NEW YORK STATE GEOLOGICAL ASSOCIATION

36th ANNUAL MEETING

MAY 8-10, 1964

GUIDEBOOK

DEPARTMENT OF GEOLOGY, SYRACUSE UNIVERSITY

NEW YORK STATE GEOLOGICAL ASSOCIATION

36th Annual Meeting — May 8-10, 1964

GUIDEBOOK

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Published by the New York State Geological Association. Additional copies available from the permanent secretary: Kurt E. Lowe, Department of Geology, City College of the City University of New York, 139th St. at Convent Ave., New York, N. Y.

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PREFACE

This GUIDEBOOK is intended to be a permanent record of the 36th annual meeting of the New York State Geological Association. The short papers accompanying the road logs of the various field trips are presented to enhance the merit of the field excursions. For the most part they summarize previous information and ideas which are pertinent to the trips; in lesser part they provide information and concepts which have not been published elsewhere but which reflect the continuing research on problems of New York State geology in the Syracuse area and in the south-central Adirondacks.

The editor's contribution in assembling this volume has been nominal. Individual authors have been responsible for the contributions which they offer here, and for the most part they have done their own proof-reading and editing of copy. The effort which has gone into the planning of the field trips and the road logs can be fully appreciated only by those who have made similar contributions to the Association in past years.

Special acknowledgment is made of the generous contributions by authors outside the Department of Geology at Syracuse University. Gratitude is expressed also to those Syracuse University students who have contributed their time, energy and enthusiasm toward making the 36th annual meeting of the Association a success.

John James Prucha
Editor and President 1964

NOTES ON THE GEOLOGY OF THE SOUTH-CENTRAL ADIRONDACK HIGHLANDS

by Dirk de Waard

GEOLOGIC RELATIONS

Present investigations in the central Adirondacks (and in the eastern Adirondacks by Matt Walton) emphasize stratigraphy, catazonal tectonics, metamorphism, and anatexis as the essential facets. A new interpretation of the geologic relations in the Precambrian of the Adirondack highlands recently proposed by Walton and de Waard (1963a, b) is summarized as follows:

1. Contrary to the impression given in Buddington's (1939) famous memoir: "Adirondack Igneous Rocks and Their Metamorphism", almost all Precambrian rocks in the Adirondacks are metamorphic rocks with metamorphic assemblages and textures. The Adirondack anorthosite is a meta-anorthosite with a granulite facies mineral assemblage in which large relic andesine plagioclase makes up a large part of the rock. Metagabbro and metadolerite commonly display a relic ophitic texture and contain cores of relic pyroxene, olivine, and plagioclase. Meta-anorthosite and associated rocks, and metagabbro and metadolerite are the only rocks which show evidence of their pre-metamorphic origin. All other metamorphic rocks are completely recrystallized and without relic textures. On the basis of their composition some of them, such as marble and quartzite, can indisputably be called metasediments. The origin of the great majority of rocks, including diverse potassic and sodic gneisses, charnockites, and metabasites, is not certain; they may have been plutonic, volcanic, or sedimentary.

2. Detailed mapping has revealed a consistent and persistent stratigraphy of alternating layers of diverse gneisses, charnockite, marble, amphibolite, and quartzite. The layered sequence, which is over 1750 meters thick, appears to envelope and overlie massifs of generally more homogeneous metamorphic rocks which include masses of anorthosite and associated rocks, charnockites, granulites, leptites, and gneisses of granitic composition. Because of this consistent relationship between the stratigraphic sequence and the underlying massifs the present, most simple interpretation is that the massifs represent a basement complex which was formed, metamorphosed, folded, and intruded during an earlier orogenic cycle, and denudated before deposition of supracrustal rocks began. The previous and alternative interpretation is that anorthositic, noritic, syenitic, and granitic masses intruded a supracrustal sequence at approximately the same stratigraphic level.

3. The structural pattern of the mapped area does not substantiate the presence of intrusive masses of batholithic dimensions and a sequence of intrusive events. The pattern is consistent with intense, deep-seated folding of basement and supracrustal sequence during the Grenville period of deformation and metamorphism. If primary flow structures were present in rocks they were obliterated and replaced by metamorphic foliation. Foliation in the stratigraphic sequence is a bedding-plane foliation, paralleling sedimentary bedding and compositional layering. In the basement complex foliation parallels the layering of the overlying supracrustal sequence. Mineral lineations and minor fold axes are parallel to fold axes of major folds. One exception to this rule is found in dome-shaped structures where radially oriented lineations occurring at a certain level indicate final-stage updoming movements. The map pattern, with sinuous belts of supracrustal rocks wrapped around basement masses, resembles in many

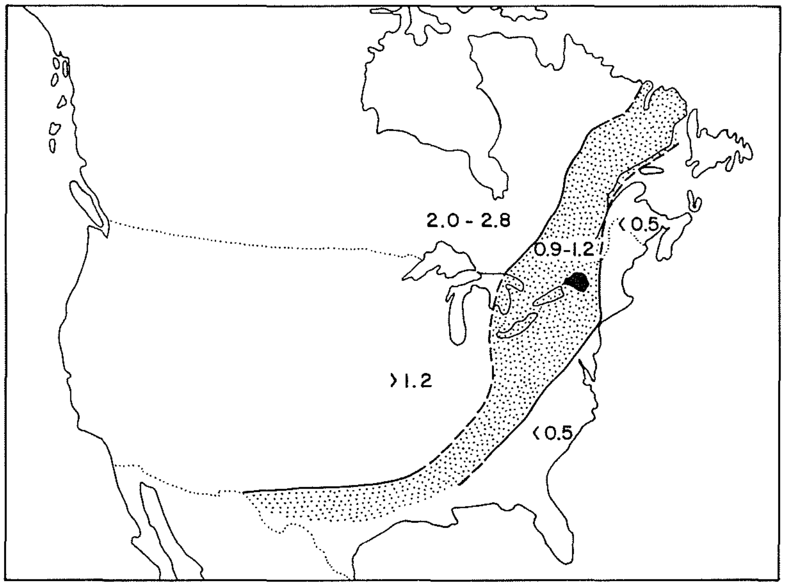

Fig. 1. Location of the Adirondack Mountains (black) in the Grenville orogenic belt. Province boundaries and ages after Tilton, et al (1962) and Stockwell (1962).

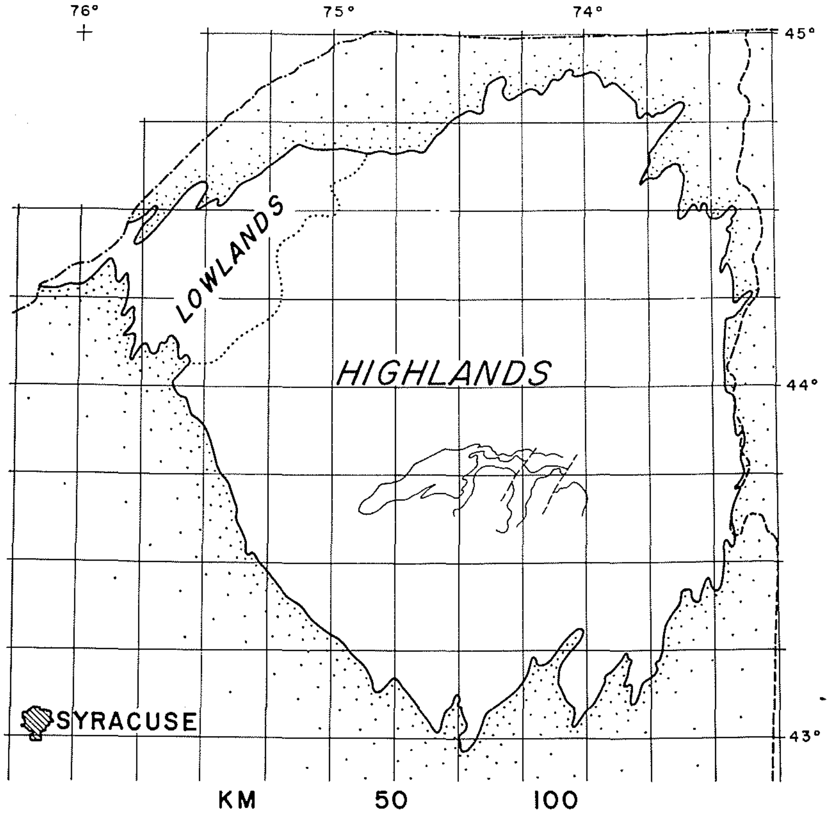

Fig. 2. Location of the investigated region in the south-central Adirondack highlands.

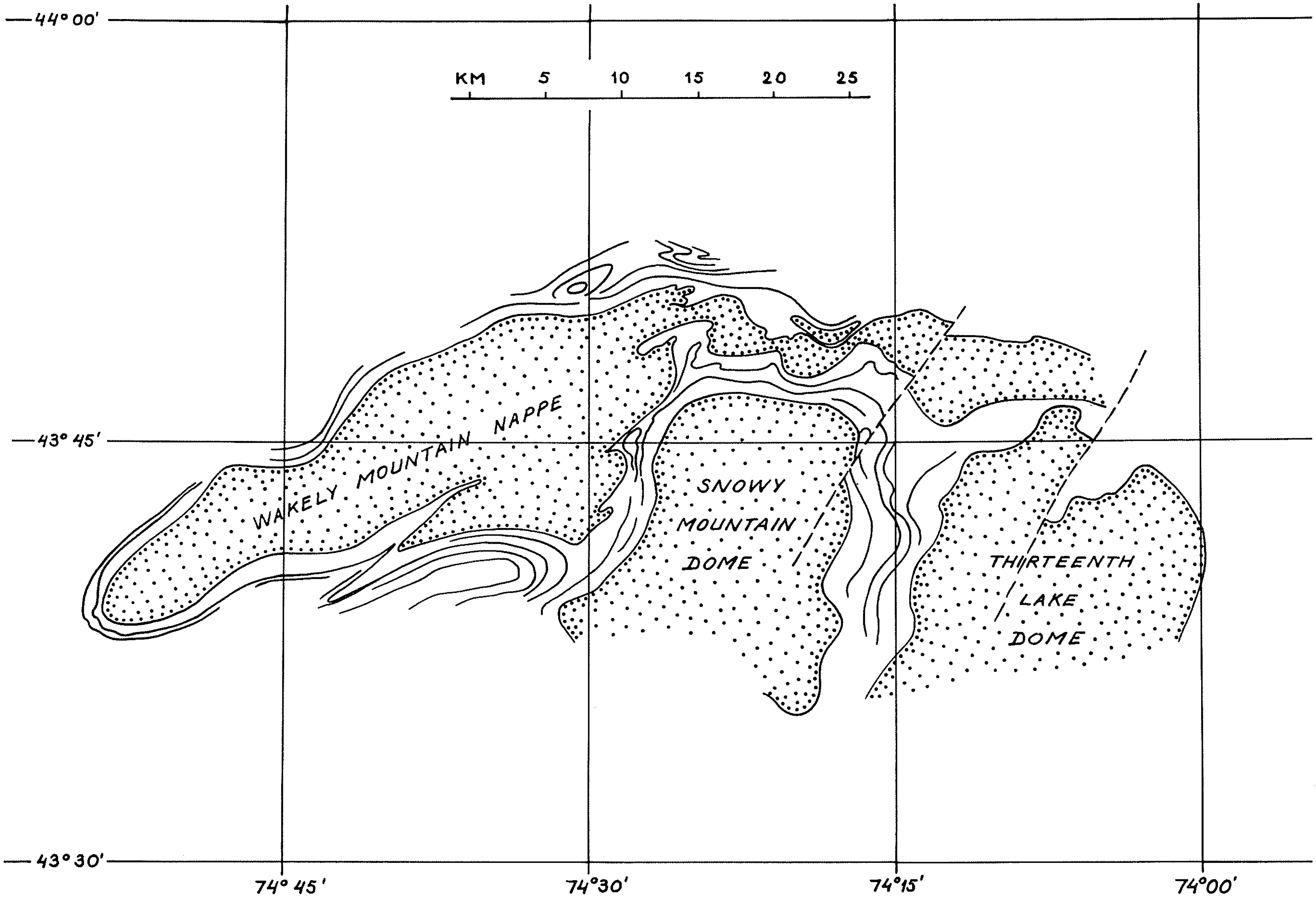

Fig. 3. Basement-supracrustal relationship in the south-central Adirondack highlands. Anticlinal cores (stippled) of basement rocks are enveloped in mantles of supracrustal rocks which join in synclinal keels.

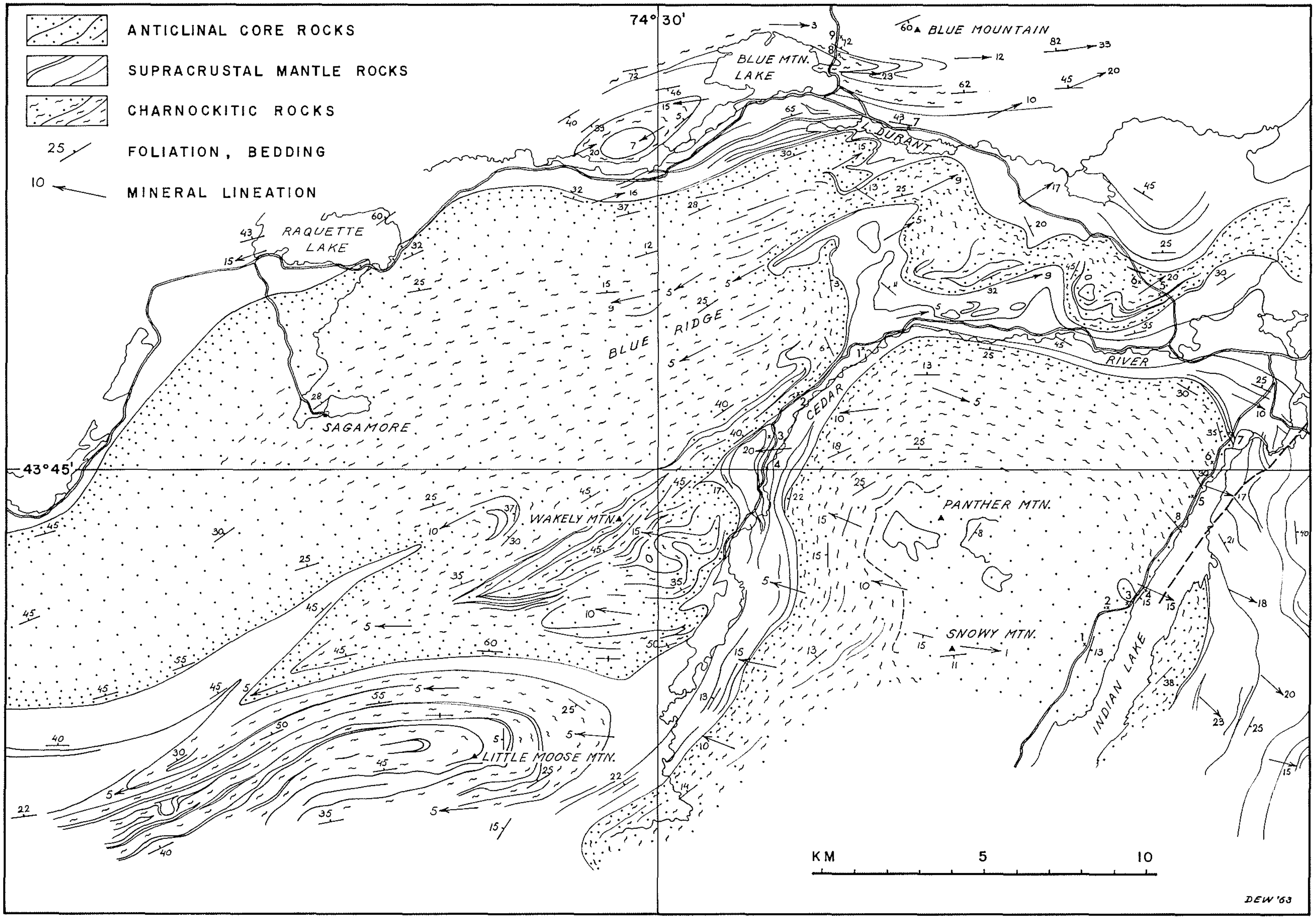

Fig. 4. Tentative geologic map of the Raquette Lake - Blue Mountain Lake - West Canada Lakes - Indian Lake region in the south-central Adirondack highlands. The map shows the major occurrences of charnockites in the basement complex and in the supracrustal sequence.

details the structural pattern of the Pennine nappes in the Swiss Alps. Basement rocks form the cores of anticlinal structures which vary in shape from domes and doubly-plunging anticlines to recumbent anticlines and nappes. The anticlinal cores are enveloped in mantles of supracrustal rocks which join in deeply-wedged synclinal keels. Catazonal environment of tectonics is demonstrated by the plastic behavior of most rock types, in particular of marble, and gneisses of granitic composition. It is further expressed in the folded shape of axial planes of folds and in the strong spatial variation of fold-axis orientations represented by the regional b-lineation pattern.

4. In rocks with granitic components migmatites occur as vaguely bordered patches and streaks of commonly unoriented, hypidiomorphic-granular granite surrounded by foliated metamorphic rock. Crocydite and stromatite are the most common migmatites in the Adirondack highlands, followed by dictyonite and nebulite. The granite of the metatect is interpreted to have developed in place or in its immediate vicinity by anatexis. During high-grade metamorphism, granite melt will form in quartz, K-feldspar, and plagioclase-bearing rocks if water is present. Small amounts of melt may have been generated throughout the rock as an intergranular film which increased the structural mobility of the rock unit during deformation. Migmatites developed by partial melting of rock of granitic composition and by migration of melt to structurally controlled sites. Dilatant sites were formed during deformation in rock units which reacted more rigidly than surrounding rocks. Anatectic melt was derived from the neighboring rock and moved into fissures of the rigid rock unit, there to form apophyses which have given rise to misinterpretation of age relations between the two rocks. The amount of metatect present in metamorphic rocks of granitic composition indicates that sufficient water was present to melt up to about 5 per cent of the rock. Granitic magmatism during the Grenville orogeny was thus limited to these venitic migmatites and to apophyses, pegmatite dikes, and some small, locally mobilized, granitic bodies. Predominantly dry conditions, apparently, prevented large-scale anatexis in the Adirondack highlands.

GEOLOGIC EVOLUTION

During the Grenville orogenic cycle, approximately 1.1 b.y. ago, supracrustal and basement rocks were metamorphosed and deformed to a complex structure of mantled domes, folds, and nappes. The basement was formed during an earlier, pre-Grenville orogenic cycle, and presumably consisted of metamorphic and plutonic rocks, the nature and origin of which are now largely obscure. Supracrustal rocks were deposited on the denudated surface of this older terrane. Basement and supracrustal rocks were intruded by olivine-basaltic magma which consolidated as gabbro and ophitic dolerite in sills and lenticular bodies. All rocks were affected by high-grade metamorphism during the Grenville period.

Evidence is lacking for the origin of gneisses and charnockites which occur interlayered with metasediments in the supracrustal sequence. Conglomerates, arkoses, and acidic volcanics may all conceivably be metamorphosed to foliated rocks of granitic composition. Conditions during metamorphism varied to the extent that most of the granitic rocks of the basement and part of those in the supracrustal sequence were metamorphosed to charnockites while others became hornblende or biotite gneisses. Metamorphic conditions also controlled the extent of magmatism during the Grenville orogeny. The occurrence of anatectic granite is limited to some small, nebulite-bordered granite bodies, and to the presence of venitic migmatites in metamorphosed rocks of granitic composition.

The present sequence of geologic events as compared with the concept of previous investigators is shown in table 1.

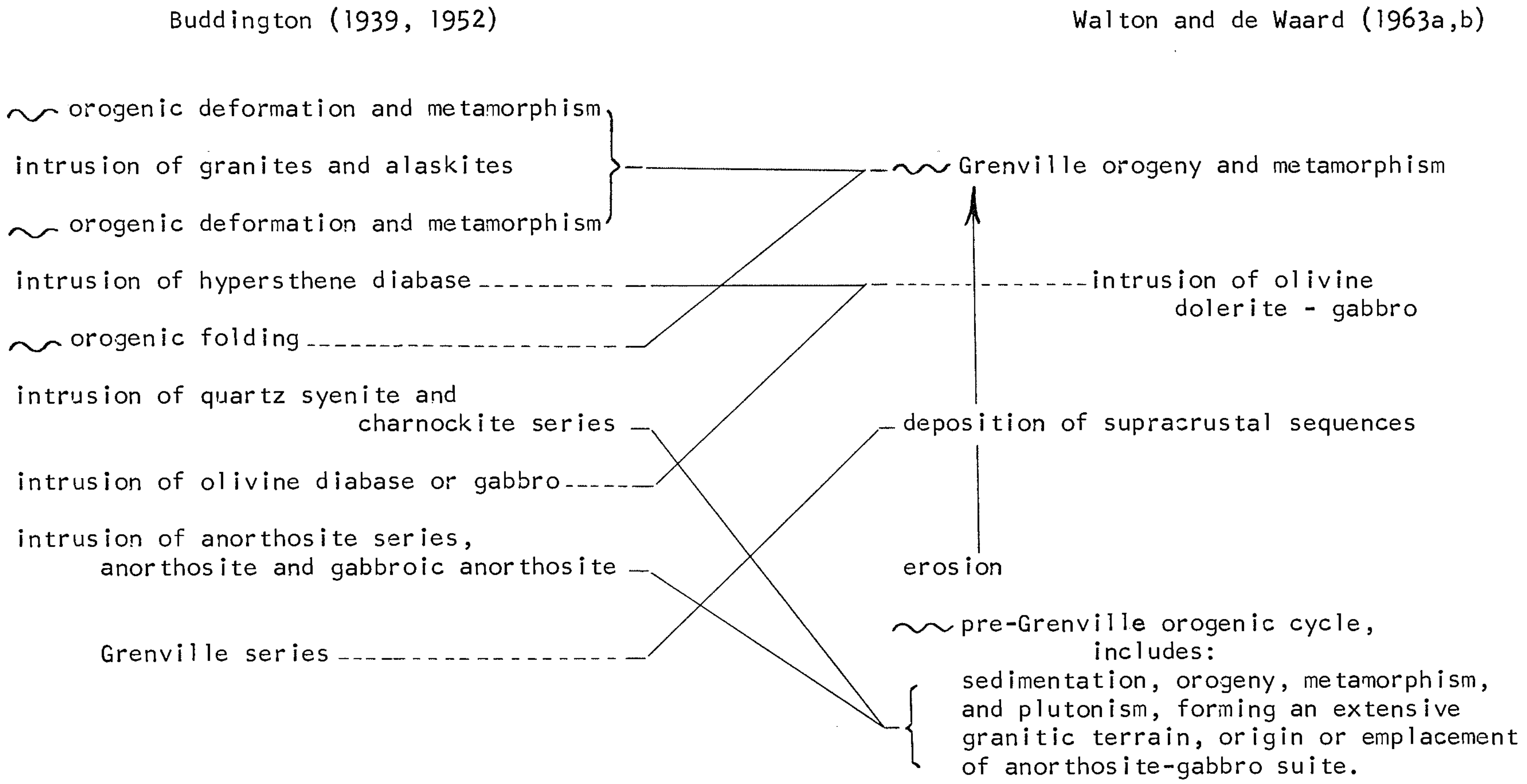

Table 1. Geologic evolution of the Adirondacks, a correlation of two concepts.

CHARNOCKITES AND CHARNOCKITIZATION IN THE CENTRAL ADIRONDACKS

Charnockites are widespread in the Adirondack highlands. They were formed during high-grade metamorphism from pre-existing quartzofeldspathic rocks of diverse origin. In part they developed from rocks of a supracrustal sequence, and in part from rocks belonging to an underlying basement complex which originated during a cycle of diastrophism, metamorphism, and plutonism, previous to the Grenville orogenic cycle.

Charnockites are confined to portions of the basement complex and to certain layers in the supracrustal sequence. Their occurrence is explained as having been formed from initially dry, pre-existing rocks of granitic composition, i.e., from crystalline rocks with sparse amounts of hydrous minerals. Charnockites in the basement complex may have developed from metamorphic and plutonic igneous rocks, and those in the supracrustal sequence from acidic volcanics.

Charnockitization is a metamorphic process. P_{load}-T conditions were above the alkali feldspar solvus maximum, above the curve for the reaction: garnet + sillimanite + quartz $\leftrightarrow$ cordierite, and below the kyanite $\leftrightarrow$ sillimanite inversion curve. P_{water} varied from place to place to form orthopyroxene in charnockitic rock units but not in biotitic and hornblendic gneiss units.

Mineral assemblages in the investigated area are predominantly those of the hornblende-granulite subfacies. In certain rock units and in layers within rock units assemblages occur which are characteristic for the sillimanite-almandine-orthoclase subfacies or for the pyroxene-granulite subfacies. Hornblende and biotite, which are common additional phases in the Adirondack charnockites, are regarded to be stable in the hornblende-granulite subfacies. Equilibrium between coexisting hydrous and anhydrous ferromagnesian phases is considered to be controlled by Mg/Fe ratios, and to be dependent upon the bulk composition of the rock, water pressure, and temperature. The difference in metamorphic facies between charnockitic and gneissic rock units is explained as the result of a difference in water pressure which reflects a difference in initial water content between these rock units.

ANORTHOSITE-CHARNOCKITE RELATIONSHIPS

Relationships between anorthosites and charnockites can be observed in the anticlinal core rocks of Snowy Mountain dome. Coarse, bluish-gray, crystalloclastic, andesine anorthosite at the center of the dome resembles the Marcy anorthosite of the eastern Adirondacks. Near the borders of the anorthosite the size of large crystals diminished locally until the rock becomes a granulated mass of plagioclase similar to the Whiteface anorthosite. In the contact zone between the anorthosite and the overlying metanorite the two rock types intermingle in an irregular, patchy fashion, with each commonly retaining its own lithologic characteristics. Less commonly an intermediate rock type with the texture of the anorthosite and the composition of the norite is found.

The metanorite is distinguished from the underlying anorthosite by its smaller grain size and higher mafic content. Metanorite with well-preserved palimpsest texture grades outward into well-foliated andesine augen gneiss and ultimately into homogeneous, streaky gneiss (fig. 5).

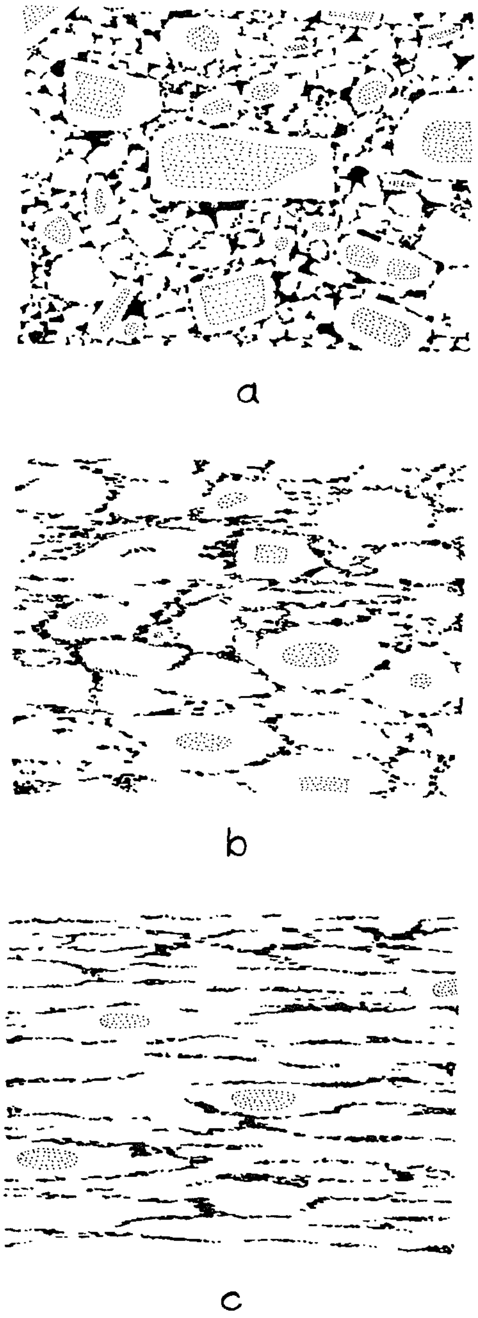

Fig. 5. Three stages in the gradual transition from (a) palimpsest texture of metanorite, to (b) weakly foliated metanorite, and to (c) well-foliated andesine augen gneiss or Keene gneiss. Andesine cores and augen are shown in stippled pattern. Approximately natural size. (From de Waard & Romey, 1963)

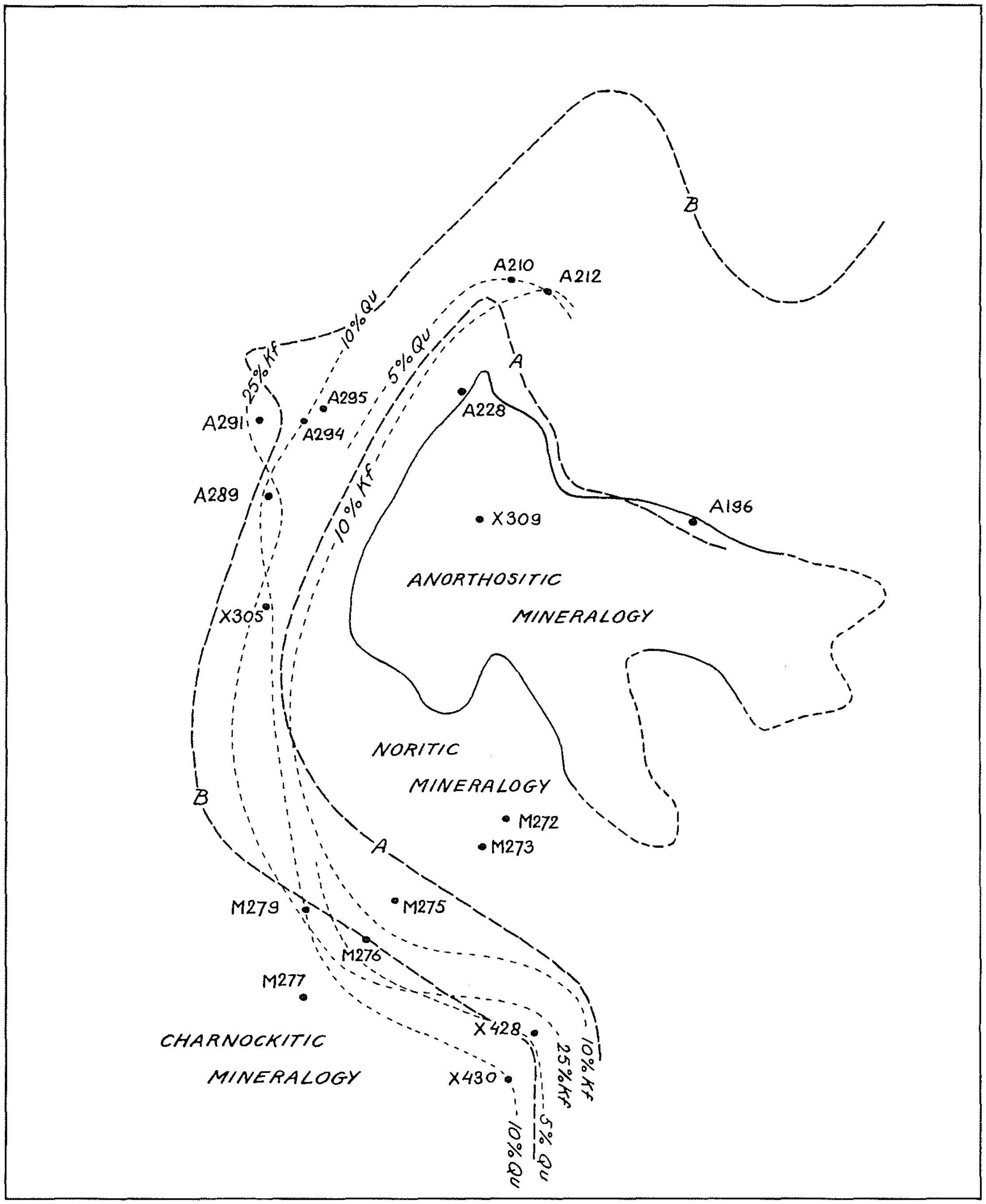

Fig. 6. Textural and compositional boundaries and gradations in the central part of Snowy Mountain dome. Arbitrary textural lines from center outward: (A) indicates the approximate location of the transition from deformed blastonoritic texture to augen-gneiss texture; (B) indicates the approximate zone in which the number of andesine augen decreases to less than one per square meter. Compositional boundaries and isopleths: solid line indicates the boundary zone between anorthosite and metanorite; dashed lines are the isopleths of 10 and 25 per cent modal K feldspar, and 5 and 10 per cent modal quartz. The intersection of structural line A with the anorthosite-metanorite boundary zone reflects the occurrence of the finer-grained and foliated Whiteface-type anorthosite developed along this part of the boundary. (From de Waard & Romey, 1963).

Concomitant with the textural transition from norite to augen gneiss and streaky gneiss, which appears to be entirely due to a gradual increase in intensity of deformation during the metamorphism of the norite, subtle changes in mineralogy also occur. While the foliation increases and the andesine augen decrease in size and number, K feldspar and quartz become noticeably present, and the gray-green, streaky gneiss which appears to be the final product in this process is in effect a quartz and orthopyroxene-bearing microperthite gneiss or charnockite.

Recrystallization, granulation, and foliation of the anorthosite and norite occurred during the Grenville period of metamorphism and deformation. The degree of metamorphism was in the granulite facies. Recrystallization was incomplete as shown by the presence of large andesine crystals and relic pyroxenes in both the anorthosite and the norite. The anorthosite behaved as a relatively rigid body during deformation with shearing and granulation occurring along fairly widely spaced planes. Granulation and recrystallization were more intense near the borders of the massif where the grain size of crystalloclasts diminishes. The metanorite next to the anorthosite had a relatively sheltered position and was consequently little deformed.

Textural gradation from metanorite to andesine augen gneiss and ultimately to charnockite is entirely due to the gradually increasing effect of deformation from the center of the dome outward.

There are two possible explanations for the concomitant mineralogical gradation from metanorite to charnockite: (a) The transition may be primary, caused during the pre-Grenville orogeny, and associated with the development of the anorthosite-norite body. The gradual increase in quartz and K feldspar may have been a factor which made the rock more susceptible to the development of foliation. (b) The transition may be secondary, caused by metasomatism during the development of foliation in the Grenville period of deformation and metamorphism. Replacement increased with the intensity of deformation. Charnockite developed by metasomatism, metamorphism, and deformation from norite. (condensed from de Waard and Romey, 1963).

MINERAL ASSEMBLAGES OF CHARNOCKITES IN THE GRANULITE FACIES

Rocks of the central Adirondack highlands have been metamorphosed predominantly in conditions of the hornblende-granulite subfacies. In the Adirondacks, as well as in other charnockite regions, there are two distinctive features which characterize hornblende-granulite-subfacies terranes, viz., (1) mineral assemblages of the hornblende-granulite subfacies consist of coexisting anhydrous phases of the granulite facies and hydrous phases of the almandine-amphibolite facies in apparent equilibrium with each other, and (2) rock units or rock layers with assemblages of the hornblende-granulite subfacies commonly occur intimately intermingled with those apparently of higher and of lower subfacies. These two related characteristics can be explained as follows.

The hornblende-granulite subfacies represents univariant equilibrium for boundary reactions between the almandine-amphibolite and granulite facies, provided that variable cation ratios in mafic phases remain constant (or divariant equilibrium if systematic changes occur). Mineral assemblages in which reactants and products of those reactions coexist are, therefore, typomorphic for the hornblende-granulite subfacies. Equilibrium between phases on both sides of the boundary reactions may have been maintained over a relatively wide P-T interval because of reciprocity between liberated water and water pressure in rocks of low permeability. Varying cation ratios influence the stability of mafic minerals and affect the P-T conditions of the reactions. Local differences in bulk composition of the rock and in water pressure and temperature may result in departures from the univariant equilibrium to either side of the boundary reactions, and intermingled development may be expected with almandine-amphibolite-facies and with pyroxene-granulite-subfacies assemblages.

The following reactions characterize the transition from the almandine-amphibolite facies to the granulite facies:

(1) hornblende + 4 quartz $\longleftrightarrow$ 3 orthopyroxene + clinopyroxene + albite + anorthite + H_2O

(2) 2 biotite + 12 quartz $\longleftrightarrow$ 8 orthopyroxene + garnet + 4 orthoclase + 4 H_2O

(3) 6 biotite + 8 sillimanite + 28 quartz $\longleftrightarrow$ 11 garnet + 12 orthoclase + 12 H_2O

(4) hornblende + 2 biotite + 17 quartz $\longleftrightarrow$ 15 orthopyroxene + 4 orthoclase + albite + 2 anorthite + 5 H_2O

(5) hornblende + garnet + 5 quartz $\longleftrightarrow$ 7 orthopyroxene + albite + 2 anorthite + H_2O

All but reaction (3) produce orthopyroxene which is the index mineral for the granulite facies. Orthopyroxene forms in a wide range of rock compositions, viz.; in all rocks except for the calcareous and aluminous rocks. The first (prograde) appearance in the field which delineates the orthopyroxene isograd is, therefore, the best possible boundary between almandine-amphibolite and granulite-facies terranes.

The hornblende-granulite subfacies, established by Fyfe, Turner, and Verhoogen (1958) is unique among the metamorphic facies and subfacies in being the only one to have the same reactions define its lower as well as its upper boundary. The left-hand sides of equations (1) to (5) represent stable assemblages in the upper almandine-amphibolite facies (sillimanite-biotite-orthoclase subfacies), and the right-hand sides represent typical anhydrous assemblages of the pyroxene-granulite subfacies. The hornblende-granulite subfacies is thus defined as the range of conditions in which equilibrium exists between the mineral phases on both sides of the reactions.

The tentative ACFK diagram for the hornblende-granulite subfacies, shown in fig. 7, represents a combination of sillimanite-biotite-orthoclase and pyroxene-granulite-subfacies diagrams. The hydrous phases hornblende and biotite, shown with dashed lines in sillimanite-biotite-orthoclase subfacies configuration, are in equilibrium with the anhydrous phases of the pyroxene-granulite subfacies which is represented by full lines.

The following charnockite compositions are typical for the hornblende-granuline subfacies and most of these are widespread in charnockite terranes. The mineral assemblages can also be predicted by applying reactions (1), (2), and (4) to assemblages of rocks similar in bulk composition belonging to the sillimanite-

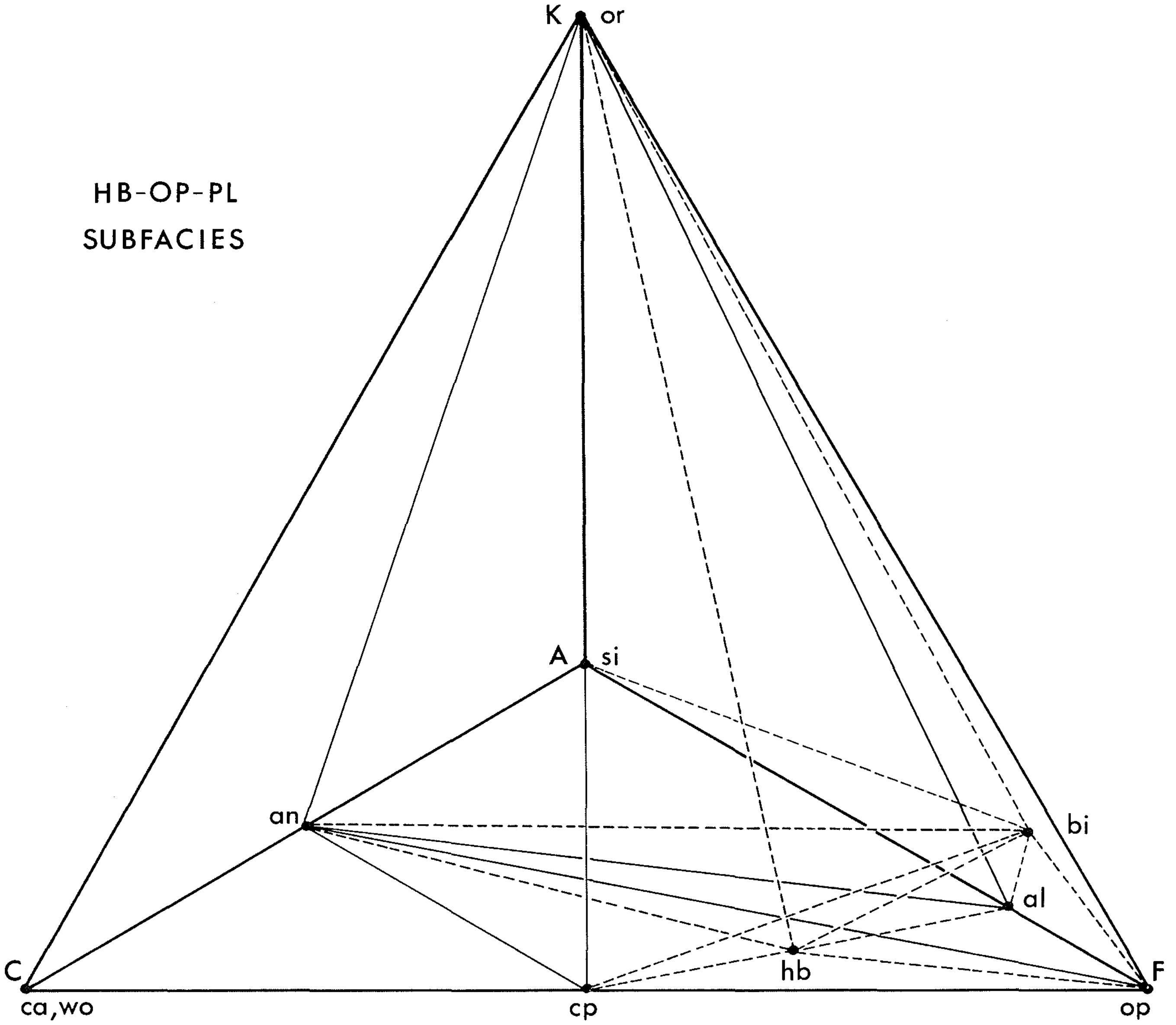

Fig. 7. Tentative ACFK tetrahedron diagram for the hornblende-granulite subfacies (hornblende-orthopyroxene-plagioclase subfacies).

biotite-orthoclase subfacies or the pyroxene-granulite subfacies which are given in the table for comparison.

si-bi-or subfacies	hb-granulite subfacies	py-granulite subfacies
K-feldspar gneisses	charnockites	charnockites or acidic granulites

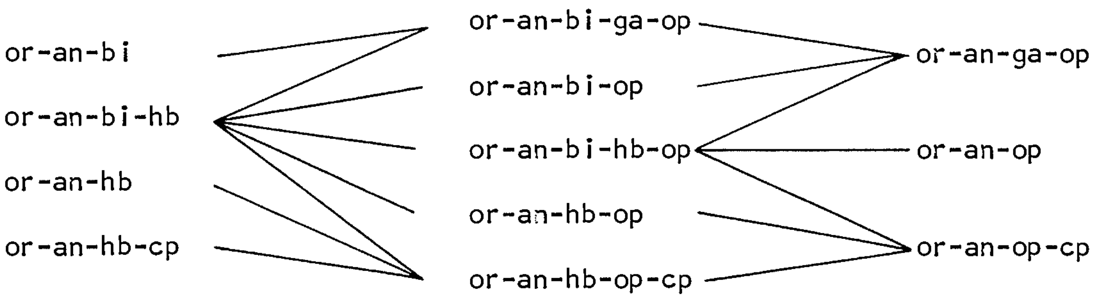

Table 2. Correlation of mineral assemblages of charnockites and chemically similar gneisses and granulites, expressed in phases of ACFK diagrams. The feldspars are commonly combined in perthite, and quartz is always present. The assemblages are listed in order of decreasing alumina and increasing lime content.

With increasing load pressure the following reaction between anhydrous phases of the granulite facies is expected to proceed to the right:

(6) 6 orthopyroxene + 2 anorthite ⟷ clinopyroxene + 2 almandine + 2 quartz

The local occurrence in the central Adirondack highlands of charnockites and metabasites in which the pair orthopyroxene - plagioclase is partly or entirely replaced by the pair clinopyroxene - (calcic) almandine suggests a possible subdivision of the hornblende-granulite subfacies into a hornblende-orthopyroxene-plagioclase subfacies and a hornblende-clinopyroxene-almandine subfacies, and a subdivision of the pyroxene-granulite subfacies into an orthopyroxene-plagioclase subfacies and a clinopyroxene-almandine subfacies. In the following table a correlation is given of mineral assemblages of charnockites in the two hornblende-granulite subfacies.

op-pl subfacies	hb-op-pl subfacies	hb-cp-al subfacies	cp-al subfacies
charnockites or acidic granulites	charnockites	charnockites	charnockites or acidic granulites

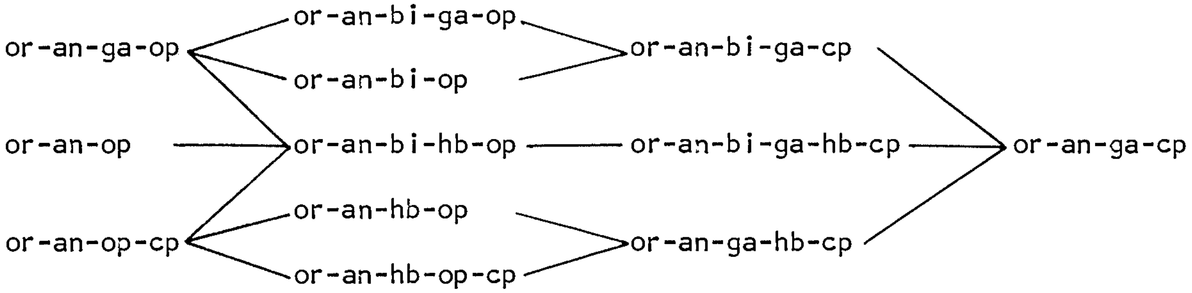

Table 3. Complete list of possible mineral assemblages of charnockites expressed in phases of ACFK diagrams (quartz always present and perthitic feldspar common) in order of decreasing alumina and increasing lime content.

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TRIP A: Cedar River - Blue Mountain section

On route 28-30, 9.3 miles east of Blue Mountain Lake and 2.1 miles west of Indian Lake village, take Cedar River Road which branches off west of the cemetary to the south.

Mileage

0 Intersection Cedar River Road with route 28-30.

6.7 Stop 1. View towards the southwest from hill opposite Cedar Bend Lodge (ask permission). In the Cedar River valley marble and other supracrustal rocks are exposed which are folded in a synclinal keel wedged in between the Snowy Mountain dome towards the south (left) and the Wakely Mountain nappe towards the west (right). Dip of foliation and bedding in the structure is to the northwest (right), and the fold axis plunges west. Dip slopes of the Snowy Mountain dome are visible towards the south. Gneisses of the Wakely Mountain nappe are exposed in Wakely Mountain, Round Top, and Blue Ridge to the west. Sugarloaf Mountain in the center is the gneissic core of the syncline.

8.5 Stop 2. Ledges in bushes on right are charnockitic gneisses which form the uppermost overturned portion of the core of Wakely Mountain nappe. Stratigraphically overlying amphibolite and marble are exposed in several places along the road.

9.6 Stop 3. Short walk up hill to the right to the first ledges of Sugarloaf Mountain. Traverse across supracrustal strata of diverse composition (marble, amphibolite, layered gneisses, diopsidic quartzite and gneiss, diopsidite) towards the core of the syncline which consists of biotite-(hornblende)-microcline-oligoclase-(pp. mesoperthite)-quartz gneiss.

10.3 Stop 4. Small trail to the left down to the Cedar River. Gorge and falls in marble. Walls demonstrate intense plastic deformation and flow folding in the marble, distortion and rotation of amphibolite pieces. Exposures of amphibolite, quartzite, and sillimanitic garnet-biotite gneiss.

0 Return to the insersection with route 28-30, and turn left towards Blue Mountain Lake.

1.1 Stop 5. On the left, about 30 meters in the bushes, is a small outcrop of amphibolitized metadolerite (sill in charnockitic gneiss of Stop 6). The amphibolite consists of andesine, hornblende, and orthopyroxene. The exposure shows some large garnet porphyroblasts (15 cm diameter) similar to those of the famous Gore Mountain occurrence. PLEASE DON'T SAMPLE THE GARNET HERE. Others may like to see this outcrop after you.

1.5 Stop 6. Road cut on the left shows typical grey-green, hornblende-bearing, perthitic charnockite of the basement core of the Wakely Mountain nappe.

7.6 Stop 7. Large road cut on the north shore of Lake Durant. The section of diverse, layered metamorphic rocks includes pink and greenish leucocratic gneisses with thin metabasic layers, marble, and calc-silicate rocks. The section forms part of the supracrustal sequence which overlies the leptites of the Wakely nappe exposed in the hills visible towards the south across the lake, and which underlies the Blue Mountain charnockite sequence towards the north. Lineations on foliation planes indicate a 30° NE plunging fold axis. The intrusive nature of marble into boudinaged layered gneiss is shown on the west end of the north side of the road cut.

9.3 Intersection of route 28-30 and 28N-30 in Blue Mountain Lake. Turn right towards Long Lake.

10.2 Stop 8. Road cut on the right just downhill from diner, in charnockite of the supracrustal sequence. The grey-green charnockite, interlayered with metabasic rocks and tremolite schist (in the brook), is part of a series of charnockitic rocks which presumably forms an isoclinally folded, complex syncline (Blue Mountain). The charnockite layers, which overlie the marble exposed in the lake and the rocks of stop 7 north of Lake Durant, form part of the supracrustal envelope of the Wakely-Mountain nappe. The Blue Mountain charnockite sequence is considered to be equivalent to the Little Moose Mountain sequence of charnockites. They are stratigraphically the youngest supracrustal rocks known in this area. The composition of the charnockite at this stop is predominantly: quartz-microperthite-oligoclase-hornblende-orthopyroxene-clinopyroxene.

10.5 Stop 9. Large exposure in the brook on the right shows pattern of typical migmatite (crocydite) in quartzofeldspathic metamorphic rocks of the Adirondack highlands. The metatect is anatectically generated granite in hornblende-biotite-quartz microcline microperthite oligoclase gneiss. The gneiss grades into charnockite and belongs to the Blue Mountain charnockite sequence.

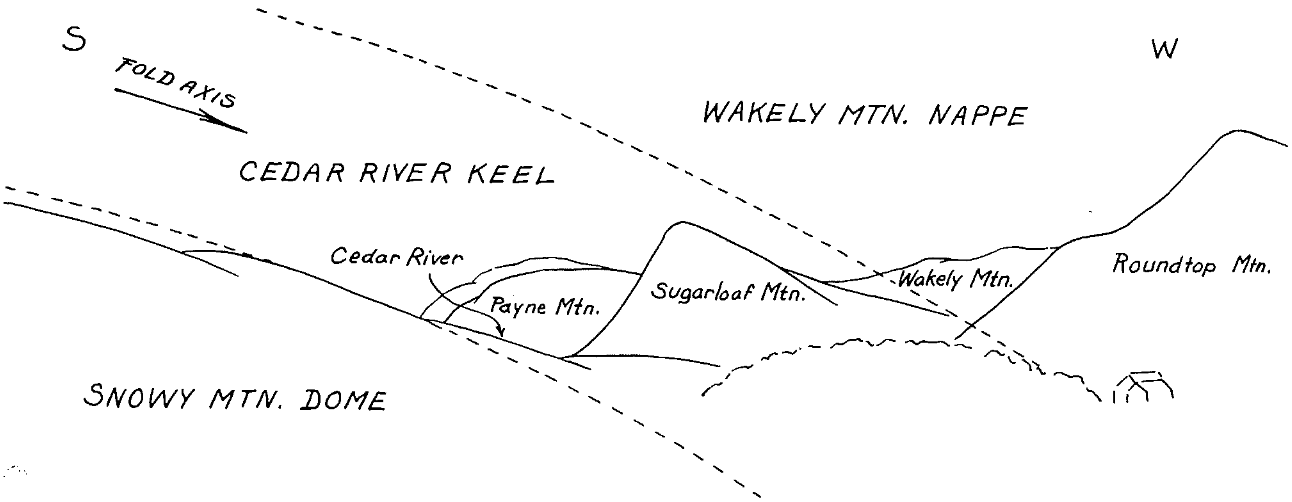


Fig. 8. View from hill at Stop 1 (Cedar River road) towards the southwest. Dashed lines demonstrate the structural relationships. Cores of anticlinal structures are separated by isoclinally folded supracrustal layers of the Cedar River synclinal keel. Note dip slopes of Snowy Mountain dome and Sugarloaf Mountain. Marble layers in the supracrustal sequence caused the Cedar River valley.

TRIP A: Snowy Mountain section (by William D. Romey)

Mileages are measured from the intersection of New York highways 28 and 30 in the center of the town of Indian Lake. Take highway 30 south towards Speculator.

Mileage

0 Intersection of highways 28 and 30 in Indian Lake village.

7.4 Stop 1. Roadcuts 0.1 miles west southwest of trail leading to the top of Snowy Mountain. K feldspar-plagioclase-quartz-andesine-pyroxene-hornblende augen gneiss (charnockitic "Keene"-type gneiss) of the type which is widespread in Snowy Mountain dome. Foliation about horizontal.

6.5 Stop 2. From the highway walk west a few yards along a narrow dirt road to flat outcrops. Andesine-pyroxene-hornblende gneiss with relict ophitic to hypidiomorphic granular texture preserved. Note relict cores of dark gray plagioclase (An_{42}) surrounded by recrystallized plagioclase (approximately An_{34}). Square masses of plagioclase are outlined by partially recrystallized mafic minerals. This rock is similar to some of Buddington's gabbroic anorthosites, but we have preferred to call it a (leuco) metanorite. Foliation dips west southwest at a low angle.

5.9 Stop 3. Large roadcut on the hill 0.4 miles southwest of the intersection of highway 30 with the lake shore road through Sabael. Anorthosite at the lower end of the outcrop is overlain by metanorite (unfoliated andesine-pyroxene-hornblende gneiss) which is in turn overlain by streaky andesine-pyroxene-hornblende augen gneiss. Both "Marcy-" and "Whiteface-" type anorthosites are present. The grain size of metanorites ranges from coarse to fine, and the original texture of the rock is preserved to various degrees in different parts of the exposure. Several small amphibolite (metadolerite) lenses may be observed in the streaky gneiss. Foliation is nearly horizontal. Walk up the steep hillside above the road to see massive ledges of anorthosite, metanorite, and a rock which is texturally and compositionally intermediate between these two types.

5.5 Stop 4. From the intersection of highway 30 with the lake shore road through Sabael walk east about 100 yards on a private road (get permission) leading to a house on a small peninsula. Outcrops are on the lake shore east of the house. Well-foliated K feldspar- plagioclase-quartz-orthopyroxene-clinopyroxene-hornblende gneiss (charnockite). Domal structure of the complex on the east side of Indian Lake can be observed from the point east of the intersection.

3.5 Stop 5. Roadcuts on the main road 0.1 miles northeast of Squaw Brook. Charnockitic augen gneiss similar to the rock seen at stop number 1 (K feldspar-quartz-plagioclase-hornblende-pyroxene-(biotite)-augen gneiss).

2.8 No stop. From the bus observe banded gneisses in roadcut. K feldspar-quartz-plagioclase-amphibole gneiss is interlayered with plagioclase-hornblende-biotite amphibolite.

2.6 Stop 6. Roadcuts consisting of well-foliated, homogeneous, leucocratic charnockite (K feldspar-quartz-plagioclase-pyroxene-hornblende-garnet gneiss). A few amphibolite layers are present. This is the granitic end-member of the "syenite" series of Buddington. This is the last stop in what we have called "anticlinal core rocks".

2.0 Stop 7. Roadcuts consisting of banded microcline-quartz-plagioclase-hornblende-pyroxene gneisses. These are the first clearly supracrustal mantle rocks overlying the anticlinal core rocks. Note intense folding of the gneisses.

Possible extra stops

1.2 Roadcuts of feldspathic gneisses containing large diopside clots. About 0.2 miles west of the road are spectacular exposures of the same gneiss in a newly reopened quarry (get permission to visit).

0 Cross-road in Indian Lake village

0.5 East of Indian Lake village on highway 28 there are flat outcrops of amphibolite and very coarse-grained white marble at the outlet to Adirondack Lake. At times of high water these cannot be easily seen.

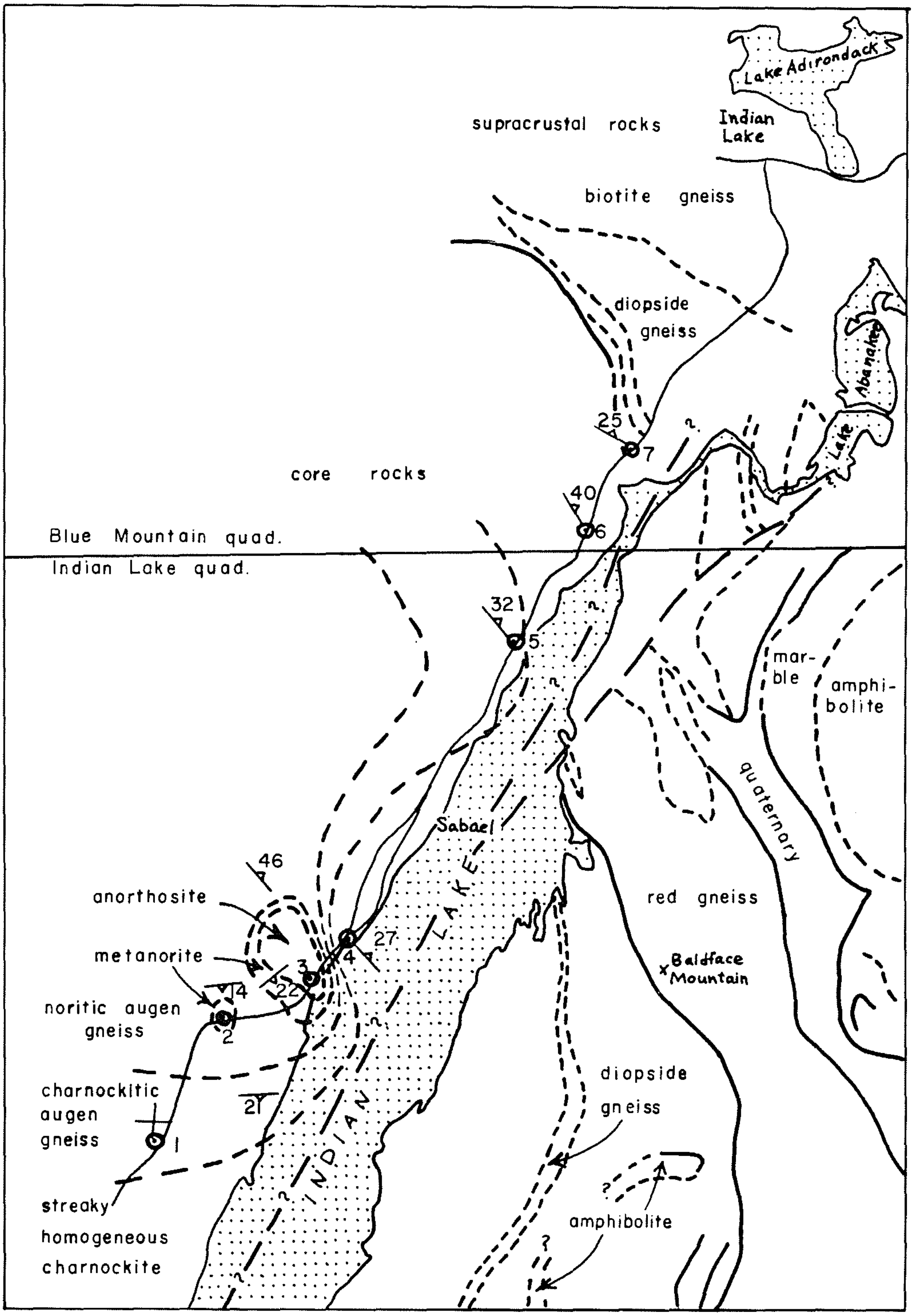


Fig. 9. Geologic sketch map of the northeastern corner of the Indian Lake quadrangle and southeastern corner of the Blue Mountain quadrangle. Data are taken from geologic maps by William D. Romey, Dirk de Waard, and Cole Letteney.

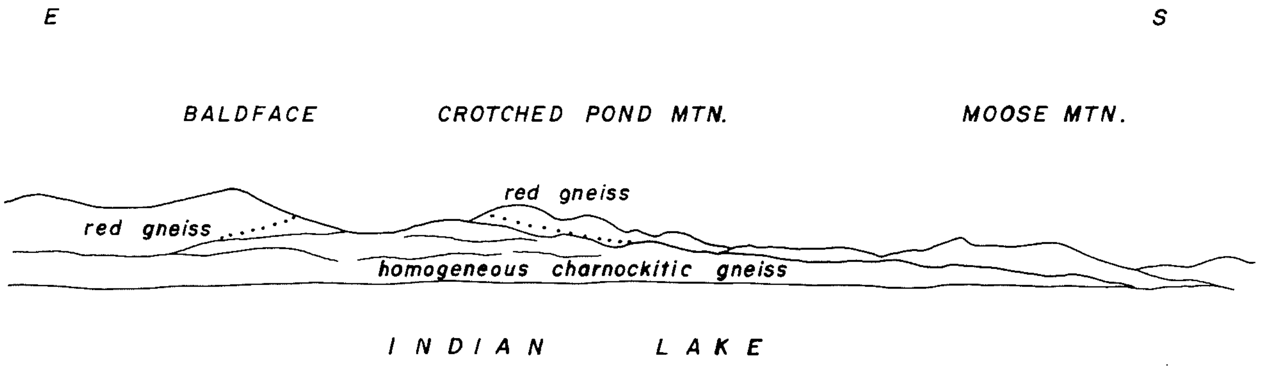
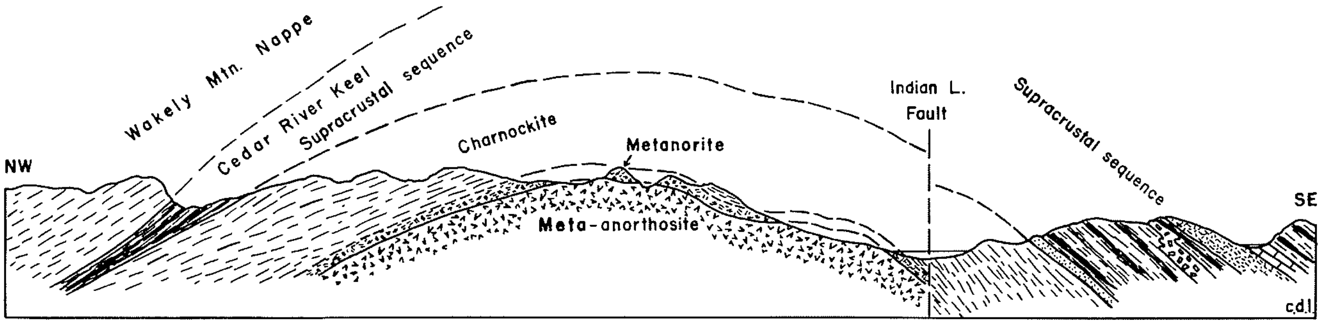


Fig. 10. View east from stop number 4 (Snowy Mountain section) across Indian Lake.



Schematic Section across Snowy Mtn. Mantled Gneiss Dome

Table 4

Approximate Mineral Content of Rocks along the Snowy Mountain Section

Legend: o - less than 5%; x - 5 to 20%; * - more than 20% ;
a - antiperthitic K feldspar in plagioclase

Rock No.	name	pf	kf	qu	hb	cp	op	ga	bi	ore
W117 (stop 2)	metanoritic gneiss	*	a		x	x	x	o		o
W118A	metanorite	*	a				*			o
W118B	metanoritic granulite	*	x		x	x	x			o
W118C	plagioclase granulite	*				o	*		o	o
W119A (stop 3)	meta-anorthosite	*	a		o					o
W119B (stop 3)	metanoritic granulite	*	o	o	x	x		o	o	o
W119C (stop 3)	noritic augen gneiss	*	x	o	x	x	x			o
W120 (stop 4)	charnockite	*	*	o	x	x	x			o
W121	charnockite	*	*	x	o	x	x			
W122	charnockite	*	*	x	x	x	x			o
W123	charnockitic augen gneiss	*	x	x	x	x	x			o
W124 (stop 5)	charnockitic augen gneiss	*	*	x	x		x		o	o
W125	charnockite	*	*	*	x	x	o			o
W126A	K spar gneiss	x	*	*	x					o
W126B	biotite amphibolite	*		o	*	o	o		o	
W127 (stop 6)	leucocratic charnockite	*	*	*	o	o	o	o		o
W128	K spar gneiss	*	*	x	x					o
W129	biotite amphibolite	*			*	o	o		x	
W130 (stop 7)	K spar gneiss	*	*	*	x	o				o

SURFICIAL GEOLOGY OF THE SYRACUSE FIELD AREA

by Ernest H. Muller

Introduction

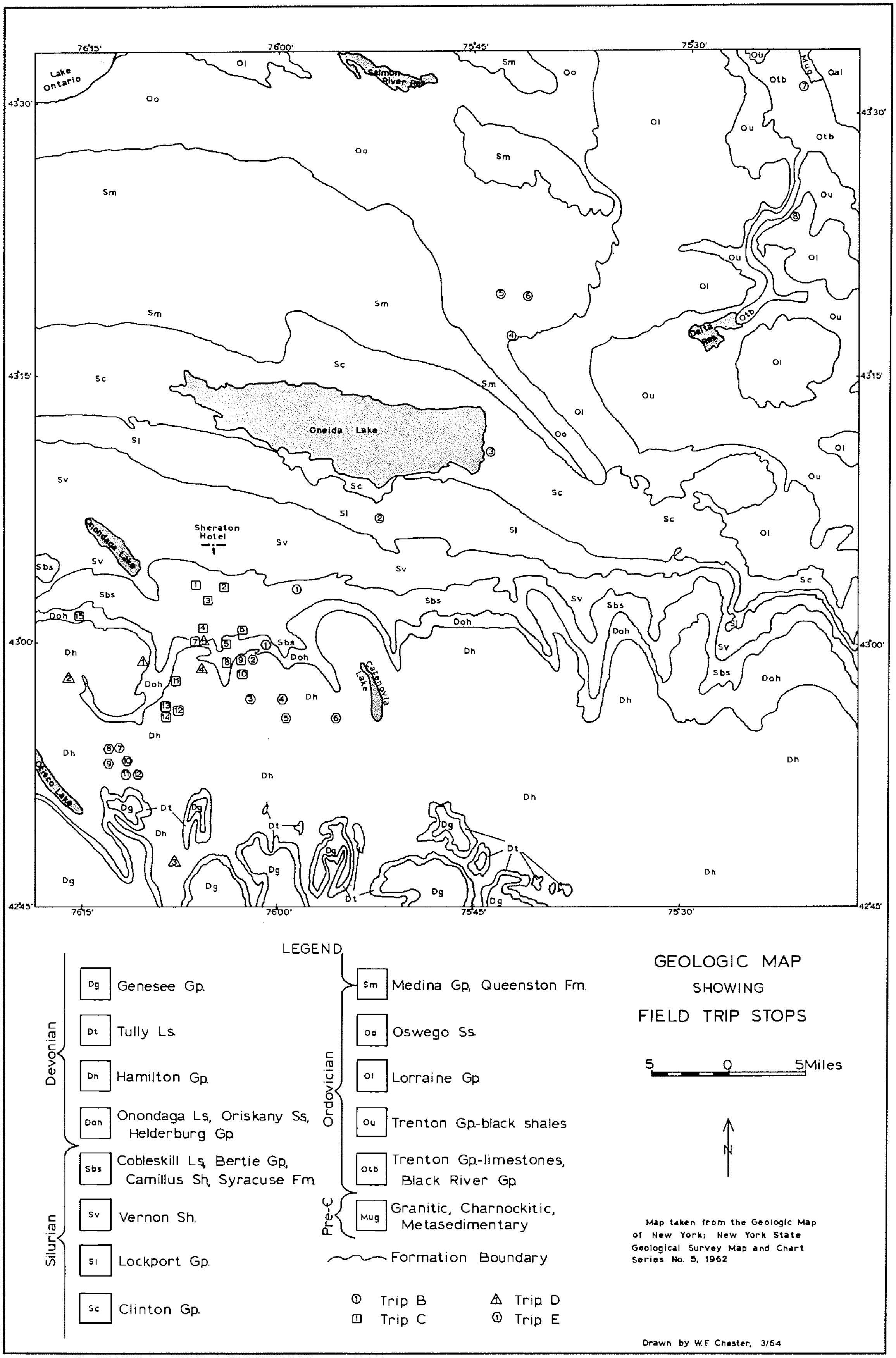
The following notes provide a frame of reference for field trips in the Syracuse area, planned for the 36th Annual Meeting of the New York State Geological Association, May 8-10, 1964. These trips range from Rome in the east to Marcellus in the west and from Boonville in the north to Tully in the south. No effort is made to provide uniform treatment throughout the area of concern; rather, relationships at certain stops are developed in detail, whereas others are treated only in general terms.

Regional relationships

Syracuse is located in the border zone between two major physiographic provinces. North of the city, undulating plains of the Ontario Lowland stretch away to Lake Ontario. Streamlined ridges of glacial till give much of the lake plain its distinctive topographic texture. South of Syracuse, the land rises more than a thousand feet within a few miles, forming the north-facing margin of the Appalachian Uplands. Northeast of Syracuse the Oneida basin, an eastward extension of the Ontario Lowland, isolates the Tug Hill Plateau from the Appalachian Uplands to which it is physiographically related.

In unglaciated parts of Pennsylvania and lightly glaciated parts of southern New York, physiographic history is recorded in accordance of summits. Following late Paleozoic regional uplift, the Syracuse area presumably experienced similarly long erosion that beveled the southward dipping strata. Because intensity of glacial scour increased northward across New York, summits south of Syracuse are rounded and reduced in elevation, retaining only approximate summit accordance. Suggestive similarity of summit elevation in the Tug Hill Plateau and the upland south across Oneida trough led Newell (1940) to hypothesize correlation of the erosion surfaces. Such physiographic correlation is presently viewed with reservation because of strong evidence of intense glacial scour and marked structural control.

Paleozoic strata are exposed in generally east-west trending zones, with almost imperceptible regional dip southward beneath progressively younger beds (fig. 1). Differing resistance of these layers has resulted in a broadly cuestaform or terraced (Schichtstufenlandschaft of Hanefeld, 1960) character which may be as much a result of glacial scour as of normal erosional processes. Terrace and summit levels are characterized by generally north-facing scarps and more gentle southward dip slopes. Thus, the broad, east-west trending basin between the Tug Hill Plateau and the Appalachian Uplands is controlled largely by the trend of Silurian sediments. Within this lowland belt, the Lockport Dolomite forms a broad buried ridge that separates the Oneida and Cicero-Canastota depressions which are developed respectively on the Rochester and Vernon Shales. Massive carbonate strata in the Upper Silurian and Lower Devonian section support sloping bench remnants in the border scarp of the Appalachian Upland.



GEOLOGIC MAP
SHOWING
FIELD TRIP STOPS

Map taken from the Geologic Map of New York; New York State Geological Survey Map and Chart Series No. 5, 1962

Drawn by W.F. Chester, 3/64

Pre-glacial drainage of the plateau

Principal elements of the weakly cuestaform topography are assumed to be pre-glacial, the product of long drainage evolution and erosion throughout the Cenozoic Era. In the lowlands north of Syracuse, thick drift cover and intensive glacial scour obscure the preglacial drainage pattern, permitting inference only as to major drainage lines (see "Bedrock Topography in the Oneida Lake Area, New York). Differential scour was concentrated primarily along strike of non-resistant beds and through existing lowlands, particularly as they lay parallel to directions of prevailing ice-flow.

In the upland south of Syracuse the pattern of glacially-deepened through valleys gives evidence of controls inherited from the deeply-incised, mature pre-glacial drainage system. Short, steep obsequent streams drained the north margin of the plateau toward inferred ancestral drainage lines in the lowland. Longer, south-flowing streams followed resequent courses, ultimately crossing the transverse folds of the Ridge and Valley Province, or doubling back northward where captured by developing master obsequent streams. Representative of the latter is the Tully-Cortland valley system which apparently had its pre-glacial outlet southwest into the Cayuga trough and thence northward.

Between Stops 2 and 3, Trip D crosses the inferred divide between obsequent and resequent pre-glacial valleys. Drilling and seismic data show a pronounced rise of about 650 feet within the 3 miles from the Solvay Process brine field south across the Tully (Valley Heads) moraine to Tully Lake (Faltyn, 1957; Durham, 1958) in the Tully-Onondaga trough. This coincidence of association of the Tully moraine and the inferred bedrock divide led Durham to hypothesize similar control of Valley Heads moraine loops in other seismically uninvestigated through valleys.

Left-bank tributaries of Onondaga Creek, such as the one at Vesper on Trip D, enter Onondaga Creek from the northwest with barbed and hanging junctures. This relationship suggests progressive capture of headward tributaries of the south-flowing stream by an aggressive obsequent ancestral Onondaga Creek. Rampant piracy so close to the border scarp argues against great antiquity of the scarp in its present position prior to glaciation. The fact that the left-bank headwater tributaries in question occupy furrows parallel to glacier flow and shaped primarily by glacial scour suggests the possibility that their orientation may be a product of glacial control, rather than a reflection of pre-glacial drainage pattern.

Streamline glacial topography

Superposed on the broadly cuestaform character of the upland, and all but obscuring this gross relationship is the pronounced molding of most ridges and summits into elongate, parallel, elliptical hills. A few miles south of the border scarp, streamline hills such as Irish Hill (Trip D, Mile 49) are drumlinoids, composed of bedrock almost without till veneer. Farther north, most streamline hills are drumlins, composed entirely of lodgment till. A few, like Mt. Olympus on the Syracuse University campus, are demonstrably rock-cored.

Streamline topographic features in the Syracuse area indicate a field of glacial flow without major discontinuity such as might suggest a significant change in flow direction during waning of the ice sheet. Where the drumlin field is particularly prominent in the southeastern outskirts of Syracuse, the prevailing orientation of long axes is N28W. Southward it curves gradually to nearly due south. Maximum deviation from areal flow direction results from deflection of flow along the scarp or into an oblique through valley.

As products of glacial molding, streamline topographic features predate stagnant and marginal ice features that may occur among them. Thus at Mile 56.7, Trip D, a drumlin just east of Barker Hill Rd. is truncated by Smoky Hollow meltwater channel.

Moraines

Topographic features of the Tully glacial series have been described by von Engeln (1921). Features of the Tully moraine are observed near Stop 3 on Trip D. This massive, valley-stopping moraine is a part of the Valley Heads moraine system which in many central New York through valleys comprises the divide between St. Lawrence and Susquehanna watersheds. As in other through valleys, the Valley Heads moraine loop at Tully is notably steep and abrupt on its proximal (northerly) margin. It is much less impressive as approached from the south, because thick outwash deposits comprise a ramp leading south from the distal edge of the moraine.

Stratified drift comprises most of the exposed area of the Tully loop moraine. Kame and kettle topography of the moraine proper pass southward into pitted outwash; kame terrace of the valley wall passes similarly into outwash plain. The Tully Lakes, occupying several of the larger kettles, resulted from burial of isolated masses of stagnant ice by outwash carried from the active ice margin. It may be inferred that during deposition of the Valley Heads moraine, the ice margin for a time stood at an "advanced Valley Heads position" south of Song Lake. Subsequently, the "massive Valley Heads" moraine was formed as the loop north of the Tully Lakes, while outwash spread southward over and around the stagnant and melting ice of the more advanced position. Similar relationships are found in Valley Heads moraine loops in other through valleys, suggesting similarity in oscillation of the ice margin, and perhaps partly explaining the massive character of this moraine.

Although the Valley Heads moraine is prominent in its looping trend across valley divides, it is not everywhere easy to trace over adjacent uplands. The Tully moraine, north of Tully (Mile 43.9, Trip D) is a conspicuous exception, with prominent constructional topography for more than 2 miles where it is crossed obliquely by the field trip route.

No radiocarbon data are yet available in the Syracuse area. Correlation of the Tully moraine depends on more or less continuous tracing southwestward to Wyoming County where Valley Heads outwash is established as having been deposited more than 12,020 years ago, and to the Colgan mastodon site in Cayuga County near King Ferry which was unvovered by receding ice more than 11,040 years ago (Merritt and Muller, 1959, p. 477).

Recessional moraines are discontinuous and patchy north of the Valley Heads moraine. This is probably a function both of recessional history and because marginal deposition took place into proglacial lakes and onto scarp slope positions vulnerable to removal by marginal meltwater streams. Stratified drift and marginal meltwater channels seen on both Trips B and D help to fill in missing history of the receding ice edge.

The one significant recessional moraine in the Syracuse area north of the Valley Heads moraine is crossed twice on Trip B. Stagnation features east of Camden, including Stops 4, 5 and 6 are part of this broad belt. Delta Reservoir occupies a reach of the ancestral Mohawk-Oneida Valley imponded initially by this moraine, and The Palisade (Trip B, Mile 112.7) is a post-glacial, bedrock gorge resulting from displacement of Mohawk River from its ancestral valley by this same imponding. This moraine is traceable from the vicinity of Camden through Eddy Hill, Stanwix and Verona. Although the relationship of this moraine to the moraine sequence in western New York is not established, Taylor's (1924) correlation of it with the Albion moraine is not supported.

Meltwater channels

Recession of the ice sheet northward from the divide-producing Valley Heads moraine resulted in imponding of pro-glacial meltwaters in many troughs at the north margin of the plateau. Initially many of these primitive trough lakes drained south across the moraine divide, but in time they developed integrated drainage westward until the ice sheet began to thin against the plateau margin in the Syracuse area. Thereafter, meltwater streams draining eastward parallel to the border scarp notched gorges from one trough to the next at the north margin of the plateau from Syracuse to Oneida. The plexus of channels near Syracuse controlled the levels of short-lived pro-glacial lakes between Lake Warren and Lake Iroquois (Fairchild, 1909; 1932a).

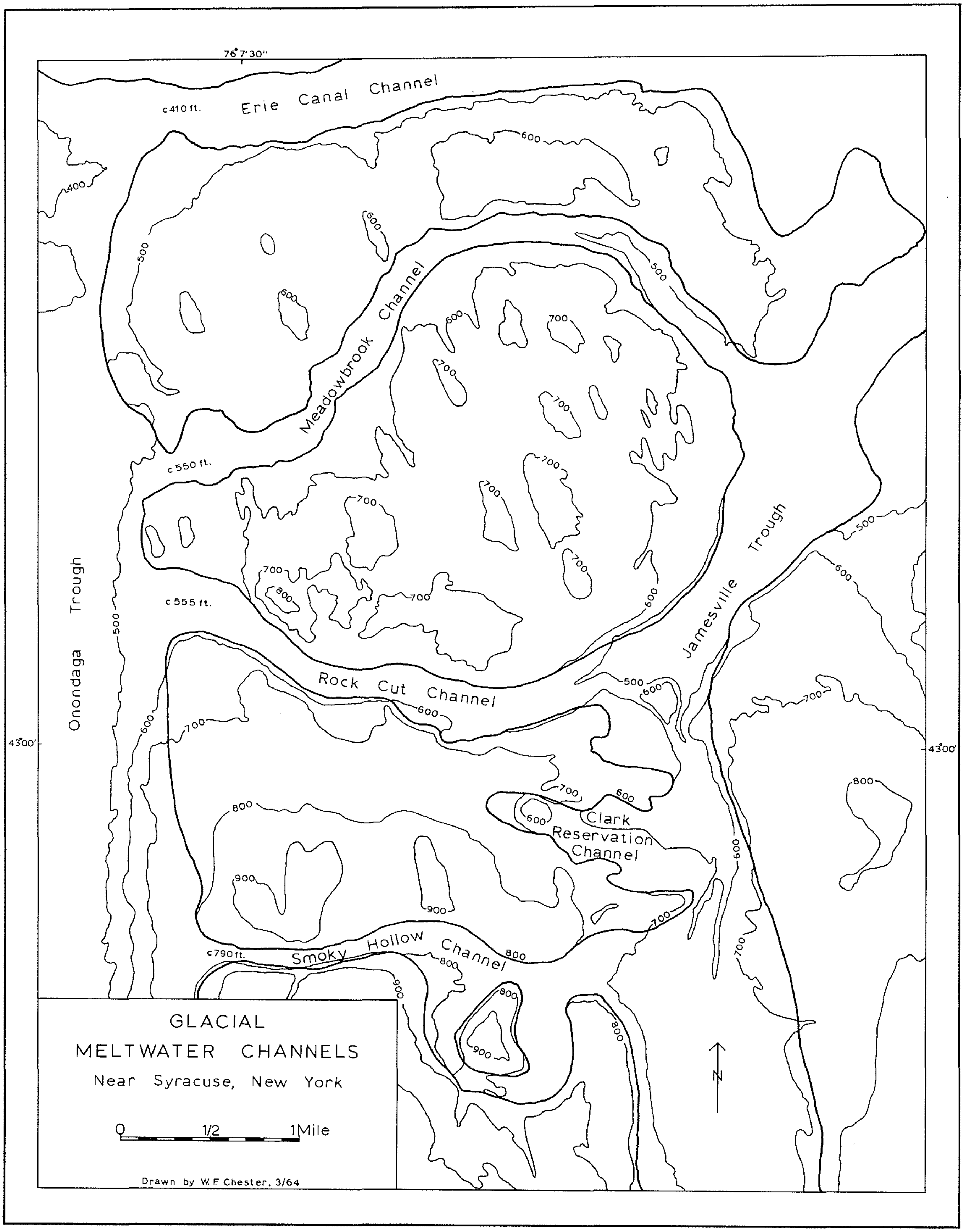
Sissons (1960) points out that glacial meltwaters flow frequently beneath, through and over the ice itself and argues that many channels in the Syracuse-Oneida area are of subglacial origin. Accumulating evidence indicates that several of the channels were occupied more than once, suggesting a complex recessional history.

Several meltwater channels visited by Trips B and D are described briefly below. These include the Syracuse channels, the Green Lake channel and Boonville Gorge.

Syracuse channels

A group of channels that traverse the ridge between Onondaga and Jamesville troughs are of dimensions that suggest they were cut by meltwater discharge from extensive imponding to the west. These channels in sequence from highest and oldest in the south to youngest and lowest in the north are Smoky Hollow, Clark Reservation, Rock Cut, Meadowbrook, and Erie Canal channels.

Smoky Hollow is a 2.25 mile long gorge, incised more than 100 ft. through the Hamilton Group to a threshold near 790 ft. msl. hanging 350 feet above the floor of Onondaga trough. Eastward the channel descends with average gradient of 50 ft/mile, cutting through the Onondaga Formation. The feature that distinguishes Smoky Hollow from other cross channels is the horseshoe-shaped meander loop (Hopkins, 1914) and umlaufberg produced by neck cutoff east of Barker Hill Road (Stop 4, Trip D). Recent unpublished studies by Sarah Street and Lawrence Cerrillo support Sissons suggestion that this and others of the Syracuse channels record a complex history of multiple episodes of glacier fluctuation. The Loop is partly filled with as much as 96 feet of stratified drift that is overlain at the west end by rhythmically-bedded lake sediments. Lodgment till overlying ablation drift is exposed in the ditch where Barker Hill Rd. rises north of Smoky Hollow. Although The Loop was not occupied by major meltwater stream after final



GLACIAL
MELTWATER CHANNELS
Near Syracuse, New York

Drawn by W.F. Chester, 3/64

deglaciation, the cutoff truncates a drumlin east of Barker Hill Rd. indicating that final meltwater action followed final molding of streamline ridges.

Clark Reservation State Park (Stop 5, Trip D) contains particularly striking evidence of meltwater scour and plunge-pool drilling. Directly northeast of the parking lot is the steep-walled basin of Green Lake (Jamesville Lake of Quereau, (1898)). At the west end, twin channels lead to a threshold about 175 feet above the lake. By analogy, the bedrock bottom of the plunge pool may well be at comparable depth below the level of the lake and cut into the Camillus Shale, but detritus and marl partly fill this basin. East of Green Lake a broad, deep channel leads to Jamesville trough. Standing at the brink of the basin one can imagine the roar of a waterfall comparable in some respects to Niagara, plunging into the amphitheater below.

About 100 yards west of Green Lake in Clark Reservation is the basin of Dry Lake. Although considerably smaller and shallower than the basin of Green Lake, this too has characteristics of a plunge pool occupied for a short interval and cut perhaps by a stream with smaller discharge. The rock threshold at 720 feet, between the two basins, rules out any suggestion of uninterrupted progressive headward migration of the falls. Rather, it raises a question as to the initial declivity responsible for originating the upper plunge-pool. North and northeast of the Dry Basin - Green Lake line are a number of other basins and a long, narrow ravine cut deeply into the Onondaga bench and underlying carbonate rocks. Several are closed basins but none are as deep as the basin of Green Lake, and none contain ponds or lakes. All have eastward-opening channels leading to Butternut trough, yet all are presently controlled by subterranean outflow. Although the origin of the features of Clark Reservation will continue to intrigue geologists, most details are presently understood in terms of subglacial and glaciomarginal drainage possibly controlled in part by previously developed and subsequently modified solution features.

Third of the Syracuse channels and the best developed is Rock Cut channel, utilized at present by Rock Cut Road, Delaware, Lackawanna and Western Railroad, and an unsightly association of junk yards. This steep-walled, flat-bottomed channel is floored by the Fiddlers Green Dolomite, with threshold at 550 feet at the west end and average eastward gradient of less than 10 ft. per mile. It is difficult to conceive of the cutting of a canyon of these dimensions during the brief time involved in northward recession of the ice margin to uncover the next lower marginal channel. Plunge-pool cutting of the magnitude that produced Green Lake basin is considered improbable in view of the higher bedrock floor of this channel. This leads to the hypothesis that cutting of the Rock Cut channel took place during several recessional episodes, an hypothesis strengthened by evidence in configuration of the south wall in the Syracuse Caves area. This location at the edge of Clark Reservation may be visited on foot (Stop 5, Trip D) if time permits. Amphitheater-like cusps cut into the south wall strongly suggest cutting by water plunging into the channel from the south where no present stream exists. Like the basins in Clark Reservation this may be a plunge-pool drilled by a subglacial or glaciomarginal stream. In either case it testifies to glacial advance south beyond Rock Cut Channel after the channel had attained essentially its present dimensions.

The fourth of the Syracuse channels, the Meadowbrook channel is narrower and less sharply incised than the Loop and Rock Cut channels. With threshold level essentially the same as that of the Rock Cut channel and with orientation toward rather than away from the ice sheet, this channel could not have carried major discharge very long. Drumlin truncation behind Manley Field House is such as to confirm that glaciomarginal drainage took place after the final episode of drumlin-molding.

The Erie Canal channel (Mile 1.6, Trip D) is utilized by Erie Boulevard and formerly by the mainline of the New York Central Railroad and the Erie Canal. Lying largely at about 410 feet, the floor of this channel is depositional rather than erosional. The succession of peat, marl over fine sand and clay underlain by coarse alluvium suggests that rising waters of Lake Iroquois inundated this channel, though it may well have been used by meltwaters during the latest glacial recession. Deep fill beneath the channel of Ley Creek suggests that it follows the course of yet another drainage line at elevation too low to have carried post-glacial meltwaters.

Green Lakes State Park

Stop 1, Trip B, visits an area of plunge-pool development in Green Lakes State Park which is almost as striking as that of Green Lake in Clark Reservation State Park. The lakes in the latter park occupy two plunge pools in a meltwater channel cut into the Syracuse Formation between Limestone Creek and the Iroquois lake plain. The western threshold at about 535 feet msl. is incised into glacial drift which in turn is so distributed into the head of the channel as to indicate that meltwater shaped the Green Lakes channel before as well as after the latest glacial episode.

Green Lake is in the shape of a ping-pong paddle with warped handle towards the north. At its deepest Green Lake is 180 feet deep, with its rock floor at less than 240 feet above sea level. Up-valley, 750 feet to the west, Round Lake is comparable in depth and dimensions. With a drop of only about 100 feet from lip to lake level, the pool has maximum depth of 171 feet (Miner, 1933). Both the variableness of depth and gorge width attest to interrupted or "leap-frogging" headward plunge-pool migration in this channel. North of the north end of Green Lake test drilling penetrated 138 feet through marl, peat, silt and clay without apparently entering either till or shale bedrock.

Boonville Gorge

One of the most striking meltwater channels in central New York is the Boonville Gorge, cut by the overflow of proglacially imponded waters from the Black River to the Mohawk Valley. Followed today by N.Y. Rte. 46, Lansing Kill and the abandoned Black River Canal it extends about 12 miles from Boonville to Hillside and the ancestral Mohawk Valley. Incised deeply into the Utica and Trenton Formations the gorge includes three somewhat diverse sections. From its northern threshold at 1130 feet, south to the point where Lansing Kill enters the gorge as a small left-bank tributary, the canyon is steep-walled but open and flat-floored on bedding surfaces of massive limestone. Southward convergence of valley walls shows this northernmost reach of Boonville Gorge to be a converted former tributary to Black River. Although modified evidence of this former valley are observable on the western wall of the valley for another mile or so, sharp incision of Lansing Kill rapidly changes the aspect of the gorge bottom. Across the former drainage divide, the canyon is deep and narrow with gradually steepening gradient. Near Pixley Falls (Stop 8, Trip B) the gorge is about 500 feet deep with shoulder-width of 2000 feet and width-depth ratio of 4:1. Less than a mile southwest of Boonville Gorge State Park is the famous "five combines", a flight of 5 locks by which the Black River Canal mounted its steepest ascent. From this point south to the hamlet of Hilltop the gorge is incised into the bottom of a gradually broadening south-flowing tributary of the ancestral Mohawk River, which it joins at Hilltop.

Lake Iroquois and its successors in the Oneida Basin

Waning of the ice sheet from the plateau border in the area between Syracuse and Oneida permitted free drainage eastward across the saddle near Rome, thus impounding proglacial Lake Iroquois. In the Syracuse area Coon (1960) distinguished 3 stages or levels of Lake Iroquois. The highest or main stage is represented by strand features at 435-440 feet msl, and is approximately marked by the course of the abandoned Erie Canal in many places east of Syracuse. Spits and barrier bars north of Syracuse are developed at 415 to 425 feet indicating a weakly developed shoreline which in many places closely parallels the main strand. Presumably the modest lowering from the main to the second or Pine Plains strand resulted from reduction of the divide at Rome.

As a result of lowering to the 395 to 400 foot level Lake Iroquois became divided into several basins. The Lockport Dolomite is assumed to underlie the east-west rise that parallels the south shore of Oneida Lake. South of this rise, on the dip slope of the inferred Lockport cuesta and the overlying non-resistant Vernon shale the subsequent basin contained a shallowing remnant of Lake Iroquois during this, the Cicero stage. Marked dune development on the floor of the Pine Plains lake stage is related to the Cicero strand and in places the shore scarp is quite distinct, though low and inconspicuous elsewhere. The Cicero and Canastota mucklands are the last remnants of this filled basin, occupying structural position similar to that of glacial Lake Tonawanda in western New York.

North of Chittenango, the Canastota swamp, comprising part of this Cicero stage basin, has been drained and developed for muckland farming. Post-Iroquois sedimentation is largely clastic in the south and east, but the peat and marl section thickens markedly northward toward the center of the basin. In the vicinity of the Sky-High Farms (Stop 2, Trip B), auger sampling yields a post-Iroquois profile that includes 1 to 3 feet of peat over as much as 16 feet of marl (Hasser, 1954). The invertebrate fauna in the marl section, as recently studied by Julia Veinus suggests possible minor oscillation in depth of the embayment during progressive filling, but it does not otherwise yield direct evidence of climatic change. In the Cicero swamp, a part of the Cicero stage basin several miles west of Sky-High Farms, a 16-ft. peat profile shows pollen zonation beginning with the early pine period (A-1) of Deevey, and ranging through progressive maxima of spruce, of pine and fir, then of hardwood species with a double peak of hemlock frequency. This succession affords a basis for correlation and interpretation of postglacial climatic change suggesting early minor temperature oscillation, with a xerothermic interval reflected by the hemlock minimum between two crests (Cox, 1959).

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GROUND-WATER RESOURCES OF THE SYRACUSE AREA[1]

by Irwin H. Kantrowitz

U.S. Geological Survey

All but the largest public water systems in the Syracuse area obtain their supply from wells or springs. Almost all farms and homes in rural areas are supplied by private wells or springs and many industries also rely on ground-water supplies to meet their needs. Current withdrawal of ground water in the area is believed to be only a fraction of the available supply. The quality of water, however, is not always suitable for many uses, including public supply.

Ground water occurs in fractures and bedding joints of consolidated rocks and in pore spaces of unconsolidated deposits. The quantity of water available depends on the nature of the aquifer and the source of recharge. Adequate supplies for domestic and farm needs (100 to 1,000 gallons per day) are almost always available. Larger quantities of water for industrial and public supplies can generally be obtained from stratified coarse-grained deposits and, less frequently, from bedrock with prominent fractures, particularly where these aquifers are in hydraulic contact with a surface-water body which acts as a source of recharge. Ground-water quality depends on the chemical characteristics of the aquifer material, and flow pattern within the ground-water reservoir, and the quality of the recharge water. The factors most commonly affecting the quality of the ground water in the Syracuse area are hardness, iron, hydrogen sulfide, and salinity.

Ground water in consolidated rocks

Table 1 shows the rock units in the Syracuse area, their dominant lithologies, and the quality of the ground water that may be expected in wells tapping each unit. Wells in the limestone units, and the Camillus Shale, Syracuse Salt, and Vernon Shale will yield as much as 230 gpm (gallons per minute) because of enlargement of fractures by the solution of the carbonates and evaporites. The yield of wells drilled in these units for domestic, farm, and other small supplies averages about 15 to 20 gpm. Wells in the other rock units in the area generally yield less than 10 gpm and are inadequate for most public or industrial needs.

Carbonate (temporary) hardness results from the solution of limestone or dolomite by ground water. The hardness of water in the Camillus and Vernon Shales is predominantly noncarbonate (permanent) hardness resulting from the solution of gypsum or anhydrite. The source of hydrogen sulfide is believed to be pyrite found in the Hamilton Group and the Lorraine and Utica Shales, and sphalerite found in the Lockport Dolomite. Although traces of iron are found in water from all the rock units, it is present in objectionable concentrations most often in the Camillus and Vernon Shales where it is probably related to the occurrence of hematite, siderite, and pyrite.

The presence of saline water (here defined as water containing more than 250 parts per million of chloride) is not shown in Table 1 because its occurrence is more closely related to patterns of ground-water movement than it is to

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[1] Data contained in this summary were collected by the U.S. Geological Survey in cooperation with the New York State Water Resources Commission. Publication authorized by Director, U. S. Geological Survey.

the chemical characteristics of the water-bearing units. Although the only salt beds in the area are found within the Syracuse, most wells tapping this formation in its outcrop area do not yield salty water because the salt at shallow depths has been almost completely dissolved. Wells drilled into the Syracuse in the area south of its outcrop generally yield saline water, and commercial brine is obtained from deep wells in Tully Valley, about 12 miles south of Syracuse. At these wells, the salt occurs 300 to 500 feet below sea level and the brine is produced by injecting fresh water into the beds and then pumping it out after it has dissolved the salt.

The major area of natural saline-water occurrence is along the lowlands occupied by Oneida Lake and the Oneida, Oswego, and Seneca Rivers. This area coincides with the major area of ground-water discharge and the presence of saline water is believed to be due to the upward and northward movement of ground water that has been in contact with and partially dissolved the salt beds beneath the Appalachian Plateau. Wells drilled more than 100 feet into the Genesee Formation or Hamilton Group in the valleys of the plateau area may also yield saline water. The occurrence of this water may be related to connate water within the rock units or to the upward movement of water from the salt beds.

Ground water in unconsolidated deposits

A till sheet commonly about 30 feet thick mantles the entire upland area in the Appalachian and Tug Hill Plateaus and a large part of the Ontario lowland. Adequate supplies of water for domestic and farm supplies are generally available from dug wells or springs, although shallow wells on hillsides and hilltops frequently are inadequate during long dry periods.

Stratified drift mantles the remainder of the area, notably in the valleys of the Appalachian Plateau, most of the Ontario Lowland, and the lower parts of the valleys of the Tug Hill Plateau. Deposition of stratified drift occurred under four conditions: 1) proglacial deposition during free drainage, 2) deposition in ice-dammed valleys, 3) deposition during Great Lakes drainage, and 4) deposition in Lake Iroquois.

Coarse-grained glaciofluvial deposits consisting largely of sand and gravel occur south of the Valley Heads moraine and in many places form a large part of the moraine itself. The sand and gravel are well sorted and are probably the most permeable water-bearing material in the area. The city of Cortland, located about 27 miles south of Syracuse and 14 miles south of the Valley Heads moraine, pumps more than 2.5 mgd (million gallons per day) from these deposits. Somewhat similar sands and gravels, deposited during free glacial drainage in the Tug Hill Plateau area, may be expected along West Branch Fish Creek.

During deglaciation of the Appalachian Plateau, lakes existed in the major valleys, dammed between the bedrock divide to the south and the ice tongue to the north. Although data are scanty, the deposits in the valleys appear to become coarser with increasing depth which is consistent with a concept of a receding source of sediment. Small but adequate domestic and farm supplies can generally be obtained from wells dug in lacustrine sand, silt or clay, and driven screened wells are common where lacustrine sands occur at shallow depths. Because the layers of gravel in these deposits are lenticular, few wells drawing from gravel yield more than 100 gpm and the average yield of such wells is only about 30 gpm.

With further deglaciation, the ice margin was against the escarpment of the

Appalachian Plateau, and eastward drainage of the ancestral Great Lakes was initiated in ice-marginal channels. Deposition of sand and gravel occurred wherever the Great Lakes waters entered standing water in the north-south valleys or where westward recession of the ice front enabled the water to abandon the marginal channels and utilize the larger north-south valleys as outlets to the lowland north of the escarpment. These sand and gravel deposits are probably not as permeable as the valley train material south of the Valley Heads moraine. They are, nevertheless, a potential source of large ground-water supplies because they generally occur in areas where stream infiltration is possible. Examples of wells in this type of deposit are a public-supply well for the village of Fayetteville that has been test pumped at 500 gpm, and a public-supply well for the village of Chittenango that yields 350 gpm.

During the last stages of deglaciation in the Syracuse area, Lake Iroquois, a proglacial ancestral Lake Ontario, occupied the lowland north of the Appalachian escarpment. Melt-water streams deposited outwash deltas in the lake which were subsequently reworked and covered by finer grained lacustrine deposits as the ice continued to recede. The sand and gravel, where it is in hydraulic contact with a surface-water body may yield large quantities of water. The village of Fulton has pumped as much as 3.3 mgd from a well field adjacent to the Oswego River. Individual wells in this system yield as much as 800 gpm.

For the most part, none of the unconsolidated deposits in the Syracuse area have undergone significant transport by ice or melt water. Therefore, the chemical nature of the deposits and, to a large measure, the quality of the ground water derived from them, is generally similar to that of the underlying bedrock. Saline water occurs notably in a few of the north-south valleys where ground water has been able to move from the truncated salt beds of the Syracuse into relatively permeable valley-fill material.

Table 1.--Water-bearing units and quality of ground water

Rock unit	Lithologic type	Quality of water
Genesee Formation	shale	generally good
Tully Limestone	limestone	hard
Hamilton Group	shale, limestone	hard, hydrogen sulfide
Onondaga Limestone	limestone	hard
Helderberg Group	limestone	hard
Cobleskill Limestone	limestone	hard
Bertie Limestone (of Salina Group)	limestone, dolomite, some shale	hard
Camillus Shale (of Salina Group)	shale, gypsum, dolomite	hard, iron
Syracuse Salt (of Salina Group)	shale, gypsum, dolomite, salt	hard, iron
Vernon Shale (of Salina Group)	shale, some gypsum & dolomite	hard, iron
Lockport Dolomite	dolomite	hard, hydrogen sulfide
Clinton Group	sandstone & shale, some limestone	hard
Albion Group[1]	sandstone	generally good
Queenston Shale	sandstone	generally good
Oswego Sandstone	sandstone	generally good
Lorraine Shale	shale	hydrogen sulfide
Utica Shale	shale	hydrogen sulfide

[1] Approximately equivalent to Medina Group of N.Y. State Geological Survey usage.

BEDROCK TOPOGRAPHY IN THE ONEIDA LAKE AREA, NEW YORK

by Irwin H. Kantrowitz[1]

U.S. Geological Survey

The accompanying map of the buried bedrock surface in the Oneida Lake area (figure1) is based on data from approximately 375 water wells in the lowland area (below the 500 foot contour) and from outcrops and scattered well data in the uplands (above the 500 foot contour). The data were collected as part of a study of ground-water resources in the Syracuse area being made by the U.S. Geological Survey in cooperation with the New York State Water Resources Commission. The bedrock topography of the area has been affected by preglacial stream erosion, glacial ice erosion, and ice-marginal stream erosion.

The preglacial drainage consisted of a major stream that flowed through the lowland now occupied by Oneida Lake and the Oswego River, and several short tributary streams. The tributary streams flowing north crossed the geologic structure (obsequent streams) whereas those flowing east or west followed the geologic structure (subsequent streams) and probably were initially developed on the relatively weak shales above (south of) the Lockport Dolomite. If it is assumed that the subsequent channels would migrate down the dip of the Lockport and that at least the south wall of the valley would be developed in the weaker shales, then it follows that the contact between the Lockport and the overlying shales should, in places, be drawn in closer correspondence with the south wall of the bedrock valley. Because of an absence of exposures in this area, the mapped contact is hypothetical (Broughton and others, 1961). Further study of bedrock topography and well logs promises to provide more detailed data for geologic mapping.

The major preglacial valley, that of the ancestral Oneida-Oswego River, appears to be a continuation of the upper Mohawk River valley (Delta Reservoir in fig. 1) north of Rome. The Mohawk Lowland, as far as Little Falls (approximately 30 miles southeast of Rome), defined as the area below the 400 foot contours south of Rome (fig. 1), may also have been a tributary or the headwaters of the ancestral Oneida-Oswego River. West of Rome the bedrock valley closely paralleled the present drainage and eventually joined the trunk river which occupied the Lake Ontario basin. Between Fulton and the west end of Oneida Lake the channel is indistinct, and the bedrock surface lacks appreciable relief.

Prominent features of glacial erosion in the Oneida Lake area are the closed basins and deepened valleys caused by the concentrated flow of ice into pre-existing channels. Wells drilled during the last century at the southern end of Onondaga Lake indicate that bedrock is about 50 feet below sea level. The altitude of the rock surface in the Onondaga valley, 16 miles south of the lake, is 250 feet above

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[1] Publication authorized by Director, U. S. Geological Survey.

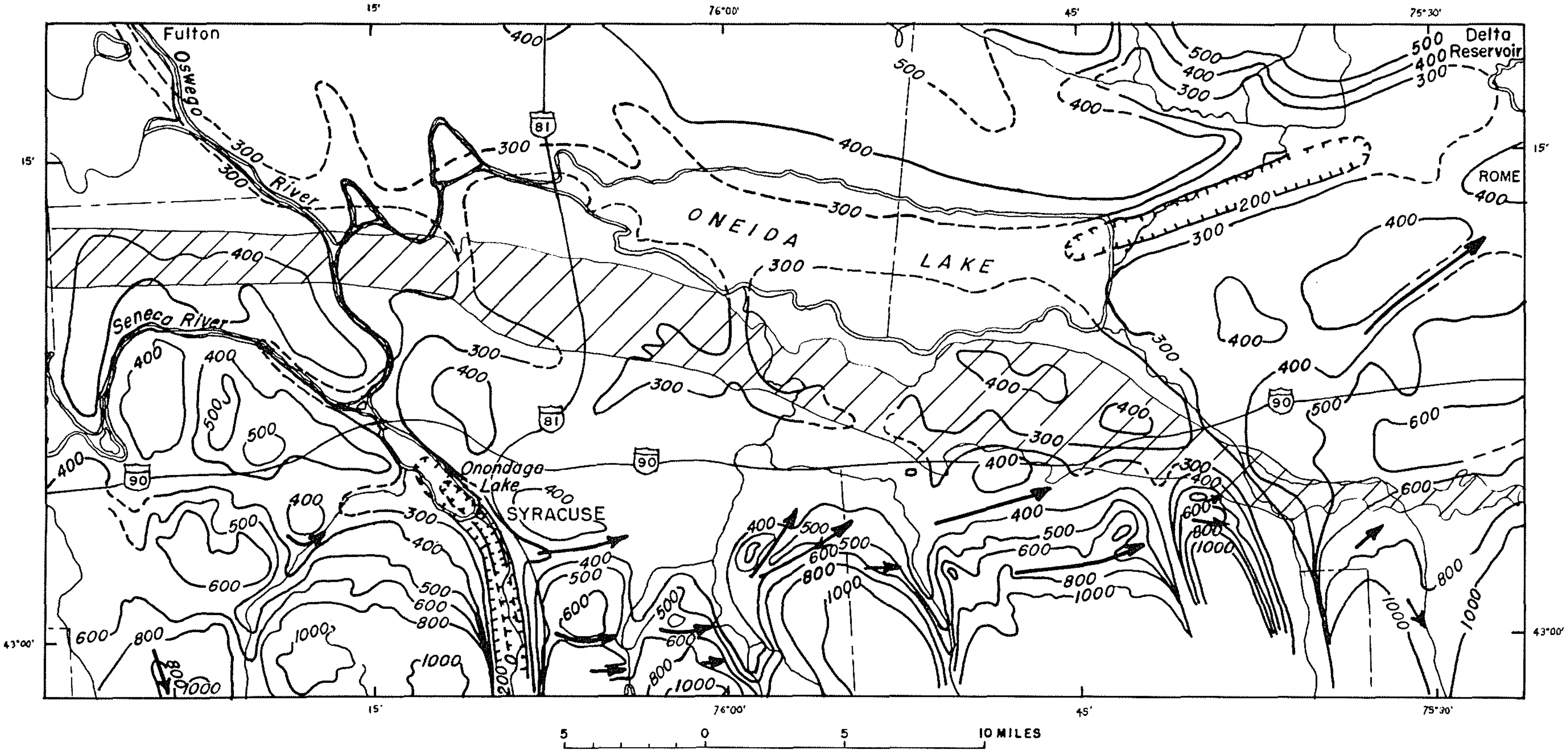

Fig. 1. Bedrock topography in the Oneida Lake area.

sea level. Closed basins also exist just south of the mapped area in many of the other north-south valleys of the southern upland area. A closed basin was formed in the channel of the ancestral Oneida-Oswego River by ice that was moving eastward around the northern highlands (Tug Hill Plateau). A similar basin exists in the Mohawk Lowland east of the area. Differential erosion by the ice has doubtless carved other smaller basins throughout the Oneida Lake area.

Bedrock erosion by ice-marginal streams was initiated when the ice abutted against the southern upland area. Presumably erosion took place during each advance and retreat of the ice as melt water and the discharge of the ancestral Great Lakes flowed along and under the ice margin. Only the larger features of Great Lakes ice-marginal drainage are shown in figure 1. The reader is referred to another section of this guidebook for a more complete discussion of marginal drainage. Owing to the cover of glacial drift which mantles the area, postglacial bedrock erosion has been largely limited to stream erosion in a few upland areas, and to solution of the carbonate rocks.

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TRIP B: GEOMORPHOLOGY OF ONEIDA BASIN AND SOUTH SLOPE OF THE TUG HILL PLATEAU

Ernest H. Muller, James S. Street and Jesse L. Craft

Total miles	Miles from last point	Route description
0.0	0.0	Assembly point: Parking lot, Sheraton Motor Inn Thompson Rd. and New Court St. Carrier Circle, near Thruway Exit 35.
		Departure time: 8:15 A.M. Sharp! All travel by bus!
		Leaving Sheraton Motor Inn, proceed 75° around Carrier Circle and turn right (S) onto Thompson Rd.
1.0	1.0	Turn left (E) before tracks. In .2 mi. bear right (SE) following N.Y. Rte. 290. Rise onto drumlinoid with veneer of red till.
2.2	1.2	Continuing on N.Y. Rte. 290, cross overpass and descend to level of Iroquois lake plain at 410 ft. msl.
4.1	1.9	Continuing on N.Y. Rte. 290, rise onto Fremont Hill, a drumlinoid that was an island in Iroquois Lake. Strand features are mapped at the 435 and 420 ft. levels. Cemetery on right (S) as road returns to lake plain is at the 430-ft. level. Cross alluvial flats of Limestone Creek.
6.0	1.9	Cross abandoned feeder of Erie Barge Canal and rise from Iroquois lake plain onto intensely scoured scarp developed on Syracuse fm. Excellent exposures of Syracuse fm in railroad cut, off route .4 miles SW.
6.1	0.1	At "t-intersection", turn left (E) to continue on N.Y. Rte. 290. Route parallels Erie Canal, with Iroquois lake plain on left and scoured, thinly veneered slopes on right.
8.3	2.2	Turn right (S) in Green Lakes State Park. Bear right, through administration area; follow winding road upslope to end.
9.6	1.3	STOP ONE. GREEN LAKES STATE PARK Examination of notched Green Lake channel and Round Lake plunge pool. Discussion of meltwater channels, plunge pool development, interrupted plunge pool migration and limnology of Green Lake. See text, p. 31.
		Return to park entrance
10.9	1.3	Turn right (E) onto N.Y. Rte 290. Embayed mouth of Green Lake channel debouched into Lake Iroquois at right.
12.1	1.2	Turn left (N) onto Kirkville Rd. Descend across weak 435 ft. strand at curve in road. Cross abandoned Erie Canal and continue north through Kirkville on littoral sand and gravel.

Total miles	Miles from last point	Route description
14.5	2.4	Cross N.Y. Thruway overpass affording broad view of nearly level Iroquois lake plain. Pine Plains lie ahead right.
15.0	0.5	Cross Fyler Settlement Road. Continue north on Kirkville Rd.
16.2	1.2	Turn right (E) onto Chestnut Ridge Rd. at Pecks Corners. East of first cross-road note yellow-brown sandy soil and irregular low relief of dune and blow-out complex related to strandline of late phase of Lake Iroquois which lies parallel and just north of the route for the next 3 miles. Dune configuration suggests dominant effective winds from the west-northwest.
17.9	1.7	Follow road in 90° curve to the right (S), then turn left (E) immediately at "t-intersection" to continue east on Chestnut Ridge Rd. through sand dune complex that borders Pine Plains on the south and Canastota mucklands on the north.
20.8	2.9	Turn left (N) onto Chittenango-Lakeport Plank Rd., In .2 mi. descend about 20 ft. across strand that marks Cicero stage of Lake Iroquois (Coon, 1960). Surface of Canastota muckland is approximately at 385 ft. msl.
21.9	1.1	STOP TWO. SKY-HIGH FARMS (Smith-Coulter Co., Inc.) Peat, marl and bottom sediments of Cicero stage of Lake Iroquois, illustrating succession in filling of post-glacial embayment. Pulmonate gastropods in marl.
		Proceed north on Plank Road across Canastota muckland.
24.2	2.3	Turn right (E) onto Lake Rd. in Lakeport. For next 7 miles, Oneida Lake is on left at 369 ft. msl, while a broad swell, elongate east-west, rises to the south of the route. Although it is virtually without bedrock exposure, this rise is considered to be an eastward extension of the Lockport cuesta.
31.3	7.1	Turn left (N) onto N.Y. Rte. 13 across Oneida Lake plain. Cross Oneida Creek and continue on minor beach ridge, one of several at 375 ft. msl. that indicate steadily prograding east shore of Oneida Lake.
33.0	1.7	Turn left at entrance to Verona Beach State Park.
33.3	0.3	STOP THREE. VERONA BEACH STATE PARK. Rest stop. Summary of Iroquois lake history and Oneida basin geomorphology as encountered en route and at previous stops.
		Return to N. Y. Rte. 13.

TRIP B (Continued)

Total miles	Miles from last point	Route description
33.6	0.3	Turn left (N) onto N.Y. Rte 13. Proceed across Oneida lake plain. Relief is less than 15 ft. for several miles to the east and the deepest part of the lake is only 55 ft. deep. This plain and basin occupy the structurally controlled lowland on the Clinton Group.
34.9	1.3	Cross Erie Canal at Fish creek between Verona Beach and Sylvan Beach. In April, 1963, wind-driven shore ice rammed across the beach and against roller-coaster in amusement park at canal outlet into Oneida Lake.
37.2	2.3	Begin rise from Oneida lake plain across Iroquois nearshore and strand deposits. Medina-Clinton contact concealed and not established as having any relation to the shore scarp. At the "Sand Bar" on right, a low cut exposes 3 ft. of red-brown sand and silt over 8 ft. (base concealed) of red to red-brown rhythmically-laminated, but not varved, clay and silt. A well 1.5 miles southeast was drilled through 250 ft. of unconsolidated sediment reported to be dominantly lacustrine. The hole bottomed at 125 ft. msl without reaching bedrock.
37.6	0.4	Turn right (E) on N.Y. Rtes 13 and 49 along a minor drift bench. Borrow pits dominantly expose ablation drift. Iroquois lake plain extends many miles east-west on right along trend of non-resistant Clinton Group.
39.2	1.6	Turn left (N) in Vienna, following N.Y. Rte 13. Cross moraine divide between Oneida and Fish Creek basins.
41.9	2.7	Turn right (E) then immediately turn left into McConnellsville on Blennes Corner Rd. Cross West Branch Fish Creek. Pass Harden furniture plant and proceed north across remnant of Williamstown outwash plain.
43.1	1.2	Turn left (W) onto paved road at "t-intersection".
43.5	0.4	STOP FOUR. G. W. BRYANT SAND PIT Examination of structures in stagnant ice deposits; discussion of aspects of sand and gravel industry. Return east to "t-intersection"
43.9	0.4	Turn left (N) onto Blennes Corner Road. Proceed north following shallow meltwater channel incised into stratified drift of kame and kettle complex.

Total miles	Miles from last point	Route description
46.0	2.1	Turn left (W) at Blennes Corner onto N.Y. Rte 69. Proceed toward Camden.
49.8	3.8	Cross West Branch Fish Creek, enter Camden and proceed west on Church Street to 2nd Street. Park and proceed to Camden Methodist Church.
50.1	0.3	LUNCH STOP. Camden Methodist Church, served in Walker Memorial by Women's Guild.
		Return east on Church St., leaving Camden. Cross West Branch Fish Creek and bear right (SE) on N.Y. Rte. 69.
52.4	2.3	Turn left onto former highway right of way, then in .1 mi. turn left (N) onto Tillinghast Rd.
52.6	0.2	STOP FIVE. CAMDEN WIRE COMPANY ESKER Examination of composition and structure as exposed in transverse and longitudinal sections of a small esker. Significance of "pseudo-anticlinal" structure in transverse section.
		Continue north on Tillinghast Rd.
54.0	1.4	Turn right (E) onto Pond Hill Rd. Continue across stagnation features marking progressive decay and wastage of the late Cary Oneida ice lobe. Climb sharply to higher bench. At top of rise note boulder gravel exposed in road cut. Poorly sorted glacial drift is thick and bedrock is unimportant as a control of local relief in this area.
54.8	0.8	STOP SIX. MACK POND KETTLE CLUSTER Examination of topographic and hydrographic relationships in a compact cluster of kettles and crevasse ridges at edge of the Pond Hill terrace.
		Proceed east on Pond Hill Rd. Cross shallow marginal meltwater drainage line before rising sharply.
56.7	1.9	Turn right (SE) onto N.Y. Rte. 285, Military State Rd. Proceed into Taberg and cross East Branch Fish Creek.
58.8	2.1	Turn left onto N.Y. Rte. 69, Military State Rd. toward Rome. In one mile note swampy area on left which is at head of one of a series of eastward draining meltwater channels.
		Just before road enters shallow cut, cemented cobble gravel can be seen in overgrown cut 200 yds south of road. Leaving roadcut, descend on Rte. 69 over 30 ft. scarp which appears to be wave-cut.

TRIP B (Continued)

Total miles	Miles from last point	Route description
61.7	2.9	Turn left in Lee, onto Lee Valley Rd. Cross Sash Factory Creek in swampy swale, the downslope continuation of meltwater channel seen on left 2.5 miles earlier. The right angle bend between channel segments suggests a subglacial meltwater escape-way.
		On right (S), shallow meltwater channelway parallels road, curving eastward at about 520 ft. msl.
64.2	2.5	Bear left at fork toward Lee Center, leaving Lee Valley Rd.
64.7	0.5	Bear left at "Stop" sign, continuing north on Mill St. toward Lee Center. Cemented cobble gravels exposed on left (W) in about .4 mile.
		Entering Lee Center, cross swampy meltwater channel with small pond on left and cannery on right. Channel alignment continues east from Lee Center as an obvious meltwater channel segment, but at slightly higher elevation than floor of the swampy channel segment that enters Lee Center from the west. Apparently segmentation of marginal drainageway resulted from development of a subglacial escapeway downslope, now occupied by Canada Creek and Mill Road south of Lee Center.
65.6	0.9	Turn right (E) in Lee Center, onto Lee Center Rd. Pass Sulphur Springs Rd. Exposures of Whetstone Gulf shale on left indicate probable source of sulfur as being from decomposition of pyrite.
		Rise sharply and proceed east across outwash bench. Pass between Rome Reservoirs and angle across bench to Stokes.
68.0	2.4	Turn left (N) onto N.Y. Rte 26, Turin Rd. at Stokes Corner. Begin rise across Quaker Hill, the southeastern tip of the Tug Hill Plateau developed on rocks of the Lorraine Group.
68.7	0.7	Minor bench and northward rise are remnants of former ice-walled meltwater channel that is better developed about a mile west, and trends eastward toward Mohawk Valley.
72.6	4.6	Cross West Branch Mohawk River at village of West Branch.
		Continuing north on N.Y. Rte. 26, rise onto diffuse moraine that trends north-south, with best development of constructional topography west of the route between Ava and West Leyden. This is the first moraine of the Black River lobe encountered on this trip. The larger Oneida glacial lobe dominated and outlasted the Black River ice in this interlobate area in the lee of the Tug Hill nunatak.

Total miles	Miles from last point	Route description
78.9	6.3	In West Leyden, jog right with N.Y. Rte 26 to cross East Branch Mohawk River. Take second right onto N.Y. Rte 294, Upper Rd., toward Boonville.
82.8	3.9	At Redmond Corner, intersection with Webster Hill Road, continue eastward and begin to descend toward Boonville. Note increase in abundance of field boulders. In about a mile pass through area of minor stagnant ice features.
85.5	2.7	Enter Boonville. In .3 mile turn left (N) onto Summit St. then turn right (E) at first corner, onto Schuyler St. Proceed through Boonville. Directly after crossing tracks, turn left (N) onto N.Y. Rte 12.
		Rte. 12 parallels the Black River Canal, built in 1855 to link navigable reaches of the Black River north of Lyons Falls with the Erie Canal at Rome. With a total of 109 locks in 35 miles the canal crossed a divide 700 feet above the Erie Canal. The substantial remains of a dozen or so locks are seen between Boonville and Sugar River which was crossed by aqueduct.
88.6	3.1	STOP SEVEN. SUGAR RIVER AT BOONVILLE QUARRY. E. G. DeLia and Sons, Inc. Examination of stratigraphic section in quarry and of solution features along Sugar River.
		Return south on N.Y. Rte. 12.
91.7	3.1	Turn right (W) across tracks on Schuyler St. into Boonville. At west side of triangle turn left (S) onto N.Y. Rte 46, Post Rd. toward Rome.
93.3	1.6	Continuing on N.Y. Rte. 46, descend 30-ft into broad flat-bottomed, rock-floored channel across ledge that controlled outflow from proglacial Port Leyden Lake through the Lansing Kill or Boonville Gorge. Continue south in channel, crossing diagonally to east side, thence back to west side to parallel the old Black River Canal.
95.0	1.7	Shale bluff in roadcut on right indicates erosivity of rock into which the Boonville Gorge is cut. From Boonville to this point the gorge has become progressively more constricted. At left where Lansing Kill enters from the east side of the valley, post-glacial notching accounts for abrupt deepening of the gorge.
97.7	2.7	STOP EIGHT. BOONVILLE GORGE STATE PARK. PIXLEY FALLS. Rest stop. Consideration of significance of Lansing Kill Gorge.
		Continue south toward Rome on N.Y. Rte. 46.

Total miles	Miles from last point	Route description
98.8	1.0	Five combines -- a flight of 5 adjacent locks on Black River Canal.
103.9	5.1	Mohawk River enters Boonville Gorge from west with development of multiple terraces now incised by both Lansing Kill and Mohawk River.
105.7	1.8	Village of Northwestern. Continue S on N. Y. Rte. 46.
108.5	2.8	Village of Westernville, on right, near apex of delta built by meltwater stream through Boonville Gorge as it debouched into small lake imponded on southwest by the moraine at Rome. The Mohawk River subsequently incised a channel that swung diagonally across the valley from Westernville leaving the terrace remnants at 550-560 ft. msl., slightly above the level of Delta Reservoir.
112.7	4.2	Delta Reservoir Dam on right (W) of route. Mohawk River, incising its channel into delta and outwash deposits swung diagonally across valley from site of former village of Delta, to intrench itself at this point into Utica shale that walled the inherited bedrock valley. The steep-walled, 80-ft. deep gorge, known as The Palisade, provides a suitable dam-site for the broad, deep bedrock valley directly to the northwest is blocked by the late Cary recessional moraine at Rome. Construction of the dam in 1911 and imponding of the reservoir inundated the village of Delta, which survives only in the name of the reservoir. Through this gorge also passed the Black River Canal, traces of which can be seen beside the road directly up-valley from the dam.
113.5	0.8	State Fish Hatchery on right (W) side of road.
114.5	1.0	Bear left, continuing on N.Y. Rte. 46 at juncture with Elmer Hill Rd. Proceed south into Rome. Griffiss Air Force Base is at left (E) across Mohawk River, after Rte. 46 has become Black River Boulevard.
117.8	3.3	Follow highway signs to N.Y. Rte. 365, bearing right at intersection, then crossing N.Y. Rte 69 to turn sharply left onto N.Y. Rte 365 south out of town.
118.5	0.7	Cross overpass over N.Y. Central R.R. and Erie Canal in middle of narrowing Iroquois lake plain. Less than 2 miles east is the highest elevation on the Erie Canal east of the Finger Lakes and the eastern end of the Iroquois plain. The Mohawk River having strayed from its westward-leading ancestral valley at The Palisade, has built an alluvial fan into the plain at this narrowest point. Flowing across this fan the Mohawk

Total miles	Miles from last point	Route description
		might as easily have drained westward, instead of eastward following the abandoned Iroquois outlet channel.
119.0	0.5	Continuing on N.Y. Rte 365, bear right onto dual highway at intersection.
120.3	1.3	Pass entrance to Rome State School and rise obliquely across low slope of Iroquois strand.
124.2	3.9	Shallow meltwater channel with threshold about 20 ft. above Iroquois strand is parallel to N.Y. Rte 365 for about 1 mile on right (NW).
127.3	3.1	Village of Verona on right (NW).
128.8	1.5	Cross N.Y. State Thruway. Continue SW on N.Y. Rte 365.
132.2	3.4	Continue on N.Y. Rte 365, leaving N.Y. Rte 365A.
133.1	0.9	Turn right (W) onto N.Y. Rte. 5 in village of Oneida Castle.
135.9	2.8	Continue west on N.Y. Rte. 5, through Five Corners. Cross Cowaselon Creek which has cut a narrow flood plain into valley-choking glacial drift. Borrow pits at left (S), west of Cowaselon Creek, are opened in kame delta complex.
136.7	0.8	Village of Wampsville, location of Madison County Court House.
140.0	3.3	Continue west on N.Y. Rte 5, following juncture with N.Y. Rte 13 in outskirts of Canastota. Samuel Champlain, French explorer fought a skirmish with Oneida Indians at village site, 6 miles south, during penetration southward from St. Lawrence settlements in 1615.
146.3	6.3	Continue west, leaving N.Y. Rte 5. at intersection with Tuscarora Rd. in north edge of Chittenango. Cross Chittenango Creek at level of Iroquois Lake Plain.
148.6	2.3	Angle right at "slanting t-intersection", returning onto N.Y. Rte. 5, Genesee Turnpike.
149.8	1.2	In Mycenae, enter Pools Brook meltwater channel. For 3 miles, N.Y. Rte. 5 utilizes the low grade of this deep, transverse gorge cut by imponded pro-glacial meltwaters escaping east from Limestone Valley. Constructional topography extending into the west end of this channel indicates that principal erosion by meltwater preceded final melting of stagnant ice at channel-head near Fayetteville.

TRIP B (Continued)

153.9	4.1	Continue west on N.Y. Rte. 5, through Fayetteville. Descend to floodplain of Limestone Creek at level of Iroquois Lake Plain.
156.1	2.2	At juncture with High Bridge Rd. continue west on Rte. 5. Descend to cross floodplain of Butternut Creek.
157.2	1.1	Turn right (N) onto Erie Blvd. In about a mile, new construction has opened exposures in Syracuse formation on left.
158.9	1.7	Turn right (N) at traffic light, onto Thompson Rd. Proceed north to Carrier Circle.
161.0	2.1	Arrive Sheraton Motor Inn, Carrier Circle; Thompson Rd. and New Court St.

TRIP D: GEOMORPHOLOGY OF THE NORTH MARGIN OF THE APPALACHIAN UPLANDS NEAR SYRACUSE

Ernest H. Muller

Total Miles	Miles from last point	Route description
0.0	0.0	Assembly point: Parking lot, Sheraton Motor Inn Thompson Rd. and New Court St. Carrier Circle, near Thruway Exit 35
		Departure time: 8:15 A.M. Sharp! All travel by bus!
		Leaving Sheraton Motor Inn, proceed 75° around Carrier Circle and turn right (S) onto Thompson Rd.
		Proceed south across lacustrine silt of Iroquois lake plain. In one mile rise onto red till-veneered shale slope.
1.6	1.6	Cross meltwater cross channel utilized as corridor by N.Y. Central R.R., Erie Boulevard and formerly by Erie Canal. Channel is below main Iroquois lake level and augering shows peat and marl over fine sand and clay, underlain by coarse alluvium, suggesting rise of Iroquois waters into meltwater channel, followed by swamp development in poorly drained basin left after Iroquois extinction.
2.0	0.4	Crossing Erie Boulevard at traffic light, proceed S on Thompson Rd. rising onto sharp slope developed on Syracuse Formation.
2.3	0.3	Turn right (W) and in .5 mile angle left (SW) past Lemoyne College campus.
3.1	0.8	Turn right (W) onto Salt Springs Rd. over drumlinized upland developed on thin till over Syracuse shales.
3.7	0.6	Turn left (S) downslope at Catholic school. Cross Genesee Street at traffic light, and turn right (SW) at next corner, onto Meadowbrook Drive. Continuing SW on Meadowbrook Drive, follow meltwater channel to its end in "t-intersection"
5.4	1.7	Turn left (S) onto Buckingham St. In .2 mile, turn right (W) onto Colvin St. Pass red till exposure in truncated drumlin at left (S) of road.
5.9	0.5	At traffic light opposite Manley Field House, turn left (S) onto Comstock St. At 3rd "Stop" street, bear left, joining Jamesville Rd. and continue south.
6.9	1.0	Turn right (W) onto Ainsley Drive. Cross tracks at Loblaws.
7.4	0.5	Turn left (S) onto Brighton Rd. at "t-intersection". On left,

TRIP D (Continued)

Total miles	Miles from last point	Route description
		railroad cut exposes section in Fiddlers Green dolomite which forms floor of flat-bottomed, steep-walled Rock Cut or Railroad Channel leading east from this point. With its threshold at 550-ft. this is one of several major meltwater channels which controlled eastward escape of water from lakes imponded in central New York through valleys, between the northward receding margin of the ice sheet and the plateau divides to the south.
		In .2 mile rise sharply over scarp developed on Manlius Group, with Elmwood Formation exposed at left near bench edge.
8.0	0.6	Turn right (W) onto N.Y. Rte 173 and 20N, the Seneca Turnpike. Descend to floor of Onondaga trough over strata of Manlius Group. Cross U.S. Rte. 11 (Salina St.) and Onondaga Creek.
		Near Onondaga Lake, about 3 miles north, the bedrock floor of Onondaga trough is 417 ft. below the surface or about 25-ft. below sea level.
9.3	1.3	Turn left (S) onto N.Y. Rte 80, Valley Drive, at first intersection west of Onondaga Creek.
10.5	1.2	Near Dorwin Springs, road ascends onto gravel bench, dissected and with low constructional topography. At right (W) massive Onondaga Limestone supports narrow benches on the valley wall. At left (E) the gravel bench is about at level of the threshold of Rock Cut Channel on opposite side of the valley.
11.0	0.5	STOP ONE. W. F. SAUNDERS & SONS, INC. GRAVEL PIT Discussion of character and structure of gravel bench in its relationship to Onondaga Trough history.
		Continue south on N.Y. Rte. 80.
12.3	1.3	Enter Onondaga Indian Reservation. Cross Commissary Creek which dissects end of 560-ft bench.
13.6	1.3	Ascend onto bench at approximately 620 ft. In .4 mile, leave Onondaga Indian Reservation.
14.6	1.0	Turn right (W) following N.Y. Rte 80 on Tanner Rd. at Gwills Corners.
15.1	0.5	Continue west on Johnny Cake Rd., leaving N.Y. Rte 80 at Griffins Corners. Rise to level of 720-ft. bench. Cross Onondaga Hill Rd. then descending toward Nichols Corners, note sand and gravel exposures on left (S).

Total miles	Miles from last point	Route description
17.1	2.0	At Nichols Corners, turn right onto Cedarvale Rd. Just before turning note red clay till in stream bank at left (S). Proceeding NW on Cedarvale Rd. follow Cedarvale meltwater channel. Note constructional topography due to deposition from stagnant, debris-littered ice on slope at right (NE).
19.0	1.9	Turn left (S) onto Amber Rd. and proceed across gravel bench at 680 ft. msl, with sharp rise to bench above 800 ft. msl on right.
19.6	0.6	STOP TWO. CEDARVALE SAND AND GRAVEL CO. Composition and structure of the gravel bench in relationship to Cedarvale Channel and Onondaga Trough history. Proceed south on Amber Rd. at base of scarp of highest bench, then rising to 800-ft. level with view to right (N) across the gently sloping surface of coarse gravel bench of the previous stop.
21.0	1.4	Continuing on Amber Rd. turn sharply south and continue ascent. Note flat-topped mesa-like delta remnant on left (E) at 800 ft. msl. near South Onondaga.
22.1	1.1	On right (W) note head of sizable meltwater channel, the Navarino Channel by which glacial meltwaters escaped southward into basin of Otisco Lake. Continue through area of moderate constructional topography deposited by stagnant ice. Note Navarino Channel paralleling Amber Rd.
23.1	1.0	Turn left (E) onto U.S. Rte. 20, Cherry Valley Turnpike, at Navarino.
24.9	1.8	At Joshua Corners, on right (SW) note level swampy area at head of minor meltwater channel which contributed to complex Amber delta deposited into a predecessor of Otisco Lake, 3 miles SW.
26.0	1.1	Turn right (S) at Lords Corners, onto Lords Hill Rd., N.Y. Rte. 80. Ascend over Hamilton section, near summit passing biohermal zone in Spafford Shale, rich in rugose corals, overlain at top by Owasco shale. When not tar-concealed by Highway Department these gullies afford fine collecting. Descend and cross open, marshy east-west valley. To left (E), Fall Ck. flows to Rattlesnake Gulf. To right (W) stagnant ice features comprise divide between Otisco and Onondaga drainage basins.
29.5	3.5	Continue south through Otisco on N.Y. Rte. 80.

Total miles	Miles from last point	Route description
31.5	1.0	Continuing on N.Y. Rte 80, bear left onto Skaneateles-Hamilton Turnpike toward Vesper. Descend SE along trough-like glacial furrow occupied by headwaters of Onondaga Creek.
34.0	2.5	Continue SE on N.Y. Rte 80 through Vesper. Cross Onondaga Creek. Enter complex Tully moraine belt where minor ridges project into this tributary trough with curvature convex to the northwest. At Fellows Falls, Onondaga Creek drops with hanging and barbed juncture into Onondaga trough, in this area called Tully Valley. To the left ahead (NE) local relief exceeds 1250 ft. from upland to trough floor on proximal (northern) flank of massive Tully (Valley Heads) moraine. The abrupt proximal border and gently graded distal slope of this moraine is characteristic of valley-blocking moraine loops of this system in central New York. Seismic refraction profiles suggest that the unconsolidated valley fill in mid-trough opposite Fellows Falls may be 400 to 500 ft. thick with the bedrock floor at 300 to 400 ft. msl.
35.6	1.6	Leave N.Y. Rte. 80. Continue south along west wall of Onondaga trough. On right Moscow shale exposed in trough wall. On left, Tully moraine with strong kame and kettle topography. Southward the kames diminish in relief and grade into kame terrace. Crooked Lake at left occupies a compound kettle.
37.9	2.3	Turn left (E) across kettle-dotted outwash plain. Stagnant ice of the Tully ice tongue extended about one mile south of this route to an "advance Valley Heads" position, before receding 3 miles north to the massive "main Valley Heads" position. The position of this moraine complex has been ascribed to bedrock topographic control at the former drainage divide. Seismic data at Tully Lake suggest depth to bedrock of about 225 ft.
39.2	1.3	Turn right at "t-intersection"
40.0	0.8	STOP THREE. GREEN LAKE (TULLY LAKES) Examination of features and materials of pitted outwash plain. Discussion of significance in terms of Valley Heads and Onondaga trough glacial history. Proceed east toward Tully.
40.5	0.5	Cross N.Y. Rte. 281 and continue east across outwash plain.
41.0	0.5	Turn left (N) onto U.S. Rte. 11 toward Tully. Continue

Total miles	Miles from last point	Route description
		through Tully on North Street. Leave outwash plain and ascend onto upland developed on Ithaca and Sherburne Formations.
43.9	2.9	Enter distal margin of Tully moraine. For next 2 miles constructional topography is strong, diminishing gradually on proximal edge of moraine.
46.7	2.8	Join U.S. Rte 11 and continue north into Lafayette.
48.4	1.7	At traffic light in Lafayette, turn right (E) onto U.S. Rte 20, Cherry Valley Turnpike. In .2 mi. turn left (N) onto Lafayette Rd. The gently curving, partly drift-filled trough of Butternut Creek is visible ahead on right, with U.S. Rte 20 swinging across at Big Bend. Crossing the upland, bedrock ridges, such as Irish Hill on right (E) are streamlined, gently molded and parallel to lineation of drumlins a few miles to the north.
53.6	5.2	Pass Bull Hill Rd. Drumlins on left (W) are composed of bouldery, lime-rich lodgment till. Alignment is N5W, as compared to N30W in outskirts of Syracuse. Artificially imponded Jamesville Reservoir on right (NE) ahead.
55.4	1.8	Bear right at fork onto Barker Hill Rd.
55.9	0.5	STOP FOUR. HORSESHOE OR LOOP CHANNEL Consideration of nature of Smoky Hollow and the Loop umlaufberg, and of their significance with respect to late Cary glacial recession. Continue north on Barker Hill Rd. Descend onto terrace that blocks upstream end of the Loop. Roadcut at the terrace edge exposes rhythmically laminated lake sediments. The eastern arm of the Loop contains kame gravels.
56.7	0.8	Cross Smoky Hollow, part of a major meltwater channel with bedrock floor just below 800 ft. msl. Sharply incised into non-resistant Hamilton shales, this outlet may have controlled drainage of imponded waters in Onondaga trough at level of highest delta in Cedarvale Channel. Note that drumlin on right (E) is truncated by wall of Smoky Hollow, indicating that channel cutting postdated final drumlin moulding. Continue north on Barker Hill Rd.
57.4	0.7	Turn right (E) in Southwood. Descend from drumlinized Hamilton upland onto channeled Onondaga bench.
58.1	0.7	Join N.Y. Rte 173, Seneca Turnpike and continue east.

TRIP D (Continued)

Total miles	Miles from last point	Route description
58.3	0.2	Turn left (N) into Clark Reservation State Park.
		STOP FIVE. CLARK RESERVATION STATE PARK Examination of features due to erosion by glacial meltwater, solution by underground water and joint control as developed near Green Lake and along south wall of Rock Cut Channel. Discussion of significance in terms of interpreted history of glacier recession.
		Return to N.Y. Rte 173 and turn left (E) toward Jamesville. On left (N) of road note deep channel leading east from Green Lake to Butternut trough.
60.0	1.7	Cross tracks and turn left (N) onto Jamesville Rd. which parallels Butternut Creek. Below falls, in .2 mi. Butternut Creek exposes type Fiddlers Green dolomite.
61.2	1.2	At fork bear right, continuing N on Jamesville Rd. Descend to floor of Butternut trough. Cross Butternut Creek and the eastern or outlet end of Rock Cut Channel is visible on left (W), notched by narrow post-glacial Rams Gulch.
61.8	0.6	Recross Butternut Creek on alluvial plain at approximate level of Iroquois Lake which may have inundated lower end of valley as a consequence of isostatic upwarp northward. Rise onto trough wall and proceed north.
63.6	1.8	Turn right (E) onto Genesee Turnpike.
63.8	0.2	Turn left (N) at traffic light onto Erie Boulevard. In about a mile note exposed Syracuse formation in new excavations on left (SW) of road.
65.5	1.7	Turn right (N) at traffic light, onto Thompson Rd. and proceed north to Carrier Circle.
67.6	2.1	Arrive Sheraton Motor Inn, Carrier Circle; Thompson Rd. at New Court St.

THE SALINA GROUP

by

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Introduction

It is a strange paradox that the Salina Group, which was of such importance in the history and early industrial development of central New York, remains one of the least understood of the Paleozoic groups in the region. After brilliant pioneering work by Vanuxem, study of Salina stratigraphy and paleontology languished for almost a century. James Hall's interest in fossils led him to direct his own efforts, and the State Survey which he so long dominated, towards better collecting grounds. The late Prof. H. L. Alling of Rochester published an excellent study of the salt deposits (1928), and contributed important petrographic information. D. H. Newland wrote several papers dealing with the Salina Group, but these center on economic geology. Short papers by Ruedemann, Sarle, Chadwick and several others discuss various aspects of Salina stratigraphy and paleontology. These publications, chiefly short notes, are widely scattered in the geologic literature. Only in the last decade has systematic study of the Salina Group been undertaken. Alling and Briggs (1961) described the regional relationships of the Syracuse and adjacent formations. Their study will be a basic reference for years to come, but they have left much to be done by future workers. The unsolved problems of the Salina Group provide a challenging field for students of stratigraphy and paleontology alike.

Geologic Setting

The Salina Group was deposited during a single great cycle of sedimentation. Above is the marine Cobleskill and below is the marine Guelph-Lockport. Between them, the Salina Group is characterized by red beds, evaporites, and a sparse fauna containing many strange forms: eurypterids, phyllocarids, scorpions, and New York's oldest known fishes. The cycle records a time of restriction of the Silurian seaways and their subsequent reopening. A marine withdrawal began earlier to the north and east, but its influence on sedimentation in central New York became notable by the time the Guelph Dolomite was being deposited farther west. Thus the Guelph is unknown east of Rochester, and its stratigraphic position in the Syracuse area is occupied by predominantly red clastics of the Vernon Shale, oldest formation of the Salina Group (Fig. 1). The writer attributes this relationship to facies change, and believes that the lower part of the Vernon is at least as old as the Guelph. An alternate interpretation may be that the Guelph is missing due to a disconformity between the Salina and the older formations. Just south of Herkimer, the Lockport is absent, and the Vernon shale overlies the Herkimer Sandstone Member of the Clinton Group (Rochester Shale equivalent). A few miles farther east, at the village of Deck, the Vernon is absent and the Syracuse Formation lies on the eroded, irregular surface of the Herkimer. The presence of at least one unconformity is certain, but its age is open to question.

According to some writers the Salina sediments record a time of marine withdrawal, but it is more accurate to say that they indicate hydrographic restriction of a particular basin. Michigan, West Virginia, New York, and the states between shared a common depositional basin during late Silurian time. For convenience, this has been called the Salina Basin (Leutze, 1960, fig. 1. Alling and Briggs,

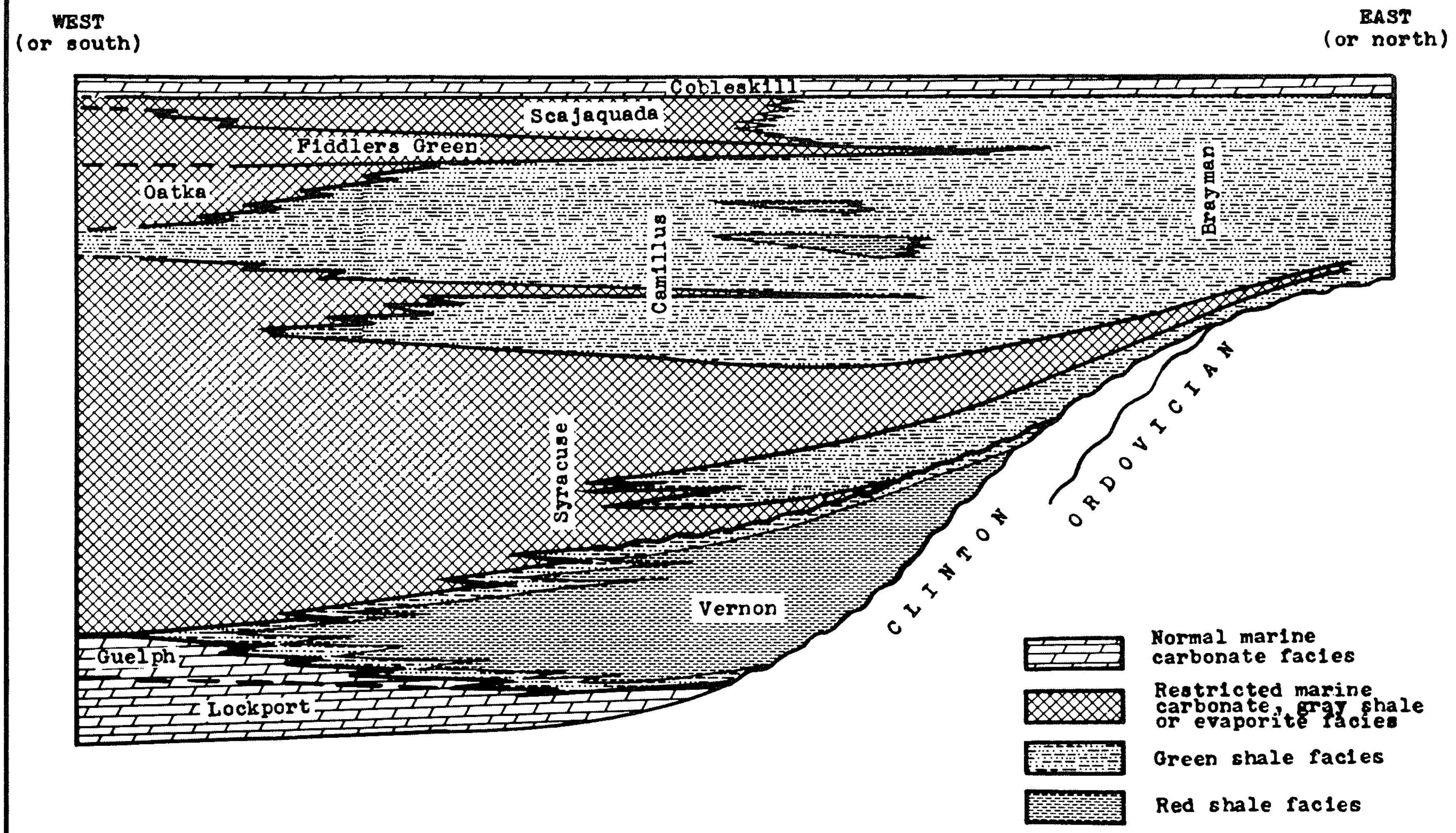

Fig. 1

Fig. 1. Diagrammatic cross section of the New York Salina Group. Not drawn to scale.

1961, fig. 12, subdivided this basin into three intimately connected basins). Throughout this area, the lithologies and faunas peculiar to a restricted basin are developed. Several brief episodes of marine invasion and retreat are recognizable in the stratigraphic sequence. In New York, the Salina marine tongues override all older Silurian deposits (Fig. 1), and this fact makes it incorrect to say that this was a time of marine withdrawal.

During the existence of the Salina Basin the Adirondack region, Appalachia, and all adjacent lands had been worn low by long erosion. They supplied only fine clastics to the great, shallow depression. The basin had intermittent (or greatly restricted) connections, via the Hudson Bay lowlands, with an Arctic seaway. Salina Basin faunas are consequently more closely related to those of Gotland and Central Europe than to British Silurian assemblages. Probably other channels connected the Salina Basin from time to time with open seas to the south and west.

When marine connections were cut off, the waters stagnated. Depending on tide, weather, and tectonic conditions, vast mudflats were either shallowly submerged or temporarily exposed. Mud-cracked layers alternate with beds containing marine faunas throughout the Salina Basin. Only hardy euryhaline organisms could survive in this environment for long. Times of evaporation which brought about the deposition of salt and gypsum were followed by influxes of less saline water. In New York State, two lentils containing marine faunas directly overlie two evaporite horizons, suggesting that marine transgressions terminated evaporite deposition.

The Type Salina Section in Central New York

The oldest Salina unit is the Vernon Shale. Although the Pittsford Shale was originally designated as the lowest member of the Salina Group, later workers generally agree that it is best to consider it as a part of the Vernon distinguished chiefly by the eurypterid fauna found in a few lentils at Pittsford. The Vernon remains one of the least understood formations in the State. It is a great wedge of bright red shale, with local lentils of green shale, dolomite, sandstone, or gypsum. that reaches its maximum thickness of 500 to 600 feet in the vicinity of Syracuse.

The highest beds of the Vernon Shale are typically green, locally interbedded with a few thin shaly dolomites. Detailed measurement of the upper part of the Vernon indicates that progressing westward, the highest red beds are found successively lower in the section. Thus it appears that the red bed facies wedges out in a westerly direction due to replacement of red shales by green at both top and bottom. There is a corresponding increase in number and thickness of dolomitic beds and green shales throughout the formation. At Ilion Gorge, not less than 95 percent of the formation is red shale. In Onondaga County, the writer estimates that red beds make up about 70 percent of the formation. West of the Genesee River, less than half of the formation retains its red color.

Because it weathers rapidly, exposures of the Vernon Shale are temporary. Erosion has developed miniature badlands on some steep slopes (Fig. 2). A field study of the Vernon might reveal continuous recognizable beds or zones within the formation. Thus far, there has been little attempt to relate one exposure to another.

The fauna of the Vernon is evidently restricted to a few very thin lentils and is known only from isolated localities. The section described by Wayland-

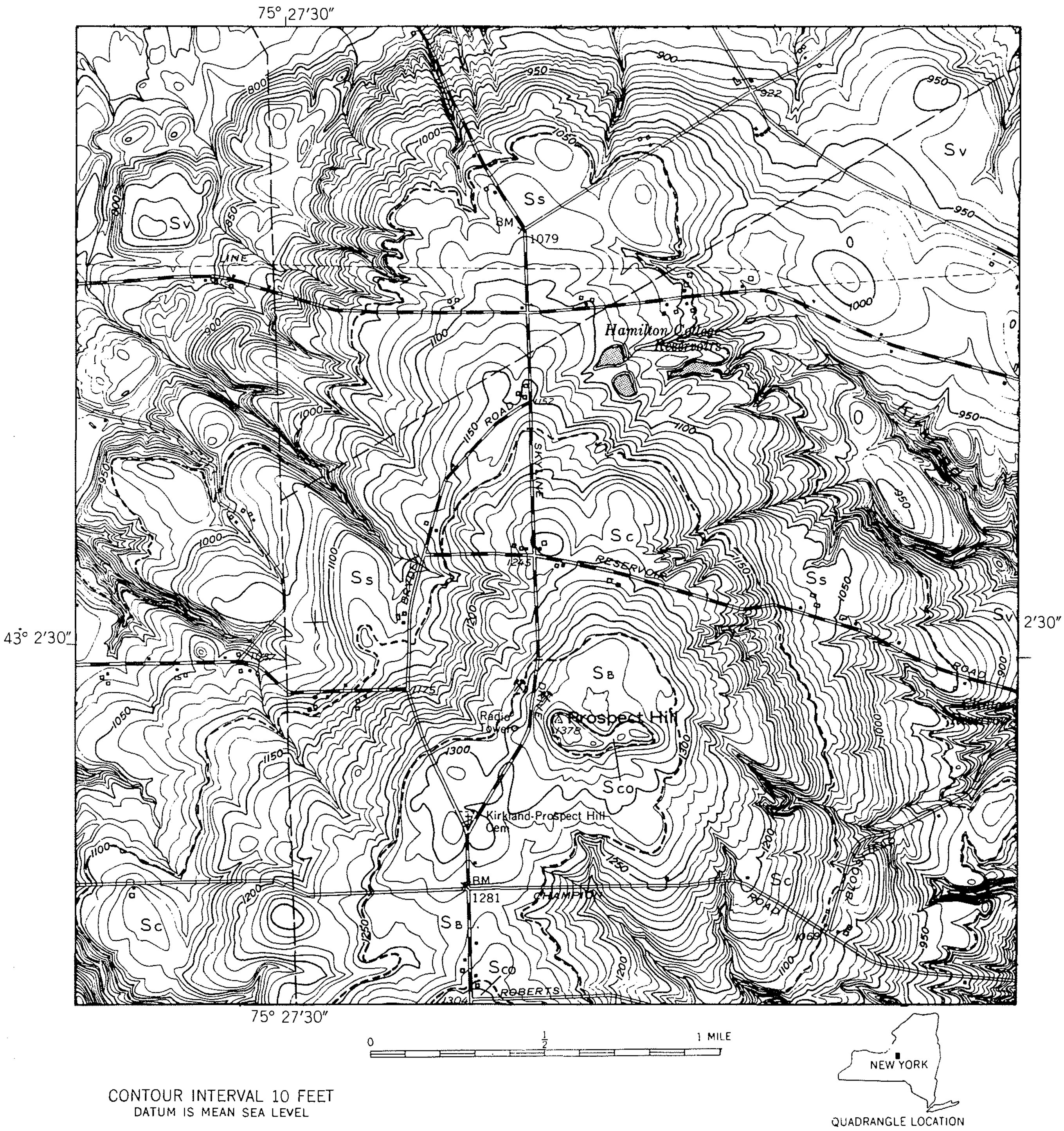

Fig. 2. Part of Clinton quadrangle showing influence of Salina Group on topography. Intricately eroded Vernon shale (Sv) underlies low ground. Typical Vernon topography in north and northwest part of map. Dolomite beds of Syracuse formation (Ss) cap Vernon to form terraces. Steeper slopes eroded on Camillus shale (Sc), as on northeast slope of Prospect Hill. Bertie formation (Sb) with resistant Fiddlers Green member at base supports plateau atop hill. Small outlier of Cobleskill dolomite (Sco) forms the pinnacle.

Smith (in Kjellesvig-Waering and Caster, 1955, p. 1042) near the town of Vernon contains the most diversified fauna: pelecypods, a gastropod, cephalopods, and two genera of brachiopods; a single siphonophore, remains of armored fishes, eurypterid fragments, and ostracodes.

The Syracuse Formation rests disconformably on the Vernon Shale at Syracuse and exposures to the east. To the west, a conformable relationship is inferred. The abrupt change in lithology from soft shale to resistant dolomite is marked by a corresponding change in topography. The lowest dolomites of the Syracuse Formation create a flat terrace which contrasts strongly with the eroded shale slopes below (Fig. 2). The Vernon Shale is almost impermeable, so that ground water flows out in springs and seeps at the formational contact.

The Syracuse Salt was originally defined as the salt and associated sediments known only in the subsurface. At the outcrop, only the overlying Camillus Shale was recognized. In 1956, the writer redefined the Camillus Shale and first published the term "Syracuse Formation" (Fig. 3) as applied to a separate mappable unit. The Syracuse Formation at Syracuse was divided by the writer into five lithologic members. The Transition Member is composed of thin gray dolomite beds which alternate with dull green shales. A pebbly, sandy bed of dolomite marks the contact with the Vernon Shale. The eurypterid genus Waeringopterus is found in the lowest part of the formation and is prolific at one horizon. This member is not fully exposed anywhere in Onondaga County, but its thickness is estimated from composite sections to be between 70 and 80 feet.

Overlying the Transition Member is a bed of structureless gray clay averaging 12 feet in thickness. Locally, blocks of bedded gypsum encased within this Lower Clay Member suggest that it is the residue of a soluble evaporite bed. Salt well logs support such an interpretation, as this stratigraphic position corresponds to a major salt bed in the subsurface just south of Syracuse.

The Middle Dolomite Member (37 to 44 feet thick at Syracuse) is composed of well-bedded gray to brown shales and dolomites. All of the dolomite beds are very impure. The gray shales at the bottom of this unit contain an abundant marine fauna composed chiefly of mollusks and brachiopods, but with Medusaegraptus (graptolite? sea weed?), ostracodes, and rare eurypterid fragments. This is the Camarotoechia zone, named for the commonest brachiopod.

A second bed of clay, the Upper Clay Member, overlies the Middle Dolomite. It resembles the Lower Clay Member in every respect save stratigraphic position.

The Upper Dolomite Member (approximately 15 feet thick) is the highest division of the Syracuse Formation. The lowest beds of the member are shaly and contain a marine fauna similar to that of the Camarotoechia zone, but with fewer brachiopods and a large, pectinoid pelecypod. The reticulate ornamentation and shape of this clam suggests that it belongs to the genus Actinopteria, and the faunal zone is known as the Actinopteria zone. This zone is only a few inches thick, but contains many fossils. The assemblage is dominated by pelecypods, gastropods, and cephalopods. Eurypterids, ostracodes, conularids, brachiopods and phyllocarids have also been found in the zone. Above the Actinopteria zone are beds of shaly dolomite and a bed of pitted dolomite known as "vermicular rock". The pits are evidently due to the leaching of some soluble mineral which leaves the remaining dolomite looking somewhat like vesicular lava. The highest part of the member is composed of thinly laminated argillaceous dolomite. Since the next higher formation (Camillus) is a shale, the contrast in lithologies is locally marked by

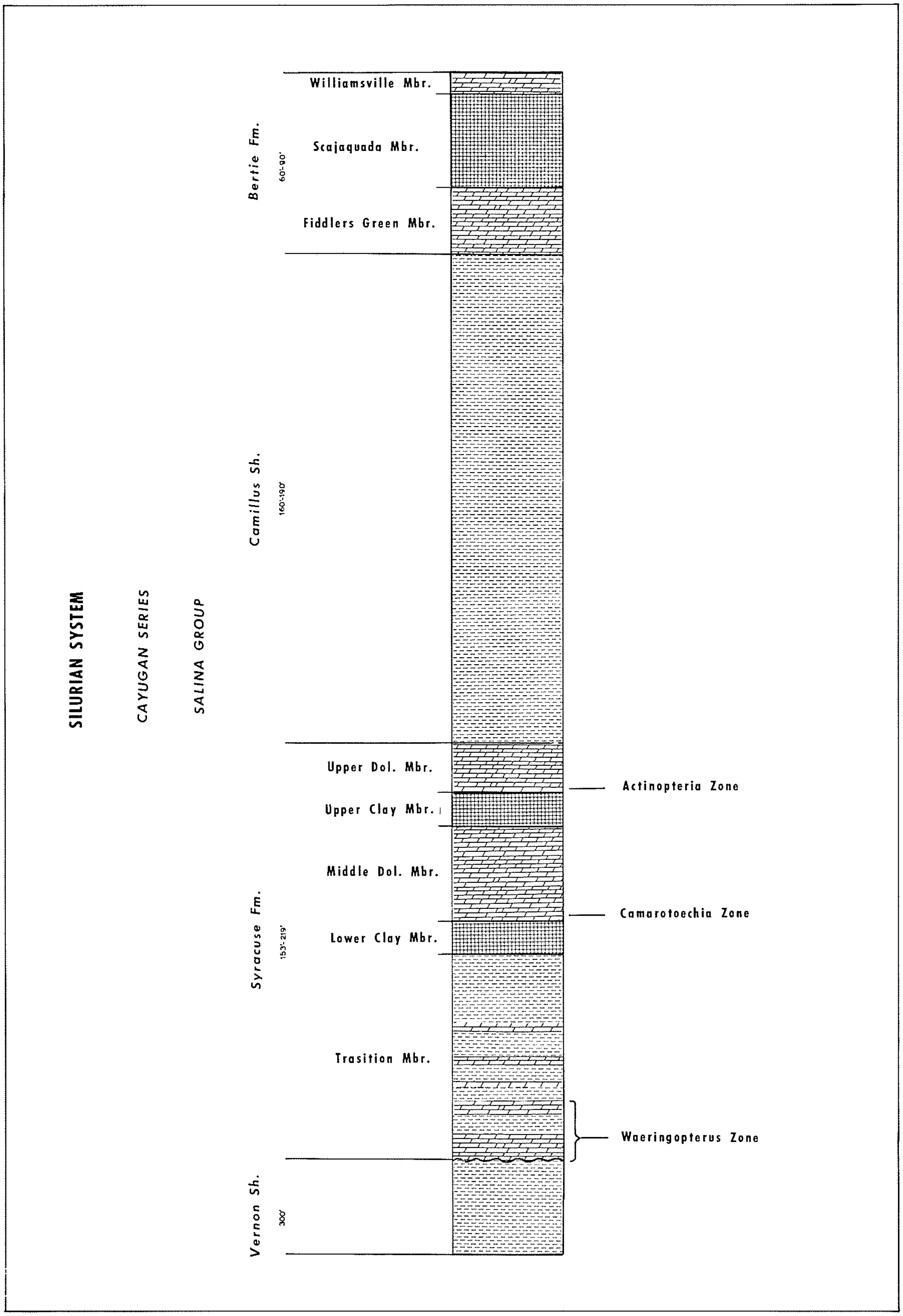

Fig. 3. Stratigraphy of the Salina Group.

a topographic bench (Fig. 2) and by waterfalls on some streams.

In the vicinity of Syracuse, the aggregate thickness of the Syracuse Formation is about 150 feet. Although there are exceptional beds, the formation can be distinguished from adjacent stratigraphic units by: 1. The abundance of dolomite and evaporites; 2. gray, tan, or brown colors; 3. the distinctly bedded character of the rocks. Both the Vernon and Camillus have a massive, earthy appearance.

The Camillus Shale is conformable with the Syracuse Formation and the two lithologies intertongue down-dip and to the west (Fig. 1). The Camillus is a homogeneous olive green shale with a maximum thickness of about 200 feet. It weathers rapidly to irregular chips which soon bury the exposure unless removed by erosion. East of Syracuse, two zones of dull red shale seem to hold fixed stratigraphic positions within the formation. A thin dolomite near the bottom thickens to the west, where it is underlain by a bed of gypsum. Gypsiferous and sandy zones are present at some outcrops of the Camillus Shale, but their continuity is unknown. No significant fossils have been reported from this formation.

The Bertie Formation is composed of three members. The Oatka Shale, considered by Chadwick to constitute a fourth member, is simply a dolomitic portion of the upper Camillus Shale. The lowest, and topographically most significant member of the Bertie, is the Fiddlers Green. It is a tough gray dolomite that is 27 feet thick at the type locality in Fiddlers Green Gorge at Jamesville and averages about 25 feet thick across most of the State. Its outcrop belt is marked by a terrace (Fig. 2) and many waterfalls. Ostracodes are prolific in this unit, and the highest beds contain the famous Herkimer County eurypterid fauna (zone of _Eurypterus_ _remipes_ _remipes_).

The Fiddlers Green is overlain by the Scajaquada Member. Its lithology is not constant along the strike, but from Syracuse to Cayuga Lake, it is an impure gypsum which was formerly quarried. At exposures where the gypsum has been leached out, the Scajaquada resembles the clay beds of the Syracuse Formation.

The highest member of the Bertie is the Williamsville, an argillaceous dolomite ("waterlime") which grades into the overlying Cobleskill Dolomite. It attains thickness of around 7 feet in western New York, where it has been extensively quarried for natural cement manufacture. This member is the main eurypterid horizon of the Buffalo area. In the vicinity of Syracuse it is similar in thickness and lithology but contains very few fossils.

Summary of Salina Paleontology

The Upper Silurian poses especially difficult paleontological problems throughout the northeastern states, where the Cayugan rocks were deposited in a restricted marine basin. The faunas in this arm of the sea were composed chiefly of hardy forms able to survive in an environment characterized by highly variable salinity, and drifting organisms. Within the confines of the Salina Basin, the following generalizations apply to typical faunas: 1. Fossils are sparse; 2. Small number of species but local abundance of individuals; 3. Corals, crinoids, and trilobites are very rare; 4. Ostracodes, eurypterids, and the rarer arthropods are relatively abundant; 5. Brachiopod and molluscan assemblages are similar in various parts of the basin and at several horizons. The entire fauna has a strong provincial aspect, with few forms which are significant for inter-regional correlation. Paleontological correlation is further complicated by the poor preservation of most calcareous organic remains in the Cayugan rocks of the regions. This condition is largely attributable to the dominance of evaporites, dolomite and red shale. Calcareous skeletons are rarely preserved in any of these lithologies, though chitinous material is frequently found in a remarkable state of preservation. Alling and Briggs (1961, p. 529 and 539, table III) have aptly summarized the difficulties of attempting to use Salina faunas in stratigraphic correlation. Eighty-two percent of the names which appear on their check list of Cayugan fossils are listed for only one formation or area, and an additional 10.7 percent are listed only twice. Consequently, any given assemblage appears to have very few species in common with penecontemporaneous assemblages in other parts of the Salina Basin, or even with the faunas reported from adjacent formations in the same area. Not only does this situation appear highly unnatural, but it also presents the non-paleontologist with an erroneous impression as to the diversity of Cayugan faunas.

Actually, Cayugan faunas are remarkably similar in all parts of the basin. Among the brachiopods, both articulates and inarticulates are represented. Lingula, a genus noted for its tolerance to variable salinity, and Orbiculoidea are both found in the argillaceous facies. It is somewhat surprising to note that they are much less common than articulates at most exposures. Camarotoechia is widespread, as are two other types: a small, smooth, rostrate form with the general appearance of Hindella or Whitfieldella, and a small dorsoventrally flattened brachiopod. The latter is represented by Schuchertella or Stropheodonta at some horizons and by Chonetes at others. It has generally been assumed that articulate brachiopods require a normal marine environment, but the persistence of the above forms throughout the Salina Group suggests that they adapted to precarious living conditions and variable salinities. Since the times when the basin was sufficiently freshened to allow the existence of normal marine faunas must have been relatively brief, judging from the thinness of the fossiliferous zones, these brachiopods were capable of rapid dispersal. Were it not for the articulate brachiopods, it would be easier to argue that the entire Salina fauna represents a brackish or fresh-water assemblage to which drifting and swimming forms were added.

Gastropods, pelecypods, and cephalopods are the common representatives of the phylum Mollusca. Most of the gastropods fall into one of two generalized types, either a high spired form resembling Hormotoma or Loxonema, or a smaller, low spired, rapidly expanding conch like Holopea. The majority of the cephalopods are either brevicones with visored apertures (Pristeroceras, Phragmoceras, Hexameroceras, Tetrameroceras, etc.), or straight orthocones. Among the pelecypods, two shapes can be expected: a Pterinea-Actinopteria type of pectinoid, and a Modiolopsis-like shell of small to moderate size.

Arthropods are abundantly represented by species of Leperditia, and less commonly by other ostracode genera. Eurypterids are abundant locally, but only in thin zones. At other horizons they are rare.

Cyathaspid fish fragments are present, particularly associated with the red bed facies. Bryozoa, conularids, scyphozoa, graptolites, and many other groups have been reported from Salina rocks, but none of these are sufficiently common or widespread to merit discussion in this synopsis.

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*Dr. Leutze's M.S. thesis and Ph.D. dissertation are important sources of unpublished information on the stratigraphy and paleontology of the Salina Group in New York State and have been added to the list of references. - Editor.

FACIES OF THE MANLIUS FORMATION (LOWER DEVONIAN) OF NEW YORK STATE

by Léo F. Laporte
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INTRODUCTION

The Manlius Formation is the basal unit of the lower Devonian Helderberg Group of New York. The Helderberg Group, itself, is a lithologically and paleontologically diverse sequence of carbonates that ranges from 30 to 300 feet in thickness; it crops out from west of Syracuse, eastward to Albany, and from there southwestward to Port Jervis and into the adjoining states of Pennsylvania, Maryland, West Virginia, and Virginia (Fig. 1).

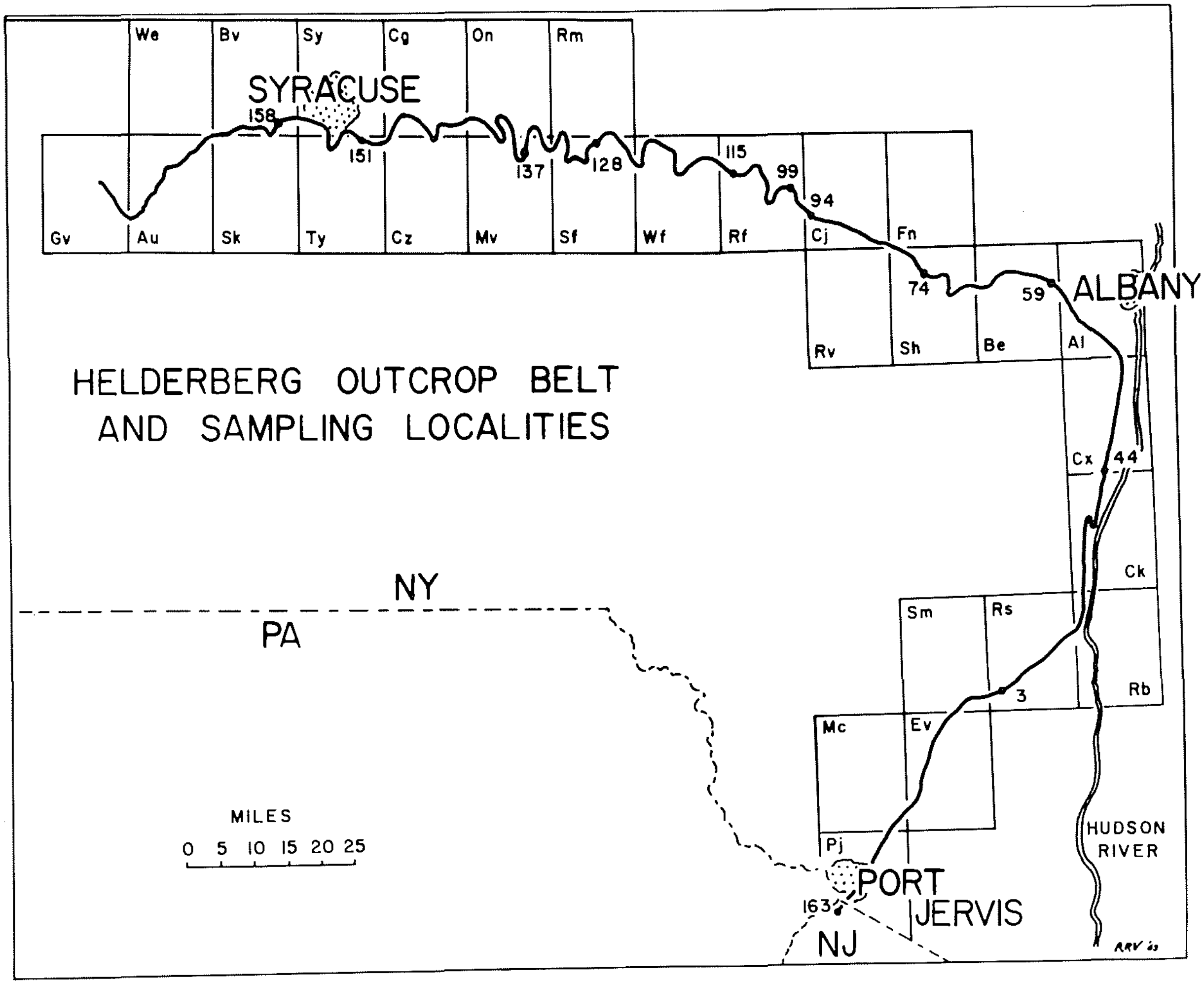

Fig. 1. Line of outcrop of Helderberg Group in New York. Numbers indicate 12 selected localities from which 200 samples of the Manlius have been studied in detail.

In New York, the Helderberg sequence is conformably underlain by the upper Silurian, dolomitic, Rondout Formation; above, a pre-Oriskany erosion surface cuts out increasingly older units of the Helderberg to the west. Detailed stratigraphic studies by Rickard (1962) have demonstrated that the various lithologic types with their associated fossil assemblages within the Helderberg Group are, for the most part, time transgressive units becoming progressively younger to the west. The Helderberg sequence, therefore, represents a series of carbonate environments which migrated westward during early Devonian submergence. These stratigraphic relationships are summarized in Figure 2. In the same report Rickard has reviewed the evidence based upon the faunal studies of Boucot (1960) and others that the Manlius is earliest Devonian, rather than latest Silurian, in age.

The Helderberg carbonates are particularly well suited for detailed paleoecological analysis because of their wide areal extent; their abundant, diverse, and well-preserved fossil assemblages; their excellent field exposures; and because of the excellent stratigraphic background that Rickard's earlier work provides. For these reasons a detailed investigation of these rocks has been begun, starting with the lowest unit in the Helderberg section, the Manlius Limestone, which is some 30 to 90 feet thick. The following discussion is a simplified summary of the initial results of this investigation, which included extensive field examination of the Manlius (47 localities) as well as detailed laboratory study of more than 200 polished slabs and 200 thin sections collected from some 12 selected localities across the state (Fig. 3). A detailed description and interpretation of the Manlius Formation is currently being prepared for subsequent publication elsewhere.

MANLIUS FACIES

General

Examination of the Manlius reveals that, lithologically and paleontologically, the unit is neither homogeneous nor randomly variable. In fact, by combining a variety of rock attributes including grain composition, texture, fossil occurrences, and primary structures three distinct sedimentary facies can be recognized. Furthermore, these facies tend to correspond with particular stratigraphic levels within the Manlius - either with named members in the central part of the state, or unnamed but distinct physical horizons in the eastern part of the state. These three facies are interpreted as being deposited very near (i.e., within several feet) to mean sea level; more specifically, either above mean tide level (SUPRATIDAL), at mean tide level (INTERTIDAL), or below mean tide (SUBTIDAL).

Table 1 summarizes the lithologic and paleontologic character of these facies and their stratigraphic occurrence within the Manlius Formation.

Supratidal Facies

This facies is a laminated, dolomitic limestone which is massive and virtually unfossiliferous. (These are the "waterlimes" of various authors.) The individual laminae, about 1/2 to 1/4 mm thick, are composed of dolomite spar and rhombs which grade into a calcite pelletal mud; the top of the lamina is a very thin, dark bituminous layer which may be the vestige of an algal mat. Deep polygonal mud cracks and "birdseye" structures are common; small burrows and rare ostracode valves are the only organic traces. Horizons rich in carbonate intraclasts, having some rounded chert fragments, and lacking fossils, are also found within this facies.

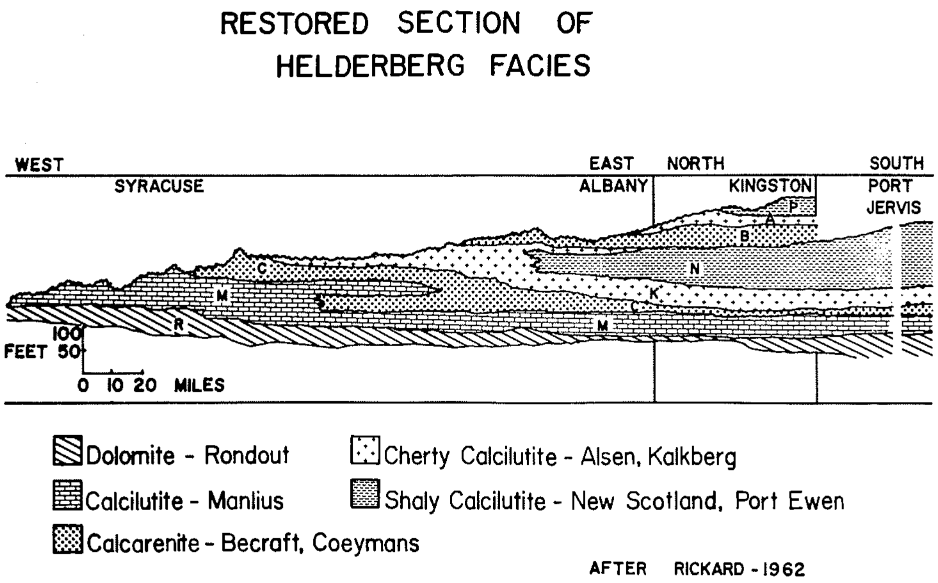

Fig. 2. Restored section of the Helderberg Group (after Rickard, 1962). Note interfingering facies relationships of various units. Rondout formation below, and pre-Oriskany erosion surface above.

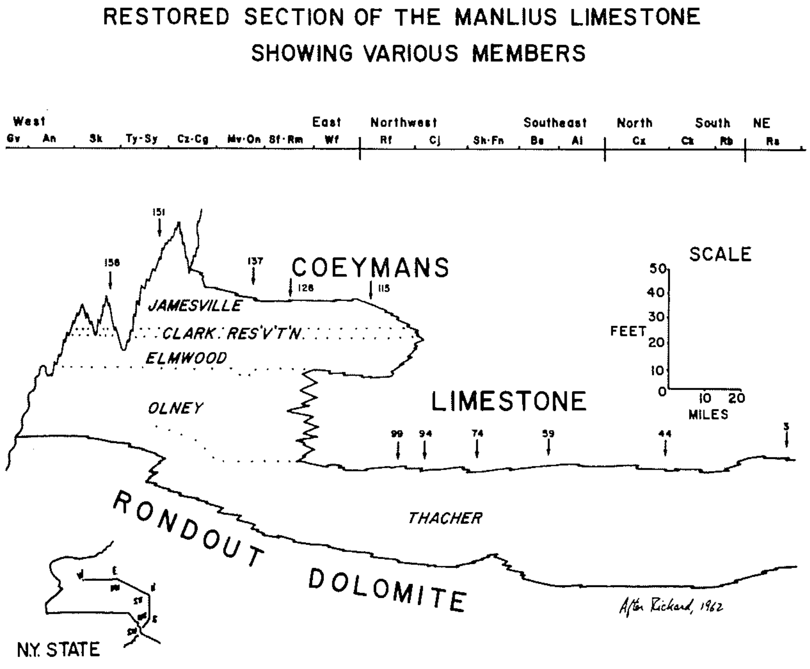

Fig. 3. Stratigraphic section of the Manlius limestone (greatly exaggerated) across New York. Five members in central New York but only one member in eastern New York.

TABLE 1

Summary of Manlius Facies

Facies	Lithology	Paleontology	Horizons
SUPRATIDAL	Dolomitic, laminated muds; mudcracks, birdseye. (Dolomitic micrites)*	Fossils rare; algal laminae, ostracodes, and burrows.	Clark Reservation, Elmwood --------------- Middle and upper Thacher.
INTERTIDAL	Interbedded pelletal lime muds and skeletal sands; occasional limestone-pebble cgls. and mudcracks. (Pelmicrites and biopelsparites)*	Fossil types few but individuals abundant. Ostracodes, tentaculids, brachiopods algal stromatolites and oncolites.	Full Thacher ------------- Lower Thacher
SUBTIDAL	Pelletal lime muds and boundstones. Medium to massively bedded; in places "reefy". (Biopelmicrudites and biolithites)*	Stromatoporoids, rugose corals, brachiopods, ostracodes, snails, and codiacean algae. Biota abundant and diverse.	Jamesville Olney ----------- Upper and middle Thacher

* Terminology after Folk, 1959

Lithologic and paleontologic attributes of various Manlius facies, and their general stratigraphic occurrences in central (above) and eastern (below)

In central New York, this facies is represented by the Elmwood and Clark Reservation Members of the Manlius. In eastern New York this facies occurs in the upper half of the only member of the Manlius occurring in that area (Thacher Member). The facies ranges in thickness from several feet to about 15 feet.

Intertidal Facies

This second facies is composed of thin to medium bedded, poorly fossiliferous, pelletal, lime muds alternating, often unconformably, with pelletal skeletal sands. (These are the "ribbon beds" of various authors.) A variety of primary structures occur in this facies including cross-stratification, ripple marks, and scour-and-fill; limestone-pebble conglomerates are also found. Thin layers in this facies may also contain oolitic grains which are either true oolites or superficially coated skeletal debris or pellets.

Fossils in this facies vary considerably in abundance; often they are found in great numbers but representing just one or two taxa. Leperditid ostracodes, tentaculitid molluscs, spiriferid brachiopods, trepostome bryozoans, and serpulid worms are most typical.

In many places the lowest part of this facies, which is stratigraphically the base of the Manlius, contains well-developed algal stromatolites and oncolites. These algal structures are composed of many thin (1 mm or less), irregular, carbonate laminae which encrust either free-lying grains, such as ostracode valves or intraclasts, ("oncolites"), or the substrate directly, forming heads of various sizes, up to 3' high and 4' long, and shapes ("stromatolites"). The individual laminae are composed of fine-grained calcite which is usually aggregated into dark clots, and fine carbonate sand and mud; some laminae are sinuous layers of sparry calcite (Laporte, 1963).

Studies of recent algal stromatolites (Logan and others, 1964) indicate that these structures are formed by encrusting mats of filamentous blue-green algae which trap and bind fine sand and mud at, and somewhat below, low-tide level. Successive mats construct successive laminations. In well agitated water these algae coat free sediment grains; as the grains roll about multiple concentric layers develop. In quieter water the mats lie on the substrate proper forming more or less continuous structures which build upward into heads, the size and shape of which are related to the strength and frequency of water movement.

In central New York this intertidal facies is represented by the full Thacher Member; in eastern New York the lower half of the Thacher Member contains this facies. The facies ranges in thickness from 20 feet in the Hudson Valley area to 40 feet in the Cherry Valley and Syracuse areas.

Subtidal Facies

This third facies of the Manlius is a medium to massively bedded, pelletal, lime mudstone, often having very abundant stromatoporoids that form a dense and compact rock of encrusting and hemispherical colonies. These stromatoporoid-rich horizons, although they lack the vertical scale and other geometrical properties of reefs, seem to have been wave-resistant structures composed of framework-building and sediment-binding organisms. Despite the presence of a muddy matrix the stromatoporoid colonies apparently were in water that was intermittently strongly agitated, for many large stromatoporoid heads are overturned and abraded.

The biota of this facies, although not as diverse and abundant as in other Helderberg units of New York, is the most diverse and abundant of all the facies within the Manlius Formation. It includes stromatoporoids, solitary rugose corals, occasional tabulate corals, snails, brachiopods, ostracodes, and codiacean algae (presumed green calcareous algae, like the modern Halimeda).

The subtidal facies occurs in the Olney and Jamesville Members of central New York, and in the middle and upper parts of the Thacher Member in eastern New York; it ranges from 5 to 30 feet in thickness.

In those areas where the Manlius grades laterally or vertically into the Coeymans Limestone (a crinoidal-brachiopod skeletal sand with little or no interstitial mud) there is an intermediate or transitional rock type between the subtidal facies of the Manlius and the Coeymans proper. This rock type is a pelletal, skeletal limestone with varying amounts of lime mud and many small echinoderm ossicles scattered throughout.

INTERPRETATION

If one compares the biologic, lithologic, and primary structural features of the Manlius with present day shallow-water carbonate environments, a number of striking similarities are evident. In particular, there is strongly suggestive evidence that parts of the Manlius Formation were deposited at, or slightly above mean sea level:

Manlius	Recent Analogue	Reference
1) Algal stromatolites and oncolites	Intertidal and just below low tidal level in Florida Keys and Andros Island, Bahamas	Ginsburg, 1960; Logan and others, 1964
2) Laminated, dolomitic, pelletal muds with stromatolites, birdseye, and mud cracks.	Supratidal areas in Florida Keys and Andros Island	Shinn and Ginsburg, 1964
3) Limestone-pebble conglomerates; interbedded skeletal sands and lime muds.	Intertidal zone of the Florida Keys	Baars, 1963; Laporte, personal observation.
4) Oolites and coated grains.	Just below intertidal zone, Great Bahama Bank.	Newell and others, 1960.

The marine character and relative diversity of the biota of the third facies (Subtidal) demands continuous marine submergence; and yet, if the other facies closely stratigraphically associated with it are truly supratidal and intertidal, then the submergence could not be great, perhaps just several feet. This subtidal facies would have developed in broad and slightly submerged muddy areas, marginal to the supratidal "islands" and intertidal flats.

If the sediment/water interface sloped gently from the supratidal zones to the completely submerged subtidal areas, there would be extensive portions of the bottom between the supratidal and subtidal zones that were alternately inundated and drained with successive high and low tides (diurnally, monthly, or seasonally). Tidal waters flooding and draining the flats would cut low gradient channels or creeks across the flats; the moving water in the continuously submerged parts of the creeks might favor establishment of stromatoporoid banks, analogous to the way modern mussel and oyster banks develop in tidal creeks cutting the broad mud flats of the Dutch Waddens (van Straaten, 1954) and the Gulf Coast (Emery and others, 1957).

Varying rates of subsidence and sediment production would influence sediment accumulation so that the sedimentary environments (and hence the individual sedimentary facies) migrated laterally, producing the Manlius' present-day aspect of relatively complex lateral and vertical lithologic and biologic variability. Radical facies changes would be expected in these sorts of depositional environments which lie so close to mean sea level. For slight changes in sea level, either tidal or eustatic, would effect major changes in many ecologic characters linked to amount and duration of submergency by marine waters.

Although particular members or parts of members of the Manlius seem to represent dominantly one facies or another, it should be realized, of course, that at any one time during Manlius deposition all three environments were present. Hence, it is predictable that careful tracing out of individual thin beds of the Manlius would demonstrate the change from one environment to another. Such detailed, bed-by-bed, stratigraphic analysis is presently being pursued, and the results should test the validity of the interpretation of Manlius facies genesis as presented here.

CHECKLIST OF MANLIUS FOSSILS

Syringstroma barretti	A	Stromatoporoid coral
Spongophylloides sp.	C	Solitary rugose coral
Favositids	R	Tabulate coral
Howellella vanuxemi	A	Spiriferid brachiopod
Brachyprion varistriatus	C	Strophomenid brachiopod
Tentaculites gyracanthus	A	Coniconchoid mollusc
Actinopteria sp.	R	Pterioid clam
Unidentified high spired snail	C	
Spirorbis laxa	C	Serpulid worm
Leperditia alta	A	Ostracode
Garwoodia gregaria	C	Green Codiacean alga
Algal stromatolites and oncolites	C	Structures formed by blue-green (?) algae

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STRUCTURAL FEATURES IN THE SYRACUSE AREA

by

N. E. Chute

The sedimentary formations of the Syracuse area have a regional southward dip of about 40 to 50 feet per mile modified in places by small faults and subsidence structures.

Faults

A number of thrust faults with a few feet to a few tens of feet of throw are known in Onondaga County. The faults cut the Silurian and Devonian limestones and dolomites but have not been found in the Hamilton shales above. As most of these faults strike N 65 to 75 W and dip mainly southward, they probably were formed by stresses of the Appalachian orogeny.

A fault in the quarries of the Solvay Process Division of the Allied Chemical Corporation at Jamesville appears to grade eastward into a monocline on the south side of Seneca Turnpike near Sweet Road. This structure was described by Schneider (1897) who thought it to be the one mentioned by Vanuxem (1842, p. 149). In the quarry the fault dips about 35 degrees southwest and has a throw of about 16½ feet (Meaker, 1958, p. 95). The first good exposure of the monocline is in the bed of the small stream that flows northward down the hillside on the south side of Seneca Turnpike a short distance west of Sweet Road (Fillmore Corners). At the bottom of the slope the Onondaga limestone is almost vertical suggesting some fault displacement in addition to the monoclinal flexure. The monocline is exposed again about 500 feet south of Seneca Turnpike in the stream course about 1700 feet east of Fillmore Corners (Stop 1, Trip E). Here the maximum dip is less and there is no visible evidence of faulting. At both of the exposures of the monocline the Onondaga limestone is displaced vertically between 20 and 25 feet (Schneider 1897, p. 460) (Meaker, 1958, p. 97).

One of the largest faults known in the Syracuse area formerly was exposed in old quarries near the junction of LaFayette Road and Seneca Turnpike in the southeast corner of the Syracuse West quadrangle. This fault has the usual WNW strike and, according to Luther (1895, p. 293), dips south 20 degrees and displaces the Manlius and Onondaga limestone 42 feet. The fault exposed on the north side of the upper quarry at the Onondaga County Penitentiary in Jamesville, 3½ miles southwest, may be the same one. At the quarry it strikes about N 70 W, dips about 20 degrees southwest, and has a throw of about 31 feet (Meaker, 1958, p. 93).

Four small thrust faults with throws of 2 to 4 feet cut the Fiddlers Green dolomite in Fiddlers Green Gorge at Jamesville (Schneider 1905, p. 308-310) (Hopkins, 1914, p. 39, pl. 9 & 10). Harrington (1952, p. 106) found three thrust faults in the Manlius quadrangle all with strikes near N 70 W. One has a throw of about 47 feet, another 14 feet, and the third is undetermined. Several more were found by Tolley (1957, p. 139-143) in the Canastota quadrangle. One of these, with a throw of 36 feet, is a continuation of one of the faults in the Manlius quadrangle to the west. Another about 0.4 mile north of the village of Perryville in the south central part of the quadrangle strikes about N 80 W and has a throw of about 80 feet, the largest throw of any of the known faults.

Joints

Two main sets of joints, one that strikes near north-south and the other near east-west, and two minor sets that strike northeast and northwest are present in the Syracuse area (DeGroff 1954). Many joints of the north-south set are unmineralized shear joints with associated feather joints, others, particularly in the vicinity of thrust faults, contain calcite veins with dolomite and minor fluorite, quartz, and solid hydrocarbon. Most of the peridotite dikes in central New York appear to be in the fractures of this set.

Inclined joints that strike about N 70 to 75 W and dip 30 to 80 degrees either north or south are locally developed in the limestones in the Syracuse area, especially near thrust faults. Some of the inclined joints are continuous vertically for many tens of feet, others are limited to a particular bed or group of beds and end upward against a shaly parting. They are particularly well developed in the Clark Reservation limestone which has long been known as the "diamond blue" because of the polygonal diamond-shaped blocks produced by the inclined joints. The oolitic texture of this limestone may account for its brittleness and ease of fracturing. Good examples of inclined joints can be seen in the lower penitentiary quarry near Jamesville (stop 8, Trip C) and in the southern part of the road cut on Route 11 (stop 13, Trip C).

A study of the stylolites in the limestones and dolomites of the Syracuse area has shown that nearly all of the steeply inclined transverse stylolite seams strike northwest, averaging about N 74 degrees W (Dunkerley, 1950, p. 42-49). These stylolite seams have the same orientation as the east-west joints and are thought (Dunkerley, 1950, p. 50) to have originated from these joints under the directed stresses of the Appalachian orogeny.

Folds

No anticlines or synclines other than small ones associated with thrust faults and sag structures are known in the Syracuse area. Dips greater than the normal regional dip of about 50 feet per mile are common in the carbonate rocks along the plateau front, but most of these are caused by sag structures and some by thrust faults. Folds formed by the Appalachian orogeny have been mapped as far north as Cortland. (Bradley and Pepper, 1938) (Wedel, 1932, map 1). According to Wedel (1932, p. 24), the Firtree Point anticline (also known as the Portland Point anticline) dies out eastward near Cortland.

Small monoclinal folds are common on the hanging wall side of the thrust faults. These, like the faults, normally strike about N 70 degrees E in the Syracuse area. The best example of such a monoclinal fold is the one described above that borders the south side of Seneca Turnpike in the northeast corner of the Jamesville quadrangle.

Subsidence Structures

In many places along the plateau front the strata exposed on limestone and dolomite benches and in quarries have sagged down locally to form structural depressions of irregular shapes and sizes. These structures have been noted and speculations made about their origin for over a hundred years, but no comprehensive study was made of them until the work of Phillips (1955).

The sag structures are known to occur from Madison County on the east to Genesee County on the west. The evidence strongly favors their origin by local solution of bedded gypsum and subsidence of the overlying strata. Solution of salt does not seem to be important in their formation. Expansion due to hydration of anhydrite to gypsum has been suggested as the cause of structures along the plateau front but none that could be attributed to upward distension of the beds from this cause are known.

Many of these structures have been observed as far west as LeRoy in Genesee County and in every case the strata have sagged down relative to the surrounding area with no evidence of upward movements. In 1963 a small scale subsidence structure was exposed in the foundation excavation for the communications building on the Syracuse University campus. A bed of gypsum about 3 feet thick in the Syracuse formation had been dissolved near a joint causing local subsidence of the overlying strata. Examples of subsidence structures will be seen in the General Crushed Stone Company's quarry (stop 4, trip C), and in an old gypsum quarry (stop 6, trip C).

The Syracuse, Camillus, and Bertie formations of the Salina Group contain beds of gypsum, and because of this subsidence structures have been observed in carbonate rocks from the Syracuse formation up through the Onondaga limestone. The gypsum of the middle member (Forge Hollow) of the Bertie formation is said by Luther (1895, p. 267) to be 65 feet thick at the Heard gypsum quarries between Syracuse and Fayetteville (stop 6, trip C). It probably is responsible for most of the structures. Those in the Fiddlers Green dolomite member, which underlies this gypsum member, formed from solution of stratigraphically lower gypsum beds.

The subsidence structures are best developed along the plateau front and near deep valleys where there has been deep ground water circulation. Fairchild (1909, p. 13) noted that limestone benches stripped of overburden by glacial meltwaters allowed ready subsurface drainage and were especially favorable for the formation of the subsidence structures.

These structures vary considerably in size and shape. According to Phillips (1955, p. 77-78) they range from a few feet to about 25 feet in depth. The slope of their sides is largely determined by the angle of dip of the beds into them which usually ranges from a few degrees to 25 degrees. Even higher dips have been observed in a few places. Many are elongated parallel to an important joint set. As they increase in size they may develop flat floors (Phillips, 1955, p. 81). Some are large enough and deep enough to be shown by depression contours on the $7\frac{1}{2}$ minute topographic maps. A number are shown this way in the southwestern corner of the Syracuse East quadrangle, particularly on the north side of the Rock Cut cross channel where the thick gypsum member of the Bertie formation is at moderate depth.

The subsidence structures are generally considered to be post-glacial. Gilbert (1891, p. 231) and Fairchild (1909, p. 13) were of this opinion and Phillips (1955, p. 93-95) reached the same conclusion. They would not have been preserved as the present topographic features if they had been overridden by glacial ice. Post-glacial origin is illustrated by a subsidence structure at the southeast end of the small drumlin at Syracuse University's SkyTop in the southwestern corner of the Syracuse East quadrangle. Part of this structure is under the edge of the drumlin and some of the side of the drumlin has slumped into it.

Unconformities

Smith (1929, p. 32) recognized unconformities in the Syracuse area below the Bishop Brook limestone, the Oriskany sandstone, and the Onondaga limestone. The Bishop Brook limestone, considered to correlate with the Coeymans limestone farther east (Rickard, 1962, p. 78), is known only on the hill northeast of the village of Manlius. The small disconformity at its base also is known only in this area (Smith 1929, p. 32).

The pre-Onondaga erosion that followed the deposition of the Oriskany sandstone apparently removed or reworked most of this sandstone, and with it the pre-Oriskany unconformity. This has complicated evaluation of the relative importance of these erosion intervals. In the eastern part of the state these unconformities are absent and, according to Oliver, (1954, p. 625) are only slightly developed as far west as the Richfield Springs quadrangle. West of this quadrangle the unconformities become more important and the Onondaga overlies successively lower formations. Oliver (1954, p. 625) is of the opinion that the multiple unconformity represents considerable time, but that most of the erosion is pre-Oriskany as "pre-Onondaga erosion involved only the partial removal and reworking of the Oriskany sandstone".

Smith (1929, Fig. 14) has shown that this multiple unconformity at the base of the Onondaga limestone in the Syracuse area ranges in stratigraphic position from the top of the Bishop Brook limestone near Manlius east of Syracuse to the top of the Olney limestone in the central part of the Split Rock quarries about 3 miles west of Syracuse. West of the Split Rock quarries the unconformity rises again so that in the vicinity of Skaneateles Falls it is near the top of the Jamesville limestone. Still farther west it descends gradually to the top of the Cobleskill a few miles west of Auburn. The pre-Onondaga disconformity will be seen at several of the stops of trip C. Cooper (1935, p. 787) has reported a disconformity at the base of the Tully limestone. Evidence for this is based on the disappearance of faunal zones westward.

Uneven contacts and a few inches of pebble conglomerate indicate the presence of widespread diastems at the top of the Vernon shale (Leutze, 1955, p. 59), at the top of Elmwood B (Fernalld, 1953, pl. 80), and at the top of Elmwood C (Johns, 1953, pl. IIIA and B). Evidence also has been found for the presence of a diastem at the top of the widespread dolomite bed in the lower part of the Thacher limestone.

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NOTES ON THE ECONOMIC GEOLOGY OF THE SYRACUSE AREA

by

N. E. Chute

Mineral production in Onondaga County dates back to the latter part of the 18th century and has been an important factor in the economy of the county every since. Industrial minerals and rocks have accounted for most of the production and natural gas the remainder. In 1962 Onondaga County ranked second in total value of minerals produced in the state and also was second in limestone production (Minerals Yearbook).

Salt

Salt springs near Onondaga Lake were visited by French missionaries from Canada as early as the middle of the 17th century. Production of salt started around the southern part of the lake in 1788, at first from the salt springs and then from wells drilled into the glacial gravels that contained brine (Newland, 1921, p. 222). Salt continued to be produced in substantial quantities for over 100 years until about 1908. The maximum yearly production, according to Luther (1895, p. 252) was attained in 1862 when the output was 9,053,874 bushels. The total production of salt in the yards around Onondaga lake from 1797 to 1904 amounted to 430,000,000 bushels or over 12,000,000 tons (Hopkins, 1914, p. 34). Decrease in the salt content of the brines and competition from other sources caused production to begin to decline about 1890 and to terminate about 1908.

In 1888 the Solvay Process Company began producing salt brine from wells in the Tully valley about 17 miles south of Syracuse. The brine is piped to the Company's plant at Solvay where it is used for the manufacture of sodium chemicals, particularly soda ash. The brine is obtained from salt beds in the Syracuse formation at depths of 1100 to 1200 feet.

Limestone

One of the largest limestone quarries in the state is operated by the Solvay Process Division of the Allied Chemical Corporation at Jamesville. The Clark Reservation, Jamesville, and Pools Brook limestone members of the Manlius formation and part of the Edgecliff member of the Onondaga limestone are quarried primarily for use in the manufacture of soda ash. Agricultural limestone also is produced, and limestone is furnished to the Alpha Portland Cement Company for manufacture of portland cement at its Jamesville plant. The part of the Onondaga limestone above the Edgecliff member is quarried separately for crushed stone.

The General Crushed Stone Company quarries the Olney limestone and part of the Thacher limestone for crushed stone at its quarry on the north side of Rock Cut Channel in the southwest corner of the Syracuse East quadrangle (stop 4, trip C).

Considerable building stone has been quarried in the past from the Manlius and Onondaga formations. In recent years dimension stone for flagging, walls, and house construction has been produced at small quarries at Brickyard Falls south of Manlius and west of Townsend Road about 1 3/4 miles east of Fayetteville. Elmwood dolomite and the top of the Olney are quarried at the former and Olney and Thacher limestone at the latter.

Sand and Gravel

Sand and gravel totalling 1,452,000 tons were produced from nineteen pits in Onondaga County in 1962 (Minerals Yearbook). Most of the production was from pits in the vicinity of Nedrow, Fayetteville, and East Syracuse where glacial deposits are worked. The gravel deposit worked on the east side of Burdick Road, a short distance northwest of Fayetteville, is of particular interest because it is a multiple delta deposited in rising glacial lake waters. A readvance of the ice covered the gravel with from a few feet to 17 feet of glacial till. Several gravel pits are operated in the large glacial lake delta deposits in Onondaga Creek Valley south of Syracuse.

Shale

The upper part of the Chittenango member and the lower part of the Cardiff member of the Marcellus shale formation are quarried by the Alpha Portland Cement Company on the east side of Gates Road east of Jamesville (stop 2, trip E). The shale is used for the manufacture of portland cement at the company's Jamesville plant. Because of a higher content of sulfur in the Chittenango due to the presence of some pyrite, barite, and gypsum, the quarry is benched and the Chittenango and Cardiff are quarried selectively. The large calcareous concretions present in two zones in the Chittenango shale are discarded in the quarry.

Light Weight Aggregate

The Onondaga Brick Company produces lightweight aggregate from Vernon shale at its plant near Warners northwest of Syracuse. The shale is quarried on the northwest side of Brickyard Road about half a mile northwest of the plant. This quarry has the best exposures of the Vernon shale in the vicinity of Syracuse.

Pottery

The Syracuse Pottery Company manufactures flower pots from red clay dug near its plant at Warners. The Onondaga Pottery Company (Syracuse China) imports its raw materials for china manufacture from outside the State.

Industrial Minerals & Rocks Formerly Produced

Gypsum, natural cement, and bricks formerly were produced in Onondaga County in important amounts. Gypsum was first discovered in New York at Camillus in 1792 and production was started in that area about 1810. For many years gypsum production was next in importance to salt in the county (Luther, 1895, p. 266).

All of the merchantable gypsum mined in Onondaga County was obtained, according to Newland (1929, p. 81) from the top of the Camillus, now called the Forge Hollow or Scajaquada member of the Bertie formation. This gypsum unit is reported to range from 25 to 65 feet in thickness. The most important quarries were between Fayetteville and Jamesville. The largest production came from a group of quarries in the wooded hills north of Woodchuck Hill Road southwest of Fayetteville (stop 6, trip C) where the gypsum is thickest. All of these quarries had stopped operating by 1909 except the Heard quarry, the largest of the group, which continued until 1914. (Newland, 1929, p. 83). The gypsum was used mainly in agriculture for "land plaster". When this use declined and purer gypsum was required for the manufacture of gypsum plaster and wallboard, the deposits in Onondaga County could not compete with the higher grade deposits in Genesee County.

Natural Cement

Rock suitable for the manufacture of natural cement was first discovered in the town of Sullivan in Madison County not far east of Syracuse. Production of cement was begun in 1818 for use in construction of the Erie Canal and soon became an important industry in Onondaga County (Luther, 1895, p. 269). It remained so until early in the present century when competition from portland cement caused a rapid decline in production.

Elmwood A and C argillaceous dolomite (waterlime) beds, with thicknesses from 3 to 6 feet, were the source of the raw stone. Quarries in these units were worked all along the outcrop and provide good exposures for study of the Elmwood beds and the overlying Clark Reservation and Jamesville limestones.

Bricks

The Syracuse Brick Company manufactured brick at its plant on Court Street in Syracuse until 1962. Vernon red shale quarried near Cicero was crushed and ground to make the clay raw material.

Quicklime

Quicklime formerly was manufactured in considerable quantity from selected beds in the Manlius and Onondaga limestone formations. Except for the lime produced by the Solvay Process Division for manufacture of alkalies, no quicklime has been produced in Onondaga country for many years. Most of the production had ceased by 1914 (Hopkins, 1914, p. 28).

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Some Aspects of Economic Geology
of Aggregate Materials in
Western New York

by
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"Perfection of means and confusion of goals seem - in my opinion - to characterize our age". Einstein, A. (1950), Out of My Later Years

Introductory Statement

The intent of this section of the guidebook is: (1) to introduce some concepts of the application of geology to our culture, (2) to show how such geologic concepts have been applied at the General Crushed Stone quarry at DeWitt, (3) to show how this orientation has led to geologic research in western New York which has helped to understand geologic interrelationships which have both social and theoretical values.

Aggregate Geology Research in a Philosophical Framework

For several years research has been done at Rensselaer Polytechnic Institute largely under the sponsorship of the New York State Department of Public Works on some fundamental characteristics of many of the rocks which are used as aggregate in New York State. The orientation of this research is not a common one in geology, and therefore the author feels that it is advisable to place the research in a "philosophical" context.

The study of aggregate materials is a part of the broad field of what might be called "extroverted" geology, or geology applied outside of itself to the human-social environment. On the other hand, "introverted" geology might be used as a description of geology applied internally or geology "as an end in itself"* and having little or nothing to do with people. "Introverted" geology in recent years has had a great upsurge, particularly in universities. Paradoxically, this upsurge coincides with a real threat of depletion of many of the rock materials on which our economy is based, and with a decrease in job opportunities for geologists.

Properties of Rocks: Characteristically geologists describe a few fundamental parameters of rocks such as color, texture, structure, and approximate mineralogy. Such parameters are meaningful in geology as a method of determining a rock's name and origin. To describe a rock properly in such a manner and to recognize the significance of the described properties requires such extensive training and experience that many geologists never acquire the needed competence. Because of the inherent difficulty in such description and the training needed, the determination of the common geologic parameters are here called "sophisticated" techniques.

*Leggett, R. F. (1963), Geology in the Service of Man in The Fabric of Geology, Addison - Wesley Pub. Co., Inc.

A problem in "sophisticated" geologic description is that it says very little about the properties of a rock which are significant to physicists, chemists, engineers, or for that matter, anyone other than geologists. And, by largely ignoring other properties geologists not only fail to communicate outside of their field but may miss important relationships which point to the origin and nature of many rocks.

What are some of the other parameters which can be measured? A partial list of those which might be considered by the geologist to be "unsophisticated" follows*:

1. chemical composition
2. insoluble residue, percent
3. reactivity in alkali solution
4. normative mineralogy
5. X-ray analysis
6. water absorption
7. specific gravity (true, bulk dry, bulk saturated, apparent)
8. rate of water absorption
9. rate of water loss in vacuum or at elevated temperatures
10. longitudinal compressional wave velocity
11. shear wave velocity
12. Poisson's ratio
13. thermal expansion
14. abrasion resistance
15. freeze-thaw soundness tests
16. magnesium sulfate soundness test
17. sodium sulfate soundness test
18. wet-dry resistance
19. pore-size distribution
20. porosity
21. permeability
22. thermodynamic character of water and ice in rock (enthalpy, free energy, entropy, etc.)
23. freeze-points for internal water
24. internal pressures during water absorption
25. internal surface area
26. dielectric constants
27. compressive strength
28. tensile strength
29. isotopic ratios

Note that so-called unsophisticated parameters are mostly quantitative and the description largely numerical. Although they also are likely to require complex instrumentation, the <u>act</u> of making the measurements is relatively routine and can generally be relegated to technicians.

*For details of most of the techniques see: Dunn, J. R. (1963), Characteristics of Various Aggregate Producing Bedrock Formations in New York State, N.Y.S.D.P.W. Eng. Res. Ser. RR 63-3, 258 pp.

Although the measurements are expressed in the language of neighboring sciences, geologists are essential as interpreters of data, as catalysts in the translating of such facts to more effective use of rock materials by men, and as advisors on sampling procedures.

Of the above parameters, the first 25 either have been or are being measured at Rensselaer as a part of the research on aggregate materials. In addition, of course, the usual geologic parameters are also being determined. It is noteworthy that a few of the measurements were taken with the view that good description is its own justification, but later were found to have valuable interrelationships with other measurements.

Sampling: Proper sampling is, in any research on rock, a particularly complicated problem and any technique used is a compromise which depends on many variables. In the case of the Rensselaer research the sampling technique used was an outgrowth of the two purposes of the research: (1) to obtain useful data about rocks in western New York, and (2) to try to correlate the data internally.

The sampling technique finally used was to log the quarry faces geologically first and then select blocks of rock which were hopefully typical of the most common lithologies which were described. All research was on these blocks. The most obvious short-coming is that it never is known how typical a block is. However, studying single blocks made it possible to make direct correlations between parameters with some assurance that all data from a block were obtained from very similar material.

(The opposite situation commonly occurs when non-geologists try to correlate measurements on geologic materials without a proper knowledge of the nature of the distribution of characteristics of rocks. Better communication between geologists and their neighbors would reduce such problems.)

The General Crushed Stone Quarry, DeWitt, New York

An example of the application of "extroverted" geology - as defined here - is in the research done at the DeWitt Quarry of General Crushed Stone Co. under the sponsorship of the New York State Department of Public Works. Plate 1 shows the characteristics measured for typical lithologies. On the column, which is a stratigraphic section of the quarry face, are located positions of samples which were taken for study. The parameters which were measured are concerned with the basic physical and chemical characteristics of the individual blocks. The intent was to make all determinations which could conceivably be of value in understanding the potential uses of the rocks.

Because measurements of this type were made for every active quarry from Utica to Buffalo which is using the Manlius or Lockport formations for crushed stone, broader understanding of the nature of aggregate materials has been obtained.

Some Relationships between Measured Parameters

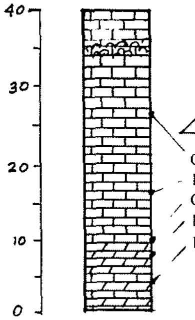
Eighty-three blocks of carbonate rock from western and central New York were studied. Because the lithologies included a wide range of carbonates, it has been possible to see some relationships of potential scientific and social value. A few typical relationships are noted below.

PLATE 1

DATA PERTAINING TO SAMPLES FROM GENERAL CRUSHED STONE CO. QUARRY DE WITT, NEW YORK

Extracted from Dunn (1963)

Stratigraphic Section of Quarry Face



Sample Designation	CHEMICAL ANALYSES											NORMATIVE ANALYSES											
												Carbonates			Clays								
	Moisture	Loss on Ignition	Insoluble Matter	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	Calcite	Dolomite	Total	Illite	Sericite	Ferri-Sericite	Chlorite	Montmorillonite	Total	Quartz	Minor Constit.	Insoluble Residue
OZ	0.00	36.72	0.92	13.18	0.67	1.02	0.05	42.95	3.52	0.03	0.41	70.02	11.99	82.01	0.00	0.00	4.86	3.10	0.00	7.96	12.34	0.65	15.84
R2	0.07	42.49	1.06	3.24	0.31	0.37	0.03	47.34	5.52	0.07	0.24	72.64	21.67	94.30	0.00	0.74	1.38	2.71	0.00	4.83	1.91	0.93	5.01
OD	0.02	38.38	3.16	11.10	2.63	1.19	0.12	25.70	17.15	0.02	0.47	4.26	76.05	80.31	7.09	0.00	0.00	0.76	3.22	11.07	5.24	0.85	18.20
RA	0.00	37.28	3.54	11.32	2.63	1.19	0.10	25.42	16.59	0.05	1.55	5.76	72.36	78.12	19.26	2.98	0.00	0.00	0.00	22.24	0.52	1.08	18.78
RB	0.00	43.04	0.98	4.28	0.50	0.65	0.05	37.78	11.65	0.04	1.02	37.22	55.82	93.04	0.00	8.62	0.00	0.00	0.00	8.62	0.15	0.72	6.46

CONTINUATION OF DATA MEASURED FOR SAMPLES SHOWN ABOVE

Sample Designation	X-RAY CLAY-MICA ANALYSES					SPECIFIC GRAVITY				% POROSITY	COMP. WAVE VELOCITY x 10^4 ft/sec			SHEAR WAVE V_t x 10^4			POISSON'S RATIO			Coefficient of THERMAL EXP. x 10^{-6} (-100° F to +160° F)			N. Y. S. D. P. W. SOUNDNESS % Loss		Deval Abrasion	% WATER ABSORPTION
	Å Gp. Rep.			Using 14Å as Unity Relative																						
	7 Å	10 Å	14 Å	7/14	10/14	Bulk Dry	Bulk Saturated	Apparent	True		Normal to bedding	Parallel to N.-S.	Parallel to E.-W.	Perp. to bedding	Perp. to ea. other and in plane of bedding		Perp. to bedding	Perp. to ea. other and in plane of bedding		Normal to bedding	Parallel to N.S.	Parallel to E.W.	$MgSO_4$	Na_2SO_4		
OZ	---	T	T	---	---	2.70	2.71	2.76	2.75	2.5	1.92	2.02	2.01										3.9	1.3	-	0.3
R2	---	X	X	---	1.3	2.73	2.73	2.74	2.74	1.2	1.93	2.08	2.09							5.00	4.64	4.64	1.4	0.0	3.2	0.0
OD	X	X	X	1.2	1.0	2.54	2.62	2.77	2.81	1.6	1.52	1.54	1.59	8.48	8.38	8.48	0.27	0.29	0.30				35.8	3.7	-	3.3
RA	X	X	X	1.3	1.5	2.60	2.68	2.80	2.81	0.3	1.38	-	1.31										36.0	5.5	-	2.7
RB	---	T	T	---	---	2.73	2.76	2.81	2.76	-	1.89	1.90	2.02										0.9	0.8	-	1.0

1. Thermal Expansion and Calcite-Dolomite Ratio:

The thermal expansion of limestones and dolomites is about what one would anticipate if the weighted thermal expansion of calcite and dolomite in the carbonate rock were corrected for quartz content. Variations from a straight line are probably caused by structural considerations and clay minerals. The range found was from 3.26×10^{-6} in/in/^{o}F for two perpendicularly oriented samples in the plane of bedding (93.95% carbonate, of which 91.51% is calcite) to 9.07×10^{-6} in/in/^{o}F (83.97% carbonate, of which 76.83% is dolomite). Samples cut perpendicular to the bedding had a tendence to have slightly higher expansions than those parallel to the beds indicating a slight tendency for the c-axes to be vertical. Contrary to previous fabric analyses no tendency was observed for limestones to have more preferred crystal orientation than dolomites.

2. Water Absorption and Soundness:

A roughly proportionate relationship exists between the weight percentage of water absorbed by aggregate in 24 hours and the magnitude of freeze-thaw test losses (tests as specified by the N.Y.S. D.P.W.). The number of exceptions to the general rule indicate, however, that freeze-thaw sensitivity is not a function of absorbed water alone.

3. Dolomite and Clay Content, and Freeze-Thaw Sensitivity:

Freeze-thaw sensitivity of aggregate, as measured by the N.Y.S. D.P.W. freeze-thaw test, has a roughly directly proportionate relationship to the dolomite content and the clay content. It was observed microscopically that dolomite crystals tend to be clear and calcite crystals cloudy. The implication was that when dolomite replaces calcite during the process of dolomitization clay is rejected to the boundaries of dolomite crystals. Reasoning that this might make the dolomite-associated clay component more available to water, i.e. more easily wetted, the following correction was made on clay content.

$$\text{(1) Wettable clay} = \frac{\%\ \text{calculated clay} \times \%\ \text{dolomite}}{\%\ (\text{dolomite} + \text{calcite})}$$

In effect, the only clay considered wettable is that associated with dolomite.

If this assumption were correct, the percent of corrected clay should be proportionate to the percent of water absorbed. Plate 2 shows that this is nearly the case for 16 of the 17 most freeze-thaw sensitive rocks of the 83 which were tested. The fact that a line which follows the trend of the points does not seem to go through the origin indicates that some water is taken up in pores not associated with clay-associated dolomite.

It is particularly noteworthy that the type of clay does not seem to be critical and that the clays detected (illite, kaolinite and chlorite) are not particularly expansive or water absorbent.

4. Wetting and Drying and Freeze-Thaw Sensitivity:

Of seventeen rocks subjected to wetting and drying cycling seven deteriorated by cracking during the test. These rocks also expanded and contracted during

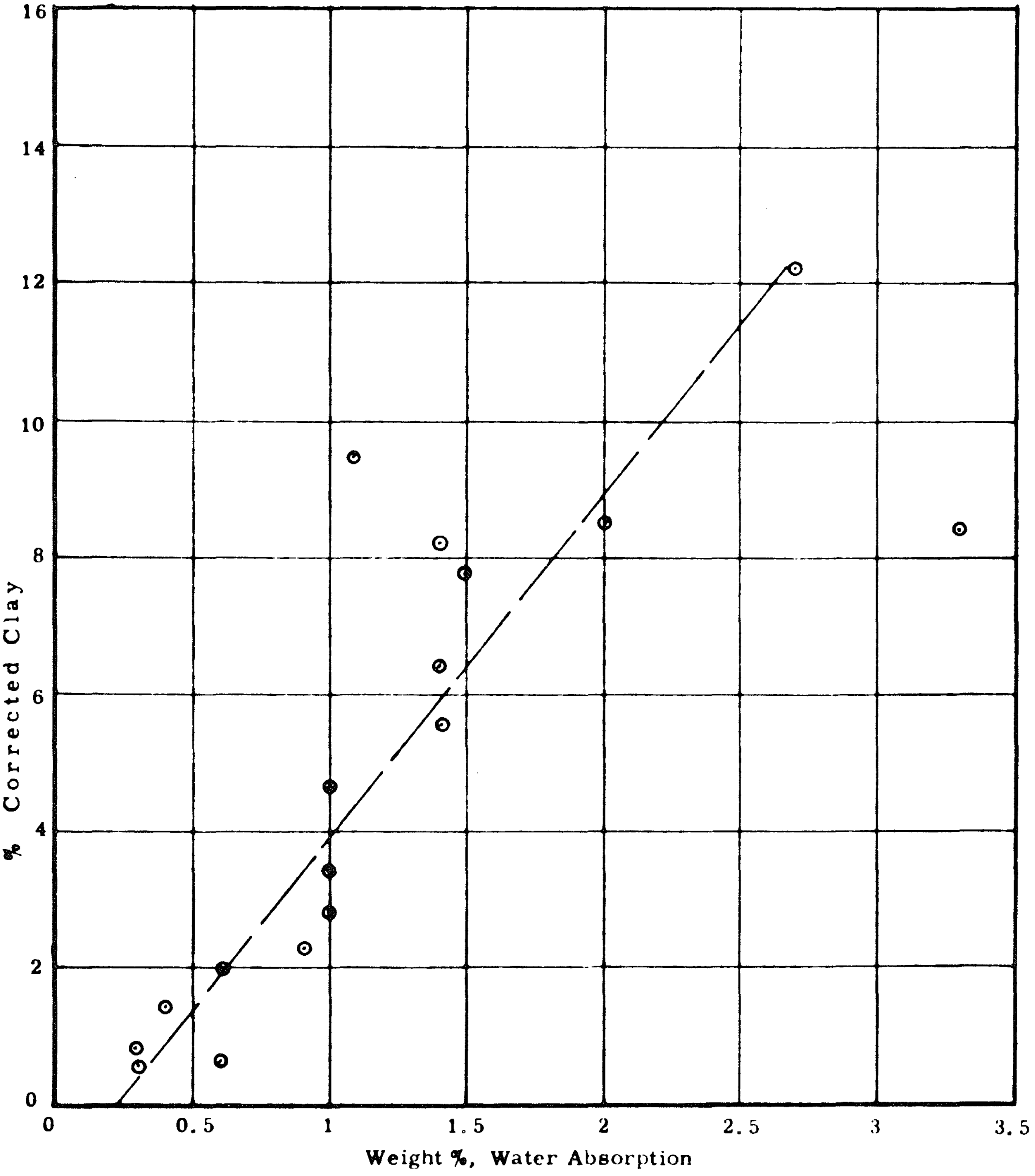


PLATE 2

PER CENT CORRECTED CLAY VERSUS PER CENT ABSORPTION
FOR 17 FREEZE-THAW SENSITIVE CARBONATE ROCKS

wetting and drying and all were highly freeze-thaw sensitive. The cause of such deterioration seems to be most reasonably associated with clays even though no expansive clays were detected.

Many of the relationships which have been determined are being used in continuing research which will lead, it is hoped, to broader knowledge of the reasons for the behavior of rocks -- to the ability to anticipate reactions to external and internal forces. Ultimately the research should lead to more definitive testing procedures for rocks and to more effective use of the common rocks around us.

5. Some Observations of Freeze-Thaw Sensitive Rocks:

   Rocks which fail on the freeze-thaw test have low outcrop tendencies. In addition they tend to absorb over 90% of their water in 24 hours and tend to retain some water even in prolonged vacuum. The high retention probably indicates low partial pressures for the retained water, low free energy and low entropy. The best guess at this time is that such water is clay-associated and is ordered, i.e. has crystalline form.

6. Some Correlations with Distressed Concrete:

   Rocks which have caused distress in concrete could have more than one cause of weakness, i.e. any two of the following: (1) freeze-thaw sensitivity, (2) wet-dry deterioration, (3) chemical reactivity with portland cement. The common denominator for these problems seems to be clay.

Concluding Statement

The communication with people working fields outside of the field of geology, such as physics, chemistry, engineering or business, is largely the province of what has been called "extroverted" geology. Geologists working in the "extroverted" fields are likely to be concerned not only with normal geologic description but with quantitative (or less sophisticated) parameters of a fundamental physicochemical nature. Geologists are essential for the interpretation of such data and the selection of sampling procedures. Basic physico-chemical characteristics were determined at Rensselaer for blocks of rock from all quarries operating in the Lockport and Manlius formations between Utica and Buffalo. The General Crushed Stone Company quarry at DeWitt is used as an example of the technique. On the basis of the research several potentially valuable relationships of a theoretical and practical nature have been observed.

TRIP C: STRATIGRAPHY AND STRUCTURE OF SILURIAN AND DEVONIAN STRATA IN THE SYRACUSE AREA

Newton E. Chute and James C. Brower

Total miles	Miles	Route description
0.0	0.0	Syracuse University Field House at corner of Colvin St. & Comstock Ave. Turn right (N) on Comstock Ave. and continue to Euclid Ave.
0.8	0.8	Turn right (E) on Euclid Ave. and continue to Wescott St. (fire station on corner).
1.4	0.6	Turn left (N) on Wescott St. and proceed to Erie Blvd.
2.0	0.6	Cross E. Genesee St. (traffic light).
2.3	0.3	Exposure of Syracuse formation on right behind Alwain Upholstering Co.'s. building. Turn right (E) on Erie Blvd.
		Erie Blvd. follows the S. side of a cross channel that carried glacial meltwater drainage eastward from Onondaga Valley.
3.1	0.8	Seeley Road intersection (traffic light), continue on Erie Blvd. for 0.1 mile.
3.2	0.1	Turn right (S) to the excavation in the Syracuse formation behind the Victor Comptometer Corporation and other buildings.

STOP 1. Upper part of the Syracuse formation.

The contact of the Syracuse formation with the overlying Camillus shale is near the highest part of the excavation. The members exposed are as follows:

Upper dolomite member - Most of this member is exposed in the face above the bench. A distinctive porous dolomite bed, referred to in the literature as "vermicular" dolomite, is exposed in the lower part of the member. The holes of the vermicular dolomite probably were filled originally by salt or anhydrite.

Upper clay member - This member is about 10 feet thick here according to Leutze (1955, M.S. thesis, Syr. U.). It is mostly concealed under the floor of the bench and the talus debris.

Middle dolomite member - Thin- to medium-bedded dolomite. A few exposures of the upper part of this member may be seen below the bench.

Total miles	Miles	Route description
3.3	0.1	Return to Erie Boulevard and turn right (E).
4.3	1.0	Thompson Road (traffic light), continue on Erie Blvd. for 0.2 mile.

Total Miles	Miles	Route description
4.6	0.3	Turn right to excavation at rear of the Victory Market.
4.7	0.1	STOP 2. Syracuse formation
		A bed of gypsum 2 to 4 feet thick in the Lower Clay member is exposed near the bottom of the excavation behind the Victory Market and the Towne Mart. This gypsum bed is overlain by the Middle Dolomite member composed of impure thin- to medium-bedded dolomite and gypsiferous shale to the top of the excavation.
4.8	0.1	Return to Erie Blvd. and turn right (SE). Proceed to E. Genesee St.
6.4	1.6	Turn right (NW) on E. Genesee St. and proceed to Hillsboro Parkway and Meadowbrook Drive (double traffic lights).
8.0	1.6	Turn half left onto Meadowbrook Drive and proceed a short distance to Kimber Road.
		Meadowbrook Drive follows a well-defined glacial cross-channel that carried meltwater drainage eastward.
8.1	0.1	Turn left (S) on Kimber Road on east side of school grounds and continue to Euclid Avenue at top of hill.
8.3	0.2	Turn right (W) on Euclid Avenue for one block.
8.5	0.2	Turn right into high school grounds opposite Guilford Road and park.
		STOP 3. Camillus shale.
		Some of the upper part of the Camillus shale formation is exposed in small gulleys on the hillside. The rock units visible are as follows:
		1½' Greenish gray thin-bedded dolomitic shale
		6½' Massive greenish gray dolomitic shale with scattered quartz sand grains. This rock weathers rapidly into small angular fragments.
		2' Dolomitic thin-bedded shale that breaks into thin slabs and resists weathering better than the greenish shale above.
		5' Gypsiferous shale and gypsum? now partly leached to clay.
		8' Covered
		2' Massive greenish gray dolomitic shale with scattered quartz sand grains similar to the greenish shale above. This exposure is in the ditch on the east side of the macadam roadway.
		Downhill, about 50 feet lower stratigraphically, 4½ to 5 feet of greenish shale with thin beds of brownish dolomite are exposed in the

Total miles	Miles	Route description
		bank at the uphill side of the playground behind the Washington School. These exposures probably are near the middle of the Camillus.
		The Camillus of the Syracuse area seems to be unfossiliferous.
		Return to Euclid Avenue and turn left (E).
8.7	0.2	Turn right (S) on Kimber Road.
		For the next 2 miles the route passes through a group of drumlins and bedrock exposures are scarce.
9.3	0.6	Randall Road junction, continue south. Between Randall Road and Guintard Road (McGee Road) the route swings west around the end of a drumlin. Continue south on Peck Hill Road.
10.6	1.3	Exposure of Cobleskill dolomite on the left side of Peck Hill Road.
10.7	0.1	Junction of Peck Hill Road with Nottingham Road. Turn left (SE) on Nottingham Road.
11.1	0.4	Entering Rock Cut gorge, the largest of the cross channels, eroded by the outflow from glacial lakes in Onondaga Valley to the west. The floor of this channel is the Fiddlers Green dolomite member of the Bertie formation. It "hangs" about 140 feet above the Onondaga Valley on the west and about 50 feet above the Butternut Creek Valley on the east.
11.4	0.3	Junction of Nottingham Road with Jamesville Toll Road. Turn right (W).
12.1	0.7	Turn right at the General Crushed Stone Company and proceed to the quarry.
		STOP 4. Rondout dolomite, Thacher limestone, and Olney limestone exposed in quarry.
		The quarry section is as follows:
		33½' Olney limestone 9' Thacher limestone 14½' Rondout dolomite
		The Rondout and part of the Thacher are exposed in the old lower part of the quarry near the primary crusher. The main operating face is in the Olney limestone.
		The Thacher here has the lithologic characteristics of the lower part of the member farther east. The contact with the overlying Olney is placed at the top of the highest zone of algal colonies and at the bottom of the lowest "drab and blue" limestone unit characteristic of the Olney.
		As elsewhere in central New York, the lower Thacher exposed in this quarry is characterized by two or three zones of algal colonies and

Total Miles	Miles	Route description
		a yellow dolomite bed from about 6 inches to 3 feet in thickness. This variation in thickness appears to be due to a diastem at the top of the dolomite bed.
		Subsidence structures are well exhibited in plan and section in this quarry.
13.1	1.0	Return to Jamesville Toll Road and turn left (E).
13.8	0.7	Nottingham Road junction. Continue east on Jamesville Toll Road.
14.0	0.2	Road cut in the Rondout and Cobleskill dolomite formations to top of grade.
14.5	0.5	Bridge over the D. L. & W. Rwy.
14.6	0.1	Junction of Jamesville Toll Road with Jamesville Road.
14.9	0.3	Turn left on the road into the Solvay Process Division's quarry property and stop at the bridge over Butternut Creek.
		STOP 5. Type section of the Fiddlers Green member of the Bertie Formation.
		The Fiddlers Green dolomite has a total thickness of about 27 feet in this area. The bottom contact with the Camillus shale is exposed on the east side of the gorge several hundred feet down stream from the bridge. The top contact is not exposed, but the mudcracked beds near the bridge probably are close to the top of the member.
		Ostracodes are numerous in a few thin layers, other fossils are rare. Eurypterids have been found in the top beds in other localities.
15.0	0.1	Return to Jamesville Road and turn right (N).
15.3	0.3	Keep right on Jamesville Road at Junction with Jamesville Toll Road.
15.5	0.2	Butternut Creek bridge.
15.8	0.3	Turn right (E) on Woodchuck Hill Road.
16.9	1.1	Maple Hill Drive junction.
17.0	0.1	Exposure of Fiddlers Green dolomite on left.
17.3	0.3	Turn left (NE) on Old Quarry Road.
17.6	0.3	Old gypsum quarry on right.
17.7	0.1	Road cut in Cobleskill dolomite.

Total miles	Miles	Route description
17.8	0.1	STOP 6. Old gypsum quarries in the Scajaquada (Forge Hollow) Member of the Bertie Formation.

Park at bend in road and walk 250 feet south to the roadway into the north quarry. This quarry exposes the upper part of the Scajaquada (Forge Hollow) gypsum member overlain by the Williamsville (Oxbow) impure dolomite member and the lower part of the Cobleskill dolomite.

Walk back to the entrance of the quarry and go southeast up the hill to the west side of the south quarry. Here there is an exceptionally good opportunity to observe the top of the Scajaquada member, all of the Williamsville member, and the lower half of the Cobleskill formation. A composite section of the north and east sides of the quarry is as follows:

- 17' Cobleskill (to top of east side of quarry)
  - 2½' dolomite with numerous closely spaced fractures in the plane of the bedding. A few stromatoporoids.
  - 10' Stromatoporoid biostrome. Numerous partly silicified undolomitized stromatoporoids in dolomitic limestone. Some small horn corals, tabulate corals, ostracodes, and small fossil fragments. This is the only locality where this biostrome is known near Syracuse, elsewhere the Cobleskill is completely dolomitized and only a few silicified stromatoporoids remain.
  - 4½' Mottled dolomitic limestone with abundant small fossil fragments and some small horn corals. This unit also is not known elsewhere in the Syracuse area.
- 17' Bertie formation
  - 6' Williamsville member - thin to medium-bedded argillaceous dolomite
  - 11' Scajaquada member -
    - 8½' Thin-bedded argillaceous dolomite with 30% or more collapse breccia due to solution of interbedded salt or gypsum
    - 2½' Top of dark brown bedded gypsum. The gypsum is reported to attain its maximum thickness of 60 to 65 feet in this area.

The location of the contact between the Williamsville and Scajaquada members is uncertain and is one of the problems to be considered at this stop.

Total miles	Miles	Route description
		A cross-section of a small subsidence structure is well exposed in the northeast corner of the quarry.
		Return to Woodchuck Hill Road.
18.3	0.5	Junction of Old Quarry Road with Woodchuck Hill Road. Turn right (NW) on Woodchuck Hill Road and return to Jamesville Road.
19.8	1.5	Turn left (S) on Jamesville Road.
20.3	0.5	Junction with Jamesville Toll Road. Continue south into the village of Jamesville on Jamesville Road.
21.2	0.9	Turn right over the railroad on Route 173 (Seneca Turnpike) in Jamesville and proceed west to Clark Reservation State Park.
22.5	1.3	Turn right into Clark Reservation State Park and stop in the parking lot.

Note: Collecting of rock samples and fossils is not permitted in this park; you will have better collecting at other stops.

STOP 7. Onondaga and Manlius formations. (Lunch Stop)

The remarkable abandoned waterfall and plunge basin in this park were formed by a river that drained a glacial lake in Onondaga Creek Valley to the west when glacial ice blocked the drainage to the north.

The lip of the falls is on the Edgecliff member of the Onondaga limestone. The Nedrow and Moorehouse members are exposed nearby at higher elevations and are at the edge of the plunge basin on the north side.

This is the type locality for the Clark Reservation and Jamesville members of the Manlius formation. These and other members of the Manlius, except the Thacher which is covered, are well exposed along the stairway on the south side of the plunge basin. The section here is as follows:

Onondaga limestone

17 to 18'	Edgecliff member, 2' of sandy limestone and calcareous sandstone at base.

Disconformity

Manlius limestone

5'9"	Pools Brook member, dolomitic limestone
19'	Jamesville limestone, numerous stromotoporoids in upper 8 feet.

Total miles	Miles	Route description
		3'3" Clark Reservation oolitic limestone
		9'10" Elmwood dolomite and dolomitic limestone member
		2'7" Elmwood C argillaceous dolomite submember
		2'9" Elmwood B dolomitic limestone submember
		4'6" Elmwood A argillaceous dolomite submember
		22' Olney limestone to bottom of exposure
23.0	0.5	Return to the park entrance and turn left (E) on Route 173.
24.3	1.3	Junction with Jamesville Road on east side of railroad tracks in Jamesville. Continue east on 173 to Route 91.
24.4	0.1	Turn right (S) on Route 91.

Road cut on left in the upper few feet of the Rondout dolomite and the Thacher and Olney limestone members of the Manlius. Some unusually large algal colonies are present in the Thacher in a zone about 3 feet thick.

24.9 0.5 Turn left into quarry.

STOP 8. Onondaga County Penitentiary quarries

The two penitentiary quarries provide exceptionally good exposures of most of the Manlius and Onondaga limestone formations. Also a thrust fault can be seen in the upper quarry.

The stratigraphic section of the quarries is as follows:

Onondaga limestone formation
- 5' Seneca limestone member (to top of quarry)
- 24' Moorehouse limestone member
- 13' Nedrow limestone member
- 23' Edgecliff member including 4½ feet of sandstone at the base (Springvale sandstone bed)

disconformity

Manlius limestone formation
- 7'3" Pools Brook limestone member
- 22'2" Jamesville limestone member
- 3'3" Clark Reservation limestone member
- 11'4" Elmwood member
  - 3'6" C submember
  - 3'0" B submember
  - 4'8" A submember
- 19' Olney limestone member

Total miles	Miles	Route description
		The strata exposed in the lower quarry range from the lower part of the Olney member to the bottom 1-foot of the Pools Brook member. The main floor of this quarry is at the top of the Olney limestone with a few inches of the bottom of Elmwood A dolomite in places. The Elmwood A and C submembers are distinguished by their yellow brown weathering color, the Clark Reservation limestone by its very light gray weathering color and diagonal fractures, and the Jamesville limestone by the massive stromatoporoid biostrome that constitutes its upper half. Most of the Pools Brook member and the overlying sandstone (Springvale sandstone bed of the Edgecliff member) are exposed in the stripped area between the two quarries. The Pools Brook is easily recognized by its thin bedding and sparseness of fossils. The Springvale sandstone is brown and contains scattered black phosphatic nodules. The upper quarry is entirely in the Onondaga limestone. Most of the floor is on the top of the Springvale sandstone. On the downthrown side of the thrust fault, at the north side of the quarry, the floor is in the lower part of the Moorehouse limestone member. The middle and upper parts of the Moorehouse member are most accessible for examination on the downthrown side of the thrust fault at the north side of the quarry, where loosely coiled cephalopods of the Halloceras bed are exposed on the floor. Oliver (1954, G.S.A. v. 65) designated this quarry as the type locality of the Moorehouse member. He derived its name from Moorehouse Flats nearby. The Seneca member is poorly represented in the quarry. All but a few feet has been eroded. The Edgecliff member contains numerous rugose and tabulate corals and much crinoid debris including some unusually large columnals. It is most easily seen at the west end of the north side of the quarry. The Nedrow member also is most accessible here. The reverse fault on the north side of the upper quarry strikes about N 70 W, dips about 20 degrees south, and has a throw of 31 feet. It is complicated in places by multiple slip planes, drag, and crushing. Small veins in north-south joints near the fault contain calcite, dolomite, fluorite, quartz, and a solid hydrocarbon. These are best seen in the Olney limestone of the lower quarry.
25.0	0.1	Return to entrance of the lower quarry and turn right (N) on Route 91 and proceed to Route 173.
25.5	0.5	Turn right (E) on Route 173.
25.7	0.2	Exposure of Edgecliff on left near top of grade.
26.1	0.4	Turn right (S) on Taylor Road.

Total miles	Miles	Route description
		STOP 9. View to south of the stripped surface on the Onondaga limestone which forms a prominent bench about 150 feet above the bottom of Butternut Creek Valley. The Marcellus and Skaneateles formations of the Hamilton Group form the steep slopes to the southeast.
		Continue south on Taylor Road for 0.8 mile to wooded tract at bend in road.
26.9	0.8	STOP 10. Coral bioherm in the Onondaga limestone. Taylor Road crosses a coral bioherm here. Most of the exposures are in the wooded tract on the west side of the road. This is the only bioherm known in the Onondaga limestone in the Syracuse area. Usually these bioherms start in the Edgecliff member and, if thick enough, extend upward into higher members. In the absence of exposures of the adjacent limestone, it is not possible to determine the stratigraphic range of this bioherm, but it appears to extend well up into the formation.
		Return to Route 173.
27.7	0.8	Turn left (W) on Route 173 and proceed west through Jamesville.
29.6	1.9	Entrance to Clark Reservation State Park. Continue west on Route 173.
31.6	2.0	Turn sharp left (S) on LaFayette Road.
		A thrust fault, which strikes about N 70 W, dips about 20 degrees south, and has a throw of 42 feet, crosses Route 173 near this road junction. Formerly it was exposed in one of the old quarries that are now filled. Present exposures east of the road junction show the Onondaga and Manlius limestones offset by the fault.
31.8	0.2	Outcrop of Onondaga limestone at edge of road on left.
31.9	0.1	Subsidence structure in Onondaga limestone in field on left. Exposed beds have an anomalous dip west because of this structure.
33.0	1.1	Road crosses west end of Smoky Hollow cross channel at an altitude of about 780 feet. This is the southernmost of the well-developed cross channels eroded between Onondaga Valley and Butternut Creek Valley by the outflow from glacial lakes in Onondaga Valley. The channel was eroded in Marcellus shale down to the more resistant Onondaga limestone.
33.1	0.1	Turn right onto Graham Road and continue south.

Total miles	Miles	Route description
33.5	0.4	<u>STOP 11.</u> <u>View of Onondaga Creek Valley</u>
		Some of the topographic, glacial, and stratigraphic features of this part of the valley will be pointed out at this stop.
		Continue south.
33.8	0.3	Turn right (downhill) on Sentinel Heights Road.
34.1	0.3	Turn left (S) on Kennedy Road. Road cuts on the new divided highway (Route 81) to right are in the Edgecliff and Nedrow members of the Onondaga limestone. The road cuts on Kennedy Road are in the Moorehouse member and the top few feet of the Nedrow member.
35.0	0.9	Turn right and proceed a short distance to Route 11.
35.1	0.1	Turn right (N) on Route 11 and park.
35.2	0.1	<u>STOP 12.</u> Top of the Onondaga limestone and Union Springs shale displaced by a small thrust fault.
		The upper 8 feet of the Onondaga limestone and about 10 feet of the Union Springs shale are exposed on the side of the deep drainage ditch on the east side of the road. Exposures of the top contact of the Onondaga such as this are rare.
		At the south end of the drainage ditch a thrust fault with a throw of about 5 feet cuts the top of the Onondaga but is absorbed in the Union Springs shale above by complex crumpling and jointing.
		Continue north to north end of large road cut on the opposite side of the bridges. Park off the road.
35.4	0.2	<u>STOP 13.</u> <u>Road cut in the Manlius and Onondaga formations.</u>
		The stratigraphic units exposed in the road cut are as follows:

Onondaga limestone formation	
11'6"	Moorehouse limestone member (to top of exposure)
11-12'	Nedrow limestone member
12'8"	Edgecliff limestone member
-----disconformity-----	
Manlius limestone formation	
10'	Pools Brook limestone member
18'	Jamesville limestone member
4'	Clark Reservation limestone member
	Elmwood C (only the top few inches exposed)

Total miles	Miles	Route description
		The lowest part of the section is at the north end of the cut where the top few inches of Elmwood C, the Clark Reservation, and the Jamesville are exposed.
		This stop provides an opportunity to compare the stratigraphic units with the same units seen at the Penitentiary quarries (stop 8) 4 miles northwest. Most of the units are similar, but one significant difference at this stop is the absence of the Springvale sandstone bed at the base of the Edgecliff member, and another is the presence of a bed with stromatoporoids and favositid corals at the top of the Pools Brook member. This bed has a small erosion surface at its base, suggesting that it might correlate with the Bishop Brook limestone exposed on the hill northeast of Manlius, which is in a similar stratigraphic position and also has an erosion surface at its base. However, the bed appears to resemble the Jamesville more closely than the Bishops Brook both faunally and lithologically.
		Inclined joints are well developed in the Nedrow member on the south side of the exit road from Route 81. Many of these are limited to certain beds and end upward against prominent shaly partings. They also are numerous in the Manlius at the north end of the road cut where the beds are slightly arched.
		Continue north on Route 11 a short distance.
35.5	0.1	Cross to the south bound lanes and proceed south to the first road right.
35.8	0.3	Turn right (W) on road into the Indian Reservation at the junction of Routes 11 and 81. Keep right at next road junction.
36.0	0.2	Turn left into large quarry.

STOP 14. Indian Reservation quarry in the Onondaga limestone, the type locality of the Nedrow member.

This quarry formerly was worked for building stone.

The stratigraphic units exposed in the quarry are as follows:

Onondaga limestone formation

15'9"	Seneca limestone member (To top of quarry).
18'6"	Moorehouse limestone member
11-12'	Nedrow limestone member
12'0"	Edgecliff limestone member (base not exposed).

The main floor at the south end of the quarry is at the top of the Edgecliff member. The south face exposes the Nedrow, Moorehouse, and Seneca members. The Tioga bentonite bed (8" to 9" thick), which Oliver (1954, Bull. G.S.A., v. 65) uses as the boundary between the Moorehouse and Seneca members, can be seen in the upper part of the

Total miles	Miles	Route description
		face where it forms a reentrant a few inches above a 4-inch layer of black chert.
		The best fossil collecting is on the main floor of the quarry where brachiopods, corals, bryozoa, and crinoid debris, including segments of unusually large columnals, are abundant.
		Climb up the south side of the quarry to observe the Tioga bentonite and the Seneca member at the top. A zone of pink chonetid brachiopods is exposed about 2 feet below the highest beds at the edge of the stripping.
		Walk east to the fence on Route 81 to observe the Union Springs shale and the Cherry Valley limestone exposed in a new road cut.
		Return to Route 11.
36.4	0.4	Junction with Route 11. Turn left (N) on Route 11 and continue to Seneca Turnpike (Route 173).
39.2	2.8	Intersection of Routes 11 and 173. Turn left (W) on Route 173.
41.0	1.8	Junction with South Avenue. Hold right on Route 173 where the road forks a short distance west of South Avenue.
41.9	0.9	Ravine in Marcellus shale on left a short distance west of the County Home.
43.7	1.8	Junction with Fay Road. Keep left on Route 173.
44.1	0.4	Turn left on Onondaga Blvd. toward Split Rock Gulf and continue to the end of the road.
44.9	0.8	STOP 15. Split Rock Quarries in the Manlius and Onondaga limestones.
		Park in old part of quarry at end of road and walk east into the easternmost quarry in the Manlius.
		The Edgecliff member of the Onondaga limestone can be seen in this quarry to rest disconformably on Elmwood A bed of the Elmwood member. The 33 feet of limestone between the Elmwood A bed and the Rondout dolomite exposed on the floor of the quarry, is considered to be the Olney member of the Manlius formation by Rickard (1962, N.Y.S. Mus. Bull., 386). The bottom 5 feet of this limestone, however, has beds characteristic of the lower part of the Thacher limestone member to the east. These beds will be examined in an attempt to evaluate their significance in resolving the problem of the "disappearance" of the Thacher.

End of Trip

TRIP E: STRATIGRAPHY OF THE HAMILTON GROUP IN THE SYRACUSE AREA

Newton E. Chute and James C. Brower

Total miles	Miles	Route description
0.0	0.0	Leave Syracuse University's Field House at the Colvin Street exit. Turn left (E) on Colvin Street.
0.9	0.9	Turn right (S) on Nottingham Road.
1.6	0.7	Distant view of hills in the Marcellus and Skaneateles formations ahead.
2.2	0.6	Junction of Peck Hill Road with Nottingham Road. Drumlin on the left and a scarp in the Manlius and Rondout formations on the right.
2.6	0.4	Entering Rock Cut Channel. This large cross channel was cut during the recession of the glacial ice by the drainage from a glacial lake in Onondaga Valley to the west.
2.9	0.3	Junction of Nottingham Rd. with Jamesville Toll Rd. Turn left (E) on Jamesville Toll Road.
3.1	0.2	Road cut on right in the Cobleskill and Rondout dolomite formations. The Cobleskill is thicker bedded and is composed of purer dolomite than the Rondout.
3.6	0.5	Bridge over the D. L. & W. Rwy.
3.7	0.1	Junction of Jamesville Toll Road and Jamesville Road. The stone crusher building of the Solvay Process Division of the Allied Chemical Corporation can be seen on the hillside to the left. Continue south on Jamesville Road into Jamesville.
4.6	0.9	Junction of Jamesville Road and Seneca Turnpike (Route 173) in Jamesville. Turn left (E) on route 173.
4.9	0.3	Exposure of the Edgecliff member of the Onondaga limestone on the left near top of grade.
6.0	1.1	Junction of Gates Road with Route 173.
6.4	0.4	Small exposure of the Cherry Valley limestone member of the Marcellus formation in road cut on left near top of rise.
6.6	0.2	View of the Solvay Process Division Quarry on left.
7.4	0.8	Intersection with Sweet Road. A monocline on a thrust fault in the Onondaga limestone is exposed on the south side of Route 173 in the bed of a small stream a short distance west of this intersection.

Total miles	Miles	Route description
7.7	0.3	STOP 1. Monocline in the Onondaga limestone and exposures of the Union Springs shale, Cherry Valley limestone, and Chittenango shale members of the Marcellus formation.
		Walk south up the stream for about 500 feet to where the top beds of the Onondaga limestone exposed in the stream bed dip northward due to the presence of a monocline that strikes about N 70 W. This monocline probably grades into a thrust fault in the Solvay Process Division's quarry. Solution-widened tension joints are well-developed in the limestone on the monocline.
		Continue up the stream to where it forks. About 15 feet of Union Springs shale and about 3 feet of Cherry Valley limestone are exposed at a small waterfall on the left branch not far from the fork. The Union Springs consists of black shale with numerous thin beds of black limestone. Styliolina fissurella, a small mollusc shaped like a pencil point, is common in the shale of the upper part of the member. The Cherry Valley limestone forms the lip of the falls. This member is noted for cephalopods and one or more may be seen in the stream bed at the top of the falls. The basal few feet of Chittenango shale, exposed in the stream bank above the falls, contains one or more thin beds of black limestone. Numerous styliolina fissurella can be seen on the bedding surfaces of some of the shale.
		Return to Route 173 and go back west to Gates Road.
9.2	1.5	View of the Solvay Process Division's quarry ahead on right.
9.4	0.2	Turn left (S) on Gates Road.
9.7	0.3	Turn left into shale pit.
		STOP 2. Chittenango and Cardiff shales.
		This shale is quarried by the Alpha Portland Cement Company for use in cement manufacture at its Jamesville plant. The upper bench is in the upper 40 to 50 feet of the Chittenango shale member of the Marcellus formation.
		Although these shales are similar in appearance, they can be distinguished easily by their streaks. The Chittenango shale, because of its relatively high content of carbonaceous matter, streaks brown when scraped by a hard object such as a geologic hammer, whereas the Cardiff streaks light gray. Examination of drill core from several test holes has shown that the change in color of the streak takes place within a vertical interval of 3 feet. The contact is placed where, in going downward, the streak becomes distinctly brown. Located this way, the contact is near the top of the lower face, 5 to 6 feet above the upper layer of large septarian concretions.

Many of the septarian concretions in the upper part of the Chittenango are several feet across. The Cardiff shale on the other hand has only a few concretions and these are seldom more than 6 inches in diameter. The cracks within the septarian concretions commonly contain calcite, ferroan dolomite, and white, platy barite. Small crystals of barite with some pyrite also coat joint surfaces in the shale in places.

Fossils are sparse or lacking in most of the Chittenango and Cardiff shales, but one or more zones near the top of the Chittenango contain numerous carbonized plant remains and a few fish scales, fish body plates, pyritized straight cephalopods, and small brachiopods. Because the shale tends to break down into small pieces after exposure for a few months, the success of fossil collecting depends on the recency of quarrying in the fossil zones.

9.8 0.1 Return to Gates Road and turn uphill (S).

12.1 2.3 Turn right on Sweet Road and continue south.

12.4 0.3 STOP 3. Road cuts and small quarry in the upper part of the Butternut member of the Skaneateles formation.

About 40 feet of the upper Butternut is exposed in the small quarry and road cuts nearby. Most of the exposure consists of shale with thin siltstone layers and silty shale that increase upward. The top $5\frac{1}{2}$ feet in the quarry is siltstone. This siltstone and the silty shale below contain some brachiopods particularly *Leiorhynchus sp*. The lowest beds exposed in the road cut are poorly fossiliferous shale that splits into thin flat pieces "paper shale", a characteristic of the shale of the middle and lower parts of this member.

Continue south on Sweet Road.

14.3 1.9 Turn left (E) on Pratts Falls Road.

14.8 0.5 Exposures of the Centerfield member of the Skaneateles formation in banks of gully beside road on left.

15.0 0.2 Turn left (S) on Hennaberry Road.

15.15 0.15 Snall exposures of the Centerfield member in road cuts.

15.25 0.1 STOP 4. Siltstone platform of the Staghorn Point coral biostrome.

Stop opposite the yellow brick house. Walk about 100 feet up the hillside on the west side of the road to exposures of siltstone strata that form a bench on the hillside. This is the siltstone platform on which the Staghorn Point coral biostrome was formed. It is about 50 feet above the base of the Otisco member of the Ludlowville formation and is an important horizon marker in the Syracuse area. The exposed section here is as follows:

Total miles	Miles	Route description
		Ludlowville formation Otisco member
		8'' siltstone bed with numerous molds of corals in bottom 2 inches
		3'0'' covered
		4'0'' siltstone platform with several thin discontinuous fossil-rich layers. Base not exposed but total thickness of siltstone probably about 6 feet.
		Turn around and return to Pratts Falls Road.
15.5	0.25	Pratts Falls Road on right, continue on Hennaberry Road.
15.6	0.1	Turn left (E) on Pratts Falls Road and proceed to Pratts Falls Park.
16.1	0.5	Turn left into Pratts Falls Park.
		STOP 5. Delphi Station and Pompey members of the Skaneateles formation.
		Observe the upper beds of the Pompey member exposed near the top of the falls. Walk right on path along the edge of the gorge to where the falls can be observed.
		The top 60 feet of the falls is Cooper's (1930, *Am. J. Sci.* v. 19) type section of the Pompey member. The resistant siltstone beds that form the lip of the falls are his *Eunella*-*Nyassa* zone that marks the top of the Pompey, distinguished by the presence of *Eunella lincklaeni*, *Athyris cora*, and *Nyassa arguta*. The lower part of the falls exposes the upper part of the Delphi Station member. The Mottville limestone member which underlies the Delphi Station member is exposed a moderate distance downstream from the falls.
		Return to Pratts Falls Road.
16.9	0.8	Turn left (E) on Pratts Falls Road.
17.1	0.2	Small shale quarry in the Butternut member of the Skaneateles formation on the right side of the road.
17.8	0.7	Turn right (S) on Watervale Road and continue south to Route 20.
18.3	0.5	Turn left (E) on Route 20 and go through the village of Pompey Center.

Total Miles	Miles	Route description
20.8	2.5	STOP 6. Road cut in the Pompey and Delphi Station members of the Skaneateles formation. This cut exposes about 115 feet of the Pompey and Delphi Station members. The 8 feet of siltstone at the top of the cut is Cooper's Eunella-Nyassa zone that marks the top of the Pompey, the same unit that forms the lip of Pratts Falls. This siltstone grades downward into gray shale. The contact between the Delphi Station and the Pompey members is not easily located and is one of the problems to be considered at this stop. Return to Pompey Center on Route 20 and continue west.
25.9	5.1	Intersection of Route 91 with Route 20 at Pompey.
31.9	6.0	Intersection of Route 11 with Route 20 in the village of LaFayette.
32.3	0.4	Road cut on the left in the Butternut member of the Skaneateles formation on road connecting Routes 81 and 20.
38.2	5.9	Intersection of Route 80 and Route 20.
38.6	0.4	STOP 7. Lower part of the Centerfield calcareous siltstone member of the Skaneateles formation. Walk a short distance north from Route 20 to the waterfalls on the lower part of the Centerfield. The deep ravine below the falls is in the Butternut shale member of the Skaneateles formation. Continue northwest on Route 20 to Hogsback Road.
39.5	0.9	Turn right (N) on Hogsback Road about 300 feet and park. STOP 8. Centerfield member. Walk southeast about 200 feet to the stream where the Centerfield member forms a waterfall. Most of the Centerfield is exposed here, and the upper part with calcareous concretions is accessible for close observation. The gradational nature of the bottom contact of the Centerfield with the Butternut member can be seen on the side of the falls. The total thickness of the Centerfield is not closely determined in this area, but may be about 30 feet. One of the noteworthy features here is the joint controlled cleft at the top of the falls through which the stream flows.
39.6	0.1	Return to Route 20 and turn back left (E).

Total miles	Miles	Route description
40.9	1.3	Turn right (S) onto Route 80 and proceed about 0.2 mile uphill.
41.1	0.2	STOP 9. Joshua Coral Reef in the Otisco shale member of the Ludlowville formation.
		This is the famous Lords Hill locality described by W. A. Oliver, (1951, Amer. Jour. Sci., p. 705-728). The coral bed is estimated to be as much as 50 feet thick in this area and to be about 90 feet above the bottom of the Otisco Member. The exposure was much better before the road ditches were coated with blacktop, but some of the corals can still be seen and collected. According to Oliver, the most common genera of rugose corals here, in order of abundance, are: *Cystiphylloides*, *Siphonophrentis*, *Bethanyphyllum*, *Heliophyllum*, and *Heterophrentis*. In addition the colonial rugose form *Eridophyllum* and several species of Favosites are present.
		Continue uphill.
41.3	0.2	Small exposures of the Ivy Point siltstone member of the Ludlowville formation on both sides of the road. The Ivy Point forms benches in this area.
41.7	0.4	STOP 10. Road cut in the Owasco member of the Ludlowville formation, and the Portland Point and Windom members of the Moscow formation.
		The section is as follows:
		Moscow formation 1'6"? Windom shale member (to top of exposure) 9'1" Portland Point member 7'6" shale and thin interbedded fossil-rich limestone layers 1'7" impure limestone, fossiliferous
		Ludlowville formation 2'3" Owasco siltstone member 2'0" Spafford shale member (to base of exposure)
		The Portland Point member, according to Cooper (1930), consists of 1 foot of crinoidal limestone overlain by 8½ feet of calcareous shale with interbedded thin layers of limestone. At this locality the basal limestone is a little thicker, and thin beds of fossiliferous limestone are present in the overlying shale for about 7½ feet above the limestone. Because of the indefiniteness of the position of the upper contact, the amount of Windom present in this exposure, if any, is uncertain.
		Continue south (uphill) on Route 80 to Kingsley Road.

Total miles	Miles	Route description
42.7	1.0	Turn left (E) on Kingsley Road.
43.8	1.15	STOP 11. Tully limestone.
		Small exposure of the upper part of the Tully limestone on the south side of the road opposite a red barn. Walk down the hill to the east a short distance and turn into the old quarry in the Tully limestone on the north side of the road. The top 5 feet of the quarry is the West Brook member below which is 10 feet of the Apulia member. The contact between them is placed at the bottom of the nodular limestone of the West Brook. The Tinkers Falls member is not exposed. Fielding (1956, MS thesis, Syracuse Univ.) estimates the total thickness of the Apulia member to be 18 feet and the West Brook member to be 9 feet in the South Onondaga quadrangle.
		The Apulia member contains crinoid fragments, ostracods, and brachiopods particularly *Hypothyridina venestula*. The coral *Lopholasma* is characteristic of the West Brook member. In addition, Fielding (1956) reported finding *Metriophyllum tullium*, *Elytha fimbriata*, *Phacops rana*, *Tornoceras uniangulare* and crinoid fragments.
		Continue east on Kingsley Road.
44.00	0.15	STOP 12. Road cut in the upper part of the Windom member of the Moscow formation.
		About 20 feet of the top part of the Windom shale member is exposed in the road cut on Kingsley Road. The shale becomes silty near the top of the exposure and is sufficiently resistant to have formed a bench about 500 feet wide. A few small calcareous concretions can be seen in this exposure and enough pyrite is present to cause considerable limonite staining. Brachiopods, pelecypods, and trilobites are present, but are not abundant.

End of trip.

CORRELATION OF THE FALKIRK AND FIDDLERS GREEN MEMBER OF THE BERTIE FORMATION

Jesse L. Craft

State University College at Cortland, New York

The Bertie formation of New York, according to Rickard (1962, p. 17-22), consists of the following members:

*Western New York	Central New York
Williamsville	Oxbow (new name by Rickard)
Scajaquada	Forge Hollow (new name by Rickard)
Falkirk	Fiddlers Green

He recognized that the members in western New York may correlate with those in central New York but, because this had not been demonstrated due to a covered interval between, he preferred to give them different names.

To try to help resolve this problem of correlation, the writer (Craft 1963) undertook a field and laboratory study of the Falkirk (Chadwick, 1917) and Fiddlers Green (Hopkins, 1914) members throughout most of their extent in the state. Observations also were made on adjacent members.

Numerous exposures of the Falkirk and Fiddlers Green members were examined and measured between Bertie, Ontario and Sharon, New York, and suites of samples were collected for analysis from six localities (see table l). The laboratory work involved study of thin sections, examination of etched surface and stained surfaces, and analyses for calcium, magnesium, iron, and insoluble material.

The Falkirk in the western part of the state is divisible into lower and upper thin-bedded units and a middle massive unit. Traced eastward, the middle massive unit thins and the upper thin-bedded unit thickens (figure 1). East of Morgansville the middle massive unit is no longer distinguishable and the whole member is thin bedded.

Near Syracuse the Fiddlers Green is very thin bedded to thin bedded with a few medium-bedded lenses. These lenses are somewhat more resistant to weathering and commonly protrude slightly from exposed surfaces. Generally the upper 7 to 10 feet is more regularly bedded than the rest of the member. Laminae 0.2mm to 0.5mm in thickness are visible on the weathered surfaces of many of the beds. The top few inches of the Fiddlers Green member is thinly laminated, dark gray (N4) to medium dark gray (N5), very fine-grained argillaceous dolomite with well-developed mud cracks. This mud-cracked zone has been observed as far east as Passage Gulf (near Cedarville), and in the Falkirk as far west as Akron Falls Park (near Akron).

In the Syracuse area the Fiddlers Green member is exposed in numerous places. The best and most complete exposure is in the gorge of Butternut Creek (Stop 5, Trip C), on the north side of the village of Jamesville, where it is 27 to 30 feet thick. Here, as elsewhere, most of the member is medium dark gray (N4) to light brownish gray ((5YR6/1) on fresh surfaces and brownish gray (5YR6/1) to light olive gray (5Y6/1) on weathered surfaces.

*The Oatka shale (Chadwick 1917, p. 173) is not present in central New York and, as its inclusion with the Bertie is questioned by some, it is omitted here.

TABLE 1

AVERAGE COMPOSITION OF THE FALKIRK-FIDDLERS GREEN UNIT

	$MgCO_3$ % *	$CaCO_3$ % *	Carbonate Total % *	Theoretical % **		Fe_2O_3 % * (Soluble Iron)	Insoluble Material Percent *
				Calcite	Dolomite		
Western Region:							
Akron Falls	41.31	53.52	94.83	4.40	90.40	.91	4.26
Morgansville	40.84	52.63	93.47	4.10	89.40	1.31	5.20
East Victor	41.00	54.26	95.26	5.60	89.70	.82	3.92
AVERAGE	41.05	53.47	94.52	4.80	89.70	1.52	4.46
Central-Eastern Regions:							
Jamesville	40.83	51.94	92.78	3.40	89.40	1.22	6.00
Passage Gulf	35.70	49.23	85.93	5.60	80.30	2.44	11.63
Sharon Center***	38.12	49.35	87.47	4.00	83.50	1.14	11.39
AVERAGE	38.55	50.18	87.73	4.30	83.40	1.60	9.67
AVERAGE OF ENTIRE AREA	39.80	51.83	91.63	4.50	87.10	1.56	6.81

* (Calculated from analyses after Cheng, et al., 1952)

** (Calculated from molecular weight of $CaMg(CO_3)$; excess $CaCO_3$ is assumed to be Calcite)

*** (Average of shaly layers sampled)

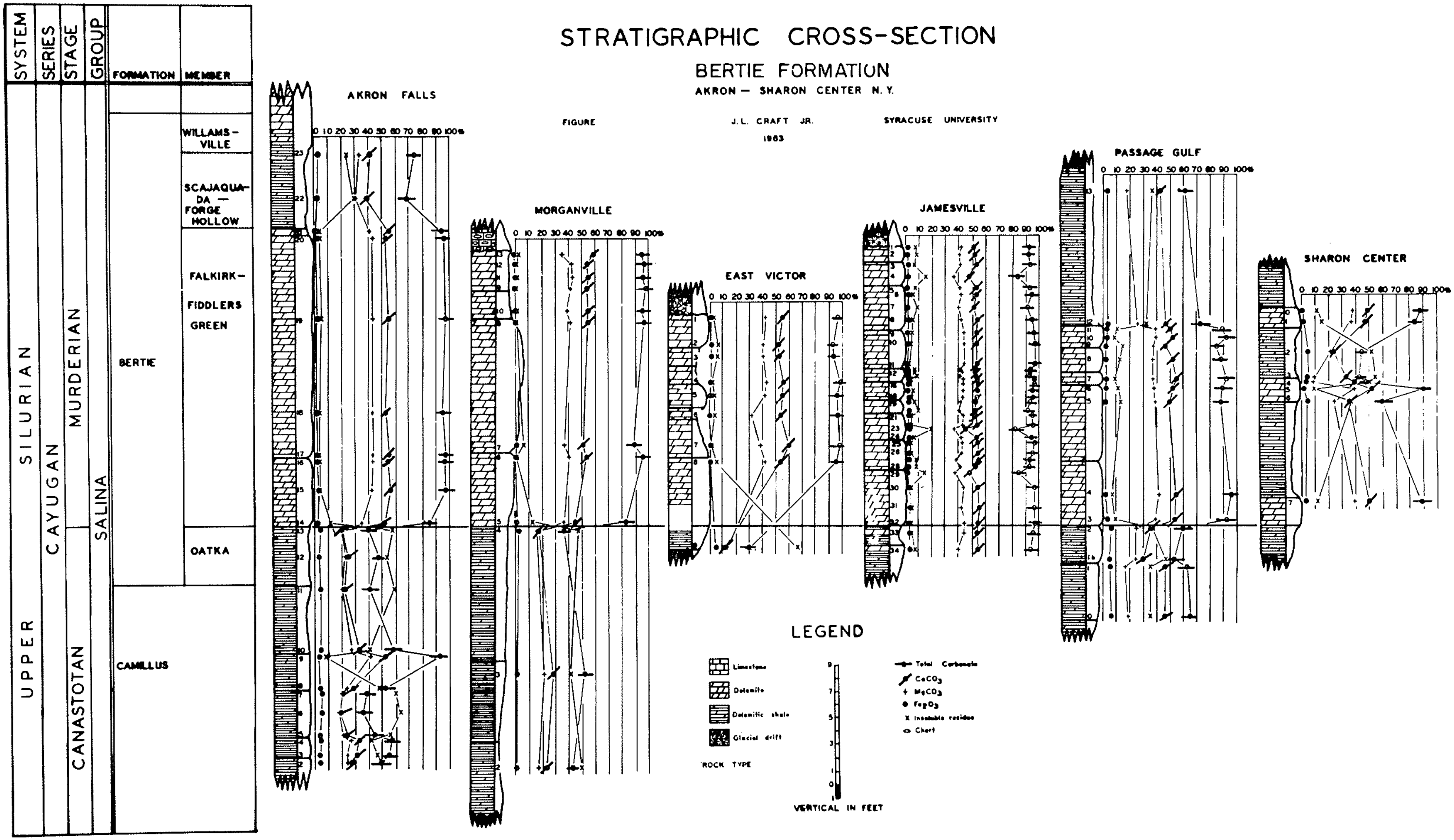

STRATIGRAPHIC CROSS-SECTION
BERTIE FORMATION
AKRON — SHARON CENTER N. Y.
FIGURE
J.L. CRAFT JR.
1963
SYRACUSE UNIVERSITY
SYSTEM
SERIES
STAGE
GROUP
FORMATION
MEMBER
UPPER SILURIAN
CAYUGAN
MURDERIAN
CANASTOTAN
SALINA
BERTIE
CAMILLUS
WILLAMS-VILLE
SCAJAQUADA — FORGE HOLLOW
FALKIRK-FIDDLERS GREEN
OATKA
AKRON FALLS
MORGANVILLE
EAST VICTOR
JAMESVILLE
PASSAGE GULF
SHARON CENTER
0 10 20 30 40 50 60 70 80 90 100%
LEGEND
Limestone
Dolomite
Dolomitic shale
Glacial drift
ROCK TYPE
9
7
5
3
1
0
1
VERTICAL IN FEET
Total Carbonate
CaCO3
MgCO3
Fe2O3
X Insoluble residue
Chert

Figure 1.

The Fiddlers Green and Falkirk are poorly fossiliferous. Ostracodes, concentrated in a few thin layers, are most common. Eurypterids have been found near the top of the member, particularly at Passage Gulf and near Buffalo. Algal colonies, some of which appear to be stromatolites, are present near the middle of the member in a few places. The largest known are east of Nottingham Road near the west end of the Boy Scout Camp in Rams Gulch (east end of Rock Cut Channel) between Syracuse and Jamesville. Others have been reported west of Syracuse near Marcellus Falls (Allenson 1955, p. 19), and east of Syracuse in the Oneida (Sachs, 1959, p.21) and Vernon quadrangles (Rhodes, 1959, p. 25).

In the Syracuse area, the Fiddlers Green is a relatively pure fine-grained dolomite, with an average composition, as shown by table 1, of 92.78 per cent total carbonates, 6 per cent insoluble material, and 1.22 per cent soluble iron calculated as Fe_2O_3 (EDTA titration after Cheng, Kurtz, and Bray, 1952). The composition of the Falkirk, as determined at three localities in western New York, is very similar to the composition of the Fiddlers Green of the Syracuse area, (see table 1), Impurities increase gradually eastward (Figure 2) until, between Van Hornsville and Sharon, the Fiddlers Green grades into the Brayman shale.

The insoluble residues of the Fiddlers Green member consist predominantly of clay minerals, quartz, small crystals of pyrite and some heavy minerals. The clay minerals, as determined by X-ray diffraction, are illite, montmorillonite, chlorite and traces of kaolinite (Seide, 1964, personal communication).

The results of this study indicate that the Falkirk dolomite member of western New York and the Fiddlers Green dolomite member of central New York are the same rock unit. The writer's data on the Scajaquada (Chadwick, 1917) and Forge Hollow (Rickard, 1953) members, although less complete than for the Falkirk and Fiddlers Green, indicate that they also are the same rock unit (Figure 3). No systematic study was made of the Williamsville and the Oxbow members, but it is probable that they too are the same unit..

The data now available is believed sufficient to justify correlating the members of the Bertie in the western part of the state with those used by Rickard for the central part. The member names to be retained, based on priority of usage, should be: Fiddlers Green, Scajaquada, and Williamsville.

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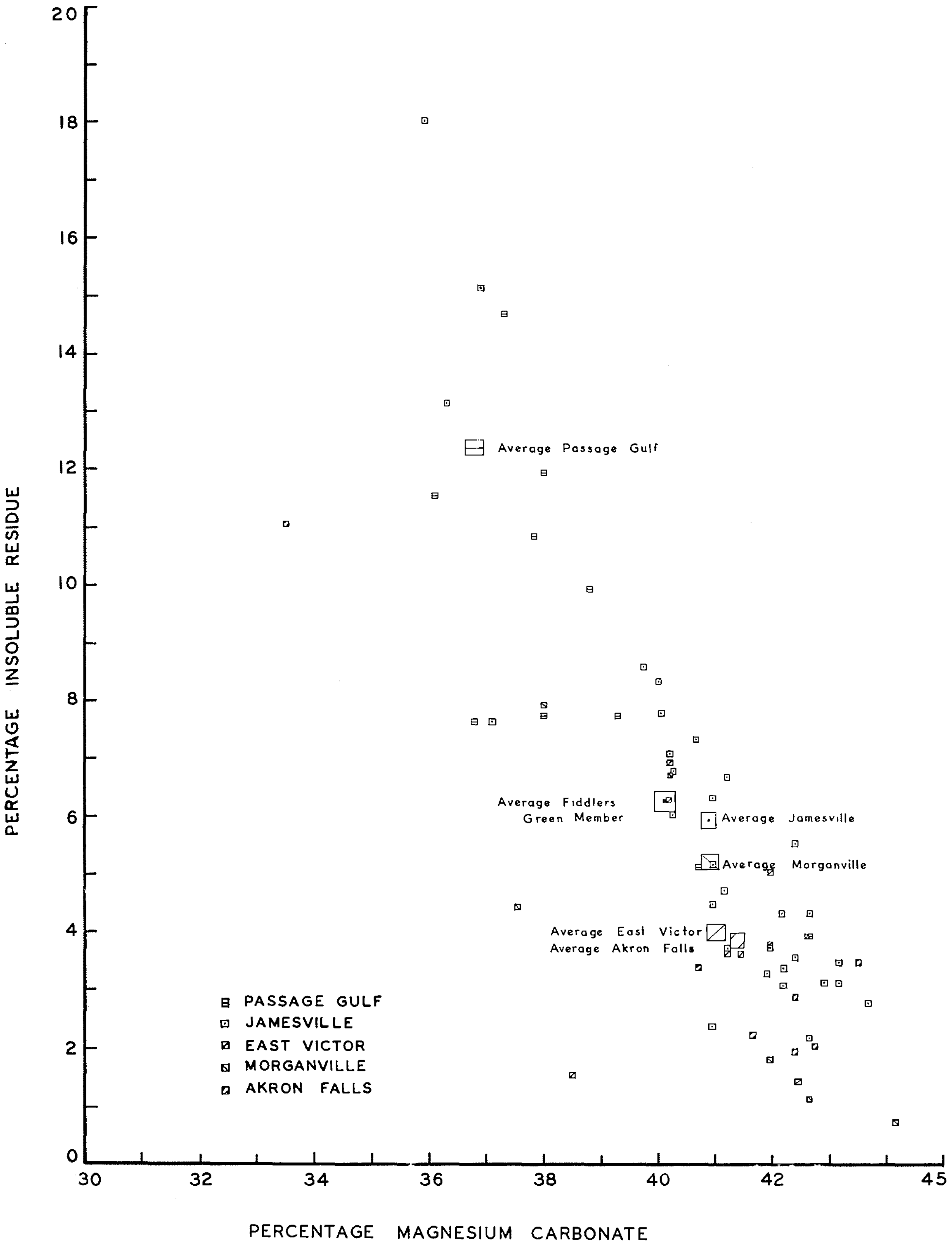

Fig. 2. RELATIONSHIP OF INSOLUBLE RESIDUES AND MAGNESIUM CARBONATE, FIDDLERS GREEN MEMBER

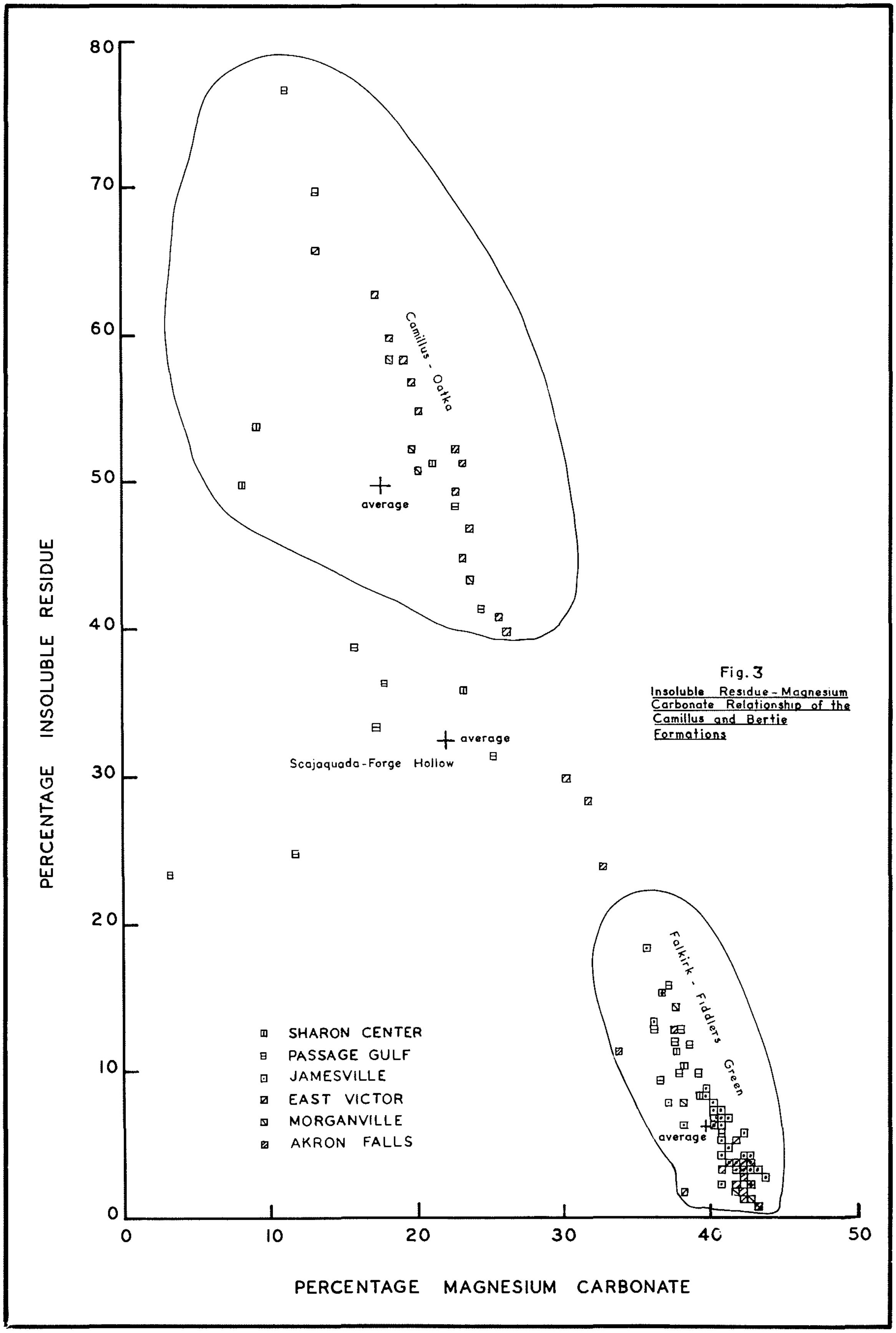

Fig. 3

Insoluble Residue - Magnesium Carbonate Relationship of the Camillus and Bertie Formations

PETROLOGY OF THE SILTSTONES IN THE LUDLOWVILLE FORMATION (MIDDLE DEVONIAN), ONONDAGA COUNTY, NEW YORK

by
Herman S. Muskatt

Introduction

The Ludlowville formation of the Hamilton Group contains a number of siltstone units that are difficult to differentiate in isolated outcrops and hand specimens. A study of these units was undertaken with one of its purposes the establishment of criteria for their recognition. For this study about 800 samples, from which 87 specimens were selected for thin-section, heavy-mineral, and carbonate analyses, were collected from 36 localities in Onondaga County.

The rock classified as siltstone in the field is flaggy to massively-bedded, and has a distinctly gritty feel. It is more difficult to break than shale and commonly develops conchoidal fractures. The laboratory work showed that silty shale contains up to about 35 percent quartz silt and that above 35 percent the rock assumes the appearance of siltstone. It also showed that between 30 and 35 percent quartz, the average modal diameter of the silt-sized quartz grains changes fairly abruptly from 0.025 to 0.035 mm. (see Table 1). The siltstones examined by the writer contain from 50 to 80 percent of silt-sized material by volume.

STRATIGRAPHY

Smith (1935, p. 44) divided the Ludlowville formation in the Skaneateles quadrangle into the Otisco, Ivy Point, Spafford, and Owasco members listed in ascending stratigraphic order. For paleontologic reasons Cooper (1930, p. 223), placed the lower contact of the Ludlowville formation at the bottom of the Centerfield. Due to the fact that the bottom contact of the Centerfield is gradational and difficult to locate whereas the top contact is sharp, the writer prefers to follow Smith and put the lower contact of the Ludlowville at the top of the Centerfield. A description of the Centerfield is included for completeness.

Skaneateles Formation

Centerfield Member

The Centerfield member overlies the Butternut member of the Skaneateles formation and is overlain by the Otisco member of the Ludlowville formation (See plate 1). In New York it extends from the Chenango Valley to Lake Erie (Cooper, 1930, p. 218-219). At Lake Erie the unit is a thin limestone, but it thickens and becomes a calcareous shale and siltstone to the east. In the Syracuse area the Centerfield is about 30 feet thick. The basal part is shaly to flaggy, unevenly bedded, calcareous, silty shale that is gradational with the underlying Butternut member of the Skaneateles formation. These basal beds grade upward into flaggy to massive, calcareous, partly cross-bedded siltstone of the middle and upper parts of the member. The top contact is marked by an abrupt change to the soft shales of the Otisco. Approximately 80 percent of the Centerfield is siltstone and because of this it forms benches and falls.

Calcareous concretions are common in zones from 2 to 8 inches thick. The concretions occur in five zones, but not more than three were observed at any one place. The five zones are, near the top; 3, 8, and 13 feet from the top; and at the bottom of the member.

Table 1.--Quartz and calcite frequency and average modal diameter of quartz. Stratigraphic distribution showing number of samples in 5 percent groupings.

%	Calcite					Quartz					Av. Modal Diam. mm
	Ce	Ot	IvP	Sp	Ow	Ce	Ot	IvP	Sp	Ow	
5		4									
10	10	21	11	3	2						
15	2		7	2	3		1				0.020
20	2					2	2	1	4		0.024
25	2		3				2		1		0.021
30		1				1	7		1		0.025
35		1		1		4	1	2			0.035
40						2	6	5			0.036
45	1					2	1	5		1	0.038
50						2	6	4			0.039
55						2		1			0.042
60						2	1	2		4	0.046
65								1			0.048

Explanation: Ce = Centerfield
Ot = Otisco
IvP = Ivy Point
Sp = Spafford
Ow = Owasco

Dashed line, based on field classification, divides the silty shale above from the siltstone below.

The Centerfield member is composed chiefly of quartz, mica, and calcite. In addition, a number of accessory minerals, listed in Table , are present. Mica decreases and quartz and calcite increase upward (Pl. 1). The modal grain size of the quartz also increases upward.

Ludlowville Formation

Otisco member

Smith (1935, p. 45) proposed the name Otisco for the shale unit, approximately 150 feet thick, which overlies the Centerfield. Although it consists mainly of silty shale and shale, it also contains about 20 feet of siltstone strata and two coral biostromes (Pl. 1). A flaggy to massive, calcareous siltstone layer, 6 to 8 feet thick, underlies the Staghorn Point coral biostrome submember of Smith (1935, p. 46), about 50 feet above the base of the Otisco. Because of its superior resistance to erosion, this siltstone unit commonly forms waterfalls and benches and is a useful horizon marker.

Another siltstone layer, about 2 feet thick, is approximately 20 feet above the base of the member. Other, thinner siltstone layers occur at various horizons within the Otisco.

Ivy Point Member

This member was divided by Smith (1935, p. 47,50) into lower and upper siltstone units and a middle silty shale unit which total about 50 feet in thickness. The lower contact of the Ivy Point with the underlying Otisco member is gradational in places. The upper contact is relatively sharp as a result of the abrupt change from siltstone to the soft shales of the Spafford member.

The lower siltstone unit is about 18 feet thick and is flaggy to massive, calcareous, and locally cross bedded. Spheroidal, calcareous concretions 3 to 18 inches in diameter are present in places. The middle unit is a shaly to flaggy, silty shale that contains a few zones of large, spheroidal, calcareous concretions. The upper siltstone unit is about 15 feet thick and resembles the lower siltstone unit in lithology and color (see Plate 1) but is less commonly cross-bedded. A zone of large concretions averaging about 8 inches in diameter, occurs in places approximately 10 feet below the top of the unit. Yellowish brown limonite spots, as much as an inch in diameter, caused by weathering of pyrite, are common in both this and the lower siltstone unit. Plant fragments are larger and more abundant in these siltstone units than in the other siltstone units of the Ludlowville formation.

The Spafford shale member is about 25 feet thick and is mostly a fissile to shaly-bedded, shale and silty shale. A flaggy siltstone, approximately 2 feet thick, is commonly present in the middle of the unit. Both the lower contact with the Ivy Point member and the upper contact with the Owasco member are relatively sharp. The upper contact may be a diastem.

This member is easily eroded and is poorly exposed except in ravines where it crops out in the reentrant under waterfalls capped by the Owasco siltstone and Portland Point limestone.

Owasco Member

The Owasco is a flaggy to massive, calcareous siltstone, commonly cross bedded, with well-defined top and bottom contacts. Thin, discontinuous, highly fossiliferous zones usually are present. Its thickness increases westward from 1 foot to about 2 feet.

PETROGRAPHY

The siltstones of the Ludlowville formation are very similar mineralogically. The same mineral species, of which quartz, mica, and calcite are the most abundant, were found in all the sections studied. A few thin-sections and heavy-mineral mounts of the Butternut member of the Skaneateles formation and the Portland Point member of the Moscow formation also were examined and found to contain the same minerals. Although the proportions of the mineral constituents vary somewhat, no consistent differences were found that are of value for identifying individual siltstone units.

Woodruff (1942, p. 69) found the same mineral assemblage in the Upper Devonian rocks of the Wellsville quadrangle. However, no fragments of quartzite and schist, such as reported by him, are known in the Ludlowville. The mineral assemblage reported by Sutton (1960, p. 30) for siltstones of the Naples Group (Upper Devonian) also is similar except for a somewhat greater amount of carbonate and chlorite.

Estimated percentages of calcite and quartz in the Centerfield and the members of the Ludlowville are shown in Table 1, and of the heavy detrital minerals in Table 2 Table also shows the average modal diameter of quartz for different quartz percentages. Other minor constituents, not listed in Tables 1 and 2, include feldspar, pyrite, mica, and carbonaceous matter.

The mineral composition of the shales is similar to that of the siltstone. The shales, however, show smaller percentages of quartz and more mica, carbonaceous matter, and pyrite. The kinds and percentages of the heavy minerals are approximately the same in both.

Light Minerals

Quartz

The siltstones contain from 35 to 65 percent quartz, ranging in modal grain diameter from 0.035 to 0.048mm. The modal grain diameter generally increases with an increase in the quartz content (Table 1), it also increases eastward toward the source of the sediment. In nearly all thin sections examined, the largest quartz grains present range from 0.05 to 0.09mm in diameter.

The quartz grains are colorless and transparent. Most contain minute mineral inclusions and also liquid or vapor inclusions. Many show undulose extinction, probably inherited from the parent rocks. Although a few of the grains are subrounded, most are angular to subangular. No secondary quartz outgrowths were observed. A few euhedral authigenic quartz crystals formed by replacing the margins of calcite shell material.

Some of the detrital grains of quartz are in contact with other quartz grains, but most are separated by calcite and mica flakes. The quartz grains are fairly evenly distributed and seldom are concentrated in laminae.

Table 2.--Stratigraphic variation of heavy-mineral frequencies in percent.

		Centerfield	Otisco	Ivy Point	Spafford	Owasco
Zircon[a]	(range)	40-88	44-92	44-81	13-79	55-84
	(mode)	60	53	55	45	60
Garnet[a]		0-28	0-32	0-19	12-84	2-65
		14	20	12	40	8
Leucoxene[a]		4-15	1-12	1-8	1-5	5-10
		13	7	8	2	6
Tourmaline[b]		0-16	0-13	5-21	0-10	0-5
		5	5	12	3	4
Rutile[b]		0-10	0-8	0-17	0-5	0-9
		5	4	7	3	5
Sphene[b]		0-6	0-11	0-4	0-3	0-3
		3	8	4	2	2
Epidote[c]		0-4	0-3	0-2	0-3	0-2
		2	2	1	2	1
Apatite[c]		0-2	0-2	0-4	0-3	0-1
		1	1	2	1	1
Amphibole[c]		0-2	0-6	0-8	0-1	0-1
		2	4	3	1	1
Clinopyroxene[d]			0-4	0-10	0-5	0-1
			2	3	2	1
Monazite[d]		0-3	0-3	0-2		0-1
		1	2	1		1
Kyanite[d]		0-3	0-1	0-3	0-1	
		1	1	2	1	
Corundum[d]		0-2	0-2	0-1		
		1	1	1		
Sillimanite[d]		0-2			0-1	
		1			1	

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[a] Present in more than 80 percent of 87 heavy-mineral mounts.

[b] Present in 51 to 79 percent of the heavy-mineral mounts.

[c] Present in 20 to 50 percent of the heavy-mineral mounts.

[d] Present in less than 10 percent of the heavy-mineral mounts.

Calcite

The shales and siltstones of all the members studied contain calcite as cement, fossils, and fillings of open spaces such as the body cavities of fossils. As shown in Table 1, most of the samples contain from 10 to 15 percent calcite. The calcite cement, where abundant, forms irregular interlocking grains, several millimeters in diameter, that enclose numerous silt grains. These calcite grains are distinguishable in thin section under polarized light. The calcite that fills the body cavities of fossils commonly is in clear, relatively coarse anhedral grains, a few of which show polysynthetic twinning.

Feldspar

A small amount of feldspar, generally less than 1 percent by volume, is present in all thin sections examined. The feldspar is polysynthetically twinned plagioclase within the albite and andesine range. No potash feldspar was found.

Mica

The fine-grained mica (illite or sericite?) is ubiquitous. It forms 15 to 45 percent of the siltstones and larger amounts of the shales. Most of the flakes of this mica are oriented approximately parallel to the stratification, particularly in the shales. Some are bent around adjacent detrital silt grains, and others are at relatively high angles to the stratification.

The siltstones and shales also contain scattered larger flakes of muscovite and biotite. The muscovite content ranges from a trace to 5 percent and the biotite ranges from a trace to 1 percent by volume as estimated from thin sections.

Chlorite

The chlorite content of the siltstones and shales ranges from a trace to about 5 percent by volume as estimated from thin sections.

Heavy Minerals

The average heavy-mineral content of the shales and siltstones studied is about 0.01 percent by weight. One specimen of siltstone contained about 0.45 percent. The relative frequencies of the 15 heavy minerals found, exclusive of pyrite, are shown in Table 2.

Zircon, garnet, tourmaline, rutile, and sphene are the most abundant nonopaque heavy minerals. Epidote, apatite, and amphibole are less abundant. Monazite, clinopyroxene, kyanite, corundum, and sillimanite are comparatively rare. Leucoxene is the most common opaque heavy mineral. The lack of magnetite and ilmenite among the heavy minerals of these rocks is noteworthy.

Zircon

Zircon is one of the most abundant of the heavy minerals and, as is shown by Table 2, occurs in all of the members studied. Most of the zircon is colorless, but some is pink. Minute mineral inclusions are common. Except for one well-rounded zircon grain with an optically continuous overgrowth of zircon, no authigenic zircon was found.

Approximately 3 percent of the zircon grains are doubly terminated euhedral crystals, 15 percent are slightly-worn euhedral crystals, and 30 percent are well-worn crystals with only parts of one or two crystal faces ramaining. The rest are rounded and have ellipsoidal to globular shapes. The average modal diameter of the zircon crystals normal to the "C" axis is 0.02mm.

Garnet

Most of the garnet ranges from nearly colorless to various shades of yellow, some is light pink or brown. The garnet grains vary in shape from subangular to rounded. No euhedral crystals were observed.

Tourmaline

The tourmaline grains are predominantly green or brown but a few colorless, pink, and blue grains were noted. Minute inclusions are common. One slightly worn euhedral crystal of green tourmaline was observed in the Ivy Point member. All of the other grains of tourmaline are rounded to well rounded and many have nearly colorless authigenic overgrowths at one end. Most of these overgrowths also show wear indicating that they formed before the grains were deposited.

Rutile

The rutile grains are red, reddish-brown, or yellow. They are generally elongated parallel to the "C" axis and, except for a few irregular grains, are subrounded to well rounded. Euhedral grains are lacking.

Amphibole

Blue-green to greenish-brown clinoamphibole was found in 14 of the 87 heavy-mineral mounts examined. A few grains of dark brown amphibole, with extinction angles of only 2 to 5 degrees, possibly lamprobolite, also were found. Most of the amphibole grains have refractive indices close to or above the aroclor (R.I. 1.66) used for mounting the heavy minerals.

Pyroxene

Pale-green to colorless clinopyroxene is present in only 8 of the 87 heavy-mineral mounts. These grains are angular to subangular. Many of the grains have extinction angles up to 38^{o}, and may be diopside. This is uncertain, however, as the exact orientation of the grains is unknown.

Leucoxene

Leucoxene, the only opaque heavy mineral present, is common in every specimen examined, and, generally, is the third most abundant of the heavy minerals, exceeded only by zircon and garnet (see Table 2). The leucoxene commonly occurs as subangular to subrounded grains.

The origin of the leucoxene is in doubt. Rutile and sphene are the only primary titanium minerals now present in the sediments, and these do not show any alteration to leucoxene.

Pyrite

Pyrite is common in the siltstones and ranges from a trace to 0.40 percent by weight. Although the greatest amount was found in two of the coarsest siltstones, the quantity generally increases as the quartz content and grain size decrease.

Pyrite occurs in isolated euhedral crystals, in spongy masses composed of minute cubes or spheres — some with a smooth surface and others faceted, and replacing microfossils pseudomorphically. Most of the pyrite tends to border or impregnate organic material.

Other heavy minerals

Sphene, apatite, epidote, monazite, corundum, kyanite, and sillimanite are present in small amounts as heavy-detrital minerals in the siltstones and shales studied (see Table). The kyanite and sillimanite are scarce, and the few grains seen are angular. The other minerals are somewhat more abundant and occur in subrounded to well-rounded grains.

Organic Material

Isotropic, brownish or black, opaque carbonaceous material occurs as streaks, patches, or specks in the shales and siltstones. It is estimated to form from 0.5 to 2.0 percent of the rock by volume. This material is more abundant in the shales than the siltstones.

PROVENANCE

The detrital minerals present in the rocks studied came from the east or southeast and probably were derived from metasedimentary and possibly some sedimentary and igneous rock. The high degree of rounding of most of the more stable minerals such as zircon, tourmaline, and the worn overgrowths on the tourmaline, and rutile, indicate that they have passed through at least one previous sedimentary cycle. These grains, therefore, could have been derived from reworked sediments. The doubly-terminated, euhedral, zircon crystals, and angular grains of clinopyroxene, garnet, amphibole, kyanite, and sillimanite indicate the presence of some metamorphic and, possibly, igneous rocks in the source area.

DEPOSITIONAL HISTORY

Repetition of shale and siltstone in the members studied is suggestive of cyclic deposition. Ecch cycle is composed of shale grading upward into siltstone (see Plate). Five such cycles of deposition can be recognized in the Ludlowville and upper part of the Skaneateles formations.

The first cycle is represented by the Butternut shale and the Centerfield siltstone; the second by the lower part of the Otisco and the siltstone platform under the Staghorn Point coral biostrome; the third by the upper Otisco beds above the platform and the lower siltstone unit of the Ivy Point; the fourth by the silty shale middle unit of the Ivy Point and the upper siltstone unit of that member; and the fifth by the Spafford shale and the Owasco siltstone. The fifth cycle is in doubt, however, as the Owasco and Spafford may be separated by a diastem.

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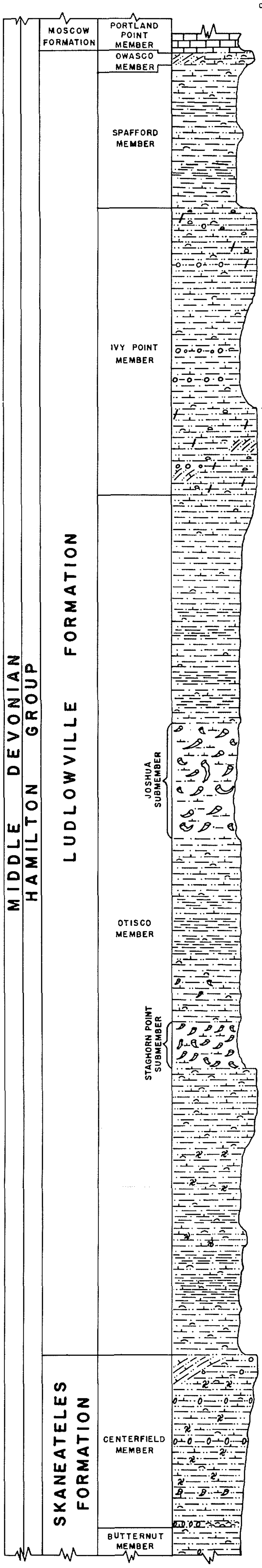
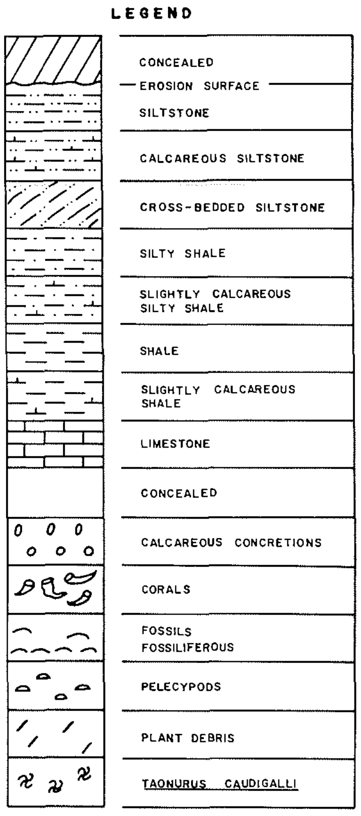


CALCITE %	QUARTZ %	QUARTZ MODAL DIAM mm	DESCRIPTION	COLOR FRESH DRY	COLOR FRESH WET	COLOR WEATHERED DRY	COLOR WEATHERED WET
15	60	.035	FLAGGY HIGHLY FOSSILIFEROUS CALCAREOUS SILTSTONE LOCALLY CROSS-BEDDED.	N5	N3	10 YR 6/2	2/2
15	20	.0225	SILTY SHALE	N5	N3	10 YR 6/2	4/2
			FISSILE TO SHALY BEDDED SILTY SHALE AND SHALE				
			FLAGGY CALCAREOUS SILTSTONE ABOUT 2 FEET THICK PRESENT LOCALLY				
15	20	.02	FISSILE TO SHALY BEDDED SILTY SHALE AND SHALE				
15 10	60 45	.045 .04	FLAGGY CALCAREOUS SILTSTONE LARGE SPHEROIDAL CALCAREOUS CONCRETIONS PRESENT LOCALLY. PLANT FRAGMENTS AND LARGE PELECYPODS COMMON	N5	N3	10 YR 6/2 5 Y 6/1	3/2 4/1
			SHALY TO FLAGGY SILTY SHALE AND SILTSTONE				
10	20	.015	SHALY TO FLAGGY SILTY SHALE WITH ZONES OF LARGE SPHEROIDAL CALCAREOUS CONCRETIONS	N4	N3	5 Y 6/1	4/1
			SHALY TO FLAGGY SILTY SHALE				
15 15	45 45	.04 .035	FLAGGY EVENLY BEDDED CALCAREOUS SILTSTONE LOCALLY CROSS-BEDDED. LARGE SPHEROIDAL CALCAREOUS CONCRETIONS PRESENT. PLANT FRAGMENTS AND LARGE PELECYPODS COMMON.	N5	N3	10 YR 6/2 10 YR 5/2	4/2 3/2
			SHALY TO FLAGGY CALCAREOUS SILTSTONE AND SILTY SHALE				
			SILTY SHALE *MEGASTROPHIA CONCAVA* COMMON TO ABUNDANT				
10	40	.03	SILTY SHALE AND SHALE. SOME FLAGGY BEDS	N5	N3	5 Y 6/1	4/1
			ZONE OF CORALS MOSTLY CYATHOPHYLLOID TYPE THICKNESS 0 TO 50 FEET				
10	50	.03	FLAGGY SILTY SHALE SOME SILTSTONE LAYERS	N5	N3	5 Y 6/1	4/1
			SILTY SHALE AND SHALE. *ATHYRIS SPIRIFEROIDES* COMMON TO ABUNDANT				
			SHALY TO FLAGGY SILTY SHALE AND SILTSTONE				
			ZONE OF CORALS MOSTLY CYATHOPHYLLOID TYPE THICKNESS 5 TO 11 FEET				
10 10	50 40	.0425 .03	MASSIVE CALCAREOUS SILTSTONE THICKNESS 6 TO 8 FEET *SPINOCYRTIA GRANULOSA* ABUNDANT	N5	N3	5 Y 5/1 6/1	3/1 4/1
			FLAGGY TO MASSIVE CALCAREOUS SILTSTONE				
10	30	.02	FLAGGY SILTSTONE AND SILTY SHALE *TAONURUS CAUDIGALLI* LOCALLY COMMON	N5	N3	5 Y 6/1	4/1
10	20	.0175	SHALY TO FLAGGY SILTY SHALE	N5	N3	5 Y 6/1	4/1
			FLAGGY FOSSILIFEROUS SILTSTONE				
			FISSILE TO SHALY BEDDED SHALE AND SILTY SHALE. SILTSTONE LOCALLY PRESENT				
			HIGHLY FOSSILIFEROUS SILTY SHALE				
15	55	.045	FLAGGY TO MASSIVE CALCAREOUS SILTSTONE LOCALLY CROSS-BEDDED. SPHEROIDAL CALCAREOUS CONCRETIONS 3 TO 6 INCHES IN DIAMETER COMMON IN PLACES	N5	N3	5 Y 5/1	4/1
15	35	.04	FLAGGY TO MASSIVE UNEVENLY BEDDED SILTSTONE. ZONES OF ELLIPSOIDAL CALCAREOUS CONCRETIONS COMMON. *TAONURUS CAUDIGALLI* LOCALLY PRESENT	N5	N3	5 Y 6/1	3/1
15	35	.035	FLAGGY UNEVENLY BEDDED SILTSTONE ZONE OF SMALL CORALS PRESENT IN PLACES				
10 10	20 10	.02 .02	SHALY TO FLAGGY UNEVENLY BEDDED SILTY SHALE TRANSITIONAL FROM BELOW	N4 N4	N3 N2	5 Y 6/1	3/1



GENERALIZED SECTION OF THE LUDLOWVILLE FORMATION AND CENTERFIELD MEMBER OF THE SKANEATELES FORMATION IN ONONDAGA COUNTY
VERTICAL SCALE: 1"=10'

PLATE 1

APPENDIX

STRATIGRAPHIC SECTION OF THE SYRACUSE AREA

Period	Group	Formation	Member	Thick-ness	Description
Upper Devonian		Tully	West Brook	10'	shaly limestone
			Apulia	18'	limestone
			Tinkers Falls	2'	shaly limestone
		------disconformity ? ------			
Middle Devonian	Hamilton	Moscow	Windom	180'	shale & siltstone
			Portland Point	9-10'	limestone & shale
		Ludlowville	Owasco	1-3'	siltstone
			Spafford	25'	shale
			Ivy Point	50-60'	siltstone & shale
			Otisco	160-180'	shale & siltstone
		Skaneateles	Centerfield	30'	calcareous siltstone
			Butternut	100-200'	shale & siltstone
			Pompey	60'	shale & siltstone
			Delphi Station	100'	shale & siltstone
		Marcellus	Mottville	45'	limestone & shale
			Cardiff	125-200'	shale
			Chittenango	100'	black shale
			Cherry Valley	3'	limestone
			Union Springs	13-15'	shale & limestone
		Onondaga	Seneca	25'	limestone with Tioga bentonite at base
			Moorehouse	20-25'	limestone
			Nedrow	10-15'	shaly limestone
			Edgecliff	8-23	limestone, Springvale sandstone at base
		--------disconformity --------			

Period	Group	Formation	Member	Thickness	Description
Middle Devonian		Oriskany?		0-20'?	sandstone, may all be of Onondaga age
		----------	disconformity	----------	----------
Lower Devonian	Helderberg	Bishop Brook (Coeymans)		0-5'	limestone
		----------	disconformity	----------	----------
		Manlius	Pools Brook	0-30'	limestone
			Jamesville	0-20'	limestone
			Clark Reservation	0-5'	oolitic limestone
			--diastem	----------	----------
			Elmwood C	2-4'	dolomite, argillaceous
			--	diastem	----------
			B	2-3'	dolomitic limestone
			A	4-6'	dolomite, argillaceous
			Olney	30-35'	limestone
			Thacher	9-26'	limestone
		Rondout		30-40'	dolomite
? Upper Silurian		Cobleskill		15-25'	dolomite
	Salina	Bertie	Williamsville or Oxbow	7'	shaly dolomite
			Scajaquada or Forge Hollow	30-60'	gypsum, shale, dolomite
			Fiddlers Green	27-30'	dolomite
		Camillus		160-190'	shale, dolomite, gypsum
		Syracuse	Upper dolomite	8-24'	shaly dolomite
			Upper clay	10-20'	clay, gypsum, dolomite
			Middle dolomite	35-40'	impure dolomite
			Lower clay	10-15'	clay, gypsum, dolomite
			Transition	90-120'	dolomite and shale
		----------	diastem	----------	----------
		Vernon		500-600'	red & green shale, shaly dolomite