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New York State Museum Bulletin

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No. 300 ALBANY, N. Y. November 1935

NEW YORK STATE MUSEUM

CHARLES C. ADAMS, *Director*

GEOLOGY AND MINERAL RESOURCES OF THE SKANEATELES QUADRANGLE

BY BURNETT SMITH PH.D.

Temporary Geologist, New York State Museum

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Geologic map 1 Paleozoic rocks. *In pocket at end.*
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GEOLOGY OF THE SKANEATELES QUADRANGLE

By Burnett Smith Ph.D.
Temporary Geologist, New York State Museum

INTRODUCTION

The Skaneateles quadrangle is situated entirely within the State of New York and is bounded on the north by parallel 43° 00′ North and on the south by parallel 42° 45′ North. Meridian 76° 15′ West forms the eastern boundary while meridian 76° 30′ West makes the western. The horizontal scale of the map expressed as a representative fraction is 1/62500, or approximately one mile to the inch. The contour interval is 20 feet. The adjacent quadrangles are Baldwinsville on the north, Syracuse on the northeast, Tully on the east, Cortland on the southeast, Moravia on the south, Genoa on the southwest, Auburn on the west and Weedsport on the northwest.

Physiographically the quadrangle is almost entirely within the Southwestern Plateau Province (Miller, '14, fig. 2) of the State. If the Limestone escarpment ("Helderberg escarpment," "Lime ledge") is conceived as the northernmost component of this plateau, then there are left over a few small areas referable to the so-called Ontario plain (Miller, '14, fig. 2). These barely intrude within the quadrangle and are found north and west of Skaneateles Falls, and, less typically north of Marcellus in the Ninemile Creek valley.

Three conspicuous depressions cut the area in a roughly northwest and southeast direction. These are partially occupied by the three beautiful Finger Lakes—Otisco on the east, Skaneateles in the center, and Owasco on the west. Owasco lake shows only its southern or upper portion, Otisco lacks only the extreme head, while Skaneateles is entirely within the quadrangle (see figures 1, 2). Having the same general trend but smaller and more shallow is Dutch hollow. In the northern part of the area two roughly east-west valleys can be seen. Of these, the "Gulf" or "Guppy Gulf" channel is southwest of Marcellus Village, while the Cedarvale channel ("South hollow," "Pumpkin hollow") is southeast. The upper or hanging valley of Bear Swamp creek and the Navarino and Joshua channels respectively north and east of Amber complete the list of more important depressions.

Ridges separate the northwest-southeast valleys, attaining altitudes well above 1500 feet in the southern portion of the quadrangle.

The bedrock of the region is nearly all sedimentary and well stratified. Typical limestone, shale and sandstone are found, while intergradations between these major lithologic types are numerous. The general dip of the strata is in a direction slightly west of south and at a rate between 25 and 50 feet to the mile. Numerous minor dips in other directions occur.

Six small igneous intrusions are known from the larger ravine at Clintonville.

Mantle rock is in origin chiefly glacial and aqueoglacial. Boulders embedded in gravels, sands or muds comprise the common glacial accumulations, while sorted or stratified gravels and sands, and some laminated clays serve to illustrate the aqueoglacial materials. Subordinate amounts of postglacial lake, swamp and stream deposits are also present in the rock mantle.

In age the sedimentary bedrock runs from late Silurian to Upper Devonian. The igneous intrusions cut Middle Devonian sedimentaries and are themselves probably referable to late Devonian time.

The mantle rock is all Quaternary and by far the greater part can be assigned to the earlier and longer Pleistocene or glacial portion of the Quaternary period. Swamp accumulations and talus together with some lake and stream material must be placed in the postglacial or Holocene division of the Quaternary.

Acknowledgments. In the preparation of the maps and the report courtesies have been received from many persons, and an almost universal spirit of cooperation has been encountered. It is manifestly impracticable to name all who have helped in field, laboratory and library. The writer must confine himself to the mention of a few individuals and institutions. These are: Dr Rudolf Ruedemann, Winifred Goldring and the staff of the New York State Museum generally; Professor Gilbert D. Harris of Cornell University; Dr Beatrice E. Bolton of Mount Holyoke College; Dr G. Arthur Cooper of the United States National Museum; Professor V. E. Monnett of the University of Oklahoma; the staff of the Cornell University Library. The writer is under particular indebtedness to Doctor Bolton for field studies on the ridge between Skaneateles and Otisco lakes and to Ethel Ostrander Smith of Skaneateles for skilful and painstaking preparation of illustrations. The source of these illustrations is indicated in each case by the credit to E. O. Smith.

Figure 1 Skaneateles lake. Looking toward head. (Photograph by E. O. Smith, December 1931)

Figure 2 Otisco lake. Looking toward head. The conspicuous Bucktail hill (just right of center) is on the Tully quadrangle. (Photograph by E. O. Smith, December 18, 1931)

HISTORICAL GEOLOGY

In the text of this section of the report the rock masses of the quadrangle, comprising both bedrock and mantle rock, will be taken up from oldest to youngest. With little disturbed sedimentary bedrock and mantle rock the relative age is determined by the order of superposition. This implies that in a series of sediments, precipitates and glacial deposits any one rock mass is younger than the underlying material on which it accumulated but older than overlying material which accumulated upon it. The order from bottom to top is the order of age. The intrusive igneous masses of the quadrangle represent matter, which, when fluid or molten, broke through or penetrated sedimentary bedrock. Therefore, as rock masses, they are younger than the bedrock which they penetrated.

Although the oldest rocks of the quadrangle are considered first in the text, this arrangement does not apply to the columnar section and table of sedimentary rocks. In these the youngest formation is placed at the top, the oldest at the bottom, of section or of table, to that extent reproducing the conditions seen in the field.

It is believed that the geological history of the quadrangle will be best introduced by presenting the following tabular summary of its sedimentary formations. See also figure 3.

SUMMARY OF SEDIMENTARY FORMATIONS, SKANEATELES QUADRANGLE

Quaternary	Holocene	Postglacial Deposits	Talus, swamp and spring deposits; some lake and stream deposits. Unconformable on all older material. As a rule without fossils but occasionally containing land or fresh-water shells and sometimes with plant remains in abundance. No extinct forms of life known from these deposits on the Skaneateles quadrangle.
	Pleistocene	Aqueo-glacial Deposits	Gravels and sands of eskers, kames, outwash plains and moraines. Gravels and sands of the deltas and beaches of ice-controlled lakes. Laminated clays of ice-controlled lakes. Unconformable on all older deposits. No contemporary fossils known from these deposits on the Skaneateles quadrangle.
		Glacial Deposits	Boulders inclosed in gravels, sands, muds and clays and boulder accumulations, sometimes without definite topographic form and sometimes in drumlinlike hills. Unconformable on all older material. No contemporary fossils known from these deposits on the Skaneateles quadrangle.

Devonian	Ithaca Member			An incompletely exposed series of shales, flags, and sandstones. Some dark shale with included sandstone lenses. Coarser beds of the member may show current ripple marks and cross-bedding. Marine invertebrates (and perhaps also fresh-water invertebrates) occur, usually in rather definite zones separated by barren strata. Land plants found associated with marine invertebrates.
	Cornell Member			Flags and shaly flags, some barren and some fossiliferous. One or two zones of *Spirifer* (*Reticularia*) *laevis*.
	Sherburne Member			At base usually a massive flaggy sandstone which makes a sharp contact with the underlying Genesee shale. Basal unit passes upward by intercalation into thinner layers. Exceptionally the basal horizon is occupied by two thin flags separated by shale. Bulk of Sherburne made up of thin flags and sandstones. Curved bedding planes, current ripple marks, and minor cross-bedding are common. "Fucoid" markings may be present. Plants and marine invertebrates occur but fossils are rare except toward the top of the member.

Devonian	Genesee Shale			A thinly-bedded black shale, often rust stained. Concretions occur at various levels. Lower contact often sharp but sometimes shown as a series of intercalations from the Tully limestone. Upper contact definite and usually conspicuous. Unfossiliferous or nearly so.
	Tully Limestone			Usually a compact, bedded limestone, grayish when weathered but of an almost olive shade when fresh. Mineral segregations and veins may be present. Exceptionally the Tully may show unbedded "reef-mound" and crinoidal clastic phases. Lower contact sharp. Upper contact often sharp but sometimes shown as a series of intercalations with the Genesee shale. Fossils numerous. Fauna marine.
	Hamilton Group	Moscow Formation	Windom Member	A fine shale, gray to almost black. Relatively homogeneous, but with many fossil bands. Apparently transitional by intercalation from the beds below. Upper contact sharp. Fauna marine.
			Portland Point Member	At base a crinoid-bearing, cross-bedded limestone containing possible shale fragments. Lower contact sharp and believed to be unconformable. Above, the basal limestone passes upward by a series of intercalations into the Windom shale. The basal limestone is a mass of fossils. Fauna marine.

Devonian	Hamilton Group	Ludlowville Formation	Owasco Member	A cross-bedded, calcareous and finely arenaceous rock. Upper and lower contacts quite sharp, suggesting erosion at base and summit of the member. Fossils marine: *Spirifer tullius* conspicuous.
			Spafford Member	A highly fossiliferous, and relatively fine, gray shale. Lower contact definite. Upper contact quite sharp, suggesting an erosion break. Marine fauna.
			Ivy Point Member	Coarsely bedded and hard shale in its lower and upper portions, with softer shale in the middle. Coarse layers may be cross-bedded. Marine fauna in which large Brachiopods and Pelecypods are numerous. Land plants associated with the marine invertebrates.
			Otisco Member	At some localities a mass of relatively homogeneous and comparatively fine gray shale. In places, one and sometimes two coral beds or zones occur about 50 and 90 feet respectively above the base of the member. Lower coral bed underlain by a hard platform. Lower contact of member sharp and conspicuous, upper contact definite. Extremely fossiliferous. Fauna marine.

Devonian	Hamilton Group	Skaneateles Formation	Centerfield Member	A very coarse shale having alliances with both limestone and sandstone. Ripple marks, cross-bedding, trails and Taonurus-Spirophyton markings occur. Transitional from the softer shale below but sharply separated by a very definite contact from the soft shale above. Fossils numerous. Fauna marine.
			Skaneateles Shale (Undivided)	Undifferentiated Delphi, Pompey, and Berwyn members. Fine and rather barren gray shales in which beds full of fossils occur at different levels. Concretions abundant in the midst of the beds. Transitional from the Mottville below and also into the Centerfield above. Fauna marine.
			Mottville Member	Fine fossiliferous shale with concretions toward the top, followed by a crinoid-bearing limestone which in turn is overlain by fossiliferous and somewhat coarser shale. Rather rapidly transitional from the Cardiff below, or, in its absence, from the Chittenango. At top the Mottville is transitional into overlying beds. Fauna marine: begins with *Leiorhynchus* and associates, but later becomes a *Phacops-Homalonotus-Spirifer* assemblage.

Devonian	Hamilton Group	Marcellus Formation	Cardiff Member	Fine gray shale well developed to the east but thinning out and becoming unrecognizable in the western part of the quadrangle. Very gradually transitional from the Chittenango shale below. More rapidly transitional into the Mottville above. Fauna meager.
			Chittenango Member	Thinly bedded black shale, often with rusty stain. Large concretions common, especially in lower part of member. Definite contact with underlying Cherry Valley. Upper part of member very gradually transitional into overlying Cardiff where the latter is present. More rapidly transitional into the Mottville where the Cardiff is absent. Fossils rare, except locally.
			Cherry Valley Member	Limestone dull bluish black when fresh with veins of rusty mineral matter. Petroleum odor when struck. Grayish and crumbly when weathered. Definite contacts with beds above and below. Cephalopod fauna with *Orthoceras marcellense* and *Agoniatites expansus*.
			Union Springs Member	Relatively thin alternations of sooty shale and dark to gray limestone. Perhaps transitional from the Onondaga below. Definite contact with overlaying Cherry Valley. The small pteropod like *Styliolina fissurella* often abundant.

Devonian	Onondaga Limestone	Mostly a heavily bedded gray limestone; compact and flint-bearing in its upper part, tending to be crystalline in its lower layers. Toward its base becoming transitional from a thin quartz sand (reworked Oriskany). The Onondaga, including the reworked Oriskany, is unconformable on older beds. Above, the Onondaga is perhaps transitional into the Union Springs. Fauna marine.
	Oriskany Sandstone	Typically a rusty quartz sandstone. It is unconformably overlain by the Onondaga limestone and its basal sand of reworked Oriskany. Below, the Oriskany sandstone is unconformable on subjacent strata. Fauna marine, but with relatively few species.

Silurian	Manlius Group	Jamesville Limestone	Blue limestone with rather heavy beds which may be subdivided by subordinate crinkly bedding planes. Stromatoporoids may be so abundant that minor bedding is obliterated. Upper surface of Jamesville has been truncated by Oriskany erosion, Onondaga erosion, or both. Lower contact with Clark Reservation usually sharp. Stromatoporoids, corals, brachiopods, gastropods, and ostracods, (Leperditias) are the most common elements of the fauna.
		Clark Reservation Limestone	A compact and homogeneous blue limestone with a tendency toward diagonal fracture which produces blocks of a roughly tetrahedral form. Upper contact with the Jamesville sharp. Contact with the Elmwood below also sharp suggesting a minor erosion interval. Fossils inconspicuous, although Leperditias may occasionally abound.
		Elmwood Waterlime	A drab waterlime apparently barren of fossils. Sun-cracks (mud-cracks), contortion of laminae, and brecciation of laminae occur. Upper surface probably eroded during initial deposition of Clark Reservation. Contact with underlying Olney seems to be sometimes definite, sometimes transitional.
		Olney Limestone	Lower part a thinly-bedded limestone showing alternating blue and drab layers. Above the beds become more massive and are usually dominantly blue though in places of drab color. Contact with overlying Elmwood appears to be sometimes definite, sometimes transitional. The Olney is apparently unconformable on underlying beds. *Stropheodonta varistriata*, *Spirifer vanuxemi*, and crinoid fragments are common. Stromatoporoids are often abundant especially in the upper more massive strata.

Silurian	Strata below the Olney Limestone	Impure limestones and shales. At least one Stromatoporoid zone. Mostly referable to the Chrysler but some of the beds are probably of Akron age.

PALEOZOIC SEDIMENTARY ROCKS

These are ancient deposits, largely marine, which accumulated during a part of Paleozoic time. They are therefore referable to one of the older geological eras and belong more specifically to the Silurian and Devonian periods of the Paleozoic. Their materials are consolidated and hardened and they constitute the bulk of the bedrock of the quadrangle.

The older or Silurian formations reach the surface in the extreme north of the area where average altitude is low. The younger or Devonian rocks are well exposed in the middle and southern portions of the region and their latest beds occupy the high divides in the southernmost part of the quadrangle. Were the surface of the area a northward-sloping plane, the exposures or rock outcrops would appear in roughly east-west belts and the traveler would merely be obliged to go south and uphill to pass from older into younger formations. In a general sense he can do this now, but the ideal condition just outlined has been modified by an erosion which has carved the surface into great northward-sloping ridges and valleys. It therefore happens that many of the older formations which outcrop well north on the ridges extend southward on the flanks of these and into the valleys. This valleyward path is accentuated by a moderate southerly dip. The latter feature, for the quadrangle as a whole, permits the examination of a thickness of strata somewhat greater than would be afforded by horizontal beds.

Silurian Rocks

Strata below the Olney Limestone

Throughout central New York the Olney limestone, unlike the formations just underneath, can usually be recognized with ease. Many quarries have been made in it and some even penetrate the entire thickness of the limestone. These factors render the Olney a useful reference plane. On the other hand, relatively few quarries descend continuously from the Olney into the beds below. There is also a paucity of good natural sections showing relations of Olney and subjacent strata. Although these conditions are a hindrance to detailed studies, the generalization can be made that the Olney is everywhere underlain by a series of dolomitic limestones, waterlimes and limy shales, which in places may attain a thickness of 150 feet. Long-established practice has been to split these dolomitic beds into a number of subdivisions. However justified this may be in good continuous sections, it must be emphasized that the named units of the series are, for the most part, markedly deficient in positive diagnostic characters and that, on this account, their identification is uncertain in limited and scattered outcrops. A further complication is caused by a probable unconformity below the Olney (Chadwick, '29, p. 10) whose base, therefore, may rest upon more than one stratigraphic unit. In view of these conditions no attempt will be made to differentiate subdivisions of the lower series on the map

that accompanies this report, and identifications in the text must be regarded as provisional.

At a number of places along the limestone escarpment, from Skaneateles Falls westward, pre-Olney rocks have been laid bare either through erosion or by quarrying. Also in the Ninemile Creek valley north of Marcellus Village strata are exposed which can be confidently placed below the Olney limestone. The beds are quite variable in character. Exceptionally they are shaly, but the usual phase is a grayish to brownish blocky limestone with irregular bedding planes which may be from but a few inches to several feet apart.

Most of these pre-Olney rocks are probably referable to the Chrysler formation of Chadwick ('29, p. 10). This author uses the term "Chrysler" for the "Rondout" of central New York. At its type section in Chrysler glen (Syracuse quadrangle) the Chrysler immediately underlies the Olney limestone. As far as the present writer has been able to determine, the type Chrysler is without fossils. Therefore, Chrysler references within the Skaneateles quadrangle are based upon stratigraphic position and a general lithologic resemblance to the Chrysler of the type section.

Less frequently pre-Olney beds can be tentatively assigned to a horizon below the Chrysler. This is indicated by the presence of chert or by silicified Stromatoporoids which suggest a reference to the Akron dolomite as interpreted by Chadwick ('29, p. 10), who places the Akron immediately below the Chrysler of Chrysler glen and regards it as the equivalent of the central New York "Cobleskill."

On the Skaneateles quadrangle the more important localities for pre-Olney rocks are the following.

North-leading road in extreme northwest corner of quadrangle. Just east of this road about 15 feet of Chrysler are seen in an old quarry (figure 5). Slightly farther back from the road, Olney limestone has been excavated. The contact between the two formations is almost visible. The Chrysler is here a lightish impure limestone passing upward into thinly bedded, mud-cracked and contorted waterlime.

Ravine cutting the limestone escarpment one-half mile east of the western boundary of the quadrangle. North of the roughly east-west road and downward in altitude to the northern boundary of the quadrangle drab impure limestones are discontinuously exposed. They are mostly referable to the Chrysler formation. A silicified Stromatoporoid (?) was noted at an altitude estimated as between

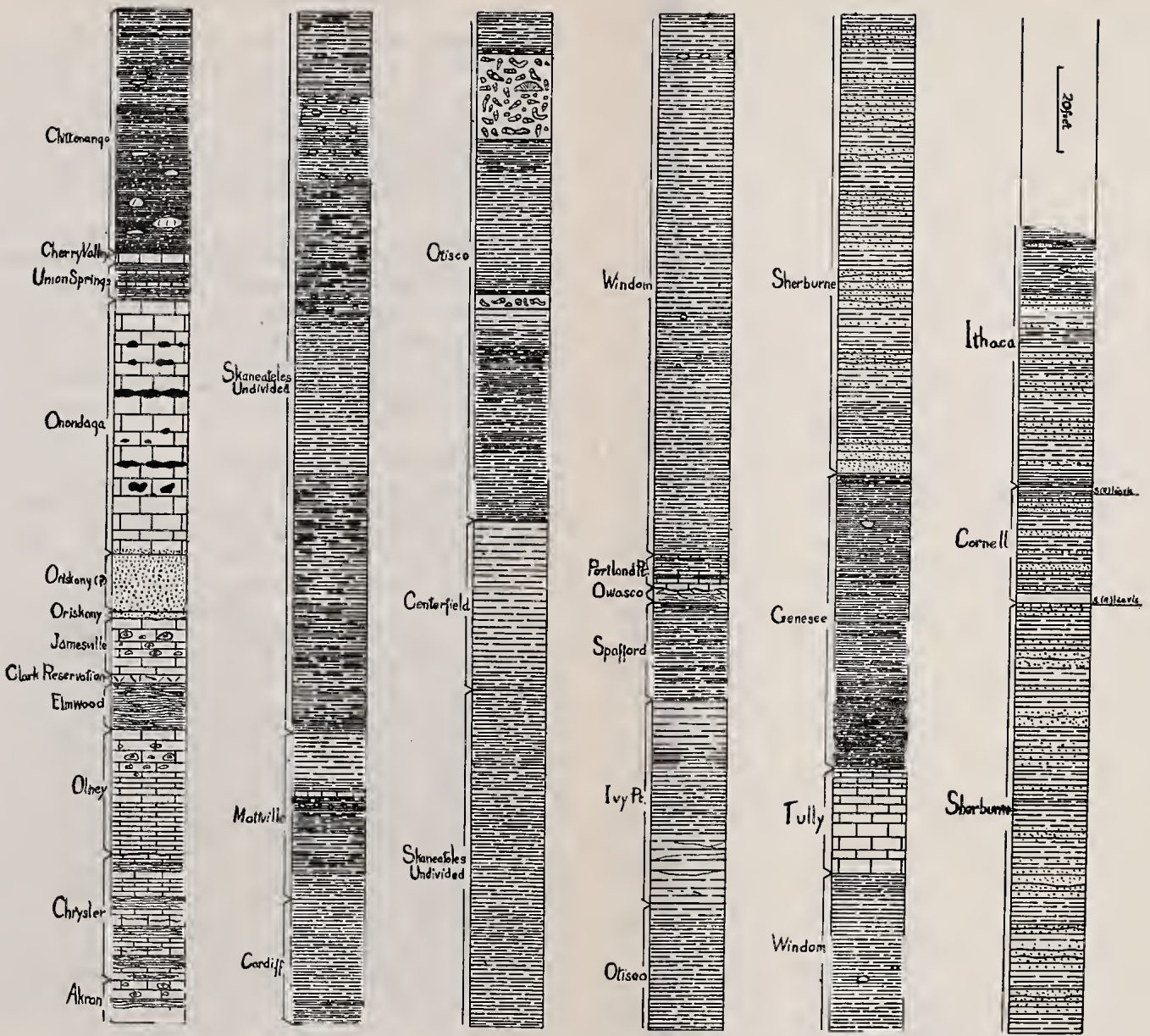

Figure 3 Idealized columnar section, from Akron below to Ithaca above, based on the Paleozoic strata of the Skaneateles quadrangle. Higher Ithaca beds occur upon the ridges but they are not sufficiently well known for inclusion in a section. Chittenango and Cardiff members of the Marcellus are not shown with maximum thickness.

30 and 40 feet below that of the road. It is therefore possible that some of the lower part of the section is in the Akron ("Cobleskill") beds. Although not exposed in continuous section with the Olney limestone, the strata regarded as Chrysler are clearly below the horizon of the Olney which is present on the scarp both east and west of the ravine. Loose blocks of blue limestone just north of the road indicate that the section in the ravine almost reaches the basal Olney.

Limestone escarpment about three-fourths of a mile east of the western boundary of the quadrangle. Here a small quarry exposes about five feet of a drab, thinly bedded waterlime which is assigned to the Chrysler (figure 8). The upper part shows mud-cracks and contortion of laminæ. It is overlain sharply and probably unconformably (disconformably) by Olney limestone. A short distance to the southwest is a small Olney quarry. Grayish drab beds outcrop on the slope below the quarry. These are likewise believed to be Chrysler.

Ravine cutting the limestone escarpment about two-thirds of a mile west of Skaneateles creek. At this locality the Olney limestone is underlain by about 20 feet of impure limestone, some of which is shaly. These pre-Olney beds are assigned to the Chrysler. At a still lower horizon occurs a zone of silicified Stromatoporoids. The latter are some 30 or 40 feet below the Olney and are perhaps referable to the Akron ("Cobleskill").

Northward projection of the limestone escarpment just west of the Cayuga-Onondaga county line near Skaneateles Falls. At the base of the northern extremity of this projection and facing westward is a small quarry in pre-Olney rocks. Some 12 feet of strata are exposed, being for the most part an impure gray to drab limestone. The upper foot or so of the section tends to be shaly. Near the top of the limestone occurs a zone of chert masses. This zone of cherts is about 35 to 40 feet below Olney quarries which are at the summit of the scarp at this point. Stromatoporoid structure was not noted in the chert, but a reference to the Akron dolomite is suggested by its presence.

Skaneateles Falls: west side of creek below dam. Here roughly 25 feet of strata are represented in a somewhat discontinuous exposure. The rocks are referred to the Chrysler on account of their stratigraphic position just below the Olney limestone. A short distance northward, still lower strata are found. These are also referred to the Chrysler formation.

East side of Ninemile creek near the northern boundary of the quadrangle. The roadside exposure at this point shows a section of about 20 or 25 feet (figure 4). Most of this is impure limestone. The upper few feet are quite shaly in appearance. The limestone contains chert and silicified Stromatoporoids and it is provisionally assigned to the Akron.

Manlius Group

The term "Manlius" was proposed by Vanuxem ('39, p. 272, 273), who described in a most precise manner the beds which are here designated as Elmwood and Clark Reservation. It is quite evident that this keen observer intended his Manlius to include much more than the strata just mentioned. This is made clear in his original description and also in the report of 1842 (Vanuxem, '42, p. 112, fig. 23, p. 115). There can be no doubt that the present Olney and Jamesville limestones were regarded as Manlius by its original author. The names now employed for these subdivisions of the Manlius were introduced at a much later date (Smith, '29, p. 25–31) in the hope of reducing a growing confusion and misconception of the group. The Manlius units recognized on the Skaneateles quadrangle are, beginning with the oldest, Olney limestone, Elmwood waterlime, Clark Reservation limestone and Jamesville limestone (figure 6).

Olney limestone and Elmwood waterlime have been very generally assigned to the Silurian and there appears to be no good reason for questioning this practice. A system reference for the Clark Reservation and Jamesville limestones rests perhaps upon less secure ground. Inasmuch, however, as positive Devonian relations have not been proved for these higher units it is deemed best to include them in the Silurian.

Olney limestone. This limestone was named from Olney station on the now defunct Auburn and Syracuse Electric Railroad. Its type section is in the east quarry at Split Rock (Syracuse quadrangle), where the entire thickness of about 33 feet is displayed. The lower 10 or 15 feet of the formation is largely made up of thin interlaminated blue and drab layers. Above this the bedding usually becomes coarser. In this upper part Stromatoporoids are fairly frequent at Split Rock, although they do not there attain the abundance shown at the same horizon in some other localities. Leperditias and crinoid fragments are common in the formation, but its most generally conspicuous and most useful fossils are *Spirifer vanuxemi* Hall and *Stropheodonta (Brachyprion) varistriata* (Conrad). With the

Figure 4 Impure limestone provisionally assigned to the Akron dolomite ("Cobleskill"). East side of Nine-mile creek near northern boundary of Skaneateles quadrangle. (Photograph by E. O. Smith, December 1931)

Figure 5 Chrysler formation. Extreme northwest corner of Skaneateles quadrangle. (Photograph by E. O. Smith, November 9, 1930)

Figure 6 Carrigan quarry, Skaneateles Falls. Section shows upper part of Olney limestone overlain by Elmwood waterlime, Clark Reservation limestone, Jamesville limestone, and Oriskany sandstone in ascending order. Hammer rests on top of Clark Reservation limestone which is here about two feet, three to four inches thick. Uppermost tier of quarry face (Oriskany sandstone) is about one foot thick. (Photograph by E. O. Smith, September 30, 1930). Ol. = Olney. El. = Elmwood. C.R. = Clark Reservation. J. = Jamesville. Or. = Oriskany

Figure 7 Olney limestone. Extreme northwest corner of Skaneateles quadrangle. (Photograph by E. O. Smith, November 9, 1930)

exception of the drab layers just mentioned the color of the Olney is dominantly blue. There is much color variation, however, and in some quarries the upper massive beds may approach gray or even drab. In such cases their darker Stromatoporoids are apt to stand out sharply.

On the whole the Olney maintains its typical condition both east and west of Split Rock. Thin blue and drab layers below with coarser Stromatoporoid beds above can be seen in practically all exposures of any extent. Likewise it is seldom that *Spirifer vanuxemi* and *Stropheodonta varistriata* fail the collector even in limited outcrops.

Except for an eroded upper surface the Olney appears to extend continuously from the type locality westward to the western boundary of the Skaneateles quadrangle. Across this stretch there seems to be a slight weakening in the dominance of the blue color in going from east to west. The most notable change, however, is an undoubted decrease in thickness. Sections do not permit one to decide the details of this reduction, but it is highly probable that the Olney is not more than 15 feet thick in the western three-fourths of a mile of the Skaneateles quadrangle. This diminished thickness may have been brought about solely by a slower rate of sedimentation to the west. On the other hand, it is not unlikely that the decrease can be correlated, at least in part, with an unconformity at the base of the Olney.

On the Skaneateles quadrangle the more important localities for the Olney limestone are the following:

North-leading road in the extreme northwest corner of the quadrangle. Just east of this road a quarry has been made in the Olney terrace. The Olney can be seen almost in contact with the underlying Chrysler, which has been exposed somewhat nearer the road in question. About 12 or 13 feet of Olney are shown in the section (figure 7). The lower part is more thinly bedded than the upper but the whole is mostly composed of interlaminated blue and drab beds. Crinoid fragments are present, while *Stropheodonta varistriata* was noted in the lower, middle and upper portions of the section. About south of this quarry and also south of the roughly east-west road another Olney quarry has been made. Here again blue and drab interlaminations occur. *Spirifer vanuxemi, Stropheodonta varistriata* and crinoid fragments are present. East of this second quarry is a wooded knoll on which Elmwood, Clark Reservation, and what are probably Jamesville beds have been found. Although neither of these two Olney quarries is in continuous sec-

tion with the beds of the knoll, the general relations indicate a much reduced thickness for the Olney limestone of this part of the quadrangle. There can hardly be much more than 20 feet of it, and probably 15 feet is a closer figure for the Olney thickness in the region.

Proceeding eastward many small excavations are found in the Olney terrace between the stations just described and those next to be considered.

Limestone escarpment about three-fourths of a mile east of the western boundary of the quadrangle. Here the Olney is seen resting on some five feet of Chrysler in a small quarry (figure 8). The contact is a sharp one and its minor irregularities suggest an unconformity of the disconformity type. The lower portion of the Olney is made up of thin blue and drab layers, while the upper part, as usual, is more heavily bedded. The highest Olney seen contains the Stromatoporoids which usually indicate that one is near the top of the formation. The section is not continuous, but, from base to Stromatoporoids, there is probably not more than 12 or 13 feet of strata. Elmwood blocks are found farther up the scarp, and, above these, blocks of Clark Reservation, with higher still, Jamesville limestone in place. Estimates based on the positions of these higher beds point to a thickness of about 15 feet for the Olney. Another small quarry has been made in the Olney a short distance to the southwest. Its relations with what is believed to be Chrysler on the slope below and with Clark Reservation and Jamesville on the slope above are such that a thickness of approximately 15 feet is probable for the Olney. Exact figures can not be put forward, but the two sections, incomplete as they are, strongly confirm a reduced thickness for the Olney of the western portion of the quadrangle. The former of these two Olney quarries has yielded *Stropheodonta varistriata* and *Spirifer vanuxemi* in addition to the Stromatoporoids already mentioned. At the latter quarry *Stropheodonta varistriata* was found.

Ravine cutting the limestone escarpment one and one-half miles east of the western boundary of the quadrangle or about two-thirds of a mile west of Skaneateles creek. This locality is of value in that it shows a fairly continuous section from the Chrysler below, through the Olney, and up into the Elmwood. Unfortunately the Olney is much disturbed so that no exact figure can be given for its thickness. Even allowing for some duplication, however, it is probably thicker than at the quarry three-fourths of a mile to the west. An estimate of 25 feet would not be unreasonable. The lower

Figure 8 Chrysler-Olney contact. About three-fourths of a mile east of western boundary of Skaneateles quadrangle. Hammer head marks the contact. The massive bed of Olney limestone is made up of interlaminated blue and drab layers. The lower surface of the Olney shows minor irregularities. Note probable mudcrack sections in Chrysler a short distance below the contact. (Photograph by E. O. Smith, November 10, 1930)

Figure 9 Olney limestone. A short distance west of Skaneateles Falls. Blue and drab layers dipping northeast. (Photograph by E. O. Smith, November 9, 1930)

layers are the characteristic blue and drab interlaminations. Higher up, the bedding is coarser, and toward the top the usual Stromatoporoid zone is seen in blue limestone. The horizon of contact with underlying Chrysler is exposed, but at this locality no sharp line of separation was seen. A better section would probably bring this into view. The passage from Olney to Elmwood is here covered but the relations are beyond question. Clark Reservation and Jamesville have been found in place on the scarp just west of this ravine. On the knoll east of the ravine a similar succession appears to be present. *Spirifer vanuxemi, Stropheodonta varistriata,* and crinoid fragments have been found in the Olney of this ravine.

East-west road a short distance west of Skaneateles Falls. Two small quarries are found along the road. The more western is south of it, the more eastern north of it. They lie respectively upon the western and northern flanks of the wooded knoll which is just west of the Cayuga-Onondaga county line. The western quarry shows the Stromatoporoid bed which is found near the top of the Olney. The eastern quarry is presumably a little farther down in the Olney for the Stromatoporoid bed is not present in it. *Stropheodonta varistriata* occurs in both quarries. The strata in the eastern quarry exhibit a strong reversed dip in a general northeastward direction (figure 9).

Northward projection of the limestone escarpment just west of the Cayuga-Onondaga county line near Skaneateles Falls. Olney limestone, with *Stropheodonta varistriata,* is the cap rock of the northern part of this promontory of the escarpment. It is not in continuous section with underlying beds, although strata perhaps referable to the Akron dolomite are found at the foot of the scarp some 35 to 40 feet below. The Olney exposures are in a line of shallow quarries, long unused. They extend from the western side of the tip of the promontory around onto the eastern side.

Skaneateles Falls: Carrigan quarry on east side of Skaneateles creek. The Olney at this quarry presents a section of from 15 to 16 feet. The lower eight feet or so are fairly coarsely bedded but show finer blue and drab laminae in places. The general color, however, is prevailingly blue. *Stropheodonta varistriata, Spirifer vanuxemi,* and crinoid fragments occur in these beds. Above these lower layers comes a Stromatoporoid zone about two feet and six to nine inches thick. The Stromatoporoids are apt to be of a color darker than that of the limestone matrix. Higher still comes about five feet of light limestone with Leperditias and what appear to be fragments

of *Spirifer vanuxemi*. Stromatoporoids have been seen in the lower part of this bed. In contrast to the condition found in some quarries to the eastward, the contact with the overlying Elmwood is an abrupt one (figure 6).

Marcellus: Ninemile creek. Olney limestone is exposed on the east side of Ninemile creek just north of the Maple Street dam which makes the large mill pond at Marcellus Village. The section is eight or ten feet thick but not a convenient one for study. From the water to near the top of the section, the beds are characteristic blue and drab Olney. *Stropheodonta varistriata* was seen.

Elmwood waterlime. The name is derived from the Elmwood district northeast of Onondaga Hill (Syracuse quadrangle), where the type section is in the Sweet quarry. The type Elmwood comprises two layers of waterlime separated by a blue limestone stratum. The entire thickness is about 12 feet. About six and one-fourth miles west (Baldwinsville quadrangle), the Elmwood horizon is occupied by waterlime only. As far as known, this seems to be the condition found within the Skaneateles quadrangle where the beds constitute a drab waterlime almost as thick as the total of the three different layers at Elmwood. Although there are lighter and darker shades, the drab color is quite uniform. On the other hand, there may be considerable variation between fine and coarse bedding and between the qualities of hardness and softness. Sun-cracks (mud-cracks), contortion of laminae and brecciation of laminae are often shown by the Elmwood. It appears to be without fossils in the Skaneateles quadrangle. Except that it is clearly of shallow water origin, the circumstances surrounding the formation of this waterlime are not understood.

Elmwood is present near Marcellus Falls (Baldwinsville quadrangle) but it has not been definitely recognized about Marcellus. It is known, however, that at Marcellus Falls the Clark Reservation and Jamesville limestones have been cut out of the section by the southward-descending Onondaga erosion surface (Smith, '29, p. 35). It is therefore possible that all three of the higher units of the Manlius—Elmwood, Clark Reservation and Jamesville—have been removed in the Marcellus region of the Ninemile Creek valley. The sections are inadequate to solve the problem.

On the Skaneateles quadrangle the more important localities for the Elmwood waterlime are the following:

Extreme northwest corner of the quadrangle. Just west of the westernmost south-leading road and just south of the roughly east-west road there is a low wooded knoll. On its east side a

few feet of Elmwood waterlime have been exposed beneath Clark Reservation limestone. Although there is no continuous section with the Olney, general field conditions show the relation with this subjacent limestone. The chief value of this locality lies in its proving that the Elmwood is still intact very near the western boundary of the quadrangle.

Ravine cutting the limestone escarpment one and one-half miles east of the western boundary of the quadrangle or about two-thirds of a mile west of Skaneateles creek. Here about five feet of the Elmwood waterlime are exposed at the top of the section. Although the contact with the Olney limestone is obscured there can be no question of the relations of the two formations.

West of the locality just noted, loose blocks of Elmwood have been seen near the top of the limestone escarpment on slopes below blocks of Clark Reservation limestone and Jamesville limestone, the last-named undoubtedly in place.

Skaneateles Falls. In the Carrigan quarry east of Skaneateles creek, is found the best Elmwood section on the quadrangle (figure 6). The drab waterlime is about 11 feet thick and, as far as observed, without fossils. Contacts with underlying Olney and with the overlying Clark Reservation are sharp. Most of the characteristic features of the Elmwood can be seen in this quarry.

At Skaneateles Falls the Elmwood is also exposed south of the bridge and again in an old quarry just east of the Cayuga-Onondaga county line. At this latter place seven feet of Elmwood are shown in section with the Clark Reservation and Jamesville.

Clark Reservation limestone. The type section is in the Clark Reservation State Park (Tully quadrangle) near Jamesville. This limestone is a compact blue bed which is usually sharply separated from limiting strata. In places (near type section) flakes of waterlime are found in its lower few inches, suggesting that the underlying Elmwood has been slightly eroded. Fresh surfaces of the Clark Reservation are apt to be quite dark in color but weathered material as it appears in old quarries or in natural exposures is commonly a light even blue. The bed is very homogeneous in texture and usually shows no fossils. The character of highest determinative value consists in its tendency to break with a diagonal fracture into blocks of a roughly tetrahedral form. This quality was described by Vanuxem ('39, p. 273) but it has not been appreciated by most later writers. Once the geologist becomes accustomed to its appearance, the Clark Reservation makes a very useful reference plane.

The distribution of the Clark Reservation is largely governed through the depths reached by Oriskany and Onondaga erosion. These ancient processes either singly or successively have removed the Clark Reservation from the section at Split Rock (Syracuse quadrangle) and again at Marcellus Falls (Baldwinsville quadrangle). The limestone has not been found about Marcellus in the Ninemile Creek valley. It is believed to be absent there, as at Marcellus Falls, and from the same cause.

For the Skaneateles quadrangle the more important Clark Reservation occurrences will now be noted:

Extreme northwest corner of quadrangle. Just west of the westernmost south-leading road and just south of the roughly east-west road at the knoll already mentioned one finds the Clark Reservation capping a few feet of Elmwood. This brings the western extension of the Clark Reservation very close to the western boundary of the Skaneateles quadrangle.

For the stretch of about two-fifths of a mile north and east of the above locality the top of the limestone scarp is furnished by the Olney beds, the Jamesville and presumably also the Elmwood and Clark Reservation being farther south on the terrace.

Limestone escarpment three-fourths of a mile to one and one-half miles east of the western boundary of the quadrangle. Throughout this belt the Jamesville tends to form the summit of the limestone scarp. Below it, at three different places, blocks of Clark Reservation were noted. At the two western of these localities, blocks of Elmwood were also to be seen still lower on the slope. The easternmost station near the ravine about two-thirds of a mile west of Skaneateles creek shows the Clark Reservation more probably in place.

Skaneateles Falls. In the Carrigan quarry east of Skaneateles creek the Clark Reservation limestone is finely displayed, making sharp contacts with Elmwood waterlime below and with the Jamesville limestone above (figure 6). It is about two feet and three inches thick and has the usual light blue color and homogeneous texture. It is further characterized by conspicuous diagonal fracturing with resultant projecting prominences and reentrant spaces. The latter represent places from which the roughly tetrahedral blocks have been removed. At this station numerous Leperditia shells can be seen on close scrutiny of some of the limestone surfaces. They are not apparent on a casual inspection.

South of the bridge at Skaneateles Falls and in the quarry just east of the Cayuga-Onondaga county line the Clark Reservation is

again shown. At the latter locality a thickness of about two feet and eight inches was measured.

Jamesville limestone. The type section is in the Clark Reservation State Park (Tully quadrangle) near Jamesville, where a thickness of 19 or 20 feet occurs. Westward of this locality the thickness has been greatly reduced by Oriskany erosion, Onondaga erosion, or both. By such means the Jamesville has been completely removed at Split Rock (Syracuse quadrangle) and at Marcellus Falls (Baldwinsville quadrangle). It is believed to be missing from the Ninemile Creek valley about Marcellus. West of Marcellus Falls the old erosion surface rises stratigraphically and the Jamesville is restored to the sections. It appears to continue on to the western boundary of the Skaneateles quadrangle.

The Jamesville is a blue limestone with, on the whole, rather heavy beds which may be subdivided in varying degree by minor bedding planes of a peculiar crinkly form. Stromatoporoids may be so abundant that these latter structures are obliterated. The Jamesville is highly fossiliferous as far as individuals are concerned. Stromatoporoids are usually conspicuous. Favosites are sometimes associated with the Stromatoporoids. Less striking but very numerous are Leperditias, while Gastropods are often well represented. A coarsely-ribbed *Spirifer* is occasionally seen. *Tentaculites* has been found in the formation but does not appear to be common.

On the Skaneateles quadrangle the more important localities for the Jamesville limestone are the following:

Limestone escarpment in the western one-half mile of the quadrangle. In this belt the edge of the scarp is Ólney limestone. Higher components of the limestone mass are found farther south upon the terrace. Just west of the westernmost south-leading road and just south of the roughly east-west road blocks of a weathered bluish limestone are found. These are referred to the Jamesville. Below occur Clark Reservation and Elmwood in descending order. Very similar rock, also assigned to the Jamesville, occurs a short distance east of the south-leading road. Its outcrop is in a small patch of woods.

Limestone escarpment three-fourths of a mile to one and one-half miles east of the western boundary of the quadrangle. Throughout this stretch the Jamesville is apt to form the top of the scarp. It also makes the surface rock of broad terraces where blocks of limestone protrude from the soil. Under such conditions there are good opportunities for the study of its fossils (figure 10). The fauna is not a diversified one but individuals are extremely abundant. The

Jamesville of this belt is highly characteristic and its stratigraphic relations are clear. The beds are not in vertical section, it is true, but the disposition of field outcrops and block rows confirms the presence of Olney, Elmwood and Clark Reservation below the Jamesville and of Oriskany sandstone and Onondaga limestone above it.

Skaneateles Falls. As in the cases of the Elmwood and Clark Reservation formations, the Carrigan quarry east of Skaneateles creek furnishes the best vertical section (12 feet, 9 inches) of the Jamesville within the area (figure 6). The limestone rests with a sharp, but probably conformable, contact upon the Clark Reservation. Although having the same general blue color as this latter formation the joint faces of the Jamesville are quite different. They present broad flat surfaces to the observer and usually display in greater or less degree the crinkly subordinate bedding planes. The underlying Clark Reservation does not show these, and its exposure is, through diagonal jointing, a series of prominences and reentrants. Above, the Jamesville is truncated by the unconformity (disconformity) below the true Oriskany sandstone.

The Jamesville is also present south of the bridge at Skaneateles Falls and likewise at the top of the quarry just east of the Cayuga-Onondaga county line. At this latter station it is in section with the Elmwood and Clark Reservation.

Devonian Rocks

Oriskany Sandstone

The term "Oriskany" was proposed by Vanuxem ('39, p. 273). It has been long employed for the quartz sandstone or sandstones which separate the Onondaga limestone from the calcareous beds below. In elucidating the Oriskany, Vanuxem ('42, p. 123, 124, woodcuts 28, 29) mentions and figures representatives of the fauna dominated by *Spirifer arenosus* and its associates. Eaton's list of species ('21, p. 428) from the type locality at Oriskany Falls (Sangerfield quadrangle) indicates the same zoologic assemblage. On the Skaneateles quadrangle this fauna is abundant only in the lower part of the lowest tier of sandstone, that is, through a thickness of less than a foot. The question then arises whether or not the sandstone which may extend in some cases 20 feet higher should also be included under the term "Oriskany." This higher sandstone is usually without fossils, although rather obscure brachiopod casts associated with phosphatic nodules have been found. There would be no objection to grouping these upper layers with the *Spirifer*

Figure 10 Stromatoporoids in Jamesville limestone. About three-fourths of a mile east of western boundary of Skaneateles quadrangle. (Photograph by E. O. Smith, November 10, 1930)

Figure 11 Onondaga limestone. West of Skaneateles Falls. Note flint (chert) nodules in limestone matrix. (Photograph by E. O. Smith, November 14, 1930)

arenosus zone were it not for the fact that many localities in central New York show a sandstone which is clearly a reworked Oriskany of Onondaga age. One of the best examples of such a condition is seen at Split Rock (Syracuse quadrangle), where there is no true Oriskany sandstone. A similar state of affairs prevails near Marcellus Falls (Baldwinsville quadrangle) in the Ninemile Creek valley. Farther south in this valley, within the area covered by this report, sections do not show the sandstone horizon. For the Skaneateles quadrangle then one is forced to draw conclusions from the quarry at Skaneateles Falls and from field outcrops northeast and west. A study of these exposures has led the present writer to the belief that much of the sandstone may be reworked Oriskany of Onondaga age. In the belt considered, however, complete sections of the sandstone are not found, nor are positive criterions at hand for a general scientific discrimination of true Oriskany and the reworked Oriskany which usually makes up the basal part of the Onondaga limestone. It is felt that from the standpoint of areal geology, the only practical course is to treat the sandstone as Oriskany except in those cases where it is present in the same joint block with Onondaga limestone.

At Skaneateles Falls the Oriskany is best seen in the western part of the Carrigan quarry east of Skaneateles Creek (figure 6). There the sandstone clearly rests unconformably (disconformably) upon Jamesville limestone. The lower surface of the Oriskany is irregular, having an eroded formation for its support, while at least one piece of blue limestone (presumably Jamesville) has been seen incorporated in the sandstone. The lower part of the lowest tier of sandstone yields the *Spirifer arenosus* fauna. This bed can be safely correlated with the true Oriskany. Above it, fossils are rare if one excepts the pipelike "fucoids" noted by Vanuxem ('42, p. 126) and the poorly preserved casts associated with phosphatic nodules. At this quarry a continuous section from bottom to top of the sandstone has not been found but in places there may be 15 feet of it.

Field outcrops northeast of Skaneateles Falls, but on the Skaneateles quadrangle, seem to be without the *Spirifer arenosus* fauna. In these, contacts with contiguous strata are invisible but there is nothing to prove that the sandstone is more than 15 feet in thickness. A short distance over the boundary, on the Baldwinsville quadrangle, however, the sandstone bed can not be less than 20 feet thick.

West of Skaneateles Falls just beyond the Cayuga-Onondaga county line the Oriskany sandstone is probably not more than three

or four feet thick, a marked reduction from the thickness at the nearby Carrigan quarry.

Farther westward in Cayuga county a number of exposures and block rows occur. The best examples of these, however, have been found where the sandstone belt passes north of the roughly east-west road which runs along the limestone "ledge." A diminished thickness for the sandstone, almost certainly under five feet, is indicated in this western part of the quadrangle.

The "lenticular" structure of the Oriskany has long been known (Clarke, 1900, p. 991, 992) but it is unfortunate that sections are neither sufficiently numerous nor complete to furnish an adequate explanation for the westward thinning of the Oriskany sandstone of this area. As an hypothesis, Onondaga erosion may be invoked to account for this reduction in thickness, but it is possible that the history has been more complex.

Onondaga Limestone

The term "Onondaga" was proposed by Hall ('39, p. 309). It is now generally used to include those calcareous beds which intervene between the Oriskany sandstone below and the first black shales of the Marcellus (Union Springs member) above. There are several phases of the limestone: the compact and flint-bearing or "Corniferous" variety, the crystalline "gray lime," and at least two shaly phases one of which is dark to black, the other greenish in color. The limestone proper, both compact and crystalline, is prevailingly gray. This is in strong contrast to the series of blue limestones below the Oriskany. The chert or flint nodules may run from almost black, through gray, to nearly white in color.

The Onondaga limestone of New York and adjacent states rests unconformably (disconformably) on older rocks (Kindle, '13, p. 301–19). As far as observed in the present area, the underlying formation is Oriskany sandstone. That this is always the case throughout the quadrangle can not be stated, for the base of the Onondaga is covered in the Ninemile Creek valley about Marcellus and the conditions there are unknown. Near Marcellus Falls (Baldwinsville quadrangle) the Onondaga lies upon the Elmwood division of the Manlius without the intervention of true Oriskany sandstone. A similar condition may very probably prevail about Marcellus but the question can not be answered with the data at hand.

As a component of the limestone escarpment in the western portion of the Skaneateles quadrangle, the Onondaga is more characteristic of the flat or rolling terrace than of the scarp itself where

lower limestones are more prominent. Such a condition prevents anything like an accurate measurement of the thickness of the formation. The 20 or 30 feet of Onondaga strata next above the Oriskany sandstone may be measured roughly, but soon the limestone forms the surface of the terrace where layers, even if horizontal, are difficult to trace. Horizontality, however, is not prevalent on the terrace, which is largely characterized by minor quaquaversal folds. Most of these were apparently formed near the surface with resultant displacement of joint blocks. Having due regard for the uncertainties produced by such factors, it is probable that a rough estimate of 60 or 70 feet is allowable for the thickness of the Onondaga limestone of the Skaneateles quadrangle. It can not be too strongly emphasized that such numbers represent nothing more than a probability.

In view of the absence of good sections it is not always easy to say which variations of the Onondaga are stratigraphic, which geographic. As far as observed, however, the crystalline phase is not strongly developed in the area and it appears to be limited to some ten feet of strata at base which are without the flint (or chert) nodules so common in the upper part of the formation. The nodules of these higher compact beds are usually arranged in bands. They are often of large size and irregular in shape. Occasionally they have coalesced in such a way that a definite stratum of flint is formed with virtual exclusion of the limestone matrix. Such a case is seen, near the top of the formation, in the large Malley quarry at Marcellus.

The fauna of the Onondaga is not only quite a diversified one but its individuals may be so crowded that they appear to make up the bulk of the rock. Corals, crinoid stems (often large), brachiopods, gastropods, and trilobite fragments are apt to be abundant. Corals seem to be more numerous in the lower somewhat crystalline portion of the formation, while brachiopods and trilobites are more common, or at least more evident, in shaly layers toward the top. In the upper part of the formation occurs also the *Chonetes* zone with its frequently pink shells.

For the Skaneateles quadrangle the more important Onondaga limestone localities will now be noted:

Stream flowing west about one and one-tenth miles south of the northwest corner of the quadrangle. From the western boundary of the quadrangle, in going upstream, isolated patches of Onondaga limestone are encountered. These are much disturbed showing dips northerly and southerly in turn. Toward the top of the Onondaga about 17 feet of relatively undisturbed strata produce a continuous

section. At about the middle of the section the *Chonetes* zone occurs. Some of the shells show the characteristic pink color. The strata are flint-bearing, and, at two horizons above the *Chonetes* zone, nodules of this substance have coalesced almost to the point of forming definite layers.

Westernmost south-leading road in northwest corner of quadrangle. Along this road and in the fields west of the hill marked 803 on the base map, outcrops of Onondaga limestone are seen. To the north there is a decided northerly dip, but on following south along the road the strata first become horizontal and finally assume the gentle southerly regional dip.

Limestone escarpment about two-fifths of a mile west of Skaneateles creek. Here an imperfect section of the lower 20 or 30 feet of Onondaga may be obtained. For a few feet above the Oriskany sandstone corals are numerous and the limestone fairly crystalline. About five feet higher a zone of small flints was noted. The upper eight or ten feet of the section show a compact limestone in which several bands of large flint nodules are present. Although the limestone matrix is not excluded from these bands there has been a tendency for the nodules to coalesce (figure 11).

Skaneateles creek at the meander southeast of Marysville. At this eastward-swinging stream bend, both natural and artificial outcrops of Onondaga limestone are displayed. Skaneateles creek flows across a few of the limestone layers, and excavations have been made both east and west of the stream. On the west, two shallow quarries have been made. On the east side, an old mill race has been sunk into the limestone, while east of the race the section is continued upward in what is probably a natural outcrop. About 15 feet of flint-bearing strata are exposed. At the northern end of the mill race a sudden northward dip occurs. Where most extreme this is slightly over 20°. Calcite veins in association with this structure indicate that it is not of surface origin. The conditions suggest a fault, but no actual dislocation of the layers has been found.

About seven-tenths of a mile north and slightly west of the above locality, the Onondaga is again encountered on Skaneateles creek. This is at the Draycott mill, where a few feet of limestone are exposed just below the dam.

Northrup quarry about one and four-fifths miles east of Skaneateles creek and at or near the northern line of the quadrangle. About 20 feet of strata are exposed in this quarry. The beds are mostly coarse and heavy and are characterized by flint masses and bands. Near the top of the south wall of the quarry pink shells have been

noted, but the *Chonetes* zone has not been recognized. Toward the top of the north wall of the quarry three thin shaly partings occur in a thickness of two and one-half feet of limestone. These partings separate limestone tiers. They are not only quite fossiliferous but their fossils are more easily obtained than are those of the limestone.

At head of "Gulf" or Guppy Gulf valley between Skaneateles Falls and Shepard Settlement. This Onondaga area is a southward projection of the limestone terrace of the Baldwinsville quadrangle. In its northern part the joint blocks indicate that the layers are still intact. In the southern part, however, several small sinks occur and the disturbed condition of the blocks points to considerable rock solution beneath the surface. The area shows the general sequence of Onondaga strata from the Oriskany sandstone (Baldwinsville quadrangle) almost to the base of the Marcellus north of "Mud lake" or "Mud pond" (the more western on the quadrangle). No accurate estimate of Onondaga thickness can be made for this region.

Large Malley quarry just southeast of Marcellus Village and south of the Hollow road. About 15 feet of strata are exposed here. The rock is mostly very fresh and in good condition. Except for the upper foot or two the limestone is in definite tiers, many of which can be followed through the quarry. Well up in the section the *Chonetes* zone is found, indicating that the top of the Onondaga is not far above. This zone is about four feet thick, being distributed through a flint layer, five thin tiers of limestone, and the upper part of still another limestone tier at base. In the lower two feet and nine inches of the quarry section *Dalmanites selenurus* is abundant (figures 12, 13).

Small Malley quarry southeast of Marcellus Village and north of Hollow road. The Onondaga strata exposed in this quarry are near the top of the formation. The chief interest of this locality is furnished by a thrust fault of a small throw. This displacement was presumably known to Vanuxem and has been mentioned or described by a number of later writers (Vanuxem, '39, p. 277; Luther, '98, p. 294; Schneider, '99; Hopkins, '14, p. 39, 40). It is one of the few proved faults in the area and until recently showed excellent views in both plan and section. Its further consideration is taken up in the part of the report dealing with structural features (figure 61).

Cedarvale. Back of the Cedarvale Mills, and northeast and southeast of the road junction, Onondaga limestone is shown in imperfect sections to a thickness of 15 or 20 feet. The exposures are partly

natural and partly artificial and approach very near the top of the formation.

In the Cedarvale channel (South hollow, Pumpkin hollow) between Cedarvale and Marcellus there is much swamp land. It is not at all unlikely that Onondaga inliers are buried under this, but, with positive evidence of their presence lacking, it has been thought better to represent the area with Marcellus as the bed rock except at its eastern and western ends where Onondaga limestone is known to occur at the surface.

Hamilton Group

The term "Hamilton" was proposed by Vanuxem ('40, p. 380) at an early date in the history of New York geology. Changes in its meaning and attacks on its validity have not prevented the survival of the term. It is employed in this report for the mass of shale, with subordinate amounts of limestone and sandstone, which is bounded below by the Onondaga limestone and terminated above by the Tully limestone. In subdividing the group a classification recently proposed by Cooper ('30, p. 118) has been extensively utilized. This author arranges a number of minor stratigraphic and faunal units, which he calls members, under the four well-known formational names—Marcellus, Skaneateles, Ludlowville and Moscow. He likewise presents evidence that an unconformity occurs at the top of the group.

For the Skaneateles quadrangle the contact of basal Hamilton with Onondaga limestone is known at but one locality. Here the line of division is apparently sharp but it is felt that the local evidence is inadequate for the support of either of the two divergent views on Hamilton (Marcellus)-Onondaga relations. It is sufficient here to note that Clarke and later Grabau have spoken in favor of gradual replacement and transgression while Chadwick presents evidence of an unconformity in eastern New York (Clarke, '01, p. 115, 137, fig. 2; Grabau, '06, p. 231, fig. 187; Chadwick, '26, p. 10).

Marcellus Formation

The term "Marcellus" was proposed by Hall ('39, p. 295) in 1839 and was used the next year by Vanuxem ('40, p. 379, 380) to include the strata from the Onondaga limestone below to what is probably the Mottville member of the Skaneateles shale above. Within the area of this map, four subdivisions of the Marcellus are recognized. These are the Union Springs, Cherry Valley, Chittenango and Cardiff. With the exception of the last named these

Figure 12 Onondaga limestone. Large Malley quarry at head of Cedarvale channel near Marcellus. Hammer shows position of flint (or chert) band in the *Chonetes* zone of the upper part of the formation. (Photograph by E. O. Smith, November 11, 1930)

Figure 13 Onondaga limestone. Large Malley quarry. Gentle regional southern dip not shown. (Photograph by E. O. Smith, November 11, 1930)

members appear to extend across the quadrangle. The Cardiff, although well developed in the eastern part of the area, is not recognizable as a separate unit at the western boundary.

Union Springs member. This name is applied by Cooper ('30, p. 132) to the strata which intervene between the top of the Onondaga limestone and the bottom of the Cherry Valley or Agoniatites limestone. The type section is in the Wood quarry about one mile south of Union Springs, N. Y. (Auburn quadrangle). Here the Union Springs is 17 feet thick, being made up of alternations of sooty shale and dark to gray limestone. The limestones become more predominant in the lower part of the member so that superficially at least it appears to grade upward from the subjacent Onondaga. This gradation, actual or apparent, may account for some of the variation in recorded thickness of the Union Springs member.

For the Skaneateles quadrangle only one complete section of the Union Springs is known to the writer. This is at the mouth of a small ravine a short distance northwest of the Jackknife ravine and approximately seven-tenths of a mile southeast of Marcellus. Here the entire sequence is shown from limestone believed referable to the Onondaga up to the bottom of the Cherry Valley. The thickness of the Union Springs, so limited, is about eight and one-half feet, or half that of the type section.

In the summer of 1932 road improvement between Marcellus and Cedarvale brought to light interesting sections of the Union Springs (figure 14).

There are a number of other places on the quadrangle where the Union Springs is found either in very limited outcrops or in loose blocks which are rather clearly only slightly removed from the parent ledge. The more important of such localities are the following: about one-half of a mile northwest of Cedarvale, about three-tenths of a mile southeast of the center of Marcellus Village along the highway to Slate Hill, the Syracuse water supply pipe line about one-third of a mile southeast of Marysville.

The Union Springs, together with the Chittenango member of the Marcellus, is responsible for the black and brownish soils so common in the region of Marcellus outcrop.

The most abundant fossil in the Union Springs is the minute pteropodlike shell *Styliolina fissurella*. It occurs in great numbers on many of the slabs and appears actually to form some of the thin limestone layers.

Cherry Valley member. The name "Cherry Valley" was proposed by Clarke ('03, table 2) in 1903. It is now applied to the heavy

tier of dull bluish black limestone which caps the Union Springs member and which was formerly known as the Agoniatites or Goniatite limestone. Its thickness seems to be about two or three feet in the area covered by this report. Weathered surfaces of the limestone may approach gray in color but the fresh material is invariably of darker shades and almost always shows veins of rusty mineral matter. If not too much weathered, the limestone emits an odor when struck. The rock tends to break up into irregular blocks. This facilitates collecting its interesting fossils. These are lacking or rare in some localities but most exposures of the limestone will yield *Orthoceras marcellense* and *Agoniatites expansus,* although not always abundantly nor as good specimens. *Styliolina fissurella* can usually be found, and less often representatives of the small brachiopods of the faunule. Occasionally fragments of Arthrodiran plates occur. The trilobite *Proetus* is not uncommon in eastern outcrops, but the writer has no record of it from the Skaneateles quadrangle.

As a rule the Cherry Valley limestone can be found either in outcrop or in loose blocks at localities where the Union Springs occurs. Like the Union Springs, however, it is often lost under the wash of fine detritus from the hills of Chittenango and higher shale. On this account there are surprisingly few good exposures of the Cherry Valley within the area.

Among the Cherry Valley localities on the Skaneateles quadrangle the following may be mentioned: about one-half of a mile northwest of Cedarvale, Jackknife ravine slightly over one mile southeast of Marcellus, small ravine about seven-tenths of a mile southeast of Marcellus, highway north of "Mud lake" or Mud pond between Shepard Settlement and Skaneateles Falls (stone pile), Syracuse water supply pipe line about one-third of a mile southeast of Marysville.

Very recent road improvement between Marcellus and Cedarvale has resulted in good exposures of the Cherry Valley limestone (figure 14).

Chittenango member. The black shale above the Cherry Valley limestone has been designated the Chittenango member of the Marcellus by Cooper ('30, p. 131). The type section is near Chittenango Falls (Cazenovia quadrangle). This shale is the Marcellus *par excellence,* which, so to speak, typifies the formational series. It is quite clear, however, that the term "Marcellus" should not be used in a larger sense for the series and in a more restricted way for the black beds above the Cherry Valley. A separate name for this shale is justified, although many geologists will probably regret the discontinuance of the older term for the rock in question.

The member is a black shale which is easily disintegrated into thin plates. Often the edges of the laminae as well as their flat surfaces, may be stained a rusty yellowish brown. Black, however, is the prevailing color in fresh material. Large concretions are a conspicuous feature in the lower part of the member. An almost complete absence of fossils usually characterizes both the black shale and the concretions.

Although the base of the Chittenango is well defined by the Cherry Valley limestone (figure 14), its top is impossible of precise delimitation at most localities. This is due to a gradation into overlying gray Cardiff shale. In its characteristic manifestation, each of these members is distinct from the other but within the transition zone criterions are intangible. In fact, colors in the shale are influenced, in no small degree, by such variable factors as light and shadow, moisture and dryness. In the Marcellus region about 90 to 100 feet of shale can be claimed as black and assigned to the Chittenango. The thickness may be slightly greater to the east but it suffers a considerable reduction in the western part of the quadrangle.

Many Chittenango outcrops are found on the Skaneateles quadrangle. Most of these are limited and not in continuous section with other strata. Some of the more important outcrops will now be noted.

Stream flowing west onto the Auburn quadrangle about one and one-tenth miles south of the northwest corner of the Skaneateles quadrangle. At this locality the basal contact of Chittenango and Cherry Valley is obscured. About five feet of typical Chittenango shale with large concretions are exposed. This is overlain by a few feet of grayer material also referred to the Chittenango. A *Leiorhynchus* zone follows and above this in turn come beds typical of the Mottville member of the Skaneateles. The section was figured somewhat diagramatically in 1916 with what is now called Chittenango shown in contact with Mottville (Smith, '16, p. 564, pl. XXII). It is believed that the interpretation then given is substantially correct, although it is possible for one to regard as Cardiff some of the grayer strata just above the typical Chittenango. In the present report the former interpretation is followed, although this may necessitate a slight expansion of the term "Mottville."

Cottle hill. On the north flank of Cottle hill a small ravine is shown by contours on the base map. Here typical Chittenango is exposed for a few feet but it is not in continuous section with higher and lower beds. The Mottville member of the Skaneateles, however, is not far above it in the section. The Cardiff shale, if present,

can hardly be represented by more than a few feet of strata (Smith, '16, pl. XXII, 3).

Between Cottle hill and the Ninemile Creek valley incomplete outcrops of Chittenango occur in the northern part of the "Gulf" or Guppy Gulf valley, which extends southward from the "Mud lake" or "Mud pond" west of Shepard Settlement.

Slate hill. From about one-half of a mile to slightly over one mile south of Marcellus village the Chittenango member is well, although incompletely, displayed on the western flank of Slate hill. The hill in question is at the junction of Ninemile Creek valley and the Cedarvale channel, being on the east side of the former and on the south and west sides of the latter. Slate hill is rather generally regarded as the type locality for the Marcellus formation.

Jackknife ravine. In a strictly geographic sense this should be considered under the preceding heading for the ravine is cut into the eastern side of the promontory separating Ninemile Creek valley from Cedarvale channel. In view of the fact that "Slate hill" has been employed locally in a somewhat restricted manner the present heading is used in the hope of obviating confusion. The Jackknife is the sharply bent ravine which is shown joining its trunk stream about one and one-fifth of a mile southeast of the main bridge in Marcellus village. The section is a nearly complete one from the Cherry Valley limestone to the Mottville (Smith, '16, pl. XXII, 5). It therefore includes the Chittenango which is nearly all visible. The actual contact of Chittenango with subjacent Cherry Valley is not shown but the passage beds from the Chittenango into overlying Cardiff are well displayed. If these be placed largely in the Cardiff, the Chittenango member will total up to about 90 or 100 feet in thickness. At this locality the usual large concretions characterize the Chittenango.

Ravine on north side of Cedarvale channel about one-third of a mile north of Cedarvale. At this locality about 75 feet of Chittenango shale are exposed in an almost continuous section. Contacts with lower and higher members are not shown but the section is very typical of the Chittenango. Concretions are large and numerous at this locality. The section has the advantage of accessibility, for an improved highway has been built in the ravine.

Ravine about one and one-tenth of a mile south and west of Cedarvale. A fair exposure of the Chittenango occurs in the central stream as depicted on the map. The passage beds into the overlying Cardiff furnish a nearly complete section.

Stream one and one-half of a mile south and a little west of Cedarvale. The Cherry Valley limestone is exposed just below the road

Figure 14 Massive Cherry Valley limestone overlain by thinly bedded Chittenango shale and resting upon the interbedded shale and limestone of the Union Springs member. Cedarvale channel about seven-tenths of a mile southeasterly from Marcellus. The Cherry Valley limestone is here about two feet, two inches thick. (Photograph by E. O. Smith, October 9, 1932)

Figure 15 Marcellus (Chittenango) shale. North side of Cedarvale channel. Note concretion in place just above hammer. (Photograph by E. O. Smith, November 11, 1930)

which crosses the stream at a point about one-fifth of a mile from the eastern boundary of the quadrangle. Just above (south of) the road typical Chittenango shale with concretions is seen. A discontinuous section of the lower part of the Chittenango and a much better one of its higher part and passage beds into the Cardiff are found in the ravine. A thickness of 100 to 110 feet is assignable to the Chittenango.

Cardiff member. The term "Cardiff" was proposed by Clarke and Luther ('04, p. 16) for the upper gray shale of the Marcellus. The type region is about Cardiff, N. Y. (Tully quadrangle), where the gray shale is apparently 175 feet thick (Clarke and Luther. '05, p. 45). At this locality it lies between black Chittenango shale below and the Mottville member of the Skaneateles above (Cooper, '30, p. 132).

Westward on the Skaneateles quadrangle an appreciable diminution of thickness is noted. Although the gradational nature of the lower portion of the Cardiff precludes exact figures, the probabilities are that 125 to 130 feet is an ample allowance for Cardiff thickness in the eastern part of the Skaneateles quadrangle.

In the Jackknife section southeast of Marcellus village not more than 95 or 100 feet are permissible for the Cardiff, while in the belt south of Shepard Settlement the reduction seems to have brought the member down to 50 feet or less in thickness. At Cottle hill very little if any of the section is definitely assignable to the Cardiff, while in the stream that passes over the western boundary of the quadrangle about one and one-tenth of a mile south of the northwest corner, the presence of the member has not been proved and the Chittenango and Mottville appear to be in contact (figure 16). This westward disappearance of the Cardiff was first announced in 1916 (Smith, '16) but unfortunately not until after several geological maps had been published depicting a "Cardiff" shale in western New York.

Skaneateles Formation

The term "Skaneateles" was proposed by Vanuxem ('40, p. 380) for the shale mass which intervenes between the Marcellus and the Ludlowville. Vanuxem's type region at, or about, the northern end of Skaneateles lake contains so few outcrops that one would hardly be justified in retaining a name based upon these alone. Nevertheless, as pointed out by Cooper, Vanuxem (Vanuxem, '42, p. 154, 155) delimited the Skaneateles on Cayuga lake. This has made the formation recognizable. In the present report the term is used

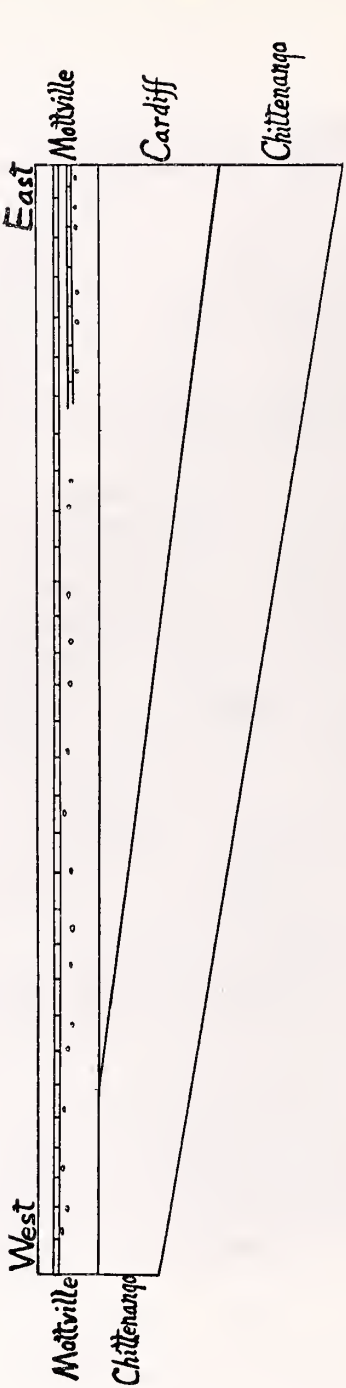

Figure 16 Diagram section showing relations of Chittenango, Cardiff and Mottville members on the Skaneateles quadrangle. Member contacts are transitional. Chittenango and Cardiff sedimentations are probably in part contemporary. Not drawn to scale.

to include Vanuxem's Skaneateles plus the Centerfield which is usually placed in the Ludlowville. Even should the faunule of the Centerfield prove closely related to those of higher beds, the member itself is clearly marked off from these by one of the most pronounced and widespread stratigraphic changes within the Hamilton of the area covered.

Viewed then from a stratigraphic standpoint the Skaneateles comprises (*a*) the Mottville limestone and shales at base, then (*b*) a mass of undivided shale which (*c*) grades upward into the hard and massive arenaceous-calcareous shale which is usually called Centerfield. The undivided shale (*b*) just mentioned, includes the Delphi, Pompey and Berwyn shales of Cooper ('30, p. 219–21).

Mottville member. This name was applied in 1916 (Smith, '16, p. 562) to the thin limestone and associated gray shales which separate the higher portions of the Skaneateles from the Cardiff and Chittenango shales below. From the paleontologic viewpoint the Mottville is noteworthy (1) as being a highly fossiliferous zone between relatively barren shales and (2) as containing at least in its upper part fossils which are more especially characteristic of higher beds. Stratigraphically the Mottville includes 20 or 25 feet of shale followed by a thin limestone, which in turn is capped by a few feet of moderately hard shale. Neither at base nor at top is the member provided with definite limital contacts. It is believed to be in the best interest of stratigraphy to extend the lower shale downward slightly at the expense of underlying beds in such a way as to bring in 25 or 30 feet of shale below the thin limestone stratum. Above this stratum about 15 or 20 feet of shale should be included in the Mottville. The member, so conceived, comprises 40 to 50 feet of strata.

In addition to its paleontologic importance the Mottville is of physiographic interest. The limestone band and upper hard shales are much more resistant than underlying and overlying shales. They therefore commonly produce waterfalls and in the western part of the quadrangle a well defined terrace with north and northwestward facing scarp. The "two-story" nature of the "Gulf" or Guppy Gulf valley (Chadwick, '23, p. 500; Fairchild, '09, pl. 4) south of Shepard Settlement is partly due to this greater durability of the harder portions of the Mottville. These form the upper shelf of the valley for some distance along its south and west wall.

Being conspicuous both paleontologically and physiographically, the Mottville is easily traced along its outcrop. This was done in 1915 (Smith, '16) and brought out the surprising fact that the under-

lying Cardiff shale, well developed toward the east, disappears or fades away when followed west, bringing the Mottville into actual contact with the black shale (now Chittenango shale) of the Marcellus (figure 16). The Mottville is therefore a key horizon in central New York, and a failure to grasp its importance has resulted in many false interpretations of the stratigraphy. This is especially the case in the belt beginning with the Auburn quadrangle and extending to Lake Erie.

Within the area covered by this report the more important Mottville sections will now be noted. Several of them were figured or mentioned in the paper just cited.

Stream flowing west onto the Auburn quadrangle about one and one-tenth of a mile south of the northwest corner of the Skaneateles quadrangle. Following upstream from the Onondaga limestone an approximately north-south road is met. A short distance east of this road Chittenango shale is encountered. Next above comes a *Leiorhynchus* zone. Although it is perfectly possible to assign this zone to the chiefly negative Cardiff, the present writer prefers its reference to the Mottville. Whichever interpretation one favors, it can be stated with certainty that the Cardiff as typically developed toward the east is no longer present.

According to this view, the Mottville is here in contact with the Chittenango and it begins with the *Leiorhynchus* zone above mentioned. Slightly more than ten feet higher in the section comes an *Ambocoelia* bed which apparently truncates the shale below it slightly. This truncation, however, is regarded as due to subaqueous erosion on the bottom of a shallow sea rather than to a true unconformity. From here on the section is almost continuous to the crinoidal limestone band and the hard shale above it. A thickness of 50 or even 55 feet is here assignable to the Mottville.

Cottle hill. The crinoidal limestone of the Mottville with associated shales above and below is exposed in a small ravine on the north flank of Cottle hill. Although the Mottville is not in continuous section with the Chittenango the latter is seen about 20 feet lower. In this interval the Cardiff may be present but in any case greatly reduced in thickness.

Mottville. The type locality is on Skaneateles creek just south of Mottville. How much a probable natural outcrop has been enlarged through railroad construction it is not now possible to say. West of the creek, the Mottville is exposed along the line of the Skaneateles Railroad while east of the creek the building of a railroad spur appears to be largely, if not entirely, responsible for a

good exposure. The type section shows the thinly bedded shale, the concretion zone, the crinoidal limestone band, and at top the more coarsely bedded shale. Fossils are abundant. A structural feature of interest is the gentle northerly reverse dip shown by the beds at the spur (figure 17).

Stream flowing into the "Gulf" or Guppy Gulf trunk stream about two and one-half miles northeast of Skaneateles and about one and three-fifths miles below Mud pond. At this locality there is an excellent outcrop of the Mottville crinoidal limestone and associated shales above and below. A group of three *Ambocoelia* beds is found about 15 feet below the limestone. These are probably equivalent, at least in part, to the *Ambocoelia* bed noted at about the same horizon near the western boundary of the quadrangle. At this "Gulf" locality some 35 to 45 feet of shale below the Mottville are assignable to the Cardiff.

Thorne ravine on southwest side of Guppy Gulf about midway between Skaneateles and Marcellus. Here the Mottville is almost completely exposed. Some 25 feet of shale below the Mottville are probably all to be assigned to the Cardiff. Above, the section passes into shales higher than the Mottville.

Jackknife ravine. The brook of this ravine is shown joining its trunk stream about one and one-fifth miles southeast of Marcellus. The ravine is sharply bent and has been cut into the promontory which partly separates Ninemile Creek valley from the Cedarvale channel (South hollow). This is an important locality for it shows the Mottville in almost continuous section with Cardiff, Chittenango and Cherry Valley in descending order. If the Chittenango—Cardiff transition zone is given to the Cardiff, this latter member has a thickness of about 95 or 100 feet. The conditions are here quite different from those encountered in the western part of the quadrangle where Chittenango and Mottville are in contact. From the Jackknife eastward the Mottville lies far above the black Chittenango shale, being separated from it by 100 or more feet of gray Cardiff shale. At the Jackknife, the limestone band of the Mottville and its overlying hard shale cause the waterfall near the head of the ravine.

Ravine on south side of Cedarvale channel (South hollow) about two miles southeast of Marcellus. In this ravine the Mottville outcrop is part way up the section. Below it, the Cardiff shale is exposed somewhat discontinuously through a thickness of about 90 feet. Above the Mottville, higher shale of the Skaneateles is exposed in an almost continuous section through a thickness of about 115 feet.

Ravine about one and one-tenth miles south and west of Cedarvale. The Mottville is exposed toward the top of this section. It contains two limestone bands with a concretion zone below. At this locality the Mottville appears to be underlain by at least 120 feet of gray Cardiff shale.

Ravine one and one-half miles south and a little west of Cedarvale. A rather limited outcrop of Mottville is found toward the top of the section. It includes a limestone band with a concretion zone and some shale below.

Ravine at east margin of quadrangle two and one-fifth miles south of Cedarvale. This section is a very extensive one beginning with the black concretion-bearing Chittenango (Tully quadrangle) and ending well up in the Centerfield member of the Skaneateles (Skaneateles quadrangle). The Mottville is here underlain by some 120 feet of Cardiff, while above, the section is almost continuous into the Centerfield. At this locality there are two thin limestone bands in the Mottville.

Skaneateles shale undivided. In the present report this designation is applied to the strata that intervene between the Mottville below and the Centerfield above. Cooper ('30, p. 219–21) divides the beds in question into three members, Delphi, Pompey and Berwyn in ascending order. Aside from sequence and except for thicknesses, apparently quite variable, that author has not yet furnished criterions for the certain discrimination of these subdivisions. Pending the publication of his extended report on the Hamilton, it is deemed best to treat these three members as undifferentiated. Cooper gives a thickness of 160 feet for the Delphi, 80 for the Pompey and 100 for the Berwyn of the Skaneateles Lake region. This totals 340 feet. The strata involved, however, are only well displayed in the extreme eastern part of the quadrangle, where the present writer has obtained a thickness of about 250 feet for the beds between the Mottville and the lower part of the Centerfield.

The beds covered by the names "Delphi," "Pompey" and "Berwyn" are, on the whole, fine and rather barren shales in which thin layers full of fossils occur at different levels. Thin limestones are present in places while one arenaceous lens or wedge has been noted. A somewhat well-defined concretion zone is perhaps to be correlated with the upper part of the Pompey member.

On the Skaneateles quadrangle complete sections of these beds occur in the ravines at the eastern boundary which are two and one-fifth and two and two-fifths miles, respectively, south of Cedarvale. The Clintonville ravine gives an extensive but incomplete exposure.

The lower portion of the series is exposed in the Thorne ravine on the south side of Guppy gulf midway between Skaneateles and Marcellus and in the ravine on the south side of Cedarvale channel (South hollow) about two miles southeast of Marcellus. The upper and middle parts of this shale mass are found in the Pudding Mill gully on the west side of Otisco lake about two miles from the foot, and at many other ravines on the west side of the Otisco valley. On Skaneateles lake the beds below the Centerfield are perhaps best shown in a ravine on the east side two and three-fourths miles north and slightly west of Fivemile point. Numerous although somewhat limited sections occur along the shores of the lake.

Centerfield member. The term "Centerfield" was proposed by Clarke ('03, p. 22) in 1903. Cooper ('30, p. 223) correlates the beds at Fall Brook point, Hall's landing and Rose Hill with the Centerfield of Cayuga lake and westward. The name is used in the present report in almost the same sense but the member has been transferred from the Ludlowville to the Skaneateles on account of its stratigraphic relations. These are certainly closer with the finer shale below from which it is transitional. Above, on the other hand, the Centerfield, as here limited, is marked off sharply from a highly fossiliferous and fine gray shale. This seemingly sudden change at the top of the Centerfield appears to be universal throughout the quadrangle. The abrupt line between hard rock below and soft rock above is responsible for numerous cascades and waterfalls and, more especially on the ridge between the Skaneateles and Otisco valleys, for a certain amount of scarp and terrace topography.

Lithologically the Centerfield of this area is difficult to define. It might be described as a very coarse shale often approaching limestone but sometimes resembling a fine sandstone. It is apparently always high in calcium carbonate and it is probably never without small grains of quartz. Although becoming less calcareous and more arenaceous in going from west to east, one can hardly question that some of its variations in appearance are due to different degrees of weathering. Fresh material appears to be, and undoubtedly is, more limy than weathered blocks which may approach sandstone in character. Wave-produced ripple marks and cross-bedding have been observed, and both indicate a shallow water origin for the Centerfield. Corals, trails and the Taonurus-Spirophyton markings seem also to support this view.

Exposures of all or much of the Centerfield are numerous within the Skaneateles quadrangle. In the deep lake valleys practically

every stream which is depicted as crossing a Centerfield belt falls over or is cascaded down much of the member. Passing northward in the quadrangle outcrops become poorer and less frequent. The northern part of the Baptist Four Corners outlier and the entire outlier west of Navarino are hypothetical. In the central and southern parts of the quadrangle, on the other hand, there is probably no member or formation as well displayed as the Centerfield. Noteworthy localities are the Skaneateles lake shore at and near Carpenter point, and again, south of Tenmile point to and beyond Hall's landing; almost every ravine on the west side of Otisco lake; Gambell's gulf at the east end of the Otisco causeway; Rose Hill. The best place to observe the sharp contact of Centerfield and overlying soft shale is just south of Hall's landing (about three-fourths of a mile northwest of Barber point) where the Centerfield dips below lake level (figure 18). The same contact is shown at Carpenter point and at Rose Hill. At most other localities the actual line is usually covered with stream wash but sections are numerous where the hard Centerfield and the soft shale above are only a few feet apart.

As the Centerfield is transitional from the beds below it is not possible to give a definite thickness for the member. Usually one finds 30 or 40 feet of hard strata below the Centerfield—Otisco contact.

Ludlowville Formation

The term "Ludlowville" seems to have been originally used by Hall ('39, p. 298) for the series which starts with the Centerfield and ends at the bottom of what is here called Portland Point limestone. As previously stated, the Centerfield has no true base and is sharply delimited from later beds. Stratigraphically its alliances are with the Skaneateles below and it is placed there accordingly. For the purposes of the present report the Ludlowville begins with the relatively soft shale (Otisco member) which follows abruptly on the Centerfield and terminates at the base of the Portland Point limestone. In the Skaneateles and Otisco valleys the Ludlowville is divisible into four units. These are the Otisco, Ivy Point, Spafford and Owasco members. The same general sequence holds for the Owasco valley but the distinctness of the units is commonly less marked.

For the Cayuga lake section Cooper ('30, figure 5) employs two member terms in describing the beds between the Centerfield below and the Portland Point above. The lower member he calls the "Ledyard" while the upper is named "King Ferry." Cooper ('30, p. 224) defines his Ledyard as the Third Leiorhynchus zone of

Figure 17 Mottville member. Limestone band and associated shales at railroad spur near Mottville. (Photograph by E. O. Smith, December 1931)

Figure 18 Centerfield-Otisco contact. Just south of Hall's landing, east side of Skaneateles lake. Shows resistant Centerfield ledge at base, the Centerfield-Otisco contact (to right of brief case), and the soft and wave-cut Otisco shale above. (Photograph by E. O. Smith, November 4, 1931)

Cleland ('03, p. 25) and says of it: "At Ensenore on Owasco Lake, east of the type section, the Ledyard shale can be identified only imperfectly and at Skaneateles Lake the fauna and lithology have changed so completely by lateral gradation from a 'Marcellus' fauna and black shale to a Hamilton fauna and blue-grey arenaceous shale, that the name Ledyard has no further significance." The present writer has examined the type section of the Ledyard and quite agrees with Doctor Cooper that the term "Ledyard" is inappropriate for the Skaneateles Lake region.

The Ledyard of the Cayuga valley is capped by a Pleurodictyum zone (Cooper, '30, p. 224). In the Skaneateles section Pleurodictyum seems to be restricted to probably less than 15 feet of strata immediately above the Centerfield. This raises at once the question of possible equivalency between the King Ferry of Cooper and perhaps the entire Ludlowville of the area covered by this report.

In view of such discrepancies between the Cayuga and Skaneateles sections it is believed preferable to use here the local names already mentioned thereby avoiding the danger of premature correlations with Cayuga valley units.

Otisco member. This term is proposed for the shale which lies upon the Centerfield and extends upward for about 150 feet. The type section is in the Millers Place ravine on the west side of Otisco lake, one mile northwest of the causeway. Except locally at one horizon and for a few feet at its top, the shale component of the Otisco is softer and more thinly bedded than the Centerfield below and the Ivy Point above. Its basal contact with the former is sharp (figure 18). The line separating Otisco from overlying Ivy Point is also quite definite but less easily recognized on account of the harder shale which occupies a few feet at the top of the Otisco member. Some sections of the Otisco present a relatively homogeneous shale containing numerous fossil bands. In other cases this uniformity is broken by one or more coral beds and by a hard coarsely bedded platform below the lower one of these. The corals are mostly of the cyathophylloid type and their superficially hornlike appearance has led to the names "staghorn" for the individual and "horn rock" for the coral-bearing strata. The individual corals are embedded in a matrix which has the texture and the color of the finer shale of the Otisco. The shale, however, is well bedded and jointed. Bedding planes and joints, on the other hand, are not common features of the coral beds whose general massiveness and sloping outcrops contrast with the blocklike structures of the typical shale.

The lower 10 or 15 feet of the Otisco are highly fossiliferous, the fossils being almost everywhere, yet concentrated in more or less definite bands. An accurate zoning and intensive study of these is most desirable but in the present writing it is sufficient to note *Tropidoleptus* in great abundance, Spirifers large and small, and *Michelinia (Pleurodictyum)*.

About 50 feet above the Centerfield occurs the lower coral bed with the hard and coarsely bedded platform on which it rests. The latter is transitional from softer shale below and ranges between five and ten feet in thickness. Its capping coral bed or "reef" is commonly about three or three and one-half feet thick but may thin down to almost nothing. Both "reef" and platform are usually to be found in more southern sections of the Otisco valley. They are both beautifully displayed in the vicinity of Staghorn point on the east side of Skaneateles lake. The point so designated is about one and one-fifth miles northwesterly from Spafford landing. The term "Staghorn Point submember" is here proposed for the coral bed or reef typically shown just south of Staghorn point (Smith, '12). See figure 19.

A few corals have been found in Carpenter Point ravine at about the horizon of the Staghorn Point submember, but no characteristic development of this coral bed is seen on the western side of Skaneateles lake. On the east shore of the lake the bed and platform disappear a short distance northwesterly from Staghorn point, their horizon being occupied by a channel filling on an eroded sea bottom, then by a northern subsidiary reef, and finally by the reef margin deposits of its northern border. These lateral transitions are very fully shown in the lake cliffs which extend northwesterly from Staghorn point (figures 23, 20, 21). On the west side of Otisco lake the Staghorn Point coral bed with hard bedded platform beneath is again seen in the Millers Place ravine and in many exposures south and east of the same. Within one-fifth of a mile to the northwest of Millers Place the Staghorn Point reef and platform are not present in a very complete section showing the proper horizon (figure 24). On the east side of Otisco lake the Staghorn Point submember, with underlying platform, is found south of a bend in the second road which skirts the lake. The bend in question is shown on the map opposite, that is, roughly northeast from the gap between the words "Otisco" and "Lake" as printed on the "water" of the lake. The Staghorn Point reef boundary then must lie north and west of this locality on the east side of Otisco lake. The evidence is admittedly far from complete but it is believed that a reef margin

Figure 19 South of Staghorn point, east side of Skaneateles lake. Staghorn point "reef" resting on hard bedded platform and overlain by softer thinly bedded shale. Coral zone somewhat over three feet thick, its top marked by head of sledge. Staghorn point in background. (Photograph by E. O. Smith, October 7, 1930)

Figure 20 North of Staghorn point, east side of Skaneateles lake. Northward sloping truncation of the main reef platform. (Photograph by E. O. Smith, October 7, 1930). *Cf.* Acad. Nat. Sci. Phila. Proc., pls. X, XI, 1912.

Figure 21 Northern margin of small subsidiary reef, Barber point, east side of Skaneateles lake. Stick points to base of thickening coral bed lying on truncated and southward-dipping shale. Shale above coral bed also dips southward. Note absence of hard platform below the coral bed. (Photograph by E. O. Smith, October 12, 1930)

Figure 22 Cliffs of Otisco shale. Looking northwester ly from Spafford landing, Skaneateles lake. Ivy point in distance. (Photograph by E. O. Smith, November 10, 1931)

trending a few degrees east of north is indicated for the Staghorn Point submember in the belt between Skaneateles lake and the eastern wall of the Otisco Lake valley. The eastern and southern boundaries of the reef are not known. As already noted, however, the bed is well developed in southern and eastern sections. It is present at the hamlet of Otisco Valley and again at Fellows Falls, both localities being on the Tully quadrangle. As the Staghorn Point coral bed appears to dip intact beneath Skaneateles lake there is probably a considerable southern underground extension of the submember.

On the west side of Otisco lake a second or higher coral zone is found about 90 feet above the Centerfield (figure 24). Its maximum observed thickness is here somewhat over 30 feet. Sometimes this entire thickness is filled with corals embedded in the rock matrix. More often there are several coral beds separated by intercalations of shale. This upper coral zone is known to occur about two-thirds of a mile northwest of the Millers Place ravine. It therefore has a greater extension in this direction than has the lower or Staghorn Point reef. On the other hand, the upper zone does not reach so far south as the lower. It has not been found at Fellows Falls (Tully quadrangle), nor at the hamlet of Otisco Valley (Tully quadrangle) southeast of Otisco lake, nor again, with one exception, in the ravines at the southern end of Skaneateles lake. In this last mentioned region corals probably assignable to the upper reef horizon have been found in the Tenmile Point ravine.

The shales above the upper coral horizon are fine at first, resembling in this respect most of the other beds of the Otisco. Toward the top of the member, however, the last few feet are coarser and this condition to some extent obscures the rather abrupt line which has been selected as the base of the succeeding Ivy Point unit.

More or less complete sections of the Otisco member are numerous in the three deep lake valleys. The best exposures, however, especially those showing relations with bounding strata, are to be found on the east side of Skaneateles lake and on the west side of Otisco lake.

Ivy Point member. This name is proposed for the chiefly coarse shale that follows the Otisco member. The type section is in the first ravine north of Ivy (or Willow) point on the east side of Skaneateles lake about three-fourths of a mile north and slightly west of Spafford Landing. The base of the Ivy Point is here about 107 feet above the Staghorn Point submember of the Otisco. The lower 15 or 20 feet of the member show some cross-bedding and are hard and coarsely bedded, qualities responsible for many beauti-

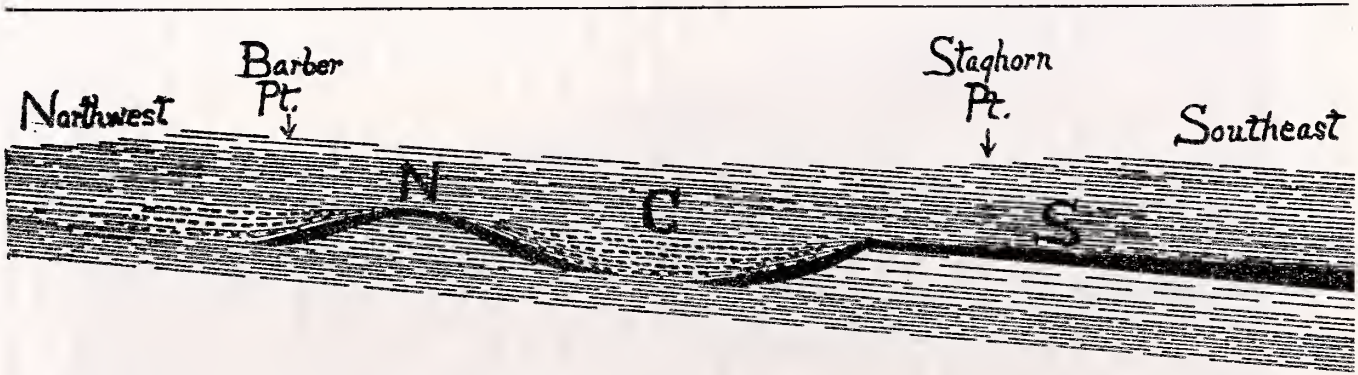

Figure 23 Diagram section of Staghorn point coral masses. Reefs in solid black. Shale in dash lines. Channel and reef-margin deposits in dash lines and elongated dots. S = Southern reef. C = Channel. N = Northern reef. See figure in Proceedings of the Academy of Natural Sciences of Philadelphia, p. 447, 1912, of which figure 23 is a modification. (Courtesy of publication committee, Acad. Nat. Sci. Phila.)

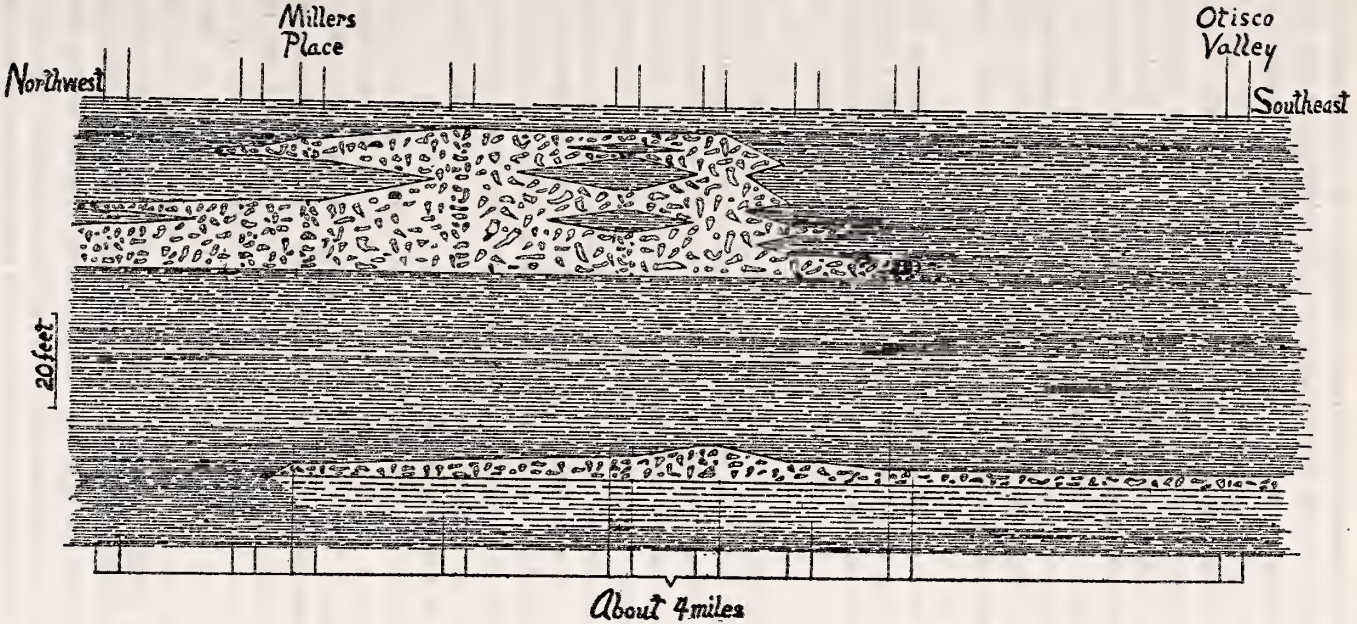

Figure 24 Idealized section showing probable reef structure in the Otisco lake valley. Section extends from the hamlet of Otisco Valley (Tully quadrangle) to about one and two-thirds miles northwest of causeway, a distance of about four miles. Diagram shows Staghorn Point reef underlain by hard bedded platform. About 40 feet higher is the larger reef without hard platform.

ful, yet dangerous, waterfalls on both sides of the Skaneateles Lake valley. Much finer shale characterizes the middle portions of the member, while at top there is a transitional return to a second coarse phase which occupies some 10 or 20 feet at the top of the unit. The entire member is about 50 feet thick, although some exposures show thicknesses in excess of this and the type section seems to be slightly less. In addition to the many ravine exposures, the lake cliffs south of Spafford Landing show more or less of the member and owe their height and boldness to its resistant qualities.

In the Otisco Lake valley the Ivy Point is well developed but its outcrop is relatively high above the lake in the belt where streams have produced little erosion. The sections are therefore notably incomplete.

In the Owasco Lake valley the member can be found at Indian Cove ravine on the east side and at Willow Point and Edgewater ravines on the west side. In these sections the harder beds of the Ivy Point are less conspicuous features than at more eastern localities.

Spafford member. This name is proposed for the relatively fine and extremely fossiliferous shale that overlies the Ivy Point member and which in turn is capped by a *Spirifer tullius* zone (Owasco member) whose position is immediately below the Portland Point division of the Moscow formation (figure 26). Limited in this way the Spafford averages about 25 feet in thickness. The type section is in the first ravine north of Ivy (or Willow) point on the east side of Skaneateles lake about three-fourths of a mile north and slightly west of Spafford Landing. Here its upper and lower contacts are quite sharp, the change taking place at the former suggesting the possibility of a minor erosion break.

In addition to this type locality there are many more or less complete sections of the Spafford in the ravines about the southern end of Skaneateles lake. The Otisco valley, on the other hand, is markedly poor in sections of this member. As in the case of the Ivy Point, the outcrop is high up on the valley wall and in the region of slight stream erosion. Owasco valley sections worthy of notice are found in the Willow Point and Edgewater ravines on the west side of the lake and in the Indian Cove ravine on the east side.

Owasco member. This term is proposed for the thin but important *Spirifer tullius* zone which follows the Spafford and is limited above by the Portland Point or basal member of the Moscow formation. Its thickness is quite variable running from perhaps as low as seven inches to as high as two feet and nine or ten inches.

The former figure is suggested by a section between Spafford Landing and the head of Skaneateles lake. The latter thickness is found in the type section at the Champney quarry about one-third of a mile west of Austin (figure 25). The member is a cross-bedded calcareous and finely arenaceous rock containing what appear to be mica flakes and particles, presumably quartz, which are capable of scratching glass. Contacts with bounding strata are sharp and suggest quite strongly some erosion at base and summit. In addition to its stratigraphic and structural relations and to its somewhat unique lithologic features the Owasco member is likewise characterized at most localities by an abundance of *Spirifer tullius* which is, by all odds, the dominating species of the faunule.

In the Owasco Lake valley the member appears to be somewhat thicker as well as more calcareous and less arenaceous than in eastern localities. On the west side of the valley the bed outcrops in the Edgewater ravine at a level about 200 feet above Owasco lake and just below the new cement road which unfortunately is not shown on the base map of the quadrangle. It is here about two feet, six inches thick and exhibits the usual sharp contacts with limiting strata. On the same side of the lake the Owasco member is also exposed in the Willow Point ravine just below a bridge near the junction of the old and new roads. Notable exposures on the east side of the valley are found at the type section already mentioned, in the Seward Point ravine below the second road bridge, and in the Indian Cove ravine below the "lake road" bridge.

In the Skaneateles valley the Owasco is well displayed at the first ravine north of Ivy (or Willow) point (figure 26) on the east side of the lake about three-fourths of a mile north and slightly west of Spafford Landing, at Staghorn Point ravine, Hall's Landing ravine about three-fourths of a mile northwest of Barber point, and other localities.

An outcrop of the member occurs in the Fisher ravine on the west side of the Otisco valley. This last named exposure is within one-third of a mile of the eastern boundary of the quadrangle.

Moscow Formation

Hall proposed this name in 1839 ('39, p. 298–300) but apparently included some of his Ludlowville as pointed out by Cooper ('30, p. 229). In the present report the revision of the latter author is used, the Moscow beginning at the base of the Portland Point. It ends at the bottom of the Tully limestone. Limited in this way the Moscow of the quadrangle is made up of two members, the Portland Point and the Windom.

Portland Point member. Cooper ('30, p. 229-31) has proposed this name for the "Tichenor" of the Cayuga Lake section. The type locality is at Portland Point on the east side of the lake. "The Portland Point has a 1-foot band of crinoidal limestone at the base, which is followed by alternations of calcareous shale and limestone for about 8½ feet." On the Skaneateles quadrangle the limestone, where measured, is slightly under two feet in thickness but it is variable in this dimension. It is a mass of fossils in which crinoid fragments are more or less conspicuous. Cross-bedding and possible shale fragments go to strengthen the suggestion of unconformity furnished by the contact with underlying Owasco. Upward the limestone passes by intercalations into the Windom shale member of the Moscow.

On the west side of the Owasco valley the limestone of the Portland Point is well displayed in the Edgewater ravine just below the new cement road, built since the preparation of the base map. On the east side it is found in the ravine about one-half a mile from the southern boundary of the quadrangle, at Indian Cove ravine just below the "lake road," at Seward Point ravine just below the second road, and in Champney's quarry about one-third of a mile west of Austin (figure 25). In Dutch hollow the limestone is found south of Niles and is especially to be noted in the north or west fork of a ravine about nine-tenths of a mile south of the hamlet. West of Skaneateles lake important exposures occur in Bear Swamp creek and in the Threemile Point ravine. On the east side of the lake many outcrops are found just above the road which runs from Ceylon (opposite Glen Haven) to Spafford Landing. Other good exposures occur at the first ravine north of Ivy point (figure 26) about three-fourths of a mile north and slightly west of Spafford Landing, at Staghorn Point ravine about one and one-fifth miles northwesterly from Spafford Landing, and in the ravine at Hall's Landing, which is about three-fourths of a mile northwest of Barber point and almost opposite Glen cove (Pray's point). In the Otisco valley the limestone is known from the Fisher ravine at the eastern margin of the quadrangle.

Windom member. This term was proposed by Grabau ('17 (*b*) p. 946) and has been used by Cooper ('30, p. 232) for the shale that intervenes between the Portland Point member of the Moscow and the Tully limestone. It is a relatively fine shale, of rather uniform lithologic character, containing numerous fossil bands not the least interesting of which is the layer or zone with *Spirifer tullius* at or near the top. This shale unit of the Moscow makes a contrast with

Figure 25 Owasco-Portland Point contact. Champney quarry near Austin. Cap is hung from the irregular upper surface of the Owasco. Owasco member is here about two feet and nine to ten inches thick. (Photograph by E. O. Smith, November 9, 1931)

Figure 26 First ravine north of Ivy point, east side of Skaneateles lake. Thinly bedded Spafford shale overlain sharply by the more massive Owasco member, which in turn is overlain by the Portland Point limestone. Canvas hat rests on upper surface of the Owasco, which member is here about one foot and three to four inches thick. (Photograph by E. O. Smith, September 23, 1930)

the Ludlowville whose abrupt contacts and changing sequences from fine to coarse make variety the rule.

Many more or less full Windom sections occur within the quadrangle. A virtually complete section is found in the first ravine north of Ivy point about three-fourths of a mile north and slightly west of Spafford Landing. Here it has a thickness of about 165 feet. A fragmentary but easily accessible exposure is given by the highway cut southeast of Borodino.

Tully Limestone

Tully was proposed at an early date (Vanuxem, '39, p. 278) for the limestone that caps the Hamilton shales. The type region is about Tully, Onondaga county, on the Tully quadrangle. Within the area covered by this report the limestone appears to vary in thickness between 25 and 36 feet. Most sections of it are obviously incomplete. Others are probably complete but the contact with overlying Genesee shale is not shown. Less commonly both contacts with limiting formations are visible and the entire thickness of the Tully is displayed. The formation is usually a compact and rather heavily bedded limestone, grayish when weathered, but, of an almost olive shade when fresh. Mineral segregations and veins may be present. At some localities there is more or less intercalation of thin shale bands especially in the upper part of the formation. Exceptionally the Tully shows a massive phase, and a crinoidal or clastic phase in addition to the usual bedded limestone.

The Tully limestone carries a characteristic and diversified marine fauna. This seems to be made up partly of indigenous elements derived from the Hamilton seas and partly of migrant forms new to the New York Devonian.

As might be expected in the case of a hard limestone separating much softer shales, the Tully is a wonderful waterfall maker. Practically every stream of any consequence which flows across the outcrop produces a fall or a cascade.

Among ravine exposures may be noted Edgewater and Indian cove in the Owasco valley; Carpenter falls on Bear Swamp creek, Glen cove or Pray's point (south fork), Threemile point (especially the south fork), Barber point (north ravine), Hall's Landing about three-fourths of a mile northwest of Barber point, and Tenmile point in the Skaneateles valley. Within the area of the present quadrangle the Tully is very poorly shown in the Otisco valley.

Among quarries in the Tully limestone may be mentioned the Mathew Reilley quarry east of the head of Owasco lake,

D. J. Fitzpatrick quarry about one and one-half miles northeast of Austin, Corrigan quarry east of Twelve Corners, Hartnett quarry east and south of Twelve Corners, two quarries in Dutch hollow respectively west and southwest of Kelloggsville, Randall quarry about three-fifths of a mile south of the Onondaga-Cortland county line, and the group of three quarries by the main road about one and one-fifth miles east and south of Borodino. For simplicity in presentation the quarries of the last named group will be referred to as the "Borodino quarries."

Borodino quarries. At these quarries the Tully presents the three phases already mentioned. They are (1) a bedded phase, (2) a heavy massive phase, often crystalline, in which bedding planes are inconspicuous or absent, and (3) a clastic crinoidal phase. The bedded limestone is here the basal component. In the south quarry it is overlain, probably conformably, by a moundlike mass of the unbedded variety. The sloping western and northern flanks of this mound are presumably eroded and the latter is overlain first by a clastic crinoidal bed and then by a wedge—or terracelike mass of unbedded limestone whose outer northern face conforms in general to the slope of the older and perhaps more centrally situated moundlike mass (figure 27). Evidence from the middle and northern quarries indicates that there may be two or more additional westward-sloping wedges or slices of almost unbedded limestone.

The structures agree in a general way with those which are usually given the coral-reef interpretation in stratigraphy. To this extent they undoubtedly tend to support the views on the Tully limestone which were expressed by Grabau some years ago ('17 (*a*), '17 (*b*)). There seems to be no good reason for questioning the theory that the mound of the southern quarry was once an accumulation of upwardly and, to a certain extent, outwardly growing organisms now largely obscured by the crystallization of the limestone. Its substratum or platform is an old Tully sea bottom made up of bedded deposits. The sloping sides of the mound are not necessarily determined by erosion but it is probable that they were alternately the sites of subaqueous erosion and deposition. That further growth of the mound should take place is to be expected. By this hypothesis the wedges or buttresses which, so to speak, are successively plastered onto the parent mound become additions to it by a process of intermittent growth.

The structures shown in the northern quarry do, on the whole, strengthen the reef accretion view. There are, however, certain factors which indicate that the explanation may not be as simple

as that already given. For instance, here the lower bedded strata dip westward in contrast to the eastward-dipping platform layers of the southern quarry. If these dips are away from an axis, the structure is anticlinal. On the other hand, a synclinal structure appears more likely and may be interpreted as a sag of the basement platform due to the weight of overlying limestone masses or mounds locally concentrated on the sea bottom. In this north quarry, however, the conditions are further complicated by the truncation of the bedded series of the platform. It is sharply terminated by a plane which dips west at an angle greater than that of the lower strata. It is quite conceivable that this plane was originally determined wholly by an erosion of the basement series. On the other hand, the surface of the plane bears slickensides having a roughly north-south direction. This opens the way for two possibilities: (*a*) the slickensides may have been formed on a preexisting erosion surface, or (*b*) the plane may be a joint, or, perhaps, a fault plane and nothing more. The latter possibility is less probable than the former, for what bedding there is in the limestone above is about parallel to the surface of truncation and the same is true for a still higher plane that marks the top of the mass in question. Further parallelism is shown by beds at the very summit of the quarry wall. In addition to the structures already noted, the north quarry, in its northern part, furnishes what appears to be a high-angle slickensided joint plane.

The Borodino quarries unquestionably merit a very thorough study—structurally, paleontologically and mineralogically. The foregoing account of them is merely a sketch of their more obvious features accompanied by tentative interpretations.

Strata above the Tully Limestone

Overlying the Tully limestone is a mass of shales, flags and sandstones that may attain a thickness of 750 or even 800 feet within the area covered by this report. Sections displaying considerable parts of the lower 200 feet of this series are not uncommon. The upper portion of the mass, on the other hand, is very poorly shown. Here limited and scattered outcrops replace long continuous sections, for the strata occupy the high divides whose streams have, as a rule, accomplished little downcutting. Unfortunately, therefore, stratigraphic interpretations among these upper beds contain an unavoidable element of conjecture.

Immediately above the Tully, at the base of the series, is the Genesee black shale. For the rocks following the Genesee the group

or formational term Portage has been adopted. This is in conformity with the practice of the United States Geological Survey, (Williams, H. S., '09, p. 5, fig. 6).

Genesee Shale

The term "Genesee" was proposed by Vanuxem ('42, p. 168, 169), and has been long used for the dense black shale that immediately overlies the Tully limestone. In some places there is intercalation of limestone and black shale, but, in others, a sharp contact separates the Tully from the Genesee.

On the Skaneateles quadrangle this shale is unfossiliferous or nearly so, black, rust-stained and very thinly bedded. Concretions occur at various levels in the formation. In thickness the Genesee averages about 65 to 70 feet but there is some variability in this dimension.

As far as observed, the summit of the formation is marked by a sharp contact with somewhat flaggy sandstone layers of a texture and character quite different from the Genesee (figure 28). Although these layers may be thick or thin the change is abrupt and the boundary a good one. This flaggy sandstone will not be given a distinct name, though it will be treated as the basal unit of the Sherburne member of the Portage.

Among those sections which show the Genesee the following are worthy of note: Tenmile Point ravine, Threemile Point ravine (north branch), Kelloggsville ravine and Cascade ravine. At each of these localities the relations with bounding strata are plain, although in the Cascade ravine the immediately overlying flag is quite thin. At the Kelloggsville and Threemile Point (north branch) ravines the Tully-Genesee contact can be seen. This contact is also well displayed in the south branch of the Threemile Point ravine. What appears to be a Tully-Genesee transition by intercalation occurs in the Staghorn Point ravine (about one and one-fifth miles northwesterly from Spafford Landing). As far as the present writer has been able to determine there is no place on the quadrangle where the Genesee has been replaced by higher beds (Williams, S. G., '87, p. 20).

Portage Group or Formation

South and west of the Skaneateles quadrangle, at the head of Cayuga lake, three subdivisions of the Portage have been recognized (Williams, H. S., '09, p. 5, fig. 6). Beginning with the oldest these are the Sherburne, Ithaca and Enfield members. The two lower units are present in the area covered by this report although it has not always been possible to separate them in a satisfactory manner.

Figure 27 About one and one-fifth miles east and south of Borodino. Southern quarry in Tully limestone. Bedded phase at base of section. Above a mound of massive limestone flanked on left by sloping deposits of the crinoidal clastic phase. (Photographs by E. O. Smith)

Figure 28 Near mouth of long ravine which is about four-fifths of a mile south of Kelloggsville. Genesee shale overlain by basal sandstone of the Sherburne. The sharp Genesee-Sherburne contact is just above the canvas hat. (Photograph by E. O. Smith, September 28, 1930)

When this can be done the data for discrimination are furnished by a zone which will be named the Cornell and given member rank. The Enfield has not been identified on the quadrangle.

The term "Sherburne" was proposed by Vanuxem ('40, p. 381) for the flagstone of Sherburne in the Chenango valley. He regarded the beds as extending westward to Cayuga lake. Prosser ('98, p. 13 of Synopsis, p. 88) has followed Vanuxem in accepting this distribution while Clarke ('98, p. 11, 12 of Synopsis, p. 43) in conforming with Prosser's suggestion has done the same in his studies of the Chenango and Cortland county sections. Both Clarke and Prosser considered the Sherburne to be unfossiliferous or nearly so in the belt from the Chenango valley to Cayuga lake. Grabau ('19, p. 424) states that the Sherburne of the Chenango valley "is devoid of marine fossils, except that in this region a few intercalations of dark shales occur, usually in its lower part, which carry a remnant of the Naples fauna, so much more abundantly developed in the equivalent rocks farther west."

In western Chenango county and in Cortland county the base of the Sherburne is determined by the Genesee, while its upper limit appears to be drawn below the recurrence of Hamilton faunules of Ithaca age. Identification is therefore dependent upon lithologic character, stratigraphic position and paucity of fossils—the last a negative character.

At Cayuga lake (Ithaca region) H. S. Williams ('09, p. 8) has placed the summit of the Sherburne just above a *Spirifer (Reticularia) laevis* zone which outcrops near the mouth of the Fall Creek gorge. This zone is followed by the Ithaca group. At an earlier date Kindle ('96, p. 29 and table) drew the line between his "Lower Portage" and the Ithaca shale a little higher or about 20 feet above the same *Spirifer laevis* zone. Both the Sherburne of Williams and the Lower Portage of Kindle are limited below by the Genesee. It can therefore be seen that Lower Portage and Sherburne are virtually synonymous terms in the Ithaca region. This is in practical agreement with the usage employed by Clarke ('98, p. 44; Prosser, '98, p. 111–13) for Chenango and Cortland counties. Prosser goes a step further and correlates the Sherburne flagstones of the Chenango valley with the Lower Portage of the Cayuga lake section.

Eastern and western Sherburne are then determined in the same way at base but the criterions for limitation at the top are different in each case. The dissimilarity does not stop here. The eastern Sherburne is stated to be barren or nearly so. In the Ithaca area, on the other hand, Kindle notes fossil localities at ten different horizons below the *Spirifer laevis* zone which outcrops near the mouth of the Fall Creek gorge.

It is therefore evident that this particular *Spirifer laevis* zone is an important reference stratum. *Spirifer laevis,* however, is not confined to this horizon, and a perusal of the literature reveals some misunderstanding of the exact position of the zone. As more is known about the distribution of the species this confusion will tend to increase unless the stratum in question is provided with a locality name.

In accordance with the foregoing considerations the term "Cornell" is proposed for the well-known *Spirifer laevis* zone which outcrops at the foot of Ithaca falls near the mouth of Fall Creek gorge at Ithaca, N. Y. The type locality is on the south side of the gorge. It is not far from the Cornell University campus and has become celebrated through the labors of the geologists of that institution. At recent visits which the writer has made during the summer the water level of the stream has been a few feet below the *Spirifer laevis* bed. Williams gives the altitude as approximately 400 feet while the Dryden topographic sheet indicates an altitude of somewhat less than 420 feet.

Virtually this Cornell horizon has been used to mark the top of the Sherburne and it has been included therein. As the present writer interprets Kindle's lists there are 25 definitely identified species in the Cornell of the Ithaca region. Twelve of these are not found in the Sherburne beneath but do occur in the Ithaca beds above. Eight species of the zone are reported from both Ithaca and Sherburne strata. One species or at least variety appears to be confined to the zone, and there are four species in which the data seem doubtful or inadequate. No case is given showing a species in the Cornell unit and also in the Sherburne beneath to the exclusion of the Ithaca. Hall ('43, p. 245 woodcut 107, figs. 1, 1*a*) apparently did not consider *Spirifer laevis* an Ithaca species, but it has since been found near the top of the Ithaca and also well down in the Sherburne (Williams, H. S., '84, p. 20; Kindle, '96, p. 19, 28 and table).

Like most other Upper Devonian species, then, *Spirifer laevis* is not completely diagnostic of any one member or formation. Except in deference to historical precedent, there is no particular reason for retaining the Cornell in the Sherburne; in fact, Kindle's figures and a number of other considerations argue for a transfer to the Ithaca. The present writer, however, favors a middle course and places the Cornell in the column giving it member rank equal to Sherburne and Ithaca. This may be criticized on the ground that the two already recognized units are thick while the Cornell is very thin. It is felt nevertheless that a tangible and fairly widespread

zone, although thin, is more important in stratigraphy than vague, varying and clumsy masses whose most notable character is thickness.

Sherburne member. Applying the principles just outlined to the Skaneateles quadrangle, the name "Sherburne" will be used for the strata that intervene between the Genesee and the quadrangle's lowest known *Spirifer laevis* zone. The latter closely resembles the Cornell member of the Portage in appearance and is correlated with it.

Limited in this way, the Sherburne of the Skaneateles quadrangle comprises a series of shales, flags and sandstones having a thickness of 200 to 220 feet. This is in practical agreement with the figure given by Clarke and Luther ('05, p. 51) for the Tully quadrangle just east of Skaneateles and also with the thickness shown by Williams ('09, fig. 8, p. 12) for the Cayuga and Tioughnioga valleys.

The location of the bottom of the Sherburne on the Skaneateles quadrangle presents relatively few difficulties. The contact between basal member and subjacent Genesee is shown in many ravines. On the other hand, the top of the Sherburne is difficult to depict for the capping *Spirifer laevis* bed is definitely known from but few localities. Throughout most of its extent, therefore, the upper limit of the Sherburne has been drawn arbitrarily.

The basal unit of the Sherburne is a flaggy sandstone which makes a sharp contact with the Genesee. The contrast with the thinly bedded black shale is striking (figure 28). As a rule, the first two or three feet of the sandstone form the crest of a small waterfall whose lower portion is in the more easily weathered Genesee. Often the upper part of the sandstone is intercalated with more shaly layers but sometimes it retains a fairly homogeneous character through a thickness of some eight feet. As far as observed, these basal beds are unfossiliferous. In some of the western sections, notably at the Cascade ravine, the horizon is occupied by two thin flag layers about ten feet apart with shale intervening between them. This condition, however, is exceptional. Among localities in which the usual massive phase of the sandstone occurs one may mention Kelloggsville ravine, ravine about four-fifths of a mile south of Kelloggsville, Threemile Point ravine (both branches), Barber point (north ravine), and Tenmile Point ravine.

A correlation of the basal horizon with some unit of more western quadrangles is hardly permissible in the light of present knowledge. It may be said, however, that its massive phase shows not a little

resemblance to the bed which overlies the black shale on the east side of Cayuga lake between Esty glen and McKinney's Station (Ithaca quadrangle).

Above its basal unit the Sherburne presents a varying series of shales, flags and sandstones. Sometimes these lithologic types are sharply alternating but more often the transitions from one to another are insensible. Shales, which in place appear typically argillaceous, are revealed under the hammer as finely arenaceous and micaceous rocks with curved bedding planes. The sandstones are not of the pure quartz type and are almost always flaggy. Stream current ripple marks, or, more properly, *rapid marks* and minor cross-bedding are common in the flags and sandstones. At one locality (Indian Cove ravine) ripple marks with definite axes were noted. These were very probably wave-produced. So-called "fucoid" markings are occasionally seen. Curved bedding planes are present in both fine and coarse layers but are more particularly characteristic of the latter.

The Sherburne is well shown in the long ravine between Glen Haven and Threemile Point and also in the long ravine on the east side of Dutch hollow slightly less than a mile south of Kelloggsville. At this last locality the beds for some feet above the basal member are unusually shaly. The lower portion of the Sherburne can be seen in the Kelloggsville ravine while the upper part is shown in the second ravine north of Spafford and in the south branch of the Threemile Point ravine. The last-named locality is of especial interest because the relations with the limiting *Spirifer laevis* bed (Cornell member of the Portage) are well displayed.

So far the writer has found no fossils in the basal layers of the Sherburne and none for 110 feet above it. The lowest fossils, some 120 feet above the base of the Sherburne, are very few in number, *Palaeoneilo constricta* (Conrad), an undetermined Goniatite, and an *Orthoceras*-like fragment being the only forms recognized. These came from the second ravine north of Spafford.

In the south branch of the Threemile Point ravine the overlying *Spirifer laevis* zone (Cornell member of the Portage) is a most useful reference plane. Within a vertical distance of 60 feet below this zone, that is, below the top of the Sherburne, the following fossils have been found:

Plant fragment
Crinoid stems, large and small
Leptostrophia interstrialis (Vanuxem)
Leiorhynchus globuliformis (Vanuxem)

Atrypa reticularis?
Ambocoelia umbonata (Conrad)
Pelecypod with concentric sculpture
Goniatites cf. *sinuosus* Hall.

Leptostrophia interstrialis occurs abundantly in two zones of this section, the lower about 45 and the upper about 33 feet below the top of the Sherburne.

Cornell member. As previously stated, this name is applied to the *Spirifer (Reticularia) laevis* bed which outcrops near the mouth of Fall Creek gorge below the Ithaca falls, at Ithaca, N. Y. The type locality is on the south side of the gorge within the Dryden quadrangle whose topographic sheet indicates an altitude of slightly less than 420 feet for the horizon.

Spirifer laevis has been reported from well below and from high above the Cornell member (Williams, H. S., '84, p. 20; Kindle, '96, p. 19, 28, and table; Clarke, '98, p. 37–39; Kindle, '06) but in the pre-Chemung beds about the head of Cayuga lake this latter horizon constitutes for the species a veritable zone of abundance which contrasts with an apparently poor representation in the beds above and below. In view of this condition in the type region it has been deemed justifiable to correlate with the Cornell member any *Spirifer laevis* optima found on the Skaneateles quadrangle at about the proper vertical distance above the Genesee shale. Unfortunately these requirements have been very rarely fulfilled in the area. Nevertheless, the few cases that can be recorded are sufficiently convincing to make equivalency with the Cornell member highly probable. Before taking up the occurrences so referred it may be said in passing that one find of *Spirifer laevis* east of Skaneateles lake is so high vertically, and probably stratigraphically, above the Genesee outcrop that the writer feels constrained to assign its horizon to the Ithaca.

The following localities yield strata that are correlated with the Cornell member:

Ravine on east side of Dutch hollow about four-fifths of a mile south of Kelloggsville. *Spirifer laevis* has been found in this ravine approximately 210 to 215 feet above the Genesee shale. Roughly 12 or 13 feet higher individuals are numerous through a thickness of seven or eight inches. The section at this point is poor, but a distribution of the species in two zones is indicated. The upper layer resembles the Cornell member in general appearance and it, together with the 12 or 13 feet of strata below, is given that correlation.

Roadside four-tenths of a mile south and slightly west of Kelloggsville. Here *Spirifer laevis* occurs in two horizons about 15 inches apart stratigraphically. This locality is not far from the preceding one and there can be no doubt about the general equivalency of the *Spirifer laevis* beds of the two stations. With the data at hand, however, it is not possible to say whether we are dealing with the upper or the lower bed of the ravine. Overlying plant beds at the roadside locality are tentatively referred to the Ithaca.

About one-half of a mile west of New Hope. On the south side of the highway leading west from New Hope, and about where the hill slope meets the flatter surface at its summit, a shaly bed replete with *Spirifer laevis* is exposed in the road gutter. The individuals of the species seem to be confined to a very thin zone which is estimated to be about 220 feet above the Genesee shale. This bed is probably an extension of the upper zone at the ravine four-fifths of a mile south of Kelloggsville.

Threemile Point ravine; south branch. At this locality *Spirifer laevis* has been found in two well-defined zones separated by nearly 25 feet of interbedded shales and flags. The lower bed is estimated to be approximately 220 feet stratigraphically above the Genesee shale. It is about two feet thick with a decided concentration of individuals of *Spirifer laevis* at the top. The upper bed is three inches in thickness. Both upper and lower layers are very like the Cornell member in appearance but the resemblance is perhaps more striking in the lower zone. The two *Spirifer laevis* beds and intervening strata are correlated with the Cornell member. As far as known, this section gives the best exposure of the member within the quadrangle. It also illustrates the relations of the Cornell with the beds above and below.

What is believed to be a young specimen of *Spirifer laevis* has been found on a loose block in the long ravine between Threemile point and Glen Haven. Further occurrence of the species will be considered under the Ithaca member.

Ithaca member. The term "Ithaca" was proposed by Hall (Hall, '39, p. 318) for the strata exposed about the head of Cayuga lake. Apparently the Sherburne was originally included under this name. For many years, however, it has been the practice to draw the base of the Ithaca series above the *Spirifer (Reticularia) laevis* bed which outcrops near the mouth of the Fall Creek gorge. For the area covered by this report the attempt is made to adhere to this practice although lack of data has frequently forced an arbitrary placing of the line.

Figure 29 Ithaca beds. Ravine about four-fifths of a mile south of Kelloggsville. Sandstone lens (with subjacent shale and sandstone) about 50 feet above the Ithaca base. (Photograph by E. O. Smith, September 28, 1930)

Figure 30 Ithaca beds. Fitzpatrick flagstone quarry, one mile north of Omro. Sledge marks top of a sandstone layer which lies in the midst of flags and shales. (Photograph by E. O. Smith, September 28, 1930)

Within the quadrangle, strata classed as Ithaca undoubtedly attain a thickness of several hundred feet. Good sections, however, are furnished only by the lower portions of the member, for the beds are high upon the ridges where the streams, largely intermittent, have accomplished little erosion of the bed rock. Knowledge of the upper layers of the Ithaca must, in this region, be derived from scattered outcrops and occasional quarries. Unfortunately the latter are few in number and seldom in condition to furnish valuable information.

The Ithaca presents a variable series of shales, flags and sandstones greatly resembling the Sherburne, but, on the whole, more fossiliferous. At some 45 or 50 feet above the Ithaca base, a distinctly more shaly phase is encountered. Lenticular flag and sandstone masses in this shale (figure 29) suggest a correlation with the *"Lingula complanatum zone"* of the sections at Ithaca (Williams, H. S., '84, p. 13, 14; '09, p. 8). The thickness of these beds is unknown. They are shown in section with the Cornell member in the ravine four-fifths of a mile south of Kelloggsville and also in the south branch of the Threemile Point ravine.

As noticed under the discussion of the Cornell member, *Spirifer laevis* has been reported not only from strata below but also from strata high above that member. What is apparently an Ithaca occurrence of the species has been found on the east side of Skaneateles lake. This is at the head of the long ravine which is shown meeting the lake just north of Barber point. It is estimated that the zone in question lies about 315 feet above the Genesee shale. This is considerably above the horizon of the Cornell member at Threemile point. The writer is without evidence of a great north-eastward thickening of the Sherburne. Likewise no unusual dips and no faulting have been seen that would bring the Cornell member into this position. For these reasons the Barber Point *Spirifer laevis* bed is given a tentative position in the Ithaca member.

As far as the writer has been able to learn, flagstone is no longer quarried within the quadrangle. Just west of the village at Spafford an old quarry can be seen in Ithaca beds. More extensive and in far better condition for study is the Fitzpatrick quarry one mile north of Omro (figures 30, 31).

PALEOZOIC IGNEOUS ROCKS

Six small igneous intrusions are known from the Clintonville ravine (Smith, '09, p. 724; Hopkins, '14, p. 52; Smith, '31) below, that is, downstream from, the Cherry Valley highway (figures 32, 33).

Their outcrops occur between the Cherry Valley highway and the last road to cross the Clintonville brook before it enters Ninemile creek. They are situated in the lower east-west part of the ravine. All cut Hamilton strata (Skaneateles shale) and are known from the south wall of the ravine or from the stream bed at the foot of this wall. The westernmost dike is approximately 1250 feet west of the intersection of stream and lower road. Its outcrop meets the stream from 45 to 50 feet above the level of the bridge at this intersection. Two feet and five inches east of this dike a second dike is encountered and one foot and six inches east of the second dike a minute stringer is found. About 202 feet east of the first dike mentioned occurs the westernmost member of an eastern group of three dikes. One foot and five or six inches beyond its east wall comes another dike. An easternmost dike is located 32 feet and eight inches east of its nearest neighbor on the west. The largest dike is the westernmost member of the eastern group. It has a width of one foot and one or two inches. At the other extreme in size is the stringer (third from the west) with a width which runs from one and one-half inches to nothing.

In attitude the dikes are vertical or nearly so and trend almost north and south. Their boundaries seem to have been determined by preexisting joint planes in the shale. Still other more or less parallel joint planes in the shale seem to have been produced by the intrusions, and being contact phenomena, they are therefore of later date than any joints which may have governed dike trend. An incipient jointing in the second dike from the west may also be a contact feature. Some slight hardening of the country rock has been noticed and this too is probably to be placed in the same category.

The westernmost dike of the six is relatively hard and firm, seeming to resist disintegration better than does the adjoining shale. It is divided into massive and slightly rounded blocks which are bounded by approximately horizontal joints. The texture is porphyritic, with phenocrysts of a bronzy mica and olivinelike grains. The next dike going east is more easily weathered and contains numerous inclusions of Hamilton shale. The latter are practically unaltered. The walls of this dike are somewhat irregular in its upper part. The minute stringer or third dike from the west is compact and relatively hard. Its walls are irregular. These three dikes are all close together and constitute the western group of greenish dikes.

The three dikes of the eastern group are light brown in color and much weathered. They are seemingly porphyritic with conspicuous mica phenocrysts. The two larger dikes are here close

Figure 31 Ithaca beds. Fitzpatrick flagstone quarry, one mile north of Omro. Northern part of quarry showing the sandstone of figure 30 now thicker and with a channelled upper surface. (Photograph by E. O. Smith, September 28, 1930)

Figure 32 Clintonville ravine. Two dikes (1–1′, 2–2′) of western group. Position of stringer indicated by the number 3. See N. Y. State Mus. Bul. 286, fig. 22. (Photograph by E. O. Smith, October 1929)

together and their rapid weathering has produced a troughlike gash in the ravine wall.

The greenish dikes to the west are not particularly conspicuous and have been overlooked more than once by geologists. The light brown dikes, on the other hand, make a striking color contrast with the gray shale. The difficulties of location and observation are here more apt to be caused by weathering of the dikes with consequent concealment by a talus of shale fragments.

The concentration of igneous intrusions in the Clintonville ravine indicates that the series is a natural one having a common source and attributable to the same period of igneous activity. This last is believed to be referable to the late Devonian and therefore included within Paleozoic time. Such an assignment is based upon probability only and should not be accepted as a final age determination. As far as the visible outcrops at Clintonville are concerned one can only say that the dikes are younger than the Hamilton strata (Skaneateles shale) which they cut.

CENOZOIC DEPOSITS

Lost Record from Devonian to Quaternary

If the reader will consult the tabular summary, he will find that the Quaternary deposits lie unconformably on all older formations. In fact, preceding the Quaternary the Silurian and Devonian bedrock had long been part of an old continent which for ages was subjected to the erosional work of rain and river and which had been in consequence carved into hill and valley.

The table also shows that the oldest Quaternary deposits are glacial accumulations of the Pleistocene epoch. The land surface on which this ice-borne material came to rest was therefore modified by a glacial erosion of later date than the degradation accomplished by rain, rivers and other nonglacial agents.

It is impossible to say how many or what formations or perhaps even systems may have been removed in this way prior to the coming of the Pleistocene ice sheet. No Paleozoics later than the Devonian, no Mesozoic rocks and no deposits of the older or Tertiary portion of the Cenozoic are known from the region covered by this report. Except for evidence of erosion there is no record here of the geological events that transpired between the Devonian and the Quaternary.

Quaternary System

The deposits of this system were accumulated during the later part of Cenozoic time. They are vastly more recent than the Paleo-

zoic formations on which they rest unconformably. They belong without exception to the superficial mantle rock and are prevailingly incoherent or soft, but occasionally cemented and hardened. The bulk of this Quaternary material is referable to the older or Pleistocene epoch which witnessed the extensive glaciation of northern lands. A lesser amount of material can be assigned to the younger or Holocene part of the Quaternary which is postglacial as far as this particular region is concerned. Although the older portions of these Holocene deposits are quite ancient, humanly speaking, their latest layers fall within historic time and may even be accumulating at the present day in favored places.

The map giving distribution of Quaternary deposits is intended to bring out the broader features only. Areas mapped with any particular conventional symbol must be understood to contain the deposit for which it stands *prevailingly* and not exclusively. Boundaries are approximate only, and nothing more than reconnaissance value can be claimed.

Portions of the limestone terrace and scarp and very steep slopes generally may be without this Quaternary mantle, but in most such cases it has pretty surely been removed by one or another of the erosive processes. No attempt is here made to differentiate these relatively small areas in which the superficial material is lacking.

Pleistocene Series

In this report the term "Pleistocene" is applied to (*a*) those materials that were actually assembled by glacial ice and also to (*b*) those nonglacial deposits that apparently were made at a time synchronous with ice-occupancy or with ice-margin retreat. When seen in good exposures, members of the former class can usually be identified by characteristic features. In the latter group the materials are largely glacial in origin but more or less modified by the action of water derived in large part from the melting ice sheet. If such modification is slight and the exposure poor there is danger of confusion with some of the glacial deposits. On the other hand, when reworking by water is more thorough the Pleistocene nonglacial materials may be confused with aqueous deposits of the later Holocene. Neither difficulty can be avoided completely. The discrimination between Pleistocene and Holocene has been in accordance with the writer's practice of assigning aqueous deposits to the former series if ice-margin drainage control appeared at all probable. In passing it may be remarked that the Pleistocene section of this report aims to be descriptive as far as possible. The more important interpretations and correlations fall within the field of the glacial specialist.

Figure 33 Clintonville ravine. Two dikes (4–4′, 6–6′) of eastern group. Auger holes emphasize the weathered condition of these two dikes. See N. Y. State Mus. Bul. 285, fig. 23. (Photograph by E. O. Smith, October 1929)

Figure 34 Road cut near Rose Hill. Sandy till. Note the nearly vertical exposure with boulders protruding from the matrix. (Photograph by E. O. Smith, December 1931)

Glacial deposits. These have been brought together and distributed by the continental glacier or glaciers of Pleistocene time. They were left in their present positions through the melting back (northward) of the ice-margin.

Lack of stratification and absence of the sorting so characteristic of sediments are the two most apparent features of purely glacial deposits. Blocks and boulders, often of large size, are indiscriminately mixed with big and little pebbles, sand, mud and sometimes true clay. Great variations occur in the proportion of large fragments to finer matrix. Occasionally the latter is reduced to a meager sand which occupies interstices between blocks, boulders and pebbles. In other cases there may be a copious clay matrix with few pebbles and boulders, the latter often small.

In most phases of glacial accumulation the boulders, blocks, pebbles and larger fragments are usually of various kinds. Some are quite local while others have been brought long distances. In this latter category are many crystalline rocks, such as gneisses, which are probably of Canadian origin. Among sedimentary rocks not outcropping on the quadrangle boulders of Medina sandstone and Clinton fragments may be mentioned. The innumerable boulders and pebbles of limestone appear to be largely local having been torn from the near-by limestone escarpment. These limestone fragments give most convincing evidence of glacial action. In fresh cuttings they often show scratches, polishing, faceted and curved faces and reentrant angles.

The finer matrix in which boulders and other rock fragments are embedded may exhibit not a little variation. At one extreme is the sand matrix made up prevailingly of quartz sand. At the other extreme is a clay with virtually no sand in it. Probably more common than either of these is the matrix made up of sand mixed with mud or clay.

Ice-laid or glacial deposits appear to be more widely distributed at the surface than are any of the other types of Quaternary material. As far as known they underlie almost all deposits of later date and hence their extent is much greater than that indicated by the surface alone. As the aqueoglacial and Holocene deposits are very largely concentrated in the valleys it is in these that the glacial deposits are most apt to be obscured. On the ridges and uplands, however, the proved areas of gravel and sand are relatively small, and even allowing for the nondiscovery of many more of these there can be little doubt that ice-produced accumulations make up the dominant mantle on the higher ground.

In this widely spread sheet of glacial material there are, of course, many exposures, but the majority of the sections, especially the natural ones, have undergone slumping and deterioration. Fresh cuts natural or artificial are to be sought whenever possible. It is now proposed to mention briefly a few of the more important exposures which are in from good to fair condition at the present time (1931):

Dutch Hollow brook near west line of quadrangle. At a southward meander of the stream there occurs an extensive exposure on the south side of the brook. The section indicates a thickness of about 110 feet of glacial material. Boulders predominate over a meager sand and mud matrix. A large proportion of the boulders are limestone and many of these show reentrants and are scratched, polished and faceted.

Dutch Hollow brook about one and three-tenths miles northwest of Niles. An ice-laid deposit occurs on the west side of the brook at this point. It consists of a bluish boulder clay with stony matrix in which limestone boulders predominate. Many of these have the characteristic glacial scratches, polishing and reentrants. The boulder clay shows for perhaps five feet and is overlain throughout most of its visible extent by a coarse gravel and cobble bed of aqueoglacial origin. At the northern or northwestern end of its outcrop, however, a wedge of laminated reddish clay intervenes between the boulder clay and the gravel. This section is important in definitely placing the boulder clay below two widespread aqueoglacial deposits of the Dutch Hollow valley (figure 35).

Niles. Just south of the settlement a number of boulder clay exposures are to be found. Downstream from the old highway bridge the low land adjoining the brook shows boulder clay overlain by cobble gravel. A foot or so of each deposit is to be seen, but

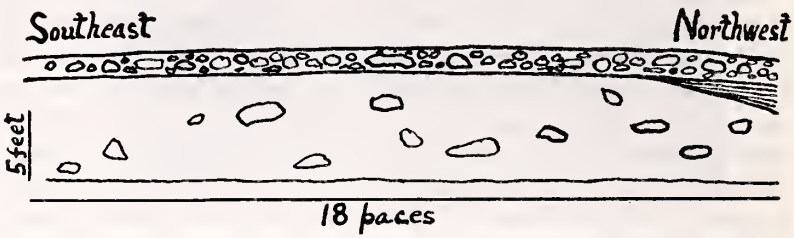

Figure 35 Dutch Hollow brook about one and three-tenths miles northwest of Niles. Diagram section with approximate scale, showing boulder clay overlain by late Pleistocene gravel. At right a wedge of Pleistocene laminated clay separates the two deposits.

the thicknesses are irregular on account of a separating unconformity. In the lower deposit the matrix is a stony blue-gray clay. Polishing, scratches, faceting and reentrants are seen on some of the limestone boulders. Upstream from the bridge just mentioned the artificial cut which straightens the course of the brook has penetrated boulder clay. There is here a good section below the fill and the material is very fresh. Probably continuous underground with these brook exposures is the till shown along the stretch of new highway which shortens the main road through the Dutch Hollow valley.

Rose Hill. A recent cut has been made in improving the road that runs up the ravine north of Rose Hill (figure 34). The road in question is not shown on the base map. Near the junction made with the north-south road to Rose Hill a sandy till has been exposed. At the present time (1931) the section approaches the vertical and the boulders project prominently from the matrix. Various kinds of boulders occur but, as usual, those of limestone show the best evidences of glaciation.

Easternmost tributary to Guppy gulf. All along the middle course of this stream many large boulders occur. At the point where the east-west road crosses the brook a fair but slumped exposure is shown. Although one rill over its surface has disclosed evidence of stratification the mass as a whole appears to be boulder clay. The boulders of limestone are beautifully glaciated.

Webber farm about two miles west of Navarino. A private road has here been constructed through and across the ravine south of the Cherry Valley highway. Excavation along this private road shows scratched, polished and faceted limestone boulders and boulders of other rock embedded in a sandy matrix that gives no sign of stratification (figure 36).

Navarino. Cuts made in constructing the Cherry Valley highway across the depression west of Navarino have revealed an interesting condition. Sandy till from four to ten feet thick is seen to overlie a few feet of stratified sand. The sand contains much quartz with well-rounded grains. The till is quite typical. Many of its boulders are of limestone and exhibit fine scratches, polishing and other evidences of glaciation. This sequence from stratified sand to till was observed in the cuttings on both east and west sides of the Navarino channel. What underlies the sand is unknown for the lower part of each section is obscured by slump.

Ninemile creek: Cherry Valley highway cut on east hill. An ice-laid deposit varying in appearance from sandy till to reddish boulder

clay has been exposed in this cut. Slumping has occurred but the size and variety of the boulders and the typical glaciation of those of limestone leave no room for doubt that the material is till. At an altitude approximating 980 feet this till is seen to overlie a stratified deposit which ranges in nature from reddish clay into sand and gravel. Some of the layers are weakly cemented. See figure 37.

Drumlins. In the region from the Mandana and western Dutch Hollow depression northward to the quadrangle line and also in the general belt between the villages of Skaneateles and Marcellus there are many hills that greatly resemble the typical drumlins of the Weedsport and Baldwinsville quadrangles. Although not so marked in character as the latter they are regarded as having the same origin as their more northern neighbors. They may be conceived as less extreme representatives of the southern fringe of the Weedsport-Baldwinsville drumlin area. The longer axes of the hills trend from north-south to northwest-southeast, the majority showing a direction more nearly north-south than northwest-southeast. It is of interest to note that these trends are in general agreement with those of the major ridges and valleys of the quadrangle. As might be expected, the material of these drumlins is well displayed in the recently improved east and west roads. Good exposures are shown along the Cherry Valley highway between Skaneateles and Auburn and in the road leading eastward from Degroff (figures 38, 39). One of these hills near the western line of the quadrangle and south of the road leading westerly from Mottville furnishes an excellent illustration of the composing materials. An excavation at its northern end discloses an unstratified sandy matrix containing boulders large and small. Many of the limestone boulders are scratched, polished and otherwise typically glaciated.

From the topographic standpoint Cottle Hill west of Mottville is one of the best drumlins of the Skaneateles area. Its height and summit altitude have been noted by Fairchild, ('07, p. 411).

Boulder residua ("pavements"). These are produced from till or other ice-laid deposits through washing by recent streams or waves (Gilbert, '98, p. 771–75, fig.; Grabau, '20, p. 531, fig. 447, p. 818). They occur at many localities within the quadrangle. A few of these are worthy of note on account of the large size of their boulders. In the bed of Dutch Hollow brook near the west line of the quadrangle and again at Niles conspicuous boulder concentrations are found. Still better examples of such residua occur on the shores of the northern half of Skaneateles Lake. Here the agent of production is wave action in the present lake. A most

Figure 36 Sandy till. Webber farm about two miles west of Navarino. (Photograph by E. O. Smith, June 20, 1931)

Figure 37 Cherry Valley highway, east side of Ninemile Creek valley. Till overlying stratified aqueoglacial material. (Photograph by E. O. Smith, August 26, 1931)

Figure 38 Drumlin about one and one-fifth miles east of Degroff. Camera looks almost west. (Photograph by E. O. Smith, December 1931)

Figure 39 Drumlin about one and one-fifth miles east of Degroff. Road cut at or near summit showing character of till. (Photograph by E. O. Smith, December 1931)

remarkable accumulation of this kind is to be seen on the east shore of the lake between Fivemile point and Borodino Landing (figure 40). In a sense such materials may be classed as Holocene deposits. Nevertheless, there has probably been little or no transportation of the boulders since glacial time and these concentrations are noted here because they give evidence of great glacial accumulations produced probably during halts in ice-margin recession.

Red clay. Red boulder clay occurs at a number of points within the quadrangle. As a rule, the deposit is not large and no very definite data are at hand for a discrimination between it and other kinds of near-by till. In the Ninemile Creek (Otisco) valley, somewhat anomalous red clays are widely distributed on the lower ground especially between the foot of Otisco lake and the mouth of the "Gulf" or Guppy Gulf channel two and one-fifth miles south of Marcellus village. Between the great gravel and sand mass that almost terminates this clay area on the north and the Cherry Valley highway on the south the red clay is largely arranged in rolling mounds that extend far out into the valley (figure 41). South of the Cherry Valley highway the most conspicuous clay masses are the benches occupying the lower slopes of the valley walls on both east and west. At most localities no trace of stratification is visible. Boulders are commonly small and usually few in number. The matrix, if so it may be termed, is a sticky red clay with little or no sand in it. The gravel and sand mass at the north already mentioned, apparently overlies red boulder clay. Evidence in favor of this view is afforded by the present surface distribution of the clay along Ninemile creek and by red clay inliers that protrude through the gravel and sand of the northern slope of the mass. The age relations of the red clay and the usual till of the area are not so clear. Recent road cuts in the clay mounds show that the red color is not confined to a mere surface film. The mounds are as red in the center as on the outside. This suggests the possibility that the color is due to some thoroughly oxidized residual soil of a preglacial land surface. If such is the case the assignment of the red clay to one of the earlier Pleistocene glaciations would be in order. On the other hand, the color may be due to a high content of ground-up Vernon shale derived from its outcrop north of the quadrangle. A stratified derivative of this red clay will be considered under aqueoglacial deposits.

In passing it may be noted that a reddish boulder clay has recently been brought to the surface by the Syracuse Water Department excavations in Clift Park, Skaneateles village.

Aqueoglacial deposits. This term is applied to deposits formed by and in water at a time contemporary with the presence of glacial ice in the general region. When such deposits originated on, in or under the ice, or, again, at the ice-margin, the water responsible for their arrangement came principally from the melting of the continental glacier. When the ice-front was more removed from the site of deposition a considerable amount of water from the land drainage was probably added to that derived from ice-melting. Whether any one aqueoglacial deposit is formed during ice occupancy, ice-front proximity or ice-front remoteness, it is probably safe to say that in most cases its materials are chiefly reworked glacial accumulations. Probably in no case is sediment from the land to be excluded. It is obvious, however, that this latter element would ordinarily tend to augment with increasing distance from the glacial margin.

Ideally then, aqueoglacial accumulations may be grouped under (*a*) those materials formed on, in or under the ice or in immediate contact with the ice-front, and (*b*) those deposited at a time when the ice-front, probably retreating, was some distance away but still near enough to be a controlling factor in the drainage of the area.

In practice it is not always easy to distinguish between the two groups of deposits just outlined. As the writer is not a glacialist and as the complexities of glacial drainage are seldom, if ever, confined to the area of one quadrangle the following account aims to be descriptive rather than interpretative.

Texturally aqueoglacial deposits range from boulder and cobble beds, through the different grades of gravel and sand to an almost impalpable clay. The coarser kinds and the gravel contain many rock fragments most of which are boulders from the older glacial till. Occasionally a coarse aqueoglacial deposit may contain abundant fragments from a very near mass of bedrock. In such cases it is not unlikely that many of the fragments were derived directly from the bedrock. The sands may have a high percentage of quartz grains. These are usually accompanied by other resistant mineral particles which owe their origin to the disintegration of crystalline rock probably in the shape of boulders. It is not uncommon for the sands to carry large amounts of limestone and shale grains. The term "clay" is usually applied to the finest material but it is not unlikely that "rock flour" is present in many cases.

The shapes of boulders, cobbles, pebbles and grains in aqueoglacial deposits are dependent largely upon the degree to which these have been reworked in water. Large fragments from the bedrock may be

Figure 40 Boulder residuum. Shore of Skaneateles lake between Fivemile point and Borodino landing. (Photograph by E. O. Smith, November 14, 1931)

Figure 41 Red clay mounds and outwash sands. Taken from west wall of Ninemile Creek (Otisco) valley north of the Clintonville ravine. Camera looks almost 75° east of north (magnetic). (Photograph by E. O. Smith, Spring of 1932)

sharp and angular. Boulders and cobbles from the till may still show facets and reentrants and more rarely even polishing and scratches. From these little modified states there is every gradation to the well-rounded cobble or pebble that has rubbed for long periods against its fellows in agitated water. Many of the larger quartz grains in the sands are well-rounded.

As noted in the preceding section, till is the prevailing mantle rock on the upland and ridges. In contrast with this condition the aqueoglacial and postglacial deposits are eminently characteristic of the lower land generally. With the exception of the gravel and sand mass at Shepard Settlement and the one intruding from the Auburn quadrangle all of the more extensive areas of aqueoglacial mantle are to be found in the larger and deeper depressions. Reasoning from analogy, and, without meaning to speculate unduly, it is not improbable that considerable bodies of such deposits lie beneath the waters of Owasco, Skaneateles and Otisco lakes. Depressions in which extensive areas of aqueoglacial deposits occur are: Dutch hollow and the Mandana pass, Skaneateles valley especially north of the lake, Ninemile Creek (Otisco) valley and the mouth of Guppy gulf, Cedarvale channel, Navarino channel and Joshua channel.

The same tendency for such deposits to favor depressions is found even upon the ridges and upon the higher ground. Minor high-level valleys are here apt to contain aqueoglacial gravels and sands, and the majority of the smaller bodies of such materials occur in these higher valleys. Cases in point are furnished by the Degroff region, the road south from Baptist Four Corners, the valley one and four-fifths miles east of the outlet at Skaneateles village, the valley one and one-tenth miles west of Ninemile creek at Marcellus village, and the Bear Swamp valley.

Topographic form terms are difficult to apply in dealing with the aqueoglacial deposits of the Skaneateles quadrangle. Many of the forms are untypical or topographically intermediate between recognized types. For instance, there appear to be all gradations between kamelike mounds and eskerlike ridges. Deltas and outwash plains are not sharply distinct while the latter on their northern faces grade into kame slopes.

Kames and eskers. In addition to the northern kame slopes of the outwash plains, kamelike hills are found in the following localities: Skaneateles valley north of the lake, valley roughly one and four-fifths miles east of the outlet at Skaneateles village, about one mile south of Baptist Four Corners, three-fifths of a mile and more northeast of Owasco village, Dutch Hollow valley both north and

south of Niles. In this last named region the higher Pleistocene terraces are apparently in part morainal and in part made up of gravel and sand sometimes arranged in kamelike hills. These latter deposits should not be confused with a lower series of Pleistocene gravels (discussed beyond) arranged along the present Dutch Hollow brook. The scale renders it inadvisable to attempt a map differentiation of all the types of aqueoglacial deposits in this valley.

Ridges given the esker interpretation are best shown in the valley one and one-tenth miles west of Ninemile creek at Marcellus Village (figures 42, 43), while less positive examples are to be found in the vicinity of Degroff and on the west side of Dutch Hollow brook just south of Niles.

Outwash deltas. The Shepard Settlement gravel and sand mass has been designated (Fairchild, '09, p. 25) "a glacial delta or outwash by glacial streams from the edge of the glacier into standing water." Regionally the mass is divisible into (*a*) a northern kame slope which is largely on the Baldwinsville quadrangle, (*b*) a plain which descends very gently southward, and (*c*) a short but steep scarp along a portion of its southern margin (figures 44–48). Within the Skaneateles quadrangle the geographic boundaries of the mass are apt to be at or near limiting streams which apparently developed close to the original dividing lines between gravel and sand on the one hand and till on the other. As far as observed on the Skaneateles quadrangle, the kame slope is made up of gravel and sand. On the Baldwinsville quadrangle one boulder clay inlier has been noted. Ploughed land on the northern part of the plain (*b*) shows cobbles with gravel and sand but on the southern part of the surface and on its southward-facing scarp (*c*) there is a great preponderance of sand. This coarse to fine arrangement of the material was apparently determined by the direction of water flow. At about the junction of kame slope and plain, excavations show gravel with prevailing westward dip. It is therefore probable that the water passed southwestward from the ice-margin. A well-developed kettle occurs in the plain (*b*) a short distance west of the westernmost north-south road which crosses the plain. This kettle is not shown on the base map but it is more pronounced than the one indicated on the kame slope to the north.

The gravel and sand masses south of Niles and the great pile of sediments athwart the Ninemile Creek (Otisco) valley two and one-third miles south of Marcellus (figure 49) are provisionally interpreted as outwash deltas. Such a tentative determination, however, does not explain the relations of the latter mass to the Guppy

Figure 42 Eskerlike ridge in high-level valley west of Marcellus village. Looking about north along the straighter portion of the ridge. (Photograph by E. O. Smith, December 1931)

Figure 43 Eskerlike ridge in high-level valley west of Marcellus village. Looking about south along the winding portion of the ridge shown in figure 42. (Photograph by E. O. Smith, December 1931)

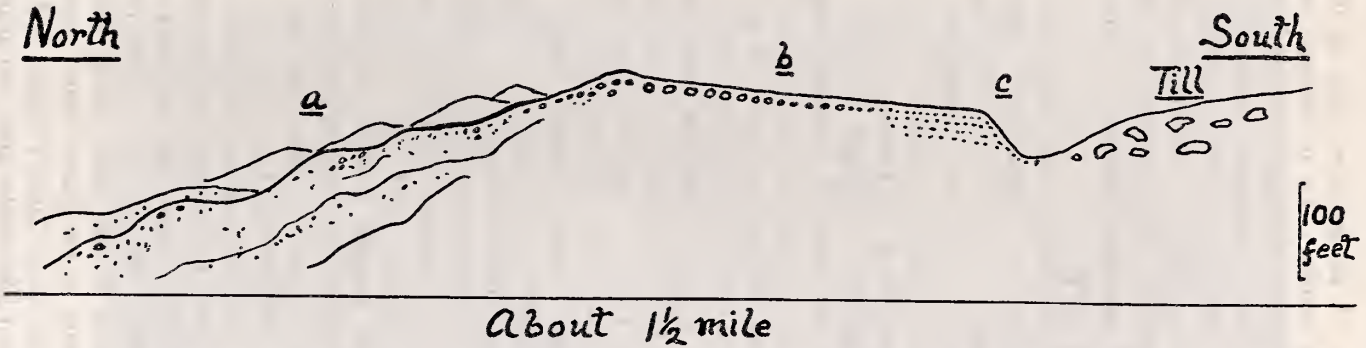

Figure 44 Idealized diagram profile of Shepard Settlement outwash delta. Extends from (*a*) northern kame slope, across (*b*) the gently-sloping plain and (*c*) abrupt scarp, finally reaching the till surface on south. The horizontal distance is about one and one-half miles.

Gulf delta north of it. A comparative study of these two bodies might yield interesting results. As at Shepard Settlement these apparent outwash deltas have irregular northern slopes which are characterized by many kames arranged in a roughly linear manner on ridges descending northward away from the main body of gravel and sand. The top of this latter is relatively flat showing inclinations toward the middle of the valley in the masses near Niles. Each of these latter and the Ninemile Creek mass is terminated abruptly on the south by a steep scarp.

A kame slope, much like those already noted, occurs seven-tenths of a mile north of Navarino. Although this appears to be continuous with aqueoglacial deposits of the Navarino channel, no definite outwash delta has, so far, been recognized.

Deltas of ice-controlled lakes. Three fine examples of deltas produced in ice-controlled lakes are present within the quadrangle. These are the Guppy Gulf, Cedarvale and Amber deltas. They have been noted and briefly described by Fairchild ('09, p. 22, 27–29, pls. 4, 21). In each case the receiving lake had its level maintained by a glacial dam which was situated north of the mouth of the contributing stream. The compound delta at Amber was built into a high-level Otisco lake, its gravel and sand being supplied by glacial waters flowing through the Navarino and Joshua channels (figure 50). At a later date in the retreat of the ice front and at a slightly lower level the Guppy Gulf delta was formed in the more northern part of the Ninemile Creek (Otisco) valley. The materials of this mass were brought to their present position by a stream of glacial water flowing through Guppy gulf. In similar manner the Cedarvale delta was produced in ponded waters of the Onondaga valley, the supplying river flowing through the Cedarvale channel. The Navarino, Joshua, Guppy Gulf and Cedarvale channels are all believed to owe their present form, if not their origin, to the erosive work of these waters from the melting ice sheet.

The Cedarvale delta of today is apparently but a fragment of a much larger deposit (Vanuxem, '42, p. 247, 248; Fairchild, '09, p. 28, 29, pls. 4, 21). Not only are portions of the delta found on the north side of the channel but a mound of cemented gravel occurs well out in the channel about one mile west and somewhat north of Cedarvale (Fairchild, '09, pl. 21). This mound has been interpreted as a remnant of old valley filling which resisted the erosion of its own stream as the glacial waters were lowered.

At Gambell's gulf on Otisco lake, Fivemile and Tenmile points and Spafford Landing on Skaneateles lake, and again at Birge point

Figure 45 Shepard Settlement outwash delta. Surface of northern part of plain showing cobbles. Camera looks southerly down the gradual incline of the plain. (Photograph by E. O. Smith, November 16, 1931)

Figure 46 Shepard Settlement outwash delta. Looking about north over the plain and showing the almost flat surface rising gently in that direction. (Photograph by E. O. Smith, November 16, 1931)

Figure 47 Shepard Settlement outwash delta. Scarp at southern margin of plain. (Photograph by E. O. Smith, November 16, 1931)

Figure 48 Shepard Settlement outwash delta. Kettle in the surface of the plain. Looking about north. (Photograph by E. O. Smith, November 16, 1931)

Figure 49 Gravel and sand mass two and one-third miles south of Marcellus. Northern kame slope of mass. Camera looks approximately south. (Photograph by E. O. Smith, May 20, 1931)

Figure 50 Amber delta (breached by recent stream) and mouth of Joshua channel. (Photograph by E. O. Smith, November 26, 1931)

(Indian cove) on Owasco lake (figure 51) much smaller masses of gravel and sand can be interpreted as remnants of deltas which were built into ice-controlled lakes. At Gambell's gulf, Fivemile point and Birge point the deltas appear to be more or less continuous inland with gravels and sands of a probably different origin. These latter deposits may be earlier or contemporary with the deltas near them but in any event they probably contributed material for delta formation.

The delta or delta remnant at Spafford Landing is on the northern or northwestern side of the point. It makes a small but well-defined bench at about 45 to 50 feet above Skaneateles lake. Many good-sized boulders and blocks occur in a matrix of gravel and sand more or less cemented. The boulders are till-derived but the blocks appear to be largely local flags with perhaps some pieces of the coarser Ivy Point layers. The stratification in this delta, although crude, is very positive. Small loose boulders with adherent cement and sand but still retaining glacial scratches have been noted at this locality.

What is probably a delta fragment or a delta derivative occurs just south of Pray's point (Glen cove) on Skaneateles lake. Here a stratified and cross-bedded gravel and sand deposit containing some boulders and cobbles may be seen on the lake shore. A landslide has exposed a good section from about 20 to 30 feet above the present water level.

It is possible that other materials may be correlatable, at least in time, with high water levels of the Skaneateles valley. At a number of localities both south and north of Tenmile point, deposits of an anomalous character are found. They contain many boulders, cobbles and smaller fragments and are more or less cemented. Many local blocks, apparently from the Centerfield, are also present. So far, no undoubted stratification has been detected in this deposit, and many of its boulders retain strong signs of glacial action. Three possibilities of origin suggest themselves. The material may be (*a*) a cemented aqueoglacial deposit whose coarseness precludes recognizable stratification, (*b*) a cemented sandy till, or (*c*) a cemented talus or landslide deposit derived largely from *a* or *b*. It is believed that aqueoglacial origin is the likeliest, but the slopes are steep and it is highly probable that some downhill sliding, either before or after cementation, has occurred.

The sand and gravel masses of delta origin are essentially shore or near shore features of the late Pleistocene water bodies. Their lower portions have lodged upon the sloping bottoms of the ancient

lakes while their upper layers were formed just below, at, or slightly above the water levels of the time. In each case the sand or gravel has acquired its original position and attitude because the ponded water of a lake checked the velocity of an inflowing stream at that point. Some of these deposits have probably been more or less reworked by the waves, but modified or not, they all illustrate the coarser and heavier materials that were laid down rapidly at the shore and on the adjoining slope beyond it.

Clays and muds of ice-controlled lakes. It now becomes necessary to consider the finer sediment that was held in suspension for long periods and finally deposited in deeper and quieter waters probably more remote from shore. The best representative of this kind of sediment is the thinly bedded or laminated clay found most extensively in the Dutch Hollow and Ninemile Creek (Otisco) valleys but not unknown from other localities within the quadrangle.

In Dutch hollow, along the brook of that name, outcrops of laminated clay are common from about a mile north of the divide (1172 feet) to the Owasco-Baptist Four Corners road. Just west of this road, near the village of Owasco, clay has been dug for a tile manufacturing plant. This is no longer in operation. The sides of the old pits have slumped greatly making observations uncertain, but an apparent absence of boulders indicates excavation in a sedimentary clay rather than in till. Downstream from this locality the laminated clay appears to be largely covered by later deposits. It occurs in the tributary valley leading southward from Degroff but has not been found in Dutch Hollow brook below that point.

This stratified clay of the Dutch Hollow valley is almost everywhere overlain by coarse gravels which usually stand well above the present brook (figures 52, 54). These cap the first (usually lowest) terrace against which the Holocene flood plain is built at any one locality. Both clay and superjacent gravel were formed when conditions in the valley were quite different from those of today. They are consequently assigned to the Pleistocene. Evidence obtained from the west side of the valley about two miles southeast of Niles indicates that the clay not only underlies the gravels of the lower terraces but may in some cases pass upward and back of them toward the valley wall (figure 55). A tributary of the main valley in this region shows the clay virtually at the valley wall overlain by Holocene alluvial fan deposits. It there dips toward the trunk stream of Dutch Hollow brook. The clay outcrops again at the main stream but at this lower point it is capped by the Pleistocene terrace gravel.

Figure 51 Birge point (Indian Cove), Owasco lake. At left foreset beds of Pleistocene delta. At right lakeward-sloping surface of Holocene cone-delta point. (Photograph by E. O. Smith, July 8, 1931)

Figure 52 Dutch Hollow brook. About one and one-half miles east and slightly south of Owasco village. Pleistocene laminated clay (folded) overlain unconformably by late Pleistocene stream gravel. (Photograph by E. O. Smith, 1930)

In color the Dutch Hollow laminated clay runs from reddish through shades of brown into an almost gray or bluish tinge. It is everywhere thinly stratified. There is, in places, an undoubted valleyward initial dip but arching and folding of the layers occur at a number of localities. The clay may even be brecciated.

The maximum thickness of this laminated clay is unknown. About one-half a mile south of Niles there are indications of some 45 feet of clay above the level of Dutch Hollow brook.

The Ninemile Creek (Otisco) valley furnishes many outcrops, natural and artificial, of stratified red clay. Whereas in Dutch hollow the stratigraphic relations of the clay are quite clear, the Otisco valley deposits are less easy to interpret for we are apparently dealing with lithologically similar materials of different ages. The sedimentary clays found north of Marietta at comparatively high altitudes upon the valley wall are believed to be older than the very similar deposits at lower levels both north and south of Marietta. The geographically higher clays are involved with sand and gravel at the Cherry Valley highway (east wall) and there lie below till. Toward the foot of Otisco lake (west shore) and along the tributary stream just south of Marietta stratified red clay of the lower altitudes can be found resting unconformably on boulder clay. It is in turn overlain unconformably by sand. At the eastern end of the Marietta section a wedge of valleyward dipping sand and gravel comes in between basal red boulder clay and the red laminated clay above. In this section the last-named deposit is capped by sand and gravel. This stratified clay at Marietta and along Otisco lake is very probably contemporary, at least in part, with the amber delta sands and gravels. The section already noted suggests this and a red clay seam intercalated between sand and gravel at Amber tends to strengthen the probability. A much disturbed stratified red clay at the mouth of the Clintonville ravine is probably to be correlated with the Marietta and Otisco Lake beds. At the Clintonville ravine the clay is overlain by Holocene alluvial fan deposits (figure 53). Red boulder clay is regarded as the source of all red clay sediments of the Otisco valley.

On the inlet of Skaneateles lake, south of the east-west road crossing the stream, there is an outcrop of a few feet of stratified mud. This mud contains an occasional pebble but, as far as observed, it is without fossils. It is overlain by gravel which is probably continuous with that of a mound east of the creek. Gravel and mud were apparently formed at a time when conditions in the valley

were quite different from those of today. On this account both are referred to the Pleistocene.

South of the Indian Cove ravine laminated red clay is indicated by rather obscure sections along the "lake road" east of Owasco lake.

In passing it must be emphasized that Pleistocene aqueoglacial clay and mud sedimentation was not necessarily contemporary in the different valleys nor even in different parts of the same valley. It merely represents one episode in a sequence of events which seems to have taken place in various localities, earlier in some, later in others.

Late Pleistocene stream gravels. As far as observed within the quadrangle, the finer Pleistocene sediments just discussed nowhere pass upward by transition into deposits of later date. In the Otisco and Skaneateles valleys, in Dutch hollow and probably in the Owasco valley the top of the clay or mud is cut off abruptly by coarser material. This latter lies unconformably on all older deposits. Occasionally it is sand, but usually this upper capping bed is a gravel of one kind or another. In a few instances this overlying mass is attributable to processes still, or until recently, in operation. This is particularly true about alluvial fans and the superjacent coating is then assigned to the Holocene. In most cases, however, the overlying gravel or sand was laid down at a time when conditions were quite different from those of the present. For the Otisco valley, evidence has been presented to show that clay on the one hand and sand and gravel on the other may be more or less contemporary. The conditions in the Owasco valley are not understood. In Dutch hollow (Fairchild, '99, p. 51, 52) and probably also in the Skaneateles valley the gravel that caps the clay or mud is attributed to the action of streams that flowed through passes and into water bodies during the later stages of ice-margin retreat. Although not formed under present conditions, these materials were probably accumulated in waters, moving or ponded, which did not stand far, if at all, above the present position of the deposit.

These late Pleistocene gravels of the Dutch Hollow valley are arranged in a varying but limited number of more or less flat-topped terraces (figure 55). These flank the present stream, and judging from the structure of the lowest terrace at any one point the order of descent is the order of age; that is, the highest terrace is the oldest, the lowest is the youngest, at any one cross-profile of the stream and its immediate vicinity. The highest terrace is apt to stand from 15 to 25 feet above the present brook and its surface

Figure 53 East of road at mouth of Clintonville ravine. Pleistocene stratified red clay overlain unconformably by Holocene stream wash. (Photograph by E. O. Smith, October 1929)

Figure 54 Dutch Hollow brook. A short distance south of the road leading eastward from Owasco village. On left Pleistocene laminated clay overlain unconformably by late Pleistocene stream gravel. On right Holocene muds underlain by Holocene stream gravel. The two gravels are more or less connected by a diagonal line of pebbles. Between the west valley wall (sky line) and the Holocene flood plain (right foreground) the Pleistocene terrace scarp is seen. (Photograph by E. O. Smith, April 24, 1931)

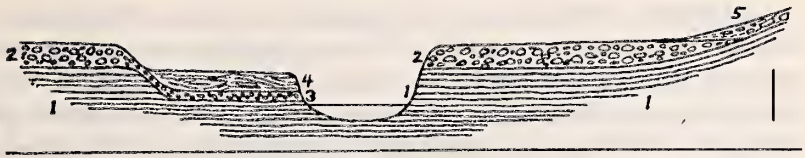

Figure 55 Ideal cross section of Dutch Hollow brook to show relations of Pleistocene laminated clay (1), late Pleistocene terrace gravels (2), basal gravel of Holocene flood plain (3), mud and sand of Holocene flood plain (4), and Holocene alluvial fan material (5). Not drawn to scale.

tends to rise slightly when followed upstream. The gravels of this low terrace series must not be confused with those of the partly morainal and much higher kamelike terrace or terraces which extend interruptedly from the Owasco cemetery southward beyond the divide (1172 feet) to the southern boundary of the quadrangle. This last point should be kept constantly in mind when one is examining the map whose scale precludes a differentiation of all the several types of aqueoglacial deposits.

Texturally the low terrace Pleistocene gravels of Dutch Hollow are very coarse. In places they contain many cobbles and even an occasional boulder of moderate size. Sorting is rough and stratification obscure but the deposit can not be interpreted as other than a stream formation. The gravel of the lowest terrace of any one station is seen to lie unconformably on the Pleistocene laminated clay. If the section includes both the lowest Pleistocene terrace and the adjoining Holocene flood plain, the Pleistocene gravel is revealed as continuous, or nearly so, with the basal gravel of the Holocene plain (figures 54, 55). This relation is due to the fact that the Holocene gravel is chiefly reworked Pleistocene gravel and the two deposits are in consequence connected by a diagonal line of pebbles leading downward from the top of the Pleistocene terrace to the lowest observed level of the Holocene flood plain.

Holocene Series

In the present report the term "Pleistocene" is used to cover glacial and interglacial subepochs and made to include the time during which the last retreating ice margin blocked the major valleys of the region and exerted a controlling influence on the drainage of the quadrangle.

The discrimination of any particular deposit as post-Pleistocene, that is, as Holocene, may be based on one or several lines of evidence, some positive, some negative. Among positive points favor-

ing a Holocene reference are: (*a*) formation by agents still in operation or only recently inactive, (*b*) superposition on aqueoglacial deposits, (*c*) obvious derivation from aqueoglacial deposits, (*d*) presence of abundant organic remains having every appearance of belonging overwhelmingly to the recent fauna or flora of the region. Negative points are lack of evidence of ice-margin control or of any other influence or agent long inactive in the area.

Flood plains and stream terraces. A great many cases might be cited that would come under this subheading. Most of the occurrences, however, point to limited areas and apparently also to slight thickness. Their treatment falls more appropriately in the field of dynamical geology. Less common are more extensive deposits that presumably attain a much greater thickness and that inferentially have been formed during a relatively long period.

The most important of such accumulations from a geological standpoint are those of the Dutch Hollow valley. Numerous sections of these materials occur between the divide at 1172 feet and the westernmost bridge to cross Dutch Hollow brook on the Skaneateles quadrangle. Sometimes there is nothing but a comparatively low gravel bank easily flooded by any freshet. At the other extreme is a vertical section of perhaps seven or eight feet disappearing under the stream bottom and rising some five or six feet (or more) above the normal water level. The section terminates at the relatively flat top of the flood plain that may go back some distance away from the brook. In cases of this kind the material is chiefly, if not entirely, mud and sand. Prostrate trees and wood fragments generally, bark and leaves are common in the lower portions of the sections. Some of these plant-bearing layers must be buried under five or six feet of sediment. Localities showing such features are not uncommon in the lower stretches of the brook in its western course. The prevailing type of Dutch Hollow Holocene section, however, is intermediate in thickness and in character between the two extremes just noted. Usually there is a fairly coarse gravel at base which sometimes can be seen to overlie unconformably the Pleistocene laminated clay. Above, the basal Holocene gravel is in turn overlain unconformably by sandy mud. This sandy mud often shows an initial dip downstream and it is frequently cross-bedded. Wood, bark, leaves and other plant fragments are common in the lower portions of the mud and are sometimes in the gravel. Although these two components of the flood plain are separated by an unconformity, this break is believed to be due to so-called contemporaneous erosion. At any rate it does not interfere with a certain amount

of interfingering between the basal gravel and the sandy mud. Several sections in the stretch between Niles and Owasco illustrate the relations of the Holocene flood plain to its nearest Pleistocene terrace (figure 54). Such sections occur where meanders have cut sideways not only through the Holocene flood plain but also into the Pleistocene terrace behind it. The Holocene deposits are seen to rest upon and against the sloping scarp of the Pleistocene terrace. The basal gravel of the flood plain rises diagonally and merges with the capping gravel of the earlier and higher terrace surface. The Holocene basal gravel is clearly derived from the Pleistocene cap gravel (see also figure 55).

Much less important localities for plant-bearing Holocene flood plain material are on the south-flowing stream in the Dutch Hollow depression and on Skaneateles inlet south of the east-west road which crosses it.

Lake-head deltas. These are like the typical delta in origin but the outline in plan is different. The latter is dependent upon the shape of the receiving water body. On the Skaneateles quadrangle these deltas are confined by the limiting walls of the Finger Lakes valleys in which they have formed and are still forming. Away from the lake into which such a delta is built its surface merges with that of the inlet flood plain. The only lake-head delta entirely within the quadrangle is the relatively small one at the southern end of Skaneateles lake (figure 56). Of somewhat greater area is the portion of the Owasco Lake delta which is shown by the map. Here, however, one is viewing but a small part of a large lake-head delta. The delta at the southern end of Otisco lake barely intrudes on the quadrangle. It is represented by a small triangular area on the western shore of the lake. Unfortunately the structure of these deposits is not displayed, what sections there are being shallow and superficial.

Cone-delta points (figures 51, 57). Streams flowing down the often steep walls of the Finger Lakes valleys have their velocities suddenly checked at, or slightly above, lake level. The result is an accumulation of material mostly under water level but partly above it. If, in its lower course, the entering stream flows through a gently sloping gorge, the topographic form or "point" produced at its mouth may have a surface approaching the horizontal. In such a case the surface is only slightly above water level but the point may extend far out into the lake. The form here is more of a delta than an alluvial cone. Illustrations of this particular combination of conditions are afforded by Carpenter point on Skaneateles lake and the point at the Pudding Mill gully on the west side of Otisco lake. At

the other extreme is the point formed by an almost ravineless stream that tumbles down the valley wall with unreduced grade. Now the portion of the point above water is an alluvial cone having a brisk incline to the very beach. Such a mass is more cone than delta even in its subaqueous portion which slopes steeply to the lake bottom. A good example of this extreme condition is furnished by an unmapped point on Skaneateles lake known locally under the names of Ivy point and Willow point. It is situated on the east shore of the lake roughly six-tenths to seven-tenths of a mile north and slightly west of Spafford Landing. By far the greater number of Finger Lakes points are intermediate between the extremes just noted. They have many features of the deltas and also of the cone, and the term used as the heading for this section is particularly applicable to them. The larger and more gently sloping points are building upward at a relatively slow rate. The steep and more conelike points may build up with sufficient rapidity to cover the lower portion of the trunk of a still growing tree.

Alluvial cones. Small or even miniature examples of these forms may be produced in almost any place on land where the velocity of running water is suddenly reduced by an abrupt decrease in grade. Excluding the cone-delta points of the preceding section, the best illustrations of alluvial cones within the quadrangle are to be found in the steep walled but moderately wide and flat-bottomed valleys. Dutch Hollow south of Niles, Guppy gulf and the Cedarvale channel furnish good examples (see figure 58). Sometimes the cones stand out sharply at the mouths of the larger tributary streams. In other cases many small parallel rills have produced a conelike fringe at the base of the valley wall. This grades into and has many points in common with talus. Such a condition is well shown in the western part of the Cedarvale channel (south and southwest wall) but the fringes are present in many other localities where stream grades are suddenly reduced.

Talus. As noted in the preceding section, there is a transitional series of deposits from alluvial cones and fringes into talus. Intermediates between the fringe and talus are common in the area. On the other hand, typical talus produced by changes of temperature and by alternate thawing and freezing is not very well illustrated. This last accumulation, involving little or no water action in its formation, is best seen along the northern front of the limestone escarpment west from Skaneateles Falls and also below outcrops of Tully limestone. A good example of Tully talus is found between the Spafford Landing and Staghorn Point ravines (figure 59).

Figure 56 Lake-head delta, Skaneateles lake. Looking from the east hill toward Glen Haven. (Photograph by E. O. Smith, May 18, 1932)

Figure 57 Threemile point, Skaneateles lake. This cone-delta point and ravine of supplying stream show on the farther (west) side of the lake. (Photograph by E. O. Smith, May 18, 1932)

Figure 58 Alluvial cone. East side of Guppy Gulf channel. (Photograph by E. O. Smith, 1916)

Figure 59 Tully limestone terrace between Spafford Landing and Staghorn Point ravines. At left, talus of Tully limestone blocks; at center, Tully limestone in place; at right, run-off wash and Genesee shale slope. (Photograph by E. O. Smith, October 7, 1930)

Swamp deposits. These have accumulated and are accumulating in many low and flat areas where the drainage is poor. Though vegetable matter is an important element in their formation the writer is unaware of the occurrence of anything approaching peat within the quadrangle. The structure of these swamp masses is not revealed, and in the absence of diggings or borings, inferences must be made from surface observations alone. Notable swampy tracts occur on the lake head deltas and in Guppy gulf and the Cedarvale channel. Other swamps of fair size in which one might expect to find deposits of appreciable thickness are Bear swamp and the low areas among the drumlins west of Baptist Four Corners.

Calcareous tufa. Small and local occurrences of this calcium carbonate spring deposit are probably widespread within the quadrangle. Loose blocks of it are occasionally found in ravines cutting the Devonian formations. The most extensive deposits of tufa noted are in the Ninemile Creek (Otisco) valley. These are distributed along the east wall of the valley between the Cherry Valley highway and the Cedarvale channel. An interesting locality may be found on the west wall just north of the quadrangle boundary. Plant fossils are quite common in the tufa, some of the leaf surfaces being well reproduced by the material.

STRUCTURAL GEOLOGY

DISTURBANCES OF THE BEDROCK

The general regional dip for the bedrock strata of the quadrangle is in a direction slightly west of south and at a rate between 25 and 50 feet a mile. Gentle reversals of this dip are seen in the railroad cut south of Mottville (figure 17), on the west side of Skaneateles lake about two miles south of Skaneateles village, and on the east shore of the same lake about one and one-half miles north and slightly west of Fivemile point. These three cases are in Hamilton strata and probably are assignable to the system of broad low arches that have been noted on other quadrangles in central New York (Williams, H. S., '83, p. 412; Kindle, '04; Kindle, '09, p. 13–15, figs. 9–10).

A striking acceleration of the regional dip is shown by the behavior of the Tully limestone in Dutch Hollow valley northwest of Kelloggsville.

In the Indian Cove ravine (south branch) on the east side of Owasco lake the Windom shale below the Tully limestone is much disturbed. The details of this condition are not understood. Appar-

ently there is a fold striking roughly east and west. No vertical displacement by faulting has been detected but evidence of a three-fourths inch horizontal dislocation is given by a small vein which shows in plan. Apparently the overlying Tully limestone is not involved in this disturbance whatever it may be.

Local but sharp deviations from the regional dip are common on the top of the limestone escarpment of the northern and northwestern parts of the quadrangle. These are usually expressed as small dome and basin folds which apparently developed near the surface at a late date. Fine examples are found on the terrace between Skaneateles Falls and the west line of the quadrangle (see figure 60). It is not unreasonable to assign these structures to Holocene time and to this extent they are probably synchronous with folds near Caledonia (New York) described by Gilbert ('91, p. 230, 231).

Some disturbances in the limestone, however, are not of this class, having probably occurred at a remote period and in connection with the presence of a considerable load of overlying rock. Here should be placed the fault near Marcellus and the acute dip reversal southeast of Marysville. The latter locality is on the east side of an eastern meander of Skaneateles creek and not far from the path of the Syracuse water supply pipe line. In an old mill race the Onondaga limestone shows a sudden northward dip. Where most extreme the angle is slightly over 20 degrees. Calcite veins indicate that this is not a surface phenomenon. No actual dislocation of the strata has been found but the conditions suggest proximity to a fault.

In the same category must be placed the fault in Onondaga limestone roughly one-half a mile south and east of the main bridge at Marcellus. The best exposure of this fault is in one of the several Malley quarries that have been excavated in the Onondaga limestone (see figure 61). The quarry in question is situated on the north side of the road running through the Cedarvale channel and a short distance west of the mapped tributary that flows from the northeast into the limestone sink at the channel head. This displacement, apparently known to Vanuxem, has been mentioned or described by a number of later authors (Vanuxem, '39, p. 277; Luther, '98, p. 294; Schneider, '99; Hopkins, '14, p. 39, 40). Until very recent years, thanks to the interest of the late William Malley of Marcellus, the fault in this quarry was well shown in both plan and section. Observations made by the writer in 1929 may be briefly summarized. The hanging wall is on the north, the footwall

Figure 60 Limestone terrace ("Lime Ledge") west of Skaneateles Falls. Basinlike fold in Onondaga limestone determining the surface contour of the terrace. Camera looks roughly east. (Photograph by E. O. Smith, November 16, 1931)

Figure 61 Malley quarry in Onondaga limestone near Marcellus. In background the hammer handle shows direction of fault plane on western quarry wall. In immediate foreground the slickensided fault plane shows in plan. (Photograph by E. O. Smith, November 11, 1930)

on the south. The angle of dip of the fault plane is between 18° and 20°. The direction of dip of the fault plane runs between 11° and 25° east of north (magnetic). The direction of slickensides is between 12° and 27° east of north (magnetic). The strata of the fault block south of, and below, the fault plane have a dip angle of 9°–10°. The dip direction is 30° or more east of north (magnetic). On the block north of, and above, the dislocation the dip angle is 5°–10° and the dip direction is apparently 40°–50° or more east of north (magnetic). The fault is regarded as a thrust, that is, the north block is on the upthrow side, the south block on the downthrow side. The amount of displacement estimated by an observer may depend largely upon his interpretation of the flint bands present in the limestone. The writer believes that the evidence points to a stratigraphic displacement of eight and one-half feet but it is conceded that the amount may possibly be as low as eight or nine inches. Some estimates in the literature are considerably at variance with the one just given. It is of interest to note that in neither fault block are the strata buckled or curved. This may be used as evidence that the fault did not take place at great depths within the crust. On the other hand, the presence of fault breccia, veins and calcite crystallizations in association with the slickensides precludes a surface origin for the structure. The outcrop of this fault could formerly be traced westward to a quarry south of the road. This latter quarry is now undergoing the fate of many other small abandoned quarries in central New York. Its use as a dump has rather thoroughly concealed all sign of the fault.

ICE THRUSTS

From a strictly scientific standpoint these could have been considered very properly in the preceding section of this report for they possess many points in common with typical faults. In view of their gradation into till, however, it is deemed advisable to accord them separate treatment. The thrusts in question occur in Hamilton strata on the west shore of Skaneateles lake between approximately three and somewhat over four and one-half miles southerly from the foot of the lake at Skaneateles (figures 62, 63, 64). Excluding a doubtful case which may possibly represent high angle faulting, the dislocations considered here are of low angle, in fact, approaching the horizontal. Though the outcropping edge of a thrust surface may appear as a straight or nearly straight line, it is believed not to be so in reality. The surfaces are apparently undulating, and the northernmost one in particular can be seen to

rise from lake level and then descend under it again in going from north to south. This indicates that one is dealing with what are on the whole gently curved surfaces.

The northernmost thrust observed occurs at the base of a lake cliff north of the two closely approaching brooks that flow into the lake three and one-fourth miles from its foot. The cliff runs roughly north and south extending for over 900 feet along the lake. The line of dislocation rises sharply from the water at the northern end of the cliff. Here it makes an angle with the bedding planes of the shale. In the course of a short space, however, the line comes into practical agreement with the bedding planes and partakes of their southerly dip. This attitude is maintained until the thrust surface passes beneath the water farther south along the cliff. At its highest point the surface is about five feet above the lake at usual level.

Most of the outcrop of this dislocation shows plainly from the lake, but as its northern discordant end is inconspicuous from a distance the observer is readily led to conclude that he is looking at a bedding plane that bounds the upper surface of a shale layer somewhat harder than those higher up. Closer examination reveals the fact that the line marks the outcrop of a basement upon which a breccia of shale fragments lies. The thickness of the brecciated zone runs from practically nothing to four inches or more. The fragments of the breccia are angular and as far as observed exclusively shale. They are usually but a few inches in longest diameter and lie embedded in an unconsolidated muddy mass having the same general color as the shale.

The surface upon which the breccia lies is usually obscured by talus fallen from the cliff. Prolonged high water may remove this to such an extent that little excavation is needed to disclose the conditions. In such a case one finds a well-polished and striated surface. The striae observed range in length from one-half an inch or less to about five inches. The direction of the majority of striae is about northwest-southeast. Some of the striae are of uniform width but the greater number are in plan widest at the northwest end, tapering off to a point at the southeast (see figure 63).

The under surface of the upper shale mass is likewise polished at its contact with the breccia, although here definite scratches have not been noted. The shale mass above the breccia is only slightly more disintegrated than is the shale in a normal cliff at the same height above lake level. Joint planes are well shown in this upper mass. These may have the same direction as the planes of the lower shale mass. Some appear to be aligned with lower joint planes, but in

Figure 62 Skaneateles lake: west shore about three miles from foot. Thrust in Hamilton (Skaneateles) shale. Somewhat curved surface of thrust plane below and at right. On left, cliff of upper thrust block with thin brecciated zone at base. (Photograph by E. O. Smith, 1921)

Figure 63 Skaneateles lake: west shore about three miles from foot. Thrust in Hamilton (Skaneateles) shale. Thrust plane surface from above showing polish and striae. Many of the striae are widest at the northwest end, tapering to a point at the southeast. (Photograph by E. O. Smith, 1921)

these much jointed masses such an appearance can hardly be taken as proof of a former continuity. A careful search, however, shows that some joint planes are not in line with any plane on the other side of the breccia. It is believed that such discontinuity of joint planes, together with the polishing, the striae, and the breccia leaves little room for doubt that movement has taken place between these two shale masses.

More southern thrust surfaces are found beyond the two closely approaching brooks already mentioned. It is not improbable that there are three distinct thrusts in this southern stretch but the number can not be determined exactly. What appear to be distinct surfaces may in reality be different parts of the same thrust. Another complication is afforded by what may be high angle faulting of a low angle thrust surface. A possible continuity between one of the more southern thrusts and the northern one should also be kept in mind.

Although the data are not at hand for complete solution of the problems of these southern outcrops they nevertheless give most instructive information. Sometimes, as at the north, a lower shale mass is separated from an upper shale mass by a thin zone of breccia. Polished surfaces are also found. An additional point in favor of movement is furnished by discordant tilted joint planes in the upper shale mass (see figure 64). A further stage shows the upper shale mass greatly disrupted, fragments of shale of large size lying at all angles and in all positions upon the undisturbed lower shale mass. Here the passage to a typical till is forcibly illustrated.

To sum up, there is more or less evidence of disturbance in the shale along the lake shore for a distance of about one and one-half miles. The indications of movement of the upper shale masses over the lower ones are (*a*) lack of continuity between joint planes of the two masses, (*b*) discordant and southward-leaning joint planes in the upper mass, (*c*) polished and scratched upper surfaces of lower mass, (*d*) polished lower surface of upper mass, (*e*) brecciated zone of shale fragments and mud between the two masses. Direction of movement is indicated by the leaning joint planes and the orientation of scratches on the top of the lower mass. It is roughly northwest to southeast. Direction of movement points at once to glacial action. Lack of induration in the breccia points to recency and to absence of burial under great rock load. Polishing and striation are very like, perhaps indistinguishable from, ordinary glacial polish and striation. The upper shale mass shows a series of fragmentation stages the last of which approaches till. It is believed that the sum of evidence points to ice thrust as the best explanation for the observed facts.

ECONOMIC GEOLOGY

The Skaneateles quadrangle comprises an area that is primarily agricultural. Manufacturing districts are mostly limited to narrow belts along Skaneateles and Ninemile creeks. Mineral industries, although at times active, have never played a dominant rôle in the development of the region.

During the preceding century in the early years of the "Machine Age," with cheap labor and inadequate transportation facilities, there were established many local enterprises and manufactures that depended upon local raw materials. At this period there was not a little local demand for building stone, quicklime, hydraulic cement, flagstone, gravel, sand and tile clay in the area covered by this report. Under modern conditions this demand has become much reduced and is now largely restricted to the needs of highway construction and repair.

For more detailed information the reader is referred to Luther's work ('98) on Onondaga county. This publication does not, of course, cover the entire Skaneateles quadrangle but it gives a good contemporary sketch of mineral industry in the central New York of the late nineteenth century.

GAS

Somewhat vague rumors of gas occurrences in central New York are occasionally heard. One's informant may have no accurate knowledge of the precise locality in such cases and it may develop that he is merely passing along hearsay information.

Luther states that "Some small gas springs occur in the vicinity of Skaneateles lake and Otisco lake, and at other localities in the Hamilton shales, but the quantity of gas is not large enough to be of commercial value" ('98, p. 297). Therefore it is not improbable that this author was acquainted with the well-known gas occurrence in the Pudding Mill ravine on the west side of Otisco lake about two miles from its foot. In this ravine gas has been seen bubbling from the water at two different stations. At the upper of these stations, some 45 to 50 feet (approximately) above Otisco lake, the gas comes from a submerged joint plane in the Hamilton (Skaneateles) shale. The plane trends about 12½° west of north (magnetic). At an altitude between 70 and 90 feet higher the stream in the ravine seems to be running at or near the summit of an irregularly fractured anticline. It is not known whether gas "springs" and disturbance of strata are related or whether their proximity is a mere coincidence.

Figure 64 Skaneateles lake: west shore about four miles from foot. Thrust in Hamilton (Skaneateles) shale. Clinometer rests upon the thrust plane. Above comes an upper thrust block with thin brecciated zone at base. Joint planes below the thrust are vertical or nearly so. Joint planes above the thrust are discordant and lean to left (southward). (Photograph by E. O. Smith, 1921)

The only other observed gas occurrence within the quadrangle is on the east side of the Owasco valley near the southern line of the map. In the south branch of the last stream shown and a short distance east of the valley road gas has been heard and seen bubbling from a submerged and roughly north-south joint plane of the Hamilton (Ludlowville) shale.

At neither the Otisco nor the Owasco valley localities has the writer tested the inflamability of the gas. At each place, however, there was ample evidence that the gas had been tested and apparently ignited by previous visitors.

As far as the writer is aware, the Owasco valley gas occurrence has never been regarded as anything more than a curiosity. The Otisco Pudding Mill emanations have apparently been viewed chiefly in the same light, although it is understood that some exploratory work was done there about 25 years ago.

The Cunningham Natural Gas Corporation of Bradford, Pa., is now (spring of 1932) drilling for gas near Howlett hill (Baldwinsville quadrangle). The opening of the drilling is in the upper part of the Onondaga limestone about one and one-fourth miles north of the north line of the Skaneateles quadrangle. The writer has been informed that a similar enterprise south of Onondaga Hill (Syracuse quadrangle) has been abandoned. In this latter case the exact location of the drill is unknown to the writer.

It is a matter of common belief that many "leases" have recently been arranged between gas companies and owners of land within the Skaneateles quadrangle. Apparently, however, these agreements have not resulted in actual drilling to date (June 1932).

LIMESTONE

Building stone. The Onondaga limestone of the quadrangle has been utilized to a limited extent for construction purposes. Luther ('98, p. 278, 279) mentions quarries at Skaneateles Falls and one-half a mile south of same. He also notes the quarries near Marcellus and says that the "cut stone for the dam at the foot of Otisco lake was taken from Maylie's quarry." The Onondaga surpasses subjacent limestones in furnishing large and fairly even blocks of workable size. Diagonal jointing in the Clark Reservation and Stromatoporoids and other irregularities in much of the Jamesville would seem to render these limestones unfit for any but the crudest building operations. The Olney limestone, or at least some of it, seems to be suitable for cellar and foundation work. The Tully is the only important limestone above the Onondaga. It is not ordinarily thought of as a building stone but the Nunnery Schoolhouse near Borodino has

been cited (Knapp, ('88 ?), p. 4; Luther, '98, p. 284) as an example of a building constructed of Tully limestone.

Road work. Most of the limestone quarried within the quadrangle finds its way in one form or another into the construction of modern highways. Many of the Tully limestone quarries are periodically reopened for this purpose.

Quicklime. The Onondaga limestone was presumably used in the quicklime kiln at the smaller Malley quarry near Marcellus. Blue limestone, however, seems to have been the raw material for most of the quicklime manufactured in the area (Knapp, ('88 ?), p. 7; Luther, '98, p. 267, 272). Within the Skaneateles quadrangle this blue limestone was probably Jamesville and Clark Reservation for the most part, although it is not unlikely that the Olney was used to a certain extent.

WATERLIME

Chief among the waterlimes of the quadrangle is the Elmwood member of the Manlius. It was formerly extensively employed in the manufacture of hydraulic cement. Luther ('98, p. 271) indicates that this industry was an important one at Skaneateles Falls some 30 or 40 years ago.

SANDSTONE

Oriskany sandstone and sandstone of Onondaga age associated with it have seldom been employed for economic purposes in central New York. Vanuxem and later Luther (Vanuxem, '42, p. 126; Luther, '98, p. 275) mention the use of Oriskany sandstone in lock construction on the Erie canal at Jordan. Luther also notes that the sandstone was quarried in the town of Skaneateles "for cellar and foundation stone, and occasionally for lining in lime kilns." The stone for the Jordan lock is believed to have come from the Baldwinsville quadrangle not far from its boundary line with the Skaneateles quadrangle northeast of Skaneateles Falls.

FLAGSTONE

Flagstone quarrying was at one time active within the area of the Skaneateles quadrangle. Most of these flags came from the Ithaca beds but the writer has been shown the location of a former quarry, now much overgrown, which was unquestionably excavated in the Sherburne.

At present the quarry in best condition is that known as the Fitzpatrick quarry one mile north of Omro (figures 30, 31). Its horizon is referred to the Ithaca. Flag production has ceased here but the old tailings are used in road work.

Another quarry, in fair shape, can be seen on the hillside just below the hamlet of Spafford. The beds here have been determined as Ithaca by Luther ('98, p. 286) and the present writer concurs in this opinion. Luther says: "The quarry at Spafford was operated vigorously at one time, and produced some very fine flagging, which was taken down the hill to Spafford's landing, thence to Skaneateles by boat. It is not now operated."

SHALE

Luther ('98, p. 280) speaking of the Marcellus group of shales says: "All the experience of men who have spent time and money in the vain search for coal in these beds has not even yet entirely destroyed the belief that it exists in large quantities, the belief resting on the presence of occasional thin seams of coaly remains of plant life, and the general carbonaceous appearance of the shales."

As far as known, within this quadrangle, the only experimentation looking toward the utilization of shale has been conducted near Marcellus by H. A. Frasch. The shale employed is apparently Chittenango and the writer has been informed that paint manufacture is the chief aim of the research which has been undertaken at Mr Frasch's laboratory near Slate hill.

GRAVEL AND SAND

Great quantities of gravel and sand are found among the aqueoglacial deposits of the Skaneateles quadrangle. Among the larger masses of these materials may be mentioned those of the Skaneateles Creek valley, Shepard Settlement, Guppy Gulf delta and the mass to the south of it, Cedarvale delta, Amber delta, and masses south and east of Niles. Many smaller areas are to be found throughout the quadrangle. These are somewhat irregularly distributed but are usually located in the valleys high or low.

CLAY

Clay is common in the glacial and aqueoglacial deposits of the region covered by this report. Many of the bodies of this material, however, are local, of uncertain boundaries or much mixed with boulders, gravel and sand. The larger clay deposits relatively free from impurities are to be found in the valleys of Ninemile creek and of Dutch Hollow brook.

Near the village of Owasco clay in sufficient quantity and requisite quality was used chiefly in tile manufacture at the plant of John H. Hare. Mr Hare states that he also made some brick. The plant is still standing but has not been running for ten years. The pits have

been dug near-by but it is not now possible to determine the exact geological conditions. There can be little doubt, however, that the stratified clay so widespread along Dutch Hollow brook was the raw material employed.

In the northern part of the village of Skaneateles clay was dug years ago for the manufacture of tile. The old "clay holes" are in the vicinity of the outlet of Skaneateles lake. It is not, however, possible to state the geological conditions, nor even the exact nature of the material used. The pits were apparently shallow and have been largely filled in artificially since the discontinuance of the industry. It is not unreasonable to suppose that the clay was sedimentary, occupying one or more depressions in a boulder clay surface. This supposition is not based upon direct evidence and represents nothing more than a probability.

FIELD TRIPS

In a period of active highway construction and of rapid changes in transportation methods it is not possible to work out a field program that will hold from year to year. In central New York at the present day the automobile is beyond doubt one of the geologist's most efficient allies. Any rapid survey of the region can be best accomplished by using the car for making distance and then operating from it on foot over a chosen area. The writer recommends this procedure for any general work, for studies on the limestone escarpment and for investigation of the side ravines of the Finger Lakes valleys. In the last case it is usually best, sometimes imperative, to park on one of the higher roads largely built back of, or uphill from, the ravine heads. One may then descend to the lake through fields and woods and return to his car by way of a ravine. On this return it is often convenient to measure with a level the vertical thickness of the ravine section. While on the subject of ravines the writer feels impelled to sound a warning which the professional geologist does not need. Let the beginner or the amateur bear in mind that in the ravine the footing may be very insecure, the rock surfaces slippery, the bordering tree branches rotten, and many rock ledges loose especially about waterfalls. The dangers of ravine climbing are much increased if one is preoccupied with the use of a level. The writer knows of no "fool-proof" method of working a ravine but suggests that whenever possible the investigators, amateur or professional, go in pairs.

If the visitor to the region is not pressed for time he may find great interest in a rowboat trip of the shores of one of the Finger

Lakes. Here again, safety requires that such a trip should only be undertaken by one familiar with the handling of small boats and even the old sailor should be reminded that the Finger Lakes are not millponds and that a storm on one of them may be very bad indeed.

The following suggestions for field trips are intended chiefly to supplement information contained in the main body of this report.

Cherry Valley highway. The geologist who is making an east-west tour along this highway may see not a little geology without getting out of the car. If time permits, however, a few very short side trips add greatly to the interest. Just before coming onto the Skaneateles quadrangle from the east and slightly more than a mile east of Joshua (Tully quadrangle) the Cherry Valley highway crosses the South Onondaga-Otisco road. If one follows south from the crossroads a very short distance he finds a celebrated coral reef of the Hamilton shale. This reef is correlated with the upper coral horizon of the Otisco valley (figure 24).

At Navarino (Skaneateles quadrangle) the Cherry Valley highway crosses the main thoroughfare between Syracuse and Amber. A short distance west of Navarino on both sides of the Navarino channel there are interesting cuts in Pleistocene superficial deposits. The latter are also deeply excavated on both sides of the Ninemile Creek valley west of Navarino.

On the western side of the Ninemile Creek valley and at the foot of the hill the car can be left at the crossroads and the Clintonville ravine visited. If there is a driver for the car, have him drive to Clintonville and wait. In such case the foot party turns northwesterly from the crossing following the lower road to the Clintonville ravine. A short distance east of this lower road disturbed Pleistocene red clay is seen overlain unconformably by Holocene stream wash (figure 53). If the members of this party now ascend the ravine, and carefully watch the left-hand wall, the Clintonville igneous dikes may be found (figures 32, 33). If the ravine is followed to Clintonville, a fair but incomplete section of the Skaneateles shale can be observed.

Rejoin the car at Clintonville and drive to Skaneateles. From the municipal parks at Skaneateles, especially from Clift Park, one has a fine view of Skaneateles lake—a view which incidentally gives a very good illustration of the Finger Lakes class of lake.

To see the type section of the Mottville member at Mottville and to visit the Carrigan quarry at Skaneateles Falls, turn north on Jordan street, Skaneateles. The Mottville section is along the track of the Skaneateles Railroad just south of Mottville (figure 17).

The Carrigan quarry showing the best section is at the northern edge of Skaneateles Falls just east of railroad track and improved highway. Section begins in the upper portions of the Olney limestone (showing its Stromatoporoid zone), passes through the Elmwood waterlime, the Clark Reservation limestone, the Jamesville limestone (with Stromatoporoids), and reaches at top the Oriskany sandstone (figure 6). The lowest tier of the sandstone carries the *Spirifer arenosus* fauna.

On return to Skaneateles follow the Cherry Valley highway to Auburn (Auburn quadrangle). Over this stretch the road crosses drumlins and drumlinized drift which serve to illustrate the less extreme or weak type of drumlin topography. Road cuts show the nature of the material composing these hills.

If one is touring the Cherry Valley highway in July, August or early September and spends the day at Skaneateles, an opportunity can usually be found for a study of points of interest along the lake shore. During the time of year just mentioned the boat of the Skaneateles Navigation Company now (1932) leaves the bridge at Skaneateles 9 a. m. on weekdays and returns to Skaneateles about 3.30 p. m. On Sunday the boat leaves Skaneateles at 10 a. m., returning about 4 p. m. On the southbound part of the trip the geologist can debark at Staghorn point and arrange with the boat's captain to be picked up at the same spot on the northbound return trip to Skaneateles. For geological features of Staghorn point and vicinity see figures 19, 20, 21, 23 and Smith ('12) of Bibliography.

Syracuse to Cedarvale, Amber, Marcellus and return. The first part of this trip would lead ordinarily through Split Rock (Syracuse quadrangle). At Split Rock the abandoned quarries of the Solvay Process Company afford good sections of the Olney limestone (including type section), the waterlime Elmwood A, and the lower part of the Onondaga limestone with its basal quartz sand of reworked Oriskany. Among many points of interest are two outstanding features. These are the unconformity (disconformity) at the base of the Onondaga and the remarkable mudcracks shown by the Elmwood. For the relations of the Split Rock section with those sections east and west of it see Smith ('29) of Bibliography.

On the Skaneateles quadrangle a short distance north of Cedarvale the road winds down a ravine in which the Chittenango member of the Marcellus is well exposed. The road then passes over the Onondaga limestone at Cedarvale and, partly on the Tully quadrangle, skirts the Cedarvale delta (see Fairchild, '09, p. 28, pls. 4, 21). Just before reaching Navarino a kame slope is seen east of

road. The first junction with the Cherry Valley highway is at Navarino. South of Navarino the Navarino channel is seen on the west, then at the channel mouth the road comes down onto the flat surface of the Amber delta (figure 50), passes the mouth of the Joshua channel, and finally reaches Otisco lake at Amber. Between Amber and the north end of the lake the road skirts the base of the Amber delta. From Marietta northward to the Cherry Valley highway the Ninemile Creek valley is flanked east and west by a fairly well-defined red clay terrace and scarp. The second junction with the highway just mentioned occurs east of Clintonville. If one wishes to visit the Clintonville dikes on this trip, see preceding pages of this section of the report. Ninemile creek is crossed on the Cherry Valley highway and then the road goes north to Marcellus. On this stretch one can look west across the Ninemile Creek valley viewing successively the Clintonville ravine and its mouth, the probable outwash delta and its northern kame slope, the mouth of the Guppy Gulf channel and then the Guppy Gulf delta. At Marcellus go to the head of the Cedarvale channel and examine the large Malley quarry (in Onondaga limestone) south of the road (figures 12, 13), the smaller Malley quarry with its fault north of the road (figure 61) and the sink with its underground stream (see Fairchild, '09, pl. 20). The writer recommends that this last feature be viewed from its limestone wall for a further descent may be accompanied by not a little discomfort and possibly by some danger.

The return to Syracuse can be made by way of the Seneca turnpike through Wellington Corner.

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APPENDIX

CONSPICUOUS AND CHARACTERISTIC FOSSILS OF THE PALEOZOIC STRATIGRAPHIC UNITS, SKANEATELES QUADRANGLE

The purpose of this appendix is to present short lists of some of the more conspicuous and characteristic fossils of the Paleozoic stratigraphic units of the Skaneateles quadrangle. Some of these units are virtually unfossiliferous, while in other cases the fossils adhere so closely to a matrix that ordinary means of extraction and determination fail. The strata below the Olney limestone have shown nothing but silicified Stromatoporoids, while the Clarke Reservation limestone seems to contain only Leperditias and these are seldom apparent. No fossils have been seen in the Elmwood which seems to be completely lacking in them. Except for a plant in a loose block presumably referable to the Genesee shale, the writer is without record of fossils from that formation on the Skaneateles quadrangle. No fossils have been noted in the mass of the Cardiff though *Leiorhynchus* occurs in a zone which could be regarded as transitional into the Mottville. No lists therefore appear for the units just mentioned. No attempt is made to name the interesting corals of the Otisco which should be studied by one who is a specialist in that group of organisms.

Olney Limestone

The following fossils have been noted in the Olney limestone of the Skaneateles quadrangle:

Stromatoporoids
Crinoid columns
Stropheodonta (*Brachyprion*) *varistriata* (Conrad)
Spirifer vanuxemi Hall
Whitfieldella sulcata (Vanuxem)?
Eurypterus microphthalmus Hall

Jamesville Limestone

The following fossils have been noted in the Jamesville limestone of the Skaneateles quadrangle:

Stromatoporoids
Spirifer cf. *vanuxemi* Hall — Loose block
S. cf. *cyclopterus* Hall
Murchisonia?
Holopea?
Leperditias

Oriskany Sandstone

The following fossils have been noted in the Oriskany sandstone of the Skaneateles quadrangle:

Orthis musculosa Hall?
Hipparionyx proximus Vanuxem
Spirifer arenosus (Conrad)
S. murchisoni Castelnau
Meristella lata (Hall)
Diaphorostoma ventricosum (Conrad)

Onondaga Limestone

For the Skaneateles quadrangle and adjoining parts of the Baldwinsville quadrangle, the following fossils have been noted in the Onondaga limestone:

Corals in general
Aulopora?
Crinoid joints
Callopora?
Trematopora?
Fenestella sp.
Orthis lenticularis Vanuxem
Leptæna rhomboidalis (Wilckens)
Strophcodonta inequiradiata Hall
S. cf. *patersoni* Hall
Schuchertella pandora (Billings)
Chonetes lineatus (Vanuxem)
Camarotœchia tethys (Billings)?
Atrypa reticularis (L)
A. spinosa Hall
Spirifer sp.
S. cf. *duodenarius* (Hall)
Athyris spiriferoides (Eaton)
Loxonema sicula Hall
Styliolina fissurella (Hall)
Halloceras undulatum (Vanuxem)
Acidaspis callicera Hall and Clarke
Odontocephalus selenurus (Eaton)
Phacops cristata Hall var. *pipa* Hall

Union Springs Member

The following fossils have been noted in the Union Springs member of the Skaneateles quadrangle:

Styliolina fissurella (Hall) — Very abundant
Obscure shells and perhaps scales

Cherry Valley Member

On the Skaneateles quadrangle the following fossils have been noted in the Cherry Valley member:

Leiorhynchus limitaris (Vanuxem)
Orthoceras marcellense Vanuxem
Agoniatites expansus (Vanuxem)
Arthrodiran plates (fragments)

Chittenango Member

The following fossils have been noted in the Chittenango member of the Skaneateles quadrangle:

Schuchertella arctostriata (Hall)
Chonetes mucronatus (Hall) — Common locally
Strophalosia truncata (Hall)
Leiorhynchus limitaris (Vanuxem) — Abundant locally
Ambocœlia umbonata (Conrad)?
Aviculopecten?
Actinopteria?
Leiopteria lævis (Hall)?
Styliolina fissurella (Hall) — Common locally

Mottville Member

On the Skaneateles quadrangle the following fossils have been noted in the Mottville member:

Corals
Crinoid joints
Reptaria stolonifera Rolle
Stropheodonta perplana (Conrad)
Tropidoleptus carinatus (Conrad)
Chonetes mucronatus (Hall)
Strophalosia truncata (Hall)
Leiorhynchus limitaris (Vanuxem)
Spirifer audaculus (Conrad)
Ambocœlia umbonata (Conrad)
Leiopteria lævis (Hall)
Modiella pygmæa (Conrad)
Goniophora sp.
Bembexia sulcomarginata (Conrad)
Styliolina fissurella (Hall)?
Coleolus aciculatus (Hall)?
Orthoceras constrictum Vanuxem
O. subulatum Hall
Homalonotus dekayi (Green)
Cryphæus boothi Green
Phacops rana (Green)

Skaneateles Shale Undivided

In the beds between the Mottville below and the Centerfield above the following fossils have been noted on the Skaneateles quadrangle:

Crinoid joints
Lingula sp.
Crania?
Stropheodonta perplana (Conrad)
Schuchertella arctostriata (Hall)
Chonetes cf. *coronatus* (Conrad)
C. cf. *lepidus* Hall
C. mucronatus (Hall)
Leiorhynchus limitaris (Vanuxem)
L. laura (Billings)
Spirifer mucronatus (Conrad)
Ambocoelia umbonata (Conrad)
Athyris cf. *spriferoides* (Eaton)
Grammysia cf. *alveata* (Conrad)

Nucula bellistriata (Conrad)
N. corbuliformis Hall
N. cf. *varicosa* Hall
N. randalli Hall?
Nuculites oblongatus Conrad
N. triqueter Conrad
Pterinea flabellum (Conrad)
Pterochænia fragilis (Hall)
Actinopteria cf. *boydi* (Conrad)
Modiella pygmæa (Conrad)
Nyassa arguta Hall
Modiomorpha subalata (Conrad)
Sphenotus cuneatus (Conrad)
Bellerophon cf. *acutilira* Hall
Pleurotomaria (*Gyroma*) *capillaria* Conrad
Pleurotomaria cf. *P.* (*Euryzone*) *itys* Hall
Bembexia sulcomarginata (Conrad)
Macrocheilus (*Holopea*) *macrostomus* Hall
Conularia sp.
Orthoceras sp.
Cryphæus boothi Green
Phacops rana (Green)
Primitiopsis punctulifera (Hall)

Centerfield Member and Transition Beds at Base

On the Skaneateles quadrangle the following fossils have been noted either in the Centerfield or in the transition beds at its base:

Corals
Crinoids joints
Stictopora sp.
Crania?
Stropheodonta perplana (Conrad)
Tropidoleptus carinatus (Conrad)
Schuchertella arctostriata (Hall)?
Chonetes cf. *setigerus* (Hall)
C. syrtalis (Conrad)
Camarotœchia congregata (Conrad)
C. cf. *sappho* (Hall)
Eunella lincklaeni (Hall)
Spirifer mucronatus (Conrad)
S. granulosus (Conrad)
S. audaculus (Conrad)
S. sculptilis (Hall)
Reticularia fimbriata (Conrad)
Ambocœlia umbonata (Conrad)
Meristella barrisi Hall?
Phthonia cylindrica Hall
P. sectifrons (Conrad)
Nucula bellistriata (Conrad)
Palœoneilo tenuistriata Hall
Pterinea flabellum (Conrad)
Mytilarca (*Plethomytilus*) *oviformis* (Conrad)
Actinopteria cf. *boydi* (Conrad)
Aviculopecten princeps (Conrad)
Nyassa arguta Hall
Modiomorpha concentrica (Conrad)
Goniophora rugosa (Conrad)
Cypricardella bellistriata (Conrad)
Cypricardinia indenta (Conrad)

Tellinopsis subemarginata (Conrad)
Pleurotomaria. A cancellated form
Proëtus macrocephalus Hall
Cryphæus boothi Green
Phacops rana (Green)
Trail or burrow
Spirophyton-Taonurus markings

Otisco Member

Beds below Platform Which Underlies the Staghorn Point Submember

The following fossils have been noted in these beds on the Skaneateles quadrangle:

Pleurodictyum sp.
Ceratopora jacksoni Grabau?
Ancyrocrinus sp.
Tæniopora exigua Nicholson
Rhipidomella vanuxemi (Hall)
Stropheodonta demissa (Conrad)
S. perplana (Conrad)
Tropidoleptus carinatus (Conrad)
Schuchertella perversa (Hall)?
Chonetes coronatus (Conrad)
C. cf. *deflectus* Hall
C. lepidus Hall
Productella spinulicosta (Hall)
Strophalosia truncata (Hall)
Eunella lincklaeni (Hall)
Camarotœchia congregata (Conrad)
Atrypa reticularis (L)
Spirifer mucronatus (Conrad)
S. granulosus (Conrad)
S. audaculus (Conrad)
S. audaculus (Conrad) var. *macronotus* (Hall)
S. sculptilis (Hall)
Reticularia fimbriata (Conrad)
Vitulina pustulosa Hall
Athyris spiriferoides (Eaton)
Phthonia sectifrons (Conrad)
Nucula bellistriata (Conrad)
Nuculites oblongatus Conrad
Palæoneilo constricta (Conrad)
P. emarginata (Conrad)
P. tenuistriata Hall
Macrodon hamiltoniae Hall
Pterochœnia fragilis (Hall)
Actinopteria decussata (Hall)
Aviculopecten princeps (Conrad)
Modiomorpha concentrica (Conrad)
Goniophora rugosa (Conrad)
Cypricardella bellistriata (Conrad)
C. tenuistriata (Hall)
Cypricardinia indenta (Conrad)
Bellerophon (*Ptomatis*) *patulus* Hall
Pleurotomaria (*Lophospira*) *trilix* Hall
P. (*Euryzone*) *lucina* Hall
P. (*Gyroma*) *capillaria* Conrad
Loxonema cf. *hamiltoniæ* Hall and *bellona* Hall

Orthoceras crotalum Hall?
Parodisceras discoideum Hall?
Conularia sp.
Primitiopsis punctulifera (Hall)?
Phaëthonides cf. *gemmæus* Hall and Clarke
Proëtus macrocephalus Hall
Cryphæus boothi Green
Phacops rana (Green)

Platform Which Underlies the Staghorn Point Submember

The following fossils have been noted in this platform on the Skaneateles quadrangle:

Tæniopora exigua Nicholson?
Rhipidomella cyclas (Hall)?
Stropheodonta concava Hall
Schuchertella perversa (Hall)
Chonetes syrtalis (Conrad)
Strophalosia truncata (Hall)
Camarotœchia cf. *congregata* (Conrad)
Atrypa reticularis (L)
Spirifer granulosus (Conrad)
S. cf. *audaculus* (Conrad)
S. mucronatus (Conrad)
Ambocœlia umbonata (Conrad)
Nucleospira concinna (Hall)?
Vitulina pustulosa Hall?
Athyris spiriferoides (Eaton)
Pleurotomaria (*Lophospira*) *trilix* Hall
Cryphæus boothi Green
Echinocaris punctata (Hall)

Beds Between the Staghorn Point Submember and the Upper Reef at Millers Place Ravine

The following fossils have been noted in these beds:

Reptaria stolonifera Rolle
Rhipidomella vanuxemi (Hall)
Stropheodonta demissa (Conrad)
S. perplana (Conrad)
Tropidoleptus carinatus (Conrad)
Schuchertella perversa (Hall)
Strophalosia truncata (Hall)
Camarotœchia congregata (Conrad)?
C. sappho (Hall)?
Leiorhynchus laura (Billings)?
Atrypa reticularis (L)
Spirifer mucronatus (Conrad)
Reticularia fimbriata (Conrad)
Ambocœlia umbonata (Conrad)
Athyris spiriferoides (Eaton)
Grammysia cf. *lirata* Hall
Nuculites oblongatus Conrad
Palæoneilo cf. *constricta* (Conrad)
Actinopteria decussata (Hall)?
Aviculopecten princeps (Conrad)
Modiella pygmæa (Conrad)?
Sphenotus truncatus (Conrad)?

Modiomorpha subalata (Conrad)
Cypricardella bellistriata (Conrad)
Pleurotomaria cf. *capillaria* Conrad
Diaphorostoma lineatum (Conrad)
Styliolina fissurella (Hall)?
Tentaculites gracilistriatus Hall
Orthoceras crotalum Hall?
Primitiopsis punctulifera (Hall)?
Cryphæus boothi Green
Phacops rana (Green)

Beds Above the Upper Reef at Millers Place Ravine

The following fossils have been noted in these beds:

Cystiphyllum
Ancyrocrinus bulbosus Hall
Tæniopora exigua Nicholson
Rhipidomella vanuxemi (Hall)
Stropheodonta concava (Hall)
S. demissa (Conrad)
S. perplana (Conrad)
Tropidoleptus carinatus (Conrad)
Schuchertella perversa (Hall)
Chonetes sp.
Strophalosia truncata (Hall)
Atrypa reticularis (L)
Spirifer granulosus (Conrad)
S. audaculus (Conrad) var. *macronotus* (Hall)
S. mucronatus (Conrad)
Vitulina pustulosa Hall
Athyris spiriferoides (Eaton)
Phthonia sectifrons (Conrad)
Buchiola speciosa (Hall)
Nuculites oblongatus Conrad
Palæoneilo constricta (Conrad)
P. emarginata (Conrad)
P. cf. *plana* Hall
Pterinea flabellum (Conrad)
Actinopteria decussata (Hall)
Aviculopecten princeps (Conrad)
Modiella pygmæa (Conrad)
Modiomorpha subalata (Conrad)
M. cf. *mytiloides* (Conrad)
Cypricardella bellistriata (Conrad)
Cypricardinia indenta (Conrad)
Tellinopsis subemarginata (Conrad)
Bellerophon leda Hall
Pleurotomaria (*Lophospira*) *trilix* Hall
Pleurotomaria (*Gyroma*) *capillaria* Conrad
Cyclonema multilira Hall
Coleolus tenuicinctus (Hall)
Orthoceras cf. *crotalum* Hall
Nephriticeras liratus (Hall)
Proëtus macrocephalus Hall
Cryphæus boothi Green
Phacops rana (Green)

Ivy Point Member

The following fossils have been noted in the Ivy Point member of the Skaneateles quadrangle:

Crania sp.	Fallen block
Stropheodonta perplana (Conrad)	
Tropidoleptus carinatus (Conrad)	Common near top of member
Chonetes sp.	
C. coronatus (Conrad)	Fallen block
Pruductella sp.	
Camarotœchia congregata (Conrad)	Fallen block
Eunella lincklæni (Hall)	Fallen block
Spirifer mucronatus (Conrad)	Common to abundant
S. granulosus (Conrad)	
S. cf. *marcyi* Hall	
Ambocoelia umbonata (Conrad)?	
Athyris spiriferoides (Eaton)?	
Prothyris lanceolata Hall	
Grammysia bisulcata (Conrad)	
G. constricta Hall	
Palœoneilo constricta (Conrad)	
Nucula corbuliformis Hall	
Pterinea flabellum (Conrad)	
Aviculopecten princeps (Conrad)	
Modiomorpha concentrica (Conrad)	
M. mytiloides (Conrad)	
Cypricardella bellistriata (Conrad)	
Bellerophon leda Hall	
Orthoceras sp.	
Trilobite fragments: perhaps *Homalonotus*	Fallen blocks
Phacops rana (Green)	Fallen blocks

Spafford Member

The following fossils have been noted in the Spafford member of the Skaneateles quadrangle:

Crinoid joints	
Bryozoa	
Crania cf. *hamiltoniæ* Hall	
Stropheodonta perplana (Conrad)	
S. concava Hall	
Tropidoleptus carinatus (Conrad)	Common
Chonetes sp.	Common
C. cf. *lepidus* Hall	
Pruductella sp.	
Eunella lincklæni (Hall)	
Atrypa reticularis (L)	
Spirifer mucronatus (Conrad)	Common
S. granulosus (Conrad)	
S. cf. *audaculus* (Conrad)	
S. audaculus (Conrad) var. *macronotus* (Hall)	
Ambocœlia umbonata (Conrad)	
Athyris spiriferoides (Eaton)	
Phthonia sectifrons (Conrad)	
Nucula corbuliformis Hall?	
Palœoneilo constricta (Conrad)	
P. emarginata (Conrad)	
Pterinea flabellum (Conrad)	
Mytilarca (*Plethomytilus*) *oviformis* (Conrad)	
Aviculopecten princeps (Conrad)	

Modiomorpha concentrica (Conrad)
M. cf. *mytiloides* (Conrad)
Cimitaria corrugata (Conrad)
Cypricardella bellistriata (Conrad)
Cryphæus boothi Green

Owasco Member

The following fossils have been noted in the Owasco member of the Skaneateles quadrangle:

Crinoid joints
Stropheodonta perplana (Conrad)
Tropidoleptus carinatus (Conrad)
Atrypa reticularis (L)?
Spirifer mucronatus (Conrad)
S. tullius Hall
Grammysia alveata (Conrad)?
Nucula or *Palæoneilo* with fine concentric lines
Aviculopecten princeps (Conrad)?
Cypricardella tenuistriata (Hall)
Styliolina?
Tentaculites cf. *T. attenuatus* Hall & *bellulus* Hall
Homalonotus dekayi (Green)
Trails or burrows roughly parallel to bedding
Spirophyton-Taonurus
Plant

Portland Point Member

The following fossils have been noted in the Portland Point member of the Skaneateles quadrangle:

Zaphrentis?
Favosites sp.
Trematopora?
Fenestella sp.
Stictopora sp.
Crinoid joints — Abundant at some localities
Crania hamiltoniæ Hall
Rhipidomella vanuxemi (Hall)
Stropheodonta perplana (Conrad)
Tropidoleptus carinatus (Conrad) — Abundant at some localities
Chonetes sp.
Camarotœchia congregata (Conrad)
C. sappho (Hall)?
Eunella lincklæni (Hall)
Spirifer mucronatus (Conrad)
S. tullius Hall
S. cf. *granulosus* (Conrad)
S. cf. *audaculus* (Conrad)
Vitulina pustulosa Hall
Grammysia cf. *alveata* (Conrad)
Taxodont pelecypod probably *Nucula* or *Palæoneilo*
Aviculopecten princeps (Conrad)
Modiomorpha concentrica (Conrad)
Cimitaria sp.
Cypricardella bellistriata (Conrad)
Bellerophon leda Hall
Proëtus cf. *macrocephalus* Hall
Homalonotus dekayi (Green)
Cryphæus boothi Green
Phacops rana (Green)
Trail or burrow roughly parallel to bedding

Windom Member

The following fossils have been noted in the Windom member of the Skaneateles quadrangle:

Small "staghorn" coral
Crinoid joints — Very abundant at one horizon
Bryozoan
Crania hamiltoniæ Hall
Rhipidomella vanuxemi (Hall)
Tropidoleptus carinatus (Conrad)
Schuchertella arctostriata (Hall)?
Chonetes setigerus (Hall)
C. cf. *lepidus* Hall
Leiorhynchus laura (Billings) — Very abundant at one horizon
Atrypa reticularis (L)
Spirifer mucronatus (Conrad) — Common at one horizon
S. tullius Hall — Known from top of member
S. granulosus (Conrad)
S. cf. *audaculus* (Conrad) var. *macronotus* (Hall)
Reticularia fimbriata (Conrad)
Ambocœlia umbonata (Conrad)
Athyris spiriferoides (Eaton)
Grammysia alveata (Conrad)
Nucula bellistriata (Conrad)
N. cf. *corbuliformis* Hall
Nuculites oblongatus Conrad
Palæoneilo tenuistriata Hall
P. constricta (Conrad)?
Glyptodesma erectum (Conrad)
Leiopteria cf. *conradi* Hall
Modiella pygmæa (Conrad)?
Aviculopecten princeps (Conrad)
Modiomorpha concentrica (Conrad)
Pholadella radiata (Conrad) — Common at one horizon
Cypricardella bellistriata (Conrad)
Gyroma capillaria (Conrad)
Loxonema sp.
Tentaculites?
Orthoceras sp.
Cryphæus boothi Green
Phacops rana (Green)
Trail or burrow

Tully Limestone

The following fossils have been obtained from the Tully limestone of the Skaneateles quadrangle:

Corals in general
Favosites sp.
Crinoid stems
Fenestella sp.
Rhipidomella vanuxemi (Hall)
Leptæna rhomboidalis (Wilckens)
Schuchertella perversa (Hall)?
Hypothyris venustula (Hall)
Camarotœchia sappho (Hall)
C. congregata (Conrad)?
Atrypa reticularis (L)
A. spinosa Hall
Spirifer sp.

Aviculopecten sp.
Cypricardinia indenta (Conrad)
Platyceras sp.
Thysanopeltis tullius (Hall and Clarke)
Cryphæus boothi Green
Phacops rana (Green)
Arthrodiran(?) bone plates

Tully fossils of the Skaneateles quadrangle have been recorded by Williams from Owasco, Niles, Borodino, Staghorn Ravine, and "Skaneateles Lake" (Williams, S. G., '87, p. 26–29).

A shale intercalation in the upper portion of the Tully limestone has yielded the following fossils:

Chonetes setigerus (Hall)
Pterochænia fragilis (Hall)
Tentaculites sp.
Stytiolina fissurella (Hall)

Sherburne Member

The following fossils have been noted in the Sherburne member of the Skaneateles quadrangle:

Crinoid stems, large and small
Leptostrophia interstrialis (Vanuxem)
Camarotœchia sappho (Hall)
Leiorhynchus globuliformis (Vanuxem)
Atrypa reticularis (L)?
Ambocœlia umbonata (Conrad)
Palœoneilo constricta (Conrad)
Modiomorpha?
Spyroceras cf. *nuntium* (Hall)
Goniatites cf. *sinuosus* Hall
Plant fragments
"Fucoids"

Cornell Member

The following fossils have been noted in the Cornell member of the Skaneateles quadrangle:

Coral
Crinoid stems
Stictopora?
Discina sp.
Tropidoleptus carinatus (Conrad)?
Schuchertella chemungensis (Conrad)?
Productella sp.
Leiorhynchus mesacostalis (Hall)
Atrypa reticularis (L)
Spirifer mesacostalis (Hall)
S. mucronatus (Conrad)
S. mesastrialis (Hall)?
Reticularia lævis (Hall)
Cyrtina hamiltonensis (Hall)
Nucula?
Palœoneilo cf. *filosa* (Conrad)
Actinopteria cf. *zeta* Hall and *eta* Hall

Pterochænia fragilis (Hall)
Modiomorpha mytiloides (Conrad)
Pleurotomaria (Gyroma) capillaria Conrad?
Goniatites cf. *sinuosus* Hall

Ithaca Member

The following fossils have been noted in the Ithaca member of the Skaneateles quadrangle:

Coral (perforate)	
Crinoid stems	
Starfish?	
Cystodictya?	
Lingula cf. *punctata* Hall and *complanata* Williams	
Discina sp.	
Leptostrophia interstrialis (Vanuxem)	
Chonetes?	
Pruductella sp.	
Camarotœchia cf. *eximea* (Hall)	
Leiorhynchus globuliformis (Vanuxem)	
L. mesacostalis (Hall)	
Atrypa reticularis (L)	
Spirifer mesacostalis (Hall)	
S. mesastrialis (Hall)	not in place
S. mucronatus (Conrad)	
Reticularia lævis (Hall)	
Ambocœlia umbonata (Conrad)	
Cyrtina hamiltonensis (Hall)	
Grammysia circularis Hall	
Palœoneilo constricta (Conrad)	
P. filosa (Conrad)	
P. cf. *muta* Hall	
Actinopteria boydi (Conrad)	
Leptodesma rogersi Hall	
L. cf. *sociale* Hall	
Pterochænia fragilis (Hall)	
Mytilarca sp.	
Spathella typica Hall	
Cypricardella bellistriata (Conrad)	
Bellerophon (Ptomatis) patulus Hall	
Tentaculites sp.	Loose block in quarry
Orthoceras bebryx Hall var. *cayuga* Hall	Loose block in quarry
Plant fragments	

At the roadside four-tenths of a mile south and slightly west of Kelloggsville plant-bearing strata are found overlying *Reticularia lævis* beds of the Cornell member. These plant-bearing strata are provisionally referred to the Ithaca. In them have been noted the following fossils:

Leiorhynchus mesacostalis (Hall)	
Grammysia circularis Hall	
Leptodesma rogersi Hall	
L. cf. *longispinum* (Hall)	
Spathella typica Hall	
Plant fragments, many carbonized	Very abundant

ADDENDUM: CORRECTION OF GEOLOGIC MAPS

Paleozoic Rocks. Very small area on east margin a short distance north and slightly east of Cedarvale. Should have Cardiff color symbol in place of Oriskany and Onondaga color symbol.

Cenozoic Deposits. About 2.56 inches below (south of) the "Ma" in the word "Marcellus" as applied to the village. Here a small patch is given a color symbol not found on the legend. It should have the color symbol for "Aqueoglacial deposits of undetermined origin."

Two uncolored areas along Dutch Hollow brook, a short distance south of Niles. Conditions here are not understood but the more northern area is believed to form part of a till inlier, the more southern area believed to be occupied largely by aqueoglacial deposits of one kind or another.

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Geologic Map 1 Paleozoic rocks

Geologic Map 2 Cenozoic deposits

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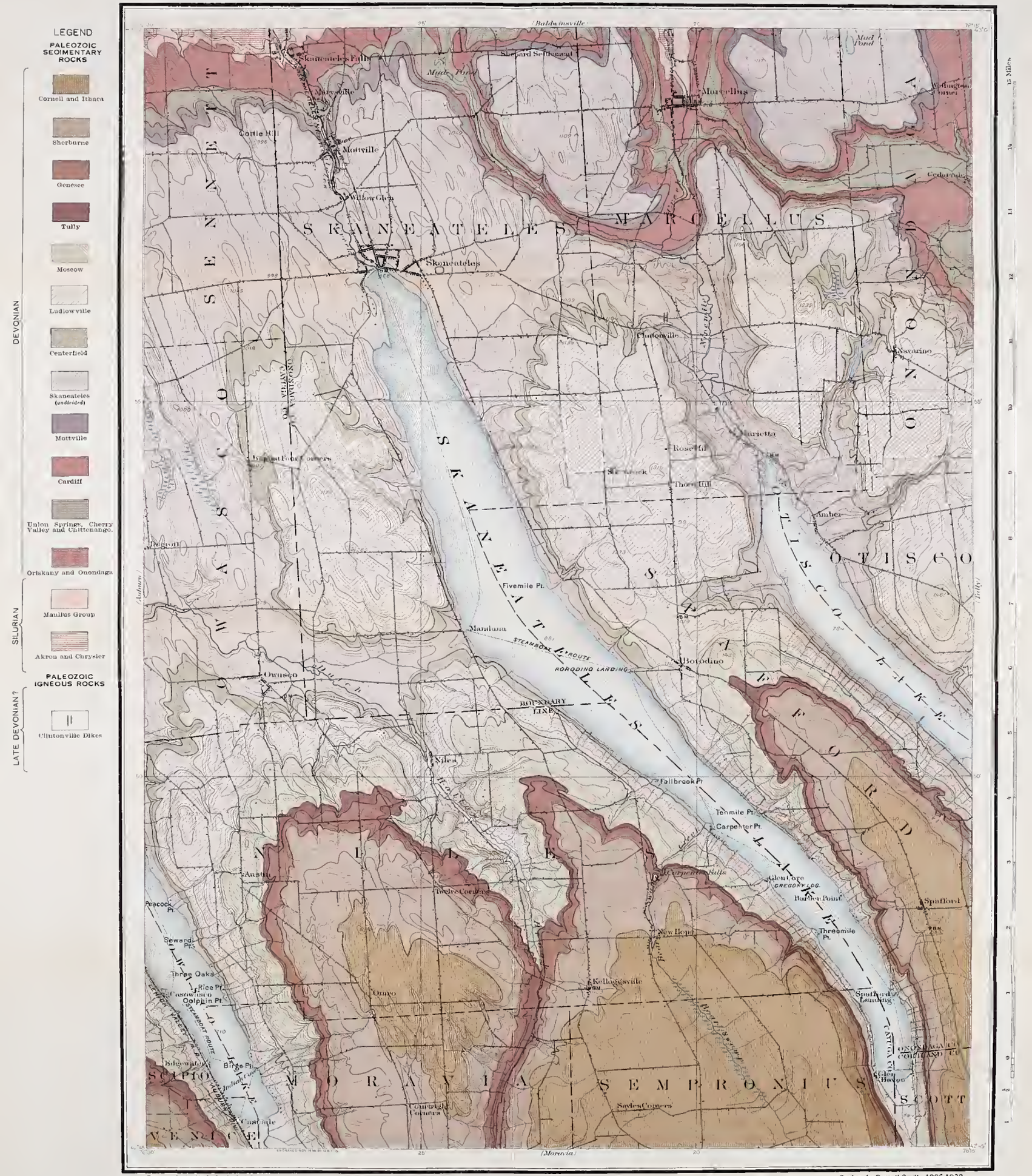

Topography by U. S. Geological Survey and State of New York, 1896

GEOLOGY OF THE SKANEATELES QUADRANGLE: PALEOZOIC ROCKS

Geology by Burnett Smith, 1926-1932

Scale 1/62500

1 0 1 2 3 5 Miles

1 0 1 2 3 4 5 Kilometers

Contour interval 20 feet

Datum is mean sea level

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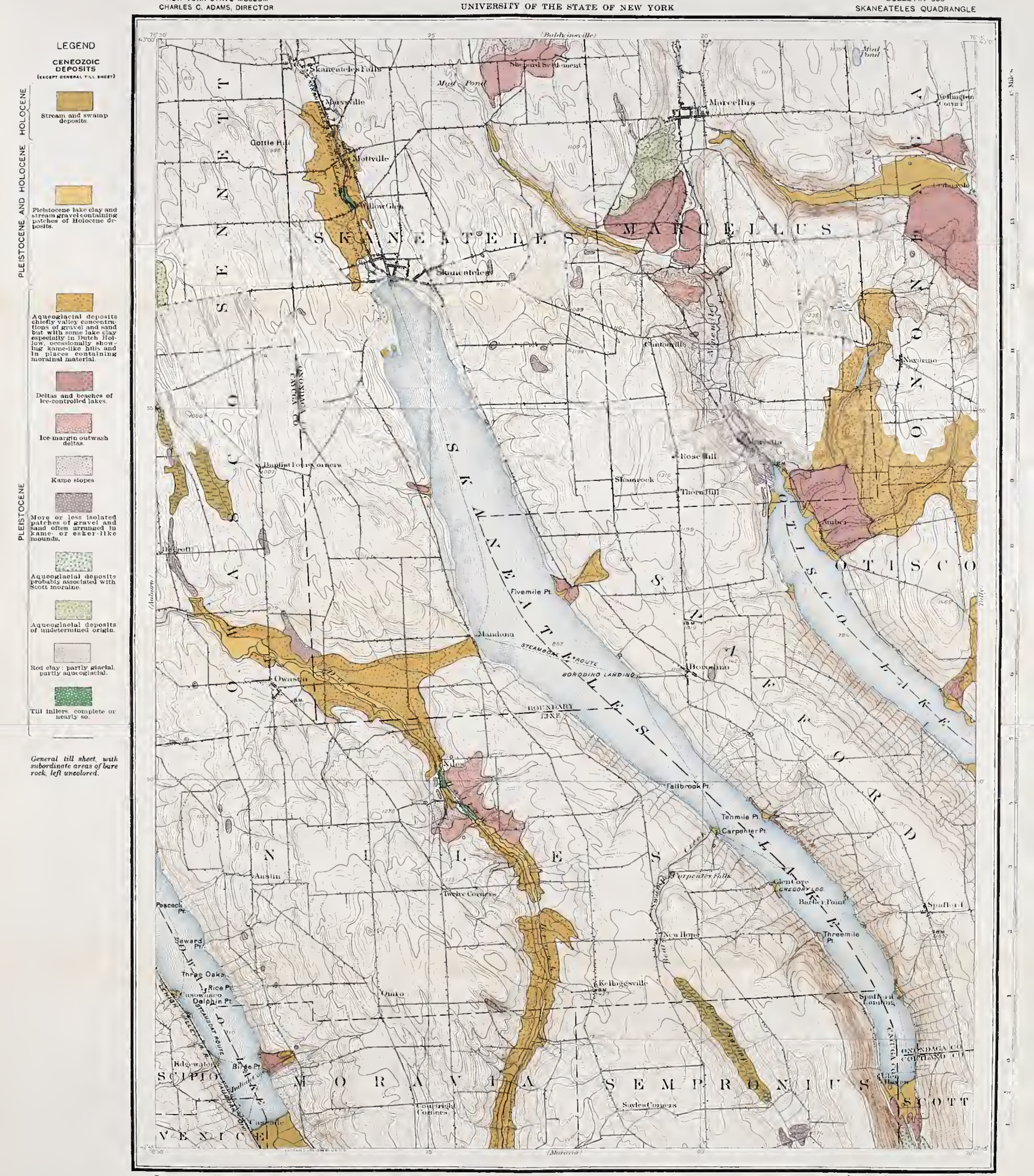

GEOLOGY OF THE SKANEATELES QUADRANGLE: CENOZOIC DEPOSITS