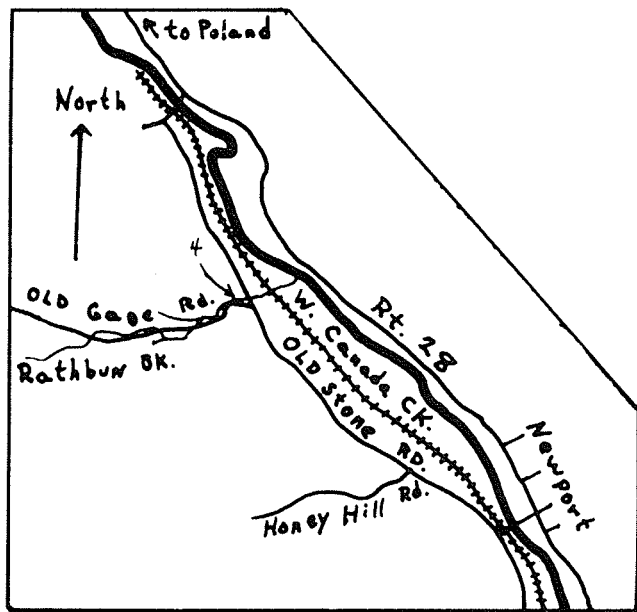
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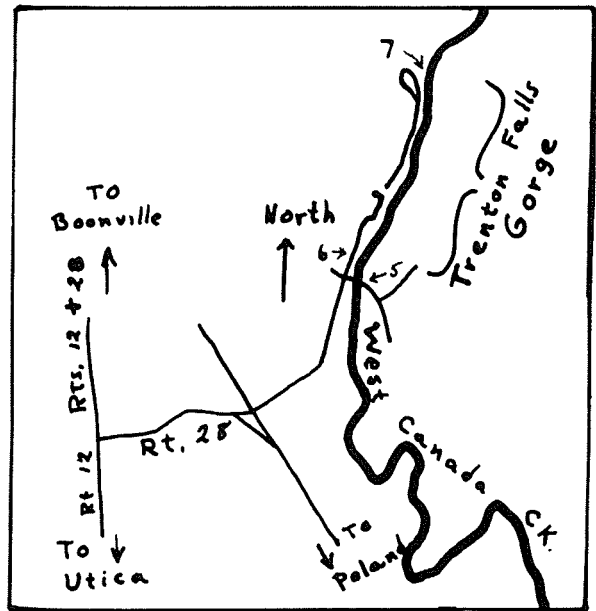
STOP 2



STOP 3



STOP 4



STOP 5 & 6 & 7

Road maps for field trip stops.

MILEAGE LOG

This mileage log is designed to start at the toll booths of the Canajoharie Exit (#29) of the New York State Thruway. Mileage was taken from a car's odometer and "hundreds" of a mile are estimated where turns occur in rapid succession. This field trip will visit the Canajoharie, Little Falls, and Remsen 15' quadrangles.

Take the Thruway to Canajoharie (Exit #29). After leaving toll booths, bear left a short distance until you reach Route 5S. Then turn right and go west until the first stop light in the village of Canajoharie. Turn left and drive a short distance until you reach the stop light in the triangular "square".

<u>*InMi</u>	<u>CumMi</u>	
0.0	0.0	At stop light in triangular "square" in Canajoharie. Turn left onto Montgomery Street.
0.05	0.05	Intersection with Moyer Street. Turn right.
0.35	0.4	Intersection with Floral Avenue on right. Turn right.
0.1	0.5	Park in parking lot on right side of road.
		<u>Stop #1:</u> Walk straight ahead on road, keeping to right of green house, until you reach the first wooden posts on the right that are blocking a macadam path. Take this macadam path down to the west bank of Canajoharie Creek. The Sugar River Limestone is exposed along the path. At the end of the path, walk about 100 feet onto the flat area to get a better look at the exposure.
0.0	0.5	Return to cars, turn around, and drive back to Moyer Street.
0.1	0.6	Turn left onto Moyer Street.
0.35	0.95	Turn left onto Montgomery Street.
0.05	1.0	Turn wide right (second right) at triangular "square" and follow signs for Route 5S.
0.1	1.1	Turn left at intersection with stop light, following signs for Route 5S West.
3.3	4.4	Turn left at stop light in village of Fort Plain, following signs for Route 5S.
0.05	4.45	Turn right (west), following signs for Route 5S.
14.45	18.9	Park on right side of Route 5S near edge of woods on right.

Stop #2: Walk to quarry 100 feet to the right (north) side of road. Then return to highway and examine exposures along south side of Route 5S.

 *InMi = Incremental Mileage; CumMi = Cumulative Mileage.

- 0.0 18.9 Return to cars and proceed straight ahead downhill on Route 5S.
- 0.8 19.7 Turn right at intersection with Route 167.
- 1.8 21.5 Crossing bridge.
- 0.15 21.65 Crossing another bridge.
- 0.15 21.8 Turn right onto Albany Street at intersection.
- 0.1 21.9 Turn left at intersection.
- 0.05 21.95 Stop light. Go straight ahead uphill.
- 0.02 21.97 Turn wide left onto Church Street and go uphill.
- 0.78 22.75 Merge right cautiously with Route 169 and continue straight ahead.
- 8.55 31.3 Stop light in village of Middleville. Proceed straight ahead through intersection onto Route 28 North.
- 1.8 33.1 Turn right and drive straight uphill.
- 0.25 33.35 Fork. Bear left, going downhill, onto Old City Road.
- 0.15 33.5 Park on either side of road before bridge over City Brook.
- Stop #3: Walk across bridge and down steps on upstream side of bridge leading to stream bed. Then, climb back to bridge and walk up the opposite bank of City Brook. Obey no trespassing signs farther upstream.
- 0.0 33.5 Proceed straight ahead, crossing bridge.
- 1.25 34.75 Junction with Route 28. Turn right, heading north on Route 28.
- 1.9 36.65 Traffic light in village of Newport at intersection with Newport Road. Turn left.
- 0.25 36.9 Turn right onto Old State Road.
- 1.7 38.6 Fork. Turn left onto North Gage Road and proceed uphill.
- 0.2 38.8 Park along right side of road.
- Stop #4: Walk to right, down farm road and be careful as you go through barbed wire fence.
- 0.0 38.8 Return to cars. Be sure gate in barbed wire fence is closed! Drive uphill 0.3 miles until you can safely turn around in a driveway and return to Old State Road.
- 0.3 39.1 Turn into first driveway on left in order to back out and face downhill. Return to Old State Road.
- 0.5 39.6 Turn left at intersection with Old State Road.

- 1.1 40.7 Bear right and continue straight on Old State Road.
- 0.3 41.0 You should now be on a narrow bridge over West Canada Creek.
- 0.1 41.1 Bear left at intersection and go north on Route 28.
- 0.5 41.6 Village of Poland, continue north on Route 28 (bear left on curve at main intersection).
- 1.5 43.1 Fork. Bear right and cross bridge, continuing north on Route 28.
- 3.9 47.0 Fork. Bear right and cross bridge, continuing north on Route 28.
- 1.2 48.2 Fork. Go straight, leaving Route 28.
- 0.1 48.3 Turn right at intersection.
- 0.8 49.1 Turn right at intersection and cross bridge over West Canada Creek.
- 0.1 49.2 Once across bridge, immediately turn right and park in parking area.

Stop #5: Walk across road (watch for traffic) and down to the exposures along the east bank just upstream from the bridge.

- 0.0 49.2 Return to cars and go back across the bridge.
- 0.1 49.3 Turn right at intersection.
- 0.15 49.45 Turn right and park in area on right side of road. Do not block dead end driveway on far right by edge of river bank.

Stop #6: Walk about 200 yards down this gravel driveway to the exposures by the powerhouse at its end.

- 0.0 49.45 Return to cars and continue driving up the paved road.
- 0.1 49.55 Stone gate. Continue straight ahead.
- 0.1 49.65 Bear right.
- 0.05 49.7 Bear left.
- 0.1 49.8 Metal (wire) gate ahead.
- 0.05 49.85 Park in parking lot after turning left, but do not block driveway or access to building. Good drinking water is available here from running faucet.

Stop #7: Walk back to road and go uphill, walking around fence gate (opening on left side slightly concealed). Continue uphill for about a quarter of a mile to the dam.

- 0.0 49.85 Return to cars, turn around, and return to Route 28.
- 0.1 49.95 Bear right.

0.05 50.0 Bear left.

0.1 50.1 Stone gate. Go straight ahead.

0.25 50.35 Intersection. Go straight ahead.

0.8 51.15 Intersection. Go straight ahead.

0.05 51.2 Intersection with Route 28. Take Route 28 (straight ahead) to Route 12.

0.75 51.95 Junction with Route 12. Turn left and take Route 12 south to Utica. End of field trip.

GLACIAL GEOLOGY OF THE NORTHERN CHENANGO RIVER VALLEY

Regional Setting

The field trip area (Fig. 1) is located in the northern reaches of the Chenango River, a tributary of the Susquehanna River drainage system. The region is covered by parts of the Munnsville, Morrisville, Hamilton, Earlville, Norwich, Sherburne, and Holmesville 7½ minute U.S.G.S. topographic quadrangles. The area has a total relief of 980 ft (1000 to 1980 ft). The bedrock is predominantly Devonian shale, siltstone, and sandstone (Broughton, et.al., 1962).

Glacial Geologic Setting

Brigham (1897) recognized the extent of the glacial sediments within the Chenango River valley from Binghamton north to the Mohawk Valley.

Tarr (1905) described the characteristics of the glacial deposits near the Finger Lakes.

Fairchild (1932) named the thick drift units in the Finger Lake region the Valley Heads moraine. He delineated two other areas of drift deposits: the Olean at the terminal moraine in Pennsylvania, and the Susquehanna Valley kames.

MacClintock and Apfel (1944) used the term "Binghamton moraine" to describe the Susquehanna Valley kames of Fairchild, indicating that this drift was deposited during a separate advance. They suggested that the Olean was

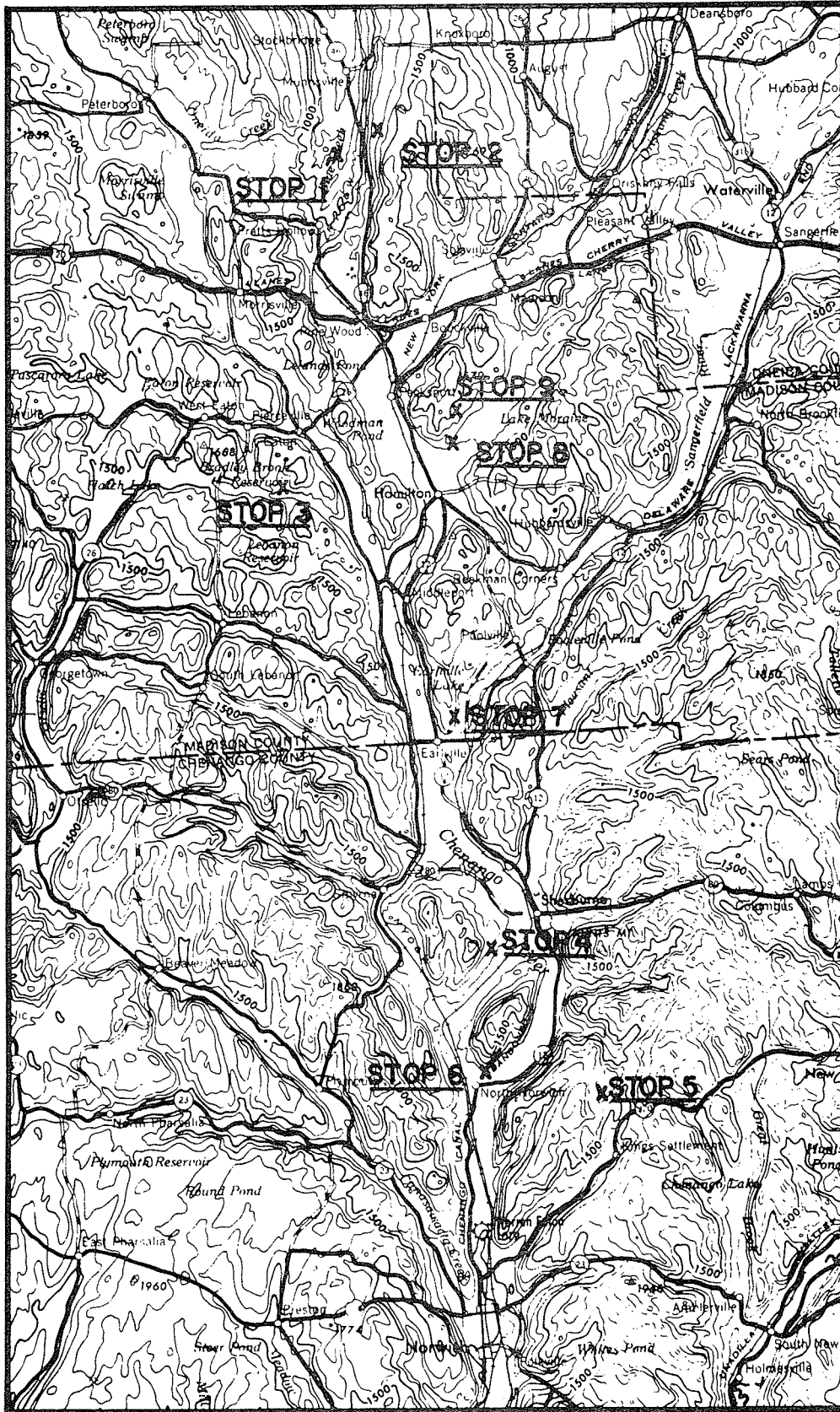


Figure 1. General field trip area (part of a Binghamton 1/250,000 map).

oldest Wisconsin; Binghamton-middle Wisconsin; and Valley Heads-youngest Wisconsin.

Peltier (1949) correlated terraces along the Susquehanna River in Pennsylvania with pre-Wisconsin, Olean, Binghamton, Valley Heads, and Mankato advances in New York.

Denny (1956) questioned the presence of the Binghamton advance in the Elmira region. He theorized that (1) the Binghamton border may be north of the Valley Heads border and therefore concealed, (2) the Binghamton border is incorporated within the Valley Heads border, and (3) there is a complete change in the character of the Binghamton materials between the type locality (Binghamton) and Elmira.

Connally (1960, 1964) indicated that the Binghamton is related to the Valley Heads advance, on the basis of heavy mineral analyses.

Moss and Ritter (1962) suggested that the Binghamton was not a separate advance, but a phase of the Olean.

Coates (1963) suggested that a single ice sheet deposited the drift with the Olean as the upland facies and the Binghamton as valley facies.

Hollyday (1969) suggested thicknesses of aquifers within the valleys in the Susquehanna River basin. This data suggests the drift in the valleys in the vicinity of the field trip ranges between 50 and 250 ft thick.

Cadwell (1972) formulated the idea of a single retreating Woodfordian ice sheet that deposited the Olean

and Binghamton deposits, with a minimum age of 16,650 \pm 1800 radiocarbon years B.P.

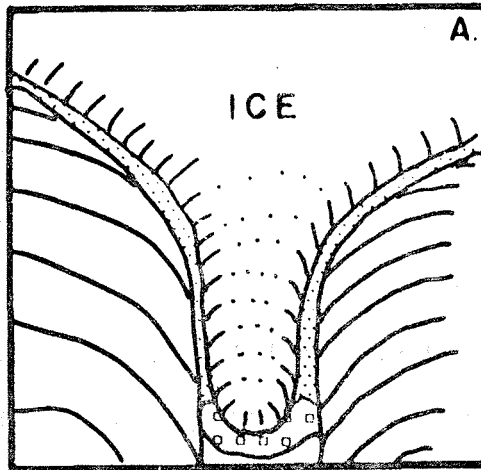
The Valley Ice Tongue

The model I have developed is one of ice protuberances, which may become stranded upon retreat of the ice sheet. These ice masses left in the valleys are called valley ice tongues. The ice tongue may extend down valley up to several miles beyond the upland ice margin (Fig. 2). Meltwater flowing from the upland margin is forced to flow between the ice and the bedrock walls creating unique and diagnostic deposits.

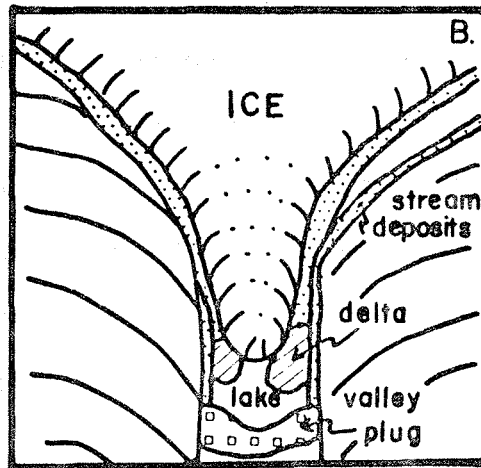
With continued retreat of the ice tongue, the high level glacio-fluvial deposits remain against the valley walls. The upper surface of these features are flat to subhorizontal, commonly areally extensive and are termed planar surfaces. Features that may commonly be associated with the retreating ice tongue include kames, kame terraces, kame deltas, valley plugs, valley train, ice channel fillings, kamefields, and eskers.

The Problem of Ice Retreat

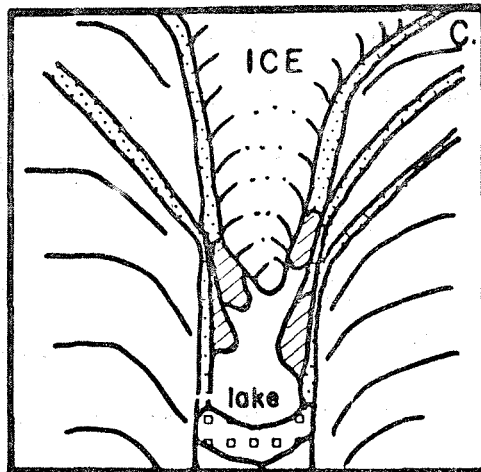
In central New York the problem of delineating the number of glaciations has been a problem. Denny and Lyford (1962) indicated that the earlier Wisconsin (Olean) ice did not build a prominent moraine at the drift border, or construct any significant moraine south of the Valley Heads



Streams flow lateral
to the ice: drift
dams the valley



Associated stream
and lacustrine
deposits



Depositional
mosaic

Figure 2. Valley ice tongue mosaic.
Diagram of a retreating ice tongue
margin and the depositional mosaic
associated with the retreat.

moraine. Hence, the problem of the manner of retreat of the Woodfordian ice sheet.

A distinction is made between the manner of retreat in the valleys and uplands. The valley margins are characterized by large accumulations of drift plugging the valley, thus providing a limit for the toe of the valley ice tongue. Kames, kame terraces, kame deltas, and valley trains may be associated with the valley ice tongue. Upland margins are characterized by marked asymmetry: stratified drift along the north-facing slope, and a surficial mantle of thin ablation till on the south-facing slope. Bradley Brook, STOP 3 on the field trip, illustrates this configuration of deposits. Figures 3 and 4 suggest a mode of formation as the ice retreats in the uplands. Plate 1 is a low angle air photograph of Bradley Brook.

Criteria for the Location of Retreatal Ice Margins

The criteria which led to the identification of the ice margin positions in the northern Chenango River valley include the following: (1) the surface morphology or shape of the upland hills, (2) the location of outflow channels in the uplands, (3) the association of upland meltwater deposits, (4) the configuration of stratified drift around umlaufbergs, and (5) the sequence of valley meltwater deposits.

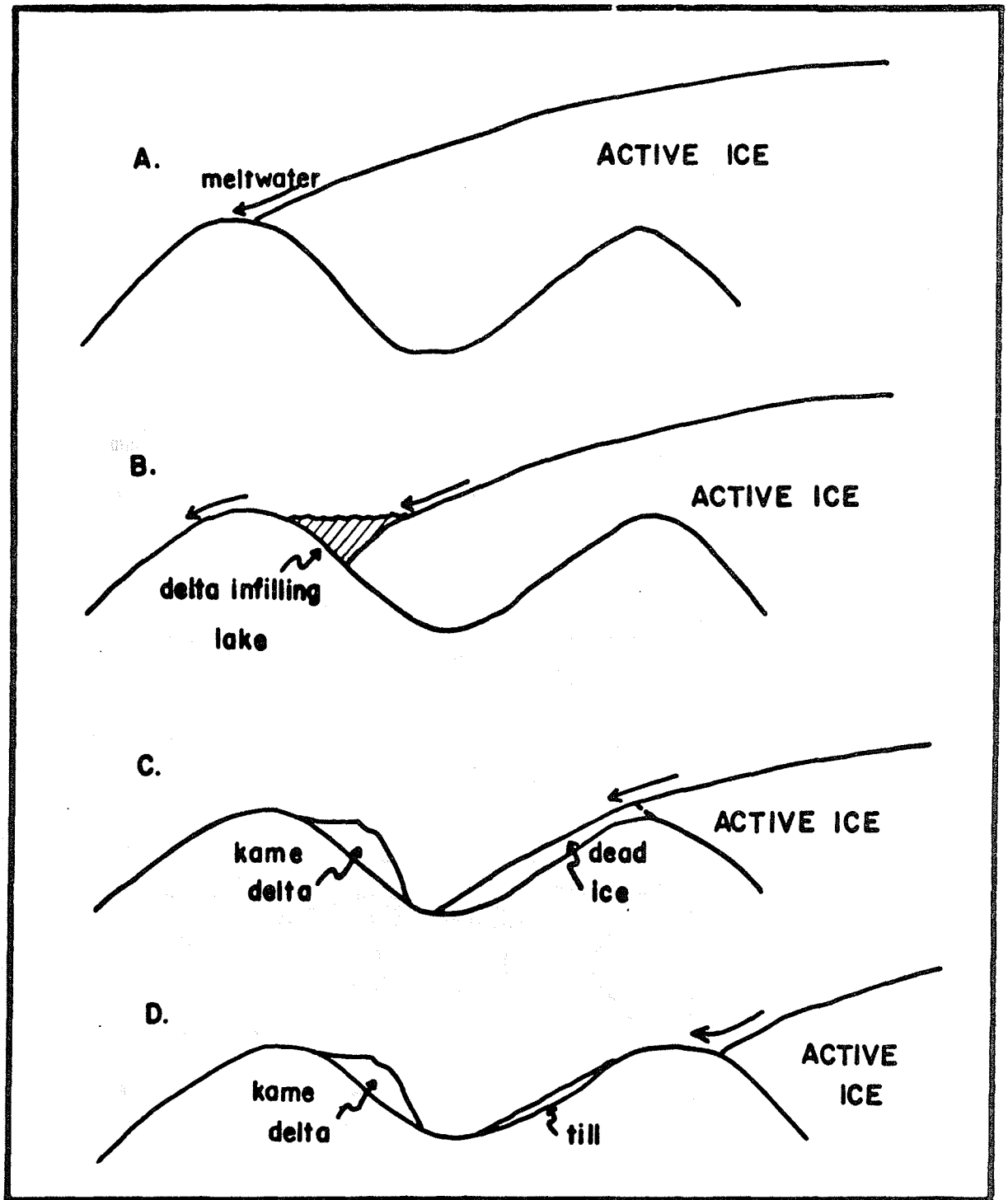


Figure 3. Diagram of the profile of upland ice retreat, as Bradley Brook. Margin locations and associated upland deposits are governed by topography which preceded the ice.

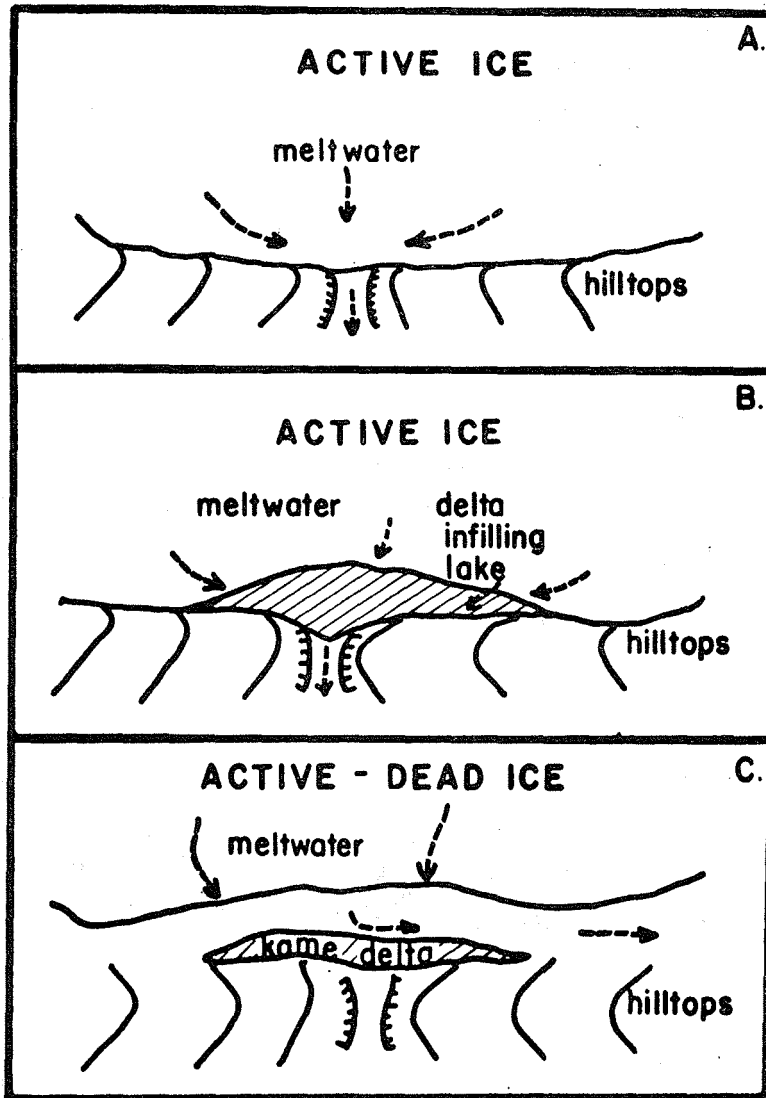


Figure 4. Plan diagram of upland ice retreat, as Bradley Brook.

- A. Ice against mountain with meltwater flowing through outflow channel.
- B. Shaded area represents deglaciated part with proglacial lake and delta. Meltwater flows through outflow channel.
- C. Continuing ice margin retreat with lake draining; outflow channel abandoned, and incisement of lateral channel.

Deglaciation Chronology

The Woodfordian ice sheet retreated primarily by backwasting in the uplands. There are no massive stagnant ice areas continuous from one valley to another across a divide. This suggests there were no large areas of ice detached from the main ice sheet. The size of the ice tongues remaining in the valleys during retreat was governed by such factors as the rate of upland retreat and the rate of valley ice melting. In areas of rapid upland ice retreat long tongues of ice could have remained in the valleys behaving in some ways similar to a valley glacier. The valley tongue retreated by both backwasting and downwasting.

Upland ice margin positions are identified in the area of the field trip (Fig. 5). During the development of margins A and B an ice tongue remained in the main river valley to about Sherburne. Kame terraces and deltas were deposited lateral to the ice tongue. At margin B the ice tongue may have retreated to about Earlville, permitting lake sediments to accumulate in the valley north of Sherburne. The dam for the lake was perhaps a shallow bedrock riegel in conjunction with alluvial fans which blocked the valley to the south of Sherburne.

Margin C is located along Bradley Brook. During the time when the ice entirely filled this valley, meltwater flowed through the outflow channel and to the south into the Lebanon Reservoir valley. Figures 3 and 4 illustrate the sequence of retreat away from the hilltops, with the



Figure 5. Retreatal ice margins
in the northern Chenango River
valley and vicinity, New York.

deposition of the kame delta and the ablation till.

During the retreat from margin C to D the hilltop to the west of Hamilton became exposed through the ice as a nunatak, and meltwater carved the meltwater channel to the north of the hill. Ice tongues remained in both the main Chenango Valley and the Hamilton-Madison Valley. A large mass of ice remained in the Moraine Lake valley while the ice was retreating and the hilltops east of Hamilton became exposed. This ice retreated northeastward, away from the Hamilton Valley ice tongue, and a large lake was formed between the retreating Moraine Lake ice and the Hamilton Valley ice. Much of this lake was filled with a large delta, and the foresets are exposed southwest of the lake (STOP 6 of the field trip).

Backwasting of the ice sheet continued through margins E and F with the deposition of kame terraces lateral to the ice tongue. The ice sheet then retreated north outside of the field trip area, and perhaps to the north of the Mohawk Valley, permitting some of the lakes to the northwest to drain via the Mohawk and Hudson Rivers.

Margin G is the terminal moraine of the Valley Heads advance, and represents a readvance of the Late Wisconsinan (Woodfordian) ice sheet. This moraine contains a series of margin positions associated with the readvance instead of a single stand. Associated with this margin are the massive valley train deposits infilling the Chenango and Hamilton-Madison Valleys, especially in the vicinity of Pratts Hollow. The valley train is traced semi-continuously to Sherburne, 19 mi south of the terminal moraine.

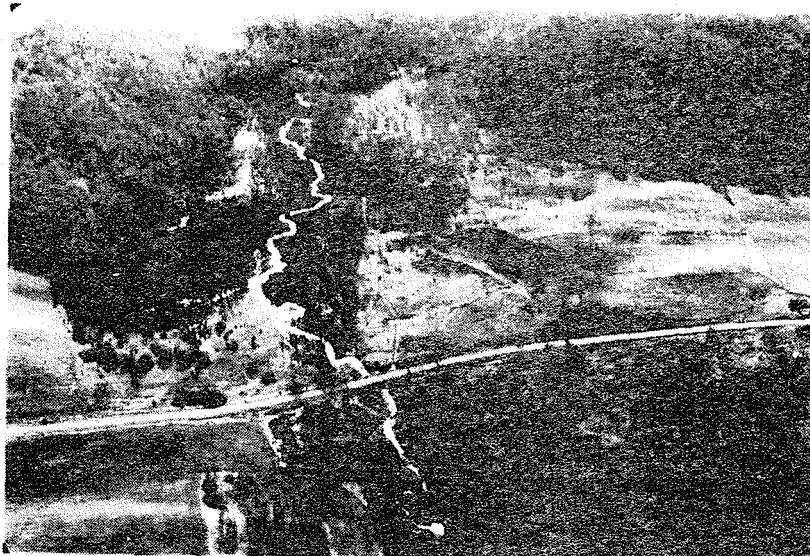


Plate 1. Bradley Brook. Low angle air photograph of Bradley Brook illustrating the location of sand and gravel in the uplands. View is to the east.



Plate 2. Chenango County Sand Pit. Block of stratified drift in unstratified drift. Note the apparent lack of horizontal stratification above the knife.



Plate 3. Chenango County Sand Pit. Block of stratified drift. Note vertical stratification parallel to orientation of knife.

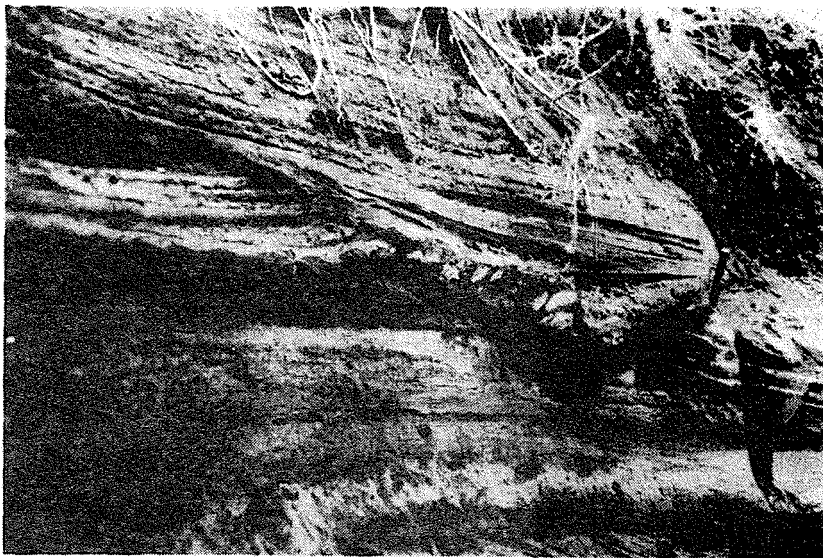


Plate 4. Chenango County Sand Pit. Contorted silts and clays. Note the light (clay) layer with ripples to the left, segmented nodules of clay in the middle, and thrusting near the knife.

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TRIP 4: ROAD LOG AND ROUTE DESCRIPTION

GLACIAL GEOLOGY OF THE NORTHERN CHENANGO RIVER VALLEY

Donald H. Cadwell

Total miles	miles	
		This trip leaves from Utica, but the road log will begin at the Colgate University entrance. To get to <u>STOP 1</u> from Utica, proceed west on Rt. 5 about 20 mi to Oneida. Turn south on Rt 46, through Munnsville. <u>STOP 1</u> is on a side road $1\frac{1}{2}$ mi south of Munnsville.
0.0	0.0	Colgate University entrance. Proceed north on Rt 12B.
3.4	3.4	Junction with Rt 46: stay on Rt 46 through the junction of routes 26 and 20.
5.3	1.9	Turn left onto unnamed road 0.2 mi north of the jct with Rt 20. This road crosses the valley train of the Valley Heads moraine. Note the many kettles. There is an intersection in Pratts Hollow, continue straight through. The crest of the Valley Heads moraine is immediately south of town; all drainage in this area is north into the Mohawk Valley. The clay beds 1 mi north of Pratts Hollow are ponded lacustrine deposits formed during the retreat of the ice from the Valley Heads moraine.
10.0	4.7	<u>STOP 1. VALLEY HEADS MORaine EXPOSURE</u> This is an exposure of glaciofluvial and glaciolacustrine sediments in an ice contact zone. These materials, therefore, were deposits adjacent to large blocks of ice. In this pit there are examples of several depositional environments: horizontally stratified sands and gravels, cross-bedded sands and gravels with 10 ft of relief, finely cross-bedded sands, and clays dipping northward at the north side of the exposure.

The lithologies in this pit are of typical Valley Heads composition. The provenance of the exotics indicates a source from the Adirondacks and Canada.

Percentage composition:

9% red sandstone
26% limestone and chert
39% locals
26% exotics

Return to the bus and proceed north.

11.3 1.3 Jct Rt 46, turn right (south).

12.7 1.4 Turn left onto Trew Hill Rd.

12.9 0.2 STOP 2. PICTURE STOP

This is a view of the Valley Heads moraine area. This is the Stockbridge valley, with the towns of Stockbridge and Munnsville to the north. The stratified drift of the Valley Heads moraine is not limited to the Stockbridge valley as well data suggests there is at least 220 ft of sand and gravel in the uplands on the west valley wall.

A question remains as to when and how this moraine was formed.

Hypothesis 1: This moraine was formed as a recessional moraine during the retreat of the same ice sheet that deposited the glacial features to the south, between Binghamton and Earlville.

Hypothesis 2: This moraine was formed during a readvance of the ice; a readvance of a Late Woodfordian ice sheet.

Return to Rt 46.

13.1 0.2 Rt 46, turn left (south).

14.0 0.9 Highest level of the Valley Heads moraine. Note the large boulders in exposures along the east side of the road.

16.4 2.4 Valley train materials that grade to the south away from the Valley Heads moraine.

17.3 0.9 Jct Rt 20; Stay on Rt 46 south.

18.1 0.8 Jct Rt 26. Turn right onto Rt 26.

19.3 1.2 Kame terrace along the west valley wall. This kame terrace is 40 ft higher than the Valley Heads valley train.

Is there a relation between this kame terrace and the Valley Heads terminal moraine?

Was this terrace formed during a glacial episode previous to the Valley Heads?

- 20.8 1.5 Enter town of Eaton.
- 21.1 0.3 Turn left onto River Road.
- 21.2 0.1 Turn right onto dirt road (just after crossing bridge) and proceed up the steep hill.
- 21.4 0.2 Turn left (south) onto Lebanon Hill Road. This detour is necessary for vehicles greater than 3 tons.

- 22.9 1.5 STOP 3. BRADLEY BROOK ICE MARGIN
This stop illustrates the character of an upland ice margin, see also Figures 3 and 4 in the text. Bradley Brook flows to the east and stratified drift is exposed along the north-facing hillslope. Ablation till mantles the south-facing slope.

The spring near the exposed face west of the road has good drinking water. PLEASE BE CAREFUL TO KEEP IT THAT WAY as several persons still obtain their drinking water from this spring.

The stratified drift was deposited during wastage of an upland ice margin. The sediments are subhorizontally stratified, with perhaps a slight dip to the east. The materials were deposited lateral to the ice and the valley walls, as meltwater flowed to the east in the Bradley Brook valley toward the Chenango River. See also Plate 1.

With continued retreat of the ice front into the next valley to the north, a thin veneer of dead ice remained on the south-facing slope in the Bradley Brook valley. The dead ice deposited a thin ablation till on a perhaps much thicker lodgment till.

The lithologies include red sandstone, limestone, chert, igneous and metamorphic exotics, and local sandstones, siltstones and shales. The percentages are:

17% red sandstone
 19% limestone
 47% locals
 18% exotics

Return to the bus and proceed south.

- 24.7 1.8 Turn left onto Geer Rd. Sand, gravel, and till can be seen in road cuts to the right.
- 25.4 0.7 Turn left, keeping the reservoir to the left. Sand, gravel, and bedrock are exposed to the right.
- 27.0 1.6 SHARP LEFT TURN IN ROAD. While descending this valley wall note the kame terrace and esker. This terrace is 40 ft above the valley floor.
- Note the kame and kame terrace on the opposite (east) valley wall.
- These kames and kame terraces were deposited when meltwater streams flowed between the ice and the valley walls. At this time there was an ice tongue in the valley extending at least several miles to the south. Additional diagram in the text (Fig.2).
- 27.4 0.4 Jct River Rd, turn right (south).
- 32.1 4.7 Kame delta units to the right. This is an exposure in one lobe of a delta. There is evidence for lobes in adjacent areas.
- At the Madison-Chenango County line continue to the south on County Rd 14.
- 35.7 3.6 Hummocky, stagnant ice topography behind the Sandy Acres Farm.
- 36.1 0.4 Jct Rt 80, turn left (east).
- 39.1 3.0 Turn right (south) onto County Rd 23.
- 40.0 0.9 STOP 4. THE BUNDY CONCRETE COMPANY
 This pit contains one of the most useable sand and gravel deposits in Chenango County and has been in operation for about 50 yrs. There are local zones and layers of sand and gravel that are cemented. The cemented arch is disintegrating rapidly: two years ago the pillars were twice as thick.
- All of the gravel is bright and exotic rich. There are, however, dull sections that result from an increase in the percentage of clays.

Percentage composition:

bright

19% red sandstone
 26% limestone
 34% locals
 21% exotics

duller

10% red sandstone
 31% limestone
 32% locals
 27% exotics

Problem 1: What is the origin of the cemented zones?

Problem 2: When did cementation occur? immediately postglacially? Recent?

Return to the highway and turn left (south)

- 41.1 1.1 Turn left onto Blanding Road
- 43.3 2.2 Jct Rt 12, turn right (south).
- 47.3 4.0 Jct County Rd 32, bear left (south) onto Rt 32. This road is just before the bridge over the Chenango River.
- The bedrock hills to the right and behind you are umlaufbergs. These are bedrock hills within the Chenango River valley and are entirely surrounded with stratified drift.
- This road traverses several good examples of kame terraces. Others can be seen along the west valley wall.
- 51.9 4.6 Jct Rt 320. Turn left (east) onto 320.
- 55.0 3.1 End of Rt 320, begin County Rd 29. Stay on the main road.
- 56.5 1.5 Turn left onto dirt road. You are on the correct road if just after the turn you see two old railroad tank cars in the weeds to the left.
- Entrance into the Whapanaka State Forest and the State Forest Truck Trail.
- 58.0 1.5 STOP 5. STATE FOREST FROST WEDGE
 Walk up into the bedrock quarry. This pit is used by the State for maintenance of the truck trails. The face of the exposure is oriented N20E along one of the joint planes. The frost wedges are developed along the other joint plane N75W.

One frost wedge is well developed. A second wedge, to the north, is partially developed.

Results of digging along the upper surface of the well developed wedge indicate the feature persists with depth. It is known to persist for at least 3 ft to the east.

What is the origin of these features?

Hypothesis 1: That these frost wedges formed during more rigorous climatic conditions after the retreat of the last glacier.

Hypothesis 2: That these frost wedges resulted from several cycles of rigorous climatic conditions and perhaps from several ice advances.

Hypothesis 3: That these are not really frost wedges, but are frost cracks or some other periglacial phenomena.

Hypothesis 4: (This hypothesis was proposed by two local farmers) that these features formed as a result of a series of gas explosions, while man was drilling for oil and gas.

Return to County Road 29, and retrace path back to County Rd 32.

- | | | |
|------|-----|---|
| 64.1 | 6.1 | Jct County Rd 32, turn right (north). |
| 68.7 | 4.6 | Jct Rt 12, turn left and cross the Chenango River. The umlaufberg is to your right. The next stop is in the sediments deposited at the southern tip of the umlaufberg. |
| 69.2 | 0.5 | Bear right, onto County Rd 23A. |
| 69.3 | 0.1 | Bear right, leaving 23A. |
| 69.4 | 0.1 | Stop sign, turn right onto North Main Street. |
| 69.7 | 0.3 | <u>STOP 6. CHENANGO COUNTY SAND PIT</u>
This is the best sand pit in Chenango County.

The upper section of this pit is composed of lake silts, sands and clays, with many ripple drift laminations. These are well stratified.

The lower section is elusive. It may not be well exposed at the time of the trip; however, it is there. In this section there are examples of strata with vertical bedding; |

horizontal bedding that abruptly ceases into an unstratified zone; and cross-bedded sands with inclinations of up to 85 degrees. We may have to dig to re-expose these features. See Plates 2, 3, and 4, elusive contorted, discontinuous, vertical bedding in pit.

The lithologies present include red sandstone, limestone and chert, local sandstone, siltstone and shales, and igneous and metamorphic exotics.

Percentage composition:

18% red sandstone
25% limestone
43% locals
15% exotics

Hypothesis 1: The lower section was deposited as a kame terrace lateral to a retreating ice mass. There was an ice readvance causing the rotation of blocks and the discontinuous units. Subsequent to the ice readvance there was a lake followed by the development of the upper lake units.

Hypothesis 2: There was ice adjacent to the lower unit during sedimentation. With the melting of the ice some of the sediments were rotated, while still frozen. This could explain the rotated and discontinuous blocks, and also those with high inclinations. A lake then developed above these sediments.

Hypothesis 3: Some outrageous hypothesis.

Retrace path back to Rt 12.

- | | | |
|------|-----|---|
| 70.8 | 1.1 | Jct Rt 12. Turn left (north). Continue north through Sherburne and the intersection of Rt 80. |
| 76.5 | 5.7 | Jct Rts 12 and 12B. Continue straight ahead on Rt 12B. |
| 81.9 | 5.4 | Intersection at the center of Earlville; turn right. |
| 82.5 | 0.6 | Turn left onto Earlville Rd. |
| 82.7 | 0.2 | <u>STOP 7.</u> COSSITT CONCRETE PRODUCTS INC. This sand and gravel pit has the largest drag line operation in the Chenango River valley area. |

Exposures in this pit illustrate the following environments of deposition: deltaic foresets; lake bottom units; braided stream deposits; and evidence of deposition near an ice margin--as faulting and slumping in an ice contact zone.

The lithologies include: red sandstones, limestone and chert, local sandstones, siltstones and shales, and igneous and metamorphic exotics.

Percentage composition:

13% red sandstone
25% limestone
47% locals
16% exotics

Return to Rt 12B in Earlville.

- 83.5 0.8 Jct Rt 12B, turn right (north) and proceed into Hamilton.
- 90.1 6.6 Light in the center of Hamilton. Leave Rt 12B and continue straight ahead onto Madison Street.
- 91.1 1.0 STOP 8. HITCHCOCK SAND AND GRAVEL PIT
This pit is a large delta complex of sand and gravel.
- Percentage composition:
10% red sandstone
34% limestone
46% locals
10% exotics
- This delta formed in a lake that existed between the ice tongue in the Hamilton valley and the ice at Moraine Lake. The Moraine Lake ice was a slowly melting remnant ice tongue whose source had been cut off.
- Return to Madison Street, turn right.
- 91.5 0.4 Turn left onto Airport Road.
- 91.6 0.1 STOP 9. PICTURE STOP.
This is a view of the Hitchcock delta and the Hamilton valley.
- Continue straight ahead to the intersection with Rt 12B.
- 92.4 0.8 Jct Rt 12B. Turn right (north) and return to Utica (about 22 mi). Turn left (south) and return to Hamilton (about 1 mi).

Geology of the Canada Lake Nappe,
Southern Adirondacks

by

James McLelland
Colgate University

Introduction

The area considered in this report covers large portions of the Little Falls, Lassettsville, and Gloversville 15 minute quadrangles (Fig. 1). Small portions of the Piseco Lake, Lake Pleasant, and Broadalbin 15 minute quadrangles are also included.

Until recently, this area has received very little geological attention. Cushing (1905) mapped the Little Falls 15 minute quadrangle and Miller (1909, 1916, 1920) conducted mapping in the Broadalbin, Lake Pleasant, and Gloversville 15 minute quadrangles. His report on the Gloversville quadrangle was never published. Cannon (1937) published an excellent report on the Piseco quadrangle, but this was principally concerned with the Piseco Dome in the northern third on the map area. Nelson (1968) published a U.S.G.S. Bulletin describing the Ohio 15 minute quadrangle immediately to the N.W. of Fig. 2. Thompson (1955-59) studied the Harrisburg 15 minute quadrangle to the N.E. of Fig. 2.

For the most part, the above studies did not concern themselves with the stratigraphic detail presented in this report. This is in part fortuitous since the best, and most revealing,

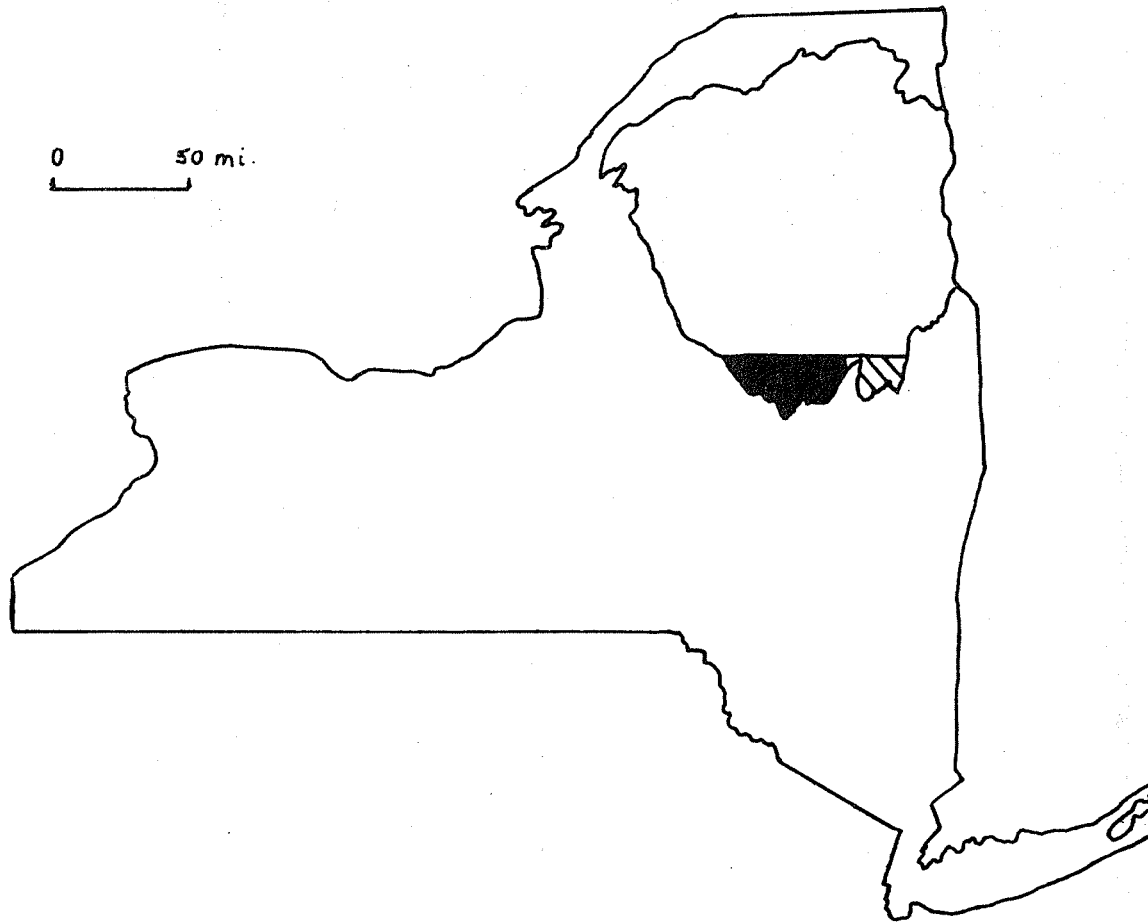


Fig. 1. Blackened area shows approximate location of the Precambrian units discussed here. Ruled area gives location of the hypothesized extension of the Canada Lake nappe.

stratigraphy lies in those areas which were either unmapped or mapped only in reconnaissance fashion.

The results of the present study (1965-1972) show that the southern Adirondacks are underlain by at least one regional isoclinal structure (Canada Lake nappe) that has been folded about several other axes. There probably exist three major periods of folding and each has occurred on a large scale. Axial traces can be followed over tens of miles. Two of the fold events (F_1 and F_2) appear to be coaxial and trend NW with a gentle plunge to the SE. The other is a NE trending fold (F_3) whose existence is postulated in this report. In addition to these folds there exists at least one other event (F_4) that has resulted in gentle warping of all other axes.

The stratigraphy of the area demonstrates that few, if any, of the major units had an intrusive origin. Charnockitic gneisses are stratigraphically coherent over several tens of miles. These and several other units, appear to be of metavolcanic origin, although a metasedimentary origin is not ruled out. Rocks of definitely metasedimentary origin are well represented by quartzites, quartzofeldspathic gneisses, and biotite-garnet-quartz-oligoclase gneisses all of which exhibit good compositional banding (usually parallel to foliation).

It does not as yet seem possible to unravel the pre-metamorphic history of the Adirondacks. Continued field work should hasten the day when this can be done.

Stratigraphy

The absolute ages of the bedrock units remains unknown. Numerous age determinations of Adirondack rocks continually yield a single age of $\sim 1.1 \times 10^9$ years (see Silver, L.T., 1968). Nor is it known which is the top or bottom of the section. Since the Canada Lake nappe is antiformal, we set the stratigraphic section outwards from the Irving Pond formation which is folded back on itself and cores the major structure. Thicknesses are approximate and do not take tectonic thinning and thickening into account.

Irving Pond formation

The Irving Pond formation is named for its exposures around part of Irving Pond which is the lake just east of Canada Lake on Fig. two. As measured from mapped contacts, the Irving Pond formation is approximately 2000 ft. (600m) thick. Lithologically, the Irving Pond formation is dominated by quartzites and feldspathic quartzites. At least 50% of the formation is composed of nearly pure quartzites. Most of these are white and glassy, but some are rose colored. Individual bands commonly measure 6 inches (.15m.) to 10 feet (.25 m.) in thickness.

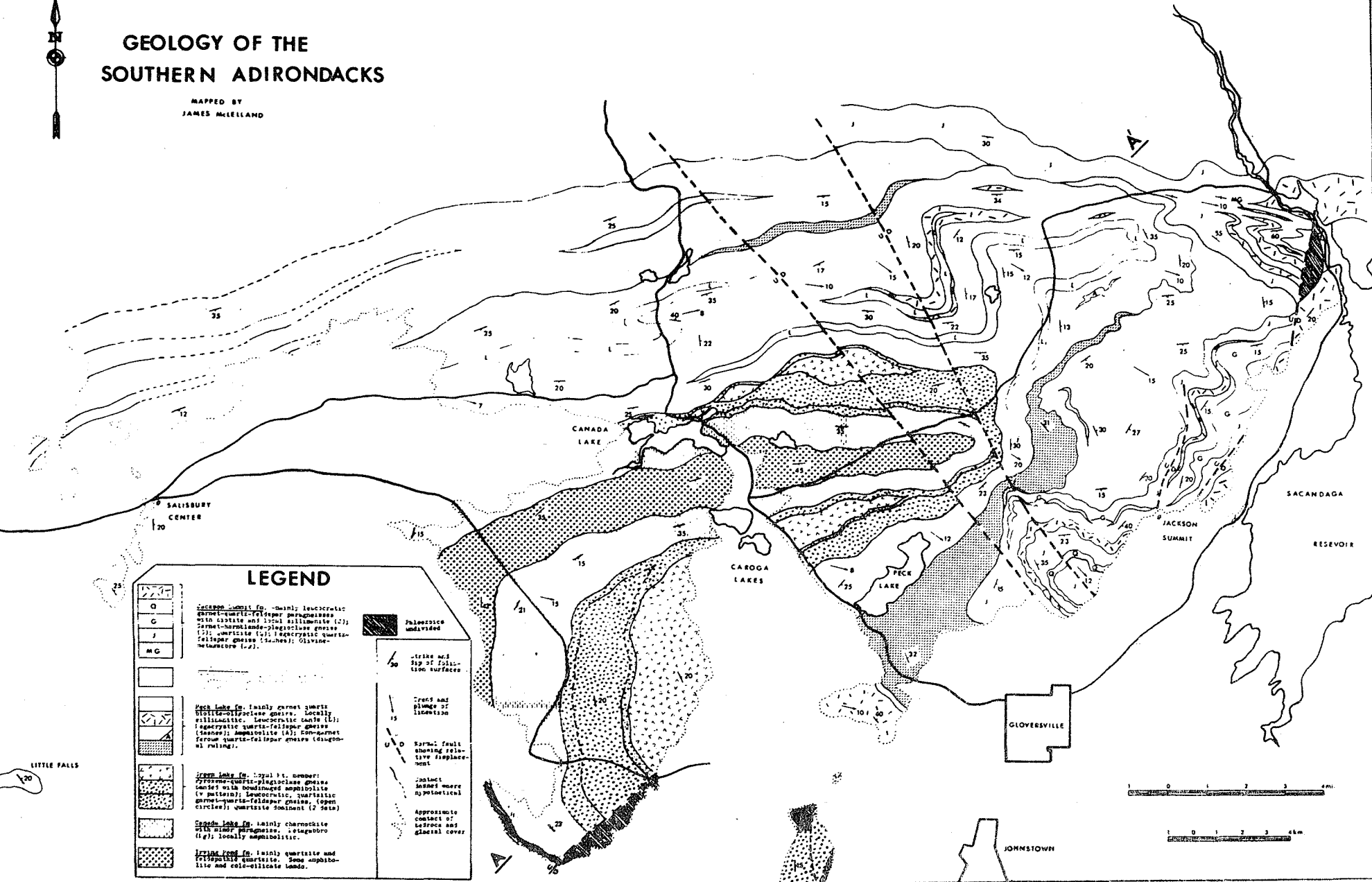
Feldspathic quartzites and quartzo-feldspathic gneisses make up from 30-40% of the formation. For the most part, these lithologies are highly quartzitic and could correctly be termed impure quartzites. Many of them exhibit fine scale layering represented by thin pelitic sheets less than .05 inches in thickness. In other instances 1-2 inch thick bands of pure quartzite alternate with equally narrow bands of pink quartzo-feldspathic gneiss.

Most of the impure quartzites and quartzo-feldspathic bands show the development of pale pink garnets. These are substantially different in color from garnets observed in the Peck Lake formation. The latter are a much deeper red.

Throughout the Irving Pond formation, there occur numerous bands, lenses, and boudins of dense, hard, dark calc-silicate and amphibolitic mineralogies. Microscopically, these are seen to consist of plagioclase, hornblende, quartz, and pyroxene. Generally, both

GEOLOGY OF THE SOUTHERN ADIRONACKS

MAPPED BY
JAMES McLELLAND



LEGEND

	Jackson Summit Fm. mainly leucocratic quartz-feldspar gneisses with cordierite and local sillimanite (2); garnet-biotite-and-plagioclase gneiss (1); amphibolite (3); leucocratic quartz-feldspar gneiss (4, 5); Olivine-tremolite (6).		Paleozoic undivided
	Peck Lake Fm. mainly garnet-quartz sillimanitic, leucocratic units (L); leucocratic quartz-feldspar gneiss (same); amphibolite (A); horn-spernet ferrous quartz-feldspar gneiss (diagonal ruling).		Caroga Lakes Fm. mainly charnockite with minor perthite, oligoclase (1); locally amphibolite.
	Little Falls Fm. mainly quartzite and chloritic quartzite. Some amphibolite and cordierite bands.		Salisbury Center Fm. mainly quartzite and chloritic quartzite. Some amphibolite and cordierite bands.
	Jackson Summit Fm. mainly leucocratic quartz-feldspar gneisses with cordierite and local sillimanite (2); garnet-biotite-and-plagioclase gneiss (1); amphibolite (3); leucocratic quartz-feldspar gneiss (4, 5); Olivine-tremolite (6).		Strike and plunge of fault
	Strike and plunge of fault		Trace and plunge of fault
	Strike and plunge of fault		Karol's fault showing relative displacement
	Strike and plunge of fault		Contact zones where synmetamorphic
	Strike and plunge of fault		Approximate contact of bedrock and glacial cover

Fig. 2. Geologic map of the southern Adirondacks.

ortho and clinopyroxenes are represented with one or the other dominating, depending on the thin section. In some instances diopsidic clinopyroxene is so abundant as to give the rock a greenish hue.

It is believed that the calc-silicate and amphibolitic layers represent metamorphosed carbonate bearing lithologies. No marble has been found in the region of Fig. 2 , but east of Sacandaga Reservoir, units correlated with the Irving Pond formation exhibit fairly abundant development of marbles. Associated with these are calc-silicate and amphibolitic bands identical to those here described. The percentage of these may have been analagous to the carbonate-pelite mixed zone observed in the Balmville limestone - Walloomsac shale transition of the Cambrio-Ordovician shelf sequence of north-eastern North America.

Near its contacts with the Canada Lake charnockites, the Irving Pond formation grades from dominantly quartzitic lithologies into garnetiferous biotite-quartz-plagioclase gneisses that closely resemble lithologies dominating the Peck Lake formation. This transitional zone is no more than 100 feet (30 m.) thick and averages close to 50 feet (20m.) across. The localizations of this zone to the vicinity of the contact may provide a clue to absolute tops and bottoms of the formations. This problem remains unresolved, but a speculative hypothesis might be that the transition zone reflects a change in sedimentary environment attendant upon an onset of volcanism associated with the Canada Lake charnockites. There are several assumptions involved here and the assignment of relative ages can be reversed. Our object in so stating the problem is to point out that detailed studies of the transition zone might well allow relative ages to be established.

Over its exposed extent shown in Fig. 2 , the Irving Pond formation exhibits no marked change in its overall character. It probably represents a metamorphosed sequence of thick sandstones, less abundant feldspathic sandstones, minor shales, and minor carbonate rich layers. It appears to be a shelf type deposit.

Canada Lake formation

This formation is named for its excellent exposures along Rte. 29A-10 at the east end of Canada Lake. According to its mapped contacts, the Canada Lake formation has a thickness ranging from 2000 to 3000 ft.

(600 -- 900 meters). These figures do not take tectonic thickening, thinning, or repetition into account.

The Canada Lake formation is almost wholly comprised of quartzo-feldspathic and charnockitic gneisses. Within these lithologies, hypersthene is only locally developed and in many instances, has been largely altered to amphibole and, to a lesser extent, biotite. It is possible that much of the amphibole in these rocks is due to retrograde metamorphism of orthopyroxene.

Within the gneisses of the Canada Lake formation, micro and mesoperthite is very widely developed. This is the same situation noted by DeWaard in the Little Moose Mt. area (DeWaard, 1962). Given the almost ubiquitous occurrence of micro- and mesoperthite in these units, they might best be referred as mesoperthite gneisses. However, we wish to stress their charnockitic affinities and, thus, refer to them as such.

Compositional banding is not strongly developed in the Canada Lake formation. However, it may be recognized by noting thin biotite rich zones and/or amphibolites. The latter occur only sporadically within the formation. Thin quartzites appear locally in the sequence, but it is rarely certain whether these are vein quartz or metasediments. By and large, the Canada Lake formation is a monotonous series of compositionally identical layers of charnockitic gneiss each measuring several tens of feet in thickness, and set apart from each other by weakly developed compositional banding.

Within the formation, there is local development of pegmatite and coarse grained quartzo-feldspathic areas. The occurrence of mafic minerals also varies throughout, but none of these variations has been mapped separately.

The charnockitic gneisses of the Canada Lake formation show features typical of the so-called "syenitic" gneisses of the Adirondacks -e.g.- flattening and stretching of quartz grains; a dark greenish color on fresh surfaces; pinkish weathering of woodland outcrops; and a white to brown weathered surface on outcrops long exposed to the sun.

Garnet is virtually absent from the charnockitic gneisses and has been recognized only at one outcrop. Likewise clinopyroxene occurs only rarely. Almost certainly, this represents original compositional

variation in the gneisses.

The contact with the Irving Pond formation is sharp and the charnockitic gneisses show no gradation into the Irving Pond lithologies. On the other hand, the Irving Pond formation shows a weakly gradational contact with the Green Lake formation; the gradation being represented by an increasing number of quartzite bands in the charnockitic gneisses.

The overall homogeneity and poor banding of the Canada Lake formation suggests that it is composed of a metamorphosed sequence of dacitic lava flows. Local amphibolite layers may represent more basic volcanism or ash falls.

The Green Lake formation

This formation is named for its conveniently located exposures along the eastern shore of Green Lake. Its thickness, as measured from mapped contacts, varies between 2000 ft. (600 meters) and 200 feet (60 meters).

The Green Lake formation is dominated by leucocratic and quartzitic garnet-quartz -two feldspar gneisses. Near its contact with the Canada Lake and Royal Mountain formations, pure and impure quartzite layers dominate. Interlayered with the leucocratic lithologies are subordinate units of amphibolite, calc-silicate, and biotite rich gneisses. Within the quartzitic and leucocratic units, garnets exhibit a characteristic pale pink color. Sillimanite is present in small amounts in almost every thin section examined.

Certain lithic similarities exist between the Green Lake and Irving Pond formations. However, the latter contains a great deal more quartzite than the former, and the quartzite occurs in much thicker bands within the Irving Pond formation. The Green Lake quartzo-feldspathic units contain much more feldspar than quartzo-feldspathic lithologies in the Irving Pond area. Concomitantly, garnet is much more ubiquitous in the Green Lake formation. Of course, the Green Lake and Irving Pond formations may be lithically gradational, were it not for the intervening Canada Lake charnockitic gneisses. The presence of this intervening and stratigraphically continuous unit makes it possible to draw the formational boundaries here observed.

The Royal Mountain member of the Green Lake formation was originally assigned a separate formational status. However, it occurs wholly within the Green Lake formation; is stratigraphically discontinuous; and occurs at several stratigraphic horizons. Therefore the unit is herein included as a member of the Green Lake formation.

The Royal Mountain member is named for its excellent exposures on the ski slopes of Royal Mountain which lies within the largest area of this gneiss shown on Fig. 2 . It is composed of a monotonous series of medium grained, white weathering, pyroxene-quartz-plagioclase gneisses banded with much boudinaged layers of amphibolite. The quantity of amphibolite varies from less than 5% to approximately 50% with the variation not appearing to have any stratigraphic continuity.

The Royal Mountain unit looks very much like the charnockitic gneisses of the Canada Lake formation and was originally mistaken for them. However, K-feldspar is very sparse (10% maximum) within the Royal Mountain. It is often necessary to stain the rocks to tell them apart. It is possible that a significant percentage of "syenitic" and "charnockitic" gneisses of the Adirondacks are analogues of the Royal Mountain pyroxene-quartz-plagioclase gneiss.

The plagioclase in the Royal Mountain member has an An content straddling calcic oligoclase and sodic andesine. This makes it more calcic than the majority of plagioclases in non mafic rocks of the southern Adirondacks.

The mineralogy, physical appearance, and lenticular aspects of the Royal Mountain formation suggest that it represents a metamorphosed series of tonalitic volcanic centers. The individual flows were intermittently layered with more basic flows or ash falls that are now preserved as amphibolite bands.

The bulk of the Green Lake formation presumably represents the metamorphosed equivalents of pure and feldspathic sandstones. Shales and graywackes appear to have been minor. Amphibolites and calc-silicate layers may represent carbonate rich portions or basic volcanic material.

Peck Lake formation

This formation is named for its good exposures along Route 29A-10, where the highway crosses the western end of Peck Lake. Excellent roadcuts are also exposed along Route 29A between Stratford and Canada Lake.

The Peck Lake formation has the greatest exposed thickness in the area. Its greatest approximate thickness is 5000 feet (1.5 km.).

The formation is composed overwhelmingly of garnetiferous biotite-quartz-oligoclase gneisses which contain small quantities of sillimanite and K-feldspar layers and streaks of quartzo-feldspathic material, give the unit a banded appearance. Amphibolite and quartzite layers also accentuate the banding. Throughout the gneiss are pods and lenses of two feldspar-quartz rocks. These are believed to have an anatectic origin and in places can be seen to cross-cut the surrounding gneisses. Garnets within the anatectites may represent refractory material.

It has proven extremely difficult to subdivide the Peck Lake formation. Leucocratic variations are easily recognizable but generally do not exhibit stratigraphic continuity. Extensive folding of incompetent units further complicates the problem. However, several continuous leucocratic horizons have been recognized and are shown on Fig. 2 . The units are dominated by garnetiferous quartzo-feldspathic gneisses. Garnets in these units have a pale pink color in contrast to the burgundy color of most Peck Lake garnets.

Within the Peck Lake formation, there occur several bands of gneisses containing large (1-4 inches long) megacrysts of microcline and/or microperthite. The lithology of these is identical to rocks of the Rooster Hill formation.

The Peck Lake and Green Lake formations show a fairly abrupt contact although the lithologies are gradational. Many Peck Lake leucocratic units resemble the dominant lithologies of the Green Lake formation. The abruptness of the change in biotite content and garnet coloration permits the contact to be drawn with considerable confidence.

Another discontinuous unit in the Peck Lake formation is the non-garnetiferous biotite-quartz-two feldspar member. This lithology occupies a stratigraphic position just below the Rooster Hill megacrystic

gneisses. Aside from the lack of garnet and greater percentage of K-feldspar, the unit is quite similar in appearance to the dominant lithology of the Peck Lake formation, bands of which occur within the non-garnetiferous member. Near the contact with the Rooster Hill formation, it becomes streaked with quartzo-feldspathic material and K-feldspar porphyroblasts. In this aspect the unit has a migmatitic appearance. In addition the greater percentage of K-feldspar enhances partial fusion and numerous anatectic pods are present. The higher degree of partial fusion has resulted in a great deal of flowage folding which increases the migmatitic appearance.

The Peck Lake formation is similar to Engle and Engle's (1956) "least altered gneiss". It is believed to represent a metamorphosed sequence of shales and/or greywackes with minor sandy layers and volcanics. The uppermost migmatitic unit probably represents a change in environment following or attendant upon Rooster Hill volcanism. Whether the formation is eugeosynclinal or not is unknown.

Rooster Hill formation

This formation is named for its excellent and accessible exposures on Rooster Hill just North and East of Stoner Lakes (STOP H).

The Rooster Hill formation is a discontinuous unit but its thickness as measured on the map averages close to 8000 ft. (250 meters). This formation is comprised of two textural varieties of compositionally identical biotite-hornblende-quartz-two feldspar leaf gneiss. In addition to these, there occur in the unit isolated bands of garnetiferous biotite-quartz-oligoclase gneiss identical to the dominant lithology of the Peck Lake formation.

By far the most abundant variation of Rooster Hill is a very distinctive inequigranular variety containing 1-4 inch long megacrysts of K-feldspar set in a medium grained groundmass of biotite-hornblende-two feldspar gneiss. The megacrysts are microcline and microperthite with the latter dominating. These megacrysts are generally flattened and aligned within planes of foliation. In a few outcrops the megacrysts exhibit an almost random orientation. Granulation of the

the megacrysts is variable. In most instances granulation is confined to margins of single crystals and the interiors are sufficiently preserved so that Carlsbad twinning may be observed.

The second textural variant of the Rooster Hill formation is an equigranular equivalent of the megacrystic unit. This equigranular member occurs at all positions in the formation, but its principal development is at the margins of the formation. It is believed that this member is a granulated variant of the more abundant megacrystic variety.

In an earlier publication (McLelland, 1969) it was suggested that the Rooster Hill formation had an intrusive origin. This argument has since been invalidated by further field work. Contacts that had been supposed to be transgressive have since been demonstrated to be conformable. New field work has uncovered over three miles of exposed contacts with the Peck Lake and Jackson Summit formations. These occur mainly in the northeastern and eastern portions of Fig. 2 .. Clean, sharp, conformable contacts are everywhere seen. Similar relationships have been observed relative to similar megacrystic units within the Peck Lake and Jackson Summit formations.

Based on the above observations, it seems virtually certain that the Rooster Hill gneisses do not have an intrusive parentage. They probably represent a series of volcanics of dacitic to quartz-latic character. The origin of the megacrysts remains obscure, but they are presumably porphyroblasts. It seems unnecessary to ascribe them to metasomatic processes as was done by Nelson (1969). Arguments that they grow across foliation are not only non-sequiturs but they are also incorrect. Close inspection of apparently cross-cutting megacrysts shows that they are actually rotated by movement along foliation planes.

The discontinuous nature of the Rooster Hill may reflect volcanism restricted to a few centers around which relatively thick lava piles developed. These lavas may have been more viscous than those presumed to have been the parents of the less siliceous Canada Lake charnockitic gneisses. This would explain the differences in stratigraphic continuity.

The Rooster Hill lithologies are similar to Buddington's (1939) Hermon Granite.

Jackson Summit formation

This formation is named for its good and representative exposures in the vicinity of the hamlet of Jackson Summit. The maximum thickness is uncertain, but the formation is at least 3000 ft. (900 meters) thick.

The Jackson Summit formation is dominantly composed of garnetiferous gneisses intermediate in mafic and quartzite content between the Peck Lake and Green Lake formations respectively. It is decidedly more leucocratic than the former and less quartzitic than the former. It also contains more minor amphibolite bands than either of the above.

Like the Peck Lake formation, the Jackson Summit formation contains conformable bands of megacrystic gneiss, lithically identical to the Rooster Hill formation. The unit labelled "G" on Fig. 2 and referred to as a garnetiferous variety is actually a garnetiferous phase of the Rooster Hill equigranular lithology.

A rare, but exceedingly important member of the formation, is the band of olivine-metagabbro exposed in the fold nose at the northeastern extremity of Fig. 2. This unit is conformable and was presumably intruded as a sill. The largest band is .75 mile (1.2km.) long and at its widest is 750 feet (.25km.) across. In the interior of the band ophitic and subophitic textures are preserved. The development of coronas in the rock enable us to set P,T conditions for the last metamorphism of the area. This is further discussed on page E-13.

The Jackson Summit formation presumably represents the metamorphosed equivalent of a thick sequence of feldspathic sandstones, sandstones, minor shales and graywackes, and acidic volcanics. It is the most variegated formation in the area.

Structural Geology

Folding

The structure of the area shown in Fig. 3 is fairly straightforward, once it has been mapped. The major structure is a recumbent isoclinal antiform F_1 cored by the Irving Pond formation and referred to as the Canada Lake nappe. The axial plane of the nappe has been refolded by several relatively open folds F_2 which cause the nappe to zig-zag from southwest to northeast across the mapped area. A third set of gentle folds F_3 cause the F_2 axes to undulate. In addition to these fold sets there probably exists a N.E. trending major fold whose position in time lies between F_1 and the currently designated F_2 . At present this fold is conjectural. It will be further discussed in section

The F_1 and F_2 folds appear to have parallel or subparallel axes, at least where they intersect one other. These axes trend approximately N.W. to E-W and plunge gently eastward. The coaxiality of these folds is best shown in the outcrops at stop K.

The geometry of the F_1 and F_2 is shown in Figs. 2 and 3. In addition, Fig. 3 shows the manner in which the F_1 axis is folded slightly to the NE in the vicinity of Canada Lake.

It is clear from Figs. 2 and 3 that the F_1 fold has undergone axial plane folding by F_2 . This may represent the continuation of the same force field during the two fold events. First the rocks were detached from their original basement and folded into a recumbent isocline which rode forward (northward?). In the process of being thrust forward the F_1 fold was thrown into a series of more open F_2 folds. The parallelism of the axes may reflect the continued action of the same stress field (subduction? continental collision?).

In the northeastern corner of the area the F_1 axial trace swings eastward. This area is one of the very few in which the F_1 fold hinge is well exposed. Here can be seen excellent examples of rodding, minor folding, and transposed bedding. As shown in Figs. 2 and 3, this region is crossed by two F_1 fold axes trending N70W. These folds are considered to be drags near the nose of F_1 . Note that the apparent relative motion is in the proper sense. In general the drag folds on F_1 are consistent in their sense of rotation, being sinistral on the

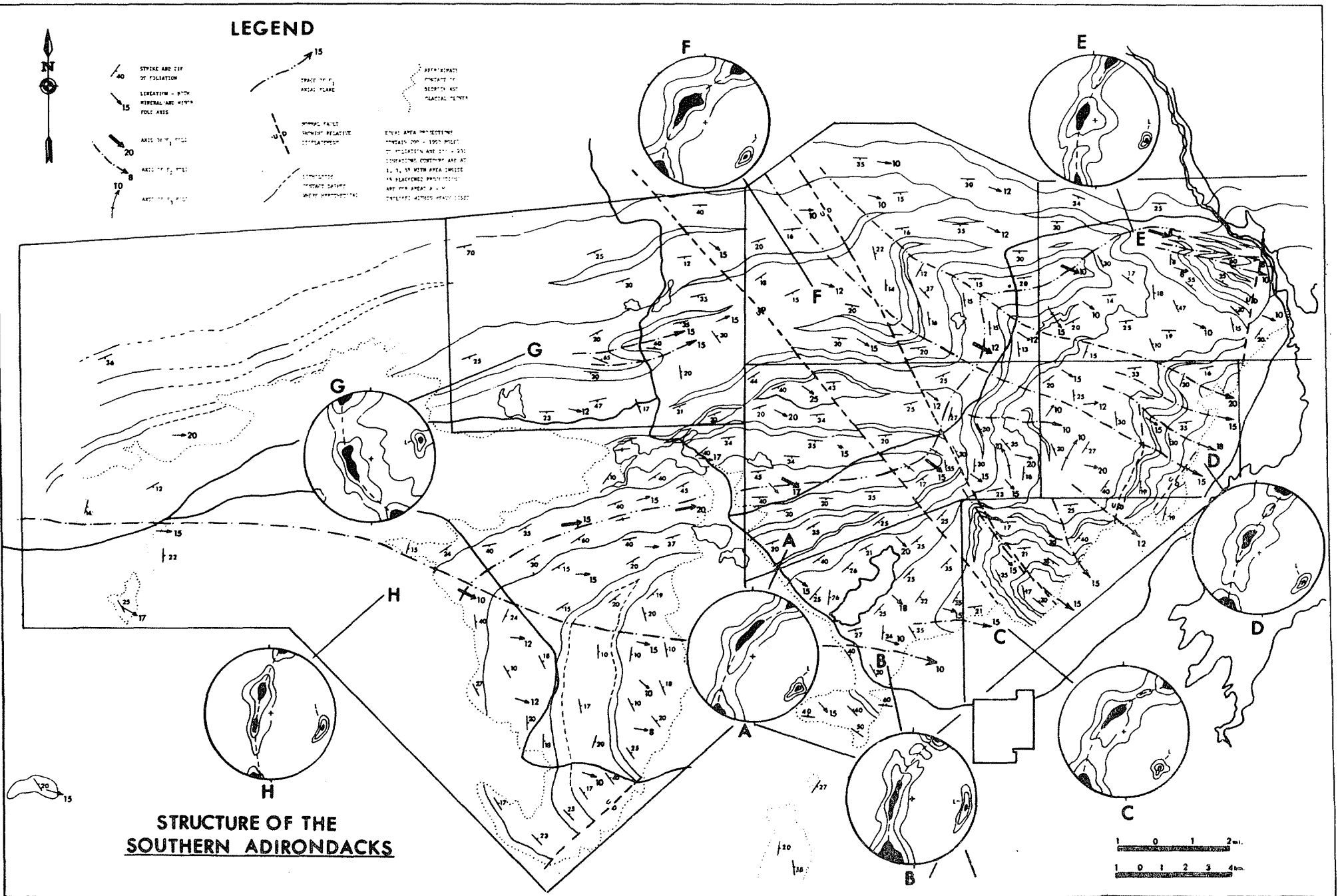


Fig. 3. Structural geology of the southern Adirondacks.

lower (northern) limb and dextral on the upper (southern) limb. The long axes of boudins are also consistent with the mapped fold axes.

North of Canada Lake there exists a sharp NE fold outlined by a unit of leucocratic gneiss in the Peck Lake formation. It is uncertain as to which event this fold corresponds. The axial plane of this fold is only slightly overturned, and it does not appear to be of the F_1 generation. However, its trend and tightness of folding is unlike that of F_2 .

It appears that during F_1 folding, the Irving Pond and Canada Lake formations behaved competently while the Peck Lake formation underwent relatively less competent deformation. This is consistent with the mineralogies of these units. The Royal Mt. member appears to have behaved incompetently relative to internal amphibolite bands. It may have been more competent than other units in the Green Lake formation. Thus the discontinuous aspect of the Royal Mt. formation may be due to mega-boudinage. This is suggested by the intense deformation of Green Lake quartzo-feldspathic units in the "necked-down" region of the northern band of Royal Mt. on Fig. 2. Alternatively, the "pinch and swell" appearance of the Royal Mt. formation could be the result of separate centers of volcanism. Similar considerations may hold for the Rooster Hill formation.

A major structural problem in the area is whether the nappe is underlain by a thrust zone. No such zone has yet been definitely located. It is postulated that the highly lineated Piseco Dome trend may represent such a zone of detachment. This speculation gains some support from the fact that the Canada Lake lithologies

are uncommon north of the dome. As the dome is approached from the south, all rock units acquire an increasing degree of rodding. This may be the result of rolling in response to thrust movement. At present the problem remains an open one.

Cross sectional and 3-d schematic news are shown in Fig. 4 and 5. Given the accompanying maps and figures, there seems little else that needs to be added in terms of words. Regional structural correlation is discussed under the section entitled "Hypothetical Extension of the Nappe".

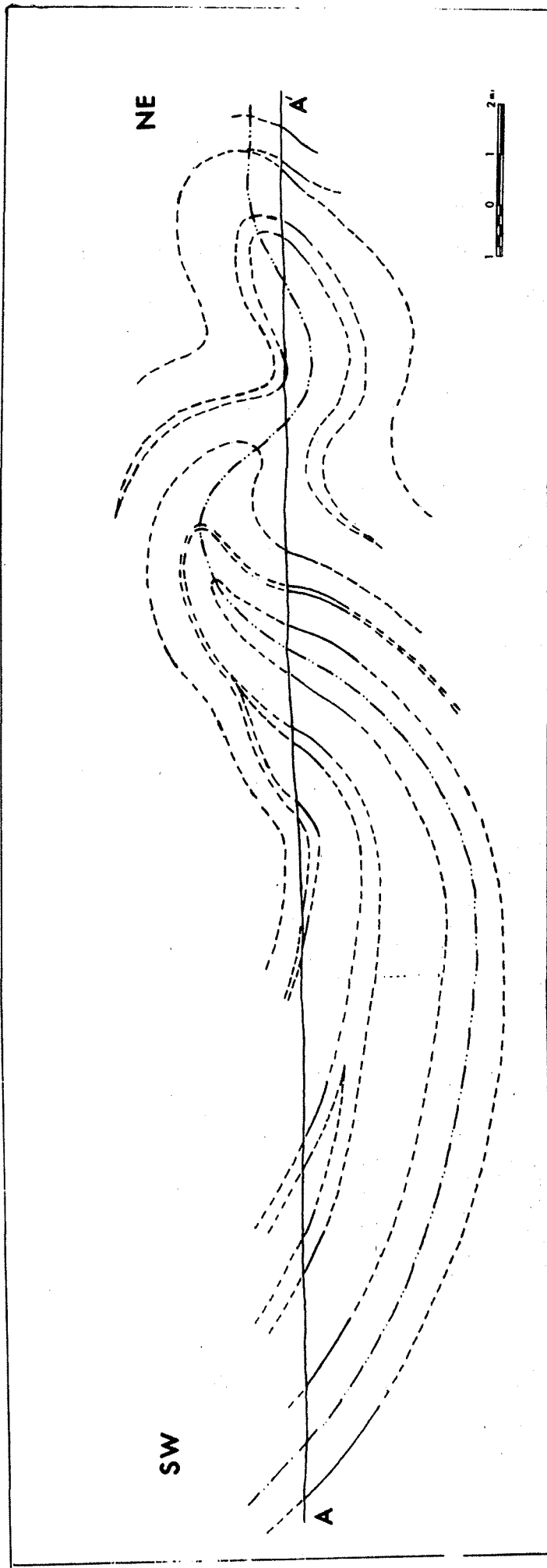


Fig. 4. Cross section across the Canada Lake nappe from A-A' of Canada Lake formation shown in vertical dash pattern.

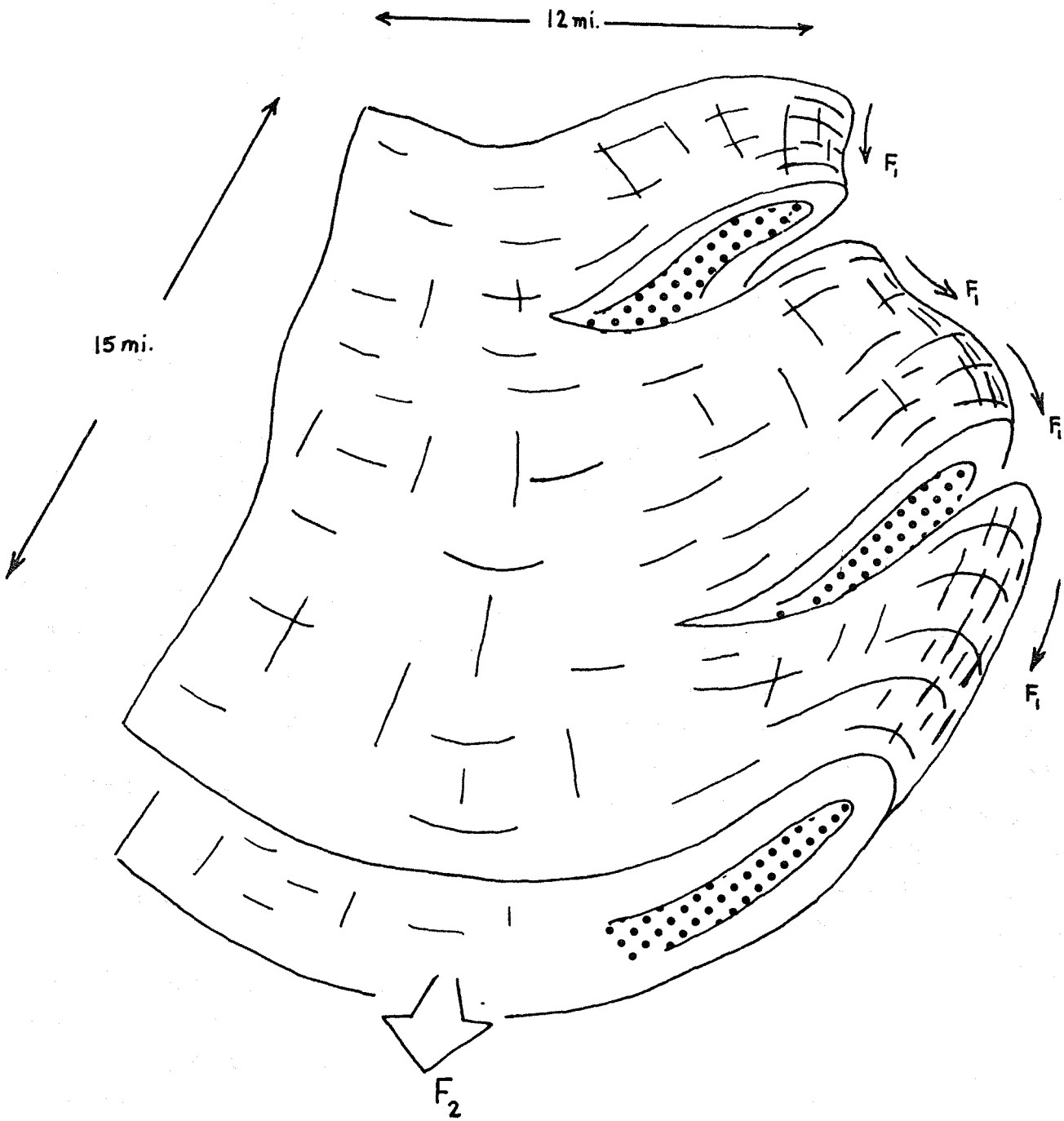


Fig. 5. Schematic 3-dimensional representation of the Canada Lake nappe. Looking from East to West. Irving Pond formation shown in dot pattern.

Hypothetical Extension of the Nappe

The detailed mapping shown in Figures 2 and 3 extends eastward to Sacandaga Reservoir. Within this area, the geological relationships are rather well understood. Beginning in 1971, the author began to reconnaissance the geology to the north and to the east of Figures 2 and 3. It became apparent that the stratigraphy of the Canada Lake nappe was repeated in the area lying between Sacandaga Reservoir and Saratoga Springs. During the summer of 1972, this work has been continued on a more detailed scale by two of the author's students, Paul Dankworth and Robert Kuhlman, both of whom are participants in an NSF Undergraduate Research Participation grant made to Colgate's Department of Geology.

Dankworth and Kuhlman have shown that a recumbent fold underlies the area east of Sacandaga Reservoir and that its axial trace trends northeastward in the southern part of the region (see Fig. 6). Moreover, they have demonstrated that the stratigraphy is remarkably like that of the Canada Lake nappe. Thus the fold (antiformal) is cored by a sequence of quartzites, impure quartzites, calc-silicates and marble. This band is correlated with the Irving Pond formation which it closely resembles except for the presence of marbles. This latter difference is easily explained in terms of a sedimentary facies change. On either side of this central quartzitic band are quartzo-feldspathic charnockitic gneisses whose small and large scale properties appear identical to the Canada Lake formation. Bordering the charnockitic gneisses are quartzites and highly quartzitic leucogneisses. These are correlated with the Green Lake formation. These units grade outward in garnetiferous biotite-quartz-oligoclase gneisses that resemble the Peck Lake formation in every way except that quartzite layers are thicker and more abundant than in the Canada Lake area. Intercalated with these units are conformable bands of megacrystic gneisses resembling the Rooster Hill lithology.

From the above description, it appears extremely likely that the sequence east of Sacandaga Reservoir is a continuation of the Canada Lake-Gloversville sequence. The absence of the Royal Mountain member and the thinning of the Rooster Hill formation can be understood in terms of increasing distances from centers of volcanic activity.

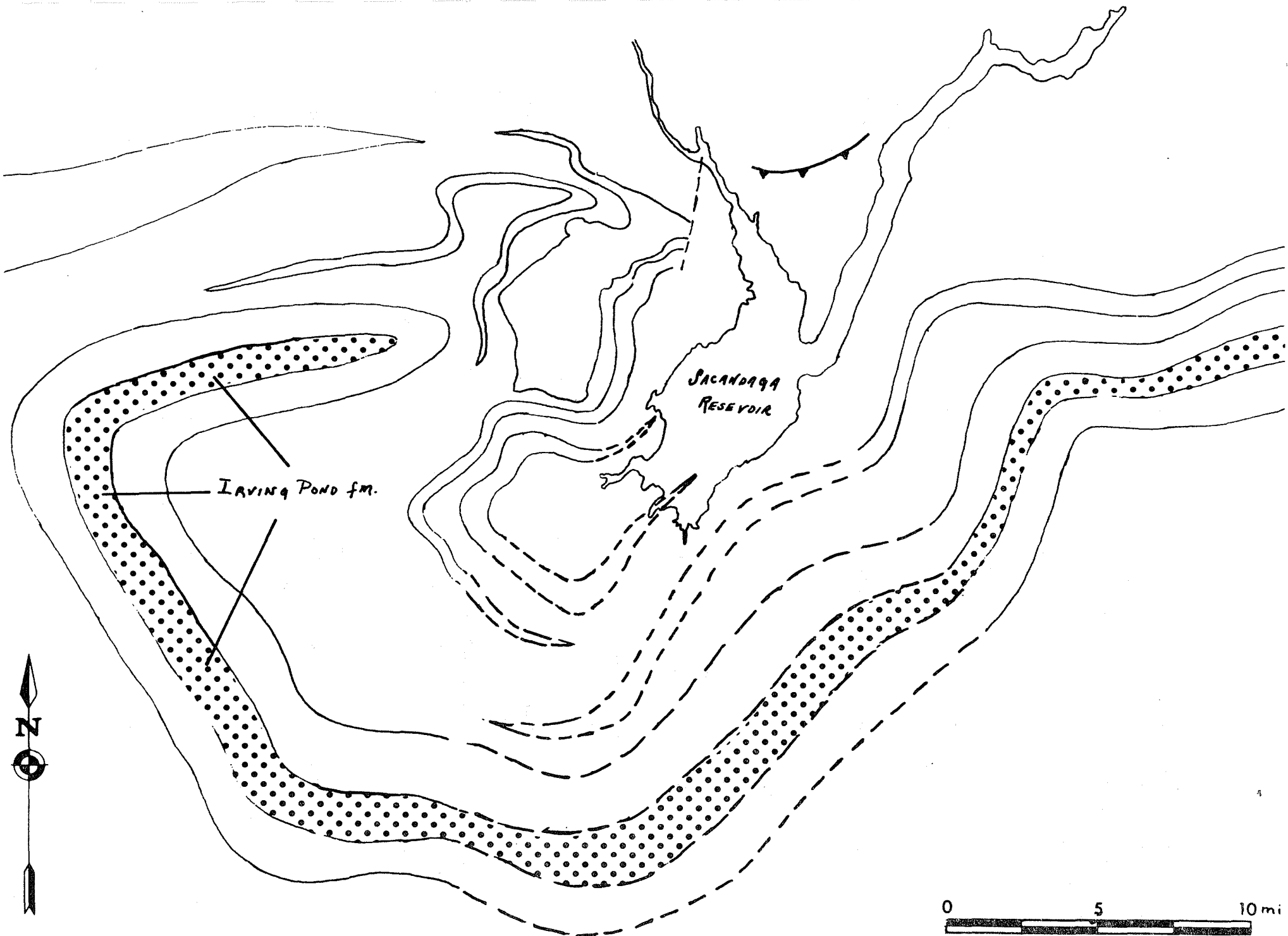


Fig. 6. Geologic sketch map showing hypothetical eastward extension of Canada Lake nappe. Dashed lines refer to areas under paleozoic cover.

As this article is being prepared, we have spent only four weeks doing detailed field work in the highlands east of Sacandaga Reservoir. Clearly, a great deal remains to be done. However, it is with considerable confidence that we offer the hypothesis that the Canada Lake nappe and stratigraphic section extends eastward towards Saratoga Springs as shown in Fig. 6. Of course, the extrapolation involved must be carried out beneath an extensive cover of Paleozoics that blanket the southern portion of the area.

In the area described above the extension of the Canada Lake nappe has an axial trend averaging close to E-W. Its axial plane dips southward at moderate angles (20° - 30°). It is crossed by a large N.W. trending F_2 synform that plunges gently S.E.. Within the core of the F_1 fold, lineation and rodding are well developed and preliminary measurements indicate that F_1 and F_2 are not coaxial, but rather, that F_2 has folded F_1 .

In order to swing the Canada Lake nappe eastward, as shown in Fig. 6, it is necessary to introduce a N.E. trending fold that passes almost directly through Sacandaga Reservoir. The existence of this fold gains support from the existence of several north and northeastward trending folds and lineations in the area. A few of these are shown on Fig. 3, but they are so uncommon as not to influence the equal area projections which are comprised of hundreds of points. To some extent, the foliation pattern in the eastern limb of the Rooster Hill formation is consistent with the NE folding. Similarly, the somewhat peculiar pattern of the southeastern exposure of the Jackson Summit formation is more easily explained by introducing this NE fold. Greater support is provided by the foliation pattern directly north of Sacandaga Reservoir. In this area the strikes swing from E-W to NE so as to define a broad, gentle anticline. This is consistent with the fold structure hypothesized herein. However, we are not yet ready to speculate with any certainty on the actual style of the folding.

The temporal position of the fold is still uncertain. We tentatively believe that it falls between F_1 and the currently designated F_2 fold. However, continued field work may alter this hypothesis.

Finally, we note that the current aeromagnetic map of the southern Adirondacks indicates anomaly patterns beneath the southern

Paleozoic blanket that are highly consistent with our hypothesis.

If our extrapolation is correct, the Canada Lake nappe has an E-W extent of approximately 45 miles and a total extent of at least 65-70 miles. This makes it a truly enormous structure. We suspect that many, if not most, Adirondack folds have similar dimensions. Presumably this reflects the scale on which deep crustal deformations occur.

Faults

Northeast trending faults and fracture zones are common in the area and have received topographic emphasis due to glaciation. They are often accompanied by considerable breccia.

The northeast trending faults account for many of the Precambrian-Paleozoic contacts, and therefore, must have substantial throw along them. However, within the Precambrian they do not manifest offsets large enough to show up on the scale of $7\frac{1}{2}$ minute quadrangle mapping.

Northwest trending faults do not show the topographic definition of the northeast fracture zones, but they generally exhibit a greater throw. Two such faults cross the Precambrian exposures of the area and are shown on Figs. 2 and 3. Neither one of these appears to extend into the Paleozoics. Whether these faults are strictly Precambrian in age is not known.

P-T Conditions of Metamorphism

Within the Jackson Summit formation there occur a few sill like intrusions of olivine metagabbro. These have been folded by F_1 movements. Since we believe the F_1 folding to precede or be approximately contemporaneous with the major metamorphism, it seems likely that the metagabbro has undergone the same progressive metamorphism as other rocks in the area. Thus any information regarding P,T conditions related to its metamorphic mineralogy, will be directly applicable to the rest of the area.

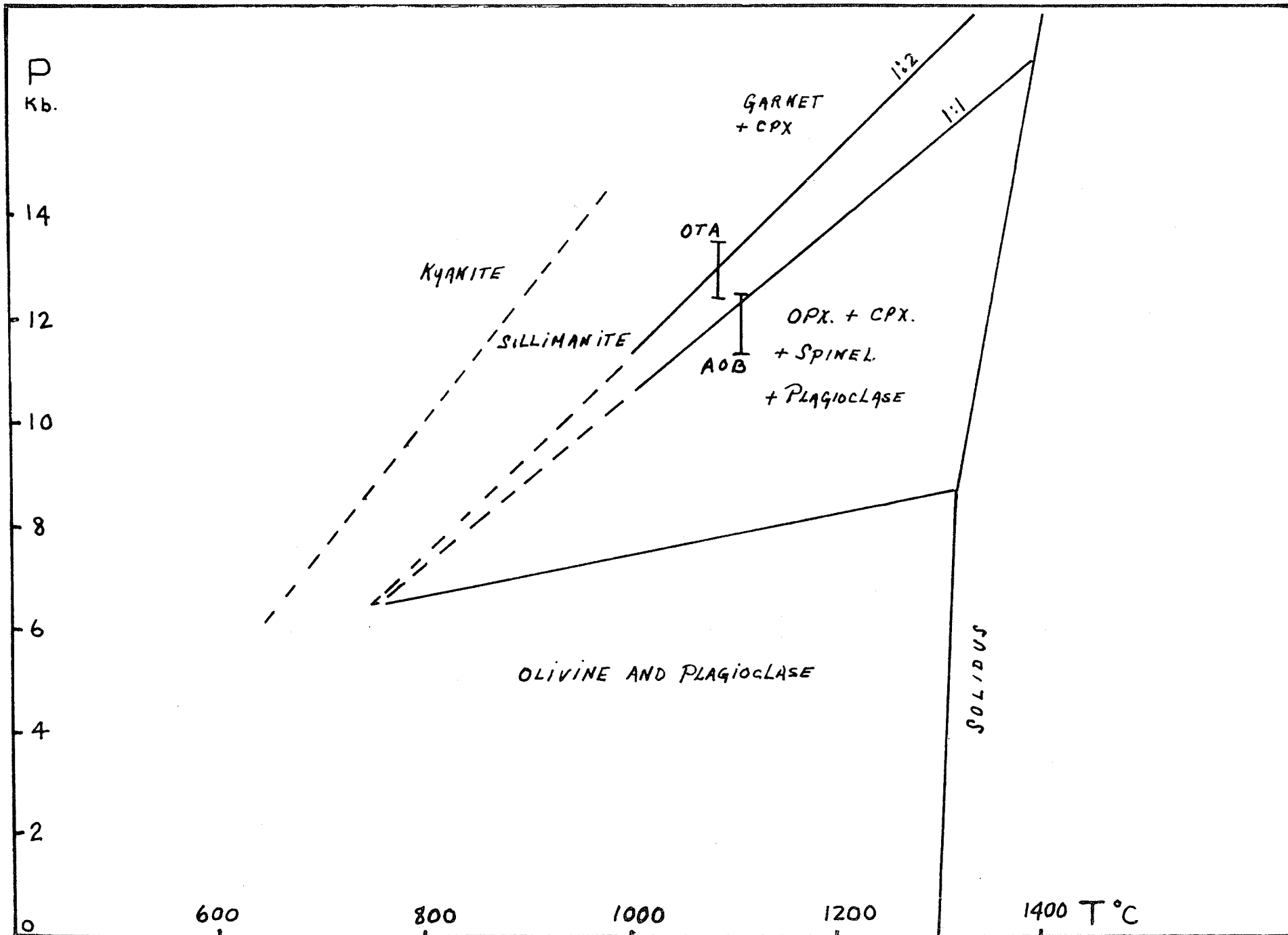
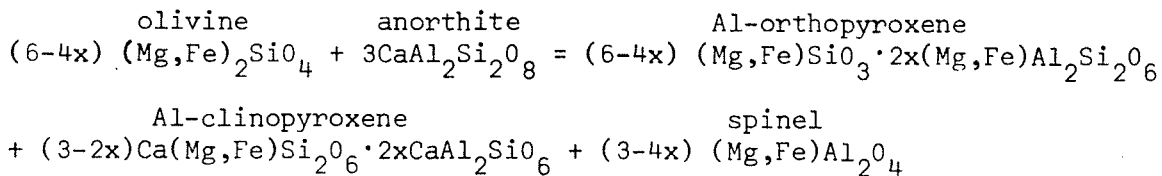


Fig. 7. Experimental P-T diagram for the anorthite-forsterite as ascertained by Kushiro and Yoder (1966). 1:1 and 1:2 refer to anorthite-forsterite ratio. The lines OTA and AOB refer to the incoming of garnet in olivine tholeiite and alkali olivine basalt respectively (Green and Ringwood, 1967).

Within the metagabbro there are developed beautiful examples of coronas. These consist of an olivine core surrounded by a shell of orthopyroxene rimmed, in turn, by a vermicular intergrowth (symplectite) of clinopyroxene and green spinel. These symplectites embay into surrounding plagioclase crystals.

During 1971 and 1972, the author and Philip Whitney of the New York Geological Survey studied these coronas and garnet bearing analogues of the N.E. Adirondacks. On the basis of microprobe data, we have substantiated their mode of origin. This work has been submitted for publication elsewhere. For coronas of the southern Adirondacks, we believe that the gross mineralogies can be explained by a reaction of the following type:



This reaction represents the sum of three partial reactions which serve to explain corona zonation, plagioclase clouding by spinel, and the behavior of the albite molecule in the process. For our present purposes, we need only consider the total reaction as given above.

Fig. 7 is a diagram in the PT plane showing the reaction boundaries found by Kushiro and Yoder (1966) for the anorthite-forsterite system. The lower line shows the boundary between the olivine-plagioclase and pyroxene-spinel fields. The upper two lines show the boundary between the pyroxene-spinel and garnet fields, for An:Fo ratios of 1:1 and 1:2. The bars labelled (OTA) and (AOB) are from Green and Ringwood (1967) and illustrate the range of pressures for the incoming of garnet in an olivine tholeiite and an alkali olivine basalt, respectively. Both rocks, and the olivine tholeiite in particular, are similar in bulk composition to the coronites of this study. Green and Hibberson (1970) have shown that addition of albite to plagioclase delays the initial olivine-plagioclase reaction to somewhat higher pressures, and addition of fayalite to olivine lowers the pressure for the initial appearance of garnet. Hence, the wedge-shaped pyroxene-spinel field is probably smaller for natural olivine/plagioclase rocks than

than for the pure forsterite anorthite system studied by Kushire and Yoder.

While due caution must be taken in applying this data directly to natural assemblages, it seems appropriate to utilize the diagram to ascertain approximate P,T, conditions of metamorphism. Accordingly, we believe the minimum metamorphic conditions to have been in the range of 800°C and pressures of the order of 7kb. Both pressure and temperature could have been somewhat higher. These conditions are consistent with those proposed by DeWaard (1967) for the Adirondack Highlands. Clearly, we are dealing with deep crustal burial and thickening.

ACKNOWLEDGEMENTS

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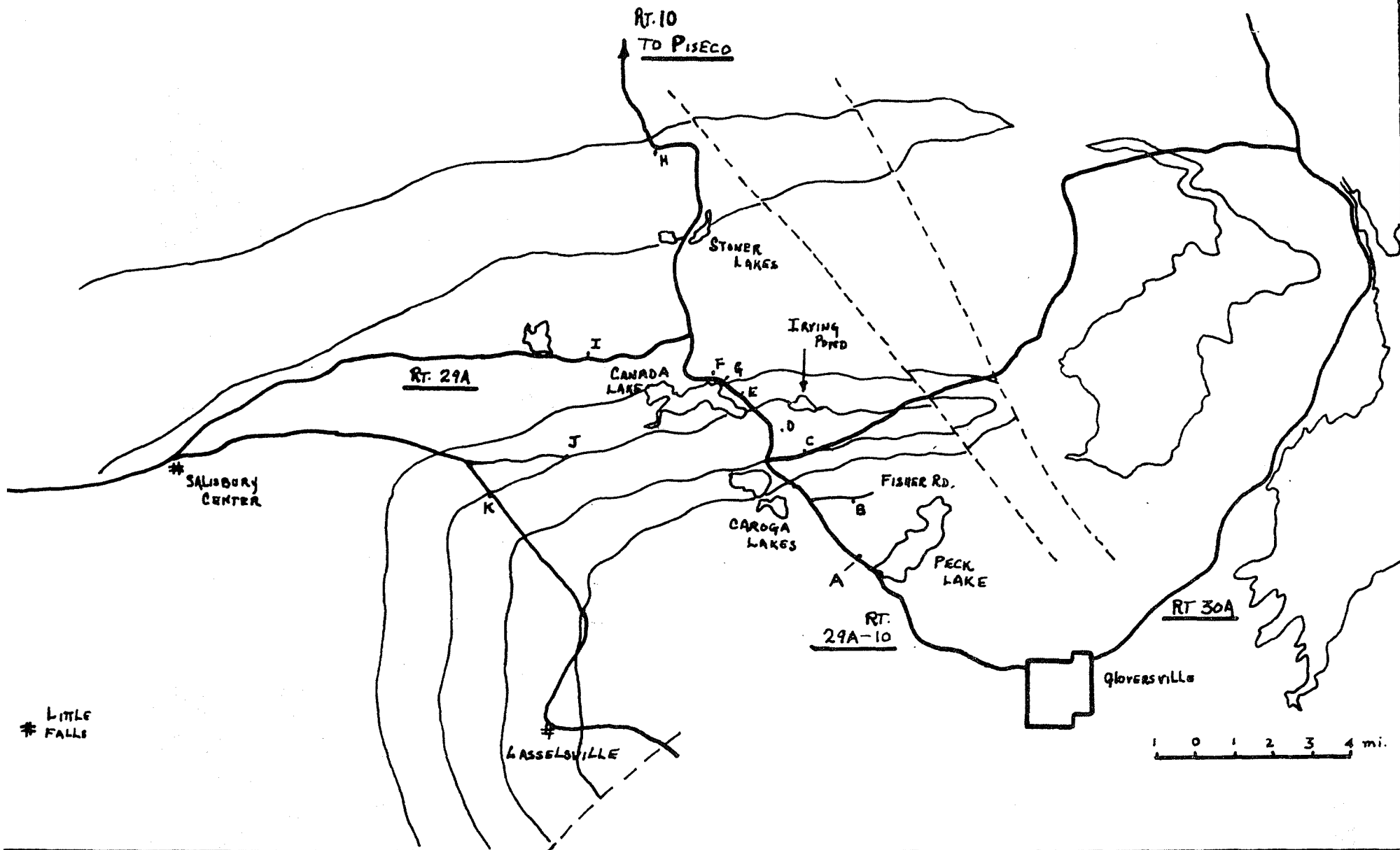
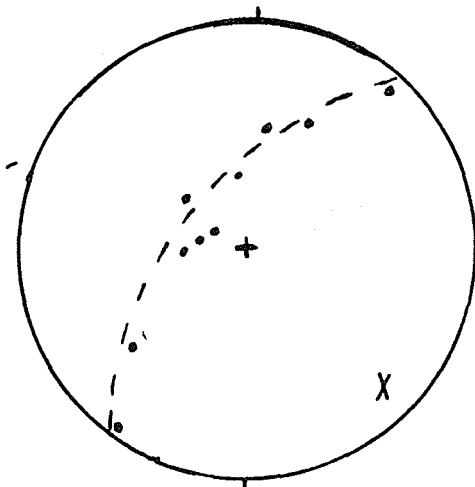


Fig. 8. Location of stops in Road Log. A complete log with mileage will be found in NEIGC Guidebook for 1969.

STOP A The Peck Lake Formation

Roadcut of garnetiferous quartz-biotite-oligoclase gneiss. Minor amphibolite and calc-silicate bands. These gneisses are the dominant lithology of the Peck Lake formation which is exposed here on the south limb of the F_1 fold. Needles of sillimanite and/or fibrolite can be seen in some specimens.

In a little overhang near ground level there is a minor fold with an axial trend of N50W, plunging 15 SE. Axial plane cleavage and lineation cut across the compositional layering of this fold. It appears that such folding and cleavage are prevalent throughout outcrops of Peck Lake gneiss. Often these features are obscured by poorly developed compositional banding. Polishing and staining reveal both folds and cleavage in many specimens and, therefore, suggest that their abundance vastly exceeds their recognition.



The entire outcrop is a "large minor" fold. Note the change of dip from one end to the other. The accompanying equal area plot is for poles of foliation in this roadcut and in outcrops directly NE of the road.

The lithologies and structures represented in this cut are typical of the Peck Lake formation. It is the structural complexities that make the Peck Lake formation difficult to work with and subdivide. It is, by far, the least competent unit in the sequence.

STOP B Royal Mt. pyroxene-quartz-plagioclase gneiss

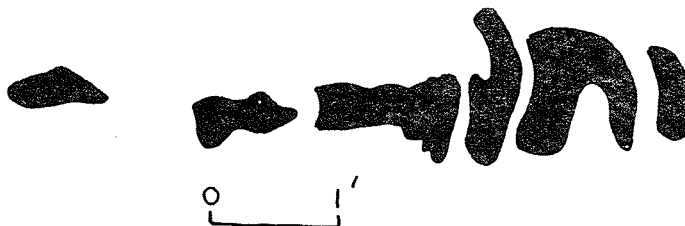
Just to the south of the road are good exposures of the Royal Mt. pyroxene-quartz-plagioclase gneiss. This locality is near the outer contact of the Royal Mt. unit, and the latter displays its fairly well banded border phase. Most of the banding is due to this amphibolites. Also present are bands and veins of granite and/or pegmatite.

STOP B (continued)

These exposures show a number of interesting features. In the first place boudinage is developed in most of the amphibolite bands. Some of the boudinage represents rather classical examples while other instances seem unusual. Consider the example exposed at the base of the large boulder just inside the woods. This is shown in the accompanying diagram.



Another example is displayed in the ledge at the top of the hill.



Neither of these features replicates the conventional concept of boudinage. Indeed, they give the appearance of igneous disruption. However, the igneous hypothesis is superfluous for these outcrops contain a good many examples of bona fide boudinage which coexist with, and are part of the systems shown above. Furthermore, the igneous hypothesis lacks merit based on the lack of disruption of some extremely thin amphibolite bands. Of course, the country rock may have been near, or at, temperatures of partial fusion. It seems more plausible that cases of peculiar looking boudinage may be of the "chocolate tablet" type (Ramsey, "Folding and Fracturing of Rocks", p. 113). This suggestion gains credence from the observation that some boudins appear to lack extension into a third dimension. In addition to this, some examples of boudinaged folds are present (Ramsey, ibid, fig. 3-59, p. 116). Still another type of boudinage results from systematic offset along shears:



In most cases the shear fractures are barely visible in the country rock. This implies that the quartz-plagioclase gneiss was in a mobile state at the time of shearing.

At the north end of the outcrop, an example of an F_1 recumbent fold is observed. The fold axis trends N40 - 50W and plunges gently south. A set of drag folds is developed on the F_1 fold.

STOP C Contact between Canada Lake and Irving Pond formations

To the south of the road are several small ledges of Canada Lake charnockitic gneisses and associated quartzo-feldspathic rocks. These exhibit the typical pinkish color of weathered outcrops in the woods. Fresh surfaces are generally dark in color.

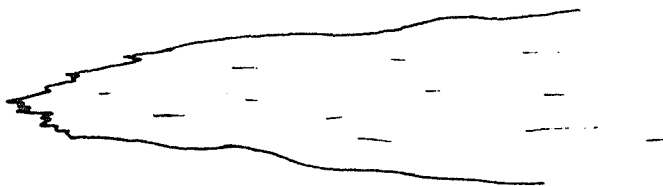
Proceed north along the old logging road to the north of the paved highway. At the intersection of it with a second logging road (grass covered) enter the woods. Here there are a number of small outcrops of quartzites and quartzo-feldspathic gneisses of the Irving Pond fm.. The contact between the two formations runs approximately along the paved road.

Immediately to the south of the small cliffs discussed above are quartzites and leucogneisses of the Green Lake formation.

STOP D Irving Pond fm. at the Core of Canada Lake Nappe

Parking area on west side of road. On the east side of the road, there is an old logging road that goes east for about $\frac{1}{4}$ mile. This road has been marked with tin can tops nailed to trees. At the eastern end of the road there is a tin can top with a square dug out around it. Upon seeing this mark, turn right and proceed directly up the hill.

(1) About 50' up on the hillside there occur good exposures of Irving Pond quartzite and feldspathic quartzite. Interbedded with these are layers of calc-silicate granulites. In this outcrop the pyroxenitic layers are particularly marked. The largest band of calc-silicate runs about 2' above ground level. It strongly resembles a fold (see figure below). However, the feature is a boudin. This contention is supported by the fact that what appear to be drag folds at, and near, the nose of the pyroxenitic layer, have an orientation



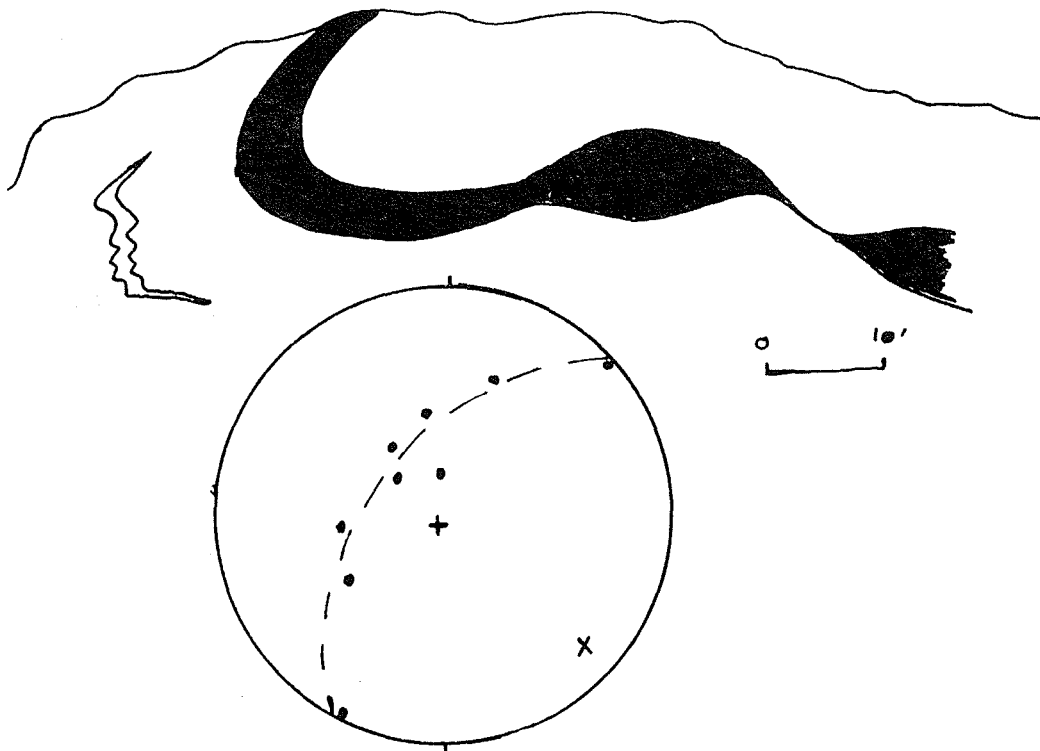
of N20E, 15 S, whereas tight minor folds in the outcrop trend N60W, 15 SE. The lineation trends approximately N60W, 15 S. It is possible

STOP D (continued)

to argue that this shows only that the pyroxenite represents a fortuitously F_0 fold. However, the evidence inveighs against this. At other places on the hillside there are features which are definitely pyroxenite boudins. The axes of these boudins trend NS to N20E and plunge down dip southward. A half a day on this hill provides strong evidence that what appear to be tight folds cored by pyroxenites are really elongate boudins.

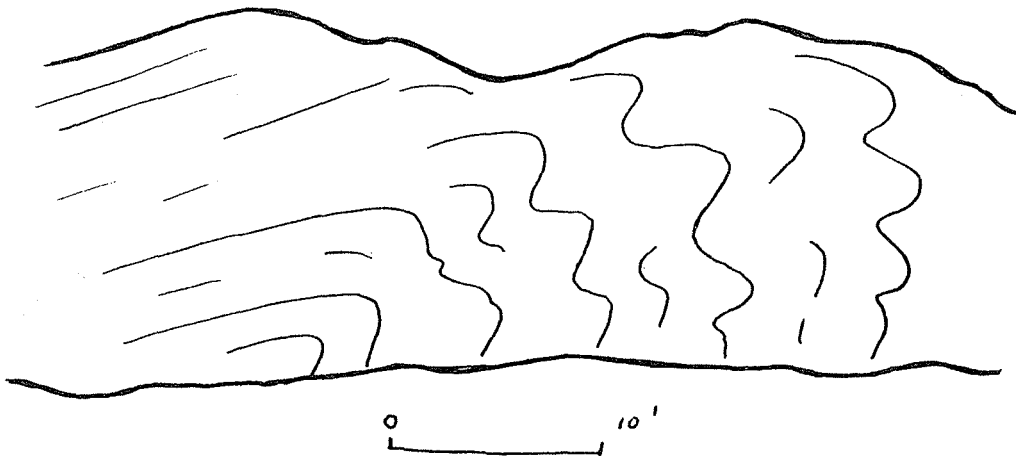
(2) Proceed on up the hillside. Several minor folds are exposed. These have axes that range from EW to N30W. All Plunge gently ($10^\circ - 15^\circ$) to the south. All have axial planes within the plane of the foliation.

(3) Follow the trail markers to a well exposed EW ledge. Here there is exposed both boudinage and F_1 folding, marked by a large layer of calc-silicate. A sketch of these features is given below, and an equal area projection of the poles to foliation is also given.



(4) Exposed in the cliff face are several excellent boudins of pyroxenitic granulite. The boudin axes trend N20E and plunge 10 S. Note the marked similarity between these boudins and the feature at station 1.

(5) Proceed down the hill and over a 20' cliff. In the cliff face one can see a portion of a large fold. Vertical dips trend N40W. Presumably these dips are associated with an F_1 fold.



(6) Follow the marked trail to a small ledge where two F_1 folds are exposed. These are typical examples of F_1 folding. Because of weathering, one can easily measure the axes as N50W, 20S.

Just a few feet farther on is station (1). For those not desiring to make the above hike, there are good exposures of the Irving Pond formation a short distance northward along 29A-10. These show the gradation from pure quartzite into garnitiferous quartzofeldspathic gneisses near the contact with charnockitic gneisses of the Canada Lake formation. This is the same contact seen at STOP C and at STOP J. Note the excellent development of minor folds with drag folds.

STOP E Canada Lake fm.

Large roadcuts in the Canada Lake formation expose typical examples of the charnockitic (mesoperthite gneisses) that comprise this thick and competent unit.

The rocks exposed here are good representatives of Adirondack "syenites" and "quartz-syenites". Not only is this genetic nomenclature misleading, but it is locally incorrect since the present rocks contain some 25-30% modal quartz (most of which is highly strung out).

Compositional layering is not particularly well developed in the Canada Lake charnockites and this observation is consistent with their proposed metavolcanic origin.

STOP E (continued)

Orthopyroxene is locally developed in the roadcuts.

Note the difference in appearance of fresh and weathered surfaces. Also note the strong resemblance of the charnockitic gneisses to the pyroxene-quartz-plagioclase gneisses of the Royal Mt. unit. It is often necessary to employ staining in order to properly distinguish these two lithologies. In stained specimens a hand lens examination often reveals the perthitic nature of the feldspars.

STOP F Royal Mt. gneiss on north limb of F₁

Across from the Canada Lake Store and Post Office, there is a large ledge of Royal Mt. pyroxene quartz-plagioclase gneiss. As at STOP C, these gneisses tend to be homogeneous except for bands of amphibolite. Unlike STOP C, the evidence here favors igneous disruption of the amphibolite bands. The most satisfactory way of explaining the features seen at road level is by partial fusion of the pyroxene-quartz-plagioclase host rock.

STOP G Green Lake fm.

Proceed east along the road between Green Lake (N) and Canada Lake (S). Looking north, note the rugged mountain known as Camelhump. The break between the two humps marks the contact between the Royal Mt. quartz-plagioclase gneiss and the quartz-biotite-oligoclase gneisses of the 29A formation. Green Lake itself straddles the contact between the Royal Mt. gneiss and a narrow band of Green Lake quartzites. Rising above the east shore of Green Lake is a steep hillside of Canada Lake charnockitic gneiss.

At the east end of Green Lake, enter the woods and observe a well exposed section of Green Lake quartzites. Proceeding up the hillside, note the well exposed contact between the microperthite gneiss and the quartzites.

Near the base of the hillside is a well exposed F₁ minor fold whose axial elements are clearly developed on the weathered quartzite band. This fold has an axial trend of N40W, 10 S. Farther up the hillside, folds in the charnockite have axial trends N50E, 10 S, etc.. It is believed that these aberrant orientations are due to the influence of a small metagabbro intrusion that defines the peak of Green Lake Mountain.

STOP H Rooster Hill metacrystic gneiss

On either side of the road, new roadcuts provide good examples of fresh and weathered surfaces of Rooster Hill megacrystic gneiss. The megacrysts consist of K-feldspar which occurs most generally as microperthite; however, orthoclase (cryptoperthite?) and microcline are also present. Microcline is best developed where shearing is most intense. Plagioclase is restricted to the groundmass where it

occurs as single crystals and as mortar aggregates. Compositionally, the plagioclase ranges around calcic oligoclase. Quartz content ranges from 20-30%. This latter parameter places the rock out of the syenite or quartz-syenite clan to which others have assigned it (Cannon, Miller, & Nelson). Mafics include biotite, hornblende, and orthopyroxene (variable occurrence). Garnet is developed locally. Myrmekite is common. The rock can be assigned a position in the charnockite family.

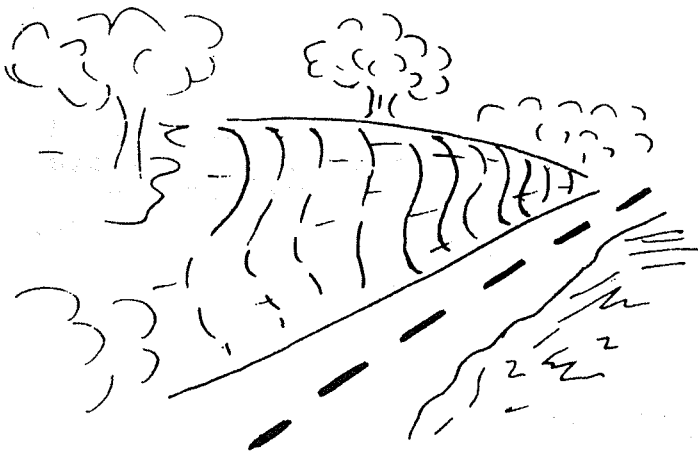
An interesting feature is the variable appearance of the gneiss on fresh and on weathered surfaces. Furthermore, the color of the megacrysts may be either dark green, pink, or white.

Throughout most of its occurrence, the megacrystic unit remains relatively homogeneous and unbanded. Foliation is usually defined by planes of fracture and mineral flattening and orientation. Locally, banding increases where bands of Peck Lake gneiss occur. This is especially true near the outer contacts. Banding also occurs in the interior, but it is rare.

STOP I Peck Lake fm. on north limb of F₁

Large roadcuts of biotite-quartz-oligoclase gneiss of the 29A formation. A cursory examination shows that these gneisses are lithologically identical to those seen at stop B. Note the leucocratic character of the apparently anatectic material. Also note the garnets in some of it.

Beginning at the east end of the outcrop, the dips change in a fashion that indicate a recumbent Z-shaped fold whose axis trends N70W and which plunges gently (5°) to the east. Of particular interest is the degree to which lineation and rodding are developed in the outcrop. On some surfaces the foliation is almost obliterated and the texture approaches that of a pencil gneiss. Good examples of F₁ minor folds are present.



Sketch showing
Z shaped fold
(sinistral fold).

STOP J Northern Contact of Irving Pond and Canada Lake fms.

Stewart's Landing. Along the shores of Sprite Creek are exposures of Irving Pond quartzites and feldspathic quartzites. In this area quartzo-feldspathic and pelitic layers increase in abundance because of proximity to the contact with the Canada Lake formation charnockitic gneisses. More typical of the Irving Pond unit are the white and rose quartzites in the side of the stream bank. West of the bridge, the percentage of quartzite increases markedly.

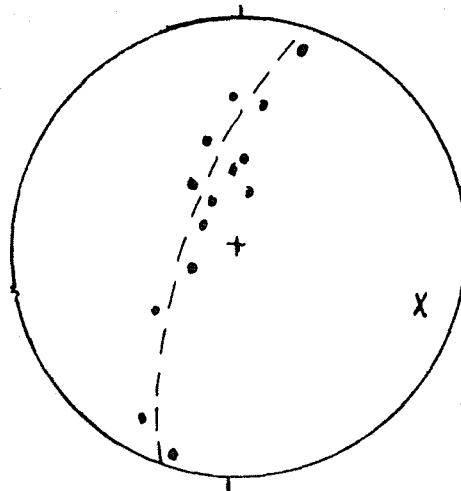
Just below the dam, there is a beautifully exposed Z-fold. This fold is rather open, and is thought to represent a minor F_2 fold. Drag folds in the outcrop reflect the major fold orientation. Note the development of axial plane cleavage in the fold.

On the west shore just above the dam, clean quartzites contact garnetiferous and biotite rich layers that occur near the outer contacts of the Irving Pond formation. This contact is exposed alongside the dirt road heading uphill. This exposure demonstrates the variable response of different competencies to a given force field.

STOP K F_1 folded by F_2 . Axial region of F_2

In Sprite Creek below highway bridge. Exposed along the creek are boulders and outcrops of Canada Lake microperthite and charnockitic gneisses. The dark layers are pyroblitic. Both ortho and clinopyroxene occur in the charnockites.

The point of major interest at this stop is the excellent exposure of F_1 folds folded along F_2 axes. Note the presence of shear slippage along one of the F_2 axes. Note also that the F_1 and F_2 axes appear to be parallel to subparallel. Lineation is strongly developed.



Paleontological Problems of the Hamilton Group

(Middle Devonian)

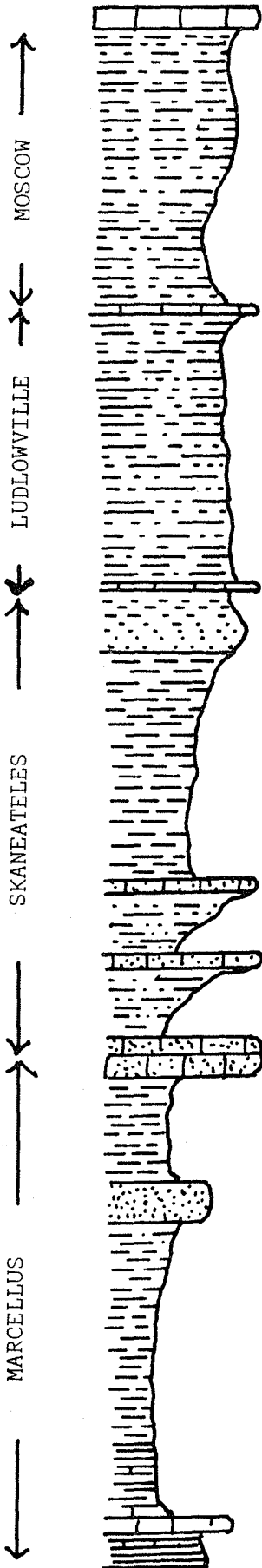
H.B. Rollins, N. Eldridge, R.M. Linsley

The stratigraphy of the Hamilton Group of the Middle Devonian of New York State was most recently treated in its entirety by Cooper (1930, 1957). The Hamilton Group of the Chenango Valley (see chart 1) consists primarily of fine clastic sediments and occupies a mid position in this wedge shaped body of rock. In the east the wedge is thickest (about 1,680' in Schoharie Valley (Gruban, 1903, p. 213) and it thins to 285' at Lake Erie in the west (Cooper, 1930, p. 121). In the Chenango Valley the Hamilton Group is 1,465' thick (op. cit. p. 121) and has a dip to the southwest of 65-75 feet per mile (op. cit. p. 119). The Hamilton Group lies unconformably on the Onondaga Limestone and is overlain unconformably by the Tully Formation.

In a very crude sense the Hamilton Group of the Chenango Valley is composed of fine-grained black shales and limestones at the base (the Marcellus Formation) and more clastic units in the upper portion (Skaneateles, Ludlowville and Moscow Formations). However within each of these formations there exists considerable variation from true mud shales through siltstones and up to fine-grained sandstones. The nature of the substrate obviously had a great effect on the faunas associated with them. The black shales are typically associated with a Leiorhynchus fauna, gray shales and siltstones with a Tropidoleptus fauna and the fine-grained sandstones are dominated by bivalves.

A more detailed discussion of some of these problems will follow in sections relating to each of the three stops of this trip.

HAMILTON GROUP



TULLY formation 22'

WINDOM member 260'

PORTLAND POINT member 5'

LUDLOWVILLE undivided 260'

STONE MILL member 1½' - 3'
CHENANGO member 60'

BUTTERNUT member 220 - 235'

POMPEY member 74'

DELPHI STATION member 80'

MOTTVILLE member 45 - 50'
PECKSPORT member 100 - 153'

SOLSVILLE member 45 - 50'

BRIDGEWATER member 195'

CHITTENANGO member 90'

CHERRY VALLEY member 3'
UNION SPRINGS member 25'

(Cardiff member)

Notes on the Paleontology of the Solsville near Morrisville, New York*

Harold B. Rollins

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Location

Borrow pit on east side of Swamp Road, 2.6 miles north of Morrisville, New York. Morrisville, N.Y. 7 1/2' quad.

Stratigraphy

This small borrow pit exposes an extremely fossiliferous section within the Lower Cazenovian Solsville member of the Marcellus Formation. The only detailed stratigraphic study of Hamilton rocks in the Chenango Valley is that of Cooper (1930), who recognized six members of the Marcellus Formation. In ascending order, these are the Union Springs limestone and shale, the Cherry Valley limestone, the Chittenango black shale, the Bridgewater shale, the Solsville calcareous shale and sandstone, and the Pecksport shales and siltstones. Cooper also noted that the Bridgewater, Solsville and Pecksport undergo a facies change to the west of the Chenango Valley and are there collectively represented by the dark gray Cardiff shale. A detailed study of this facies complex has never been undertaken. This locality is situated beyond the western extremity of the Solsville as delimited by Cooper (1930). Some of the faunal elements are, however, distinctively Solsville, again according to Cooper. These include Nephriticeras maximum, Paracyclas lirata, Gosselettia triquetra, and Cornellites flabellum. It was primarily on the basis of this faunal assemblage that Rollins, Eldridge and Spiller (1971) considered this exposure to be in the Solsville facies.

*Scientific Contribution No. DEPS-72-231

Fig. 1 presents a very generalized stratigraphic section of the Solsville at this locality. Note the indicated layers of fossil shell concentrations.

Paleontology

This locality has, in the last few years, contributed much to our knowledge of the paleontology of the Hamilton Group. Preservation of the fossils at this locality is perhaps unsurpassed anywhere in the Middle Devonian of New York State. For example, the molluscan shell microstructures are still preserved. Even ghost structures of originally aragonitic shell material can be discerned under thin section and polished-etched slab examination (Rollins, Eldredge and Spiller, 1971). If you carefully examine shell fragments of the large bivalve Gosselettia triquetra, you can see with the naked eye preservation of coarse prismatic shell layers. Naturally etched surfaces of Cornellites flabellum quite often also display coarse shell microstructure.

This exposure has also provided the earliest occurrence of preservation of the body of a tubicolous spionid polychaete worm (Cameron, 1967). The worm was interpreted as commensal with the bivalve Cornellites flabellum (Hall). Shell borings of this polychaete are also common in specimens of Spinocyrtia granulosa, Gosselettia triquetra, etc., especially in the upper terrace of the exposure. Apparently, only the epifaunal organisms were colonized by this polychaete. The worm tubes are not found on the infaunal bivalves, such as the nuculids. A coaction, perhaps commensal, is indicated, rather than post-mortem colonization of the host shells by the worms.

Critical stages in the evolution and dispersion of the trilobites Phacops iowensis and Phacops rana were preserved in this small exposure, as discussed by Eldredge (1972, and elsewhere in this guidebook).

Also found at this locality is one of the best preserved and most diverse molluscan faunas in the Hamilton rocks of Central New York State. To date, only the gastropods and monoplacophorans have been studied in detail (Rollins, Eldredge and Spiller, 1971). The pleurotomariacean Bembexia sulcomarginata

(Conrad) is very abundant, and can be found throughout the entire exposed section. Spiller (unpublished ms, 1971), following factor analysis of populations of B. sulcomarginata, has determined that this species exhibits sexual dimorphism.

Excellent specimens of Ruedemannia trilix (Hall), another pleurotomariacean, can be obtained from the upper terrace of this exposure. Ruedemannia is considered ancestral to the very common and well-known Worthenia of the Upper Paleozoic.

The lower dark calcareous shales at this locality have provided most of the available specimens of the unusual bellerophontacean gastropod Praematuratropis ovatus (Rollins, Eldredge and Spiller). This little snail is interesting for at least two reasons. First, it retains throughout ontogeny a very pronounced median keel that would have drastically restricted the available space within the shell and presumably would have made impossible total retraction of the cephalopodal mass. This, in conjunction with an extensive inductura, suggests that this gastropod had an internal shell. Secondly, Praematuratropis ovatus is one of the few Hamilton forms "missed" by the great James Hall in his monographic treatment of the Paleontology of New York.

Near the top of the exposure can be found slabs of a highly weathered calcareous siltstone which contains beautifully preserved molds, largely molluscs. The greatest diversity of gastropod species was recognized from this thin interval. Diligent collecting should provide you with a rare specimen of the monoplacophoran Cyrtionella mitella (Hall), complete with internal mold, preserving the muscle scars. A complete tabulation of the gastropods found to date at this exposure is included in the accompanying faunal list.

It should not be assumed that the paleontological potential of this little borrow pit in the Solsville has been exhausted. The beautifully preserved bivalve fauna has not yet been carefully studied, for example. Also of interest is the occurrence of epizooites. If you look closely at some of the brachiopods and molluscs you collect, you will see epizoic bryozoa, corals, and inarticulate brachiopods, besides the aforementioned worm borings. Gastropod-bryozoan symbiosis is present from the Paleozoic to the Recent, and is very obvious at this locality.

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- Cooper, G.A., 1930, Stratigraphy of the Hamilton Group of New York: Parts 1 and 2. Amer. Jour. Sci., v. 19, p. 116-135, 214-236.
- Eldredge, N., 1972, Systematics and evolution of Phacops rana (Green, 1832) and Phacops iowensis Delo, 1935 (Trilobita) from the Middle Devonian of North America. Bull. Amer. Mus. Nat. Hist., v. 147, p. 45-114.
- Rollins, H.B., Eldredge, N. and Spiller, J., 1971, Gastropoda and Monoplacophora of the Solsville Member (Middle Devonian, Marcellus Formation) in the Chenango Valley, New York State. Bull. Amer. Mus. Nat. Hist., v. 144, p. 129-170.

Locality: Solsville mb., Marcellus Formation borrow pit on east side of Swamp Rd., 2.6 miles north of Morrisville, N.Y. Morrisville, N.Y. 7 1/2' quadrangle

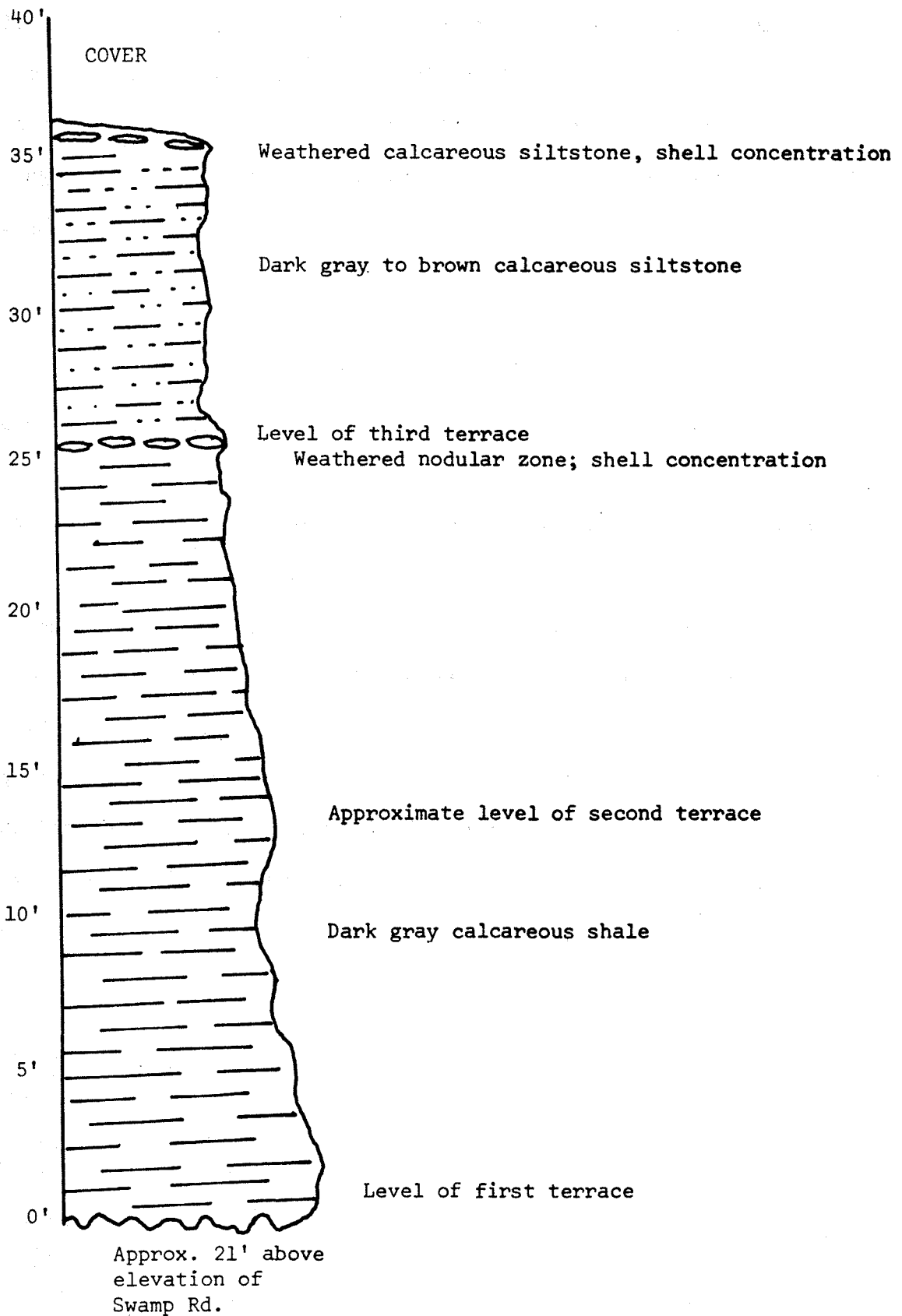


Figure 1

Partial Faunal List
 Peterborough South Quarry
 Solsville Member, Marcellus Formation
 Hamilton Group

Coelenterata

Conularia undulata

Bryozoa

Paleschara incrustansHederella filiformisMonotrypella abruptusReptaria stoloniferaTaeniopora exiguaAulopora sp.

Brachiopoda

Orbiculoidea mediaLingula deliaCupularostrum congregataMucrospirifer mucronatusSpinocyrtia granulosaAmbocoelia umbonataChonetes scitulusSpinulicosta spinulicostaRhipidomella penelopeMediospirifer audaculusProtoleptostrophia perplanaTropidoleptus carinatus

Mollusca Bivalvia

Grammysioidea alveataGrammysia arcuataG. bisulcataG. circularisG. obsoletaNucula lirataNuculites oblongatusNuculites oblongatusN. cuneaformisCornellites flabellusGosselettia triquetraModiomorpha mytiloidesM. concentricaM. subulatorParacyclas lirataGoniophora hamiltonensisLeptodesma spinigerum

Cephalopoda

Tornoceras discoideumMichelinoceras constrictumBactrites aciculumSpyroceras crotalum

Gastropoda

Bembexia sulcomarginataGlyptotomaria (Dictyotomaria) capillariaGyronema lirata?Holopea hebeMourlonia subzonaMurchisonia miculaNaticopsis sp.Palaeozygopleura hamiltoniaePatellilabia (Phragmosphaera) lyraPlatyceras (Platyceras) erectumPlatyceras (Platyostoma) sp.Praematuratropis ovatusPtomatis rudisRetispira ledaRuedemannia trilixSinuitina brevilineatusTreospira (?Angyomphalus) peneglabraTritonephon rotalineae

Monoplacophora

Cyrtoneilla mitella

Arthropoda

Phacops ranaGreenops boothiEchinocaris sp.

Echinodermata

Ancyrocrinus spinosus

Stop 2 "Pierceville" Quarry (Bradley Brook Quarry)
Paleoecology of the Ludlowville Formation, Hamilton Group

By R. M. Linsley

This quarry exhibits three distinctive facies of the Ludlowville Formation. The lowest unit (the Chonetes facies) is exposed in the front ledge of the quarry nearest Soule Road and consists of about fifteen feet of dark gray shale with small amounts of silt. Faunally this unit is dominated by brachiopods, and the total faunal content will be discussed more fully later. Lying on top of this unit is a thin (six inch) calcareous shale unit (the Spinocyrtia facies). This unit is exposed in a very low ledge about twenty feet back from the front face of the quarry. It consists of densely packed brachiopods (Spinocyrtia, Athyris and Mucrospirifer). Calcite from the shells of these animals has permeated the surrounding sediment and transformed what was probably a fairly soft shale into a durable, hardened calcareous shale. The uppermost unit (the bivalve facies) is exposed in the upper quarry floor and the back wall of the quarry. This unit is a fine grained siltstone and the fauna is dominated by a wide variety of epifaunal and infaunal bivalves.

THE CHONETES FACIES

In 1968 the Paleoecology class of Colgate University, (Austin Belschner, Regis Dandar, Hermann Karl, James Lydic and Robert Marengo) under the direction of R. M. Linsley and J. P. Swinchatt studied the lowest unit (the Chonetes facies) of this quarry. Bulk samples were broken down and a faunal tabulation was made. (See accompanying Table). Obviously the brachiopod Chonetes dominates this fauna to a very remarkable degree. (An interesting note on this is that the total assemblage was tabulated in three separate lots of about 1,000 individuals in each lot. The percentage of Chonetes in each of these lots was 76.98%, 76.23% and 76.48%. I have no explanation for the fantastic consistency in these counts.) The Chonetes are concentrated in layers throughout this lower unit and locally can form thin coquinas. In between these thin Chonetes

TABLE 1

Table of Faunal Analysis of the Chonetes Facies of the Pierceville Quarry

<u>Genus</u>	<u>Number of Individuals</u>	<u>% of Total Sample</u>
<u>Chonetes</u>	2491	76.55
<u>Nucula</u>	156	4.79
<u>Ambocoelia</u>	135	4.15
<u>Mucrospirifer</u>	90	2.77
<u>Nuculites</u>	43	1.32
<u>Grammysia</u>	24	0.74
<u>Ruedemannia</u>	24	0.74
<u>Devonochonetes</u>	22	0.68
<u>Orbiculoidea</u>	18	0.55
<u>Actinodesma</u>	15	0.46
<u>Greenops</u>	15	0.46
<u>Phacops</u>	12	0.37
<u>Palaeoneilo</u>	12	0.37
<u>Protoleptostrophia</u>	12	0.37
<u>Hyolithes</u>	11	0.34
<u>Rhipidomella</u>	11	0.34
<u>Tornoceras</u>	9	0.28
<u>Palaeozygopleura</u>	9	0.28
Bellerophontid	8	0.25
<u>Taeniopora</u>	7	0.22
Wood fragments	7	0.22
<u>Goniophora</u>	6	0.18
<u>Lingula</u>	6	0.18
<u>Spyroceras</u>	6	0.18
<u>Dipleura</u>	5	0.15
all others	<u>101</u>	3.10
Total	3255	

coquinas the fauna consists primarily of the brachiopods Mucrospirifer, Ambocoelia, Chonetes and Devonochonetes, the infaunal, palp-feeding, bivalves Nucula and Nuculites, the filter feeding bivalves Grammysia and Actinodesma and the grazing gastropods Ruedemannia and Palaeozygopleura.

However, the most notable feature of this lower unit is the variable distribution of the brachiopod Chonetes. Four bedding surfaces will be discussed to illustrate the kinds of distribution that have been noted. For ease of discussion these will be called 1. "cluster", 2. "strip", 3. "storm" and 4. "normal."

In order to interpret the significance of these blocks we must make some assumptions regarding the life positions of some of these animals and the hydrodynamics of their dead shells in the presence of waves or currents. I assume that the living position of Chonetes is concave side up (brachial valve up) so that the plane of commissure is held up away from the fine sediment of the substrate. Hydrodynamically this is not a stable position for the shell. Any current tends to move the shell and frequently flips it over. From this fact alone I suggest that the depth of water for the deposition of these beds was below normal wave base, i.e. with depths in excess of eight fathoms.

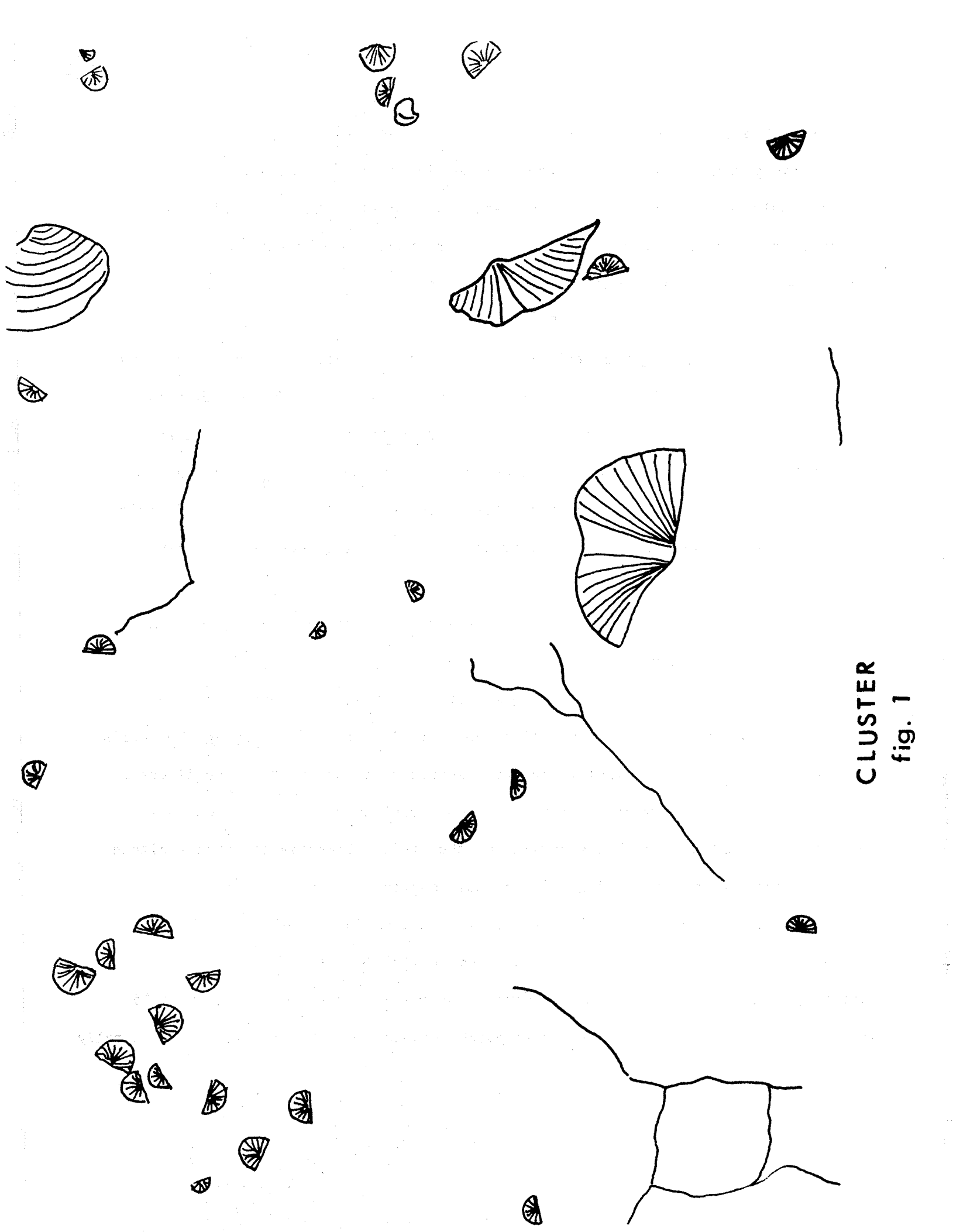
In flume experiments conducted on Chonetes the shells tended to flip over so that the concave (brachial) valve was down and to orient themselves with the hinge line perpendicular to the current. Because of the near-symmetrical cross-section of the shell from anterior to posterior, there is not much distinction in the direction that the shell faces relative to the current. Most frequently the beak points into the current, but it is only a slightly statistical advantage over the 180° rotated position. In experiments with wave action the chonetids tended to align themselves with the hinge line at a 45° to 90° angle to the wave front, although there was a great deal of variation in these results.

Similar experiments with Mucrospirifer gave much more consistent results than did those with Chonetes. I assume that Mucrospirifer was attached by the pedicle to the substrate with the plane of commissure perpendicular to the sea floor. Therefore it makes little sense to talk about pedicle or brachial valve up as the normal living position. In current experiments there was a decided tendency for these shells to come to rest with the sulcus down and the interarea parallel to the current direction. In wave experiments these shells act as rollers and align with the interarea perpendicular to the wave front, but no particular directional orientation.

As a result of these experiments it is theoretically possible to distinguish between current and wave oriented shell deposits. In current orientation the interareas of Mucrospirifer and Chonetes should tend to be at right angles to each other, while wave orientation should cause them to have parallel alignments.

THE CLUSTER BLOCK

The cluster block is relatively typical of the bedding planes in between the storm layers. Figure 1 shows a portion of this block with one of the clusters in the upper left corner. On the original block there were three such clusters. Within the clusters the ratio of upright to overturned shells is seven to forty-seven, whereas in the central (non-clustered) portion of the block the ratio is eleven to twenty one. From this I conclude that these clusters are not normal living "nests" of brachiopods, but are accumulations of dead shells. A size frequency distribution graph for the entire block shows a bell shaped distribution curve which supports this conclusion. A rose diagram showing orientation shows some preferential orientation in a N-W, S-E direction. In summation, the cluster block shows the effects of current orientation, but because of the lack of sufficient numbers of Mucrospirifer it is impossible to differentiate between waves and unidirectional currents. The fact that the



CLUSTER
fig. 1

clusters exhibit more evidence of current action than the central area suggests that possibly there were other factors influencing this distribution. The results would be similar if the central area had a plant cover which diminished the current action in these areas. The clusters then could be attributed to current swept barren areas within the plant cover.

THE STRIP

The block containing the strip is a rather unusual block in that it contains a two inch wide strip of shells down the center of the block. These strips can be seen at various levels throughout the lower Chonetes facies of this quarry. Some of them have been seen to reach lengths of six or seven feet, although most of them have lengths of one or two feet. Unfortunately it is very difficult to trace these because of the difficulty of stripping these rocks along a given bedding plane.

The shells of Chonetes found within the strip were predominately overturned (93 overturned to 23 upright) whereas in the areas adjacent to the strip the number of upright and overturned was equal (12 overturned to 12 upright). Once again this suggests current as an active agent within the strip, tipping the shells over, but somehow not affecting those areas surrounding the strip. Rose diagrams of shell orientation show very strong alignment trending NE - SW with less well demarked alignment of the shells outside of the strip. Likewise the shells within the strip are predominately larger individuals suggesting that the current which aligned the shells also winnowed out the smaller individuals.

As in the cluster block, vegetational cover would explain the relatively undisturbed appearance of the larger portion of the block, while the strip would be consistently interpreted as a barren patch between current dampened (vegetationally covered?) areas.



STRIP

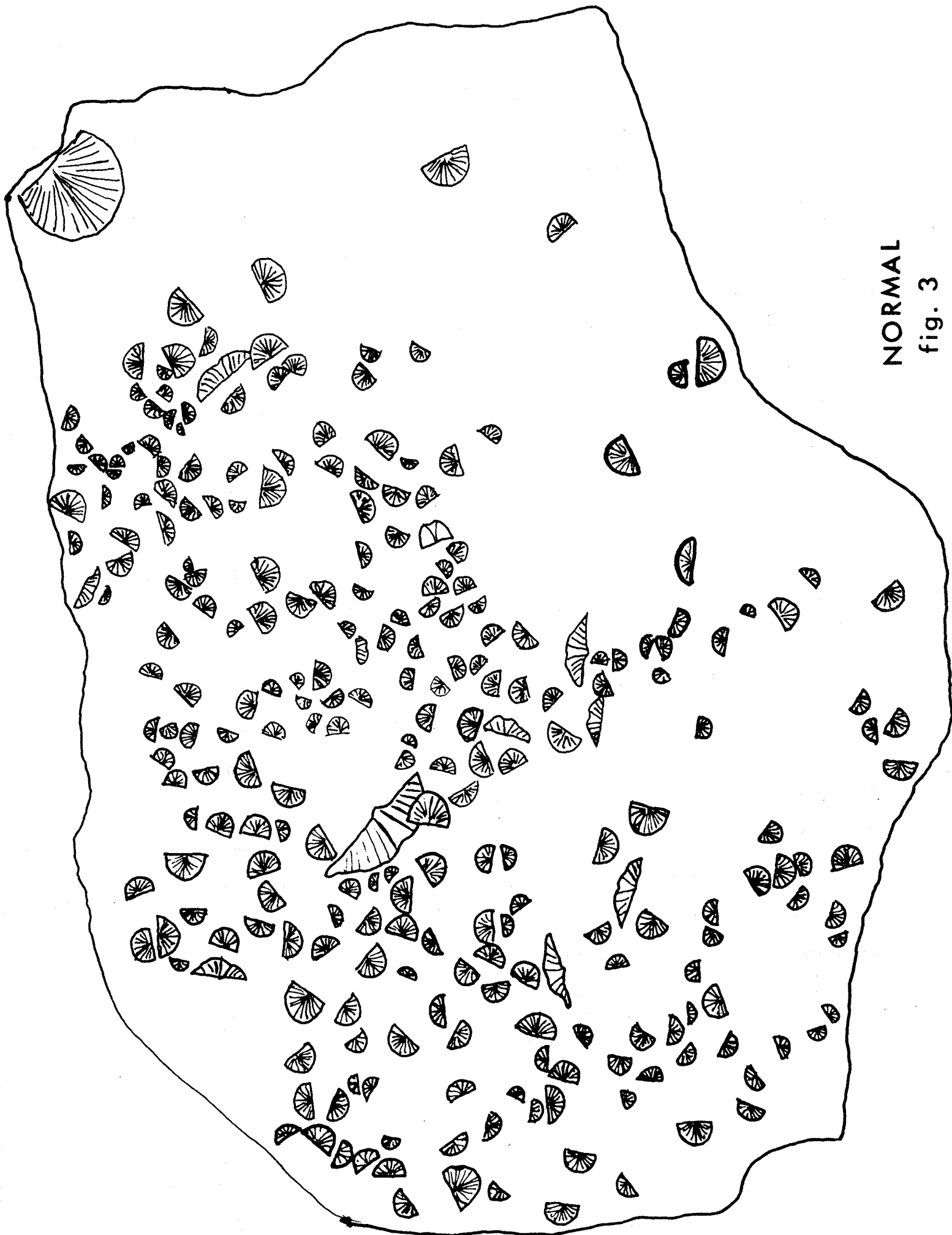
THE STORM BLOCK

Both the Storm Block and normal block have similar outward appearances and although figure 3 is actually a diagram of the normal block it greatly resembles the storm block as well. Throughout the Chonetes facies these units consisting of thin pavements of Chonetes can be found every one or two inches. Many of these layers can be traced along the entire quarry face, a matter of one or two hundred feet.

The ratio of overturned to upright shells in the storm layer is 66 to 16. This strong preponderance of overturned shells suggests that the area was strongly current swept. In this block were found enough specimens of Mucrospirifer so that orientation rose diagrams could be constructed for both Mucrospirifer and Chonetes. Both diagrams show strong preferential orientation with the axis of Mucrospirifer at right angles to that of Chonetes. According to our flume experiments this would indicate orientation by currents rather than by wave action. This is further substantiated by the size frequency diagram which indicates that most of the small specimens have been winnowed out and primarily large specimens are left.

THE NORMAL BLOCK

The final block that was studied was collected with the presumption that it was another example of a storm layer. However subsequent analysis of the block showed it to be quite different indeed. To begin with on this block the number of upright specimens greatly outnumbered those that were overturned (170 to 66) which certainly suggests that this particular bedding surface was relatively unaffected by any major currents. The orientation rose diagram for this block showed more or less random orientation of both Chonetes and Mucrospirifer. Finally the size distribution plot is definitely bimodal and the block has far more small individuals than any of the others.



NORMAL
fig. 3

It thus seems obvious that this block had a considerably different history from the others. The bimodal size distribution of Chonetes strongly suggests that this is an example of an instantaneous census of a catastrophic mass mortality. Most of the sample consists of small individuals (3mm to 6mm along the hinge line). Small individuals of this size range are quite rare on all of the other blocks. There is also a fairly large population ranging from 7-10 mm with a gap between these two populations. It seems obvious that Chonetes was a seasonal breeder (perhaps annually) and that the population consists of adults plus young that were growing up. This entire population was then killed more or less instantly preserving these ratios. Yet this mass mortality was accomplished without disturbing the living position of our sample, probably by a period of rapid sedimentation. This thesis suggests that this bedding plane was exposed for a considerable period of time (perhaps more than one year) and yet was covered with relative suddenness, perhaps by the influx of sediments caused by a major storm.

Thus the environment of deposition for the Chonetes facies of this quarry is interpreted to be a quiet current swept sea bottom with periodic periods of rapid sedimentation. The presence of Lingula would suggest water no deeper than thirty feet, but the apparent lack of wave orientation of shells suggests that the sea floor was below average wave base, i.e. deeper than fifty feet. Yet within this layer we have indirect evidence that these sediments were deposited within the photic zone. This is suggested by the areas on blocks where the current was dampened (by beds of algae?) and also by the abundance of Phacops and Greenops. It seems improbable that trilobites with eyes as well developed as those two genera would live below the photic zone. I thus conclude that the water depths for these beds were between fifty and one hundred feet.

THE SPINOCYRTIA FACIES

The Spinocyrtia facies is a thin calcareous shale overlying the Chonetes facies. It is characterized by closely packed clusters of brachiopods, particularly Spinocyrtia granulosa, Athyris spiriferoides and Mucrospirifer mucronatus. The development of this layer is attributed to a long period of very slow deposition which has allowed the development of crowding by successive spat falls. This layer seems distinctly different from the brachiopod nests that have been developed in western New York (Beerbower, 1971), in that they seem to cover very broad areas. However this bed has not been treated in any detail and I hesitate to make any elaborate conjectures in the absence of any detailed studies. The hardened calcified nature of this layer I believe to be attributable to the migration of calcite from the brachiopod shells into the surrounding sediment as a post depositional event.

THE BIVALVE FACIES

The sediment of the upper facies is a good siltstone perhaps even grading into a fine sandstone. Presumably this represents a shallower water regime, although no sedimentological studies have been carried out on this unit as yet. Faunally this unit is dominated by bivalves with Grammysia, Modiomorpha, Palaeoneilo and various pectinoids as the most noticeable elements. In general the individual members of this fauna are markedly larger than those of the Chonetes facies. Chonetes is replaced in abundance by Spinocyrtia, Greenops by Dipleura, Nucula by Grammysia etc. Another aspect of this unit is the abundant burrows of Taonurus attesting to the thorough reworking of this sediment after deposition.

I would expect this unit to have been deposited in water above wave-base (less than fifty feet) so that the substrate was frequently current swept creating a shifting substrate. This would account for the replacement of the small sessile brachiopods by the more mobile molluscs. Further elaboration of the paleoenvironments will have to await an analysis of the sedimentological and paleontological features of this unit.

Partial Faunal List

Pierceville Quarry

Ludlowville Formation, Hamilton Group

Coelenterata

Aulopora elleri

Favosites sp.

Bryozoa

Sulcoretepora incisurata

Brachiopoda

Petrocrania hamiltoniae

Lingula punctata

Lindstroemella aspidum

Oehlertella pleurites

Mucrospirifer mucronatus

Spinocyrtia granulosa

Mediospirifer audaculus

Ambocoelia umbonata

Athyris spiriferoides

Tropidoleptus carinatus

Rhipidomella penelope

Protoleptostrophia perplana

Devonochonetes coronatus

Longispina mucronatus

Devonchonetes syrtalis

Chonetes vicinus

Spinulicosta spinulicosta

Cyrtina hamiltonensis

Elytha fimbriata

Mollusca - Bivalvia

Solemya vetusta

Orthonota undulata

Grammysia bisulcata

G. arcuata

G. cuneata

G. globosa

Bivalvia (cont)

Nucula corbuliformis
N. opima
N. lirata
Nuculites oblongata
N. triqueter
Palaeoneilo constricta
P. emarinata
P. fecunda
P. muta
P. plana
Parallelodon hamiltoniae
Actinoptera decussata
A. boydi
Cornellites flabellus
Leiopteria sayi
L. rafinesquii
Aviculopecten fasciculatus
Lyrnopecten macrodontus
Pterinopecten undosus
Modiomorpha cencentrica
M. mytiloides
Pholadella radiata
Cypricardella tenuistriata
Cimitaria recurva
Goniphora hamiltonensis

Gastropoda

Ptomatis rudis
Naticonema lineata
Palaeozygopleura hamiltoniae
Ruedemannia trilix
Platyceras sp.
Dictyotomaria capillaria

Cephalopoda

Tornoceras discoidea
"Orthoceras" sp.
Spyroceras crotalum

Hyolithida

Hyolithes neapolis

Tentaculitida

Styliolina sp.

Arthropoda

Greenops boothiPhacops ranaDipleura dekayiEchinocaris punctataRhinocaris columbina

Annelida

Taonurus

Plants

Protolepidodendron sp.

Notes on the Trilobites of the Hamilton Group of the Chenango Valley Region

Niles Eldredge

The American Museum of Natural History

There are but three trilobite species commonly occurring in the Hamilton Group in the Chenango Valley region: Phacops rana (Green, 1832), Greenops boothi (Green, 1837), and Dipleura dekayi (Green, 1832). As indicated, these three species were among the first trilobites to be described in North America, and with the possible exception of Elrathia kingii (Meek) from the Middle Cambrian Wheeler shale of Utah, one of these -- Phacops rana -- has come to be perhaps the most familiar of all trilobites of this continent.

All presumably valid trilobite species of the Hamilton Group of New York are listed in Table 1. A comparable list for the midwest is given by Stumm (1953). Hall and Clarke (1888) remains the most complete and indispensable source of information on the morphology of these trilobites. Of the remaining species not mentioned above, only the proetid Dechenella rowi (Green, 1838) is likely to be encountered in the Chenango Valley area, especially in the Stone Mill limestone exposed in the quarry along Roberts Road in West Eaton. This and other remaining taxa will be discussed only insofar as they bear on the biogeography and provenance of the Hamilton fauna.

BIOSTRATIGRAPHY: Dipleura dekayi, Phacops rana, and Greenops boothi occur nearly throughout the Hamilton Group; P. rana and G. boothi also occur in the younger Taghanic Tully limestone. Though not yet documented in the Taghanic of New York, D. dekayi has been reported from the Taghanic Thunder Bay limestone of northeastern Michigan (Stumm, 1953).

The oldest rocks bearing Hamilton trilobites in the Chenango Valley region are exposed in the Peterborough South quarry and have been assigned to the Solsville Member of the Marcellus Formation (Rollins, Eldredge, and Spiller, 1971). Phacops rana crassituberculata and Greenops boothi constitute

rare elements of the fauna of the dark shales at the base of the quarry.

Phacops becomes more common in the calcareous siltstone nodule fauna higher in the quarry.

The distribution of the three major species in the Skaneateles Formation seems to be facies controlled. The Mottville, Delphi Station, and Pompey Members rarely produce Phacops rana. Occasional specimens of P. rana rana are found, but this species does not become abundant until the Butternut Member. In contrast, Dipleura dekayi and Greenops boothi are locally abundant in the various members of the Skaneateles Formation; D. dekayi is particularly common in the sandy upper beds of both the Delphi Station and Pompey Members. A quarry in the Colgate sandstone on the campus of Colgate University has produced a large number of small D. dekayi reported by Cooper (1935). Greenops boothi is found in both the lower shales and upper sandy beds of these members.

All three species occur in fair numbers in the Ludlowville and Moscow Formations of this region, associated with a well developed Tropidoleptus fauna. P. rana rana and Greenops boothi are common in the Stone Mill limestone and overlying Panther Mountain Member of the Ludlowville Formation. Particularly fine, frequently complete specimens of G. boothi are abundant in some exposures of the Panther Mountain Member. Dipleura dekayi is less common, and when found in sediments of the Upper Hamilton Group, is usually associated with Greenops and Phacops in the Moscow Formation.

In sum, P. rana only occurs with the Tropidoleptus fauna in the Chenango Valley region; it becomes even more abundant in the calcareous shales and limestones in western New York and the cratonal interior. Greenops boothi and Dipleura dekayi occur both in the normal Tropidoleptus fauna and in coarser clastics associated with epifaunal bivalves, large bellerophonacean gastropods, and the rhynchonellid Camarotoechia. Greenops boothi, like P. rana, also occurs in the western facies, but becomes far less common than P. rana except in certain units (e.g. Deep Run Member of the Ludlowville Formation near Avon,

New York; Centerfield Member of the Ludlowville Formation at Blossom, N.Y.; Widder Formation near Ardonia, Ontario). Dipleura dekayi becomes rare in Hamilton rocks west of the vicinity of Pompey, New York.

BIOGEOGRAPHY: There seems to be at least two separate sources for the Hamilton trilobite fauna. A distorted view of the problem arises if only the three common species are considered, since it is highly unlikely that any of them were derived from older North American species. There are species of Otarion, Cordania (Mystrocephala), and Dechenella in Gedinnian, Siegenian, Emsian, and Eifelian rocks which may (or may not) be closely related to those from the Hamilton Group. I have not studied these trilobites in detail, however, and there is as yet little evidence on which to determine the provenance of the Hamilton species of these genera. It seems likely, however, that at least some of these species are in fact closely related to older species, particularly those of the Onondaga limestone.

This is emphatically not the case for P. rana, G. boothi, and D. dekayi. Of these three -- the most common elements of the Hamilton trilobite fauna -- the first two are definitely, and the third probably, derived from Old World Province Eifelian species. Phacops rana, as suggested by Hall and Clarke (1888, p. 24) is the sister species of Phacops schlotheimi (Bronn) of the Eifelian of Germany, and is unrelated in any meaningful way to the "native North American" Phacops lineage which includes, among others, P. logani, P. cristata, and P. iowensis (Eldredge, 1972). In addition, P. rana occurs in the Eifelian of the Spanish Sahara (Burton and Eldredge, in press). Greenops boothi is the sole described North American representative of the Asteropyginae, a subfamily of dalmanitids of the Lower, Middle, and Upper Devonian of Europe and Africa. It is therefore clearly a migrant to the Appalachian faunal province. Early reports of Greenops in Eifelian North American rocks are in error (Stumm, 1954); however, P. J. Lespérance (pers. comm.) has recently collected an asteropyginid in the Lower Devonian of the Gaspé Peninsula.

There are few Emsian (Esopus, not Schoharie) and no Eifelian homalonotids in North America. The Lower Devonian Trimerus vanuxemi (Hall) is clearly related to the Silurian Trimerus delphinocephalus (Green), but seems quite different from Depleura dekayi. Valid species of Dipleura do occur, however, in the Eifelian of Europe and South America, and it seems likely, although by no means proven, that D. dekayi was also derived from a stock living outside the Appalachian faunal province. Thus the most conspicuous trilobites -- both in terms of size and numbers -- seem to be migrants which, to some extent at least, were able to supplant native North American taxa which might have occupied comparable niches in the Middle Devonian.

VARIATION AND PHYLOGENY IN PHACOPS RANA: Specimens of P. rana from various quarries in the Chenango Valley region figured prominently in a recent study of this species (Eldredge, 1972). I recognize five subspecies of P. rana, of which P. rana crassituberculata Stumm and P. rana rana occur in the Hamilton Group of New York; P. rana norwoodensis (Stumm) is found in the Tully Formation. These subspecies are distinguished by a variety of ornamental features, and especially by the number of vertical columns of lenses (dorsoventral files) in the eye. Nearly all population samples of P. rana show no variation in number of dorsoventral files. P. rana crassituberculata, for instance, always has 18 dorsoventral files wherever it occurs over the cratonal interior (e.g. Silver Creek limestone of Indiana; Silica shale of Ohio; lower Arkona shale of Ontario). All P. rana of Cazenovian age (Marcellus and Skaneateles Formations and their correlatives) over the cratonal interior have 18 dorsoventral files (both P. rana crassituberculata and P. rana milleri (Stewart)); there is one exception). There is no intergradation ever seen between the 18 dorsoventral file forms and the 17 dorsoventral file form P. rana rana, which first appears in the midwest in correlatives of the basal Tioughniogan Centerfield limestone.

The sole exception to this generalization occurs in the Peterborough quarry, where a variable population sample has been amassed. Some specimens have the full 18 dorsoventral files, while others show only a partial development of the 18th file: still others have but 17 files. Above the Solsville, all P. rana of the Hamilton Group have 17 dorsoventral files and are referred to P. rana rana. Thus P. rana rana occurred in the exogeosynclinal sea during Upper Cazenovian time, while its more plesiomorphic relatives persisted throughout this interval in the epeiric seas to the west. A more extended discussion of the evolutionary significance of this pattern -- and of a second, similar pattern in sediments of Taghanic age -- is given in Eldredge (1971), and the study is more fully documented in Eldredge, 1972.

The Peterborough quarry has also produced a single cephalon of Phacops iowensis alpenensis (Stumm). This specimen, along with a single pygidium of this species from the Frame Member of the Mahantango Formation in southern Pennsylvania, constitutes the only known sample of P. iowensis east of Arkona, Ontario. This occurrence is of further interest since P. rana and P. iowensis are almost never found in even the same formation. A discussion of the interactions between these two species can be found in Eldredge (1972).

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Table 1

Distribution of trilobites in the Hamilton Group of the Chenango Valley region. The fifth column refers to occurrences known outside of the immediate vicinity of the Chenango Valley.

TAXON	MARCELLUS	SKANEATELES	LUDDLLOWVILLE	MOSCOW	HAMILTON GROUP
<u>Phacops rana crassituberculata</u>	X				X
<u>Phacops rana rana</u>		X	X	X	X
<u>Phacops iowensis alpenensis</u>	X				X
<u>Greenops boothi</u>	X	X	X	X	X
<u>Dipleura dekayi</u>		X	X	X	X
<u>Dechenella rowi</u>			X		X
<u>Dechenella macrocephala</u>					X
<u>Otarion craspedota</u>					X
<u>Cordania gemmaea</u>					X

Partial Faunal List

Deep Spring Quarry

Moscow Formation, Hamilton Group

Bryozoa

StictoporaReptaria stolonifera

Brachiopoda

Lingula punctataRhipidomella penelopeTropidoleptus carinatusCupularostrum congregataDevonochonetes coronatusAtrypa "reticularis"Ambocoelia umbonataElytha fimbriataMucrospirifer mucronatusSpinocyrtia granulosaAthyris spiriferoides

Bivalvia

Grammysioidea alveataGrammysia arcuataG. bisulcataG. ellipticaG. cuneataG. globosaG. lirataG. constrictaOrthonota undulataTellinopsis submarginataParallellodon hamiltoniaePalaeoneilo mutaNucula corbuliformisN. opimaN. bellistriataN. lirataNuculites oblongatusProthyris lanceolataCornellites flabellusAviculopecten fasciculatusActinoptera decussataA. boydiPterinopecten undosusLeiopteria rafinesquiiGlyptodesma erectumModiomorpha concentricaM. mytiloidesGoniophora rugosaCypricardella bellistriataParacyclas ellipticaSphenotus truncatus

Gastropoda

Mourlonia lucina

Dictyotomaria capillaria

Platyceras sp.

Nautiloidea

Spyroceras crotalum

Paradiceras

Hyalolithida

Hyalithes ligea

Arthropoda

Phacops rana

Greenops boothi

Dipleura dekayi

Echinocaris punctata

Plants

Protolepidodendron sp.

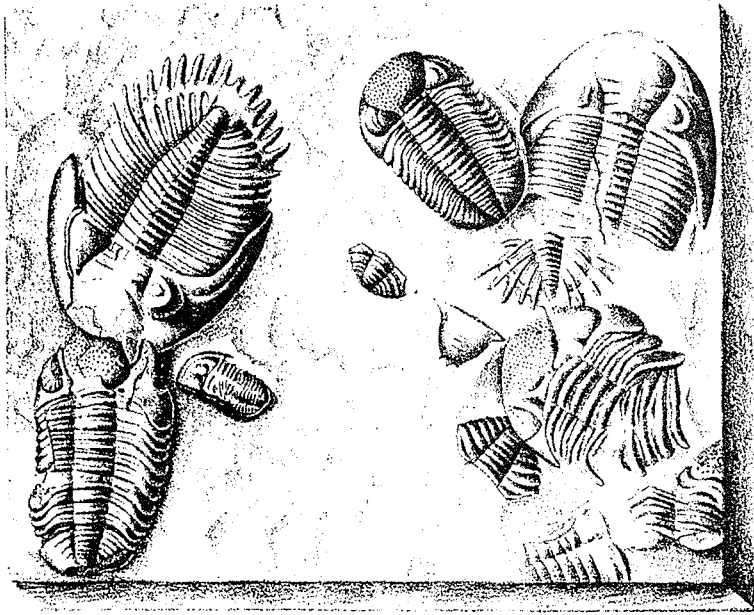
TRIP F ROAD LOG

Cumulative Mileage	Miles since last point	
0.0	0.0	Begin trip at traffic light in Hamilton, New York (junction of Broad Street and Payne Street. Head North on N.Y. 12B
0.6	0.6	Hamilton village limits
0.9	0.3	Road climbs up onto Kame terrace
1.7	0.8	Outcrop of Pecksport Shale Member, Hamilton Group, on right
1.9	0.2	Road forks. Take left fork, N.Y. 46
2.8	0.9	Junction with N.Y. 26. Continue straight on N.Y. 46
3.2	0.4	Junction with U.S. 20. Turn left (west)
3.5	0.3	Continue on U.S. 20, taking left fork
6.4	2.9	Morrisville village limits.
7.0	0.6	Turn right (North) at second light onto Cedar Street
9.1	2.1	Stop #1. Solsville Member, Marcellus Formation, Hamilton Group
		Turn around and return to Morrisville
11.2	2.1	Junction with U.S. 20. Turn left, then immediate right (South) onto Eaton Street.
12.4	1.2	Turn right at junction
14.2	1.8	Enter village of West Eaton. Turn left on N.Y.26.
14.9	0.7	Enter village of Pierceville. Turn right onto Bradley Brook Road
16.5	1.6	Bradley Brook Reservoir on right. Continue straight
17.1	0.6	Turn right on Soule Road
17.2	0.1	Park on shoulder
		Stop #2. Ludlowville Formation, Hamilton Group
		Turn around and return to Bradley Brook Road
17.3	0.1	Turn right on Bradley Brook Road
19.9	2.6	Enter village of Lebanon. Turn left
20.6	0.7	Take right fork (Reservoir Road)
21.5	0.9	Turn right onto Deep Spring Road
22.6	1.1	Park on shoulder. Outcrop on the right is Stop #3. Moscow Formation, Hamilton Group
		Turn around and return to Reservoir Road

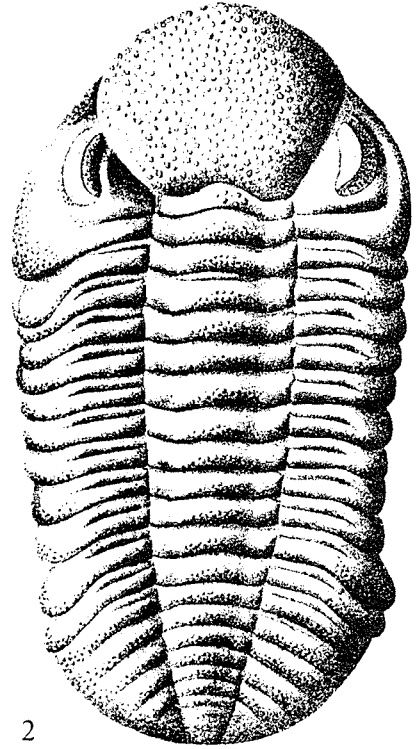
Cumulative Mileage	Miles since last point	
23.7	1.1	Turn right on Reservoir Road
25.0	1.3	Turn right at junction
26.0	1.0	Cross River Road. Continue straight on Nower Road
26.6	0.6	Junction with N.Y. 12B. Turn left
31.9	5.3	Stoplight at Hamilton

End of log

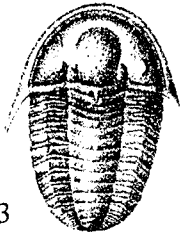
COMMON HAMILTON TRILOBITES



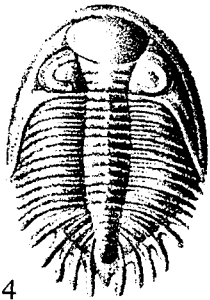
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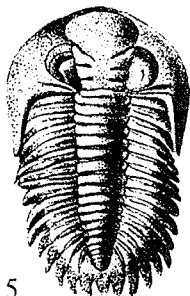
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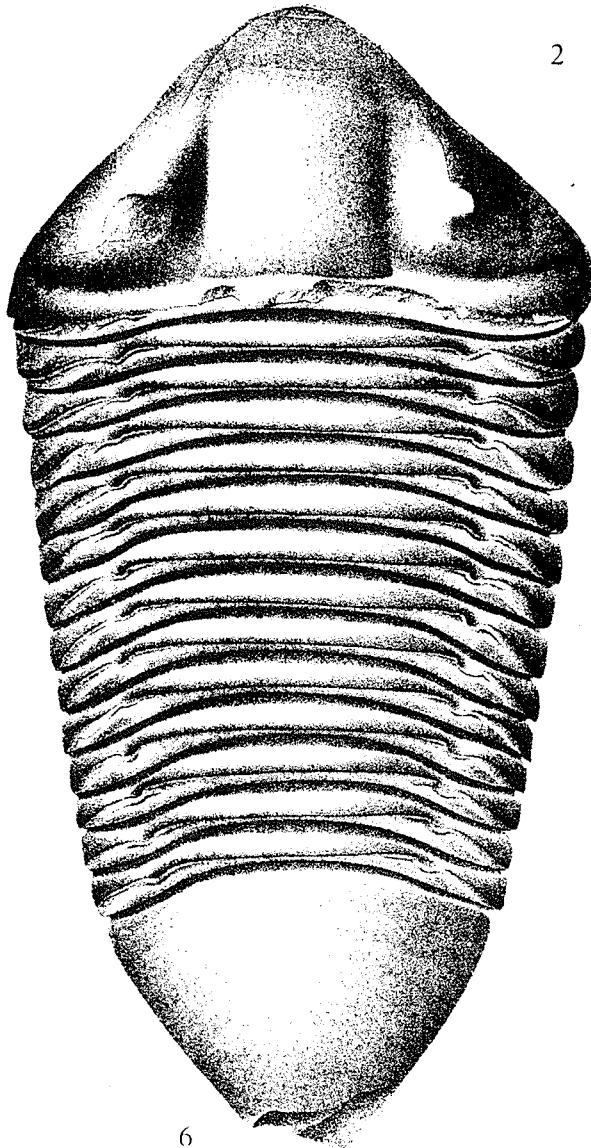
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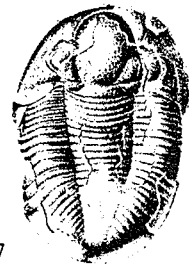
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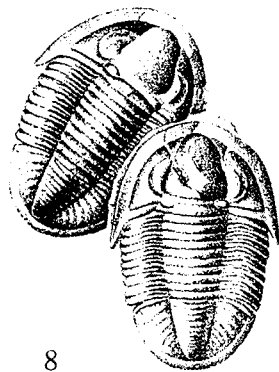
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PALEOECOLOGY OF A BLACK LIMESTONE,
CHERRY VALLEY LIMESTONE, DEVONIAN, NEW YORK STATE

John Cottrell
University of Rochester

The Cherry Valley Limestone is documented in the literature as early as 1842 when Vanuxem referred to the "Goniatites" or "Agoniatites Limestone" of the Marcellus Formation in his publication of Geology of New York: Third Geologic District. In 1903, Clarke proposed the name of Cherry Valley Limestone for the "Agoniatites Limestone"; named for the excellent exposure in Cox's Ravine just south of the village of Cherry Valley. This section was presumed to be typical of the Marcellus Formation throughout western New York.

The Cherry Valley Limestone is known to extend for 160 miles across central New York from its westernmost outcrop in Flint Creek near Phelps, Ontario County to the easternmost outcrop in Onesquethaw Creek near Clarksville, Albany County. The Cherry Valley overlies the Union Springs Member of the Marcellus Formation and is capped by the Chittenango Shale Member. To the east the Cherry Valley grades into the Stoney Hollow Sandstone and to the west joins with the upper beds of the Onondaga Limestone.

Perhaps the Cherry Valley is best known for its unique assemblage of cephalopods as documented by Flower (1936). Previous work has been done mainly by Clarke (1901), Grabau (1906),

Cooper (1930,1933), Smith (1935), Flower (1936,1943), and Rickard (1952),

The previous environmental interpretations of the Cherry Valley Limestone as a product of a highly reducing environment are untenable due to the presence of an abundant benthonic fauna in most parts of the unit. At the type section, the Cherry Valley is four feet thick and consists of a thin basal black limestone with numerous small brachiopods and abundant cephalopods, a middle nodular unit of interbedded micrites and silty shales, and an upper black limestone with abundant brachiopods, ostracodes, and cephalopods. Thin zones containing the coral Aulopora separate the lower and upper limestone units from the central nodular unit. In the easternmost outcrops, these zones with Aulopora thicken and comprise most of the Cherry Valley.

To the west, the Cherry Valley undergoes a series of faunal and lithologic changes, thinning to less than half the thickness of the type section. The basal limestone grades into a brown to black micrite with a fauna dominated by trilobites and brachiopods; cephalopods are absent. Shales disappear from the middle unit which thins and is characterized by a fauna of Aulopora and brachiopods. The uppermost unit exhibits an abundant gastropod fauna at some localities and in the westernmost section is characterized by corals and brachiopods. As in the east, the coral facies expands and comprises most of the Cherry Valley.

The Cherry Valley apparently reflects deposition in shallow, calm waters, affected by cyclic variation in delivery of clastics possibly combined with sea level fluctuation. Circulation and

oxygenation were effective enough to support an abundant and relatively diverse benthonic fauna.

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ROAD GUIDE FOR CHERRY VALLEY FIELD TRIP.

STARTING POINT: Holiday Inn, Downtown Utica

<u>MILAGE</u>	<u>DIRECTIONS</u>
0.0	East on Genesee Street to Route 5S.
0.6	Turn right on Route 5S East.
11.2	Bear right, continue on 5S East.
11.5	Ilion, New York
12.3	Go straight ahead at the light, off of 5S East and onto Main Street, Ilion, New York.
14.5	Turn right on Route 51 South
23.9	Turn left on Route 20 East.
31.9	Richfield Springs, New York
35.4	Warren, New York
38.3	Intersection Route 80.
40.7	East Springfield, New York
47.9	Turn right at sign for Mohawk Campsites 300 yards before TeePee; bear right at Y.
48.1	STOP #1: The Cherry Valley Limestone outcrops for several hundred feet along the roadside and is one of the most extensive outcrops available for study. This location was chosen as the type section for the study conducted during the summer of 1968. The contact between the Cherry Valley and the Union Springs member below is gradational over a distance of 0.2 feet. The lowermost portion of the Cherry Valley contains abundant brachiopods and ammonoids. It is a medium grained dark gray skeletal limestone separated from the middle beds by a thin zone of <u>Aulopora</u> . The central unit is a nodular bed composed of medium grained limestone interbedded with argillaceous layers. The limestones, up to 0.6 feet thick, are broken into nodules; a case of sedimentary boudinage. The central unit is only slightly fossiliferous. The zone above the central unit is similar to the basal unit in that it contains a thin zone of <u>Aulopora</u> which separates it from the massive bed above. The uppermost unit of the Cherry Valley is a massive medium to coarse grained limestone with abundant orthocone nautiloids and brachiopods. The brachiopods found in the uppermost layers vary from those found in the basal layers. The Cherry Valley is gradational with the shales above which are extremely fossiliferous with brachiopods and bryozoans.

MILEAGEDIRECTIONS

- 48.1 Turn around, return to Route 20.
- 48.3 Turn left onto Route 20 West.
- 51.7 Outcrop of Cherry Valley on the right at the top of the hill.
- 54.9 East Springfield, New York.
- 60.6 Warren, New York.
- 63.4 Richfield Springs, New York.
- 72.8 Turn left onto Gulf Road, 50 yards before Mac's Fruit Stand
- 73.2 STOP #2: The Cherry Valley Limestone has thinned from a thickness of 4.2 feet at the type section to 2.9 feet at this Gulf Road section. Again the Cherry Valley is gradational from the underlying shales and cephalopods and brachiopods are present in the lowermost layers. Here we see the first introduction of trilobites to the Cherry Valley fauna. Fragments of cephalon, thorax, and pygidium can be found in the lower unit. The Aulopora zone at the top of the lower unit is not as well defined, and Aulopora seems to be present within the middle unit only. The middle unit has thinned from 1.9 feet at the type section to 0.8 feet and retains its nodular appearance. A few brachiopods and Aulopora comprise the fauna of the middle unit. The upper unit is gradational from the overlying shales and contains abundant brachiopods and cephalopods. It is a fine to medium grained black limestone with some replacement of shell material with coarse grained rusty calcite. The shales and limestone layers of the Union Springs member below show some evidence of folding.
- 73.2 Turn around, return to Route 20 via Gulf Road.
- 73.6 Turn left onto Route 20 West.
- 75.6 West Winfield, New York.
- 78.9 Bridgewater, New York.
- 86.4 Sangerfield, New York.
- 93.6 Madison, New York.
- 95.6 Bouckville, New York.
- 97.7 Turn right onto Route 46 North.
- 103.2 Turn left onto Pratt Road.
- 103.8 Turn right onto Falls Road.
- 105.5 STOP #3: The Cherry Valley Limestone outcrops for several hundred feet along Falls Road and along the banks of Oneida Creek. The thickness of the section fluctuates between 2.1 and 2.8

feet with the greatest variation being seen in the upper unit. Again trilobites are present in the lower unit and crinoids make their first appearance in the western sections. They appear as single crystals of calcite in the medium grained black limestone of the lower beds. Brachiopods and cephalopods also comprise the fauna of the lower beds. The middle unit is separated from the upper and lower units by irregular surfaces and maintains its nodular appearance. A few brachiopods and Aulopora are the only noticeable fauna. The upper unit consists of a fine to medium grained limestone which grades into the shales above. Cephalopods and brachiopods are abundant.

- 105.5 Turn around, return to Pratt Road via Falls Road.
- 107.2 Turn left onto Pratt Road.
- 107.8 Turn right onto Route 46 South.
- 113.3 Turn right onto Route 20 West.
- 116.4 Morrisville, New York.
- 123.6 Nelson, New York
- 127.3 Cazenovia, New York
- 129.0 Turn right onto Route 92 West.
- 133.7 Oran, New York.
- 136.4 Manlius, New York.
- 136.8 Junction with Route 173, turn left at light.
- 137.0 Go straight ahead at light staying on Route 173.
- 138.9 STOP #4. The final stop on the field trip is perhaps the most picturesque. The Cherry Valley Limestone outcrops in a stream bed approximately 300 yards from the road. Actually two outcrops may be seen at this location as the stream splits and allows for two exposures. The left branch of the creek offers the better section. The lower unit of this section is a fine grained black to brown limestone with a fauna consisting of mainly brachiopods and trilobites. Some evidence of crinoids is seen in single crystals of calcite within the fine grained limestone. The large ammonoids and orthocones are missing from the fossil assemblage. The middle unit consists of a nodular black fine to medium grained limestone with apparent secondary calcite replacement. There are few fossils present and some very thin shaly interbedding. The upper unit consists of a basal bed which closely resembles the middle unit in lithology. It has the nodular appearance of the middle unit yet lacks the shaly interbedding. It has a scattered fauna of brachiopods and corals. The middle layer of the upper unit is the most fossiliferous with abundant brachiopods and cephalopods. Corals and crinoids are present also. The uppermost layer of the Cherry Valley is a dense fine grained black limestone gradational from the shales above. Very few fossils are present.
- 138.9 Turn around, remain on Route 173 to Chittenango.

MILAGEDIRECTIONS

140.0	Manlius, New York.
147.0	Chittenango, New York.
147.4	Junction Route 5 East, bear right onto Route 5 East.
155.8	Wampsville, New York.
159.8	Onieda Castle, New York.
161.0	Sherrill, New York.
164.7	Vernon, New York.
172.6	Kirkland, New York.
176.2	Turn left onto Route 5A East.
177.8	New York Mills, New York.
180.2	Utica, New York.
181.7	Junction Route 5S East, stay on Route 5S East.
182.3	Turn right onto Genesee Street.
182.9	Holiday Inn --- HOME AT LAST!!

SEDIMENTARY ENVIRONMENTS AND BIOSTRATIGRAPHY OF THE TRANSGRESSIVE
EARLY TRENTONIAN SEA (MEDIAL ORDOVICIAN) IN CENTRAL AND NORTHWESTERN
NEW YORK

by

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INTRODUCTION

The fossiliferous marine limestones and shales of the Ordovician Trenton Group of New York has been studied by many paleontologists and stratigraphers for well over 150 years. Along with the underlying Black River Group (fig. 2), it has become well-known among geologists as part of the medial Ordovician standard reference section of North America. However, the geology of the Trenton Group still poses several relatively complex problems of interpretation for the application of stratigraphic, paleontologic, and paleoecologic principles. Specifically, there is still "...confusion and disagreement regarding the correlation of the upper Black River and lowest Trenton in New York and Ontario" (Kay, 1942, p. 599) (see also Fisher, 1962; Textoris, 1968; Cameron, 1969a, 1969b; Walker and Laporte, 1970).

The modern approaches to the paleoecologic study of carbonate rocks, such as sedimentary petrography (Cameron, 1968), fossil community analysis (Porter and Park, 1969; Park and Fisher, 1969, Cameron and Mickevich, 1972), population paleontology (Ross, 1967), primary sedimentary structures (Chenoweth, 1952; Cameron, 1968), have just recently been applied with emphasis to parts of the medial Ordovician Trenton group of central and northwestern New York. Many previous investigators who have studied these formations have been, by necessity, primarily concerned with lithostratigraphy, such as statistical analysis of rock types (especially Chenoweth, 1952, and Lippitt, 1959), biostratigraphy and correlation, and mapping.

Although many faunal lists have been made for the New York sections (e. g., Cameron, 1968; Fisher, 1957; Chenoweth, 1952; Kay, 1953, 1937, 1933), most major fossil groups are in need of thorough restudy, using modern paleontologic approaches and techniques. However, a few groups in New York have received careful attention and revision in recent years. These include the Brachiopoda (Cooper, 1956), Ectoprocta (Ross, 1964, 1967), conodonts (Schopf, 1966), and calcareous algae (Cameron and Awramik, in preparation).

This field trip will illustrate and summarize a detailed time, lithic, and faunal microstratigraphic framework for the lower Trenton Group, i. e., the Rocklandian, Kirkfieldian, and Shorehamian stages, in central and northwestern New York. The limestones of the upper Black River Group beneath the lower Trenton Group will also be examined at several stops. This will then form the basis and provide the confidence for reconstructing the environments of deposition and determining the paleogeography. Special emphasis will be placed on statistical analysis of the rock types both from detailed field measurements and carbonate petrography, small scale physical and biological correlation, primary sedimentary structures, trace fossils, fossilization, and fossil community analysis. This information should better document the initial and subsequent wider transgression of the Trentonian sea.

The specific purposes of this field trip are to:

- 1) Demonstrate the stratigraphic succession and its lateral variations.
- 2) Discuss and evaluate the age relationships and time correlations of the various formations by
 - a) Examining the diverse faunas and
 - b) Demonstrating the lateral continuity of major lithic and biologic characteristics.
- 3) Examine and evaluate the criteria for determining the extent and significance of the disconformity along the Black River-Trenton boundary.
- 4) Examine and evaluate the criteria for determining the conditions and environments of deposition and paleogeography.
- 5) Examine fossilization and reconstruct fossil communities
- 6) Determine temporal and spatial relationships between fossil communities and sedimentary environments in a transgressive sequence.

This field trip guide will summarize previous work on the lower Trenton Group in the Little Falls Port Leyden and surrounding 15' quadrangles and incorporate new data in support of reinterpretations of the stratigraphy and sedimentary environments of the lower Trenton Group in this area. The Little Falls quadrangle is located along the southwestern margin of the Adirondack Mountains and is included in southern Herkimer County. The Port Leyden quadrangle is located in Oneida County north of Boonville, New York, west of the Adirondacks. Good exposures of medial Ordovician limestones are to be found along the Mohawk River, East Canada Creek, West Canada Creek, and Black River valleys and those of their tributaries. Stops for this trip are located in the quadrangles mentioned. Many small abandoned limestone quarries in the Little Falls quadrangle contain excellent exposures of the Black River-Trenton boundary.

REGIONAL GEOLOGIC SETTING

Lower Paleozoic strata dip gently to the west and southwest from the Precambrian rocks of the Adirondacks in this region; subsurface contours drawn on the base of the Black River-Trenton combined indicate a one-half to 2 degree dip regionally (Flagler, 1966, pl. 5). A few northeast-southwest trending normal faults cut Paleozoic and Precambrian rocks, e. g. near Little Falls and Dolgeville (Cushing, 1905a; Kay, 1937).

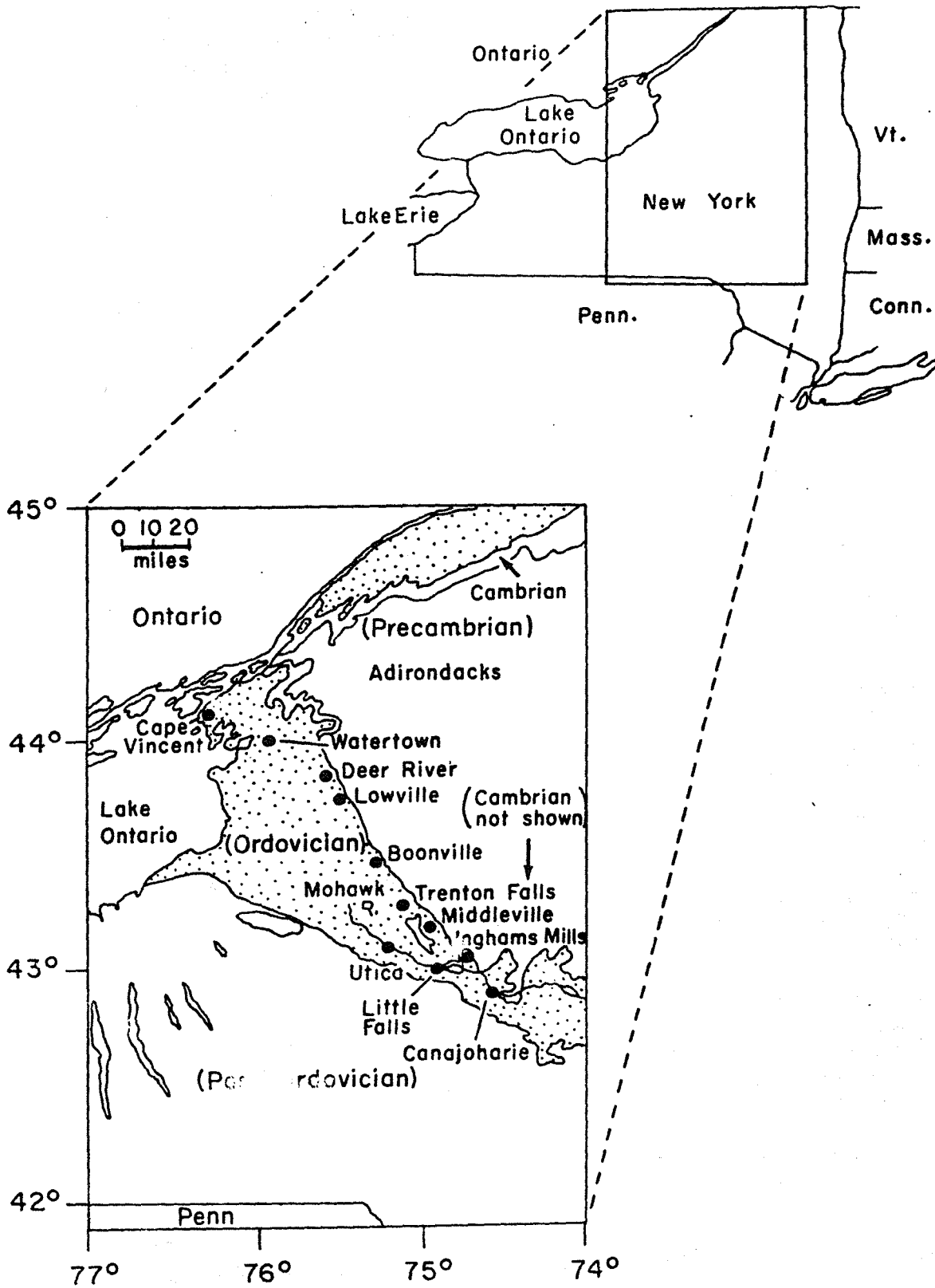


Figure 1. Geologic outline map of study area.

The late Cambrian Little Falls Dolomite underlies Ordovician rocks and overlies the Precambrian basement complex of igneous and metamorphic rocks in southern Little Falls Quadrangle. To the northeast, however, the medial Ordovician Gull River Limestone overlaps the Little Falls Dolomite to lie directly on the Precambrian (Cushing, 1905a, Young, 1943), as it does farther north in Oneida County (Young, 1943, fig. 3).

LOWER TRENTONIAN AND UPPER BOLARIAN STRATIGRAPHY OF CENTRAL NEW YORK

Introduction:

The late Bolarian Black River Group beneath the Trenton Group consists of three formations (Pamelia Formation, Gull River Limestone, and Watertown) which are overlain by the lower Trenton Selby, Napanee, Kings Falls, and Sugar River limestone formations (fig. 2). The Pamelia, Watertown, and Selby formations will not be seen on this field trip. The others are described below in their order of deposition.

The stratigraphic classification used herein (Fig. 2) follows that of Kay (1968b) with modifications for the lower Trenton Group from Cameron (1967, 1968, 1969a, 1969b). A thorough historical review of the early classifications of these limestones can be found in Kay (1937, p. 237-249); for a review of later work, see Cameron (1968, 1969b).

Bolarian Series:

The Gull River Limestone was deposited in supratidal to shallow subtidal marine conditions during the Lowvillian Stage; apparently neither Chaumontian (uppermost Bolarian) (Walker, 1969) nor pre-Lowvillian rocks are present in central New York (Cameron, 1969b). The Bolarian age is indicated by conodonts (Hasan, 1969). The Gull River lies successively on early Ordovician (Canadian) limestones and dolostones along the Mohawk River, on late Cambrian Little Falls Dolomite northward in the Little Falls quadrangle, and on Precambrian along its northwest-trending outcrop belt to the Port Leyden quadrangle (Cushing, 1905a; Young, 1943). The thickness of this formation varies in a southeasterly direction from 54 feet at Lowville, New York, to 30 feet at Inghams Mills (figs. 2 & 3; Stop #1) (Young, 1943; Cameron, 1969b).

The lithology of the Gull River is varied and complex, but it is characterized by light gray weathering, dove gray calcilutite (sublithographic), called "birdseye" limestone by the early geologists in New York State. Granule and flat pebble calcirudites and impure argillaceous calcisiltites are sometimes frequent. Horizontal laminae, fenestral fabric, stylolites, mudcracks (Fig. 5), and burrows are common sedimentary structures. Some of the horizontal laminae originated by current action, but most were probably produced by algal accretion (algal? mats).

Fossils are generally uncommon in the Gull River Limestone (see Young, 1943, for a comprehensive faunal list, and Walker and Laporte, 1970, for a fossil community analysis). The abundant vertical burrow Phytopsis (Fig. 7) and small ostracods occur throughout the Gull River.

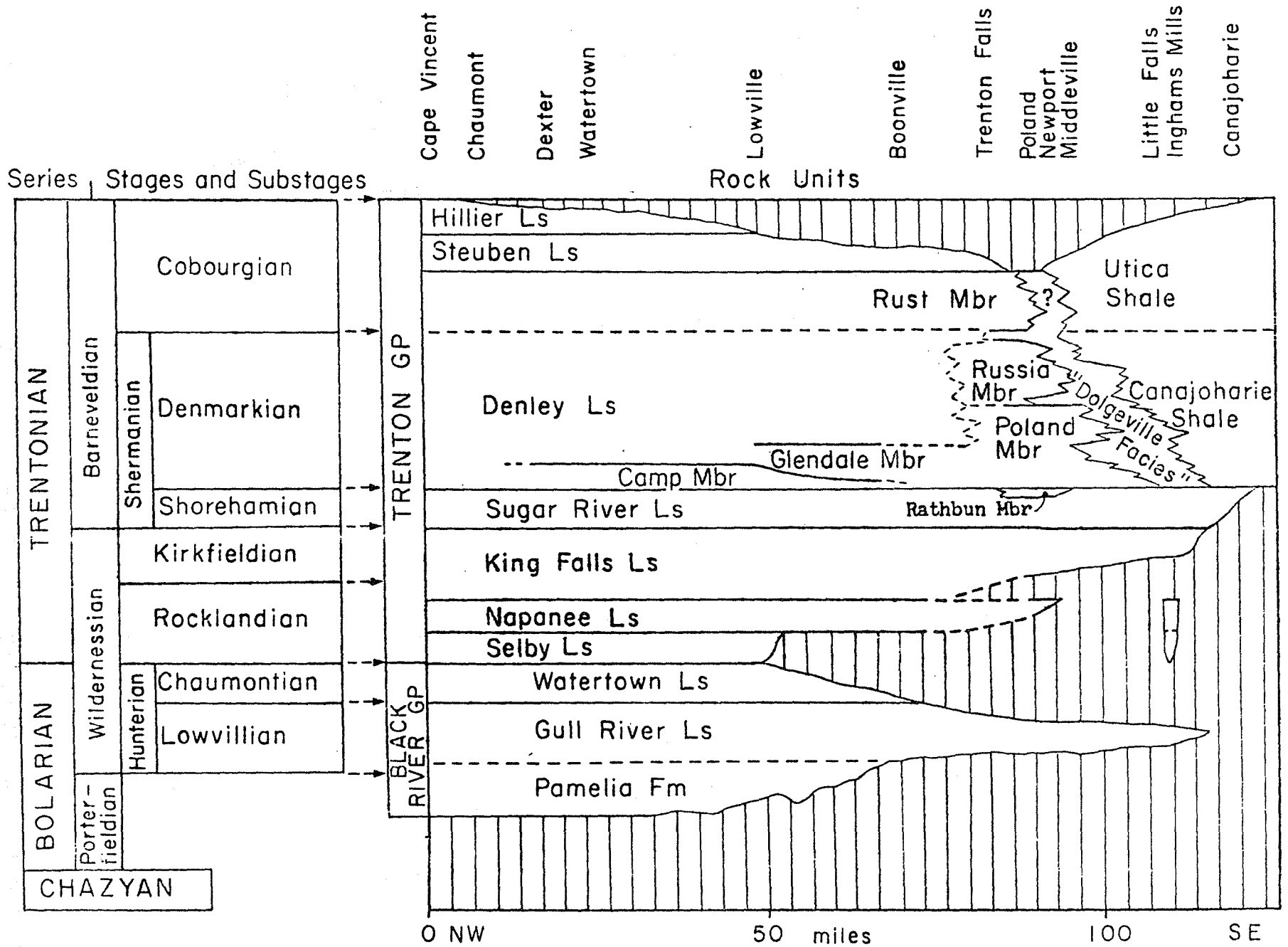


Figure 2. Medial Ordovician stratigraphic classification and nomenclature for central and northwestern New York.

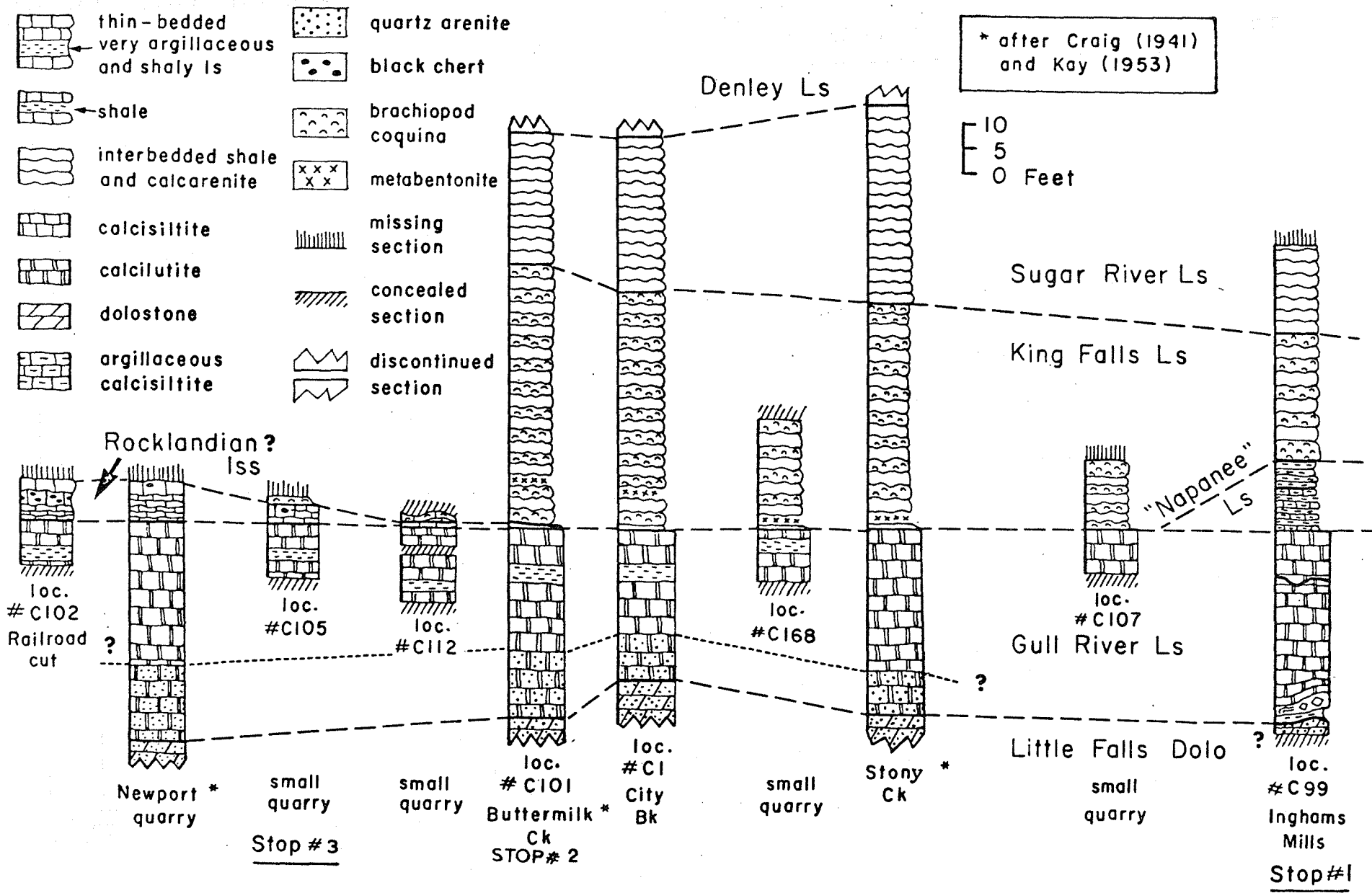


Fig. 3. Measured sections of upper Bolarian and lower Trentonian limestones between Newport and Inghams Mills, New York.

Top #1. Inghams Mills

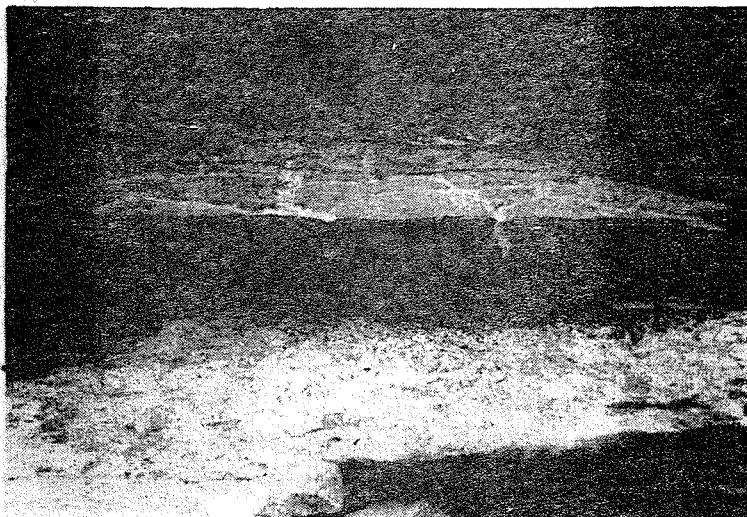
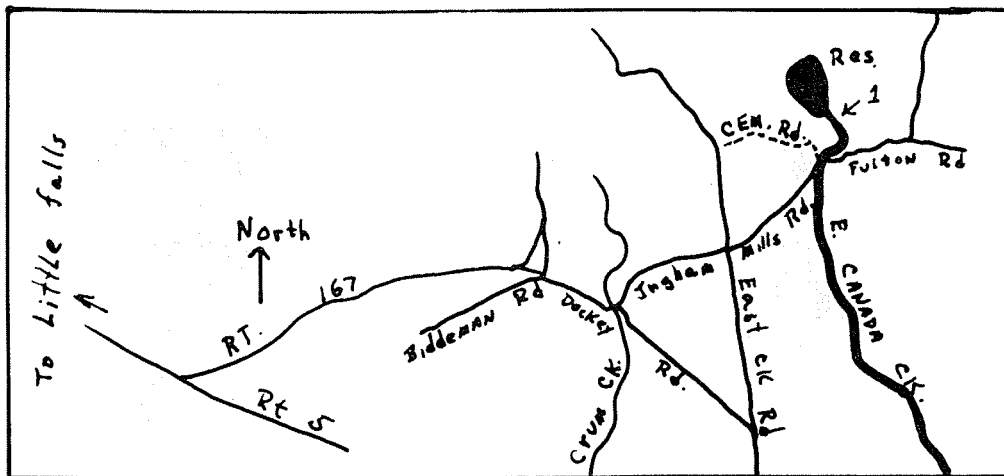


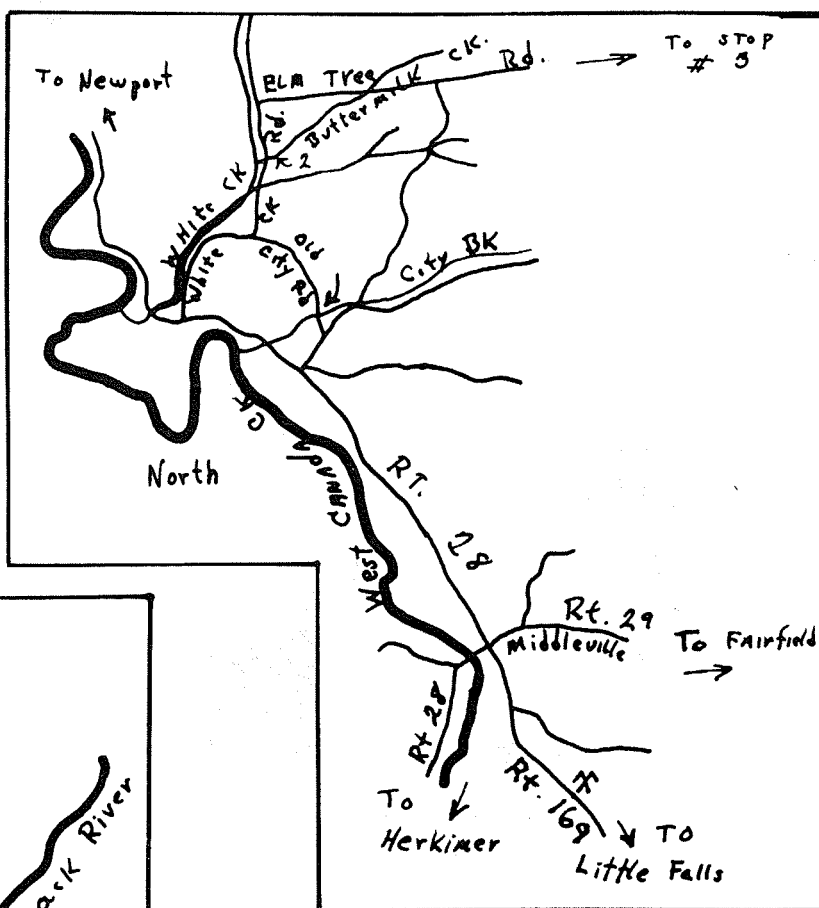
Fig. 5. Mudcracks in Gull River Limestone.



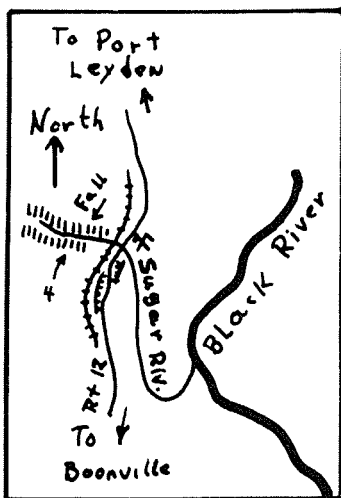
Fig. 4. Slump breccia at base of Gull River Limestone.
(Scale is shown by 6-inch ruler in all photographs.)



stop 1



stop 2



stop 4

Road maps for field trip stops.

FIG. 6

Loc #1. Inghams Mills

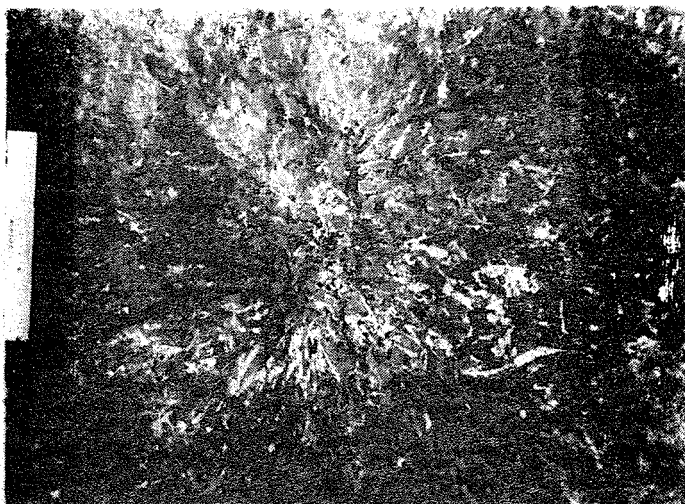


Fig. 8. Top view of whole Tetradium cellulosum colony from top of Gull River Limestone.



Fig. 7. Upper Gull River Limestone showing vertically burrowed (Phytopsis) beds, darker subtidal facies, and channel deposits.

The large ostracod Eoleperditia fabulites, snails, trilobite fragments, cryptosome bryozoa, and the tabulate coral Tetradium cellulolum are relatively common. T. cellulolum (Fig. 8) and the vertical burrow Phytopsis are characteristic of the Gull River and are often abundant.

Lower Trentonian Series:

The Trentonian Series represents the time during which the limestones and shales of the Trenton Group were deposited. It is subdivided into stages of which the lowest three are in ascending order the Rocklandian, Kirkfieldian, and Shorehamian (fig. 2). The Rocklandian Stage is defined by the Doleroides ottawanus and succeeding Triplesia cuspidata assemblage zones. During the Rocklandian Stage the Selby, Napanee, and lowest Kings Falls limestones were deposited. The lower Rocklandian Selby Limestone at the base of the Trenton Group pinches out north of Boonville, New York, and will not be seen on this field trip (figs. 1-2). The medial Rocklandian Napanee Limestone is continuous from southeastern Ontario southward to Boonville. Farther south, after about 20 miles of non-exposure, it is replaced by an unnamed facies which pinches out about 2 miles north of Middleville, New York (figs. 1-2). East of Middleville, there are no Rocklandian limestones until Inghams Mills, New York, where an unnamed "lens" of early to medial Rocklandian limestones and shales occur. The late Rocklandian Stage is represented only in the lowest 10 to 15 feet of the Kings Falls Limestone from Boonville northward where the upper half of the T. cuspidata Zone is found (Cameron, 1968). The Kirkfieldian Stage is not defined by formally named zones, but lies between the top of the Rocklandian T. cuspidata Zone and the base of the Shorehamian Stage. The Kirkfieldian Stage is represented by the remainder of the Kings Falls Limestone formation. The Shorehamian Stage is defined by the Cryptolithus tessellatus Zone and is represented by the Sugar River Limestone (fig. 2).

Napanee Limestone:

The Napanee Limestone formation (Cameron, 1967, p. 147) was defined by Kay (1937, p. 255) "...as including the beds overlying the Selby limestone...and underlying the..."Kings Falls Limestone in southeastern Ontario and northwestern New York. It is subdivided into the following lithofacies: (1) shaly calcisiltite of central New York, (2) cherty calcisiltite of central New York, and (3) shaly calcisiltite of northwestern New York and southeastern Ontario (Cameron, 1968, p. 79). The third lithofacies is the most widespread and is of medial Rocklandian age (lower Triplesia cuspidata Zone.) The exact age of the cherty calcisiltite is problematic, while the shaly calcisiltite of central New York (Inghams Mills area) ranges from early to medial Rocklandian in age.

Shaly Calcisiltite of Central New York- Thirteen feet of interbedded calcisiltite and calcareous shale, divisible into two unnamed members, comprise the lowest Trentonian limestones in the Inghams Mills area (Stop #1; Figs. 7-8; Kay, 1937, pl. 3, fig. 1). The lower member (7½ feet) is composed of chocolate brown weathering interbedded shales and argillaceous, burrowed, black calcisiltites, while the upper member (5½) is composed of medium gray weathering, dark gray to black, less argillaceous, burrowed



Fig. 10. Subsolifluction fold in lower "Napanea Limestone".

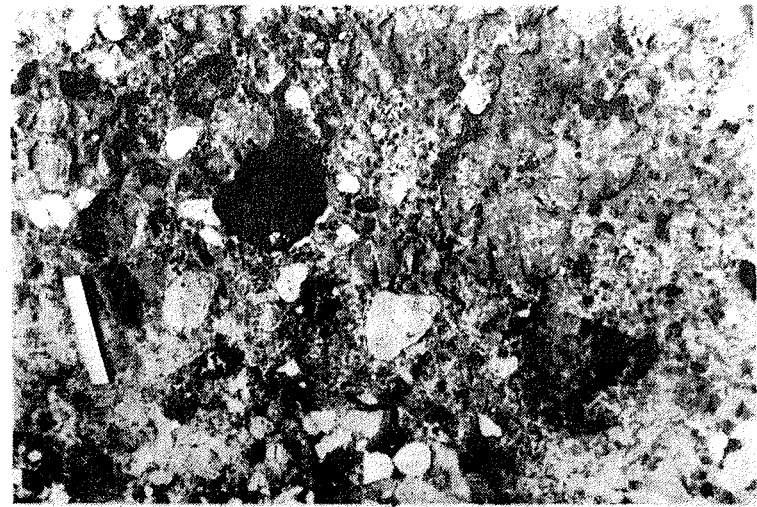


Fig. 11. Limestone conglomerate at base of Kings Falls Limestone.



Fig. 9. Disconformity between lower "Napanea" and Gull River limestones.

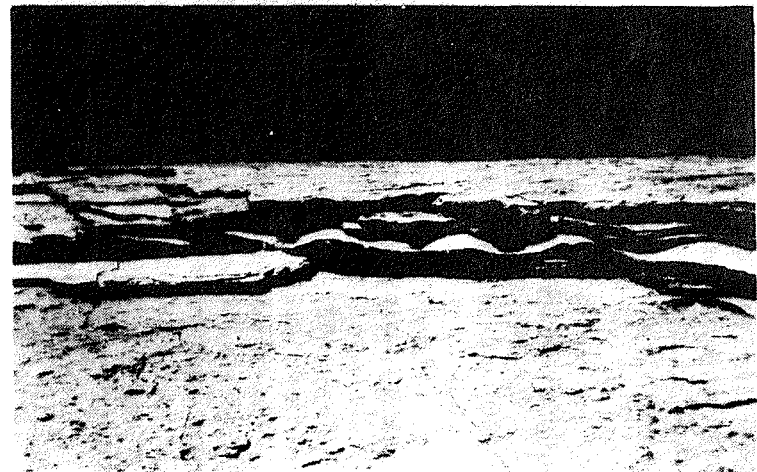


Fig. 12. Pararipples in lower Kings Falls Limestone.

calcsiltites (micrites and biomicrites) and thinner interbedded calcareous shales. Horizontal and cross-laminations are absent, probably due to complete burrow reworking. Skeletal calcarenites (biosparites) are sparse but increase in frequency towards the top of the upper member. The surfaces of these limestones exhibit extremely well-developed loading casts, suggesting that the weight of overlying sediments had deformed these limestones because they were still incompletely consolidated after burial.

Because these Rocklandian limestones (especially the upper member) resemble the upper Rocklandian Napanee Limestone of northwestern New York in that they are composed of interbedded calcsiltites and shales, they are tentatively referred to as "Napanee Limestone". The Napanee also outcrops in the southern Adirondacks, present in the unfaulted outlier at Wells where about 10 feet are exposed (Fisher, 1957). Elsewhere in the Mohawk Valley of central New York Rocklandian limestones are absent.

The "Napanee Limestone" at Inghams Mills contains the Doleroides ottawanus Zone in the lower member whose fossil diversity and abundances are much less than those of the upper member (Cameron, 1968, 1969b). The lower member is characterized by D. ottawanus, Isotelus, the burrow Chondrites, Eridotrypa, ostracods, and straight nautiloids; other bryozoa, brachiopods, and trilobites, and snails and clams are rare to uncommon. The upper member contains the Triplesia cuspidata Zone and is characterized by T. cuspidata, Chondrites, Eridotrypa, Dalmanella, diverse snails, diverse brachiopods, diverse trilobites, and corals. Conodonts have been studied from this unit by Schopf (1966) and Hasan (1969).

Cherty Calcsiltite of Central New York - This lithofacies or unnamed member of the Napanee Formation is composed of medium gray weathering, dark gray to black, generally medium-bedded and heavily bedded, irregularly burrowed, argillaceous, brittle fracturing, sparsely fossiliferous micrites. A few fossiliferous biomicrites and biosparites are occasionally present. Black chert nodules occur frequently in the thicker northerly sections near Newport where thin shale layers begin to appear in the middle of the facies. Burrows occur as interconnected non-vertical and vertical burrows resembling Camaraccladia of the upper Bolarian Watertown Limestone and as burrow reworking which has apparently destroyed any original current laminations. "Corrasion" surfaces mark its contacts with the Gull River and Kings Falls limestones (Kay, 1953, fig. 28). Maximum thickness of this facies is about 7 to 8 feet in the vicinity of Newport but it decreases to zero southward 2 miles north of Middleville. Due to concealment by Pleistocene sediments, no exposures of this interval can be found north of Poland for 23 miles until Boonville where the more typical Napanee Limestone is present at this stratigraphic level. Although few time-diagnostic macrofossils (Rafinesquina reported by Craig, 1941, and Kay, 1953) have been identified from the "calcsiltite lithofacies", conodonts (Hasan, 1969) indicate a Trentonian age.

The fossil assemblages of this facies are relatively large (Cameron, 1968, Table 9, p. 89-90) and is characterized by echinoderm fragments, mollusks, ostracods, bryozoa and corals. Comminuted skeletal material comprise about 17% of the facies in thin-section. Echinoderm fragments, non-vertical burrows, brachiopods, and large ostracods (leperditiids) are

common at all exposures, while cup corals (Lambeophyllum), large colonial tabulate corals (Foerstephyllum), and a large stromatoporoid (Stromatocerium) trilobites and snails are rare to common at almost all localities. Collecting is difficult, however, due to the massive nature of these limestones.

Northern Shaly Calcisiltite - The next lower Trentonian outcrops to the north are at Boonville along the Black and Sugar rivers, 23 miles north of Poland and expose $19\frac{1}{2}$ to 21 feet of more typical Napanee limestone lying between the Watertown and Kings Falls limestone formations (fig. 2). This facies doubles in thickness in northwesternⁿ most New York north of Watertown and then thins westward again in southeastern Ontario where it is 20 feet thick in the type section at Napanee (Cameron, 1968). The contact between the Napanee and Watertown is usually a corrasion surface, while the contact with the Kings Falls Limestone is usually gradational and is drawn at the first prominent thick, coarse-grained, shelly calcarenite, such as along Sugar River at Stop #4. Detailed information on the Napanee Limestone can be found in Cameron (1968, p. 91-117).

The Napanee is dominantly burrowed calcisiltites interbedded with thin calcareous shales, but a few calcilutites occur in the lower half and skeletal calcarenites increase in abundance towards the top. The calcisiltites and the few calcilutites are sparsely fossiliferous, mud pellet bearing micrites that contain infrequent, thin, discontinuous, skeletal laminae. X-ray analysis of some calcareous shales from two exposures along the Black River east of Boonville indicate a composition of calcite, illite, quartz, koalinite, and feldspar. The last two occur in small amounts, and in thin-section some dolomite rhombs can be found. The less abundant calcarenites are dominantly poorly sorted (micritic) biopelagites and biomicrites in which skeletal material is abundant (about 30%) and mud pellets frequent (about 12%). Some of the coarse beds are horizontally laminated or cross-laminated. Apparent current directions measured from cross-laminated beds indicates a strong preference for northeastward to eastward moving currents during the deposition of the Napanee. The few pararippled biosparites in the lower Napanee from Bonvilleⁿ to Lowville indicate a similar dominant current direction.

The fossil assemblages from the Napanee Limestone are characterized by echinoderm fragments, brachiopods, bryozoans, mollusks (mostly gastropods), and trilobites (Cameron, 1963, tables 10 & 11). The most common fossils are the brachiopods Dalmanella and Sowerbyella. Small ostracods, strophomenid brachiopods, the tiny brachiopod Protozyga, the burrow Chondrites, horizontal burrows and the bryozoans Stictopora, Eridotrypa, and Prasopora are common. The brachiopod index fossil Triplesia cuspidata is frequent. Where burrows are abundant, such as in the calcisiltites, skeletal fossils are rare. The burrows in the lower beds of the Napanee include many discrete, near-vertical branching and almost U-shaped burrows.

Kings Falls Limestone:

The name Kings Falls Limestone was proposed by Kay (1968) to replace the lithic use of the term "Kirkfield" which was restricted to use as a stage named Kirkfieldian. The formation has a maximum

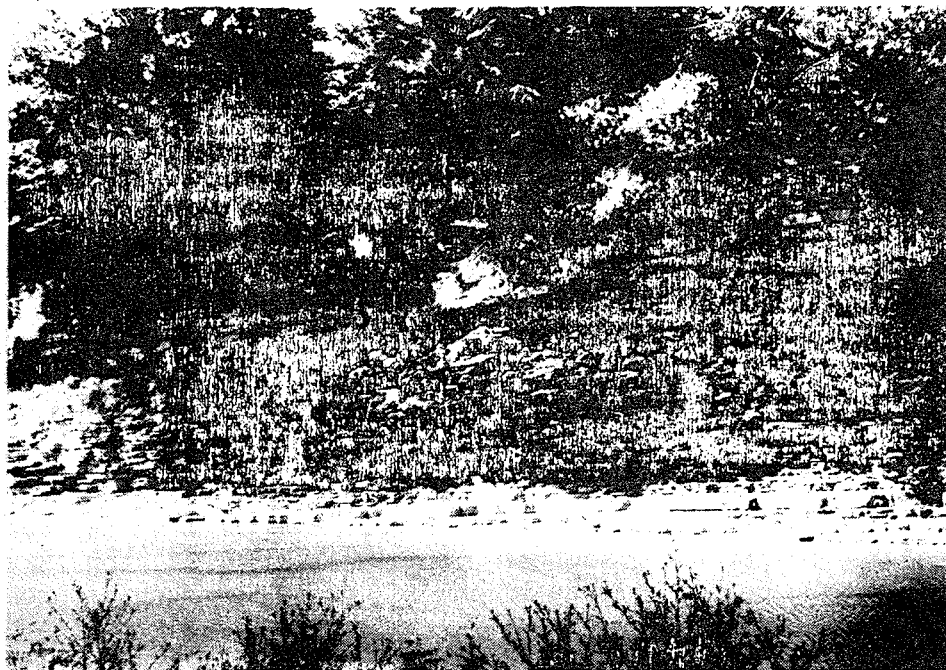


Figure 13. Napanee and lower Kings Falls limestones along Sugar River (Stop #4). Note the thick calcisiltite beds of the lower Napanee (see fig. 14 below), lensing beds of the upper Napanee, and massive overhanging beds of the lower Kings Falls. Senior author in shadows at right-center forms scale.

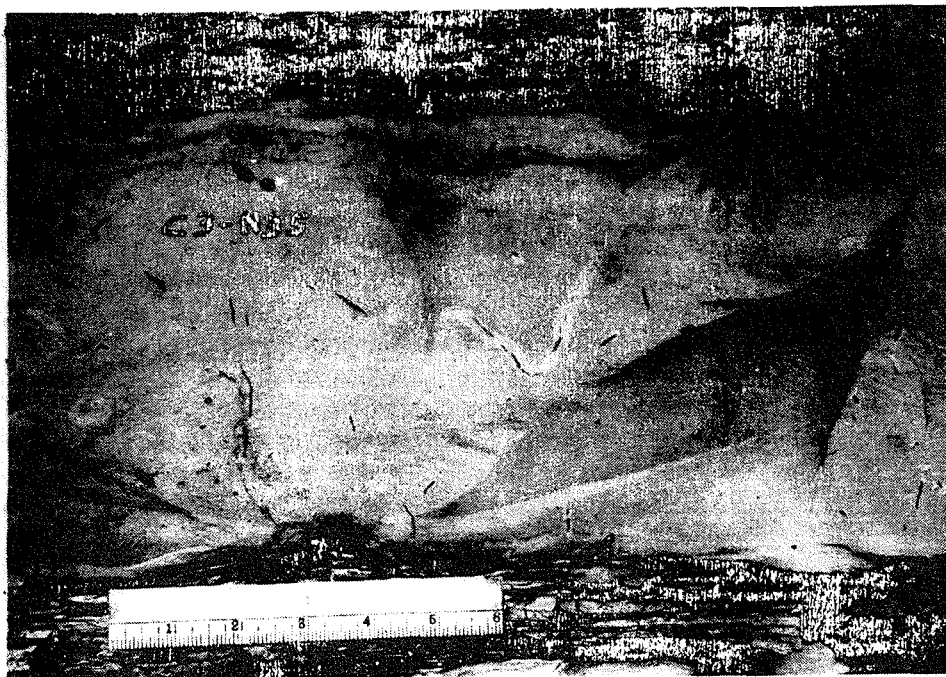


Figure 14. Close-up of a thick, burrowed calcisiltite bed in the lower Napanee Limestone (locality C3, "lower ledges" along the Black River, Boonville, New York).

thickness of about 100 feet at its type section along the Deer River between the towns of Copenhagen and Deer River, New York. To the south-east it thins to about 65 feet at Lowville and maintains essentially the same thickness to Boonville. Further south the formation thins again being about 45 feet in the area of Newport (North of Middleville) 23 feet at Inghams Mills (Stop 1) and 0 feet at Canajoharie. Two broadly defined lithofacies of the Kings Falls are recognized in the field: (1) shelly calcarenite of northwestern and central New York and (2) an overlying non-shelly calcarenite of northwestern New York. The boundary between the two lithofacies is lithically determined by a sharp decrease in the percentage of shelly calcarenite.

Shelly Calcarenite of Northwestern and Central New York -

This facies is characterized as dark grey to black, grey weathering, coarse-grained, relatively massively bedded, shelly calcarenite (fig. 16) with interbedded thin calcareous shales. Fine and coarse-grained calcarenites are frequent (fig. 15) and calcisiltites are present also. Silicification, especially of brachiopods, seems to be limited to this facies.

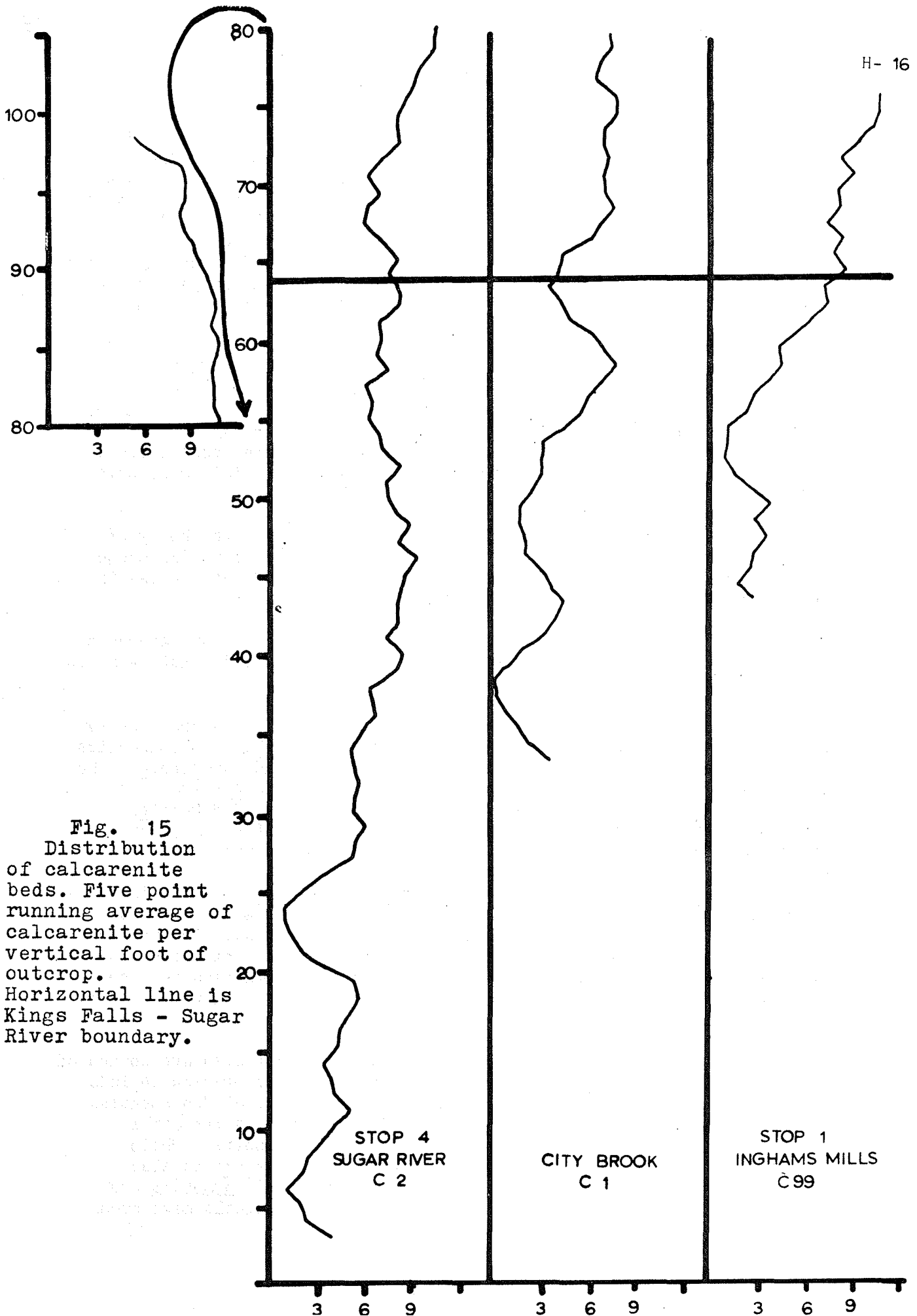
Outcrops of the Kings Falls in central New York are wholly of this facies. In northwestern New York it has been traced as far north as Roaring Brook, south of Lowville. The occurrence of this facies is yet to be determined in outcrops further to the north.

Pararippled, cross-bedded and sheet laminated beds are abundant and characteristic of this facies. Current movement was dominantly southwest to northeast (Cameron, 1968).

Fossil assemblages of the shelly calcarenite facies are heavily dominated by the brachiopods Dalmanella and Sowerbyella. Strophomenids are common along with the bryozoa genera Eridotrypa and Stictopora. The trilobites Isotelus, Flexicalymene, Ceraurus and Encrinurus are present. The snails Horotoma, Liospira, Sinuities, Phragmolites and Subulites are locally abundant. In the lower levels at Sugar River (Stop #4) the brachiopod Triplesia and the coral Lambeophyllum are common.

Non-shelly Calcarenite of Northwestern New York - This relatively massively bedded facies is lithically distinguished by a dominance of calcarenites and a scarcity of shelly arenites (figs. 15, 16). An increase in horizontal burrows and a decrease in pararippled and laminated beds also serve to discriminate this facies. The facies comprises the upper 30 feet of the Kings Falls at Sugar River and has also been traced as far north as Roaring Brook, South of Lowville.

The assemblages of the non-shelly calcarenite facies are dominated by the bryozoan genera Eridotrypa and Prasopora. Other Bryozoa include the general Eshcaropora, Stictopora and several species of fenestrates. The brachiopods Dalmanella, Sowerbyella and strophomenids are still quite common. Flexicalymene is the most abundant trilobite. Whole specimens of this species are occasionally found. Ceraurus is also abundant. Among the snails only Sinuities, Liospira and Horotoma are found. Several different varieties of Pelmatozoan columnals have been observed in this facies.



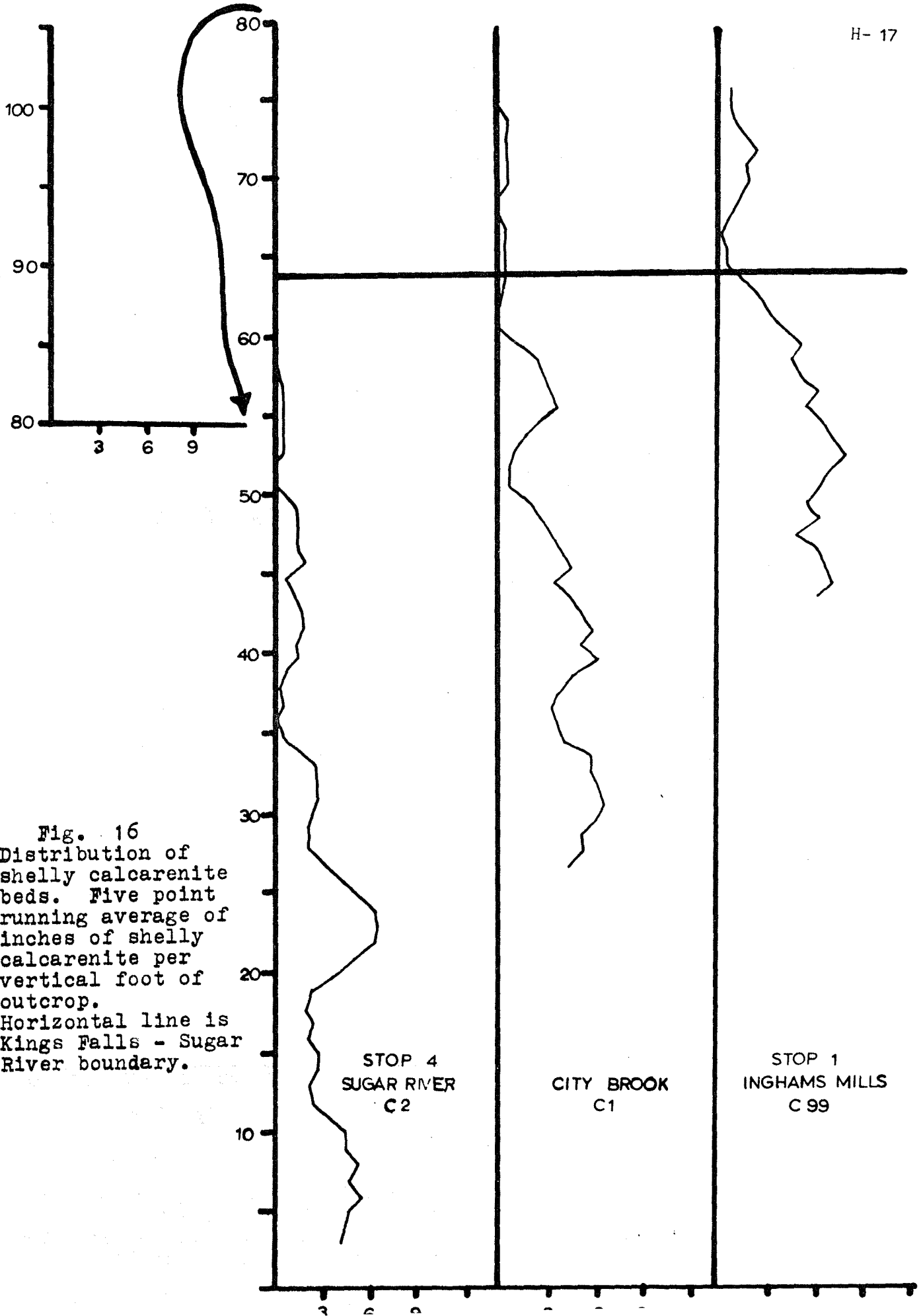
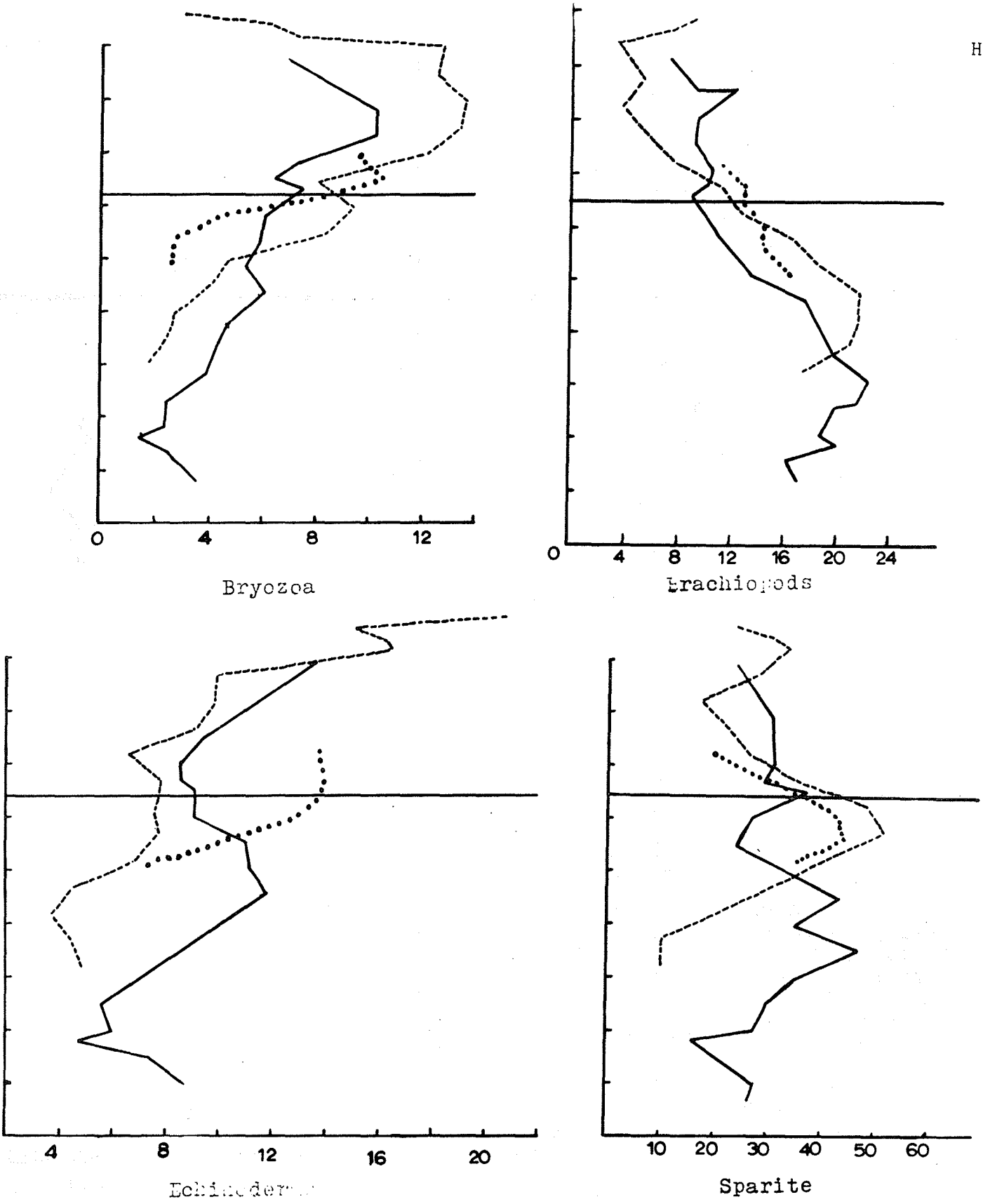


Fig. 16
Distribution of shelly calcarenite beds. Five point running average of inches of shelly calcarenite per vertical foot of outcrop. Horizontal line is Kings Falls - Sugar River boundary.



Bryozoa

Brachiopods

Echinoderms

Sparite

Fig. 17

Five point running average (expressed in percent) of petrographic data. Horizontal line is Kings Falls-Sugar River boundary. Dotted line is Inghams Mills. Dashed line is Buttermilk Creek. Solid line is Sugar River. Vertical axis divided into 10 foot intervals.

Sugar River Limestone:

Kay (1968) proposed the name Sugar River Limestone to replace the lithic use of the term "Shoreham" which is now restricted to use as a stage named Shorehamian. The formation is thickest in northwestern New York where it is about 40 feet thick. In central New York it is about 35 feet thick in the Middleville area and further south it progressively thins to 17 feet at Canajoharie. In central New York, an upper member, the Rathbun Member, is distinguished.

Lithically the Sugar River is a dark-grey to black, thin-bedded, non-shelly calcarenite (fig. 15) with interbedded thin calcareous shales. In northwestern New York shales increase in abundance southward to Boonville (Chenoweth, 1952). Farther south, after a covered interval of about 25 miles, the shales of the Sugar River formation decrease southward from Middleville to Inghams Mills and Little Falls (Cameron, 1968b) and decrease even more to Canajoharie. Relatively massively bedded, large Prasopora - bearing calcarenites are found in the upper pre-Rathbun Sugar River Limestone in central New York. The limestones of the Sugar River are dominated by burrow-reworked beds though cross-laminated and pararippled beds are not uncommon.

High diversities of bryozoa, pelmatozoa, and brachiopods characterize the Sugar River formation. Epiboles of the bryozoa Prasopora occur at several levels. Large branched colonies of Eridotrypa are occasionally seen. Other bryozoan genera include Stictopora, Escharopora, Pachydictya and several unidentified fenestrates. At least a dozen pelmatozoan species have been distinguished from their columnals. The brachiopods include Dalmanella, Sowerbyella, Platystrophia, Dinorthis and the inarticulate Trematis. Strophomenids are scarce. Important trilobites of the Sugar River include the index fossil Cryptolithus along with Flexicalymene, Ceraurus and Calyptaulux.

Rathbun Member - The Rathbun Member (Kay, 1943) has been recognized as comprising the topmost Sugar River at outcrops in the valley of West Canada Creek and its tributaries (Chenoweth, 1952; Kay, 1953). The Rathbun is as much as 10 feet of relatively thick-bedded calcisiltites and shales with a few coarse shelly calcarenites. To the southeast, the member rapidly thins to extinction.

EARLY TRENTONIAN TRANSGRESSION

The Rocklandian, Kirkfieldian and Shorehamian rocks of central New York represent a transgressive sequence in which a medial Ordovician sea transgressed apparently from the west to east according to the NW-SE outcrop belt. Evidence for this transgression can be found in the stratigraphic relationships of the formations. The basal Selby formation, which is found in northwestern New York, thins out to the southeast and disappears altogether in the area south of Lowville. The overlying Napanee formation extends farther to the south but quickly pinches out in the area north of Middleville.

northwest

southeast

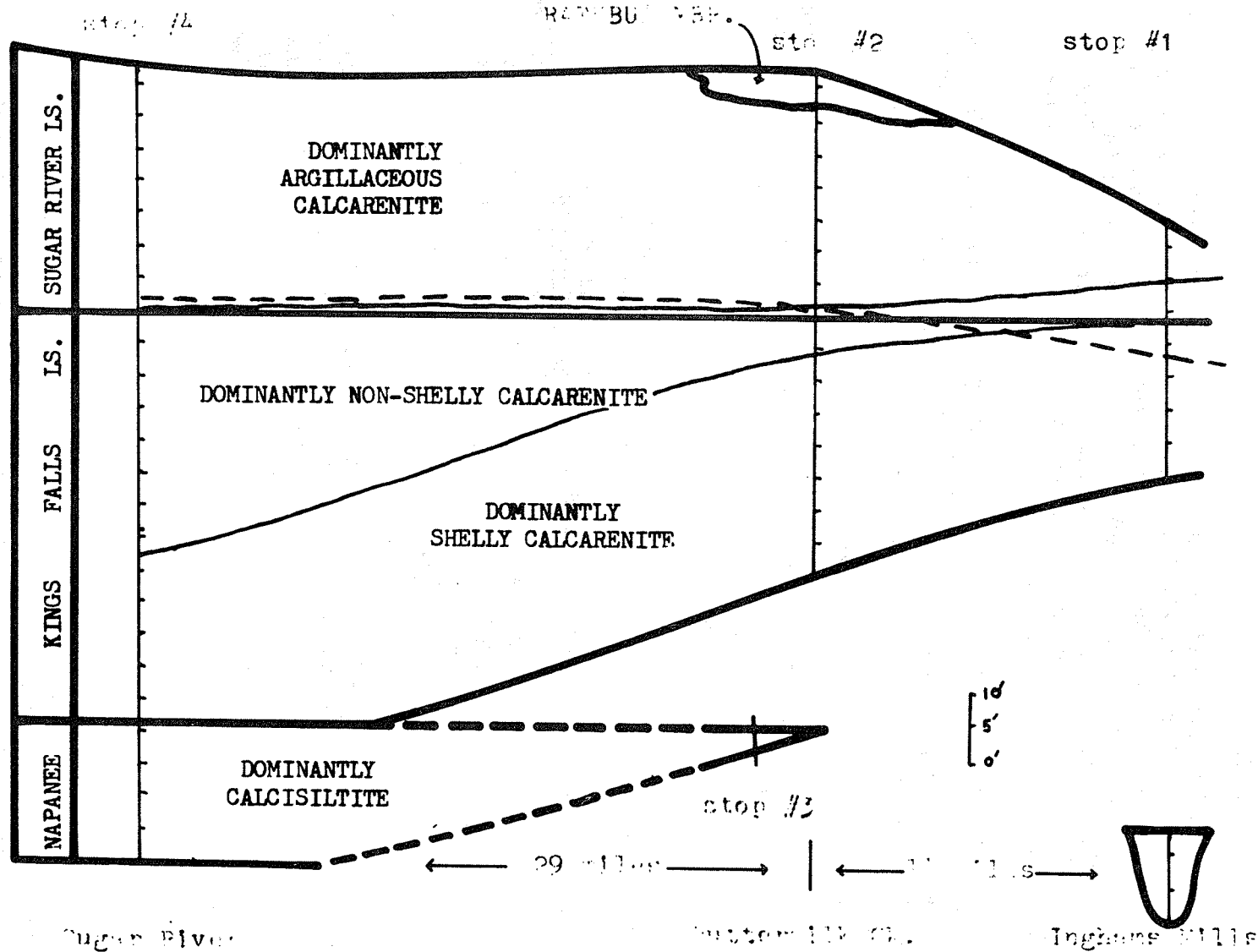


Figure 18. Distribution of the major dominant lithologies in the lower Trenton Group.

The age of the base of the Kings Falls formation becomes progressively younger to the southeast. In the area of Boonville there are 12 feet of Rocklandian aged lower Kings Falls limestones, but in central New York, the Rocklandian lower Kings Falls is absent, indicating the lower Kings Falls is Kirkfieldian in age. At Inghams Mills a basal conglomeratic interval occurs at the base of the Kings Falls, indicating, along with other evidence, a disconformity. The Kings Falls disappears west of Canajoharie, so that the basal Trenton limestones at Canajoharie are represented by a thin (17 feet) Sugar River Limestone. Farther east the Sugar River pinches out entirely (Park & Fisher, 1969).

In the area of Middleville, a thin metabentonite layer (an altered volcanic ash) in the lower Kings Falls occurs progressively lower in the section towards the southwest, being at 9 feet at Buttermilk Creek (Stop #2), 7 feet 1/4 mile south at City Brook, 2 feet 3 miles to the southeast at Stony Creek, and absent further east.

Other lines of evidence for an early trentonian transgression come from the study of primary structures. Cross-laminations, sheet laminations, erosional surfaces and intraclasts, suggestive of a high energy shallow water environment, are relatively common in the Rocklandian and lower Kirkfieldian limestones. These structures become progressively less common in the upper Kirkfieldian limestones and are uncommon in the Shorehamian Sugar River Limestone. Burrow-reworked beds are common in the Sugar River suggestive of quieter, deeper water conditions.

Fossil assemblages change in a manner which can be related to the transgression. This will be discussed in the section below on biostratigraphy.

SEDIMENTARY ENVIRONMENTS

The sedimentary environments of the Napanee, Kings Falls, and Sugar River limestones will be briefly discussed along with the evidence for them. The northern shaly calcisiltite lithofacies of the Napanee Limestone probably represents a relatively shallow-shelf lagoonal situation protected by land (Adirondackia) to the east and an offshore shoal on the west. This is indicated by the dominance of fine-grained sediment (shales and calcisiltites) and the abundance of burrow-reworking. No mudcracked beds, dolomitized algal mats, abundant intraclasts or well developed vertical burrows are present west of the Adirondacks to indicate either inter or supratidal conditions. Faunal diversity is relatively low. The lower 10 feet may represent the shallowest water sediments of the lower Trenton sequence because it contains some rare vertical burrows, minor scour-and-fill, more cross-laminated beds and some pararippled beds.

The burrowed, dominantly non-laminated, shaly calcisiltite lithofacies of central New York at Inghams Mills probably represents a narrow embayment of the early and medial Rocklandian sea. The massive, burrowed, cherty calcisiltite lithofacies of central New York probably represents a very nearshore shallow water environment with much of the finer-grained lime mud and argillaceous material being carried out into the offshore shelf lagoon. The shelly calcarenite lithofacies of the

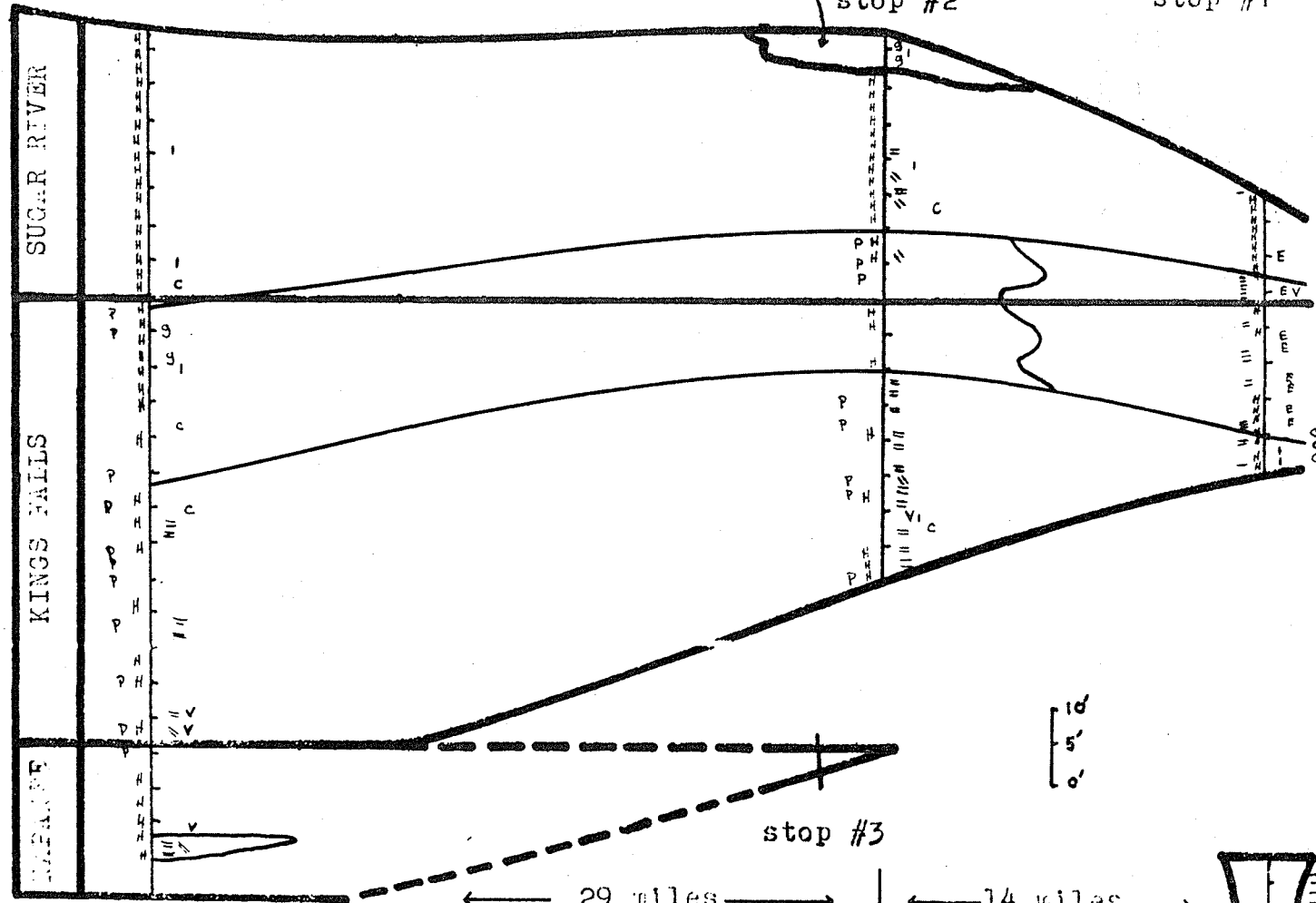
northwest

southeast

RATHBUN MBR.

stop #2

stop #1



Sugar River

Buttermilk Ck.

Inghams Mills

Fig. 19. Generalized distribution of major physical and biological sedimentary structures in Rocklandian and Kirkfieldian limestones. Go to Fig. 20 for interpretations in terms of depth zonation.

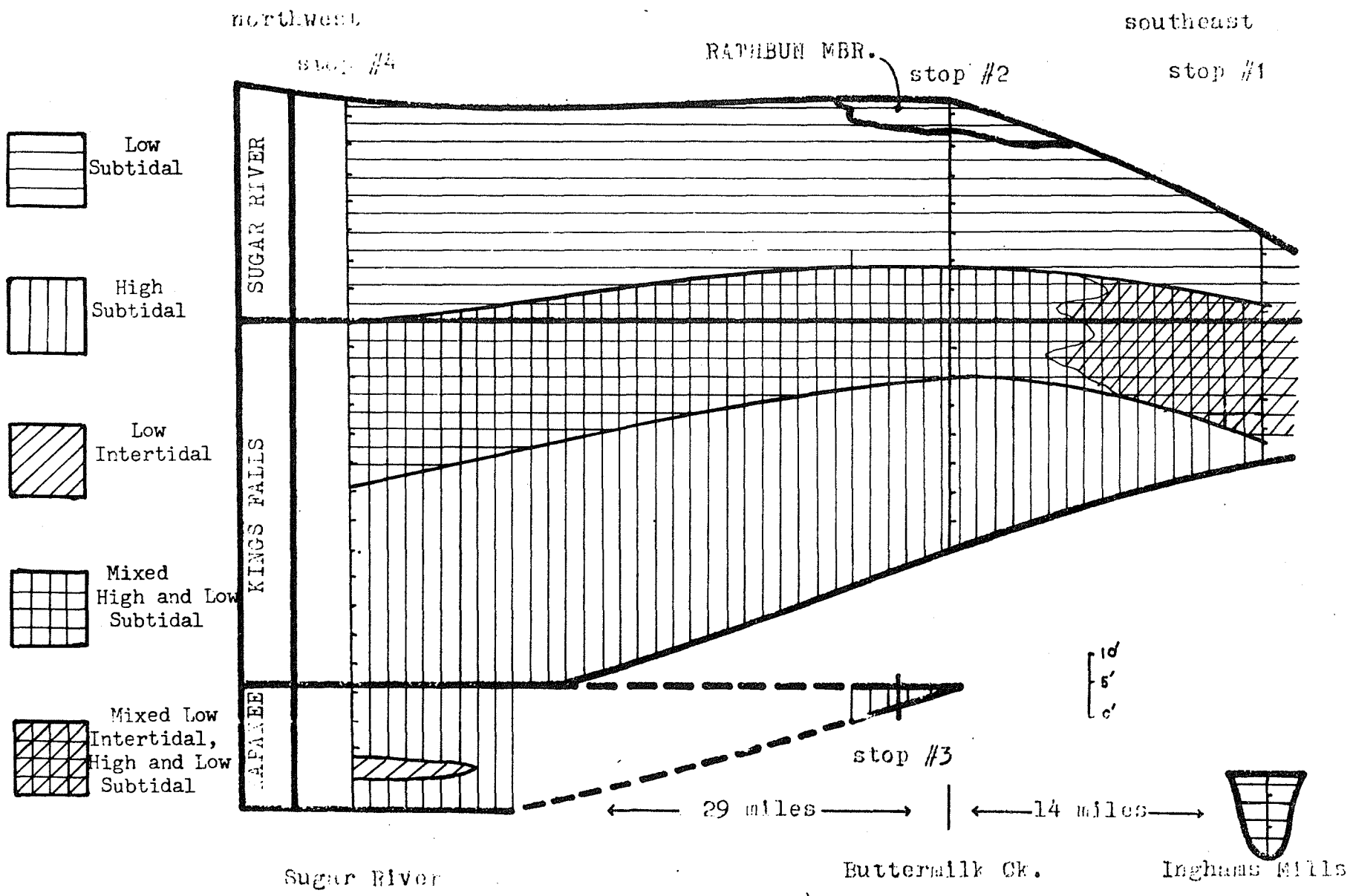


Fig. 20. Generalized depth Zonation of Rocklandian and Kirkfieldian limestones. Based on physical and biological sedimentary structures (see fig. 19).

Kings Falls Limestone contains many cross-laminated, sheet laminated, and pararippled beds, indicative of much wave and current activity, frequently with high flow regimes. We suggest an offshore shoaling environment for much of the Kings Falls Limestone. The lower Kings Falls in northwestern New York is transitional with the lagoonal northern Naponee Limestone. The non-shelly calcarenite lithofacies of the Kings Falls Limestone is also highly laminated, but more burrow-reworked beds are present, indicating somewhat deeper water conditions.

The top of the Kings Falls is transitional with the Sugar River Limestone which almost lacks laminated beds because the limestones are so highly burrow-reworked, producing a lumpy or rubbly outcrop. This formation probably represents the farthest offshore as well as the deepest water conditions of the early Trentonian transgressing sea.

BIOSTRATIGRAPHY

Introduction

Lower Trentonian fossil assemblages change in a manner which can be directly related to the transgressing sea. Environments are somewhat arbitrarily divided into low intertidal, high subtidal and low subtidal.

The assemblages of both the Rocklandian and the Kirkfieldian reflect adaptations to the stresses peculiar to their shallow water environments. In both, the shallowness of the water, through current and storm activity, allowed sediment instability. The assemblages which lived on these unstable substrates have a higher percentage (54%) of mobile species than in the deeper water environments of the Shorehamian. Few fragile epibenthonic pelmatozoans or bryozoa are found.

Also related to the stressfull nature of these shallow water environments is the fact that the assemblages are overwhelmingly dominated by specimens of one species or another. In the Kirkfieldian and Rocklandian the brachiopods Dalmanella or Sowerbyella generally dominate. In the Rocklandian the brachiopod Triplesia or the coral Lambeophyllum also occasionally dominate assemblages.

By Shorehamian times the transgression had reached its maximum extent. Assemblages of these rocks reflect quiet, stable conditions on a level sea bottom. A lower percentage (32%) of the species were mobile than in the shallow environments. Many species of fragile pelmatozoan and bryozoa are present. Bedding count diversities are very high but no single species dominates.

Low Intertidal to very High Subtidal Assemblages

The low intertidal to very high subtidal environment dominated during Rocklandian times. Fossils are scarce in these rocks and the diversity is low compared to other environments; reflecting highly stressfull conditions. The species present can be divided into two groups.

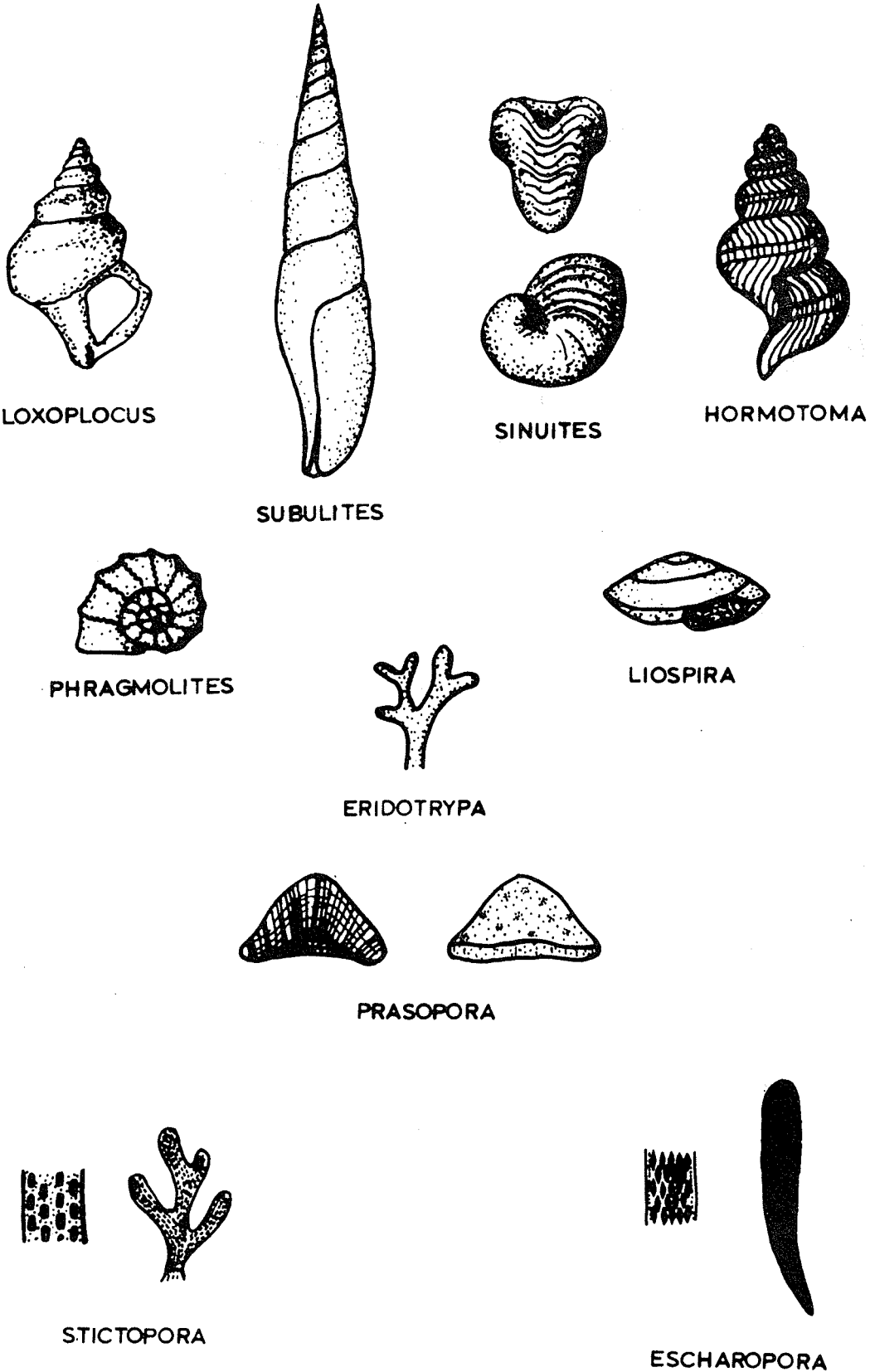
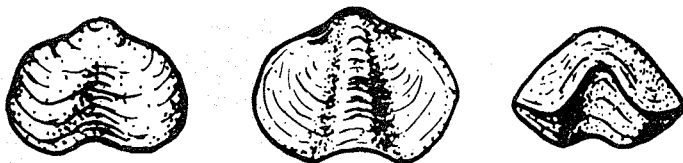


Fig. 21

Snails and bryozoa of the lower Trenton. All figures approximately natural size except for closeups of Stictopora and Escharopora. External and internal views of Prasopora are given.



TRIPLESIA



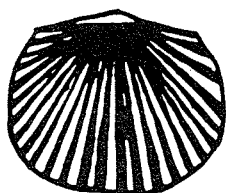
SOWERBYELLA



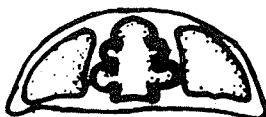
PLATYSTROPHIA



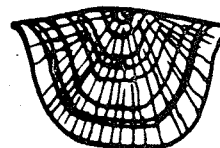
DALMANELLA



DINORTHIS



FLEXICALYMENE



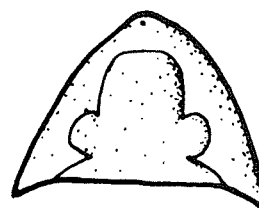
STROPHOMENID



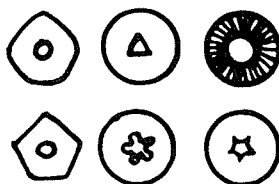
CERAURUS



CRYPTOLITHUS



ISOTELUS



PELMATOZOAN
COLUMNALS

3 X

1/3 X

Fig. 22
Brachiopods, trilobites and pelmatozoan columnals of the lower Trenton. All figures approximately natural size unless indicated.

The first consists of many species which are also present in great numbers in the other environments which suggests that they were tolerant of a wide variety of environments and thus were well suited for rapidly changing intertidal conditions. Among these are the brachiopods Dalmanella and Sowerbyella, the strophomenid brachiopods, the trilobites Isotelus and Ceraurus, one crinoid and the bryozoans Prasopora, Eridotrypa, and Stictopora.

A second group consists of a number of species which are highly mobile and restricted to the intertidal environment. Among these are several taxodont clams, some vertical burrowers and the ostracod genus Eolepreditia. Such species may reflect a general adaptation to the substrate instability of the intertidal environment.

High Subtidal Assemblages

The highest diversity of species is found in the high subtidal environment which dominated during deposition of the upper Napanee and Kings Falls sediments. A high diversity of snails and trilobites and a low diversity of pelmatozoa and bryozoa characterize the assemblages of this environment

Characteristic snails are Sinuities, Liospira, Subulites, Hormotoma, and Loxoplocus. The trilobites include Ceraurus, Encrinurus, Isotelus, and Flexicalymene. The brachiopods Dalmanella and Sowerbyella along with the strophomenids are abundant in this environment.

The high subtidal of the Rocklandian stage is characterized by the brachiopod Triplesia, the horn coral Lambeophyllum and abundant and diverse ostracods.

Low Subtidal Assemblages

Towards the end of the transgression during Shorehamian time, a quiet sub-"wave base" environment became established. Without sediment instability, mobility became less important to survival. This is reflected in the faunal assemblages by the decreasing percentage of mobile species and an increasing number of fragile epibenthonic forms. At least 12 species of pelmatozoans have been recognized from their columnals. 10 species of bryozoa have also been identified. Among these are Prasopora, Eridotrypa, Escharopora, Stictopora, and Pachydictya. Neither the bryozoa nor the pelmatozoa make up large portions of the shallow water assemblages. Trilobites are still common and are represented by Flexicalymene, Cryptolithus and Ceraurus. The brachiopods Platystrophia and Trematis are restricted to the deep water environment. Snails, clams, nautiloids and corals are very rarely found.

DESCRIPTION OF STOPS

Stop #1. Inghams Mills (Locality #C99):

Four medial Ordovician formations are exposed at this outstanding

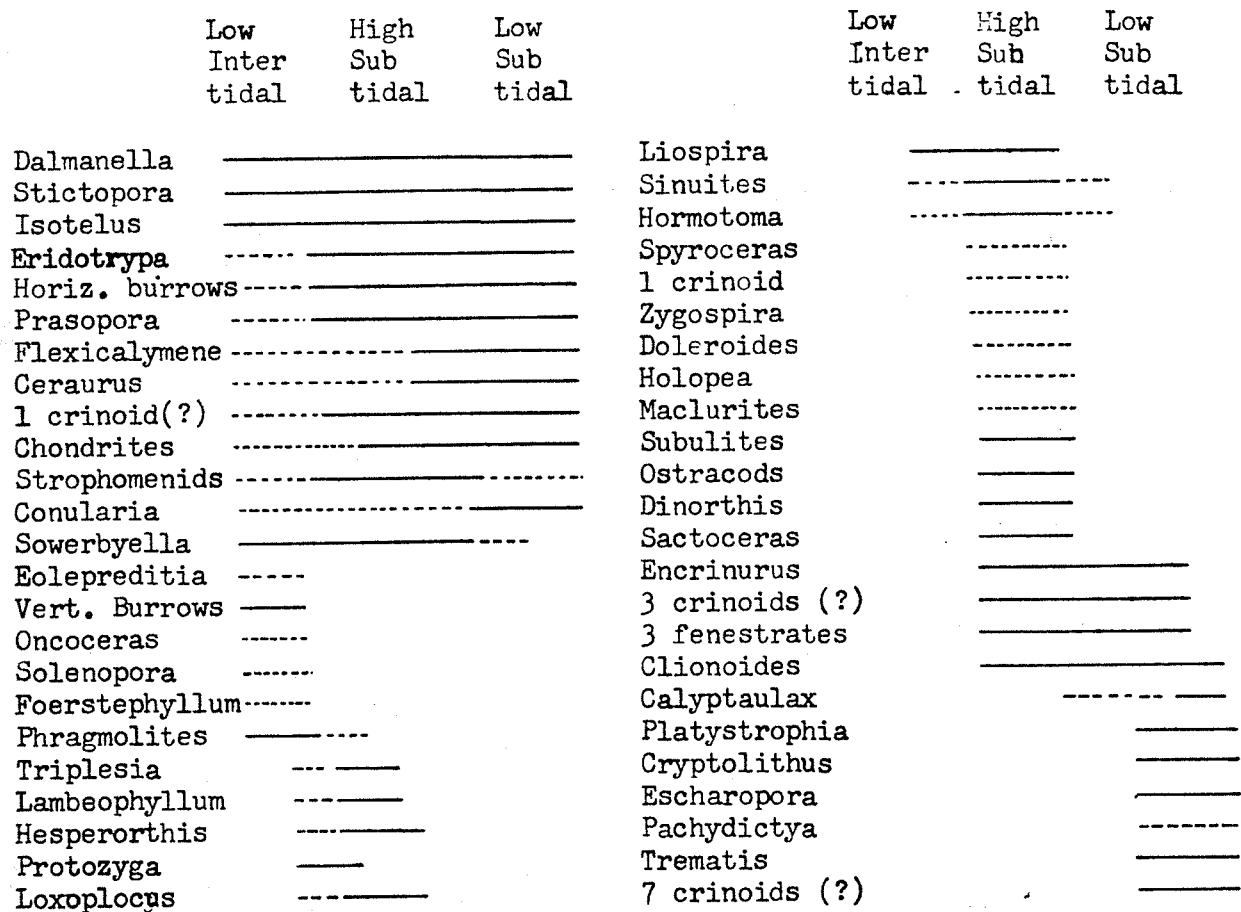


Figure 23. Paleocological distribution of many of the lower Trenton species.

outcrop on East Canada Creek. Lithologies, sedimentary structures, fossil assemblages, formational boundaries and paleoecology will be examined.

Gull River Limestone. About $29\frac{1}{2}$ to 30 feet of Gull River Limestone are excellently exposed here and overly the Little Falls Dolomite of late Cambrian age. A thick dove gray shaly limestone is present at the base. Within the lowest 3 feet is a slump breccia which possesses limestone blocks up to $2\frac{1}{2}$ feet in diameter. This probably formed as a result of instability over the irregular depositional surface of the Little Falls Dolomite.

The next $16\frac{1}{2}$ feet contain horizontally laminated (algal?), dove gray calcilutites with abundant vertical burrows (Phytopsis), a few ostracods, and frequent stylolites. Frequent mudcracks confirm an intertidal or lagoonal origin.

Thin shales are common in the lower 10 feet. The folded limestone layers reported by Cushing (1905a, pl. 6) from the lower Gull River Limestone at this exposure apparently formed as a result of settling over compacting thick shale lenses (Cameron, 1969b, fig. 6).

Between $16\frac{1}{2}$ and $22\frac{1}{2}$ feet an apparently subtidal, irregularly burrowed essentially non-laminated, massively bedded, dark gray to black calcisiltite zone contains Foerstephyllum halle, Lambeophyllum profundum, Hormotoma, Loxoplocus, Isotelus, cryptostome bryozoa, straight nautiloids, and pelmatozoan debris. Most of these species were interpreted as being subtidal by Walker and Laporte (1970).

Immediately above these deeper water sediments, the intertidal or lagoonal facies begins to reappear. This is a vertically burrowed, horizontally laminated (algal?), limestone intraclast-bearing, fossiliferous calcilutite and calcisiltite zone. Fossils from this interval include Tetradium cellulorum, Eoleperditia fabulites, Lambeophyllum profundum, Isotelus, cryptostome bryozoa, and pelmatozoan fragments. Near the base of this zone a sediment filled tidal meander (?) or channel up to 7 feet wide and 2 feet deep is excellently exposed in two faces of the outcrop. Note the structure and composition of the sediment filling it.

At about 27 feet, a 9 inch thick calcilutite bed contains scores of whole Tetradium cellulorum colonies in life position, representing a wave baffle community as described by Walker (1969). They cover 50% to 90% of the bed which contains a thin veneer of limestone pebble conglomerate. One can readily see how the fine-grained sediment was trapped in and around these delicately branching tabulate corals.

The top of the Gull River Limestone is riddled with burrows (dominantly vertical) partially filled with the black lustrous carbonaceous mineral anthroxolite. Several inches of irregular relief over the top of this bed marks the disconformity between the Black River Group and the Trenton Group.

"Napanee Limestone"- The lowest 13 feet of the Trenton limestones can be divided into $7\frac{1}{2}$ feet of chocolate brown weathering interbedded calcareous shales and argillaceous calcisiltites above. The contact between these two subdivisions is slightly gradational. The surfaces of the limestone layers exhibit extremely well-developed loading casts. In addition, the lower subdivision contains an unusually well-developed and fully exposed intraformational fold (Fig. 10) similar to those described by Chenoweth (1952) from the Sugar River Limestone in northwestern New York. Fossils are common (see text above) in these protected subtidal limestones.

Kings Falls Limestone - Twenty-three feet of the Kings Falls Limestone disconformably overlies the Napanee (Cameron, 1969b). A polymictic conglomerate (dominantly limestone clasts) and shelly calcarenites mark the base of the formation. The upper contact with the Sugar River is determined by a sharp decrease in brachiopod shell calcarenites and an increase in encrinitic bryozoan rich calcarenites (Cameron, 1969b). These field observations are supported by 5 point moving average curves constructed from point-counts of thin-sections (Fig. 17) and analysis of the lithology of each bed of the Kings Falls and Sugar River Limestone (Fig. 16).

Pararippled and/or conglomeratic shelly calcarenites with some horizontal burrows are common in the first 4 feet of the Kings Falls. The succeeding 19 feet of the formation represents rapidly fluctuating environments. Scour-and-fill intraclasts pararipples and laminated beds indicate shallow waters for most of this interval, but there are several feet of rubbly weathering, burrow reworked strata within this interval that reflect deeper water conditions also.

The brachiopods, especially Dalmanella, dominate the assemblages of the lower 20 feet of the Kings Falls formation at Inghams Mills. Other common brachiopods include Sowerbyella, Dinorthis and the strophomenids. Snails are locally abundant in this interval among these are Hormotoma, Loxoplacus, Liospira and Sinuites. The alga Solenopora was common in the lowest bed but has been overly collected. Other common species of the Kings Falls at Inghams Mills include the trilobite Flexicalymene, the bryozoa Stictopora and one crinoid.

Sugar River Limestone: Fourteen feet of the Sugar River Limestone are exposed. The top of the outcrop at the base of the dam is probably near the top of the pre-Rathbun Sugar River because large Prasopora are found there. At this locality the Sugar River has many relatively massive, laminated beds.

Pararippled, sheet and cross-laminated beds and scour-and-fill structures are common in the lower few feet along with thin-bedded, burrow-reworked zones. Higher up there is an alternation of laminated and burrow-reworked horizons.

Diversities in the Sugar River formation are much lower than in the Kings Falls or in the Sugar River elsewhere. Larre colonies of the bryozoan Prasopora and Eridotrypa are common and dominate the assemblages. Snails are absent and brachiopods are much less diverse and abundant.

The cryptostome bryozoa and the pelmatozoans are more diverse and common. The trinucleate trilobite Cryptolithus, which is the Shorehamian index fossil, is present in the Sugar River. The inarticulates Trematis and Lingulasma are present near the top of the outcrop.

Stop #2. Buttermilk Creek (locality #C101):

The Gull River, the Kings Falls and the Sugar River (including 5 feet of the Rathbun Member) limestones are exposed here. There are 40 feet of the Kings Falls and 38 feet of the Sugar River Limestones.

Kings Falls Limestone - The Kings Falls disconformably overlies the Gull River. Pararippled, sheet and cross-laminated, horizontally burrowed beds are common throughout the Kings Falls Limestone. A few beds are vertically burrowed and others contain intraclasts. Some intervals have been extensively burrowed causing weathered beds to have a rubbly appearance, especially at the base of the formation. These intervals are uncommon, however, and a dominantly high subtidal environment is postulated.

The contact between the Kings Falls and the Sugar River is again well-defined petrographically by an increase in encrinitic, bryozoan-rich material and an accompanying decrease in brachiopods and sparry calcite cement (Fig. 17). At City Brook, 1/4 mile to the southeast, shelly arenites, decrease markedly at 43 feet above the base of the Kings Falls (Fig. 16), and inferentially at about the same level at this locality.

Assemblages of the Kings Falls are numerically dominated by the brachiopod Dalmanella. Few bryozoa and pelmatozoan species occur. The snails Sinuities, Phragmolites, Loxoplocus, and Liospira occur up to 15 feet. Prasopora begins to occur in small numbers at 10 feet.

Sugar River Limestone - From 40 to 49 feet in the section lithologies and sedimentary structures are gradational between the Kings Falls and the Sugar River limestones. This interval is dominated by thin, burrow-reworked beds, however, and is assigned to the Sugar River formation. Pararippled, sheet and cross laminated beds are common and slightly deeper water conditions are inferred .

Above 49 feet there a few laminated beds and thin, burrow-reworked beds dominate except for the top few feet of the formation. Here several relatively massive beds are found in the pre-Rathbun Sugar River which may indicate shallowing waters.

Several feet into the Sugar River formation at the 44 foot level several species begin to appear which seem characteristic of the deeper water environment. Among these are the articulate brachiopod Platystrophia, the inarticulate Trematis, the trilobite Cryptolithus, and the bryozoa Escharopora. These species continue to occur into the top of the Sugar River formation. The pelmatozoans become more diverse and common in these beds. Above 60 feet fenestrate bryozoa and cystoids

plates occasionally appear. Large Prasopora occur in the uppermost pre-Rathbun Sugar River.

Stop #3. Small quarry (locality #C105) :

The purpose of this stop is to examine a black chert-bearing, subtidal "calcsiltite lithofacies" of lower Trentonian age lying between $9\frac{1}{2}$ feet of Gull River and one foot of Kings Falls limestones (Fig. 3). This $3\frac{1}{4}$ foot unit is composed of massively bedded, medium gray weathering, irregularly burrowed, dark gray to black, argillaceous, and somewhat conchoidally to brittlely fracturing limestones with irregular wavy bedding surfaces separating $\frac{1}{2}$ to 3 inch thick continuous and discontinuous layers. Its contacts with the Gull River below and Kings Falls above are marked by "corrasion" surfaces. Although diagnostic Trentonian macrofossils have not been identified from this exposure, conodonts (Hasan, 1969) indicate a Trentonian age for this facies and a Bolarian age for the Gull River limestones below.

The Gull River limestones are composed of light dove gray to medium gray calcilutites and calcsiltites. Fenestral fabric, horizontal laminae (algal?), limestone intraclasts, stylolites, and thin shale layers are frequent. The vertical burrow Phytopsis is common, while infrequent body fossils only occur within the upper $2\frac{1}{2}$ feet, including Eoleperditia fabulites, small ostracods, Loxoplocus, strophomenid brachiopods, and Tetradium cellulolum.

Stop #4. Sugar River (locality #C2):

Four formations are exposed here: the Napanee, Kings Falls, Sugar River, and the Denley Limestones.

Napanee Limestone - The Napanee Limestone formation at this locality is about 20 feet thick and is wholly within the northern shaly calcsiltite lithofacies. The base is under water and the upper contact with the Kings Falls is marked by a prominent 18 inch thick shelly calcarenite bed (Fig. 13). The lower half is dominated by many almost barren conchoidally fracturing calcilutites and calcsiltites several of which are quite thick. Calcarenites occur sporadically throughout but are more common in the upper half. Horizontally laminated calcsiltites are frequent in the lower half, the top of which is marked by a poorly developed pararipple, while the upper half contains frequent shelly sheet laminated beds. Low angle cross-laminations are found in the middle and become somewhat shelly towards the top. The burrow Chondrites and large and small horizontal burrows are present throughout. Note that most of the laminated beds are burrowed at their tops.

The fauna of the Napanee is described generally in the text above. Dalmanella-dominated, bryozoan, brachiopod and trilobite assemblages are present. Cup corals may be found at about 10 feet and snails become more common in the upper half of the exposure along with occasional clams.

Kings Falls Limestone - The Kings Falls is 64 feet thick at Sugar River. The lower 12 feet of the formation is of Rocklandian age as indicated by the presence of the upper Triplesia cuspidata assemblage zone (Cameron, 1968). The upper contact with the Sugar River Limestone is drawn at the top of a prominent pararippled bed at the top of the water fall (Chenoweth, 1952). The field boundary corresponds well with the petrographic criteria cited previously (Fig. 17).

The lower 35 of the Kings Falls is dominated by shelly (Fig. 16) cross-laminated, sheet laminated, and pararippled arenites. Horizontal burrows are common but are not dominant. A high subtidal environment is inferred.

The succeeding 29 feet of strata is transitional in character between the Kings Falls and the Sugar River limestones. The bedding continues to be relatively massive and cross-laminated strata are common. Horizontal burrowing is more abundant and shelly arenites are infrequent (Fig. 16). On the whole this interval is most similar to the Kings Falls. Water conditions are probably deeper than in the first 30 feet of section where cross-laminated beds were much more common.

The Rocklandian brachiopod Triplesia cuspidata and the horn coral Lambeophyllum occur in the lower 12 feet of the Kings Falls. The snails, Sinuities, Liospira, Phragmoloites, Subulites, Loxoplocus and Hormotoma gracilus occur up to 25 feet. The brachiopods Dalmanella and Sowerbyella dominate the beds of the lower Kings Falls, but not to the extent observed in the more nearshore outcrops to the southeast. Between 25 and 50 feet the diversity drops, but between 50 and 65 feet the assemblages resemble those of the lower 25 feet.

Sugar River Limestone - The formation is about 40 feet thick at this locality, its type section. The Camp Member (Chenoweth, 1952) of the Denley Limestone (Kay, 1968) overlies the Sugar River and is poorly exposed on the cliffs above the water fall on the north side of the river. The Glendale Member (Chenoweth, 1952) of the Denley comprises the top of the cliff. The Sugar River is again dominated by thin, burrow-reworked beds. A few cross-laminated beds are occasionally observed. Relatively calm deeper waters are inferred for the Sugar River Limestone.

Deep water species appear in the Sugar River. The bryozoa and pelmatozoa become more diverse and common. The brachiopods Trematis and Platystrophia appear along with the Shorehamian trilobite Cryptolithus. In the upper few feet of the formation the bryozoa and pelmatozoan diversity drops and the snail Sinuities appears suggesting a shallowing of the water.

ACKNOWLEDGEMENTS

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MILEAGE LOG

This mileage log is designed to start at the toll booths of the Herkimer Exit (#30) of the New York State Thruway. Mileage was taken from a car's odometer and "hundreds" of a mile are estimated where turns occur in rapid succession. This trip the Little Falls and Port Leyden 15' quadrangles.

<u>*InMi</u>	<u>CumMi</u>	
0.0	0.0	Toll booths of the Herkimer Exit (#30) of the New York State Thruway. Leave toll booths and proceed straight ahead.
0.1	0.1	Turn right, taking Route 28 North. Get into left lane.
0.2	0.3	Stop light. Turn left (north), continuing on Route 28 North.
0.25	0.55	Stop light. Junction with Route 5. Turn right (east) onto Route 5. Proceed through Herkimer (6 more stop lights) towards Little Falls.
7.55	8.1	Stop light. Proceed straight ahead. (Do not bear right.)
0.3	8.4	Stop light. Proceed straight ahead.
0.2	8.6	Stop light. Proceed straight ahead. (City Hall on right.)
0.2	8.8	Stop light. Continue straight. (School on left.)
0.15	8.95	Stop light. Bear left. You are now on combined Routes 5 and 167. Get into left lane.
0.65	9.6	Blinking yellow light. Turn left onto Route 167 North.
2.65	12.25	Proceed straight ahead, leaving Route 167 and passing Esso Station on your left. Now on Dockey Road.
0.15	12.4	Intersection with Bidleman Road. Proceed straight ahead.
0.4	12.8	"Y"-intersection after small bridge. Bear left onto Inghams Mills Road.
0.75	13.55	Intersection with East Creek Road. Continue straight.
0.75	14.3	After coming down hill, continue straight onto dead end dirt road. Poor exposures of Napanee Limestone on left.
0.05	14.35	Turn right and cross small wooden bridge.
0.04	14.39	After crossing bridge, take right fork in dirt road.
0.02	14.41	In front of building, turn left.

 *InMi = Incremental Mileage; CumMi = Cumulative Mileage.

- 0.02 14.43 Turn left, back onto dirt road.
- 0.05 14.48 Park on grass along right side of dirt road.
- Stop #1: Walk to right, through the grass, and proceed to the right of the wire fence, walking beneath the power lines.
At the stone wall along the edge of the field, bear left and walk along the wire fence. CAUTION: Poison ivy often grows in abundance along this path.
Opposite the brick building, turn right and proceed very carefully over the boulders and across the creek towards the base of the outcrop. The boulders you will have to walk over to get to this exposure are sometimes unstable and tend to move when stepped or climbed upon. Be careful!
- 0.0 14.48 Return to cars and drive straight ahead on the dirt road.
- 0.02 14.5 Turn left onto dirt road leading from the power plant.
- 0.05 14.55 Bear right, crossing small wooden bridge. Then, bear left.
- 0.05 14.6 Intersection with Inghams Mills Road. Proceed straight, uphill.
- 0.8 15.4 Intersection with East Creek Road. Turn right.
- 2.15 17.55 Intersection with Route 167. Turn right onto Route 167, heading north.
- 0.4 17.95 Turn left onto Bronner Road.
- 0.65 18.6 Intersection with Murphy Road. Continue straight on Bronner Road.
- 0.6 19.2 Bear right where Bronner Road turns right. Davis Road is to left.
- 0.2 19.4 "Y"-intersection. Bear left, continuing on Bronner Road.
- 1.4 20.8 Intersection with Burrell Road. Turn left (south).
- 0.3 21.1 Intersection with Yellow Church Road. Turn right (west).
- 0.7 21.8 Intersection with Route 170. Proceed straight ahead. Yellow Church Road changes name to Top Notch Road.
- 0.7 22.5 Intersection with dirt road. Bear right, continuing on paved road.
- 1.5 24.0 Intersection with Cole Road. Continue straight. Note that Top Notch Road changes name to Rockwell Road.
- 0.75 24.75 Acute angle intersection with Route 169. Go north on Route 169.
- 6.3 31.0 Stop light, downtown Middleville. Proceed straight ahead onto Route 28 North.
- 1.8 32.8 Turn right and drive straight uphill.
- 0.25 33.05 "Y"-intersection. Bear left, going downhill, onto Old City Road.

- 0.7 33.75 Turn sharp, acute, right onto White Creek Road.
- 0.55 34.3 Park carefully along right side of road before and after bridge.
- Stop #2: Walk upstream through the edge of the field on the south side of Buttermilk Creek, climb under wire fence, and continue along north bank of stream until you reach exposures of the Trenton Group.
- 0.0 34.3 Return to cars and drive straight ahead.
- 0.25 34.55 Intersection with Elm Tree Road. Turn right.
- 2.35 36.9 Intersection with Hard Scrabble Road. Turn left, continuing on Elm Tree Road towards the village of Norway.
- 0.36 37.26 Beware: Very bad sharp right bend in road 0.2 miles ahead.
- 1.1 38.36 Intersection with Newport Gray Road. Proceed straight ahead up the hill. You are now driving on Newport Gray Road.
- 0.1 38.46 Intersection with Dairy Hill Road. Turn sharp, acute, right.
- 0.4 38.86 "Y" intersection with dirt road. Bear left and continue on paved road.
- 3.35 42.21 Intersection with dirt road on left. Bear right, continuing on paved road.
- 0.55 42.76 Short dirt path for a car on right. A small garbage dump on south side of path.
- 0.01 42.77 Turn right onto a second dirt path and park.
- Stop #3: Walk along path (an overgrown old dirt road) for about 400 feet to a small quarry.
- 0.0 42.77 Return to cars, back out, and return (north) the way you came.
- 0.53 43.3 Intersection with dirt road. Bear left, continuing straight on paved road.
- 3.35 46.65 Bear right and continue on paved road.
- 0.45 47.1 Turn sharp, acute, left onto Newport Gray Road.
- 0.2 47.3 Continue straight downhill on Elm Tree Road.
- 1.7 49.0 Turn right, continuing on Elm Tree Road.
- 2.25 51.25 Turn left onto White Creek Road.
- 1.4 52.65 Intersection with Route 28. Turn right and go north on Route 28.
- 1.9 54.55 Newport, N. Y. Continue straight uphill on Route 28.

- 3.8 58.35 Poland, N. Y. Continue north on Route 28 (bear left at main intersection in village).
- 1.5 59.85 Fork. Continue north on Route 28 (bear right and cross bridge).
- 3.9 63.75 Fork. Continue north on Route 28 (bear right and cross bridge).
- 1.2 64.95 Fork. Bear left.
- 0.9 65.85 Junction with Route 12. Turn right and go north on combined Routes 12 and 28.
- 11.4 77.25 Fork. Bear left and continue north on Route 12.
- 7.1 84.35 Boonville, N. Y. Continue north on Route 12 (road curves to right).
- 3.0 87.35 Kings Falls Limestone exposures on both sides of Route 12. Quarry in the distance off to the right across Sugar River in foreground is in the Watertown and Gull River limestones of the Black River Group.
- 0.15 87.5 Exposure of upper Napanee and lower Kings Falls limestones on left side of Route 12.
- 0.05 87.55 Park on right shoulder of road just beyond entrance to quarry.
- Stop #4: Walk back to bridge and walk upstream along the north bank (nearer side) of Sugar River to the railroad bridge.
- 0.0 87.55 End of field trip. Return to cars, turn around, and head south on Route 12 which will take you directly into Utica.

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Introduction

Uniformitarianism triumphed over Catastrophism in the days of Hutton and Werner, but skirmishing between modified catastrophist and uniformitarian views has been sporadically renewed down to the present time. Such has been the controversy over the channeled scablands of the Columbia Plateau. Similarly, divergent views have entered into conjecture regarding the meltwater channels south and east of Syracuse -- conjecture as to duration of drainage diversion which they record, and as to the relative roles of channel scour and plungepool migration in their development.

This field trip is planned to present evidence of a limnic hlaup, and episode of truly catastrophic stream erosion and canyon cutting resulting from precipitate down-cutting of a drift dam in Rock Cut Channel. The objective is to present arguments supporting a new look at the Syracuse channels (Muller and Hand, 1972). Very candidly, where the evidence permits alternative interpretations, we shall blandly espouse that interpretation which best fits the view that exceptional catastrophic events as well as normal processes have shaped the channels south and east of Syracuse.

Although the channel system in question was certainly initiated prior to the last major episode of Wisconsin glaciation (Sissons, 1960; Muller, 1964), the focus of this excursion is upon development during recession of the Wisconsin ice sheet and the story begins as the ice margin receded from the Valley Heads Moraine along the southern limits of the field trip route.

Early Development of Meltwater Lakes

The northern margin of the Appalachian Plateau in the Syracuse area is deeply cut by glacially-modified through valleys that extend south from the Ontario Lake Plain and well across the divide into Susquehanna and Allegheny River drainage. The actual divide between northward and southward drainage in these valleys is the Valley Heads Moraine, one loop of which (the Tully Moraine of von Engel, 1921), crosses Onondaga Trough 12 miles south of Syracuse. As the ice front retreated from the Valley Heads position, the steep north slope of the moraine served as a dam to impound meltwater in Onondaga Trough and other through valleys. Initial drainage was southward over the moraine, whose crest today stands at an elevation of 1200 ft. Immediately north of Tully Moraine, the lake in Onondaga Trough was more than 600 ft. deep.

Continued recession of the ice front exposed saddles in the highlands between troughs and resulted in lateral connections between the lakes. One by one, the southward outlets were abandoned and lakes occupying Butternut and Onondaga Troughs drained westward into Otisco Trough (Lake Cardiff Stage).

Eventually, ice recession freed still lower outlets east of Butternut Trough, allowing discharge from Onondaga and Butternut Troughs to escape eastward toward the Mohawk Valley. Also, at this time, water began to discharge into the Cedarvale branch of Onondaga Trough from other lakes still farther west. One result of this was the building of deltas whose remnants still record major lake level stands in Onondaga Trough.

Smoky Hollow Channel

The cross channels by which meltwater drained from Onondaga Trough eastward into Butternut Trough are shown in fig. 1. Southernmost of these channels is Smoky Hollow, a gorge 100 feet deep, with steep walls and flat floor, incised into Hamilton Shale. The eastern half of this gorge includes a distinctive ingrown meander loop with neck cutoff isolating an umlaufberg. The complex history of this part of the channel is demonstrated by inset deposits of till, lake sediments, and fluvial gravels. Evidently, Smoky Hollow was created during one or more episodes of meltwater escape that occurred prior to final Wisconsin glaciation. It became filled with till and related sediments during ice advance, and subsequently re-excavated by meltwater drainage during the most recent deglaciation. We suppose that most, if not all, of the Syracuse cross channels have had similarly complex histories.

Clark Reservation Channel

Smoky Hollow was abandoned once the ice margin had retreated enough to allow water to escape from Onondaga Trough by a more northerly route whose elevation was below the 790-foot threshold of Smoky Hollow. The newly diverted flow produced no well-defined channel throughout the western part of its course, though it scoured a broad area essentially free of drift. At Clark Reservation State Park (STOP 4), the flow dropped rapidly from 760 feet to 720 feet, then spilled over a waterfall to a plunge pool 100 feet below. The resulting amphitheater-like basin is now occupied by Green Lake, 57 feet deep, and the channel carved by the migrating falls extends approximately 3/4 mile to Butternut Trough. Just west of the lip of the falls (and within the access channel) is a depression 300 feet across and about 60 feet deep that may be a sinkhole produced or enlarged by intense ground water activity while the falls was active. The local hydraulic gradient at that time would have involved a drop of 120 feet within a horizontal distance of 800 feet.

Rock Cut & Nottingham Channels

The next two channels farther north are Rock Cut and Nottingham Channels. It is clear that in their present form they post-date Clark Reservation Channel, but their relationship to one another is more problematic. Free drainage through Rock Cut (threshold at 555 ft.) would have precluded later activation of Nottingham Channel (accessible only across a sill at 700 ft.). On the other hand, assigning Rock Cut a younger age than Nottingham violates the simple south-to-north activation sequence that has been favored by most previous workers. One tactic has been to ignore Nottingham Channel altogether, if necessary by relegating it entirely to an earlier interglacial epoch, but this is unacceptable in view of the fresh, well-developed plunge basin found at the head of this channel (STOP 5). Alternatively, Nottingham Channel may have been carved not by through drainage, such as accounts for the other cross channels, but by off-ice or even sub-ice drainage unrelated to the lake in Onondaga Trough. Sissons (1960) has shown that certain of the smaller channelways in the Syracuse area were cut by waters flowing into or off of the ice itself. Such an explanation seems unlikely in the present situation, however, inasmuch as the shape of Nottingham Channel suggests inflow from the south, the channel is similar in size to other adjacent cross channels, the channel below the plunge pool is graded to the same 600-foot level as is Clark Reservation Channel, and the 700-foot access route is underlain by bedrock

Onondaga Lake

⑧

363

⑦ Erie Canal

410



⑥ Meadowbrook

550

555

700

④ Nottingham

⑤ Rock Cut

③

740

760

② Clark Reservation

① Smoky Hollow

790

ONONDAGA TROUGH

BUTTERNUT (JAMESVILLE) TROUGH

One mile

Figure 1. Cross channels connecting Onondaga Trough with Butternut Trough. Circled numbers indicate sequence of activation and abandonment. Typed numbers indicate present threshold elevations.

apparently scoured free of till.

We will argue that there is a better explanation which entails ice-marginal and near-ice drainage, exclusively.

Evidence for Catastrophic Diversion

The south wall of Rock Cut, at a position midway along its length, displays two small plunge basins that were active for a brief time in carrying water from Onondaga Trough over the south rim of Rock Cut and into the main gorge. The presence of these fresh plunge basins implies that Rock Cut already existed prior to the most recent deglaciation and that it had subsequently become filled with drift. Flow from the plunge basins flushed most of this drift from the eastern end of the channel, but base level control farther east (at about 600 ft.) prevented scouring to the full depth of the present channel (550 ms1). There remained approximately 50 feet of fill in the re-excavated part of the gorge. In fig. 2A these conditions are designated the Early Rock Cut phase.

The fact that the waterfall responsible for these two plunge basins did not continue to shift westward and clear out the entire length of Rock Cut can be explained by invoking a drift barrier between the Rock Cut plunge basins and the access route to Nottingham Channel and at the same time freeing Nottingham Channel of ice. The flow which previously had spilled into Rock Cut now was diverted northward to Nottingham Channel, gaining 40 feet of vertical advantage in the bargain. (The 760-foot threshold in fig. 2A refers to the more easterly of the two plunge basins, now occupied by a trailer park. This elevation is very nearly the same as for the threshold at Clark Reservation. The plunge basin that was abandoned in favor of Nottingham Channel lies partially buried beneath drift in fig. 2A. Its threshold elevation is 740 ft, as indicated in fig. 1.

While Nottingham Channel was active (fig. 2B) the postulated drift barrier must have been exceedingly vulnerable to headward sapping by gullies. (These gullies may have been fed in part by seepage through the barrier.) In time, the barrier was breached, releasing catastrophic flow through the entire length of Rock Cut. Immediately after this diversion from Nottingham Channel, the main discharge through Rock Cut flowed for 2000 feet over unconsolidated drift with a gradient of at least 6 or 7 percent. Behind this flow was Onondaga Trough Lake, with an area of 24 square miles, whose surface fell 100 feet as Rock Cut was flushed. For every foot of downcutting in Rock Cut, an additional 15,000 acre-feet of reservoir volume was tapped. In short order, the rate of channel cutting across the drift barrier must have exceeded the rate of drawdown of Onondaga Trough Lake, establishing a condition of rapidly increasing discharge which could only be retarded as channel efficiency began to match diminished discharge from the shrinking reservoir.

In the terminology of Thorarinsson, a limnic hlaup had occurred.

Augmenting the normal flow through the cross channel system, the abrupt drawdown of some 50 billion cubic feet of water involved in lowering the level of Onondaga Trough Lake from 710 feet elevation to 600 feet created sufficient discharge to maintain flow 60 to 80 feet deep through Rock Cut. Evidence for this includes the presence of a boulder spit constructed across the mouth of the more westerly plunge pool high on the south wall of Rock Cut (elev. 640 ft.), and the occurrence of boulder gravels in a levee-like deposit sealing the east end of Nottingham Channel (figs. 2C and 3).

At the eastern end of Rock Cut Channel are remnants of a large (1 x 2 mi) delta consisting of boulder gravels deposited where the catastrophic flow from Rock Cut expanded into the northern end of

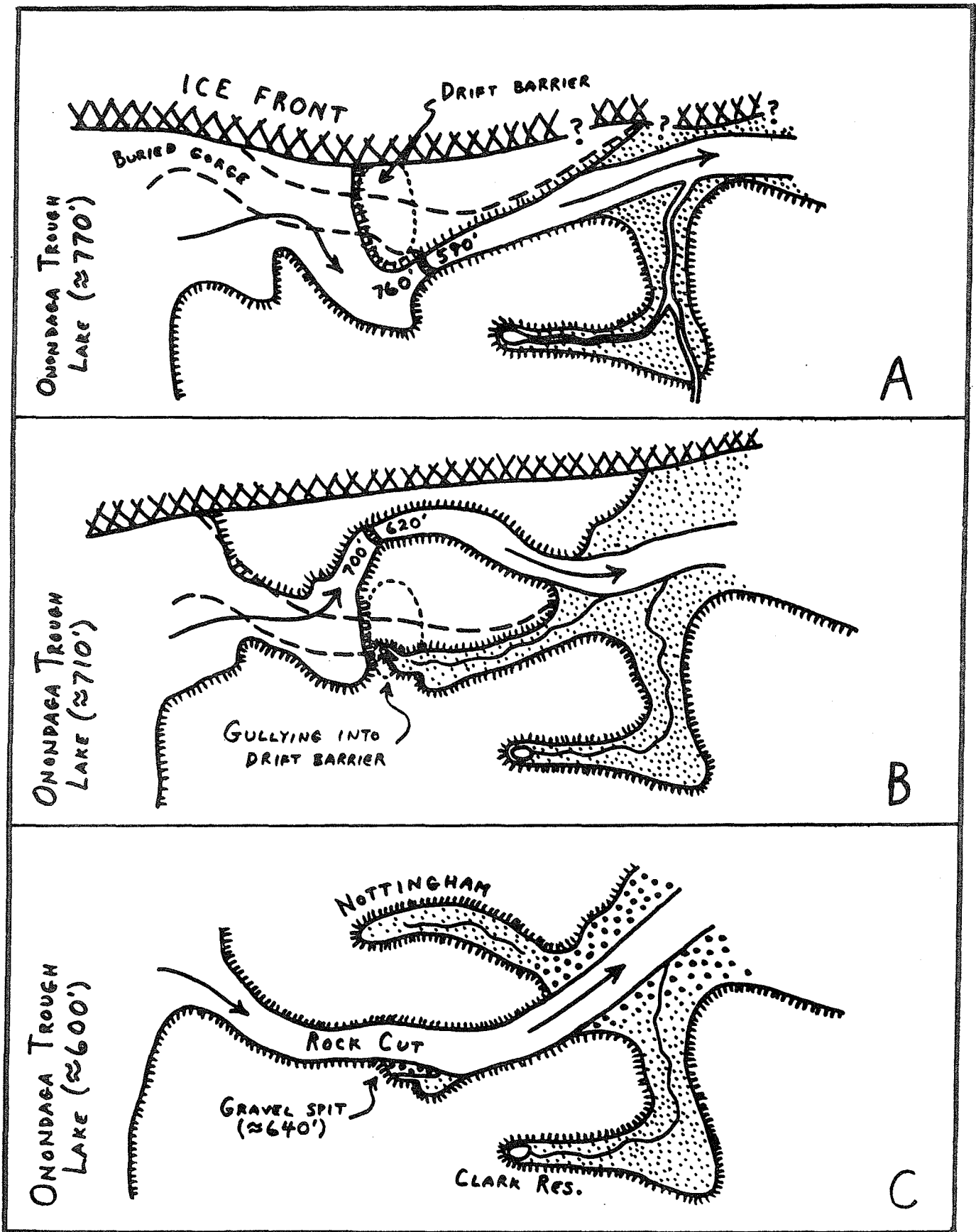


Figure 2. Evolution of drainage routes leading to the (re-)excavation of Rock Cut and Nottingham channels. A. Early Rock Cut phase. B. Nottingham phase. C. Late Rock Cut phase.

Butternut Trough. The levee across the end of Nottingham Channel is in fact part of a sizeable remnant of Rock Cut Delta preserved on the west side of Butternut Trough (fig. 3). The 1- to 3-foot boulders characteristic of this deposit will be seen in a gravel quarry at STOP 3. Still larger boulders (occasionally 5 to 6 feet in diameter) were swept across Butternut Trough to form the delta remnant preserved at the western end of High Bridge (White Lake) Channel. Some examples of these "pebbles" will be seen displayed in the front yards of homes along Cedar Heights Drive.

At the time of these events, it was High Bridge (White Lake) Channel that carried the flood waters eastward from Butternut Trough. Thus, the flow discharging across most of the Rock Cut Delta margin was constrained to change direction by nearly 90° upon crossing the lip of the delta. The redirected flow then followed the southeastwardly-expanding scourway along the delta margin into High Bridge Channel (fig. 4). Flow separation in the lee of the delta, combined with the required redirection of flow, must have maintained an active vortex that prevented the delta front from building all the way across to the bedrock slope on the northeast flank of this scourway.

The collected floodwaters again became confined upon entering High Bridge Channel, where the flow must have been at least 60 feet deep (the difference in elevation between White Lake and the lip of Rock Cut Delta). At the eastern end of this channel is High Bridge Delta (fig. 4), a feature resulting from expansion of flow similar to that which occurred in the northern end of Jamesville Trough. Foreset and topset beds will be observed in a gravel pit at STOP 2, where pebbles are mostly smaller than 2 inches, and rarely as large as 18 inches in diameter. These gravels are distinctly finer-grained than those of the Rock Cut Delta.

Except for minor erosion by Limestone Creek, we interpret the morphology of High Bridge Delta as primary. Dividing the delta into two unequal parts is a channel 1000 ft wide and 70 ft deep which apparently carried most of the discharge in the brief period during which the delta was constructed. The delta and scour levels near 600 ft elevation appear to have been adjusted to the same flow that deepened the floors of Rock Cut and High Bridge Channels to 530 or 550 feet, requiring water depths of 70 to 80 feet in the more restricted portions. Such flow could have been sustained only by catastrophic discharge from the Onondaga Trough Lake, an event whose duration was probably best measured in hours.

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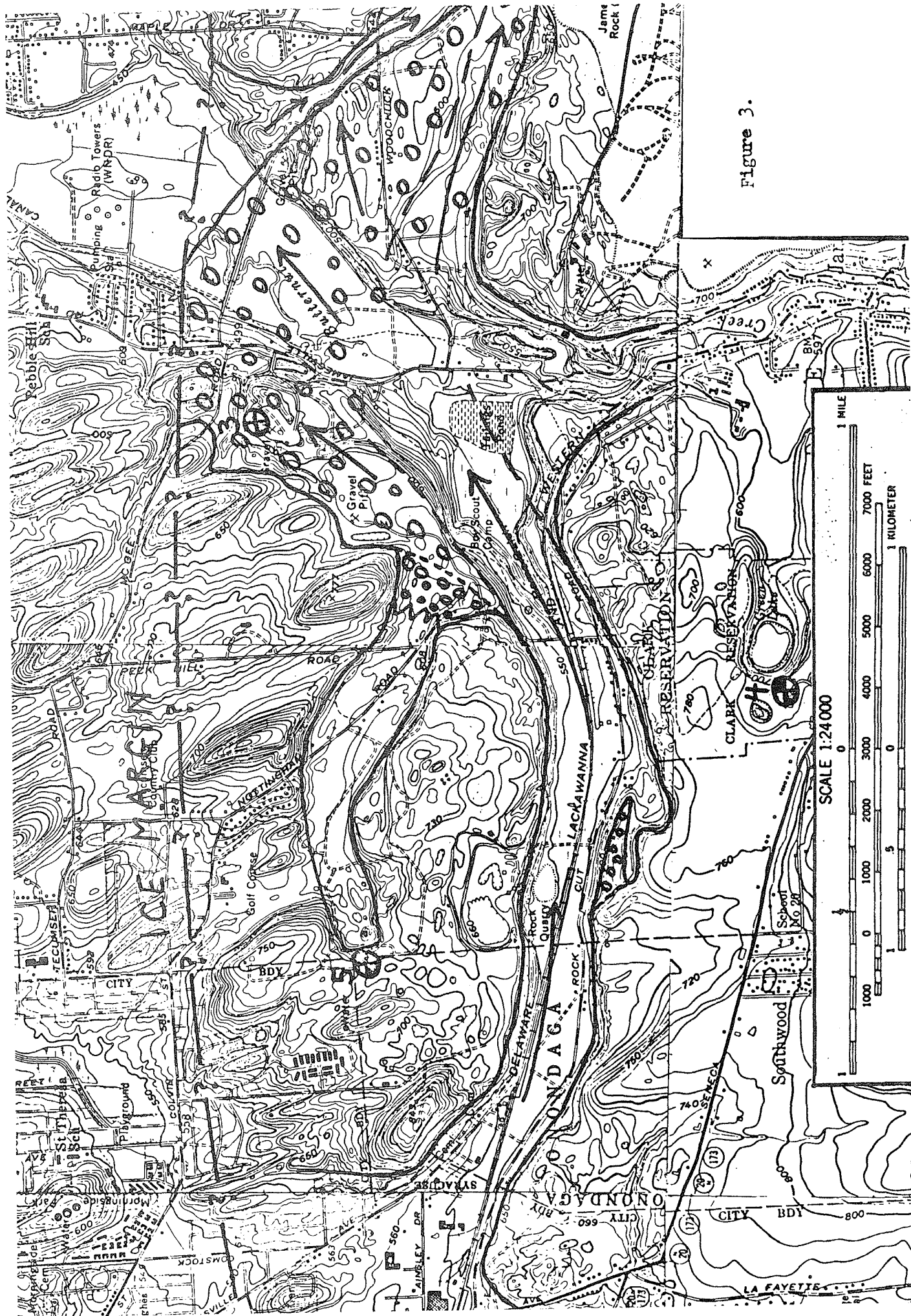


Figure 3.

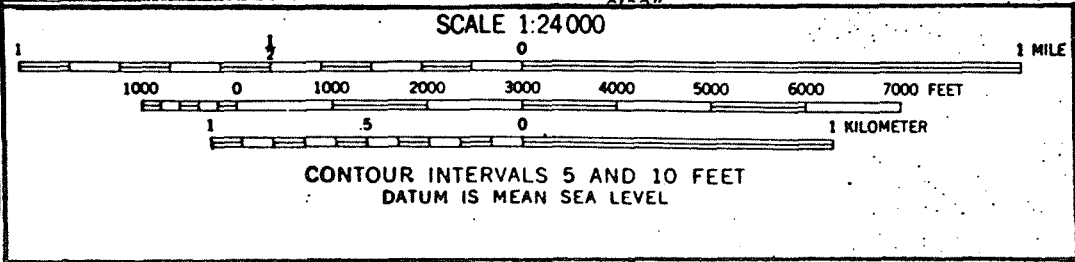
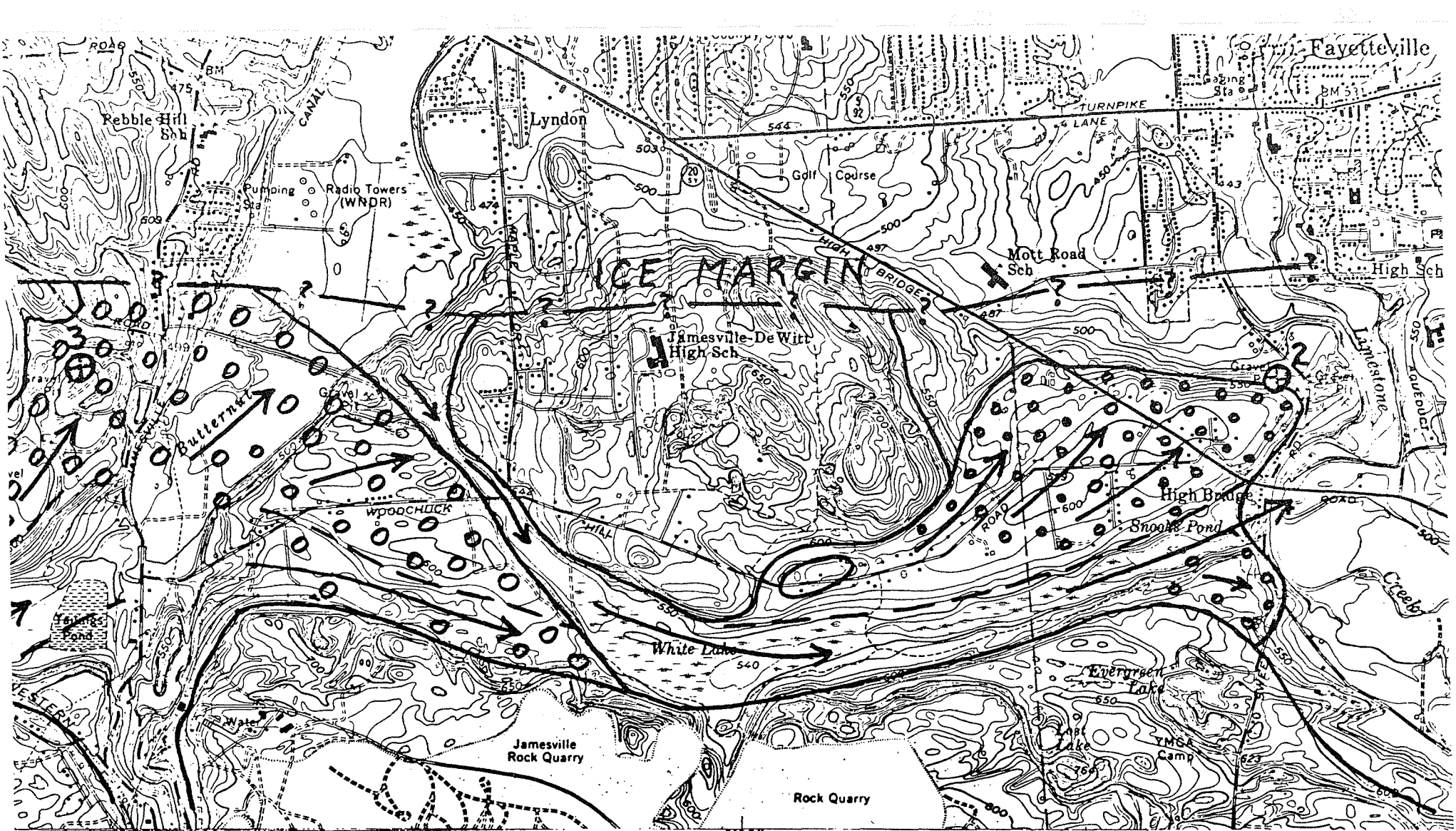


Figure 4.

The field trip route passes across U.S. Geological Survey 7½-minute quadrangles in the following sequence:

Hamilton	Canastota	Syracuse West
Munnsville	Manlius	South Onondaga
Morrisville	Syracuse East	Otisco Valley
Cazenovia	Jamesville	Tully

ROAD LOG

Mileage

Cum.	Int.	
		Hamilton 7½-min. quadrangle
0.0	0.0	Leave Hamilton, driving north on NY 46 and 12B across Valley Heads outwash plain. Enter Munnsville 7½-minute quadrangle.
1.0	1.0	NY 12B forks NE; stay North on 12B.
5.0	4.0	Turn left (west) onto US 20 at Pine Woods. Proceed west across Valley Heads outwash plain. Kames and kettles of early ("advance") phase of Valley Heads Moraine are south of US 20, but the massive, divide-forming moraine ridges are 1.5 miles north. Leave Chenango-Stockbridge trough. Road cuts expose Skaneateles shale members. Enter Morrisville 7½-minute quadrangle.
8.4	3.4	Continue west through Morrisville. In 6 miles enter Cazenovia 7½-minute quadrangle.
15.6	7.2	Enter village of Nelson. In 0.2 mi. turn right (north) at Nelson Inn onto two-lane, blacktop road.
18.3	2.7	Coty Corners. Stop sign and cross road. Continue straight.
19.6	1.3	Cross East Road. Continue straight.
19.6	1.6	Christainson Corners. Intersection with Peterboro Road and Canastota-Fenner Road. Main road curves left. Continue nearly straight on Canastota-Fenner Road. In half mile, enter Canastota 7½-minute quadrangle.
22.7	1.5	STOP 1. Park on shoulder at crest of hill for overview of regional relationships and introduction to meltwater drainage conditions at margin of ice sheet during wastage at the edge of the Appalachian Plateau. Evidence of subglacial and englacial meltwater flow. Continue north on Nelson Road.
23.1	0.4	Turn sharp left (west) at intersection with Bosworth Road.
24.4	1.3	Turn right (north) at "T-intersection" onto Quarry Road. Descend steadily northward, passing exposures of Onondaga, Helderberg and Cobleskill Formations. Old Lehigh Valley RR alignment follows meltwater channel east to Cottons.

- 26.2 1.8 Cross Osborne Road. Continue north on Quarry Road. Constructional topography and thick drift at left ahead fill the former valley of Canaseraga Creek, forcing the creek to cut a narrow rock-walled postglacial gorge through Syracuse Formation and Vernon Shale along Creek Road.
- 27.9 1.7 Intersection with NY 5. Turn left (west) onto NY 5. Roadside exposures of red and green Vernon Shale and red shale-crammed lodgment till.
- 30.3 2.4 At flashing amber caution signal in outskirts of Chittenango, proceed straight, temporarily leaving NY 5 and continuing on Tuscarora Road.
- 32.7 2.4 Turn right, rejoining NY 5.
- 33.9 1.2 Enter Mycenae. For approximately the next 3 miles, from Mycenae to Fayetteville, NY 5 follows the well-defined Pools Brook glacial meltwater channel. Inset lodgment till shows a complex history of channel development.
- 36.1 2.2 Entrance to Green Lakes State Park, location of Green and Round Lakes, both of which are meromictic and have been the object of intense and diverse limnologic studies. Both are situated in the Green Lake glacial meltwater channel.
- 36.9 0.8 Enter Fayetteville
- 38.1 1.2 Cross NY 257. Proceed west on NY 5.
- 38.6 0.5 Cross Limestone Creek, then turn left (south) at traffic light onto High Bridge Road which becomes Sweet Road.
- 39.4 0.8 STOP 2 Gravel pit on right (west) side of High Bridge Road.
- Character and structure of High Bridge Delta built where the High Bridge (White Lake) Channel entered Limestone Trough Lake. Note clast size and dominance of carbonate rocks.
- Continue south from gravel pit on Sweet (High Bridge) Road.
- 39.7 0.3 Turn right just before reaching NY 92 highway overpass.
- 39.9 0.2 Stop sign. Cross NY 92, following Woodchuck Road westward.
- For about 0.5 mile from this intersection, the road crosses the constructional upper surface of the High Bridge Delta. During flushing of Rock Cut Channel, the catastrophic discharge escaped eastward through High Bridge Channel. At peak discharge the whole delta may have been covered with water. The main channel is south of the road. Its floor is at about 530 feet above sea level, whereas the top of the delta stands at 600 feet. From this we infer that the water in High Bridge Channel was at least 80 feet deep during delta development.

The road continues along the north side of the main channel, occupied by White Lake. Toward the west, the road is located on bedrock.

- 41.8 1.9 Descend into scour channel maintained by vortex in lee of Rock Cut Delta. The near (northeast) wall of this scour channel is bedrock while part at least of the far (southwest) side is the depositional front of the Rock Cut Delta. Delta foreset beds are parallel to the present slope. The material is sand and gravel with boulders several feet in diameter.
- 42.0 0.2 Maple Drive enters from right. Bedrock exposed in roadcut along Maple Drive just north of intersection. Continue straight (west) on Woodchuck Hill Road.
- 42.2 0.2 Turn right onto Cedar Heights Drive and follow its winding course until you encounter Will-O-Wind Drive for the second time. You are now on top of the Rock Cut Delta. The favored lawn ornaments in this housing development are boulders 4 to 6 feet in dimension. These boulders occur here in delta topset beds at an elevation of 600 feet about 50 feet above the floor of Rock Cut Channel from which they were derived.
- 42.7 0.5 Turn left onto Will-O- Wind Drive.
- 42.8 0.1 Turn right and then right again onto Woodchuck Hill Road, heading west.
- Immediately after turning onto Woodchuck Hill Road, note the broad channel-like depression to the left (south) on the grounds of the Dewitt Fish and Game Club. This channel is 700 to 1000 feet wide; its axis lies about 35 feet below the adjacent delta surface and slopes gently westward, i.e. up-current. We conclude that this channel developed during catastrophic discharge from Rock Cut Channel, at a time when water level stood near 600 feet in elevation.
- Presumably, most, if not all, of the delta surface was under water at one time, but channels accomodated a disproportionate part of the flow. The situation is similar to, but with less pronounced channelization than in the High Bridge Delta.
- 43.2 0.4 Fluvial boulder gravels in road cut on left. The valley into which we are now descending was cut subsequent to formation of Rock Cut Delta and so transects the delta, isolating the remnant we have just crossed from other remnants west of Butternut Creek.
- 43.4 0.2 Turn right onto Jamesville Road. Continue north, crossing Butternut Creek. Do not turn right onto I-481!
- 43.9 0.5 Turn left into large gravel pit.

STOP 3 Heavily worked pit exposing remnants of deltaic structure, part of the delta built by Rock Cut Channel into Butternut Trough Lake. Note boulder size, north-eastward-dipping foreset beds and irregular surface upon which the delta was built. The delta surface is more than 60-feet above the floor of Rock Cut Channel.

In contrast to the material in the delta at Stop 1, black shale is a constituent in the gravel here, though black shale is not present as bedrock north of Rock Cut Channel. We conclude that a) Rock Cut Channel had been carved into bedrock prior to the most recent glaciation; b) Black Marcellus Shale had not yet been stripped from the area north of Rock Cut Gorge at the onset of the most recent glaciation; c) Marcellus Shale as well as 80 feet of Onondaga Limestone was stripped from the plateau margin north of Rock Cut Channel by late glacial erosion; d) some of the glacially eroded debris rich in black shale and Onondaga Limestone was deposited as drift fill within Rock Cut Gorge; and e) catastrophic erosion of the drift-fill dam in Rock Cut Channel delivered this material for deposition in the delta built into Butternut Trough Lake.

Leave gravel pit, turning right (south) onto Jamesville Road.

- 44.9 1.0 I-481 enters from left. Continue straight, south, on Jamesville Road.
- 45.2 0.3 Boulder gravel at top of the exposure on the right across Butternut Creek is part of a small remnant of the Rock Cut Delta with its surface at about 610 feet above sea level. The gravel displays crude foreset bedding dipping southeast (to the left, out of the exposure face) and graded bedding. The boulder gravel rests upon finer sediments including both lacustrine silt and sand and lodgment till.
- 45.5 0.3 Bear left, following sign to Jamesville.
- 46.4 0.9 Turn right (west) onto NY 173 in Jamesville.
- 47.3 0.9 Till in roadside exposure on left contains little or no black shale fragments in spite of its location south of Rock Cut Channel from which shale-bearing drift was eroded to build the delta at Stop 3. We hypothesize therefore that during the last glaciation, all black shale north of this position had been removed by the time the glacier had changed from an erosional to a depositional regime.
- 47.6 0.3 Turn right into Clark Reservation State Park and proceed 0.2 mi. to parking area.

STOP 4 and LUNCH

North of the parking lot is the steep-walled basin of Green Lake (Jamesville Lake). At the west end, twin

channels lead to a lip 175 feet above lake floor. The lake is about 55 feet deep, with unknown thickness of marl and detritus infilling. Eastward a broad channel leads to Butternut trough. About 100 yards west of Green Lake is the smaller basin of Dry Lake, which also bears the appearance of a plunge basin, occupied for a shorter interval and cut perhaps by smaller discharge. The surrounding rock bench at 710 to 720 feet above sea level is relatively bare of either drift or alluvium. North and northeast of Green Lake are several much smaller basins. All have eastward-opening channels leading to Butternut Trough and all are presently controlled by subterranean outflow. The features of Clark Reservation reflect the work of subglacial and glaciomarginal drainage controlled in part of previously developed and subsequently modified solution features.

- 43.1 0.5 Leave Clark Reservation. Turn left (east) onto NY 173.
- 48.7 0.6 Enter Jamesville. In another 0.6 mile, cross railroad tracks and immediately turn left onto Jamesville Road. Do not cross creek.
- 50.2 1.5 Bear left (nearly straight) at "Yield" sign. Continue on Rock Cut Road (Jamesville Toll Road). In 0.1 mile the road turns sharply for railroad overpass. Caution: Single-lane bridge on double curve.
- 50.7 0.5 Excellent view of Rock Cut Channel. The view is west, i.e. upstream. The gorge is 2000 feet across from rim to rim. Farther west the gorge narrows slightly, but is never less than 1300 feet across. The flat valley floor, averaging about 130 feet below the rim, is 1000 feet wide. Floor and walls are composed of Upper Silurian and Lower Devonian carbonate rocks. The floor, on Fiddlers Green Dolostone is at 555 feet above sea level.
- 51.0 0.3 Turn right (north) onto Nottingham Road. Cross Rock Cut Channel.
- 51.5 0.5 Cross axis of Nottingham Channel at oblique angle.
- 51.9 0.4 Bear left at "Y" with Tecumseh Elementary School on right.
- 52.1 0.2 Turn left into "Drumlins", Nottingham Knolls Country Club.

STOP 5. Nottingham Channel leads from a plunge pool near the southwest edge of the golf course and drained into Butternut Trough Lake. At its outlet it appears to be sealed off by boulder gravels of Rock Cut Delta, presenting the anomaly that though located north of Rock Cut Channel, it seems to have ceased to exist prior to final cutting of the Rock Cut Channel.

Leave "Drumlins", turning right (east) onto Nottingham Road.

- 52.4 0.3 Bear right at Tecumseh Elementary School.
- 52.6 0.2 Cross Rock Cut Channel

- 52.8 0.2 Turn right (west) onto Jamesville Toll Road (Rock Cut Road).
- 53.2 0.4 The plunge basin behind the trailer park on the left (south) was carved by a waterfall during an early stage of drainage through the east end of Rock Cut Channel. By that time Clark Reservation Channel had been abandoned, its sill having been some 30 feet higher than the top of the south wall of Rock Cut Channel at this location. Drainage therefore spilled into Rock Cut Gorge from the south wall and flowed eastward within the gorge to Butternut Trough.
- For this to occur, Rock Cut must have been incised essentially to its present level during an earlier episode of channel cutting. Most, if not all of the drift that had been deposited in the eastern half of Rock Cut Channel during the prior ice advance was flushed out down to the 600-foot level or lower.
- Another less well-developed plunge basin was carved as a scallop in the south wall of Rock Cut 700 feet or so farther west, but is not readily seen from the road.
- 53.4 0.2 Boulder gravel exposed behind trailers on left. These gravels include clasts more than 2 feet in diameter and form a gravel spit built across the plunge pools on the south side of Rock Cut. Large scale cross-bedding has a southward component into the plunge basins.
- This spit is interpreted as being a product of the limnic hlaup which introduced the late phase of Rock Cut drainage. The top to the spit is 640 feet above sea level, 90 feet above the floor of Rock Cut Channel at this point, thus placing an upper limit of about 90 feet on the depth of water during catastrophic discharge through Rock Cut Channel.
- 53.8 0.4 This is the inferred location of the drift barrier which diverted meltwater northward during the active life of Nottingham Channel. Breaching of this barrier released the waters of the lake impounded in Onondaga Trough and produced the catastrophic flood responsible for many of the features we have seen today.
- The barrier is presumed to have consisted of drift, which must have been thoroughly saturated and may well have been quite permeable. If the drift was permeable, springs discharging on its east flank may well have contributed to erosion and subsequent failure of the dam.
- The Onondaga Trough Lake stood at 700 feet and extended to the west flank of the drift barrier. The barrier could not have been much more than 2000 feet wide, separating the lake waters from a potential discharge route 100 feet lower.
- 54.9 1.1 Leave Rock Cut Channel at its west end, entering Onondaga Trough.

- 55.1 0.2 Turn left (south) onto East Brighton Avenue.
- 55.6 0.5 Turn half-right onto Lafayette Road (Not onto NY 173).
- 56.7 1.1 View of Onondaga Trough on right (west). Note the broadly rounded, u-shaped cross profile, the result of glacial modification of a pre-existing stream valley. The road here would have been under about 20 feet of water at the time that Clark Reservation waterfall was active. With the shift of discharge to the plunge pools along the south side of Rock Cut Channel, this became the temporary shoreline. Activation of Nottingham Channel dropped lake level about 40 feet below the road. Breaching of the drift barrier in Rock Cut Gorge let the lake drop another 100 feet. Each foot of lowering of lake level during removal of the drift barrier meant an additional 15,000 acre-feet of water to escape through Rock Cut and High Bridge Channels.
- 56.9 0.2 West end of Smoky Hollow Channel on left (east). This is the highest, and the first of the several channels to have been activated by post-Valley Heads glacial recession. When the floor of Smoky Hollow controlled the level of Onondaga Trough Lake, the water must have been about 380 feet deep.
- 57.1 0.2 Turn right onto Graham Road.
- 57.3 0.2 Excellent view of Onondaga Trough. Looking southward, one can see the juncture of Onondaga and Cedarvale Troughs (arms of a y-shaped, glaciated valley system) and Tully Trough (stem of the "y"). Terraces visible along the flanks of Onondaga Trough and across Cedarvale Trough are remnants of deltas which record changing lake level in Onondaga Trough.
- 57.8 0.5 Turn right (west) on Sentinel Heights Road
- 58.0 0.2 Turn left (south) onto Kennedy Road
- 59.0 1.0 Turn right toward I-81.
- 59.1 0.1 Turn right at "Yield" sign onto US 11, North. Immediately on passing through overpass, turn left (south) onto I-81.
- 59.7 0.6 Terrace gravels on near (east) side of Onondaga Trough below road.
- 66.6 6.9 STOP 6 in REST AREA for overview, resume and final discussion
- Continue south on I-81.
- 68.8 2.2 Tully (Valley Heads) Moraine. Crest of the moraine stands at 1200 feet, but the valley floor drops 600 feet within a half mile to the north. South of the moraine crest the outwash plain spreads for many miles toward Cortland. This is the moraine that separates southward drainage from the formerly ponded northward drainage.

70.0 1.2 Crest of the Tully Moraine. Outwash plain to south ahead.
70.6 0.6 Leave I-81 at Tully Exit (Interchange 14). Junction with
NY 80.

END OF ROAD LOG

LITTLE FALLS DOLOSTONE (UPPER CAMBRIAN)

J-1

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Utica College

The Little Falls Dolostone (Clarke, 1903, p.16) has an estimated thickness of 200 feet in the Middleville area (Kay, 1953, p. 37). The unit nonconformably overlies greenish syenite gneiss of Precambrian age.

In this area the Little Falls is largely a thick-bedded, sandy, medium-grained dolostone that weathers to a tan or buff color. Chert nodules and stringers are not uncommon. Some sandstones and conglomerates are found near the base of the unit. Except for the abundant colonial algae Cryptozoon, in cabbage head form, the unit seems to be barren in this area. Because of this apparent barrenness, the sequence of dolostones in the Middleville area is tentatively considered as "Little Falls".

Interest in the Little Falls by mineralogists goes back a long time. Eaton (1824, p.73) reports on the well-developed quartz crystals present in this unit. In places there are zones with packets (vugs) of authigenic quartz crystals. The crystals are generally small, short prismatic to almost equant in shape, doubly terminated, and water clear. Occasionally larger crystals (3 to 4 inches or more) are present. These larger crystals are rarely clear and usually are full of inclusions or flawed. Often associated with the quartz is a black lustrous carbonaceous mineral known as anthraxolite with a composition near that of coal but with different physical properties (Dunn and Fisher, 1954). For example, it does not ignite. Locally the quartz crystals have been termed "Little Falls Diamonds", "Herkimer Diamonds", or "Middleville Diamonds". There have been numerous occasions when local inhabitants have brought in these well-formed, clear quartz crystals for examination, refusing to believe they are not real diamonds, and in several cases, not allowing one to remove the specimen from their hand.

Other minerals often found in the Little Falls Dolostone include:

Calcite
Dolomite
Pyrite
Marcasite
Galena
Sphalerite
Chalcopyrite (?)
Hematite
Glauconite (?)

The glauconite (?) was first reported by Cushing (1905, p. 27) and appears as light-green to bluish-green thin coatings and spots and generally is concentrated in zones. The writer is presently examining this material petrographically and awaiting a report on its X-ray analysis.

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TRIP 10: LITTLE FALLS DOLOSTONE (UPPER CAMBRIAN),
AND HERKIMER DIAMONDS, MIDDLEVILLE, N. Y.

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Total Miles	Miles from last point	<u>Route Description</u>
0	0	Treadway Inn parking lot on New Hartford St., .4 mi north of Utica North-South Arterial (rtes. 5 & 12). Use N.Y. Mills exit. Leave parking lot and turn left (S) onto New Hartford St.
0.4	0.4	North-South Arterial Entrance to rte. 5 (EAST), 8 (NORTH), and 12 (NORTH). Take Arterial
1.7	1.3	Utica College campus seen to left (N)
3.1	1.4	Noyes St. inters. Factories of Utica Cutlery and Duxbak (outdoor clothing and equipment).
4.4	1.3	Mohawk River Valley flood plain
4.9	.5	Mohawk River
5.1	.2	Cross over N.Y.S. Thruway
5.15	.05	Rte. 5, turn right (E) to Albany, bear left
6.2	1.1	Rte. 8 (Coventry Ave) inters. (to Speculator) with 5, turn left (N) onto rte. 8.
7.0	.8	Cosby Manor Rd "T-inters.", turn right (E) onto Cosby Manor Rd. For the next few miles as you look to the right (S) across the Mohawk Valley physiographic subprovince you will see the northernmost escarpment face of the Allegheny Plateau.
10.4	3.4	Newport Rd. inters. (Baker Corners), turn left (N) onto Newport. Hummocky glacial topography along this road, many erratics.
16.0	5.6	"Y-inters." of Newport Rd with Butler Rd. Bear right and continue on Butler Rd.
17.0	1.0	In middle distance to left (N) is a presumed wave-planned hill top formed when this area (West Canada Creek valley) was a lake during the Pleistocene.
19.2	2.2	Intersection Summit Rd (E-W) with Cook Hill Rd on right (S) and Fishing Rock Rd. on left (N). Turn left (N) onto Fishing Rock Rd. Slope drops down to West Canada Creek
19.7	0.5	<u>STOP 1.</u> Exposure of glacial varves about 10 feet thick seen in the ditch on the right (E) side of the road. There are an average of

about 10 couplets per inch which would therefore suggest that this 10 foot exposure took about 1200 years to accumulate. Other varves, stratigraphically higher, are found across the road.

Continue downhill (N)

- 20.4 0.7 Cross R.R. tracks
- 20.7 0.3 Higher, abandoned flood plain of W. Canada Creek. Meander scars seen at base of hills to right (W). Eastern Rock Products Middleville Quarry seen to left (E) across West Canada Creek.
- 21.2 0.5 Cross R.R. tracks
- 21.4 0.2 STOP 2 Exposures of Precambrian syenite gneiss. This is considered to be an inlier.
- Continue S on Fishing Rock Rd.
- 21.9 0.5 Inters. with Rte. 28. Middleville turn left (NE) and cross West Canada Creek. (A right turn onto rte. 28S will take you to the Ace of Diamonds, a commercial "diamond" hunting ground, about 0.5 miles from the inters.)
- 22.0 0.1 Inters. of rte. 29 with 28N at traffic light. Turn left (NE) and continue with rte. 28N.
- 23.1 1.1 STOP 3 Quarry of Eastern Rock Products Inc., Plant No. 6 Middleville, N.Y. The quarry is on the right (E) side of the road, the operating plant is on the left (W) side of the road.

The company is a subsidiary of Koppers Corp. The quarry operation, which began in the winter of 1964, achieved its top production during 1971. About 350,000 tons of rock were processed during that year. Almost all production goes into light and heavy construction use. Some is used for rip-rap and some for "cement" blocks. Upon special order a "filter-media stone" is produced to be used for filtration in sewerage treatment plants. The largest percentage of business is for state projects. The plant does the crushing and screening as well as special mixtures according to specifications.

Because of company regulations the quarry has not been carefully examined by the writer. However, cursory examination on several occasions has shown the Little Falls dolostone (Upper Cambian) to be barren except for "cabbage-heads" of Cryptozoon found in the talus in the southeastern corner of the quarry. In that same corner the greenish spots and coatings of glauconite (?) have been found. Quartz crystals, pyrite, dolomite, and calcite are relatively common along the northwest face of the quarry. Galena, sphalerite, and chalcopyrite (?) have also been found in this part of the quarry.

Continue N on Rte. 28 (South on 28 takes you to Herkimer and the N.Y. State Thruway).

26.5	3.4	Newport, center of town.
30.6	4.1	Poland, inters. with rte 8. Continue with rte. 28(N), 8 (S)
32.1	1.5	"T-inters." Rte 8 (S) branches off from rte 28 (N), turn left onto rte. 8 (S) to Utica. (Rte. 28 (N) continues on to inters. with rte. 12)
42.5	10.4	Cosby Manor Rd. "T-inters." on left, continue south on rte. 8
43.3	0.8	Cross rte. 5, continue on rte. 8
43.6	0.3	N.Y.S. Thruway entrance, continue on Genesee St.
44.4	0.8	Whitesboro St. inters. after bridge, turn right onto Whitesboro
44.8	0.4	Utica War Memorial Auditorium on left.
45.0	0.2	"T-inters." with Liberty St., bear right
45.1	0.1	Turn right into Arterial entrance, bear right for rtes. 5 (W) and 12 (S); around curve bear left for 5 (W), 12 (N), <u>NOT</u> 5A.
48.6	3.5	N.Y. Mills <u>exit</u> from arterial onto New Hartford St. (N)
48.9	.3	Treadway Inn

END OF TRIP