THE ALMOND MORAINE OF THE WESTERN FINGER LAKES REGION, NEW YORK

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ABSTRACT

THE ALMOND MORAINE OF THE WESTERN
FINGER LAKES REGION, NEW YORK

By G. Gordon Connally

The purpose of this dissertation is to delineate the border of what has been referred to as the "Binghamton Drift Sheet" in the western Finger Lakes region. The region is located in south-central New York State; from the Genesee River on the west to Seneca Lake on the east. Field work, consisting of reconnaissance of all roads, stratigraphic description of critical drift exposures, and collection of samples for laboratory analysis, was performed during the summers of 1960 and 1961. Laboratory work consisted of disaggregating the samples, separating the heavy minerals, and counting and recording heavy mineral relative frequencies. From the raw data, garnet ratios (ratios of purple garnet to red garnet) and stability ratios (ratios of unstable: hornblende, hypersthene, and monoclinic pyroxene; to total garnet) were computed.

Three major morphostratigraphic units were identified. These are, in ascending order, the Almond Moraine, the Arkport Moraine, and the Valley Heads Moraine. The oldest drift in the region is Olean till; its terminal moraine is south of the study area. The Almond Moraine is tentatively correlated with the Kent Moraine of northwestern Pennsylvania and Ohio, while the Valley Heads Moraine is correlated with the Lake Escarpment complex of the same area. The Arkport Moraine may be either recessional-Almond or advance-Valley Heads. Possible correlations with New England by other workers are noted.

Previous attempts at rock-stratigraphic correlation are discussed and evaluated. Two new formations are defined as the Olean Formation (older) and the Canaseraga Formation (younger) on the basis of garnet ratios. The Olean Formation contains appreciable red garnet, indicating a provenance in the central Adirondack Mountains while the Canaserage Formation shows a dominance of purple garnet, suggesting a provenance north of Montreal and Ottawa.

The term Binghamton is redefined as a magnafacies, of both formations, in which conglomeritic lenses of bright, valley-fill deposits are common. In the Olean Formation these lenses are named the Chenango member and in the Canaseraga Formation, the Goff Creek member. At present, the Canaseraga Formation appears to have the Almond Moraine as its southern boundary (or the Valley Heads Moraine where it overrides the Almond).

A composite time-stratigraphic column is adopted from many sources. It divides the Wisconsinan glacial stage into five glacial substages separated by four intraglacial sub-stages.

Valderan substage
    Two Creeks intraglacial substage
Woodfordian substage
    Farmdalian intraglacial substage
Southwold? substage
    Port Talbot intraglacial substage
Dunwick? substage
    St. Pierre intraglacial substage
Basal Wisconsinan substage

Using published dates, the Almond Moraine is interpreted as marking the maximum Woodfordian advance except where it is overridden by the Valley Heads Moraine (in general, a recessional Woodfordian Moraine). Thus, the Canaserago Formation was deposited during Woodfordian time. The Olean Formation was probably deposited during Basal Wisconsinan time and its terminus represents the maximum Wisconsinan glaciation in the area. The Dunwich, Southwold and Valderan substages are not represented by glacial deposits.

Stability ratios were not found to be useful in correlation, refuting a suggestion made previously by the writer.

THE ALMOND MORAINE OF THE WESTERN FINGER LAKES REGION, NEW YORK

By

G. Gordon Connally

A THESIS

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During the field season I was privilaged to work with, talk to, and learn from many fine geologists. Among these men I single out Ernest H. Muller of Syracuse University for special recognition. His interest, advice, help and encouragement were a source of stimulation throughout this study.

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INTRODUCTION

Purpose

This dissertation concerns part of a continuing study by the writer, the larger purpose of which is to map the glacial deposits of the Finger Lakes Region, New York. The aim of the present treatment is to delineate the border of what has been referred to as the "Binghamton Drift Sheet" of western New York. An effort is made to establish criteria which can be used in correlating this drift, and subjacent deposites, with deposits in continguous areas.

Geographic Setting

The western Finger Lakes Region, as defined for the purposes of this study is bounded on the west by the Genesee River, on the east by Seneca Lake, and on the south by the Pennsylvania State line. The northern border is roughly the northern edge of the Appalachian Upland (Broughton, _et al._, 1962) or the northern end of the Finger Lakes themselves in the troughs that partially dissect this upland. The area is approximately bounded by 42° 45' North latitude, 42° North latitude, 76° 45' West longitude, and 78° West longitude (see Fig. 1). The area is covered by the Portage, Nunda, Wayland, Naples, Hammondsport, Belmont,

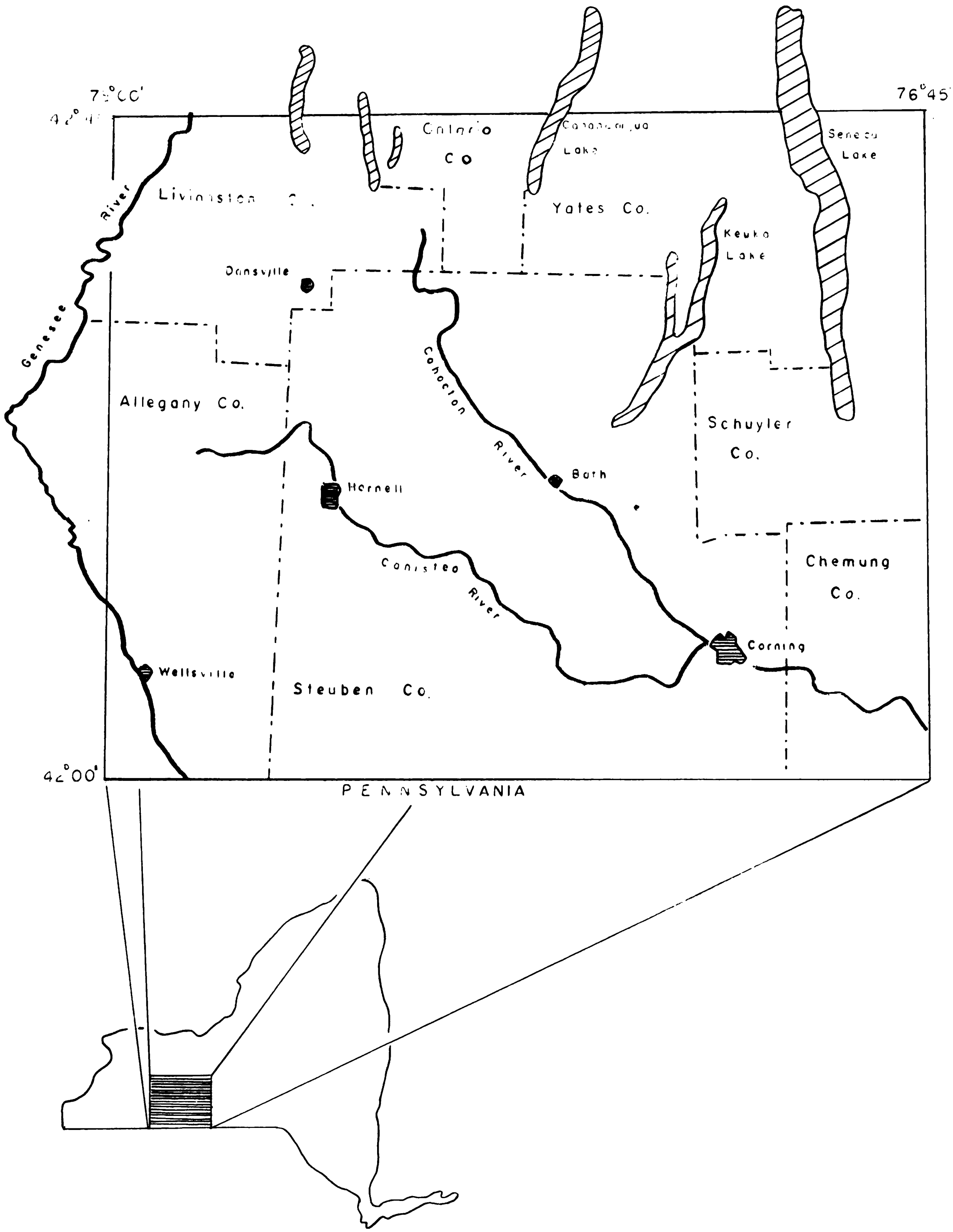

Fig. 1.--The geographic setting of the western Finger Lakes.

Wellsville, Greenwood, Woodhull, Corning, and Elmira fifteen-minute quadrangles.

Politically, the area consists of Steuben Co. and parts of Ontario, Yates, Schuyler, Allegany and Chemung Counties. The major cities are Corning (17,085), Hornell (13,907), Bath (6,166), Wellsville (5,967), and Dansville (5,460), with the rest each having populations under 5,000.

Corning is the industrial center of the eastern part of this region while Hornell and Wellsville dominate the industry in the west. Corning is, of course, the home of Corning Glass, while Hornell handles railroad repairs and Wellsville once was the center of a thriving oil and gas industry. The remainder of the economy is based on agriculture and the tourist trade. The Canandaigua Lake and Keuka Lake valleys are the settings for extensive vinyards which supply major wineries in Naples and Hammondsport. The lowland area surrounding Dansville supports tree nurseries and "muck farms." Stony Brook State Park near Dansville, and Watkins Glen State Park attract many tourists, as do the shores of the Finger Lakes. The region is also noted for Alfred University and the associated Ceramic School of the University of the State of New York.

The region can be divided into three hydrologic provinces; the Genesee River drainage basin, the Susquehanna drainage basin, and the Finger Lakes drainage nets. The Genesee River province is located on the western border of the region. The River itself is one of very few northerly flowing trunk streams in the eastern United States. The divides between this basin and the adjacent drainage areas appear to be little modified from the preglacial boundaries. The divide between the streams which flow north into the Finger Lakes troughs and the southerly drainage of the Canisteo and Chemung Rivers is determined by morainic deposits at the southern end of each of the lowland troughs. On the upland, the divide is governed by the Portage Escarpment which separates the Appalachian Upland from the Ontario Lowland.

The region has a relief of about 1900 feet, varying from a ground elevation of 2341 feet west of Greenwood to 445 feet at Watkins Glen. This does not take into account the depth of water in the Finger Lakes but is probably much less than prior to glaciation in any case. The present hills are almost barren of glacial deposits while the valleys contain a thick fill of stratified drift. Erosion of the uplands and filling in of the lowlands has undoubtedly produced a more subdued landscape.

Geologic Setting

During the Paleozoic Era the region was more or less continuously submerged, from Cambrian through Devonian time. During the early Paleozoic it was miogeosynclinal and during the Silurian and Devonian Periods, exogeosynclinal. The sediments deposited were dominantly clastic with lesser accumulations of evaporites and carbonates. There may be as much as 9,000 feet of rock overlaying the basement, however, only about 4,000 feet are exposed in this region. At the end of the Paleozoic Era the Appalachian Revolution produced some very gentle domes and a regional dip to the south of about 40 feet per mile.

During the Meozoic and Cenozoic Eras the region was subjected to erosion which may have produced one or more peneplains (Coates, 1963). Subsequent crustal unrest then elevated the region and streams cut rather deep valleys, partially dissecting the raised erosion surface(s). These streams flowed northward, at the present sites of the Finger Lakes troughs, and into the Ontarion River (Horberg and Anderson, 1956) which occupied what is now the Lake Ontario depression.

During the Pleistocene Epoch great ice sheets moved slowly southward into New York State. The glaciers moved into the Ontarion River valley and gouged out the present lake basin. Lobes of ice were forced southward up the tributary valleys and carved out deep, steep sided troughs that are mostly occupied by the Finger Lakes today. In excavating the major tributary valleys, the glaciers left the minor tributaries stranded above the levels of the troughs. These stranded tributaries are now observed as hanging valleys whose streams enter the Finger Lakes over steep cataracts or water falls such as the ones at Watkins Glen.

The bedrock exposed belongs to the Hamilton, Genesee, Sonyea or West Falls Groups, all of Devonian age (Broughton, *et al.*, 1962, Fig. 17). It comprises interbedded gray shales, siltstones and sandstones deposited in shallow marine water on the Catskill Alluvial Plain, or dark gray and black shales of deeper water origin. Bedrock is mantled by thin drift on the uplands and by thicker deposits of glacial, glacio-fluvial or glacio-lacustrine origin in the lowlands. The intervening slopes are either exposed bedrock or mantled with thin colluvial deposits derived from bedrock. The age of the drift is discussed extensively in the body of this dissertation but it can be stated here that it is probably all Wisconsinan.

Previous Work

Initial work was reported on the "Terminal Moraine" of western New York and northeastern Pennsylvania by Upham (1879), Chamberlain (1883), and Lewis (1884). Tarr (1905) was the first investigator to recognize the Valley Heads Moraine when he mapped the drift at the heads of the Seneca Lake and Cayuga Lake valleys. Succeeding workers also noted the presence of morainic loops in other major valleys of the Finger Lakes Region. Fairchild (1932b) proposed correlation of these loops and thus formalized the Valley Heads Moraine. In the same paper Fairchild noted the presence of patches of drift between the Valley Heads Moraine and the "Terminal Moraine" to the south. Foremost

among those mentioned are the kame areas of Franklinville and Almond.

The next major study of the region was by MacClintock and Apfel (1944) on the drift of the Salamanca Re-Entrant. On the basis of topographic and lithologic character these authors recognized two moraines rather than one "Terminal Moraine." On the west side of the re-entrant they recognized the Binghamton Drift and on the east side, the older, Olean Drift. Their interpretation was that the Binghamton Drift was the result of a glacier which overrode the Olean deposits on the western side.

The Olean Drift was defined by a pebble lithology dominated by shale and siltstone of local derivation and a topographic expression which is subdued. This moraine was correlated with the old "Terminal Moraine" which traverses northern Pennsylvania. The Binghamton Moraine was defined by bold topographic expression and by a pebble lithology in which exotics of limestone and crystalline rocks are present. This pebble lithology was termed "bright gravel."

The Binghamton Problem

By a series of north-south traverses, MacClintock and Apfel located the southernmost point at which bright gravel is found in the major valleys. Among these points were the kame areas of Franklinville and Almond. The authors suggested that the extensive deposits of bright gravel south of Binghamton were best suited as a type locality and therefore, adopted the name Binghamton Drift.

MacClintock (1954), in a reconnaissance study of the Finger Lakes region, found that the depth of leaching was about the same for both the Valley Heads and Binghamton drift sheets and contrasted with that for the Olean Drift. On the basis of this work he proposed the Bangor Moraines of Delaware Water Gap, the drift of northeast New Jersey, the Harbor Hill Moraine of Long Island, and the "lower till" of Massachusetts as correlates of the Olean Drift. The "younger drift" of the Catskill Mountains, the Portland Drift of Delaware Water Gap, the drift of Middletown Connecticut would then be correlates of the Binghamton and Valley Heads Moraines.

Denny (1956) failed to find Binghamton Drift in the Elmira region. He suggested that it either was overridden by the Valley Heads glacier or that it is not manifested by its type topographic or lithologic character. Denny did however admit the possibility that Binghamton Drift exists between the Elmira region and the Catskills, emerging from beneath a Valley Heads cover. In any case, Denny suggested that the Valley Heads Moraine is correlative with either the Harbor Hill or Ronkonkoma Moraines and that the Olean Drift is unknown in New England.

More recently, Moss and Ritter (1961) have concluded that all the drift south of the Valley Heads Moraine between the Elmira region and the Catskills is Olean and not Binghamton. This means that the type Binghamton deposits are not correlative with the better known "Binghamton" of western New York with which this study is dealing.

Connally (1959) recognized a consistency in the heavy mineral suites from localities in the Valley Heads Moraine and suggested that a similar relationship might exist for other New York Moraines. Dreimanis (1961) and Connally (1960) have also shown that the heavy minerals from the Olean Drift easily identify this deposit. Thus the "Binghamton" Drift of western New York appears to be sandwiched between two drift sheets which are significantly different from it with respect to their heavy mineral suites.

Present Study

Because the question has been raised as to the presence of the topographic "Binghamton" Drift in the type lithologic locality, the writer (Connally, 1961) has adopted a suggestion by Merritt and Muller (1959) and restricted the name Binghamton to a rock stratigraphic term. In the present study the term is further used in this manner, thus retaining the significance of the type locality. In this study the term Almond Moraine is adopted for the morphostratigraphic equivalent of the moraine of Binghamton lithology west of the Salamanca re-entrant.

In order to determine the northern limit of the Almond Drift, the exact position of the Valley Heads Moraine must be determined. To the knowledge of the writer there has not been any previous attempt at field correlation of the various loops of Valley Heads Moraine. The necessity for field correlation of the Almond Moraine is also obvious. Muller (1957, 1964) has located the old "Binghamton" Moraine from the Salamanca re-entrant to the Genesee River, west of the Finger Lakes. Denny (1956) and Moss and Ritter (1962) have denied the presence of this moraine, or its equivalent east of the Finger Lakes. Thus it is hoped that the present study will bridge the gap and permit some conclusion concerning the absence of the Almond (nee Binghamton) Moraine in the eastern Finger Lakes region.

FIELD WORK

Seventy days of field work were done during the summer of 1960, followed by an additional 77 days during the summer of 1961. This work was partially supported by Graduate Student Honoraria from the New York State Museum and Science Service.

The major part of the time was spent in reconnaisance of the region by automobile. All passable roads were driven at least once, and preferably once in each direction. Using the existing road network for traverses, all of the visable glacial deposits were mapped on available base maps; either 1:24,000 or 1:62,500. In lowland areas coverage was more complete since the road network was fairly dense. The upland areas were fairly well covered in the northern tier of quadrangles. In the southern tiers however, somewhat less detailed work could be accomplished since most of the land has fallen into disuse and consequently, so have the roads. The valley walls were seldom accessible.

Constructional Topography

In this region it is possible to distinguish between constructional topography and erosional topography in most instances. Erosinal topography is caused by stream activity, glaciation, or by some combination of these agents. Where erosion has dominated, bedrock is generally exposed or is close to the surface. Examples of erosional topography are the valley walls of the Finger Lakes troughs. Here bedrock is either exposed or is covered by a thin veneer of colluvium. Although the knobs and vales are gently rounded bedrock is always present in the roadside ditches which are swept clean by runoff every spring.

Constructional topography may be the result of stream, glacial, or lacustrine deposition. Generally the constructional topography in this region has a hummocky appearance in the lowlands where the depositional agent is not always easily identified. The only absolute interpretations are made on the basis of fresh exposures. These are plentiful north of the Almond border. On the upland areas a glacial origin is assumed for all constructional deposits, from bold moraine to undulating plains.

Most interpretations in the valley sites are based on exposures in the cutbanks of streams or in the many gravel pits that pock-mark the region. These exposures are so plentiful in the low-lying areas that only exceptionally good ones were examined. In the upland, however, all exposures which could be found were examined, due to their paucity. Observations were recorded at each exposure examined and suggested field correlations noted. Where exposures were sufficiently fresh, or where a locality was thought to be critical a sample was extracted for laboratory analysis.

A description of the field sites which were cited in this text are given in Appendix 1.

Field Sites

The field sites visited are shown in Figure 2 (in Volume 2). The sites are numbered chronologically. The first number designates the year collected. For example site 60-41 was the forty-first locality described during the 1960 field season.

At each site the nature of the material was described, although sometimes only a notation of the topography was made. In other cases a complete lithologic description of the material was recorded. In critical areas, where more than one drift sheet was suspected, a complete stratigraphic section was recorded. Due to the large areal coverage of this study, many potential stratigraphic sections were intentionally ignored even though detailed study is certainly warranted in the future.

At each site where till was sampled, the color and texture were noted along with a qualitative judgement as to the pebble lithology. Where possible the fabric was determined from 5 to 10 oriented till stones. These fabrics are not considered definitive. The interpretive value is in some cases questionable because in a region of such relief these sedimentary structures tend to conform with the alignment of the major topographic features. Where stratified drift was sampled, a qualitative judgment on pebble lithology was always made. The presence or absence of ice-contact structures was also noted and in many cases the depositional agent was inferred from such evidence. Texture was determined by rubbing moist material between two fingers, which is qualitative to a certain degree.

Until completion of this study the writer regarded till color as a highly variable property, however, this did not prove to be the case. The plotting of field data shows that till color can be consistant within given units, even though the terminology might be quite subjective. This will be discussed in a later section.

Field Correlations

By darkening areas of constructional topography on the map with a colored pencil, the pattern of constructional topographic features became apparent in valleys and along major highways. As each road segment was driven, all constructional areas were so noted. Where roads were few and far between, the trend of deposits was observed and correlation was established where these trends appeared to intersect those of deposits bordering adjacent roads. Most correlations are of this type.

In some areas no linear trend could be noted on the ground and a topographic map or soils map was examined for clues. Where topographic lineaments or linear soil trends could be found on a map they were then used to correlate between known constructional deposits. In either of the above cases the correlations are considered to be well established.

In some places there were no readily apparent topographic trends or map lineaments. In these localities correlations are suggested using existing topography as a guide. For instance, correlation might be inferred from the existance of a steep valley wall rather than by invoking a tie-in across an interfluve. The writer believes that his "well established" correlations would be adopted by any other geologist familiar with the area. The suggested correlations are considered as provisional.

Field correlations were usually well supported by the subsequent laboratory analyses. Where laboratory work suggested alternative possibilities the writer re-examined field data before making a judgment. These cases are few and are discussed below. A copy of each field map is included as Appendix 2.

Field samples were labeled and stored in polyethylene bags to prevent dessication. This preserved the field color and texture and also made the samples more susceptable to disaggregation during laboratory analysis.

LABORATORY PROCEDURE

The procedure for preparation of samples for heavy mineral analysis is similar to that described previously by the writer (Connally, 1960). In brief, the samples were disaggregated, wet sieved for the entire sand fraction and then sieved for the desired fraction. This fraction was then split until a portion weighing about 10 grams remained. Whenever possible the sample was split so that one-half could be stored for future use or for re-runs in case of experimental error. A flow sheet for the laboratory preparation is given in Figure 3.

More than sixty samples had to be processed and about one-half of these were compact till samples or indurated gravel. Moss and Ritter (1961) have shown that acid treatment affects the resulting heavy mineral suite in at least a qualitative sense. Rather than risk possible alteration or destruction of some grains, the writer decided to perform disaggregations in tap water.

Each sample of till was split by hand, due to the compact nature of the till. The sample was broken into clods and an attempt was made to choose an equal volume of clod material for each of the two splits. One sample was stored and the other disaggregated for testing.

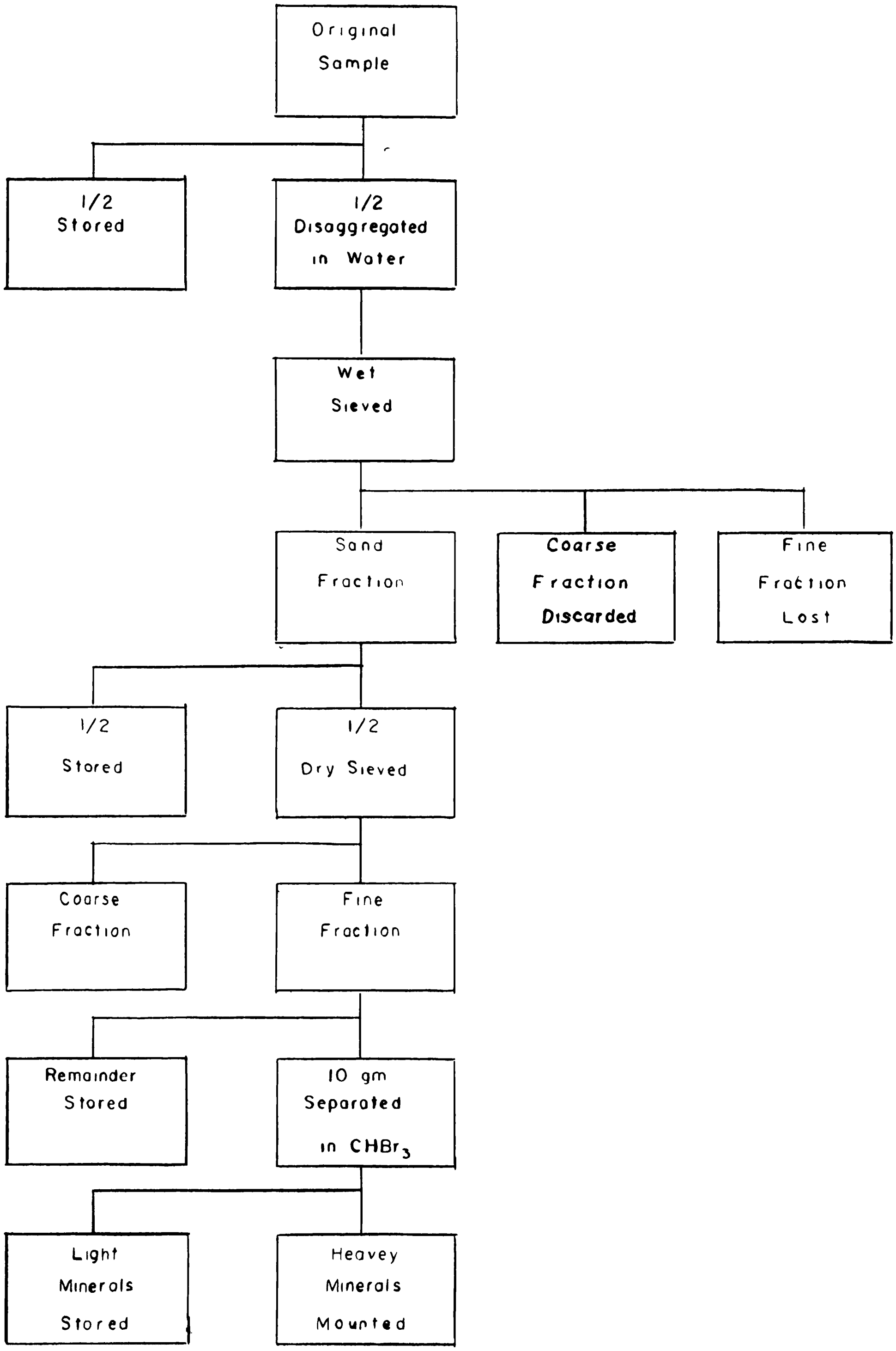

Fig. 3.--Flow sheet for Laboratory Preparation.

The test sample was then placed in a 600 ml. beaker and covered with tap water. The speciman was left in this bath for about 24 hours, with only occasional stirring. Then the sample was stirred vigorously and poured onto a nest of sieves. Any sediment remaining in the beaker was washed onto the sieves with a jet of water.

The wet sieving served to separate out the sand fraction, between .062 and 2.000 mm. (Wentworth-Udden grade scale). This material was next poured onto a 2000 micron sieve and was washed through a 250 micron sieve and a 62 micron sieve with a very gentle, indirect stream of water. The 250 micron sieve was nested between the other two only for convenience, in order to eliminate the sediment overload on the lower sieve. The coarse fraction (above 2000 microns) was discarded while the fine fraction (below 62 microns) was lost with the water flushed out through the lower sieve. The sand fraction was then washed from the 62 micron sieve and the 250 micron sieve into a clean 600 ml. beaker and allowed to dry in a drying oven.

It had been found previously (Connally, 1960) that the fraction between .062 and .350 mm. was the most desirable to work with in heavy mineral analysis. Thus, the dried sample was again split with a Jones Sample Splitter (Krumbein and Pettijohn, 1938, p. 45) and one portion was sieved for the desired fraction. As there was no mechanical device available, the samples were sieved by hand. Although some error may have been introduced at this point, it is considered negligible.

The coarse fraction (above 350 microns) was stored for possible future use while the desired fraction was prepared for heavy mineral analysis. This preparation entailed splitting until a portion weighing about 10 grams was obtained. Next the sample was weighed on a Mettler analytical balance, accurate to the nearest milligram, and stored in a stoppered bottle, ready for separation.

The steps outlined above, for till samples, were also followed for samples of stratified drift. Disaggregation and wet sieving are obviously not necessary for this type of sediment, however, the writer wished to insure that any error inadvertantly introduced during sample preparation would affect all samples equally.

Heavy Mineral Separation

The heavy fraction of the sand was separated using purified bromoform ($CHBr_3$) having a specific gravity of 2.87 at 20°C. The separation was carried out by the standard method for heavy liquids outlined by Krumbein and Pettijohn (1938, pp. 335 and 343).

A separatory funnel was filled with bromoform to within 3 cm. of the top. The prepared sand was poured onto the surface of the liquid and gently agitated until all of the heavy minerals collected at the bottom of the funnel. When the separation was complete the stop cock was opened long enough to allow only that portion of the liquid seen to contain heavy minerals to pass through. The heavy mineral grains dropped onto a conical filter paper, and the bromoform was permitted to drain off. The grains were then washed with ethyl alcohol (C_2H_5OH) and allowed to dry.

The dry mineral grains were transferred to a 50 ml. beaker and again weighed on the analytical balance. From these figures as compared to the weight of the unseparated fraction, the percent by weight of heavy minerals present in the sample was calculated (see Table 1).

Separation of Magnetic Grains

The magnetic grains in the heavy fraction were removed. The primary reason for this was to concentrate the non=opaque minerals for optical study. More than 99% of the minerals attracted to the magnet were opaque so this separation removed much opaque material. A second reason for this separation is that the percent by weight of magnetic grains is easily determined in this manner. Previous data (Connally, 1960) suggested that percent of magnetic grains might be useful in recognizing Olean drift. More extensive sampling in the present investigation, however, does not support this thesis.[1]

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[1]Lawler (1962) has presented data which relates magnetic anomolies to the type of glacial deposit examined. It may be that a systematic variation would exist if these data were reinterpreted on this basis.

A small hand magnet was used to effect the separation (also see Connally, 1960). The percent by weight of magnetic grains is reported in Table 1.

Mineral Identification

The heavy minerals, minus the magnetic fraction were mounted on petrographic slides using Canada balsam (n=1.54) heated on a small hot plate. Usually the sample was split prior to mounting; with one-half being stored as previously noted. Occasionally the dearth of heavy minerals made it necessary to mount the entire fraction.

The minerals were identified with a petrographic microscope using crystal form, cleavage, fracture, color, pleochroism, extinction angle, elongation, interference figure, optical sign and 2V as definitive characteristics. Although many minerals were identified only red garnet, purple garnet, hornblende, hypersthene, and monoclinic pyroxenes were counted as individual categories. (For a more complete list and a discussion of minerals previously reported also see Connally, 1960). A brief discussion of the heavy minerals used in this study follows.

Garnet

Garnet is present as grains which exhibit conchoidal fracture and very little rounding. Red, orange, pink, purple, and colorless varieties are all present. The garnets are divided into two categories for the purpose

TABLE 1.--Heavy mineral and magnetic percentages.

Sample Number	Heavy Mineral %	Magnetic %	Sample Number	Heavy Mineral %	Magnetic %
60-17a	0.9	5.6	61-3	0.3	3.0
60-17b	1.6	11.0	61-5	1.7	6.2
60-19	3.5	11.5	61-8-2	2.0	10.9
60-21	2.8	10.2	61-9-1	1.1	3.7
60-23	1.4	10.9	61-9-2	1.0	5.0
60-24	1.5	10.0	61-10	1.4	9.4
60-30	0.2	5.0	61-11	0.8	8.2
60-32	1.2	12.6	61-14	1.4	2.2
60-37	1.3	2.5	61-15	1.2	6.9
60-41	1.3	2.3	61-18	1.8	3.9
60-45-I	2.2	4.7	61-19	2.7	7.3
60-45-II	1.8	4.2	61-20-1	1.2	13.2
60-46-I	1.4	4.4	61-20-2	0.8	11.0
60-46-2	2.1	0.0	61-21	0.5	2.8
60-52	0.8	5.2	61-23	0.2	8.8
60-56	1.7	7.5	61-24	1.3	39.9
60-57-1	1.7	14.4	61-25	0.9	10.0
60-57-2	1.6	9.1	61-27	0.5	16.3
60-60-1	0.3	4.5	61-28	0.2	10.4
60-60-2	2.4	4.9	61-29	2.1	12.2
60-61	1.8	4.2	61-30	1.6	1.2
60-62	2.0	2.1	61-39-1	1.6	11.3
60-63	2.5	1.5	61-39-2	2.0	9.4
60-65	2.3	2.1	61-42	2.2	12.1
60-71	2.0	2.0	61-45-1	1.5	4.4
60-72	2.5	2.2	61-45-2	1.3	7.4
60-73	1.1	3.4	61-47	0.9	8.6
60-75-I	2.8	1.1	61-49	1.8	5.2
60-75-2	1.0	0.1	61-50	1.6	8.8
60-76	1.2	9.9	61-55-1	2.1	0.0
			61-55-2	6.2	1.3
			61-58	2.1	6.5

of indicating provenance. The red, orange and pink varieties each exhibit a distinct color and were counted as red garnet, while the purple and colorless garnets appear to grade into one another and were counted as purple garnet. The garnet was distinguished by its color and isotropism.

Hornblende

Hornblende is present as prismatic grains with rounded ends and an extinction angle less than 20°, or in some cases as irregular grains. The grains vary from those that are translucent to those that are opaque in the center and translucent only on the edges. All grains exhibit pleochroism, mostly of the green to brown variety.

Hypersthene

Hypersthene and enstatite are members of the isomorphous series of orthorhombic pyroxenes. This series is present as stubby prismatic grains predominantly pleochroic from light green to pink or red (hypersthene) or in a few instances; colorless (enstatite). Some of the grains of hypersthene possess inclusions of brown plates in parallel alignment (schiller structure) which distinguish the variety bronzite. The series was recognized by parallel extinction.

Monoclinic Pyroxene

Monoclinic pyroxene, including augite and diopside, are included in one group and are present as worn, elongate clevage fragments. The grains are light green in color and have an extinction angle of about 55° with respect to elongation. The grains were distinguished by the extinction angle and the lack of pleochroism.

Frequency

All other minerals were lumped into one category for the purpose of reporting mineral frequency. Between 200 and 700 grains were counted on each slide. The frequency with which each of the above described categories is present was recorded and converted to a percentage of the total grain count. The percentages are recorded in Table 2.

The counting was done with the aid of a petrographic microscope and a square grid pattern superimposed on the bottom of the slides. It was found sufficient to count every other square of the grid on all but a few slides. Counts were recorded on a blood cell counter which was borrowed for this project from the New York State Museum and Science Service.

TABLE 2.--Heavy mineral frequency.

Sample Number	Red Garnet	Purple Garnet	Hornblende	Hypersthene	Clino-Pyroxene
60-17a	5.6%	7.4%	26.1%	9.9%	3.7%
60-17b	11.4	18.9	12.2	3.5	1.6
60-19	13.7	9.8	33.3	14.8	5.5
60-21	10.4	14.7	35.1	9.7	6.4
60-23	9.8	16.1	36.1	10.2	4.9
60-24	8.4	11.9	29.4	7.7	2.8
60-30	6.0	11.9	41.7	9.7	6.6
60-32	6.5	9.9	37.5	7.0	7.5
60-37	7.4	10.4	20.1	3.7	4.7
60-41	6.7	12.6	16.1	5.4	5.4
60-45-I	6.9	11.4	14.4	6.4	8.9
60-45-2	6.1	9.8	17.0	3.6	5.2
60-46-1	4.8	7.7	26.4	8.4	5.0
60-52	8.9	6.6	17.0	5.0	2.3
60-56	7.5	10.2	24.6	9.7	2.5
60-57-1	10.7	10.7	31.9	8.4	5.0
60-57-2	8.1	12.3	28.8	9.2	5.0
60-60-1	0.4	0.0	3.5	0.8	0.0
60-60-2	0.3	0.0	0.5	0.0	0.0
60-61	4.8	6.3	24.8	4.0	5.3
60-62	1.7	1.2	3.8	3.5	0.9
60-63	1.3	1.9	4.5	0.9	0.8
60-65	0.8	0.8	1.1	0.9	0.8
60-71	4.6	4.6	10.5	3.3	2.8
60-72	4.5	8.3	8.2	3.1	2.7
60-73	5.5	4.1	7.4	3.8	0.5
60-75-1	1.6	1.9	5.4	0.5	0.5
60-75-2	0.8	1.0	1.8	0.5	0.0
60-76	13.8	14.0	11.6	6.9	3.9
61-3	11.1	10.5	18,0	0.2	3.1
61-5	6.9	8.0	7.7	1.1	3.3
61-8-2	9.2	13.9	22.3	5.3	4.7
61-9-1	12.0	17.1	12.5	4.3	3.7
61-9-2	6.5	7.1	6.3	2.1	3.7
61-10	8.5	12.7	19.1	6.9	4.2
61-11	10.0	11.8	22.7	7.0	5.2
61-14	1.8	3.7	4.1	0.6	0.8
61-15	6.9	7.5	13.8	2.5	2.8
61-18	3.5	6.9	5.5	2.0	0.8
61-19	3.9	9.4	11.2	3.3	2.9
61-20-1	5.7	10.6	21.2	4.4	3.4
61-20-2	6.2	9.9	18.6	4.4	3.4

TABLE 2--Continued

Sample Number	Red Garnet	Purple Garnet	Hornblende	Hypersthene	Clino-Pyroxene
61-21	9.4%	9.4%	6.8%	5.4%	1.4%
61-23	4.3	10.1	6.8	1.4	1.1
61-24	9.8	8.4	7.4	5.6	2.1
61-25	12.9	12.6	13.8	4.0	2.6
61-27	5.8	12.5	12.0	2.4	2.9
61-28	6.6	9.6	20.5	9.9	4.8
61-29	9.6	14.2	10.7	3.8	1.5
61-30	1.3	1.7	3.6	1.3	0.8
61-39-1	7.4	14.7	31.0	4.4	2.7
61-39-2	9.3	16.4	21.8	6.1	2.9
61-42	10.3	18.5	18.8	5.9	2.3
61-45-1	5.9	14.5	22.4	6.8	2.1
61-47	10.6	11.8	10.6	4.3	2.0
61-49	6.9	13.3	18.2	4.4	2.5
61-50	6.1	11.1	25.5	7.2	3.3
61-55-1	2.2	5.8	5.5	2.4	1.4
61-55-2	2.1	2.4	3.9	0.9	0.8
61-58	8.2	11.7	12.6	3.0	2.5

MORPHOSTRATIGRAPHY

According to Frye and Willman (1960) "A morphostratigraphic unit is defined as comprising a body of rock that is identified primarily from the surface form it displays; . . ." However, lithologic relationships cannot be ignored when exposures of drift are common. It would be unwise to ignore the relationship between the lithology of a drift sheet and its topographic expression. Therefore morphostratigraphy becomes litho-morphostratigraphy where one seeks a morpho-rock unit just as many stratigraphers seek time-rock units.

In the discussion that follows the lithology, or at least some lithologic parameters, is used to characterize each unit even though they are termed morphostratigraphic units. The dependancy of topographic expression on lithology has been noted and discussed by Moss and Ritter (1962) for similar drift deposits in the eastern Finger Lakes region.

Three morphostratigraphic units are recognized in this region. These are the Valley Heads Moraine, the Arkport Moraine (new), and the Almond Moraine (new name). The Valley Heads is the youngest and the Almond the oldest. Each of these units is superimposed on a terraine that was glaciated when the Olean drift was deposited.

The discussion below is adopted from a progress report (Connally, 1962) submitted to the New York State Museum and Science Service. Where laboratory work has suggested alternative correlations they are discussed under subsequent topics and are merely noted here. If the reader wishes to follow the topographic continuity he may refer to the field maps in Appendix 2. An index to these maps is given in Figure 4, and is also included in the Appendix. The field grid designation (i.e. J-9) is given in the text when a new map area is being described. In general, the description is from west to east.

The Valley Heads Moraine

The drift of the Valley Heads Moraine manifests itself dominantly as stratified drift which is characterized by bold morainic topography. This morainic topography is generally limited to the heads of present stream valleys and to the flattened interfluves separating the valleys. On the valley walls there is a scarcity of drift, with the exception of kame terrace remnants. Till exposures are limited to stream cuts near the stratified deposits, but are absent from the bold topography.

The Valley Heads border appears to follow the present valley contours, as if the valley lobations had been controlled almost entirely by pre-existing topography. On the valley walls and interfluves the drift border is subparallel

PORTAGE J-7	NUNDA J-8	WAYLAND J-9	NAPLES J-10	PENN YAN J-11	
ANGELICA K-7	CANASERAGA K-8	HORNELL K-9	BATH K-10	HAMMONDS-PORT K-11	WATKINS GLEN K-12
BELMONT L-7	WELLSVILLE L-8	GREENWOOD L-9	WOODHULL L-10	CORNING L-11	ELMIRA L-12

Fig. 4.--Index to the field maps included in Appendix 2. The symbols refer to a field grid.

to existing topography illustrating somewhat less topographic control than in the adjacent lowlands.

The outer limit of the main Valley Heads advance is marked by continuous constructional topography, with associated meltwater channels. In some places there appear to be patches of drift south of the main advance border. Thus, it is suggested that the massive, main glaciation was preceeded by a slightly more attenuated phase that was either of much shorter duration than the "massive phase" or was masked and dissected by meltwater deposits of the massive phase. The more southerly patches of drift are hereafter referred to as the "advance phase."

Striations on the bedrock surface beneath the drift are rare, and where found tend to parallel topographic trends. The only reliable striae are at sites 60-32, 61-6, and 61-7. Site 60-32 is west of Dansville (J-9) at an elevation of 1480 feet and shows a direction of N 15° W which is parallel to the valley wall. Sites 61-6 and 61-7 are located on the interfluve between Keuka Lake and Lamoka Lake (K-11) at an elevation of 1420 feet and are about two miles apart. Here the striae trend N 15° W and N 20° W, respectively which also parallels the trend of existing topography.

The dominance of waterlaid drift and the topographic control of the glacial border suggest a thermophysically

Temperate glaciation during Valley Heads time.[2] In other words, the Valley Heads glacier was essentially at its pressure-melting point throughout its entire thickness. The concordance of striae and existing topographic trends also tends to support this suggestion. This interpretation is consistant with the observations of Denny (1956) for post-Olean deposits in the Elmira region.

The nature of the till associated with Valley Heads ice is highly variable, owing to at least four small pulsations of the terminus of the ice lobe, and also to the presence of ponded waters immediately adjacent to the ice. North of the terminal position, the till is generally coarse textured ranging from fine sandy loam to silt loam. The till is blue when fresh, is firm, and contains many till stones. The stones show very little stream rounding and are generally polished and striated.

Exposures of two or more tills are common in proximity to the terminal deposits. Although the writer has examined only a few of these in detail, the upper till in most cases

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[2]Since completion of the preliminary drafts of this dissertation, Maynard M. Miller has presented a paper entitled "Thermophysical Characteristics of Glaciers and Ice-Sheets as a Factor in Interpretation of Pleistocene Geology," Mich. Acad. Sci., 68th Meeting, 1964. Professor Miller's views support the interpretations of the writer on a theoretical basis although he points out the tentative nature of such conclusions due to the number of factors involved. This agreement is not surprising as the views of the writer were formulated on the basis of previous conversations with Professor Miller.

is a blue, silt till, similar to more northerly exposures. It is overlain by a coarse cobble gravel which was deposited by northward flowing streams. Underlying tills vary in their texture and generally reflect the nature of the sediment beneath them. The sediments which separate the tills are lacustrine silts, clays, or sands which evidently were easily incorporated by the overriding ice. This suggests repeated attenuations, into pro-glacial lakes and onto lacustrine deposits. These lower tills are generally chocolate brown and have a clay or silty clay texture, reflecting the overridden lacustrine rhythmites. In places the tills are yellow-brown and sandy, indicating interim glaciofluvial sedimentation in an oxidizing environment.

A description of the field relationships shown on the maps in Appendix 2, follows.

Genesee Valley

From the Genesee River (J-7), east to the Canaseraga-Newville Creek divide (J-8) both the massive Valley Heads and the advance phase of the Valley Heads are found. From the Genesee east to Keshequa Creek two moraines run parallel to each other, the massive phase at 1250 feet and a recessional moraine at 1420 feet. The massive phase rises to 1800 feet on the west bank of Keshequa Creek and descends into the valley one mile south of Dalton. The moraine again rises to 1800 feet on the east valley wall and gradually descends eastward into the Canaseraga Creek valley where it crests at 1360 feet. Here it forms the divide between Canaseraga Creek and Newville Creek, three and one-half miles southeast of Nunda.

From this divide the moraine turns north and rises to 1500 feet forming a "nose" of drift south and east of Barkertown. From Barkertown north, the moraine rises rapidly to 1980 feet on the north end of the interfluve between Nunda and Dansville, where it forms the divide between Wildcat and Sugar Creeks.

The advance phase appears as a "nose" of drift extending beyond the massive phase in the Keshequa and Canaseraga Creek valleys. In both cases the drift is weakly constructional and mantled with outwash from the later advance.

Canaseraga Creek (Dansville) Valley

On the west side of the Genesee-Canaseraga interfluve north, southwest, and south of Westview the moraine is manifested in bold, constructional topography which crests at about 1900 feet. The moraine appears to follow the ridge bordering Sugar Creek on the east, and descends into the Sugar Creek valley one and one-half miles west of Ossian. The south bank of Sugar Creek is weakly constructional at an elevation of 1440 feet, south and west of Ossian. One mile southeast of Ossian the moraine crests at 1480 feet in a bold loop breached by the valley. From this point it turns north and crests at 1660 feet on a spur between Ossian and

Dansville (J-9). From this crest the moraine descends into the Canaseraga Creek valley and loops across this valley five miles south of Dansville (K-9), at about 1260 feet.

On the east side of the valley the moraine rises abruptly to 1560 feet trending eastward into the Stony Brook valley two miles northwest of South Dansville. From this point the moraine rises to 1480 feet on the east side of the valley wall and turns northeast for four miles at this elevation (J-9). At Perkinsville the moraine loops north across the wide valley to Clover Hill and then west to East Hill. Here the distal side faces north and is apparently mantled with outwash. The moraine continues around the west side of East Hill and rises toward the north end of the interfluve between the Canaseraga and Springwater valleys, where it crests at 2040 feet. On this interfluve the moraine is characterized by bold, constructional topography having a relief of 20 to 80 feet.

The advance phase is well illustrated on the Canaseraga-Canisteo divide forming a concave loop north, east, and west of the village of Moraine (K-9) and by a similar loop extending to within one mile of the village of Canaseraga on the west (K-8). As in the Genesee valley, the topography is subdued, due to a mantle of pro-glacial outwash from the massive phase.

Hemlock Lake (Springwater) Valley

On the east side of the Springwater-Canaseraga interfluve (J-9) the moraine is illustrated by bold, constructional topography from the crest at the north, along the ridge to Pokomoonshine Hollow. The moraine descends from 1820 feet south of the hollow, to 1400 feet southwest of Wayland. From this point it is inferred to loop to the east, joining with an isolated patch of morainic topography on the rock island two miles northeast of Patchinville. This would account for the diversion of pro-glacial meltwater into the channel south of "the island."

The moraine is inferred to turn north from the rock island, looping back across the valley to the north and joining the boldly constructional moraine that runs from 1500 feet, west of Wayland to 2100 feet on the north end of the Springwater-Naples interfluve.

Canandaigua Lake (Naples) Valley

The Valley Heads Moraine is absent from the northern end, and eastern side of the Springwater-Naples interfluve. It is inferred at an elevation of 2100 feet, from the north end of the spur to a point two miles south of the Ontario County line. Here there is a patch of constructional topography at 2000 feet which descends southeast and joins the massive lowland topography one-half mile south of Garlinghouse (J-10). In this sector the moraine lies at 1480 feet, descending further to its terminus near the Steuben County line at 1400 feet. The terminus loops across the Cohocton River valley at 1360 feet, from northwest to southeast, turning north at North Cohocton. From North Cohocton the moraine rises abruptly to a crest of 1960 feet on the Pine Hill spur, and then drops to 1500 feet just north of Ingleside where it forms the divide between Reservoir Creek and Twelvemile Creek.

From Ingleside the moraine turns north around the bedrock spur and then turns due east, rising from 1600 to 2100 feet in a five mile stretch along the south wall of the Flint Creek valley. Here the topography is particularly bold and recessional moraines are well developed at 1660 feet and 1500 feet.

Subsequent laboratory work has suggested an alternate correlation. This will be discussed under the section on rock stratigraphy. It is probable that the high level moraine is actually correlative with the Almond system, while the recessional moraines are the Valley Heads (and Arkport?) equivalents.

Prattsburg Valley

Two miles south of Italy Hill the high level moraine turns southward into the Prattsburg valley. The moraine maintains its boldly constructional nature along the ridge to the southwest until it reaches the headwaters of Center Creek, three miles northwest of Prattsburg. From this point there are three alternatives for correlation with the Keuka Lake lobation.

There are two well developed morainic loops within this valley, as well as drift on the valley walls at the southern end of the valley (K-10). The northerly loop is south of Prattsburg (J-10), while the southerly one is at Renchans (K-10). The writer (Connally, 1962) originally proposed a Valley Heads correlation with the morainic loop at Renchans via the rim of the west valley wall, even though very little constructional topography has been noted immediately adjacent to the valley. The Renchans loop appears to be equivalent to a moraine in the Keuka Lake lobation north of Bath, as shown by a meltwater channel on the east side of the valley and its association with the Keuka Lake lobe.

An alternative which is almost as attractive is to correlate the Italy Hill segment with the distinct morainic loop east and south of the village of Prattsburg (J-10). This moraine rises toward the north to an elevation of 1700 feet and then turns east and south at the Waldo Creek divide (J-11). From here the moraine is traceable south to a point two miles west of Urbana (K-11) where it undeniably younger than the traditional Keuka Lake, Valley Heads correlate.

A third possibility is that the Italy Hill segment is correlative with a very bold, constructional segment of moraine that trends south along the east wall of the West Creek valley (K-10) to a point one-half mile east of Wheeler's Hill Church. The valley loop associated with this segment appears to have been sluiced away. However, there may be an apparent correlate on the Prattsburg-Keuka Lake interfluve west of Mitchelsville. The writer originally considered this southerly moraine to be correlative with the Arkport Moraine, however, the laboratory work suggests that this may actually be the terminus of the Almond advance in this area.

Keuka Lake Valley

Although the correlation of the Renchans loop with the Valley Heads Moraine is adopted in this report, it is unattractive from many standpoints. The main difficulty is that the moraine is absent from the Prattsburg Keuka Lake interfluve and must be inferred around the north end of the interfluve until it descends to 1360 feet at Mitchelsville. The moraine then swings southward to join the bold, constructional topography north of Bath. It terminates in a slightly concave loop about one mile north of Bath, at an elevation of 1140 feet.

From its terminus the moraine turns north and rises to 1600 feet on the Keuka Lake-Mud Creek interfluve (K-11). The moraine is present as weakly constructional drift on the upland until it reaches the north end of Mount Washington two and one-half miles southeast of Hammondsport, where a bold kame-moraine is present.

Mud Creek Valley

From an elevation of 1880 feet on Mount Washington the moraine descends southeast into Birdseye Hollow and follows the west wall of the Mud Creek valley south at 1140 feet. The moraine loops around Kettle Lake and just north of Parker Lake, inclosing bold, constructional topography on the proximal side.

On the distal side of the morainic loop, is another loop of subdued topography which includes the Round Lake, Parker Lake, and Paterson Lake kettle holes. The southern loop is mantled with outwash from the massive phase of the Valley Heads and may represent nothing more than the advance phase. It is also possible that this loop is correlative with the Almond Moraine as discussed below.

On the east valley wall the moraine trends northeast for 10 miles. The moraine rises from 1140 feet in Mud Creek to 1900 feet, one mile southwest of Hall's Corners (K-12) on the north end of the Mud Creek-Seneca Lake interfluve. As usual, the moraine is manifested as weak, constructional topography on the tributary divides and as bold topography in the tributary valleys.

Seneca Lake Valley

From the north end of the interfluve, the moraine turns south to Beaverdams, descending gradually to 1280 feet. The moraine traces the eastern border of the interfluve and forms the divide between Mud Creek drainage and Catherine Creek or Seneca Lake drainage.

From its terminus at Beaverdams the moraine rises to the east to 1560 feet and then trends east along the Schuyler County line, north of Johnson Hollow, and into the Catherine Creek valley. Except for the border at Johnson Hollow the writer is in complete agreement with the earlier work of Tarr (1905). Tarr placed the border on the northeast wall of the Johnson Hollow valley, while the writer places it on the western wall of the Catherine Creek valley (K-12, L-12). The garnet ratio from Field Site 61-11 tends to substantiate the latter interpretation, as discussed under rock stratigraphy. The writer has not attempted any field study to the east of the Seneca Lake valley.

The Arkport Moraine

During the 1961 field season a new morphostratigraphic unit was discovered, intermediate in position to the Valley Heads and Almond Moraines. This unit is here named the Arkport Moraine for the massive kame deposits immediately north of Arkport, New York (K-9). The Arkport Moraine is similar to both the Valley Heads and Almond Moraines in many respects. The drift is dominantly stratified with very little till exposed. The border is almost continuous, being absent only from valley walls, and is controlled by pre-existing topography almost as much as the Valley Heads Moraine. There is, however, only one phase to this moraine without any recessional deposits being recognized.

The gravel associated with this moraine is "bright" but is dominated by red sandstone rather than carbonates. The till is exposed in only four localities, and always as a thin smear of till over stratified gravel. In all four locations the till is brown to brownish-gray, moderately pebbly, calcareous, and has a silty clay matrix.

In the valley lobations the morainic border is indistinct and is suggestive of a recessional Almond phase similar to the Clymer and Findley Moraines (Shepps, et al., 1959) farther west. On the upland surfaces, however, the moraine has a bold expression and is much more suggestive of an independent advance similar to the Lavery or Defiance Moraines to the west. At present there is little evidence to support one or the other of these hypotheses.

Specific observations on the Arkport Morine are noted below.

Canisteo Valley

The westernmost expression of this moraine is at the head of Bennett Creek (K-8), three miles northwest of Canaseraga. Here the moraine is manifested as bold kame material and forms a divide which evidently reversed the pre-Arkport drainage in this valley. From Bennett Creek the moraine crosses the upland and descends southward to the Canaseraga Creek valley, north of Whitney Crossings.

From Whitney Crossings the moraine is inferred to cross the valley and join a "nose" of drift which crests at 1520 feet in the south tributary to Slader Creek. The moraine then turns north and east, rising to 1600 feet and continues southward along the west wall of the Canisteo River valley (K-9). The moraine is continuous and descends to 1300 feet at Webbs, north of Bald Hill, illustrating the blockage of ancestral Canacadea Creek.

The moraine has been sluiced away in the valley bottom by pro-Valley Heads drainage. However, it is inferred to swing north from Webbs and join the bold, constructional topography north of Arkport, for which it is named. From Arkport the moraine trends northeast, rising to 1900 feet on the west side of Cream Hill. The moraine encircles the hill and forms the divide between the Carrington Creek and Stony Brook drainage on both sides of Cream Hill, southeast and southwest of Beachville. It then trends north to Sand Hill (J-9) where it crests at 2020 feet as it turns east toward Loon Lake (K-9). The moraine descends into the Neil Creek valley where it rests at 1700 feet and forms the Neil Creek divide. The ice evidently caused a reversal of Neil Creek drainage, as a steep bedrock gorge has been cut to the south.

Cohocton Valley

The moraine runs north from Loon Lake, rising to 1900 feet in one mile (J-9). The moraine again descends, via a small drainage divide, into a tributary of Blackcrick (this stream is unnamed on the fifteen minute series quadrangle but is located in the extreme southeast corner, north of the village of Cohocton) on the west, then rises again to the north and trends east along the south valley wall. The moraine is inferred to be present at the north end of Blackcrick Hollow and to be responsible, at least in part, for this gorge. The moraine continues east to the hill southwest of Atlanta (J-10) and then descends southward to 1300 feet just north of Cohocton. At Cohocton the drift constricts the Cohocton River, although Valley Heads drainage was evidently effective in carving a channel through it.

The moraine is present on the east valley wall north of Kirkwood but is not traceable on to the interfluve. There is a suggestion of thin drift in places on the Naples-Prattsburg interfluve, however, the moraine is probably lost in the compound morainic system on the north end of the interfluve which was discussed under the Valley Heads Moraine. As a matter of fact, the moraine north of Kirkwood is probably correlative with the Almond Moraine, as discussed on the following pages. In any case, this is the eastern most point at which the Arkport Moraine is definitely recognized at present even though it may prove to be correlative with one of the moraines in the Prattsburg valley.

The Almond Moraine

The necessity of adopting the new term "Almond" Moraine was discussed above, in the Introduction. The name Almond was chosen for the prominant kame-moraine near the village of Almond (K-9), as this was one of the first deposits noted by early investigators.

The Almond drift does not lend itself to generalization as well as does the Valley Heads drift. The drift of the valley lobations is similar to the Valley Heads drift in its bold topographic expression, the predominance of stratified drift, and the tendency to follow local topography. Although not continuous on the uplands, the moraine is generally present on the valley walls and interfluves, south of the Valley Heads border. Another feature of this drift is the presence of till within the complex of morainic topography, particularly on the uplands.

The Almond ice was controlled by pre-existing topography in the valley lobations. On the interfluves and valley walls, however, the glacier apparently advanced without as much regard for local topography. This is borne out by the fact that the Almond Moraine loops across depressions that the Valley Heads ice would seemingly have occupied. On the basis of the limited topographic control during glaciation and the presence of unstratified moraines, it may be inferred that the glaciation during Almond time was thermophysically less temperate than during Valley Heads time. This glaciation would appear to be intermediate in thermophysical character between the Valley Heads ice and the Olean ice (as discussed below).[3] As the Almond Moraine is thought to be missing from the Elmira region, these conclusions are not in conflict with those of Denny (1956).

The nature of the till associated with the Almond ice is less variable than the Valley Heads till. This is possibly due to the suggested colder englacial conditions and an apparent lesser number of pulsations of the ice. Only two such pulsations have been noted in exposures examined thus far.

The till is generally a firm, calcareous, blue, loam to sandy loam deposit which contains many pebbles of "bright" gravel. In the valley lobations the till may have a finer matrix due to the incorporation of silts, and the till stones may consist of stream-rounded cobbles. The kame material found on valley walls and within the valley lobations has a distinct Binghamton lithology, although it may be somewhat diluted by local constituents high on the valley walls.

The upland morainic segments, generally thought to be missing, are well displayed on the interfluves. Although these segments are discontinuous, they display bold topography in many places.

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[3] See footnote 2, page 31, and the discussion of the thermophysical character of Olean ice on page 52.

Exposures in the valleys adjacent to the main lobations illustrate two pulsations of the ice. In many places two tills may be found which are separated by contorted, lacustrine silts. The lower till is typical Almond till while the upper one is generally finer textured and sparsely stoney, which reflects the lacustrine nature of the overridden sediments. Nowhere does the intervening sediment or the upper till contain oxidized material. This suggests no appreciable retreat between the two episodes.

Genesee Valley

E. H. Muller (personal communication, 1962) has located the Almond Moraine immediately adjacent to the Genesee River in the vicinity of Oramel (K-7). The writer also recognizes the moraine on the interfluve above Keshequa Creek (J-8), some distance to the northeast. The connecting link between these two positions, however, has only been tentatively identified.

The westernmost point at which the moraine is known in detail is east of the village of Granger, three miles north of Short Tract. From this point the moraine rises east and then descends into the headwaters of Rush Creek at School No. 6 (K-8). The moraine again rises to the southeast to an elevation of 2000 feet where it is present as a hummocky ridge trending southeast and then northeast toward Keshequa Creek. The moraine crosses just north of the Keshequa-Fry Creek divide and turns south along the east wall of the Fry Creek valley. The moraine is absent from the valley wall for about one mile but is recognized again on the upland as bold, constructional topography adjacent to School No. 17. From this patch of drift, the moraine descends into the Black Creek valley where it forms the divide between Black Creek and an unnamed tributary of Canaseraga Creek. A drainage reversal of ancestral Black Creek was caused by the Almond Moraine at this point.

Canisteo Valley

From Black Creek the moraine probably trends southeast and is correlated with the constructional "nose" of drift at Gas Springs on the headwaters of Slader Creek. From Gas Springs the moraine can be traced due east along the north wall of Slader Creek at about 1920 feet. It is then postulated to turn south into the headwaters of the east branch of Slader Creek and to connect with the bold, constructional topography west of North Almond at about 1900 feet. It continues south along the east bank of a tributary to the Canisteo River, and then across the Canisteo valley one mile west of Bishopville. The moraine is traceable on spurs and in valley "noses" for an additional eight miles to the south where the terminus is located at about 1700 feet, two miles south of Alfred (L-8, L-9). The writer has expressed reservations (Connally, 1962) about placing all of the drift between Almond and Alfred, in the Almond system. Although laboratory work serves to cast further doubt on the morphostratigraphic continuity of this segment, detailed field work is necessary before a definitive statement can be made.

In the same report mentioned above, the writer has noted an absence of drift on the south valley wall, as well as in the Canisteo River valley south of Hornell (K-9). Laboratory analyses suggest that the Almond glacier was present south of Hornell and that its deposits were sluiced away by meltwater accompanying deglaciation. On this basis the moraine is inferred to be present as far south as Canisteo, however, detailed field work will be necessary here also, before the terminus is accurately known. On the east side of the valley, the drift is again present as a low undulating deposit on the Carrington Creek-Big Creek divide, at 1500 feet.

The former presence of ice in the Carrington Creek valley is further supported from the deflection of ancestral Big Creek into a bedrock gorge at its mouth. From this divide the moraine trends northeast into a lobation south of Haskinville where it forms the divide between Neil Creek, Carrington Creek, and Castle Creek. The moraine can be traced as a bold, constructional ridge to the east, along the south bank of Neil Creek.

Cohocton Valley

Two miles southwest of Wallace (K-10) at 1740 feet, the moraine turns south while descending into a small lobation in Castle Creek. Here the moraine crests at 1600 feet and is manifested as a kame-moraine. The moraine then turns south around the spur separating Castle Creek and Goff Creek to form another bold kame and kettle lobation in Goff Creek.

The moraine again crests at 1600 feet in Goff Creek and turns east along the south valley wall. From here it rises to 1700 feet and noses into Ridge Glen and Chamberlain Creek with boldly constructional topography in both places. From Chamberlain Creek the moraine was originally thought to trend south and join a subdued "nose" of drift in Wolf Hollow and then run abruptly north along the west flank of Brooks Hill. The moraine actually is missing from Brooks Hill but was correlated, in the field, with a weakly constructional deposit in Knight Creek, one mile west of Bath. From this point the moraine was traced east along the east branch of Smith Run and across Mount Washington (K-11) to the Mud Creek valley, as discussed under the section on the Valley Heads Moraine.

No matter which deposite is chosen as the eastern extremity of the Almond system, it is clear that the moraine has lost its characteristic, bold identity and has probably been masked by meltwater deposits of the Valley Heads

Moraine. The proximity of the two moraines leaves little doubt that the Valley Heads glacier overrode the older deposits in this region, as has been suggested by Denny (1956).

Laboratory analyses, discussed below under Garnet Ratios suggest that the Naples-Prattsburg interfluve (J-10, K-10) was unaffected by post-Olean ice even though it is north of the Almond Moraine. This suggestion is supported by striations found at site 60-74 on this interfluve, four miles northeast of Avoca (K-10). These striae trend N 72° E and are interpreted as being the result of southwesterly flowing Olean ice (as opposed to the more southerly flowing Almond and Valley Heads ice). Moss and Ritter (1962) have illustrated the significance of flow direction in differentiating between Olean and post-Olean glaciations.

Thus, the Almond Moraine may actually terminate somewhere near Kanona (K-10) and loop northward along the east wall of the Cohocton River valley. This would presume that it was sluiced away by deglaciation, except possibly at Kirkwood (J-10) as discussed above under the Arkport Moraine section.

In this case, the Almond Moraine would be overridden by the Valley Heads Moraine on the north end of the Naples-Prattsburg interfluve, rather than at Bath. Even so, it might still be found beyond the Valley Heads terminus in the Prattsburg (K-10) and Mud Creek (K-11) valleys.

Olean Drift

Field work beyond the terminus of the Almond Moraine has not proved fruitful to date. The Olean drift is thin in most places and exposures are limited to cutbanks in the valley bottoms. Very little stratified drift is in evidence although till exposures are common. There is some stagnant ice topography at the heads of valleys, however, it has either been greatly modified (e.g. by slumping, solifluction, etc.) or never was very bold to begin with. At present only four quasi-continuous morainic segments have been identified.

The nature of the till associated with the Olean ice is extremely uniform. Nowhere has more than one till been noted. This is to be expected since the localities examined would be situated well back from the terminus of the glacier and so would not reflect minor fluctuations. The till is only slightly calcareous and is leached to a depth of 10 or 12 feet where it has been exposed to soil formation. The till is olive to green in color, and has a matrix of clay, silty clay, or clay loam. Exposures are generally clogged with slabs of shale and siltstone of local derivation, however far-travelled till stones may be present in proportions indicating a Binghamton lighology.

The absence of stratified drift and the highly modified appearance of the constructional topography have also been noted by Denny (1956). This is suggested as evidence of Polar, or at least Subpolar glaciation during Olean time. As a Polar glacier is one that is below its pressure-melting point throughout (as contrasted with a Temperate glacier, see p. 31), very little meltwater would be associated except possibly accompanying final deglaciation. Thermally polar conditions could persist, however, in one sector of the ice sheet while temperate conditions prevail in another.

Risingville Segment

This is a segment of weakly constructional topography which extends east, west, and south of Risingville (L-10) along the south valley wall of Michigan Creek. A gravel pit on the proximal slope of this moraine reveals a gravel of Olean lithology, leached for 4-6 feet and oxidized for 6-13 feet. A concentration of meltwater from ice at this position evidently caused the downcutting of the oversteepened valley now occupied by Goodhue Creek. Such a feature might suggest unusually rapid deglaciation.

Although there is no field evidence to support further extension of the Risingville segment it is probably correlative with another, four miles to the northwest (K-10, K-9). This is the Campbell Creek segment which trends northeast from Oregon School (five miles from Risingville) at an elevation of 1860 feet. The moraine follows the south valley wall of Campbell Creek for about eight miles, crossing the divide between Campbell and Stephens Creeks.

South Canisteo Segment

From the north branch of Tuscarora Creek, one mile east of South Canisteo (L-9), this segment is traceable to the south into Liberty Creek and is then inferred to trend southwest to the southern flank of Milwaukee Creek. In both places the topography is weakly constructional and correlation is only tentative. It is possible that this segment correlates with patches of kame material in Bennett Creek, near Norton Hollow although field evidence has not yet been found to support this.

Purdy Creek Segment

The fourth segment is located two or three miles south of Hartsville (L-9), forming the divide on the west, south, and east of the headwaters of Purdy Creek. This segment is manifested as moderately strong constructural topography, looping south from White School and northeast again to Call Hill School. It is possible that this moraine also correlates with the patches of drift in Bennett Creek, but again field evidence is missing.

Morphostratigraphic Correlations

The correlation of the Olean drift toward the east and west offers little apparent complication, at present. This drift sheet appears to be the southernmost in all areas of New York State, from the re-entrant in the old "Terminal Moraine" on the Allegheny River near Salamanca, to the

Hudson valley. The present problem is not in finding the correlate of the Olean drift but in finding the line along which this drift sheet was overridden by younger ice sheets.

The Almond Moraine is probably correlative with the Kent Moraine of eastern Ohio and northwestern Pennsylvania (Glacial Map of the United States east of the Rocky Mountains). Muller (1964) has traced the Kent Moraine through Chautauqua County and into Allegany County, New York. While there is no direct link between the Almond Moraine east of the Genesee River and the Kent Moraine on the west, this correlation seems most probable based primarily on the relationship with the Valley Heads system in both areas.

There are two possibilities for the eastward correlation of the Almond Moraine. Moss and Ritter (1962) have shown that there was no intervening glaciation between the Olean and Valley Heads glaciations from the Elmira region to the Catskill Mountains (the eastern Finger Lakes region). Thus, the original suggestion of Denny (1956) that the Valley Heads glacier overrode the Almond ("Binghamton") deposits has been supported by those authors, and by the writer. In the present case it would appear that the Valley Heads ice overrode the Almond deposits along the north end of the Naples-Prattsburg interfluve.

A second possibility is that the Almond glacier formed the high level moraine on the Naples-Prattsburg interfluve and that the apparent recessional moraines, north of, and lower than, the high level moraine, are actually correlates of the Valley Heads Moraine of the Dansville-Naples sector. Thus, the Valley Heads Moraine from the Prattsburg valley east, would be correlative with the Almond Moraine. This solution to the "Binghamton problem" would obviously create a somewhat similar "Valley Heads problem."

One of the strongest objections to the second alternative is that there is, to the writer's knowledge, no evidence for a correlate of the Dansville-Naples Valley Heads segment north of the type Valley Heads deposits of the Seneca-Cayuga Lake lobation. Although there must be some doubt about the eastern equivalent of the Valley Heads Moraine, its western counterpart is well developed all the way to Pennsylvania, where it is known as the Lake Escarpment Moraine (Leverett, 1934).

Recently Winters (1961), Leighton (1959), and Gravenor and Kupsch (1959) have been concerned with the differentiation of deposits formed directly by rapid ablation of active glaciers, from those resulting from slow downwasting of stagnating ice. These authors agree that the only satisfactory method for differentiating such landforms is careful lithologic mapping, rather than by cursory analyses of morphology alone. Since a detailed consideration of rock stratigraphy is beyond the scope of the present study and also since considerable variation in topographic control is involved, no definite statement of the state of the ice depositing these moraines can be made without some degree of reservation.

The above notwithstanding, the writer concludes that the Valley Heads Moraine and the Almond Moraine both represent readvances of the glacier that retreated from the Olean terminus. Although much stagnant ice topography is present in sheltered areas, the continuity of morainic ridges on interfluves suggests active ice, as does the constancy of the drift types within each of the morainic systems. As discussed above, the slight differences in the relationship of the moraines to pre-existing topography have been used to infer a different thermophysical character for each of the glaciations represented.

The problems associated with the interpretation and correlation of the Arkport Moraine have also been discussed, above.

A composite map showing the morphostratigraphic correlations is included as the first map in the series of individual field maps in Appendix 2.

ROCK STRATIGRAPHY

Ever since MacClintock and Apfel (1944) separated the drift sheets of the Salamanca re-entrant, investigators have been attempting to find definitive criteria which will allow long distance correlation of the Olean, Almond (nee, Binghamton) and Valley Heads drift sheets. Although many separate rock stratigraphic correlations have been suggested, it still remains to define rock units, and propose formal names for them. The writer will summarize the historical development of the attempted definitions of rock units. Then the units will be redefined for this region, on the basis of information gathered during the present study.

Pebble Lithology

MacClintock and Apfel chose the lithology of the pebbles present in the drift to define their rock units. Till lithology has often been used erroneously as a synonym for pebble lithology. As glacial formations vary in texture from petromict conglomerates to very sparsely pebbley mudstones, pebble lithology is not usually representative of total till lithology. Although pebbles should certainly be accounted for in areas where the formations are conglomeritic, they are essentially unimportant in other areas.

MacClintock and Apfel defined the "Binghamton" drift as containing a significantly high percentage (usually 30% or more) of limestone and other crystalline rocks. They defined the Olean drift as being essentially exotic free drift, made up of pebbles of locally derived siltstones and shales. Since then many investigators, among whom are Merritt and Muller (1959), Moss and Ritter (1962), Connally (1962), and Coates (1963), have demonstrated that these are lithofacies and that they are gradational and may both be found within a single drift sheet.

Denny (1956) originally suggested that the bright gravels might be stream gravels that were overridden by advancing glaciers and remained restricted to stream valleys. Conclusive evidence for this interpretation is reported by Moss and Ritter for the Olean drift. These workers have related bright deposits to pre-glacial valleys which head near the Onondaga escarpment to the north ("through valleys"). The facies distribution of pebble lithology has been recognized by the writer in the Almond drift sheet and by Merritt and Muller in the Valleys Heads drift.

The writer proposes that Binghamton drift be used as a restricted term in a rock stratigraphic sense only. He further proposes that the term be used to designate a magnafacies in the regressive Wisconsinan deposits of western New York, just as the term Chemung is restricted by Woodrow and Nugent (1963) in the transgressive Devonion

Catskill deposits of the same region. This magnafacies is found in each drift sheet, with thick conglomeritic lenses of bright, valley-fill deposits in the valleys, surrounded by a dull upland facies on the dissected plateau. It is replaced by a Valley Train magnafacies to the south and a Lake Plain magnafacies to the north. A simplified restored section of this relationship is depicted in Figure 5a and Figure 5b.

Depth of Leaching

Thornbury (1940) showed that depth of leaching could be used as a time stratigraphic tool, when differentiating drift of stage status. His work involved the problem of differentiating between Illinoian and Wisconsinan deposits.

MacClintock (1954) attempted to use depth of leaching to differentiate deposits on a Substage level. MacClintock used depth of leaching to illustrate differences between Olean drift and Almond (Binghamton) drift in New York. He also showed similarities between Almond drift and Valley Heads drift. He pointed out that time, size of carbonate particles, percolation rate, precipitation, temperature, biota, and soil type all affect the depth of leaching. By holding as many factors constant as possible he believed that he could validate his "Binghamton" border in New York State and could correlate the drift of western New York with that present in New England.

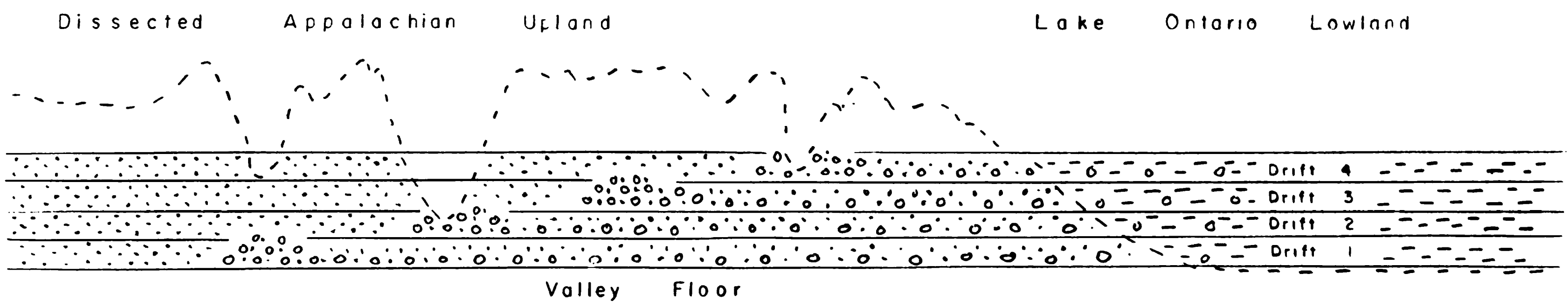

Fig.a 5.--The relationship between topography, geographic position, and regressive deposits of successive drifts sheets.

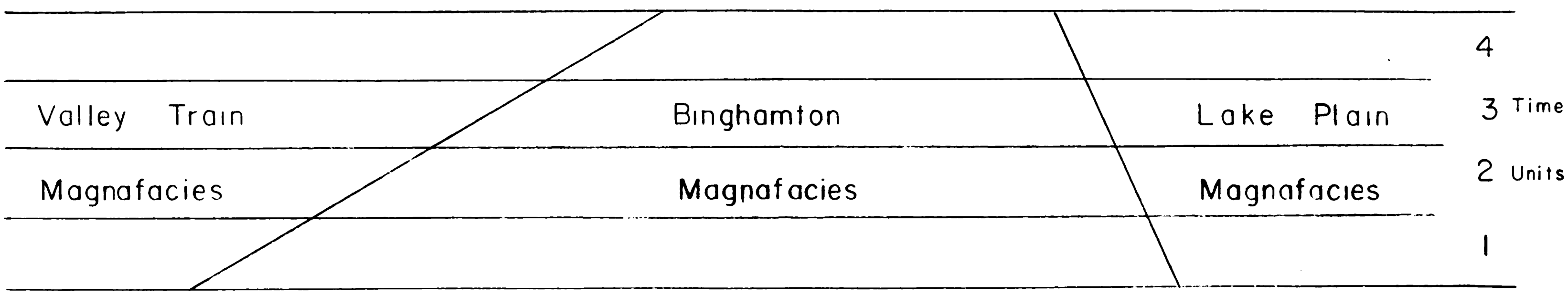

Fig. 5b.--The relation of formal stratigraphic units and magnafacies.

Merritt and Muller (1959) have shown that the depth of leaching is inversely proportional to the carbonate content of the drift. Thus, depth of leaching merely reflects part of the lithology of the drift, as used by MacClintock, and therefore describes a rock unit rather than a time unit. Merritt and Muller also suggest that the carbonate content of the pebble fraction is not necessarily a reflection of the total carbonate content of the drift.

Holmes (1952) and Moss and Ritter (1962) have illustrated the progressive dilution of the coarse carbonate fraction as one travels down current (down glacier). Merritt and Muller also illustrate progressive dilution of the finer fractions, as distance from the carbonate source increases. This variation in total carbonate content is due not only to dilution by materials which are being added to the glacial load by erosion at the base of the ice, but also by depletion of the carbonate due to deposition. Therefore, depth of leaching within the Binghamton magnafacies should prove to be essentially the same for all rock units in a given geographic area.

Texture

Texture has come to be used in a very restricted sense by Pleistocene stratigraphers. Pettijohn (1957, p. 13) states that the texture of a sedimentary rock includes the size, shape and arrangement of the constituent grains.

However, texture has come to be used in the restricted sense of the soil scientist, meaning size only.

Holmes (1960) has done an excellent job of demonstrating the evolution of till stone shape, working particularly in western New York. However, the coarse fraction of till does not necessarily define shape for all fractions. In a stratified facies shape is more variable than in till, owing to the further complication of water rounding. The importance of arrangement (frabic) is discussed below, under a heading of its own.

Due to many complicating factors, texture is further restricted to mean till texture; and even within this narrowed definition, till texture is further restricted to mean till-matrix texture. Texture is generally reported using the designations of the soil scientist (see Millar, Turk and Foth, 1951, p. 48) or as ratios between sand, silt, and clay.

White (1960) has summarized the classification of glacial deposits in northeastern Ohio using texture as one of his key criteria. Shepps, _et al_. (1959) has illustrated this technique in Pennsylvania, as has Muller (1964) in extreme western New York. In the dissected plateau area of New York the writer has shown that the texture of a till matrix is a direct reflection of the material immediately below the till (Connally, 1962). Street (1963) has also shown a vertical variation within a related sequence of tills in the region in question as well as relating texture to underlying deposits.

Although texture, in its restricted usage, may be helpful in local correlation of the unstratified facies of some formations, it cannot be adopted as a definitive characteristic for rock units in this region.

Heavy Minerals

Heavy minerals have been used to define rock units in the past. Heavy minerals are restricted to the intermediate, sand fraction of a deposit. Unlike pebble lithology, texture, color, and fabric they may be used in both the stratified and unstratified lithofacies of formations. For this reason, and those that follow, the writer prefers using heavy mineral assemblages in attempting to define rock units.

Heavy minerals survive long distances of transportation with much less loss than rock fragments (Plumley, 1948, pp. 570-576). Their provenance can therefore be used to infer a distant source area, and hence to determine the regional direction of former glacial movement. Another advantage is that they are not bulky, being easily stored and worked with. Fortunately, in the western Finger Lakes region there are no sources for non-opaque heavy minerals (Connally, 1962, p. 262) which would dilute the assemblage.

Garnet Ratios

Dreimanis, Reavely, Cook, Knox and Moretti (1957) made initial examinations of tills in Ontario and adjacent areas in Canada. Their results indicate that heavy minerals give evidence of the source of the glacier which deposited these tills. They used heavy minerals to differentiate tills and to infer glacial "flow lines." In a later report Dreimanis (1960) clearly established a source for red and for purple garnets found in Ontario and in New York. A dominance of red garnet illustrates a source in the central Adirondacks or in the Lake Superior "Province" north of Lake Huron. A dominance of purple garnet indicates a source north of Ottawa and Montreal.

Lewis (1960) has also worked with garnet ratios in tills of western New York. The writer worked with garnet ratios in stratified drift of the same general area (Connally, 1960). The results of these investigators, and Dreimanis (ibid) are consistent in defining two distinct source areas for the drift in this study.

In the northern, post-Olean, drift sheets a dominance of purple garnet is well established. The ratio is usually 1.4 or greater for known Classical Wisconsinan deposits. The ratio is usually 1.2 or less for Olean deposits in this region. Thus, regional "flow lines" can be established which suggest that earlier, Olean, glaciation had a center of outflow in the Adirondack Mountains, the ice moving from northeast to southwest. This interpretation is consistant with the conclusions of Moss and Ritter (1962) based on striae and fabric studies. The later glaciations (Almond and Valley Heads) had sources in the region north of Ottawa and Montreal and entered New York State from the Lake Ontario basin.

The results of the present analyses, which are reported below in Table 3, Figure 6, and the section on "Rock Units," fully support the above interpretations.

More recently Wingard (1963) has attempted to establish trends for heavy minerals in the western Finger Lakes region. He reports ratios of purple garnet to red garnet (clear/red) that are anomalously high for all areas. When subjected to some reinterpretation, however, his other data support the flow directions noted above.

As all Wingard's ratios are dominated by purple garnet he treats the rest of his data as though all samples have a common provenance. If two sources are recognized in terms of the morainic boundaries which are established in this study (see Figure 6), then his data may be reinterpreted.

Wingard's southern tier of sample sites are all south of the Almond-Valley Heads Moraines. If these sites (at least 9, 10, 14, 15, 16 in his Plate 15) are thereby taken to represent a separate source area, not related to the more northerly sites, then a progressive dilution of the heavy

Table 3.--Purple garnet/red garnet ratios.

Sample Number	Purple/red	Sample Number	Purple/red
60-17a	1.3	61-3	0.9
60-17b	1.7	61-5	1.2
60-19	0.7	61-8-2	1.5
60-21	1.4	61-9-1	1.4
60-23	1.6	61-9-2	1.1
60-24	1.4	61-10	1.5
60-30	2.0	61-11	1.2
60-32	1.5	61-14	2.0
60-37	1.4	61-15	1.1
60-41	1.9	61-18	1.9
60-45-I	1.6	61-19	2.4
60-45-II	1.6	61-20-1	1.9
60-46-1	1.6	61-20-2	1.6
60-46-2	1.5	61-21	1.0
60-52	0.7	61-23	2.3
60-56	1.4	61-24	0.9
60-57-1	1.0	61-25	1.0
60-57-2	1.5	61-27	2.2
60-60-1	0.1	61-28	1.5
60-60-2	0.1	61-29	1.5
60-61	1.3	61-30	1.4
60-62	0.7	61-39-1	2.0
60-63	1.4	61-39-2	1.8
60-65	1.0	61-42	1.8
60-71	1.0	61-45-1	2.5
60-72	1.8	61-45-2	1.5
60-73	0.8	61-47	1.1
60-75-1	1.2	61-49	1.9
60-75-2	1.3	61-50	1.8
60-76	1.1	61-55-1	2.7
		61-55-2	1.2
		61-58	1.4

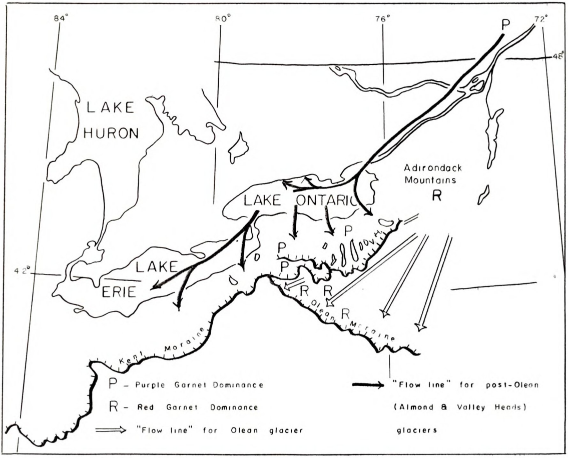

Fig. 6.--"Flow lines" established from garnet ratios. Modified from Dreimanis (1960a, 1960b)

fraction takes place from two different directions for the separate deposits. The dilution takes place from north to south behind the Almond and Valley Heads Moraines. In the Olean drift to the south, the dilution takes place from east to west. A similar pattern may be recognized with respect to other of Wingard's data; namely the percent of garnet (his Plates 12 and 15) and the percent of magnetics (his Plate 6). Again, by reinterpretation these data would appear to support the previously mentioned directions of former ice disbursement.

Coated Heavy Minerals

Moss and Ritter divided the heavy minerals into uncoated opaque minerals, uncoated non-opaque minerals, and grains coated with iron oxide. These authors found few coated minerals (less than 24%) in Valley Heads till, but over 74% coated grains in the Olean till. Intermediate percentages were found within the lenses of "bright gravel" in the Olean.

Coates (1963) states: "The author is very surprised that all Olean samples of Moss and Ritter show coated heavy minerals greater than 74%." In view of the following, the writer is not at all surprised at the results of Moss and Ritter. The key to the heavy mineral coatings lies in the statement of Moss and Ritter that: "Because till cuts extending into the unoxidized zone could not be found in the uplands, a constant depth of 4 to 6 feet was adopted. . ."

Because of the low percentages of carbonates in the upland facies and the higher percentage in the bright gravels of the lowland, one should expect upland samples to be well within the zone of oxidation. Lowland samples should also be much fresher at the stated depths. In fact, the high carbonate content of the Valley Heads drift precludes much oxidation at depth.

In these terms, coating ratios for heavy minerals probably reflect the sampling technique employed. In this instance, they are not suitable as a stratigraphic tool.

Color

Color, like texture, is used in a restricted sense to designate the color of the matrix of till. For this reason color is of little value in defining a glacial formation which may contain coarse, stratified members. Although previously the writer (Connally, 1962) has described the Olean till as having a consistant "olive" or greenish color, it is realized that this notation is extremely subjective. The descriptive term "olive" (actually, olive-drab) has been agreed to by other workers (Street, personal communication) and in this case is considered to denote a useful distinguishing characteristic.

Generally color is not thought to be definitive of an entire till unit, but it is consistant enough to be suggestive for correlation within local areas. Figure 7 (in

Volume 2) shows the limit of olive till in the western Finger Lakes region. It will be noted that this till is confined to the area south of the Almond and Valley Heads moraines. Exceptions to this are the tills at sites 60-63 (near Casaseraga Creek) and 61-3 (near Seneca Lake). These were originally considered to be older, overridden deposits when visited in the field, before a color relationship was established.

Fabric

Wright (1957) and MacClintock (1958) have illustrated the tendency for ice to cause the alignment of pebbles parallel or perpendicular to the direction of glacier movement. Moss and Ritter (1962, Fig. 7) show the parallelism of striations and fabric between the Finger Lakes and the Catskills. North of the Valley Heads border the trend is south-southeast, while south of the Valley Heads border the trend is southwest. This means that the northerly trend is almost perpendicular to the southerly trend in the Olean drift.

The trends of Moss and Ritter suggest only two glaciations in the eastern Finger Lakes region. Their initial glaciation is the Olean, coming from the Adirondacks; their second being the Valley Heads, coming from the Lake Ontario depression. This is in agreement with the above noted trends established by garnet ratios, and would appear to preclude the presence of Almond ice in this region, south of the Valley Heads Moraine.

Although fabric studies include more than just the matrix of a rock unit, they are applicable only to tills. Furthermore, in such a completely dissected area they should be restricted to upland tills. Lowland tills and stratified deposits tend to be channeled by pre-existing valleys as shown by the more southerly extension of ice in valleys than on uplands.

Though fabric studies, supported by observations on striations underlying the drift, are probably the most informative studies in this region and adjacent ones, they can not be used to define suitable rock units.

Rock Units

Krumbein and Sloss (1951, p. 27) state that: "A formation is a genetic unit and represents a response to an environment, or a series of environments, and such environments must be limited geographically as well as temporally." They also state: " . . . formations should be distinguished as much as possible on the basis of lithologic unity . . . " and "Formations should be established with boundaries that may be readily traced in the field . . . ."

It is obvious that the glacial deposits of the western Finger Lakes region fit into the first statement. They are limited geographically by definition and most certainly represent a response to particular environmets. The temporal limitations are also present and are dealt with under the section "Time Stratigraphy" below.

Many investigators have attempted to establish lithologic properties that are essentially uniform. From what has been discussed, however, it is evident that all attempts at field definition have failed and that such attempts are either to be abandoned or criteria will have to be employed which are not recognizable in the field.

Definitions

The writer has adopted the latter view, and therefore will attempt to define formations on the basis of heavy minerals. Specifically, ratios of purple garnet to red garnet are proposed as definitive characteristics for two formations.

The problem of a type section for Pleistocene deposits is a complex one. The units which lie beneath the extensive basal unconformity are too variable to be useful, while the unconformity itself is understood. In a regressive glacial sequence there is seldom an identifiable overlying unit, thus the upper and lower limits of the formation are useless concepts. Another complication is that suitable exposures must be fresh. This means that they are being vigorously eroded at present.

Because of the ephemeral nature of most outcrops only a type area is designated. While garnet ratios are the definitive characteristic, other properties will be mentioned. The other properties may vary beyond the limits to be mentioned without affecting the usefulness of the definitions based on garnet ratios.

The writer proposes that all of the Wisconsinan deposits of this region be called the Finger Lakes Group (new). This includes all unconsolidated rock units above the pre-Wisconsinan unconformity. The basal formation of the Finger Lakes Group is the Olean Formation (redefined) while the upper one is the Canaseraga Formation (new). The type area for the Finger Lakes Group is the Finger Lakes region of western New York State.

The Olean Formation includes all of the glacial drift and associated glacio-fluvial deposits between the unconformable contact with bedrock at the base, and the disconformable overlying contact with the Canaseraga Formation. The Olean Formation is named for exposures of till and gravel exposed near Olean, New York as described by MacClintock and Apfel in 1944.

The unstratified facies of the Olean has a clay or clay loam matrix with a typical olive color. Till stones are common, and may either be local or exotic, although they are of local derivation in the type area. The till is only slightly calcareous as determined with 1N HCl, and may be leached as much as 12 feet below the surface. The definitive characteristic of the Olean Formation, in the western Finger Lakes region, is the dominance of red garnet over purple garnet. Although the ratio (purple/red) is usually less than 1.0 it varies locally to 1.2.

The stratified facies of the Olean may be locally important, as in the region between the Finger Lakes and the Catskills. It is found in valley bottoms and may exhibit exotic pebbles. It forms a series of discontinuous lenses within the Olean, of which the one in the Chenango River is probably typical. Although this type area is outside the western Finger Lakes region, it has been well described by Moss and Ritter. This lense phenomenon is therefore named the Chenango member (new) of the Olean Formation.

The upper formation in the Finger Lakes Group is the Canaseraga Formation. The Canaseraga includes all of the drift between the Olean (or bedrock where the Olean is absent) and the present erosion surface. The Canaseraga is named for exposures of till on tributaries to upper Canaseraga Creek, in the vicinity of the village of Canaseraga, New York.

The unstratified facies of the Canaseraga has a silt or silty clay matrix and is grey or blue-grey in color. Till stones are common, and are usually more exotic than those of the Olean Formation. The till is calcareous below the zone of leaching, which is usually not more than 4 feet in depth. The definitive characteristic is a dominance of purple garnet over red garnet. Although the garnet ratio (purple/red) is typically greater than 1.4, it can be as low as 1.2.

The stratified facies of the Canaseraga forms an important part of this formation. It is usually found in valley bottoms and tends to exhibit many exotic pebbles. It forms a series of discontinuous lenses, of which the ones in Goff Creek, west of Bath, New York are thought to be typical. These discontinuous lenses are referred to as the Goff Creek member (new) of the Canaseraga Formation.

The geographic division between the Canaseraga Formation and the Olean Formation, from which it has regressed, is the Almond Moraine. East of Prattsburg where the Almond system has been overridden, the Valley Heads Moraine is the dividing line. At present, the drift north of the Valley Heads border is included in the Canaseraga Formation because it cannot be differentiated rock stratigraphically. The only difference between the Canaseraga drift and Valley Heads drift is that they are separated by a morphostratigraphic unit; the Valley Heads Moraine.

Correlations

Following the definitions established above, the morphostratigraphic borders must be altered somewhat from the original field correlations. Table 3 lists the garnet ratios for the field sites; Figure 8 (in Volume 2) shows the aerial distribution of red and purple garnet dominance. The two principle changes based on heavy minerals are in the Canisteo River valley south of Hornell (K-9) and on the Naples-Prattsburg interfluve (J-10).

Purple garnet is found to dominate in till samples from sites 61-30 and 61-42 (K-9). This correlates them with the Canaseraga Formation and necessitates the extension of the Almond Moraine into the Canisteo valley.

The second change in interpretation is necessitated by finding the samples at sites 60-73, 61-21, and 61-25 (K-10) dominated by red garnet. This evidence, supplemented by the striae direction of N 72° E at 60-74 suggests the conclusion that this area is only vaneered with Olean drift and that it was probably not glaciated after the Olean glaciation. This evidence further suggests a change in the interpretation of the Almond Moraine as discussed with respect to the Cohocton Valley section (K-10).

TIME STRATIGRAPHY

Theoretically a time-stratigraphic market is a distinctive deposit, desposited synchronously all over the world. In practice, however, a time-stratigraphic marker is any recognizable deposit which is laid down more or less contemporaneously within a large area.

In glacial stratigraphy there is much doubt concerning the degree of time equivalence represented by the various deposits of a single glaciation. Depending on which figures are adapted for the rate of glacial advance (see Flint, 1955) deposits in Canada are a few hundred to a few thousand years older than the deposits in the United States. Presumably, deposition could have begun beneath the ice in Canada, long before the glacier reached the United States, pre-dating the southerly deposits.

Therefore, interglacial or intraglacial (see Leighton, 1960) deposits have become the dominant time stratigraphic markers. As climatic conditions affect a large area contemporaneously, deposits are sought which are climate-sensitive. Thus far, only lacustrine or paludal sediments offer real hope. Antevs (1945) has shown how inorganic sediments may be used to advantage in limited areas, however many problems arise in counting varves, the solution of which seems to require too much subjective interpretation. Organic sediments are a more reliable tool of the glacial stratigrapher. The first reason for this is that pollen profiles (see Darrah, 1961) may be obtained and correlated on a regional basis. Secondly, radiocarbon dates may be obtained from a sequence and from these, a finite time scale may be established.

Radiocarbon Dates

Radiocarbon dates may actually be of two kinds. The first is as noted above where a deposit of organic sediment, usually peat, yields a date for an interglacial or intraglacial age. This date is then used as a limit for the underlying or overlying deposits. The second type of date is much rarer and for some interpretations more satisfactory. It is obtained from organic material, usually trees, incorporated in glacial deposits by the overriding of a glacier. This date is then a very close approximation of the glacial advance. Unfortunately, none of the latter type have been found in New York State.

Pleistocene Chronology

The Pleistocene Epoch has been divided by many workers into four glacial stages (see Flint, 1957, pp. 335-341) separated by three interglacial stages. There is little agreement at present on the absolute chronology of the time units, but recent finite dates suggest that the Wisconsinan stage commenced about 70,000 years before present. The names for the Pleistocene stages are listed below.

Wisconsinan stage
   Sangamon interglacial stage
Illinoian stage
   Yarmouthian interglacial stage
Kansan stage
   Aftonian interglacial stage
Nebraskan stage

The Wisconsinan has further been subdivided into at least five substages. Recently, Frye and Willman (1960) have redefined the nomenclature for the classical deposits of the Lake Michigan lobe. In Figure 9, the Frye and Willman classification is illustrated along with its more familiar predecessor.

In this study the writer adopts the post-Altonian part of this classification. The first reason is that it represents the doctrine of the Illinois State Geological Survey in describing the type localities for Wisconsinan time-stratigraphic units. A second reason is that the philosophy behind the proposal of the Woodfordian substage cannot help but be adopted by a worker in New York State. Their discussion might well be about New York when they say: "The Woodfordian substage . . . contains about 30 recognized end moraines. Although recording in minute detail the successive configurations of the limit of glacial ice, the individual moraines cannot be traced with certainty across re-entrants within the lobe. They are not adaptable to

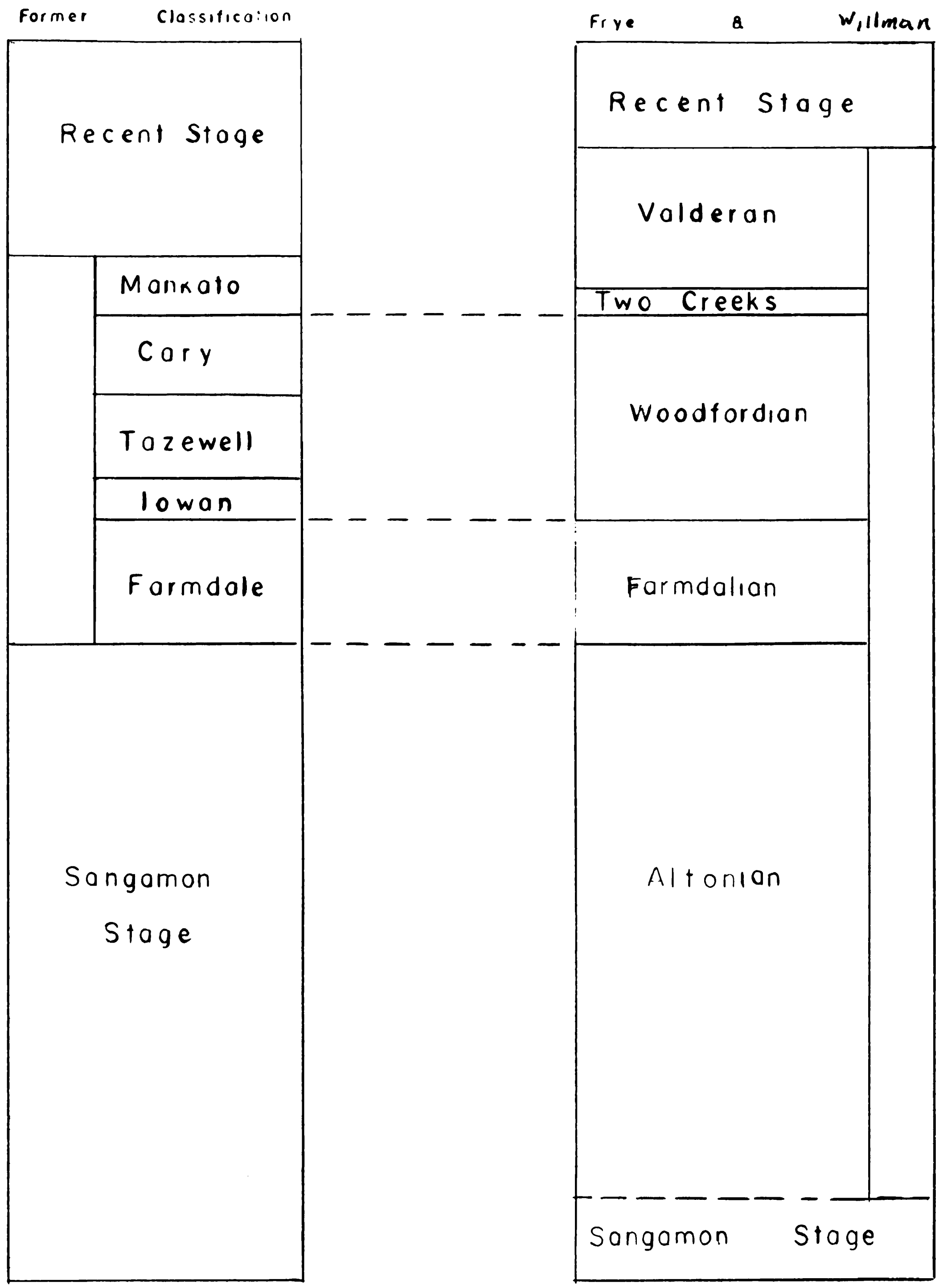

Fig. 9.--Classification of the Wisconsinan Stage after Frye and Willman.

treatment as time-stratigraphic units both because of the extremely short time span represented by an individual moraine and their lack of sufficient continuity."

In the Lake Erie-Ontario lobe the Altonian substage of Frye and Willman apparently should be further subdivided. Dreimanis (1960) reports a range of dates for the Plum Point "interstadial" (intraglacial substage) beds which correlate them with the Farmdalian of Frye and Willman. Below the Plum Point beds, in descending order is, the Southwold drift, the Port Talbot "interstadial" beds, and the Dunwich drift. Recently, Dreimanis (personal communication, 1963) has discovered more "interstadial beds" beneath the Dunwich drift, and a basal, red till beneath them. This lowest intraglacial deposit would presumably be correlative with the St. Pierre "interstadial" beds of Terrasmae (1958).

In terms of the foregoing, the composite Wisconsinan column adopted by the writer is listed below.

Wisconsinan stage

- Valderan substage
  - Two Creek intraglacial substage
- Woodfordian substage
  - Farmdalian intraglacial substage
- Southwold? substage
  - Port Talbot intraglacial substage
- Dunwich? substage
  - St. Pierre intraglacial substage
- Basal Wisconsinan substage

Sangamon interglacial stage

Time-Stratigraphic Correlations

The Olean Formation

The lower limit for the Olean Formation is the Sangamon interglacial stage. Frye and Willman place this stage at 50,000 to 70,000 years before present. As the St. Pierre beds date at 66,000 and there is apparently Wisconsinan drift beneath this, the lower limit of 70,000 is accepted here. Thus, the Olean is at least 70,000 years old.

The upper limit for the Olean Formation may be a finite date of 64,900 ± 1500 years (GRN 3213) as reported by Muller (personal communication), from the Otto intraglacial site. The Olean till is reported by Dreimanis (1960) to underly the Otto peat. There is also a possibility that Olean Formation overlies the Otto peat as reported earlier by MacClintock and Apfel (1944). Dreimanis, however, feels that the overlying gravel is associated with the peat rather than with subsequent glaciation.

Lewis (1959) has shown that the basal unit at Gowanda, New York is also Olean. This unit incorporates shells that have been dated at greater than 35,000 years. If a finite date should be obtained which is correlative with the Otto intraglacial; then the Olean would also be equated to the Southwold drift of Dreimanis. This relationship is depicted in Figure 10.

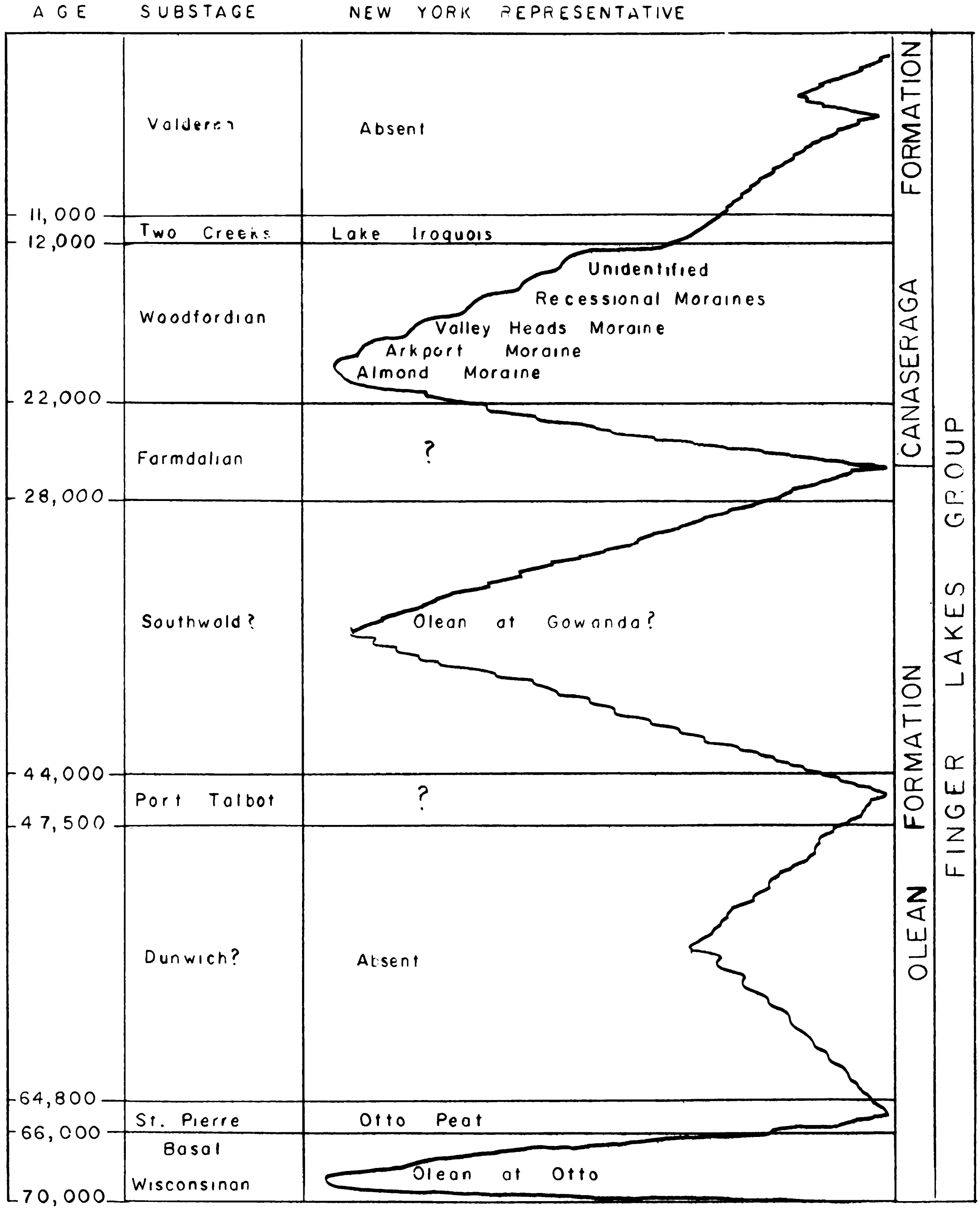

Fig. 10.--Diagramatic representation of the Wisconsinan Column for New York State.

The Canaseraga Formation

The Canaseraga drift also has only limiting dates, from neighboring areas. The only finite lower limit in New York State is the previously mentioned 64,900 years. If the inference drawn by White (1960) is correct that the Kent till of northeastern Ohio is equivalent to the Cary Moraine in Illinois, then this gives a much younger limit to the Canaseraga.

The Kent Moraine in Ohio has been assigned to Cary time by MacClintock and Apfel (1944), MacClintock (1954), and White, *et al*. (1957). It has been assigned to early Cary by Muller (1957, 1964) and Shepps, *et al*. (1959). The New York equivalent (Almond) would also be Cary or early Cary.

The Almond Moraine (as well as the Arkport and Valley Heads Moraines) is superposed on the Canaseraga Formation. Indeed, the Almond Moraine appears to be the southern limit of this formation. Thus the entire Canaseraga appears to have been deposited during Cary time.

Subsequent to the aforementioned assignments, Frye and Willman re-evaluated the type area. According to these authors, the term Cary merely denotes a morphostratigraphic unit of Woodfordian age. Thus the lower limit becomes 22,000 years.

The upper limit for the Canaseraga drift is any date for Lake Iroquois (Hough, 1958; Fairchild 1932a). Lake

Iroquois wasthe pre-Ontario lake in the Lake Ontario basin and as such is the latest glacial event to affect western New York. According to Karrow, et al.(1961) Lake Iroquois must have been in existence during latest Woodfordian and Two Creeks time. This would place an upper limit of about 12,500 years on the deposition of the Canaseraga Formation.

Another significant date is 14,000 $\pm$ 350 for the upper limit of the Kent till in Ohio and Pennsylvania. This date is from basal peat and marl in a Kent kettle. This dates the recession of the Woodfordian glacier from the Kent Moraine and therefore probably from the Almond Moraine also.

The age of the Valley Heads and Arkport Moraines is uncertain, however, the Valley Heads was assigned to Cary by Flint (1957), Holmes (1952), and MacClintock and Apfel (1944). It has been assigned to late Cary by Muller (1957), White, et al. (1957), and White (1960). This positions it as another recessional Woodfordian deposit, younger than the Almond Moraine.

Stability Ratios

Previously, the writer has suggested that heavy minerals could be used as a time-stratigraphic indicator (Connally, 1960). He used ratios of unstable minerals (Hornblende, Hypersthene, and Monoclinic pyroxene) to stable minerals (all garnet) to characterize deposits having a common provenance but differing in age. These were termed stability ratios. It was found that younger deposits had higher ratios and the inference is that they have retained more unstable material due to their youth. Independent physical evidence (Connally, 1960, Plates 8 and 9) suggests that the instability is due to intrastratal solution.

During the present study the writer has again computed stability ratios for hornblende, hypersthene, and monoclinic pyroxene for the Canaseraga Formation. The purpose is to compare values from the proximal sides of the various moraines in order to examine the age relationships. These values are recorded in Table 4.

No laterally consistant variations are indicated for any of the stability ratios computed. A similar decrease in the ratios is again noted for any given north-south traverse. However, the ratios vary from one point to another along each of the three moraines. Although this is not thought to invalidate any of the writer's previous conclusions, it does refute the suggestion that stability ratios might be used as a tool in time-stratigraphic correlation.

TABLE 4.--Stability ratios for hornblende, hypersthene, and monoclinic pyroxene.

Sample Number	Hornblende / Garnet	Hypersthene / Garnet	Monoclinic Pyroxene / Garnet
60-17a	2.02	0.76	0.29
60-17b	0.40	0.12	0.05
60-23	1.42	0.63	0.23
60-24	1.39	0.39	0.19
60-30	1.45	0.38	0.14
60-32	2.33	0.54	0.37
60-37	1.13	0.21	0.26
60-41	0.83	0.27	0.27
60-45-I	0.78	0.35	0.49
60-45-II	1.07	0.23	0.33
60-46-1	2.12	0.67	0.62
60-46-2	1.75	0.68	0.32
60-56	1.39	0.55	0.14
60-57-1	1.49	0.39	0.23
60-57-2	1.41	0.45	0.24
60-61	2.23	0.36	0.48
60-63	1.41	0.45	0.24
60-72	0.63	0.24	0.21
60-75-1	1.54	0.15	0.15
60-75-2	1.00	0.29	0.00
61-5	0.52	0.08	0.22
61-8-2	0.96	0.23	0.20
61-9	0.43	0.15	0.13
61-10	0.90	0.32	0.20
61-11	1.04	0.32	0.24
61-14	0.74	0.11	0.15
61-18	0.53	0.19	0.08
61-19	0.85	0.25	0.22
61-20-1	1.30	0.27	0.18
61-20-2	1.16	0.27	0.21
61-23	0.47	0.09	0.08
61-27	0.66	0.13	0.16
61-28	1.26	0.61	0.30
61-29	0.45	0.16	0.06
61-30	1.21	0.42	0.26
61-39-1	1.40	0.20	0.12
61-39-2	0.85	0._4	0.11
61-42	0.65	0.20	0.08
61-45-1	1.10	0.33	0.10
61-45-2	0.67	0.22	0.10
61-49	0.90	0.22	0.12
61-50	1.48	0.42	0.19
61-55-1	0.70	0.30	0.18
61-55-2	0.87	0.21	0.17
61-58	0.63	0.15	0.13

CONCLUSIONS

1. The name "Binghamton" should be restricted to, and used as, a rock-stratigraphic term. It should be used to designate the magnafacies in the drift in which lenses of bright, valley-fill, gravel are present.
2. The name Almond should be adopted for the morphostratigraphic equivalent of the old "Binghamton Moraine" in the western Finger Lakes region.
3. There are three morphostratigraphic units in the western Finger Lakes region; the Almond Moraine, the Arkport Marine, and the Valley Heads Moranie. These moraines trend East-West across the region.
4. The Almond Moraine is the oldest. It is quasi-continuous from the Genesee River to the vicinity of Bath, New York and is the southernmost moraine in this region.
5. The Arkport Moraine is intermediate in age and position. It is continuous from Bennett Creek, near Canaseraga, to the Cohocton River. It cannot be traced east or west of these points

This moraine could be either an advance phase of the Valley Heads glaciation or a recessional phase of the Almond. No evidence has been found to favor either alternative.

6. The Valley Heads Moraine is the youngest moraine and is continuous from the Genesee River to Seneca Lake. East of Bath the Valley Heads glacier evidently overrode the Almond deposits. In this area the Valley Heads Moraine is the southernmost.
7. On the basis of distinctive ratios of purple garnet to red garnet, the glacial drift can be divided into two formations. The older formation, termed the Olean, exhibits ratios that are usually 1.2 or less. The younger formation, termed the Canaseraga, exhibits ratios that are usually 1.4 or higher.
8. The provenance of the Olean Formation is in the central Adirondacks, as indicated by the presence of appreciable amounts of red garnet. Thus, the Olean glaciation may have originated in the Adirondack Mountains, or been abetted by ice from this region. In any case, it had the Adirondacks as a disbursing center.
9. In the area occupied by Olean drift, the valleys are filled with gravel lenses. These form a

sequence of discontinuous lenses in the Olean Formation and are named the Chenango member of the formation.

10. The provenance for the Canaseraga Formation is probably north of Ottawa and Montreal. The glacier is presumed to have traversed the St. Lawrence lowland and moved into western New York State via the Lake Ontario depression.

11. The Canaseraga Formation has a discontinuous sequence of lenses similar to the Olean formation. These are named the Goff Creek member of the Canaseraga Formation.

12. Although "stability ratios" may be related to the age of drift deposits, they do not appear to be useful in correlation.

SUGGESTIONS FOR FUTURE STUDY

1. The Prattsburg valley, and the adjacent upland, should be studied in detail. The many morainic ridges that loop across this valley should be correlated with their equivalents in the Keuka Lake valley to the east and the Naples valley to the west. In this manner it will be possible to locate the exact point at which the Valley Heads glacier overrode the Almond Moraine.
2. The upper Canisteo River valley, west of Hornell, should also be studied in detail. In this study an attempt should be made to establish the age relations for the abundance of water-laid drift present. It should be possible to differentiate between Almond and Pre-Almond deposits, thus positioning the Almond Moraine more definitely.
3. A trend surface analysis should be made for the heavy minerals in both the Olean and the Canaserage Formations. In this study "flow lines" might be established more definitely and local sources of contamination detected.

4. As an extension of the present aerial study, the southern tier of quadrangles should be mapped in order to locate any other Olean morainic segments which may be present.
5. As another extension of this study, the more northerly quadrangles should be investigated in order to depict the recessional history of the Valley Heads glacier.

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APPENDICES

APPENDIX I

A DESCRIPTION OF THE FIELD SITES CITED IN THE TEXT

Each field site is identified by a combination of numbers and letters. The first set of numbers indicates the field site number as cited (described on page 13 The second set refers to the map grid number (described in Figure 4) preceded by the ninth of the map in which the site is located. The last set is the approximate elevation of the field site.

For the sake of brevity, common symbols for feet and inches are used. In addition, all numbers are given by digits.

<u>60-32; SW, J-9; 1480</u>

There is 0.5' of firm, brown, calcareous till on bedrock. The till contains a great deal of "bright" gravel and either lies on, or incorporates, lacustrine sediment which is found at the base of the till. The till caps a bench of Chemung-type sandstone which crops out in the adjacent roadcut. This lithology evidently caused the resistance of the ledge. In places the till has been washed away and prominant striae are revealed

60-63; NE, K-8; 1500

A cutbank in Slader Creek exposes a till with "bright" gravel. The till is apparently north of the Almond border but is not the characteristic blue color. The color is the olive of the pre-Almond drift seen at other sites south of the Almond Moraine. The till is stoney, firm and calcareous with a silty clay matrix. At one point it grades up into an oxidized zone which is overlain by calcareous alluvium. This may be a truncated paleosol. The sample was taken from beneath the oxidized zone.

60-73; C, K-10; 1300

A gravel pit in kame-type outwash is apparently the terminus of the Valley Heads Moraine in the Fivemile Creek valley. At this time (July, 1960) I have an inkling that this is pre-Valley Heads. The sample is from the base of a 50' face which reveals sand and gravel which is almost rhythamically bedded. The lithology of the gravel is Olean and the bedding is from the east.

60-74; NC, K-10; 1800

This is an abandoned quarry in a flat potato field. The cap rock, beneath the soil, is a polished and striated siltstone. The striae trend N 72° E and are well exposed. There are two prominant joint sets at N 84° E and N 12° W.

<u>61-3; NW, K-12; 1260</u>

A gravel pit, 1/2 mile E. of North Beaver Dams School reveals a 12' face of unoxidized, calcareous, gravel over olive, silty clay, gravelly till. The till appears to be oxidized immediately below the gravel and blends into olive at the base. This is tentatively interpreted as the Valley Heads terminus overlying Olean till.

<u>61-6; NC, K-11; 1440</u>

Striae are observed on a polished, ripple marked, siltstone which trend N 15° E, parallel to the Keuka Lake valley.

<u>61-7; C, K-11, 1420</u>

Two observations were made, about 60' apart. Both recorded striae trending N 20° E.

<u>61-11; SC, K-12; 1300</u>

A roadside ditch exposes a loam till. The till is bluish-purple, stoney ("bright") and leached for almost 5'. It is calcareous for 2' above bedrock, where it was sampled. A fabric determined from a few stones gives a direction of N 45° E, indicating deposition from the Catherine Creek lobation.

61-21; NW, K-10; 1300

This is a gravel pit on the Tenmile Creek valley wall. The pit is Olean in every respect and is probably a kame terrace remnant. The sample is unleached at about 15' beneath a stripped surface but there are leached pebbles at this depth.

61-25; C, k-10; 1320

This is an active gravel pit with a 60' face. The gravel is foreset and "bright" but it is imbedded in an oxidized sand. The bedding is from N 165° E and the sample is from a 15' sand lense.

61-30; SC, K-9; 1500

A cutbank on Cunningham Creek shows 2-3' of blue, silty clay till. The till is very stoney with limestone present in sub-Binghamton (less than "bright") proportions. The till is firm and fresh. The upper 8" is oxidized to yellow brown below which the blue is mottled with olive. The till is overlain by 6" of finely laminated sand.

61-42; SC, K-9 1400

A gravel pit reveals bright, kame-type gravels with the bedding obscured.