Contrib. by: John Rodgers

GUIDE

for

21st ANNUAL FIELD MEETING

of the

NEW YORK STATE GEOLOGICAL ASSOCIATION

GEOLOGY OF THE CAYUGA LAKE REGION

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"Hammers an' chisels an' a',
Chisels an' fossils an' a';
The deeper we go, the more we shall know
Of the past an' the recent an' a'."

(Song of a Geologist, Rob't. Dick, 1858)

Ithaca, New York

May, 1949

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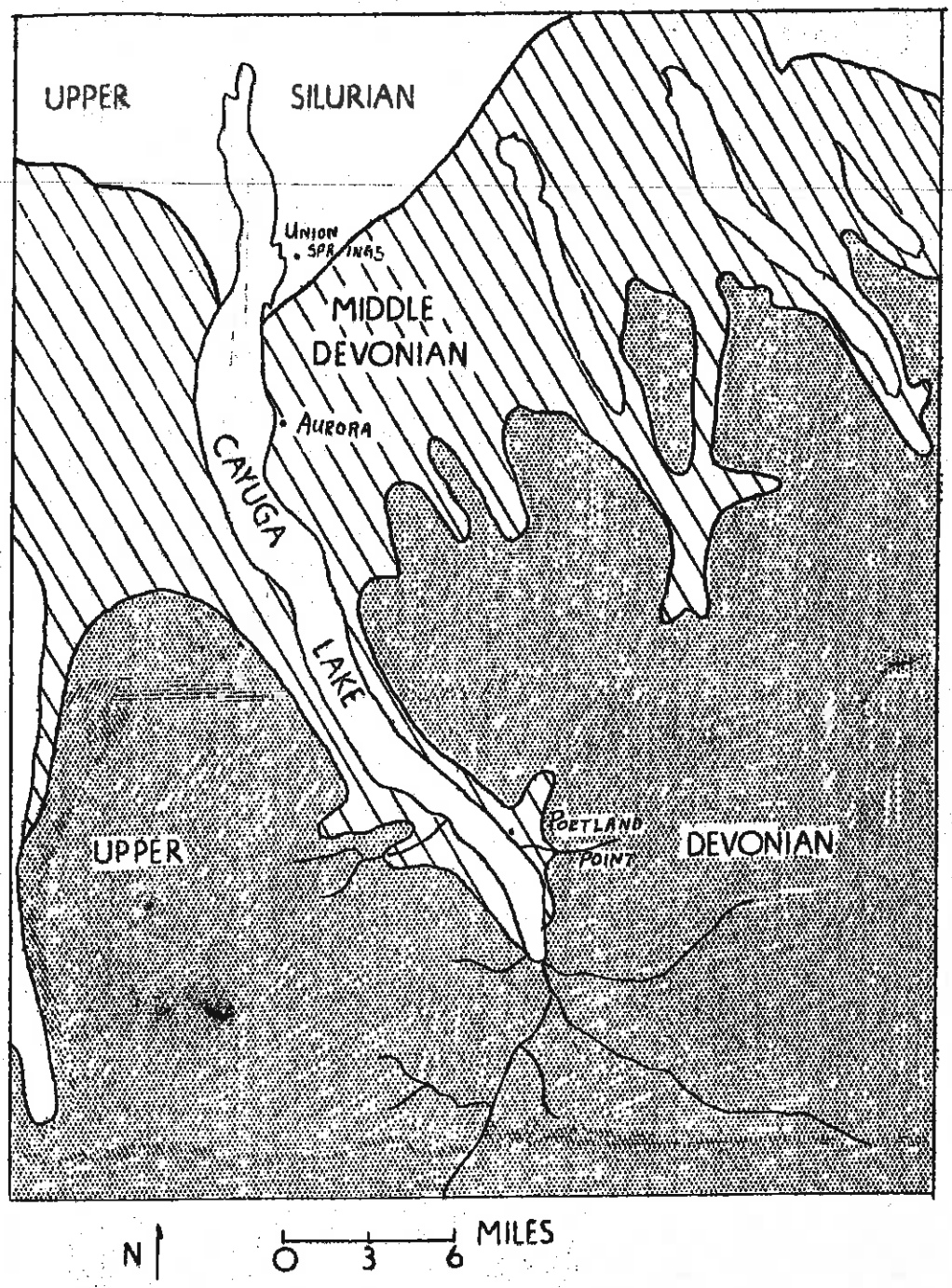
Cayuga Lake Region

GEOLOGIC MAP OF CAYUGA LAKE REGION



SUMMARY OF GEOLOGIC HISTORY
of the
CAYUGA LAKE REGION

(for geologic map and cross-section see pp. 1, 3)

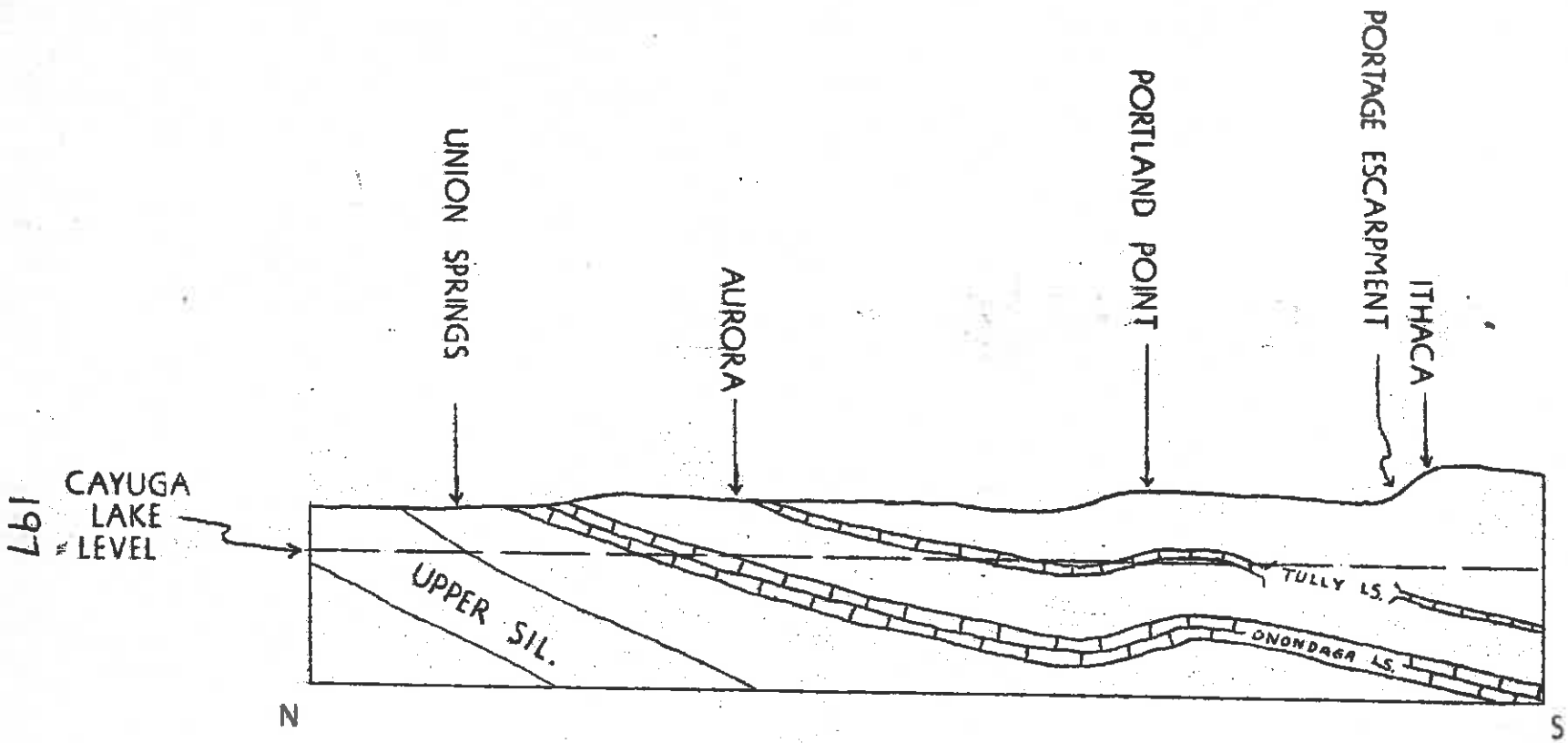
During the Paleozoic Era this region lay in part of the Appalachian Geosyncline and was more or less continuously covered by a shallow sea into which sediments were carried from the old land-mass of Appalachia to the east. The sediments were mostly sands, silts, and clays with occasional layers of calcareous muds and oozes, the latter predominating during the Ordovician, clastics and calcareous types during the Early and Middle Silurian, calcareous sediments and evaporites (salt and gypsum) during the Late Silurian, and clastics during the Devonian. The total thickness of Paleozoic rocks in the region is about 8000 feet, but only the uppermost part of the Silurian (Cayugan) and about 3000 feet of overlying Devonian are now exposed. The regional dip averages about 50 feet per mile to the south, on which are superimposed low folds whose axes trend northeast-southwest, - the outermost of the Appalachian folds.

At the close of the Paleozoic the Appalachian Revolution, with its lateral pressures from the southeast, produced the gentle folds, small faults, joint systems, and regional dip. It is likely that the igneous dikes of the region were intruded at the same time.

During the succeeding long period of relative quiet the streams, aided by various weathering agencies, slowly wore away the rock. This condition continued long enough for the whole region to be eroded to an essentially flat plain near sea level, called a peneplain. It was probably completed sometime during the early or middle part of the Cenozoic era.

Crustal disturbances then elevated the peneplain, probably very slowly, several hundred or a few thousand feet. Streams flowing over this plateau-like country developed valley systems which dissected the uplifted peneplain. Those portions which escaped destruction may be recognized today as a succession of hilltops at about the same elevation.

One of the streams on the peneplain followed approximately the course of the present Cayuga Lake and is referred to as the Cayuga river. The bottom of this pre-glacial valley was at about the elevation of the Cornell campus. The river was fed by many tributaries whose courses are indicated by the upper portions of such streams as Fall, Cascadilla, Six Mile, Buttermilk, Enfield, and Taughannock creeks. At that time there were no waterfalls and gorges, the streams being well graded.

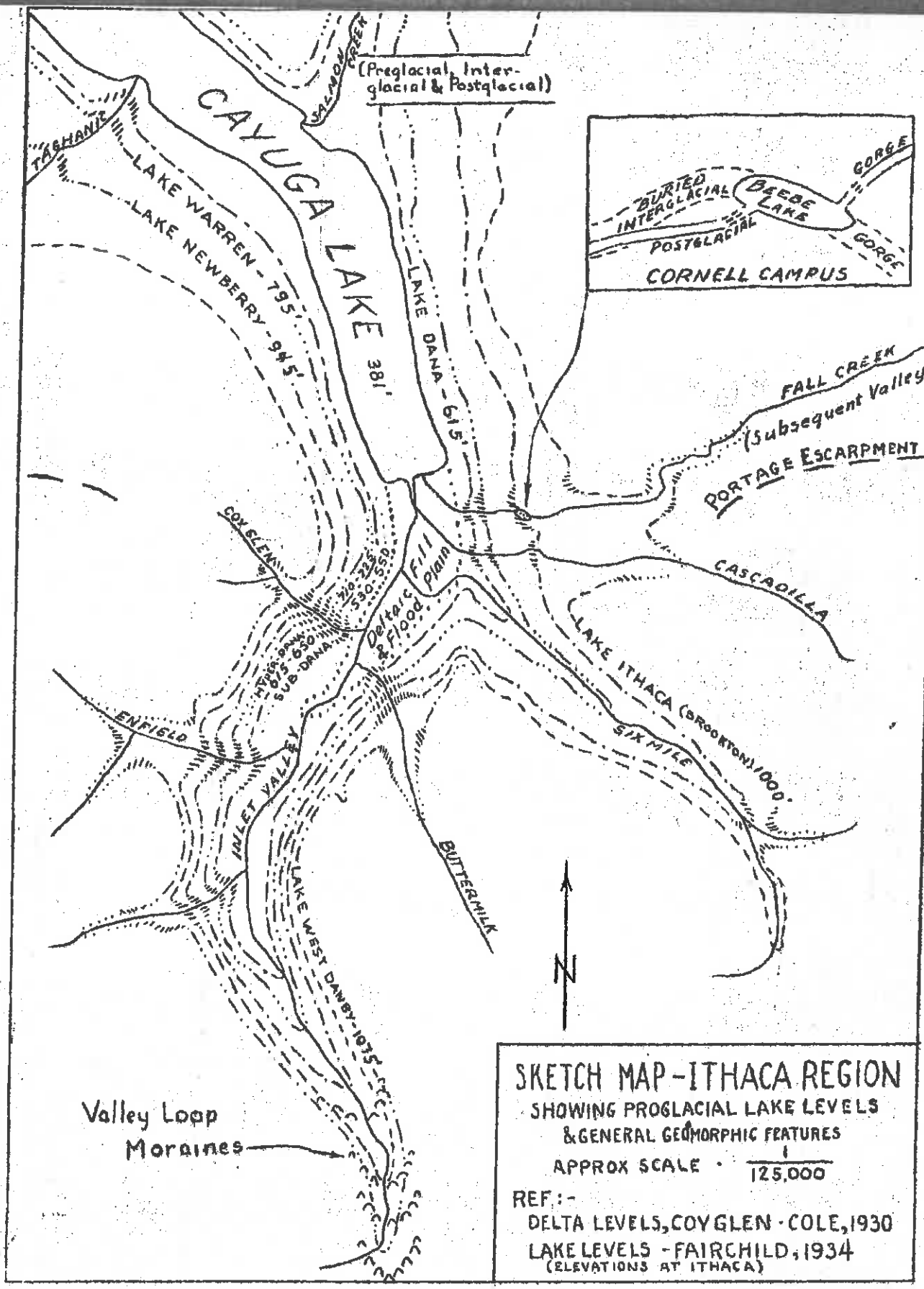


NORTH - SOUTH STRUCTURE SECTION OF CAYUGA LAKE REGION

At the beginning of the Pleistocene, a great ice sheet began to move slowly southward from its center in eastern Canada, overwhelming the northern part of this country and extending as far south as New York City and into Pennsylvania. Its thickness, although unknown, was sufficient to cover the highest hills in this region. The slowly moving glacier found the Cayuga river valley a convenient course. The flow was therefore concentrated in the valley and resulted in about 1000 feet of erosion, so that the valley bottom is now below sea level. This valley has the U-shaped cross section typical of all glacial valleys. The tributary streams, being crosswise to the direction of ice movement, were not greatly eroded. When the ice ultimately melted they were left isolated far above the new bottom of the main valley, so that they are now hanging valleys. As the streams in these valleys reached the steep slopes of the deepened main valley they formed a series of rapids and cut into the rock, developing waterfalls and gorges (Fall and Cascadilla Creeks, the north and south boundaries of the Cornell campus.)

It is known that in this region the ice age was interrupted by at least one warm inter-glacial period which was of much longer duration than our present post-glacial warm period. Gorges cut by the inter-glacial streams are generally broader and with more gently sloping sides than those cut since the melting of the last glacier. The inter-glacial valleys are largely filled with glacial till left by the last ice sheet and are exposed only locally where the post-glacial streams have partially reexcavated them. The post-glacial gorges and waterfalls have been formed within the twenty or thirty thousand years since the last ice sheet disappeared. Because the valleys were irregularly filled with moraine material, the new streams had to pick their way from one low point to another over the rough surface, and their courses only locally correspond with the inter-glacial gorges (Enfield Gorge, southwest of Ithaca).

The general slope of the land in this region is to the north. As the ice front melted back, the glacial waters were ponded between the ice to the north and the high land to the south, and overflowed southward into the Susquehanna river. As the ice continued to melt northward, it uncovered lower outlets and allowed the lake to drop to successively lower levels. At each level the incoming streams built deltas with the loose material which they were removing from the land surface. These abandoned high level deltas are called hanging deltas. The flat on which the city of Ithaca has been built is a delta which has been formed at the present lake level by material brought there by such streams as Cascadilla, Fall, Six Mile, and Inlet creeks.


(Preglacial, Interglacial & Postglacial)
SALMON CREEK
CAYUGA LAKE 381'
TAUGHANNIC
LAKE WARREN - 795'
LAKE NEWBERRY - 945'
LAKE DANA - 615'
BURIED INTERGLACIAL
BEEBE LAKE
GORGE
POSTGLACIAL
GORGE
CORNELL CAMPUS
FALL CREEK
(Subsequent Valley)
PORTAGE ESCARPMENT
COYGLEN
330-225
530-550
Delta & Flood Plain
CASCADILLA
LAKE ITHACA (BROOKTON) 1000'
SIX MILE
ENFIELD
INLET VALLEY
675-650
SUB-DANA
BUTTERMILK
LAKE WEST DANBY - 1075'
N
Valley Loop Moraines
SKETCH MAP - ITHACA REGION
SHOWING PROGLACIAL LAKE LEVELS
& GENERAL GEOMORPHIC FEATURES
APPROX SCALE · 1/125,000
REF:-
DELTA LEVELS, COYGLEN - COLE, 1930
LAKE LEVELS - FAIRCHILD, 1934
(ELEVATIONS AT ITHACA)

GEOMORPHOLOGY
(see geomorphic map, p. 5)

The Cayuga Lake Region lies chiefly within the Southern New York section of the Appalachian Plateaus Province which Fenneman (1928) characterizes as a mature, glaciated plateau of moderate relief. A more complete statement of the topographic stage would be:

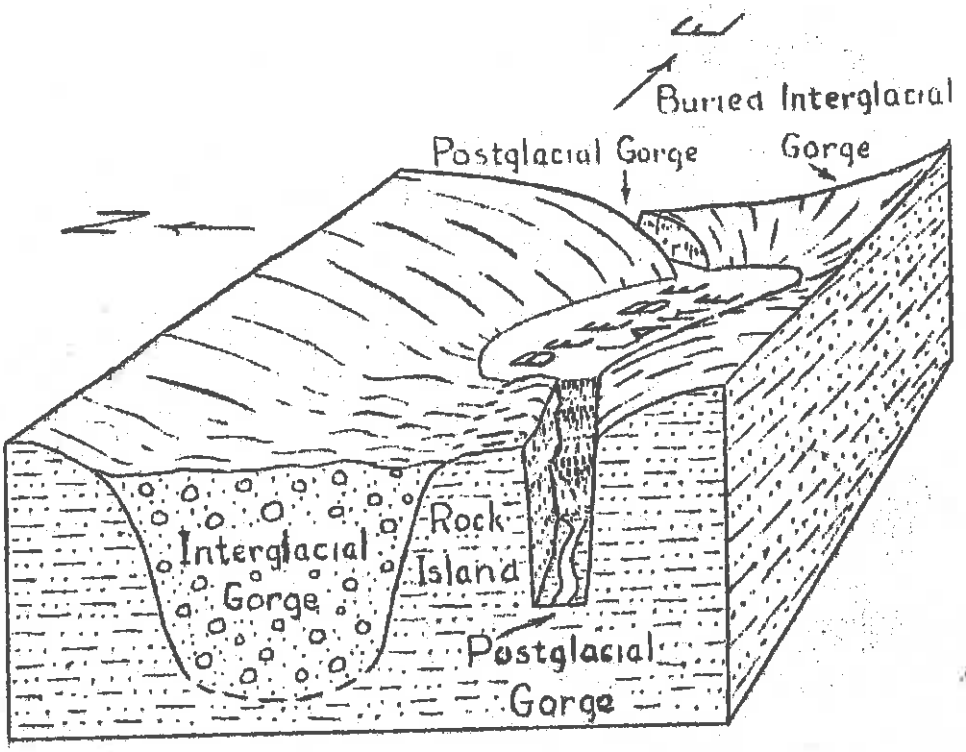
> A mature plateau region of cuestaform type in an n+1 cycle of erosion with features of topographic youth superimposed on it by the accident of continental glaciation.

The uplands are beveled by the Allegheny (Schooley) erosion surface (Fridley, 1929; Cole, 1938) below which occur straths of the Niagara (Harrisburg) erosion surface and into which were carved the floors of the preglacial valleys. The preglacial valleys in turn have been modified variously by glaciation and locally by postglacial erosion.

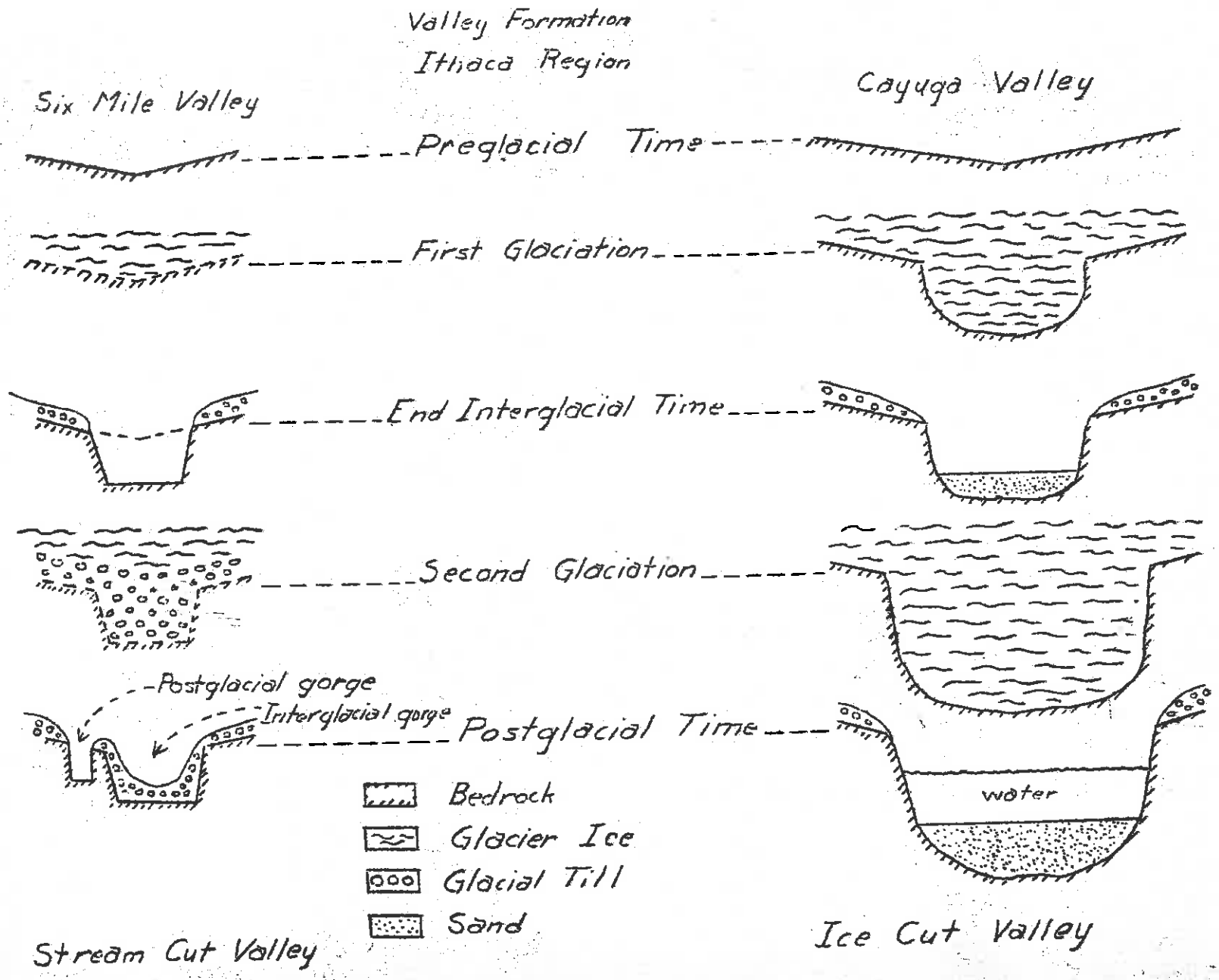
Two fundamental topographic types are seen with clarity in any comprehensive view of the region: (1) the preglacial features, of which an outstanding example is the east-west trending Portage escarpment dominating the uplands, whereas (2) the glacially modified terranes, of which the overdeepened and steepened trough of the Cayuga valley is a classic example, are characteristic of the lowlands. A combination of pre-, inter-, and post-glacial features is found in the valley of Fall Creek which flows along the base of the Portage escarpment for the last few miles of its course.

This is a subsequent valley of preglacial origin and retains in the large view its original configuration, but in detail it has been modified by a masking of glacial deposits and by the development within its confines of inter- and post-glacial valleys. Although the large subsequent valley must be viewed from a distance, the development of the various gorges is displayed on the Cornell campus in the vicinity of Beebe Lake which occupies a portion of the interglacial gorge which has been re-excavated postglacially (see diagram on p. 7).

The major erosive work of the ice occurred along north-south lines in the area, and was selective. Pre-glacially, the Cayuga trough was occupied by a stream which carved a valley that was north-sloping. The continental ice crowding down through this valley eroded it to such



POSTGLACIAL AND INTERGLACIAL GORGES OF FALL CREEK AT BEEBE LAKE CORNELL CAMPUS


Valley Formation
Ithaca Region
Six Mile Valley
Cayuga Valley
Preglacial Time
First Glaciation
End Interglacial Time
Second Glaciation
Postglacial gorge
Interglacial gorge
Postglacial Time
water
Bedrock
Glacier Ice
Glacial Till
Sand
Stream Cut Valley
Ice Cut Valley

a degree that the present floor of the trough is at least 54 feet below sea-level, whereas the ice rode over the east-west valleys and intervening uplands with slight, if any, erosion (see diagrams, p. 8).

In consequence of this selective activity, the valleys joining the Cayuga trough show progressive degrees of hanging. Inlet valley which is in the southern continuation of the Cayuga trough had its floor reduced in level so that it joins the Cayuga trough at an accordant level.

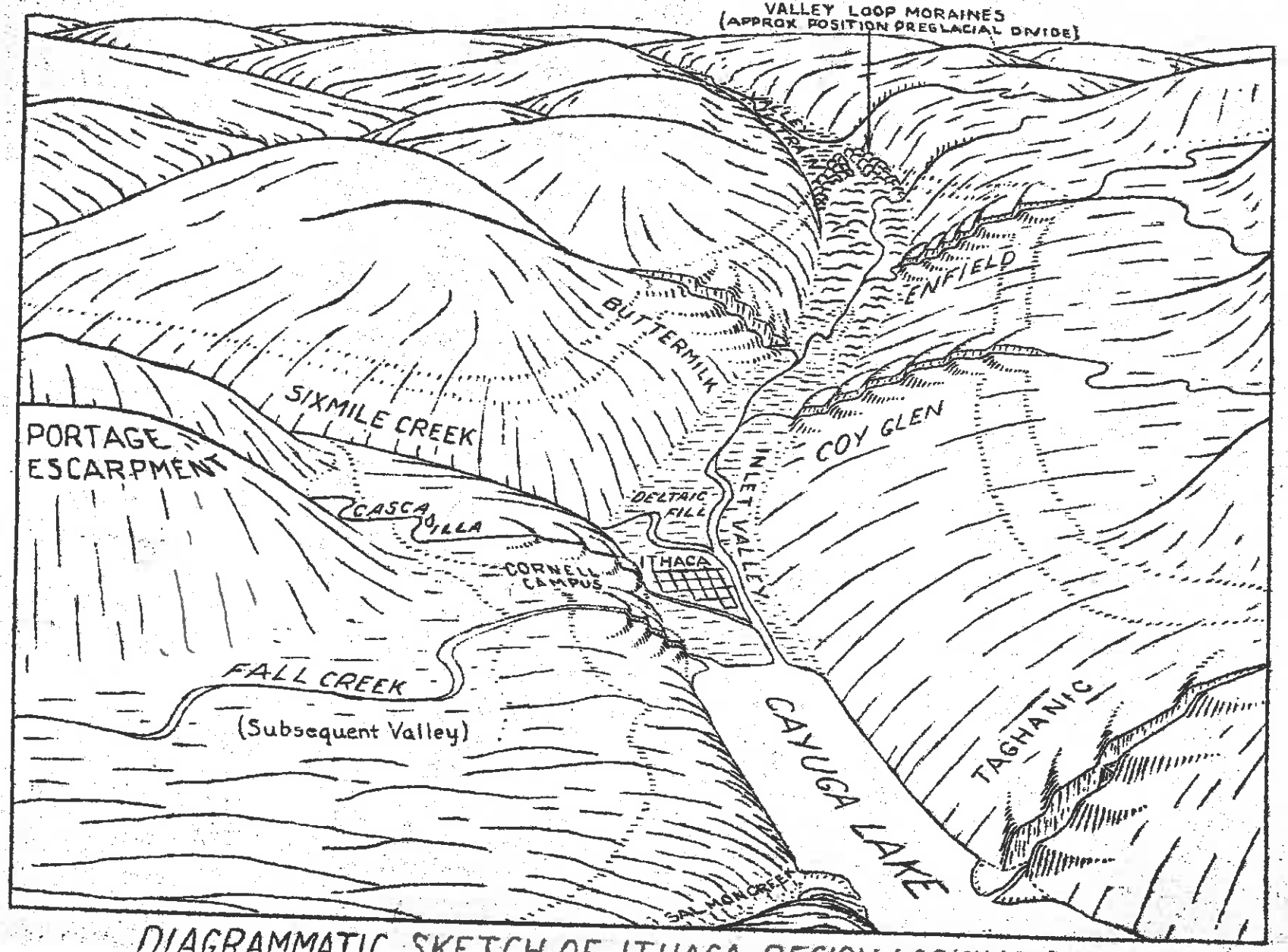
Six-Mile valley which trends southeast from the Cayuga trough was eroded moderately, whereas Cascadilla and Fall Creek valley were largely undisturbed. Therefore, from south to east there is a progressively greater hanging relationship as these valleys join the Cayuga trough.

Cayuga Lake is the final (for the moment) lake in a long series of lakes which developed as the ice retreated northward (Fairchild, 1934). After the recession of the ice over the divides at the heads of Inlet and White Church valleys, lakes were formed in front of the ice. With progressive retreat of ice, successively lower outlets for the lakes became available. However, after a new outlet developed, the lake became stabilized for a period of time before a new outlet formed.

At each stand of the lakes, the inflowing streams built deltas similar in every respect to the modern delta at the mouth of Taughannock (Taghanic) Creek. Every time the lake level dropped the deltas of that lake would be trenched by the stream which had formed it and a new delta would be formed at the new and lower stand of the lake. Therefore, each stream has built and partially destroyed a series of deltas in post-glacial times (see figure on p. 10).

The most clearly defined set of hanging or fossil deltas (good sources of gravel) are those associated with Coy Glen which is on the west side of the Cayuga trough about 1.5 miles south of Ithaca (Cole, 1930). However, high-level deltas may be observed at Taughannock Gorge and on the Cornell campus. The chemistry building, Baker Laboratory, is built on such a delta.

Since Cayuga Lake attained its present surface level of 382 feet above sea-level, the streams discharging into the south end of the lake have built a vast delta from about the vicinity of Buttermilk Falls to the present south end of the lake, and it is still being extended. These delta deposits have been covered by floodplain materials, and it is upon these that the main section of Ithaca developed. Later, the city spread to the valley walls, and at present is enlarging to include some of the uplands.



DIAGRAMMATIC SKETCH OF ITHACA REGION LOOKING SOUTH

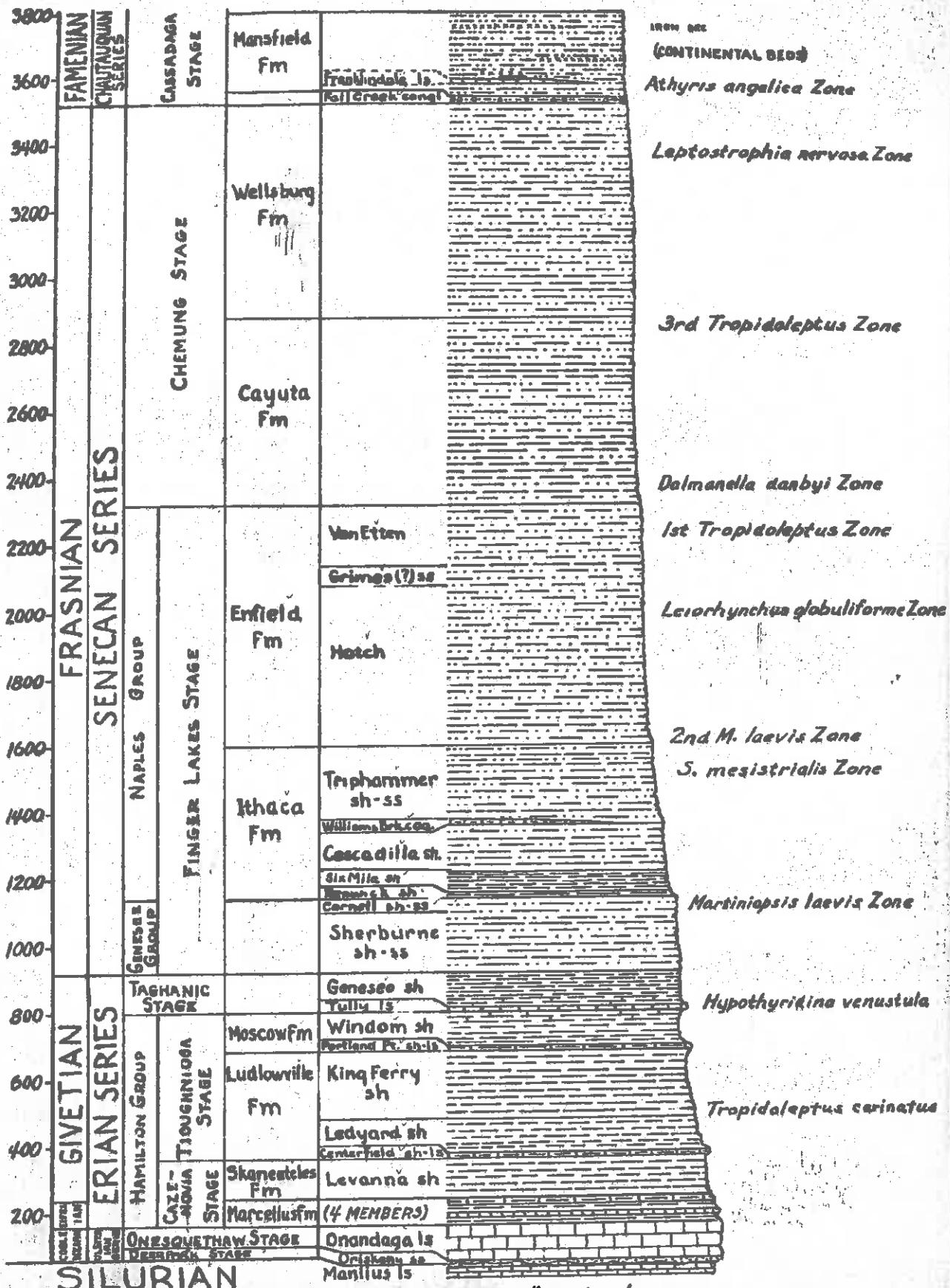
STRATIGRAPHY AND PALEONTOLOGY

The general stratigraphic section of the Cayuga Lake Region is shown on the figure (p. 12), and the subdivisions, names, and thicknesses of the rocks need not be further elaborated. Analysis of the distribution of fossils throughout the Middle and Upper Devonian (Lower Devonian rocks are lacking in this region) indicates that the faunal succession is not at all simple: throughout there are different faunas, some of them apparently disappearing and reappearing in a perplexing manner. Further, from the section it is apparent that the lithology of the rocks varies, with different kinds appearing and disappearing, often reappearing again higher up. The lithology of a sedimentary rock unit reflects, of course, the sedimentary and aqueous environment in which it was laid down. Similarly, the fauna living where a certain type of sediments is being deposited is closely adjusted to that particular environment. Once this is understood, similarity of faunas in different formations having the same lithology is to be expected, and the differences in such faunas in the same rock types up and down the column are due primarily to the effects of evolution with time and intermingling. Because of this complexity of fossil faunas, the Devonian stratigraphy of this region is still, after 110 years of study, not thoroughly worked out. Here only the broad features of the interrelationships of the faunas can be noticed.

The upward continuation in time and in the geologic column of the same lithology containing similar fossil faunas is a phase. Thus, referring to the chart of relationships (p. 14), the similar lithologic and overall faunas of the eastern part of the Hamilton-Tully-Ithaca-Enfield succession represents a phase. At any one time in the column two or more phases may exist side by side in the area of deposition, as for instance during Ithaca time, when the Naples Fauna with its characteristic lithology occupied the area to the west, the Ithaca Fauna to the east, and still farther eastward was the continental Catskill Fauna and Flora. Each of these segments of three phases is a <u>facies</u>. Diagrammatically the relations of phases and facies may be represented as follows:

facies	facies	facies
phase	phase	phase
facies	facies	facies

DEVONIAN SECTION IN THE CAYUGA LAKE REGION



VERTICAL SCALE: 1" = 400'

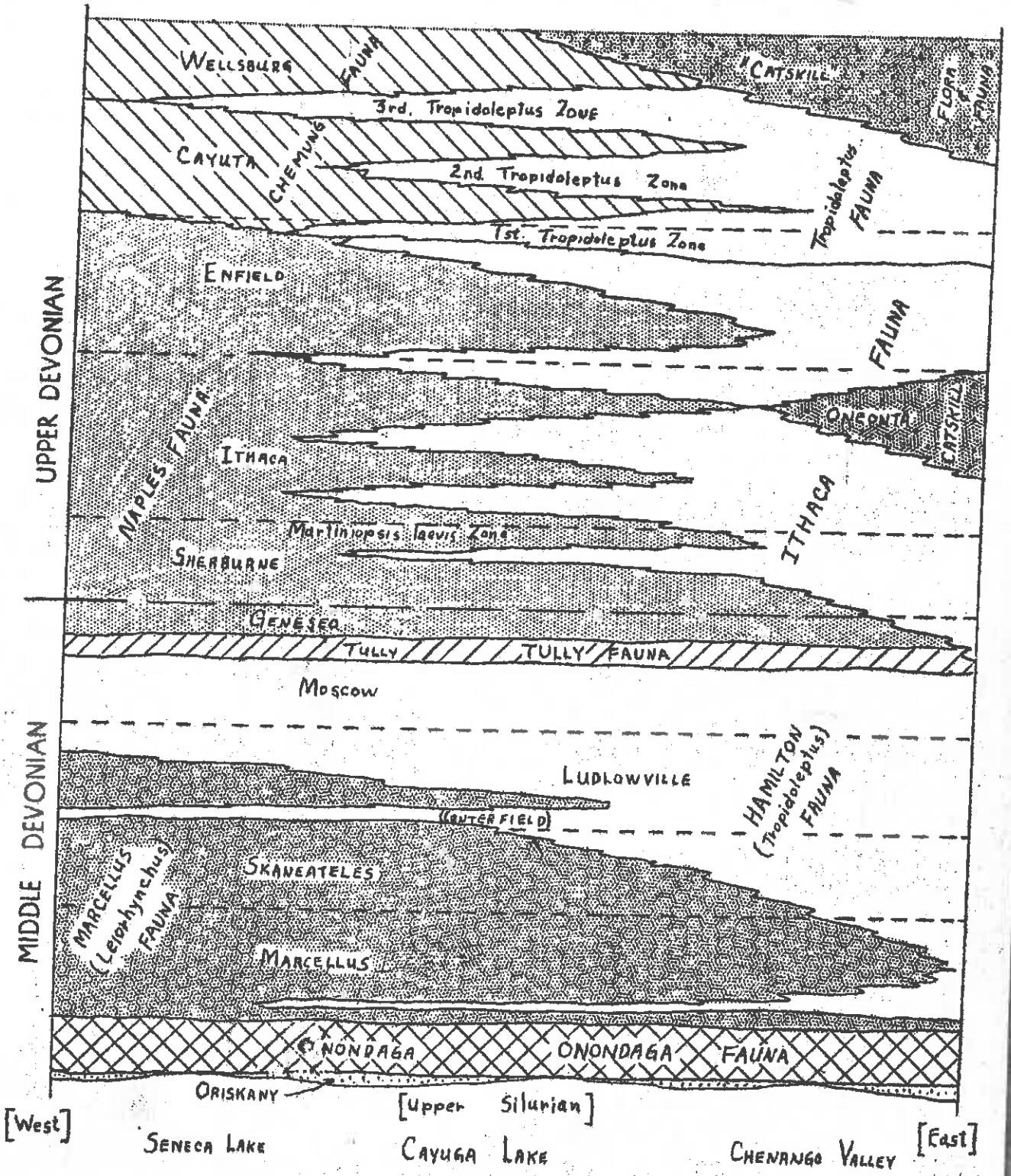
The relations actually are never so neatly defined as just shown, and in the Cayuga Lake Region they are more nearly as shown in the chart, page 14. Here only the east-west relations are indicated. A more complete picture could, of course, be prepared if the north-south relations were known. Further, it is found that each of the phases and facies can be divided into subphases and subfacies reflecting slightly different environments within each. The problem of nomenclature for these relations is complex and only broad terms are used here. There is yet work to be done.

Middle Devonian Faunas

The Oriskany sandstone, representing the deposits of a renewed advance of the sea at the commencement of Middle Devonian time, is marked in the Cayuga Lake Region by its fauna of mostly large brachiopids, Rensselaeria, Meristella, Costipirifer, Acrospirifer, Hipparionyx, Costellirostra, and Chonostrophia. Other types are rare: Platyceras, Cyrtolites, Tentaculites, and Pterinea. Few of the genera and species continue upwards in this area into the overlying Onondaga limestone, - there is an unconformity between the two units.

The faunas of the Onondaga limestone and overlying Hamilton group include facies faunas of three phases: Onondaga Fauna, Hamilton (Tropidoleptus-Mucrospirifer) Fauna, and the Marcellus (Leiorhynchus) Fauna. The Onondaga is characterized by the abundance of corals (rugose, tabulate, and stromatoporoid), crinoids, brachiopods (Paraspirifer, Fimbrispirifer, Leptaena, Meristella, Pentamerella, Atrypa, Megastrophia), rare pelecypods, gastropods, often large (Platyceras, Pleuronotus, Platyostoma), cephalopods (Spyroceras, Ryticeras, Goldringia) and trilobites (Anchiopsis, Calymene, Coronura, Odontocephalus, Phacops, Proetus). This is the clear water, shelf phase of the Middle Devonian in areas distant from the influx of clastics from landmasses where life conditions were at the optimum. In places coral-reefs are developed.

The Hamilton Fauna represents, on the other hand, the nearer-shore phase with muddy bottoms and less favorable conditions for many groups, especially corals and palmatozoans (stromatoporoids, for instance, are unknown in the Hamilton in this region, but are common farther to the west in Michigan where ecologic conditions similar to those of the Onondaga continued into Hamilton time). For some groups, such as pelecypods, the Hamilton conditions were more favorable than in the Onondaga. Characteristic of the Hamilton faunal facies are the brachiopods: Tropidoleptus, Mucrospirifer, Spinocyrtia,



DEVONIAN FAUNAL RELATIONS IN CENTRAL NEW YORK (DIAGRAMMATIC)

Brachyspirifer, Rhipidomella, Pustulina, Camarotoechia, Eunella, Ambocoelia, Athyris, Stropheodonta, Protoleptostrophia, Douvillina; pelecypoda: Modiomorpha, Cypricardella, Cornellites, Aviculopecten, Goniophora, Grammysia, Orthonota, Panenka, Nucula, Palaeoneilo, Glyptodesma, Actinopteria: gastropods: Bembexia, Loxonema, Platyceras, Platyostoma; cephalopods: Michelinoceras, Spyroceras, Nephriticeras, Tornoceras; trilobites: Proetus, Phacops, Dipleura, Greenops; bryozoa, tabulate and rugose corals (but rarely in any such abundance as in the Onondaga); echinoderms: crinoids (Gennaeocrinus, Ancyrocrinus, Dolatocrinus, Taxocrinus), blastoids (Devonoblaster); and other groups.

The Marcellus Leiorhynchus facies fauna, composed of few species and sporadic occurrence of large numbers of individuals, occurring in fine-grained dark to black, rarely calcareous muds, was contemporaneous with the Onondaga and Hamilton faunas but represents a phase of environment where bottom conditions were unfavorable, even for mud-loving types. Such areas were probably well off-shore with poorly oxygenated water. Characteristic forms are Leiorhynchus, Orbiculoidea, Pterochaenia, Styliolina, and occasional wanderers from more favorable sites.

After the close of Onondaga time the Cayuga Lake Region was occupied during the ensuing Hamilton time by the Tropidoleptus and Leiorhynchus facies faunas more or alternately, whenever the conditions for either existed (see chart of faunal relations), with a tendency for the Tropidoleptus fauna to extend its area of occupancy farther and for longer periods as time went on.

At the close of Hamilton time, conditions for deposition of more nearly normal limestone developed with the deposition of the Tully limestone. During this time the Hamilton fauna continued to occupy the region but it was modified slightly but very distinctly by immigration of Eurasiatic elements from the west or northwest where these elements had existed, during the latter part of Hamilton time, as part of the well-known Stringocephalus provincial fauna of Europe, Asia, and northwestern North America. Genera indicative of this minor and first invasion of "foreign" forms into the Tully sea are: Hypothyridina, Scutellum, and Sphaerospongia. These elements, however, disappeared at the close of Tully time, when the Hamilton fauna also moved elsewhere from the Cayuga Lake and New York Region, as the old Marcellus fauna, now considerably modified and reappearing as the "prenuncial" Naples facies fauna, marked by an influx of "foreign" pelagic goniatites such as Manticoceras and Probeloceras, returned

during Geneseo time, the closing unit of Middle Devonian time.

Upper Devonian Faunas

The Ithaca facies fauna is a modified, less varied Hamilton facies fauna adapted to slightly less favorable conditions, and lacking many common Hamilton forms such as corals and trilobites, and some brachiopods, notably Tropidoleptus, but with a few new types such as Platyrachella mesastrialis, Tylothyris mesacostalis, Schizophoria impressa, Cryptonella eudora, etc. In turn the Chemung fauna is a modified Ithaca fauna with new forms such as Cyrtospirifer disjunctus. At several horizons in the upper Enfield and Chemung formations there are recurrences of the earlier, purer, Tropidoleptus fauna, modified by time and an excursion elsewhere since the end of Tully time with Tropidoleptus, Cypricardella, Rhipidomella, Platyrachella marcyi, Mucrospirifer, etc.

The Naples facies fauna, dominant in the lower Upper Devonian to the west, appears in the Cayuga Lake Region at several horizons in the Geneseo ("prenuncial"), Sherburne, Ithaca, and Enfield, and interfingers with the Ithaca fauna. It is characterized by its largely pelagic and occasional benthonic elements, such as Manticoceras, Honeoyea, Buchiola, Paracardium, Orbiculoidea, Leiorhynchus, Stylioline, Pterochaenia, etc. It is similar to, and a modified version of the earlier Marcellus Leiorhynchus facies fauna, with immigrant Eurasiatic elements and generally adapted to less rigorous conditions than the dark-black shales. Eastward the Martiniopsis ("Reticularia") laevis subfauna, with more benthonic types, including Plumulina plumulosa, the curious feather-like hydroid (?), is developed, especially in the Cayuga Lake Region.

The Catskill phase of continental or subcontinental deposits, with land plants, freshwater fishes, and freshwater mussels, is more or less continuously developed to the east of the Cayuga Lake Region, but enters the area only in the Late Devonian to the south near the Pennsylvania line.

STRUCTURAL GEOLOGY

Folds and Faults

The folds in the Cayuga Lake Region are diminished Appalachian foreland folds. They have a more or less east-west trend and are superimposed on the regional dip. According to Bradley and Pepper (1938, p. 29) the arrangement of the folds "is characterized more by lack of system than by any clearly defined system. Folds that are plainly traceable across the area are exceptional; most of them are rather short and almost haphazard in their arrangement." In general, however, the axes trend northeastward to eastward and plunge gently southwestward to westward. The most northerly fold in the Cayuga Lake Region is the Portland Point anticline. Another lies a few miles south of Ithaca, its axis running nearly through Danby. Ithaca lies above the deep syncline between the two.

The crest of the Portland Point anticline (map, p. 17) is marked by a low-angle thrust fault, visible in the competent Tully limestone in the southwest corner of the cement quarry. In the incompetent Windom shale (Moscow fm.) below it is scarcely traceable. On the opposite side of the lake, at the foot of Taughannock Falls, is another thrust fault, perhaps a continuation of the quarry fault. In both cases the thrust came from the south, with displacements of 30 to 100 feet.

Joints

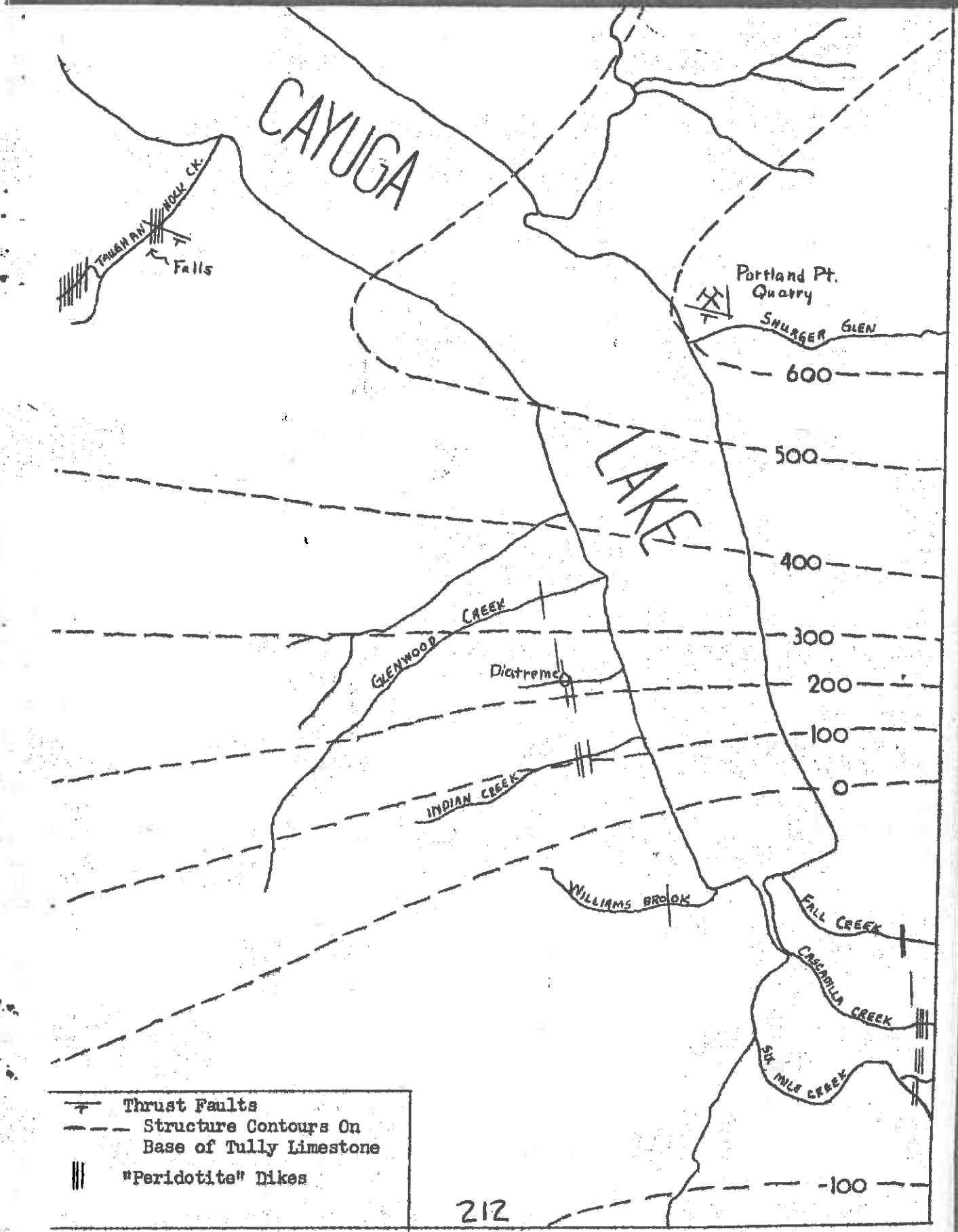
This region is classic ground for the study of joint phenomena. First illustrated in 1843 by James Hall, the magnificently exposed joints in the Sherburne formation on the east shore of Cayuga Lake a few miles north of Ithaca are familiar features of many geology textbooks.

There are three joint sets in the region (see map of joint pattern p.19), and Sets I and II constitute a system:

Set I. The master or dip joints, composed of two conjugate shears intersecting at very acute angles (10°-30°) arranged with their mean direction swinging progressively from N 15-30 E eastward from Cayuga Lake to N 40-50 W to the west.

Set II. The strike joints, about perpendicular to the master joints of Set I. In plan, a series of slightly sinuate concentric arcs. To the westward the direction is about N 60 E, shifting centrally to N 70 E. They are better developed than Set III.

Set III. Tension joints arranged concentrically with a strike in the south of about N 85 W, and well-developed only in the south-



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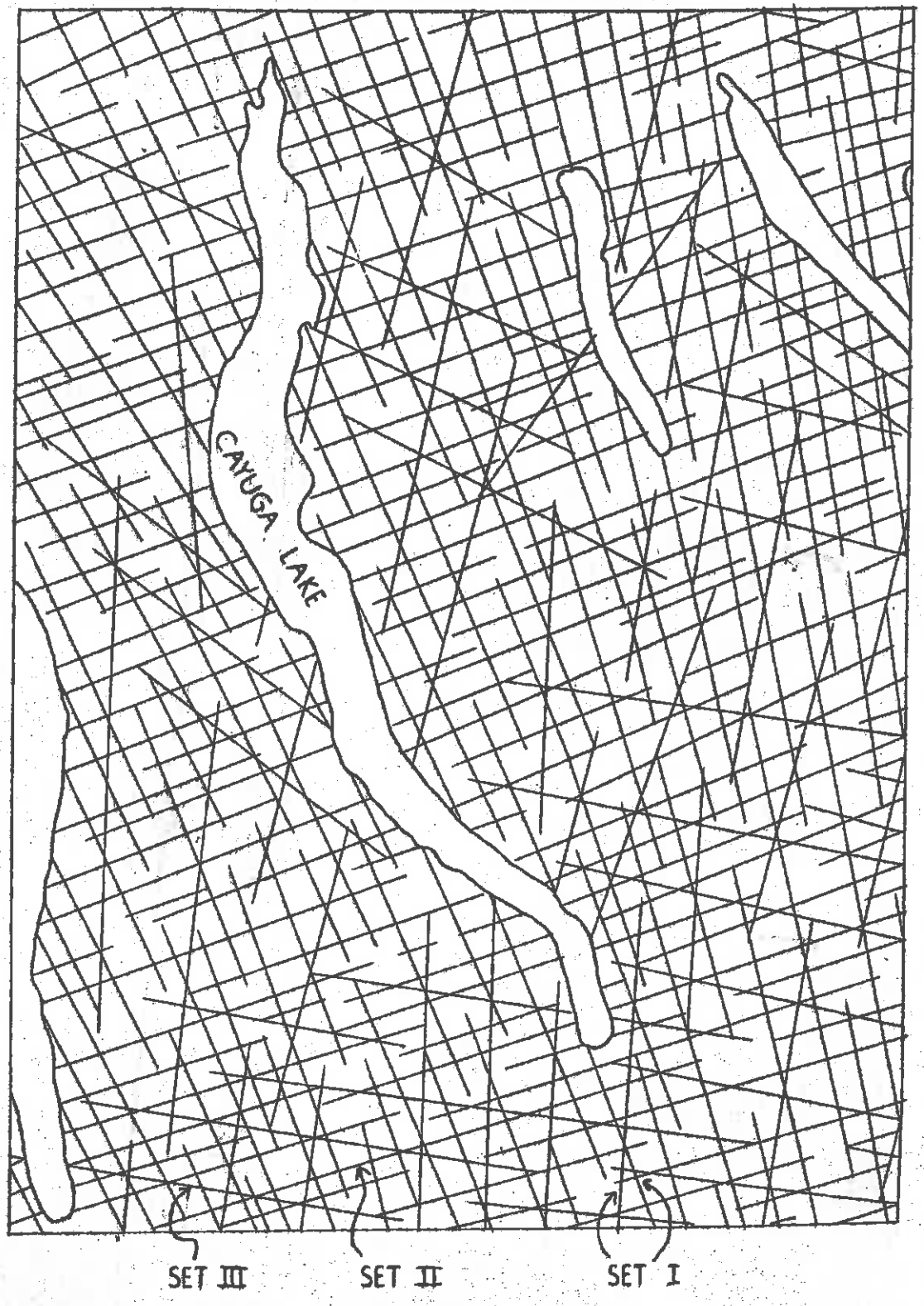
STRUCTURAL AND IGNEOUS GEOLOGY OF THE ITHACA REGION

JOINT PATTERN IN CAYUGA LAKE REGION



western part of the Cayuga Lake Region. They are tentatively attributed to later tension effects than Set II.

The master or dip joints of Set I are believed to have resulted from simultaneous compression and tension (shearing), at right angles, and were the earliest formed. Those of Set II, the strike joints, developed progressively in areas of local weakness as a result of tension transmitted through the basement rocks. Their local departures from right angles to Set I show the influence of local plunging folds and variations from regional dip. These joints are not the result of Appalachian folding but may have resulted rather from the same stresses before folding began, - the first effects of the stresses. Set III may be a later effect of the folding.

En Echelon Fractures

In the lower part of Taughannock Gorge, where the upper surface of the Tully limestone has been swept clear of the overlying Genesee shale and debris, there is exposed a beautiful set of short, open, en echelon tension gashes and long shear planes, in a thick stratum of this competent formation. These suggest local rotational stress. The tension gashes trend N 60 W and the shears N 50 W. This occurrence is on the north flank of the Portland Point anticline just north of the axis which here is nearly east-west in trend. Torsional stresses resulting from development of this fold may have been responsible for the gashes and shears, after the manner described by C. M. Nevin (1942, p. 114). The local operation of such stresses may have opened the first-formed dip joints (Set I) into which the dikes of the region were shot upwards from deep reservoirs, in places so abruptly as to be accompanied by explosive ascents (diatremes).

IGNEOUS ROCKS

The dikes referred to above are intrusions of alnoite ("peridotite", "kimberlite"). They occur in many places in the Cayuga Lake Region (map, p. 17) and are similar to those in Clintonville and Syracuse to the northeast. They are part of a system extending from the Momteregian hills near Quebec, across New York, western Pennsylvania, eastern Kentucky, western Kentucky, southern Illinois, and eastern Missouri to eastern Kansas, - a 1500 mile arc, variously referred to as the "Chestnut Ridge Disturbance" and the "Ohio Valley Disturbance". Washington (1922) remarked that these dikes appear

to be surficial extensions of a general body of magma which underlies the greater part of this area."

At least 65 dikes are known to occur around the head of Cayuga Lake, and those near Ludlowville were known in 1839 (Vanuxem, p. 260). All strike in the same direction, approximately north-south and follow either east or west components of the N-S conjugate shear joint set (Set I). None has a known linear extent of more than half a mile (Portland Point Quarry) and all soon pinch out in both directions. Their thickness ranges from literally paper-thin (especially at foot of Taughannock Falls) to about 12 feet (Williams Brook). Usually they are about 6 inches thick. At two sites they give way to modest-sized "pipes" or diatremes where the intrusive mass is a highly-altered, calcite-seamed mass with a roof of shattered country rock and containing xenoliths of underlying rocks, some of them derived from the deep-lying Pre-Cambrian basement 6000-8000 feet below.

The fresher dike rock is black to dark green and dense (Williams Brook, Cascadilla Creek) and shows brown mica prominently and fresh light green olivine, but the latter is usually serpentinized. With alteration the rock becomes lighter green (Portland Point Quarry) or greenish gray (Taughannock Falls), and weathers to an orange-brown soil (above Taughannock Falls). Originally the rock is presumed to have been composed of abundant phenocrysts of olivine and brown mica in a fine-grained groundmass of magnesia mica, melilite (only in freshest rock), perofskite, apatite, and magnetite. The principal secondary minerals are serpentine, chlorite, calcite, and pyrite. Minor minerals present in very small amount are: chromite, picotite, graphite, red garnet (pyrope), bright-green diopside, and enstatite. All of these minerals have been found in the diamond-bearing kimberlite of South Africa, but no diamonds have yet been found in the Cayuga Lake Region dikes or in others of the same system.

The date of the intrusions is not positively known. The youngest rocks intruded along the line of disturbance are Pennsylvanian, and there is no reason to suppose they are other than an effect of the Appalachian Revolution. Sheldon (1927, p. 366) summarized the date for the Cayuga Lake Region:

"Fault stresses began early in the Appalachian Revolution and continued until after the joint planes and dikes were formed. The joint planes formed early in this time. The dikes were intruded later possibly at the climax of activity, but still before the end of fault movements."

ECONOMIC GEOLOGY

Salt

The Upper Silurian beds south of their outcrop to the north contain numerous beds of rock salt and gypsum, the latter no longer worked. At Portland Point, on the crest of the anticline, the salt is reached at depth of about 1800 feet by two shafts and is mined. A short distance to the north at Myers Point, the salt is procured in the form of brine from wells. The location of the salt works is determined partly by the uplift due to the anticline (less distance down to the salt) and partly due to immediate proximity of a railroad.

Limestone

At Portland Point, on the crest of the anticline, the Tully limestone has been quarried for many years for the manufacture of cement at a large plant located on the lake shore, to which the rock was transported from the quarry above by aerial cableway. The plant has been closed since June, 1948.

Natural Gas

The Portland Point anticline has been tested several times to the Oriskany sandstone but little more than a show of gas has been found. But on the next anticline to the south of Ithaca, several wells drilled to the Oriskany in the vicinity of Danby produced marketable quantities (2,000,000-5,000,000 cu. ft. per day). However, by the time a pipe-line was laid, the pool was virtually exhausted. Test drilling continues hopefully and sporadically on this anticine.

Building Stone

Since early days, the sandstone layers in the Ithaca and Enfield formations of the Upper Devonian have provided flagstone and building stone. A large quarry (now covered over, alas) about 150 yards down the slope to the northwest of McGraw Hall provided all the stone, except for the trim (which is Onondaga limestone from the Union Springs region 40 miles down the lake), for the first three Cornell Buildings; Morrill, McGraw, and White. In the course of working this quarry, many fossils were obtained, some of them new species described by James Hall, H. S. Williams, and others.

At present the only operative quarries are in the Enfield formation in the Cascadilla Creek valley about 3 miles east of the campus. One is owned by the university and provided the stone for Willard Straight Hall, Barton Hall, and Balch Hall. New fossils

have been discovered in this quarry, notably the peculiar branching sponge Protoarmstrongia, described by Dr. K. E. Caster, and a remarkable alga, soon to be described by Prof. L. C. Petry.

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FIELD TRIP, FRIDAY AFTERNOON, 13 May, 1949

Route. NW out of Ithaca via Route 15 towards Trumansburg. From west end of State St. highway ascends and traverses more or less continuous outcrop of middle part of Ithaca formation, - shales and flagstones. (See geologic section, p. 26.)

Stop 1. Williams Brook, 1.3 mi. from west end State St.: elevation, 640 ft., lake at 382 ft.:

a. Lookout Point: General view of southern Cayuga Lake Region: Schooley erosion surface; Portage escarpment; Cayuga trough; hanging valleys of Fall, Cascadilla, Six Mile, and Inlet Creeks. Thinness of till over rock walls of valley; hanging deltas; modern delta. Gentle southerly regional dip; south limb of Portland Point anticline.

   Walk up road to

b. Williams Brook, 0.1 mi. Up the creek, about 100 feet W of bridge is outcrop of alnoite dike, 12 ft. thick, trending N-S, in direction of dip joints (Set I). Dike rock here least altered of any in this district.

Continue on Rte. 15 to junction of Willow Creek Rd.; along this road to Hoyer Farm, 2.45 mi. from Stop 1:

Stop 2. Hoyer Farm. Walk down slope eastward through orchard to igneous intrusion (diatreme) in creek bed about 300 yds. from farm. Different situation from dike seen at Stop 1.; effect of explosive ascent of dike material.

Willow Creek Rd. to White Schoolhouse Rd. to Taughannock Creek bridge just W. of R. R. bridge. Across bridge and up left bank of creek 200 yrds.:

Stop 3. Upper Taughannock Creek. Lower Ithaca formation in creek bed. Highly developed joints of Set I. Ripple mark. Small dikes in dip joints; various states of weathering of dike rock.

Back along same road, under R. R. underpass to

Stop 4. Upper Taughannock Gorge. Meandering course of gorge. Ithaca-Sherburne contact (paleontological) about half-way down wall of gorge.

Stop 5. Taughannock Falls. Lookout point: knickpunkt falls; Contact of Sherburne-Geneseo 100 ft. up from foot of falls.

Continue down road toward lake, passing over 3 hanging, post-glacial, high-level, deltas. Modern delta at lake level, now being built by Taughannock Creek.

Stop 6. Lower Falls, Taughannock Gorge. Cap-rock falls over Tully limestone, and weak Moscow (Windom) shale below. Transition beds to Geneseo above. Geneseo shale in gorge walls, with joint-controlled recesses and buttresses. En echelon fractures on top bed of Tully (see p. 20). On north side of gorge at first bend (stepping stones 150 yds. upstream from fractures), in transition beds of Tully-Geneseo, there can be collected sparse representatives of the "pre-nuncial" Naples facies fauna: Probeloceras lutheri, Buchiola speciosa, Pterochaenia fragilis, Styliolina, Orbiculoidea, and occasional fish and plant fragments.

Return to Ithaca (Cornell Campus).

Geologic Section in Vicinity of Taughannock Falls

Upper Devonian:

Ithaca formation (above R. R. Bridge)----------100' exp.

Sherburne formation----------200'

Middle Devonian:

Geneseo shale (incl. trans. to Tully)----------135'

Tully limestone---------- 12'

Moscow formation (Windom member) to lake level------ 6'

In Taughannock Gorge the upper few feet of the Moscow shale outcrops below the Tully limestone, which forms a low falls near the entrance to the gorge. Above the Tully are 4-5' of transition beds (bit. sh.-ls.) into the Geneseo. For a few hundred feet above the falls, the top bed of the Tully, dipping north on north limb of Portland Point anticline, forms bed of creek. The steep walls of the gorge show a complete section of the Geneseo with the Sherburne above it. At the main falls, a mile up the gorge, which are 195' high, the Geneseo extends about halfway to the crest of the falls, and 200 ft. of the Sherburne forms the upper part of the 300' high gorge wall. The contact with the overlying Ithaca formation is conformable and the boundary is paleontological, not lithological.

FIELD TRIP, SATURDAY, 14 MAY, 1949

Route. Northward from Ithaca via Route 90 through Ludlowville, King Ferry, and Aurora to Union Springs, about 37 miles north of Ithaca, near the north end of Cayuga Lake.

Geologic Section in Vicinity of Union Springs

Middle Devonian:

Oatka Creek black sh.[3]----------80-100'

Cherry Valley limestone[3]---------- 1½'

Union Springs black sh.[3]---------- 12'

Onondaga limestone[2,3]---------- 125'

Oriskany ss.[2](patchy, not always present)--------- 0-4

Upper Silurian (Cayugan):

Manlius ls.[1,2]----------25'

Rondout ls.[1]----------40'

Cobleskill ls.---------- 8'

Bertie ls.----------10'

Camillus "sh." (ls. and gypsum)----------35'

Fiddler's Green ls.----------25'

Stop 1. Roadside quarry 1 mi. NE of Union Springs. Exposure of lower beds of the Manlius (massive beds) and top of the Rondout beds (platy beds forming floor of quarry). Very few fossils. Local deviations from southerly regional dip in this region are ascribed to effects of settling due to irregular solution of gypsum or changes of volume due to modification of gypsum to anhydrite in the underlying Camillus shale.

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1 - seen at 1st stop; 2 - seen at second stop; 3 - seen at 3rd stop.

Stop 2. Yawger's Woods, 1.75 mi. E of Union Springs. Leave buses just south of the old Yawger farm, walk about ¼-½ mi. west down farm lane to the woods. In midst of woods is a low escarpment, formed by the resistant lower few feet of the Onondaga limestone and the massive Oriskany sandstone overlying the thin-bedded, platy limestones of the top of the Manlius. This is a famous locality for the Oriskany, here replete with fossils: Rensselaeria ovoides, Hipparionyx proximus, Meristella lata, Costispirifer arenosus, Acrospirifer murchisoni, etc. The Manlius just below the Oriskany contains the guide fossil Crispella vanuxemi, large ostracods (Leperditia), and occasional parts of eurypterids.

Stop 3. Old Wood quarry, 1 mi. S of Union Springs. East face of quarry shows excellent section of upper beds of Onondaga limestone, with transition beds into overlying black, sooty Union Springs shale member of Marcellus formation. Near top of exposure is the Cherry Valley bituminous limestone (here with only very rare specimens of its famous cephalopod fauna: Agoniatites vanuxemi, Centroceras marcellense, etc.), with a few feet of Oatka Creek black shale member above. Note local reversal of dip. Poor collecting.

Stop 4. Moonshine Falls, on Paines Creek, 1½ mi. SE of Aurora.

Paines Creek Section

Middle Devonian (Hamilton):

	Portland Point ls. (at Black Rock)----------	5'
G.A. Cooper's typical Ludlowville section	King Ferry shale----------	200'
	Ledyard shale (Leiorhynchus fauna)----------	175'
	Centerfield "limestone" (falls)----------	25'
	Levanna sh. (below falls)----------	300'

The Centerfield, a shaly limestone, is an intercalation of the Hamilton Tropidoleptus fauna between the Marcellus Leiorhynchus fauna in the Ledyard shale above and the Levanna shale below. Fossils are scarce in these two members, but the Centerfield is very

fossiliferous: corals: Favosites hamiltoniae, Heliophyllum halli; bryozoa; blastoid: Devonoblaster leda; brachiopods: Pustulina pustulosa (guide), Mucrospirifer mucronatus, Spinocyrtia granulosus, Brachyspirifer audaculus, Fimbrispirifer divaricatus, Chonetes mucronatus, Ambocoelia umbonata, Elytha fimbriata, Athyris spiriferoides, Eunella lincklaeni, Rhipidomella vanuxemi, Douvillina inaequistriata, Protoleptostrophia perplana, Centronella impressa, Tropidoleptus carinatus, etc.: pelecypods: Cornellites flabellum, Aviculopecten princeps, Actinopteria boydi, Grammysia arcuata, Tellinopsis subemarginata, Palaeoneilo constricta, Parallelodon hamiltoniae, Cypricardinia indenta; gastropods: Ptomatis patulus, Bucanopsis leda, Bembexia capillaria; cephalopods: "Orthoceras" spp., Nephriticeras liratus, Tornoceras uniangularis; tribolites: Dipleura dekayi, Phacops rana (large individuals), Greenops boothii.

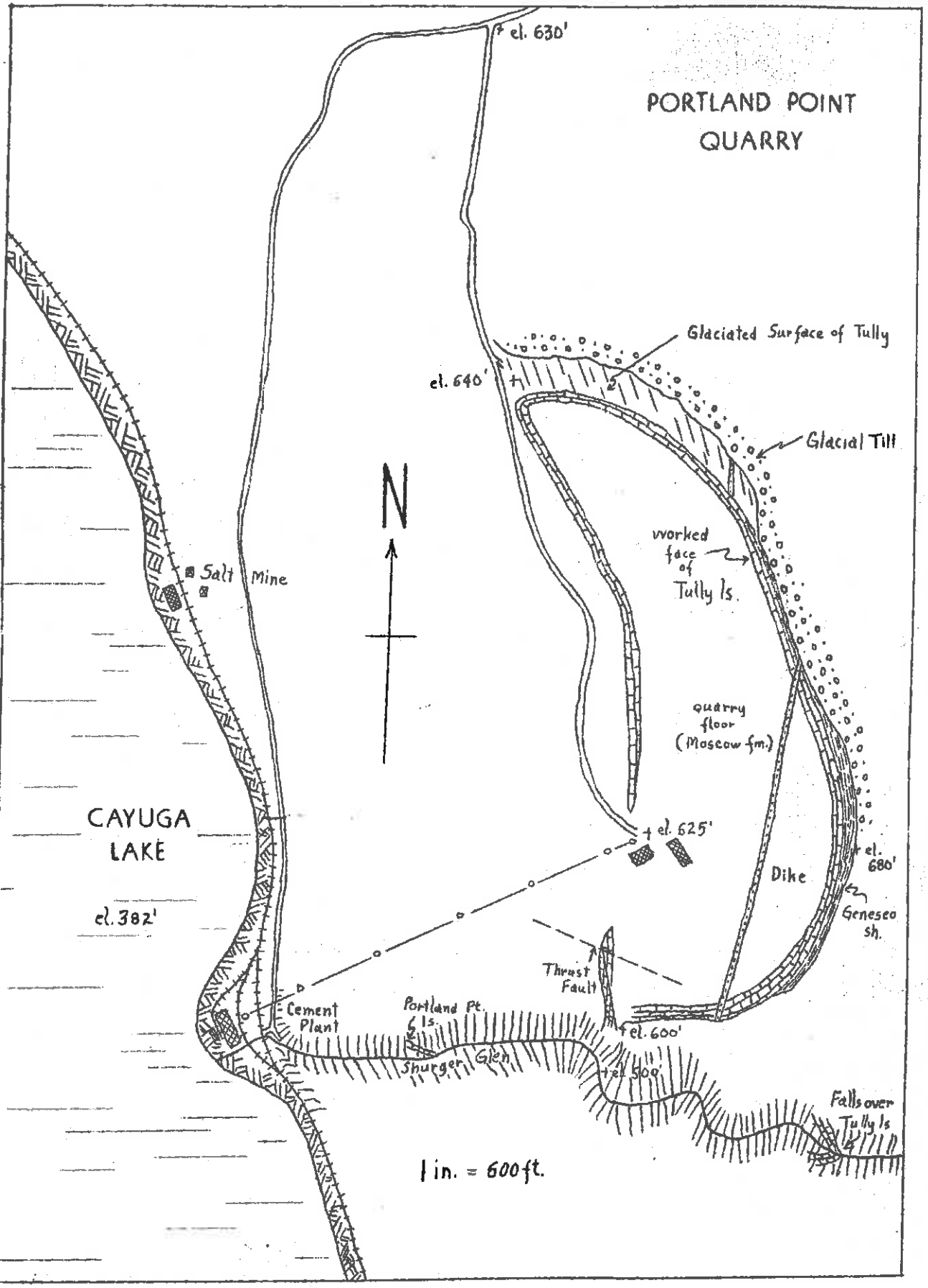
About 100 yards upstream from the falls is the top of the Centerfield, marked by a very sharp contact with the overlying fine, dark Ledyard shale, which contains the sparse Leiorhynchus fauna (Leiorhynchus laura, Ambocoelia umbonata, Chonetes lepidus, Buchiola speciosa, Nucula corbuliformis, Pterochaenia fragilis, Styliolina fissurella, "Orthoceras", Tornoceras discoideus). The topmost layer of the Centerfield is a thin phosphatic zone, indicative of a diastem. This unconformable relation of the Centerfield with the Ledyard shale and conformity with the Levanna shale of the Skaneateles formation suggests that the Centerfield is the topmost member of the Skaneateles rather than the basal member of the Ludlowville.

LUNCH

Stop 4. Portland Point quarry, 2 mi. SE of Ludlowville (just above word "Norton" on topographic sheet). Leave buses at north end of quarry, walk around east side to southwest corner, and pick up buses again at buildings for return to Ithaca.

Glacial grooves and scratches are well shown on the surface of the Tully limestone at the north end of the quarry.

A prominent alnoite (serpentinized) dike extends about a half-mile over the quarry floor from the middle of the east side across to the south side above Shurger Glen. A second, smaller one cuts through the Geneseo shale in the northeast part of the quarry.


PORTLAND POINT
QUARRY
+ el. 630'
Glaciated Surface of Tully
el. 640'
Glacial Till
N
worked face of Tully ls.
Salt Mine
quarry floor (Moscow fm.)
CAYUGA LAKE
el. 382'
+ el. 625'
+ el. 680'
Dike
Geneseo sh.
Thrust Fault
Cement Plant
Portland Pt. ls.
+ el. 600'
Shurger Glen
+ el. 500'
Falls over Tully ls.
1 in. = 600 ft.

The quarry is astride the crest of the Portland Pt. anticline. In the southeast corner of the quarry there is exposed a small low-angle thrust fault in the Tully ls. and Windom sh.

Section in Portland Pt. Quarry and Shurger Glen

Middle Devonian:

Quarry

- Geneseo black sh.----------lower 20'
- transition beds to Tully ls.---------- 5'
- Tully formation:
  - West Brook member, fossiliferous----------8-9'
  - Apulia member, few fossils, except Hypothyridina venustula--------8-9'

Lower Shurger Glen

- Moscow formation:
  - Windom member, very fossiliferous (upper 5-6' in quarry floor)----------175'
  - Portland Pt. limestone and sh.---------- 9'
- Ludlowville formation:
  - King Ferry sh. member, to lake level---------- 50'

The Geneseo black, bituminous shale is sparsely fossiliferous, but careful search has brought to light several land plants (drifted in); Eospermatopteris, Archeosigillaria; fresh-water fishes: Dinichthys, and crossopterygian scales; marine fossils: Styliolina fissurella, Orbiduloidea, Lingula, Paracardium, Leiopteria, Probeloceras, etc., representing the "prenuncial" Naples facies fauna.

The Tully limestone formation here is not very fossiliferous. Most of the fossils are Hamilton species, except for Hypothyridina venustula. Fragments of placoderm armor-plate (Dinichthys and "Aspidichthys") and jaws (Rhynchodus) have been found.

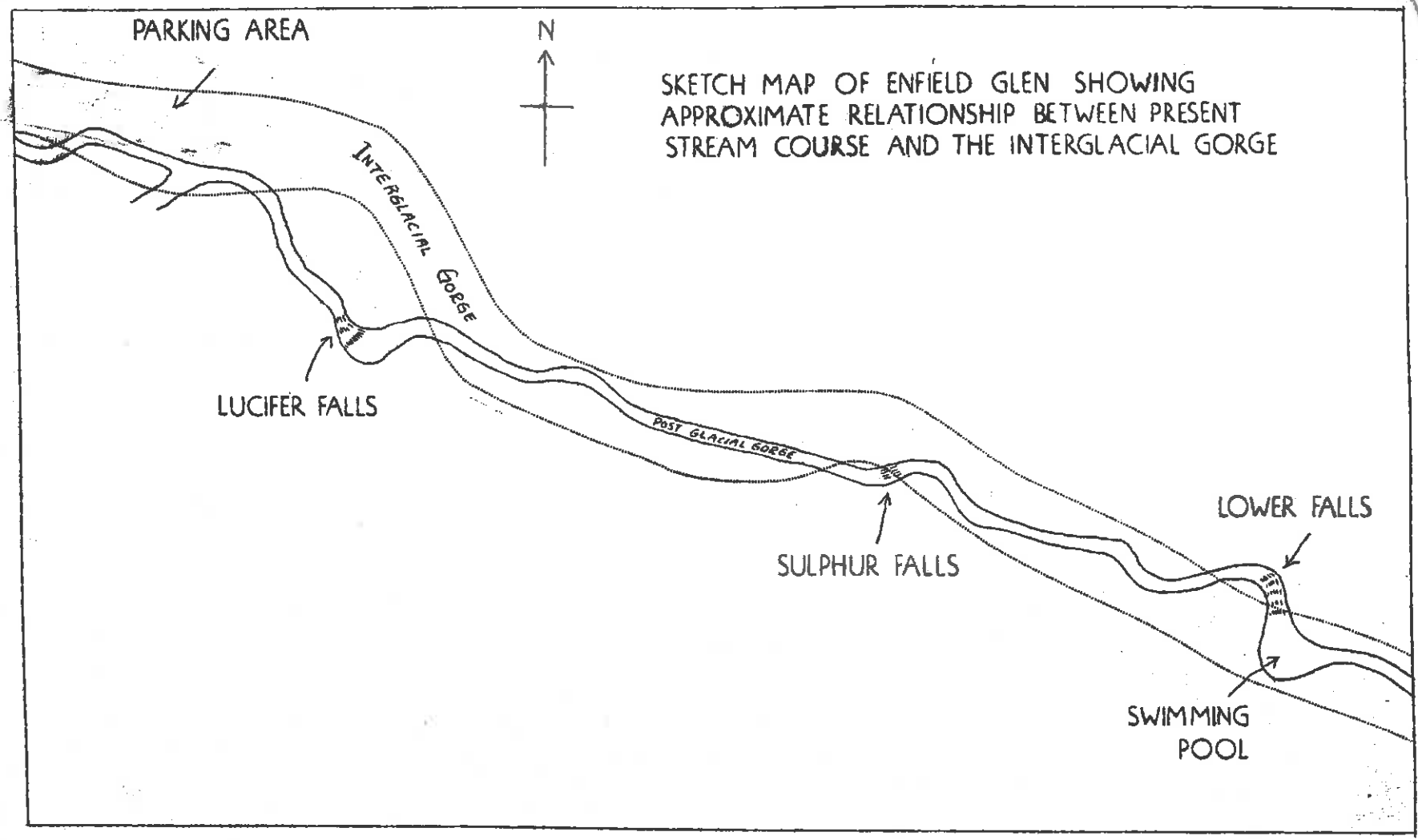
Fossils are extremely aboundant in the Windom member of the Moscow, which is here a calcareous shale with coquinite lenses. The fauna is very similar to that of the Centerfield and contains upwards of 150 species representing the rich Tropidoleptus fauna.

The following trip, not part of the planned program, is suggested for Sunday morning for those who wish to see more physical features and the character of the Upper Devonian Enfield formation:

ENFIELD GORGE (Treman Park)

Located about 7 mi. SW of Ithaca. Drive south from Ithaca on Route 13 to junction with Route 327. Turn west on Route 327 and follow signs to Upper Entrance and on to parking space, which is located where the present creek has cut a wide gorge in the filling of the pre-glacial valley. Walk down gorge.

Features: Mature pre-glacial valley on upland. Parking area and playground are in interglacial gorge (see map on next page). Postglacial gorge begins below parking area. Remarkable joint development. Joint plane guidance of stream. Potholes. Enfield formation (shales and flagstones) in upper part of gorge, Ithaca formation (shales and flagstones) in lower part. Ripple mark and cross-bedding. Change in character of gorge below Lucifer Falls. For most of remainder of its length, the stream follows the interglacial gorge. Occasionally it swings to one side far enough to encounter bed rock. In consequence of such diversions short stretches of the postglacial gorges have been eroded in bedrock, as above the swimming pool.


PARKING AREA
N
SKETCH MAP OF ENFIELD GLEN SHOWING
APPROXIMATE RELATIONSHIP BETWEEN PRESENT
STREAM COURSE AND THE INTERGLACIAL GORGE
INTERGLACIAL GORGE
LUCIFER FALLS
POST GLACIAL GORGE
SULPHUR FALLS
LOWER FALLS
SWIMMING
POOL

THE CAYUGA LAKE REGION, NEW YORK