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State University of New York at Binghamton, Ph.D., 1973
Geology

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LATE WISCONSINAN DEGLACIATION CHRONOLOGY
OF THE CHENANGO RIVER VALLEY
AND VICINITY, NEW YORK

by

Donald Herbert Cadwell

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in
State University of New York
at Binghamton
1972

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Accepted by the Faculty of the Department of Geology in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

Donald R. Coates	Donald R. Coates (Advisor)	27 June 1972 (Date)
Paul Enos	Paul Enos	5 June 72
John H. Moss	John H. Moss	5/17/72
Leonard Vacher	Leonard Vacher	20 June 1972

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INTRODUCTION

Purpose

The basic objective of this paper is to reconstruct the history and manner of deglaciation in the Chenango River area of New York. To accomplish this objective it was necessary (1) to evaluate the planar-surface features within the Chenango River valley and parts of the Susquehanna and Unadilla River valleys with respect to the manner of deglaciation (2) to map the surficial geology and evaluate the sediments deposited and landforms created (3) to delineate between the "Binghamton" and "Olean" type sediments, and (4) to reconstruct a Pleistocene history with the relationship between glacial drift and the retreating ice margin.

In this study the answers to several important problems are delineated: (1) the Binghamton problem--the spatial and temporal relations of two lithologically distinct, mappable units, the Binghamton and the Olean (2) the planar surface-terrace problem--the origin of prominent, flat, subhorizontal surfaces within the confines of the trunk and tributary valleys; these surfaces are generally areally extensive and occur above the present river level, and (3) the problem of ice retreat--the characterization, delineation, and interpretation of ice margin sequences both in the valleys and in the uplands. Part of the problem of.

ice retreat is the time and space relations of the valley and upland ice margins.

General Background

Geographic Setting

The study area is bounded on the west by the Finger Lakes, on the east by the western Catskills, on the south by the Pennsylvania-New York boundary, and on the north by the Mohawk Valley. The region is covered by the Binghamton, Ninevah, Deposit, Greene, Oxford, Unadilla, Norwich, New Berlin, and Morrisville U.S.G.S. quadrangles (1:62,5000 series) (Fig. 1). The study area, with a total relief of 1140 ft, has a more subdued landscape to the north towards the Valley heads moraine. Local relief in the vicinity of the city of Binghamton is 1037 ft (840 to 1877 ft). The local relief near the city of Norwich is 980 ft (1000 to 1980 ft). The Morrisville area local relief is 665 ft (1275 to 1940 ft).

Geologic Setting

The Devonian bedrock in the study area is divided into six groups (Broughton, 1962). The Lower West Falls, Sonyea, and the Genesee Groups are Upper Devonian; the Hamilton Group is Middle Devonian, and; the Onondaga Limestone and Helderberg Group are Lower Devonian. The Upper and Middle Devonian units are composed of interbedded gray shales,

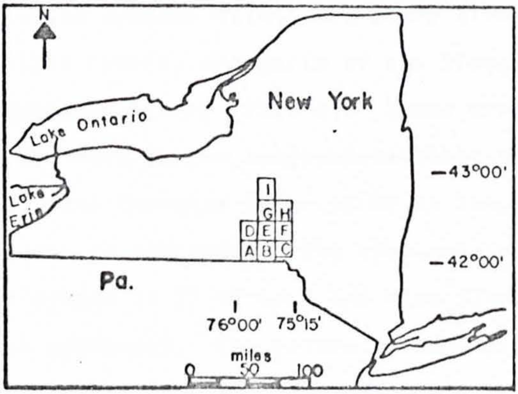


Figure 1. General location of the study area in New York. Letters refer to 15' (1:62,500) U.S.G.S. quadrangles. A. Binghamton; B. Ninevah; C. Deposit; D. Greene; E. Oxford; F. Unadilla; G. Norwich; H. New Berlin; I. Morrisville.

siltstones, and sandstones. The Lower Devonian units are limestone. Bedrock is generally mantled by till in the uplands and by stratified drift in the valleys.

In the study area, only materials from Wisconsinan time are preserved. Crowl (1972) indicates there are isolated remnants of Illinoian age deposits (?) south of the Wisconsinan glacial border in Pennsylvania. The materials in the Chenango River valley, and vicinity, are of the Woodfordian Stadial, indicated by the radiocarbon age of 16,650 ± 1800 yr B.P. (BGS 86) from a kettle hole bog associated with retreatal ice margin zone 1 (Plate 1).

Hydrography

The major fluvial systems within the study area are the Chenango and Unadilla Rivers, and parts of the Tioughnioga, Otselic, and Susquehanna Rivers (Fig. 2). These drainages are all parts of the much larger Susquehanna River basin in New York State. The Chenango River is 80 mi long and flows generally south to southwest. The combined Unadilla-Susquehanna River system is 77 mi long and also flows generally south to southwest. The rivers presently flow on thick accumulations of glacial, glaciofluvial, and glaciolacustrine sediments. The thickness of these sediments may in places be as great as 350 ft. The average thickness of drift in the valleys is about 100 ft (Fig. 3).

Previous Work

A summary of previous investigators who have worked in the vicinity of the study area and the pertinence of their contribution to the present study is shown in Table 1.

Techniques

Field. Field work was conducted during the summers of 1969, 1970, and 1971. The major part of the time was spent in reconnaissance of the region, along all passable roads. All visible glacial deposits, both in the valleys and the uplands, were mapped on 1:24,000 base maps. Many of the mountains were traversed in an attempt to delineate

Figure 2. Major rivers within the study area.

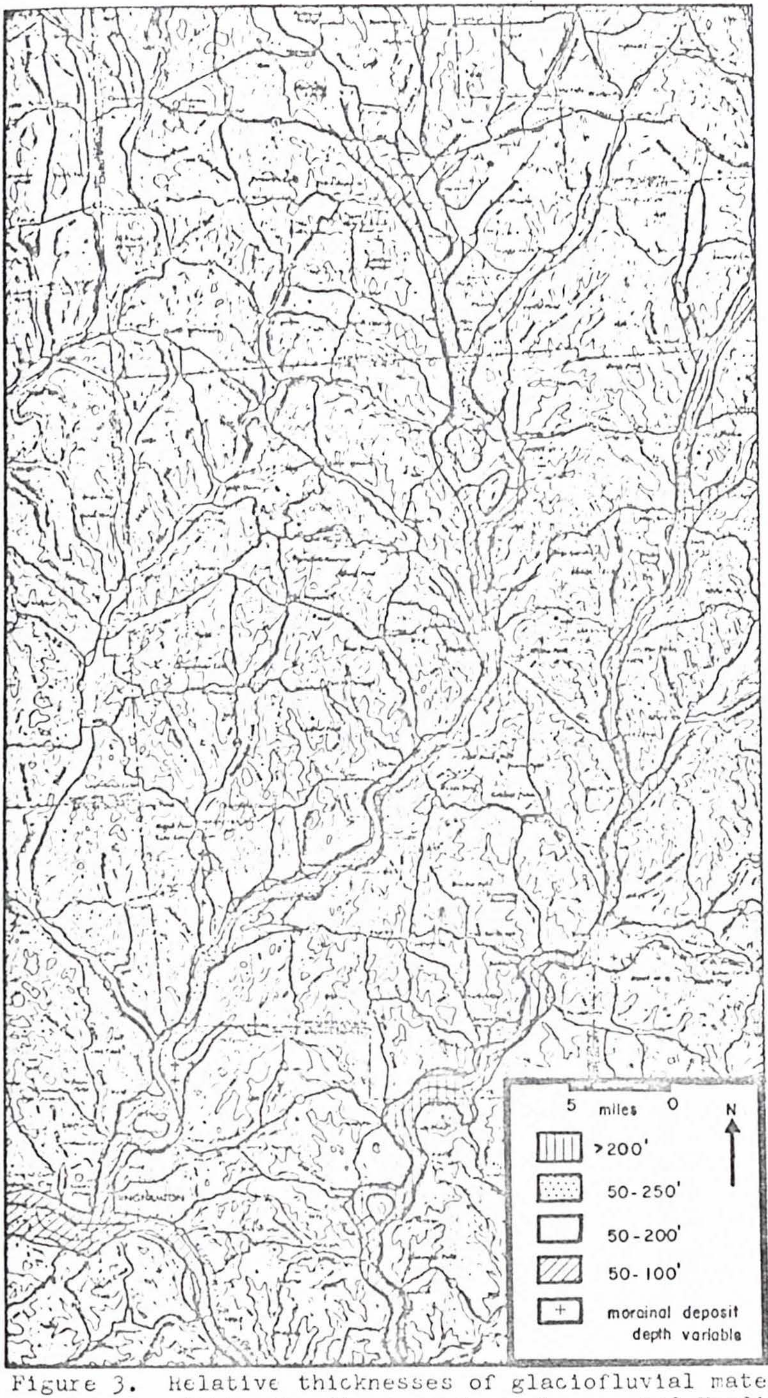


Figure 3. Relative thicknesses of glaciofluvial materials within the Chenango, Susquehanna, and Unadilla River valleys (after Hollyday, 1969).

Table 1. Summary of previous workers, their contribution, and the pertinence to the present study.

Author	Contribution	Pertinence to present study
Upham (1879) Chamberlain (1883) Lewis (1884)	Reported on "terminal moraine" in Pa.	Location of terminal moraine in Pa.
Brigham (1897)	Recognized extent of sediments within Chenango River valley from Binghamton north to Mohawk Valley; indicated glaciers retreated from Binghamton with important pauses, or readvances, near Chenango Forks and Oxford.	Suggested two areas to examine closely, Chenango Forks and south of Oxford
Tarr (1905)	Described characteristics of Valley Heads moraine near Finger Lakes	Delineated Valley Heads boundary
Fairchild (1925)	Described water-laid deposits in upper Susquehanna Valley and tributaries (Chenango and Tioughnioga)	Indicated importance of glacial meltwater deposits in study area
Fairchild (1932)	Delineated three areas of glacial deposits-Olean material at the terminal moraine; Susquehanna Valley kames; Valley Heads moraines	Indicated importance of Susquehanna Valley kame area
MacClintock and Apfel (1944)	Named the Susquehanna kame area the Binghamton moraine, from a Binghamton glaciation; Valley Heads-youngest Wisconsin, Binghamton-middle Wisconsin, Olean-oldest Wisconsin; higher Ls, lg, meta, red ss in Binghamton than Olean	Delineated Binghamton as separate advance

Table 1. - cont.

Author	Contribution	Pertinence to present study
Peltier (1949)	Correlated terraces on Susquehanna in Pa. with pre-Wisconsin, Olean, Binghamton, Valley Heads, and Mankato advances in N.Y.	Found terraces to match each advance
Denny (1956)	Questioned the presence of Binghamton advance in the Elmira region; the Binghamton deposits may be north of Valley Heads border and covered by it; incorporated within the Valley Heads; or complete change in character of materials between Binghamton and Elmira	Doubtful presence of Binghamton in Elmira region
Connally (1960, 1964)	Indicated Binghamton related to the Valley Heads advance	Binghamton related to Valley Heads
Moss and Ritter (1962)	Binghamton not a separate advance, phase of Olean; Valley Heads drift north of Valley Heads moraine; Olean drift south of Valley Heads moraine	Binghamton not separate advance
Denny and Lyford (1962)	Olean ice sheet at maximum extent did not build a prominent moraine, nor construct any moraine south of the Valley Heads moraine, nor deposit any prominent glaciofluvial features within 15-20 mi of the drift border	Extent of glaciofluvial deposits at drift border
Coates (1963)	Single ice sheet deposited what had been called Olean and Binghamton advances; Olean as upland facies, Binghamton as valley facies	Upland and valley facies

Table 1. - cont.

Author	Contribution	Pertinence to present study
Muller (1965)	Summary of the Quaternary of N.Y.S.; descriptions of Olean, Binghamton, and Valley Heads drift sheets	Descriptions of drift sheets
Coates (1966a)	Asymmetry of north and south-facing hillslopes; till shadows	Till shadow on south-facing hillslope
Hollyday (1969)	Thicknesses of aquifers within the valleys in the Susquehanna River basin	Thickness of drift within the valleys
Bloom (1971)	Glacial-eustatic and isostatic controls of sea level since the last glaciation	Backwasting-downwasting model for deglaciation
Cadwell (1972)	Delineation of valley and upland retreatal ice margin zones of retreating Woodfordian ice sheet	6 retreatal ice margin zones

precise boundaries between a constructional glacial feature and the bedrock valley walls (with or without till and colluvium).

Eighty-six samples were collected from 58 localities. Eighty samples were from glaciofluviatile sediments and 6 were from tills. A complete stratigraphic section was drawn for each exposure indicating sample location within the exposed face or outcrop. Samples were obtained either as grab samples, from across the entire face at the locality, or from specific depositional units. Sedimentary analyses were conducted in the laboratory.

Wood and other organic materials were obtained from a core in a kettle hole bog that is located north of the Chenango Valley State Park, and 300 yds southeast of the bridge across the Chenango River at Chenango Forks, New York. Fourteen grams of wood was obtained from a sandy-clay zone at a depth of 29-31 ft.

Laboratory. To analyze 49 samples, each was shaken with a Ro-Tap for 15 min through 11 sieves at whole Ø intervals (-4 to 4Ø, 16 to .064 mm). The sediment on each sieve was weighed for cumulative weight-percent distribution. Mean, standard deviation, skewness, and kurtosis were calculated by the graphic method of Folk (1968). A pebble count of 100 grains, each larger than 4 mm (-2Ø), was made on 63 glaciofluvial samples, to determine percentages of limestone, red sandstone, crystallines, chert, quartzite, and local siltstone,

sandstone, and shale.

Definitions

Definitions of possibly unfamiliar terms used in this study are presented in Table 2.

Table 2. Definition of terms.

Ablation till--drift believed to have been deposited from a superglacial position through the melting of underlying stagnant ice.

Backwasting--the melting backward (up ice) of an ice frontal margin.

Binghamton--the term given by MacClintock and Apfel to a proposed separate glacial advance in the vicinity of Binghamton, N.Y.

Downwasting--the diminishing of glacier ice in thickness during ablation.

Erratic--a transported rock fragment different from the bedrock on which it lies, either free or as part of a sediment.

Exotic--rock fragments introduced from other regions. An exotic is an erratic of material alien to the watershed.

Facies--lithologically distinct units deposited by the same retreating ice mass.

Lateral channel--channel carved by meltwater flowing lateral to the ice.

Local--sandstone, siltstone, and shale derived from bedrock within the study area.

Lodgment till--till deposited beneath a moving glacier, characterized by compact fissile structure and stones oriented with their long axes parallel to the direction of flow.

Nunatak--an isolated hill or peak which projects through the surface of the glacier.

Olean--the term proposed by MacClintock and Apfel for a separate glacial advance, the type locality is Olean, N.Y.

Table 2. - cont.

Outflow channel--channel carved by meltwater flowing from the ice margin, usually across a bedrock divide.

Planar surface--depositional features that are flat to subhorizontal on the upper surface; generally within the confines of the valley.

Polar ice sheet--a cold ice sheet with the temperature well below the pressure melting point.

Riegel--the tread of a stairlike longitudinal profile of bedrock in a valley.

Stagnant ice zone--topography created when an ice sheet retreats by downwasting,or backwasting, such that dead ice becomes separated from the active ice front and drift is deposited onto the melting ice.

Temperate ice sheet--a warm glacier at, or near, the pressure melting point; during winter the upper surfaces are frozen.

Till shadow--thick accumulation of till on south-facing hillslopes.

Umlaufberg--an isolated bedrock hill (outlier), within the confines of the valley; surrounded by glaciofluvial sands and gravels.

Valley Heads--term given to the late Wisconsin glacial advance, at the north end of the study area.

Valley ice tongue--southerly protuberance of ice remaining in the valleys during the retreat of the ice in the uplands.

GLACIAL EROSION

Erosion is demonstrated by through valleys, outflow channels, lateral channels, riegels, striations, and depths of glacial erosion. Where bedrock is not weathered too deeply, striae record directions of movements of abraiding material transported by the ice. Striations trend from due south to S 44 W and average about S 30 W. Most of the bedrock is friable sandstone,siltstone, and shale; consequently, striae are not usually preserved.

Within the glaciated Appalachian Plateau of New York are deep valleys, (e.g., the Finger Lakes) that were carved by the advancing glacier into the then north-flowing stream valleys. These are called "through valleys" because the glacier cut a channel through from one drainage basin to another. Other, less prominent, valleys (e.g., the Chenango River valley) are also "through valleys" but have thick accumulations of drift in the headwater region. Figure 4 is a cross profile of the east tributary to the Chenango River, and is located in the vicinity of Madison. Well data in the area suggest that the valley floor is at least 210 ft, and may be as great as 290 ft below present river level. Figure 5 is a cross profile of the Chenango River valley south of the village of Greene, and illustrates the parabolic shape of the bedrock walls. It is estimated that the bedrock floor has been deepened about 410 ft. Figures 6a and 6b are cross profiles of the Genegantslet Creek near Greene, and

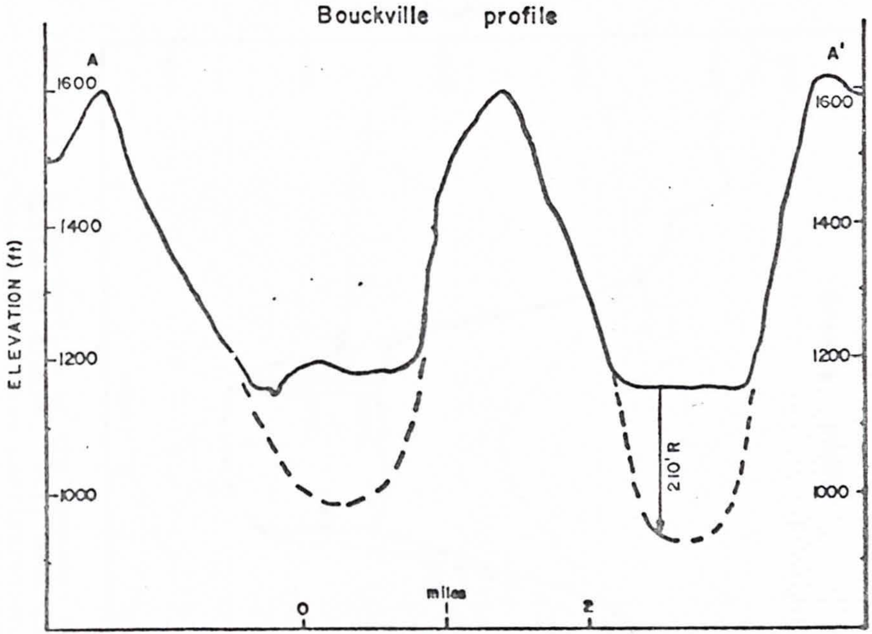


Figure 4. Cross profile of the eastern tributaries to the Chenango River valley at Bouckville. The suggested valley bottom configuration is based on well data.

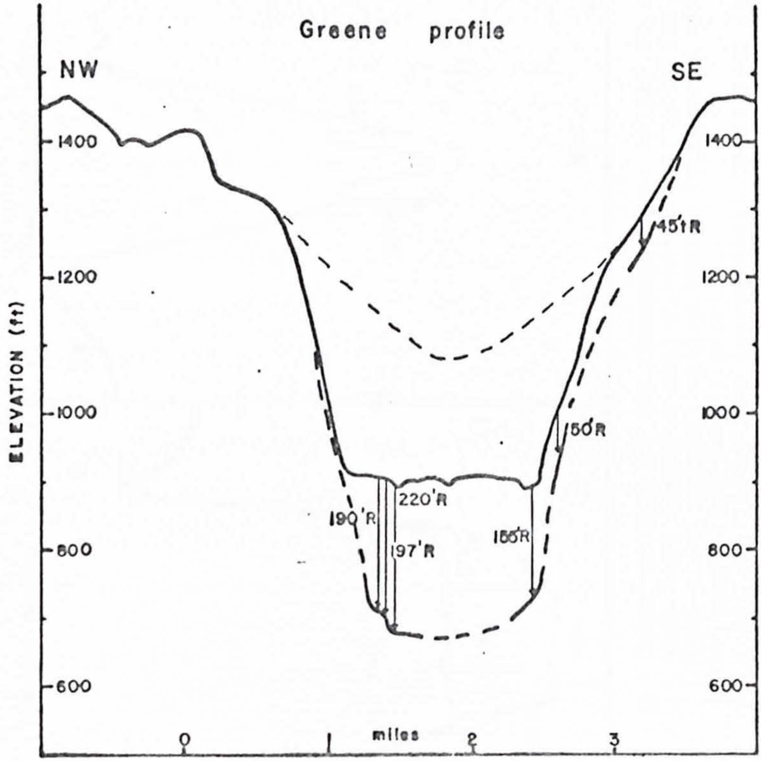


Figure 5. Cross profile of the Chenango River valley at Greene. Well data suggests the valley bottom configuration. The dashed line above the valley bottom is an estimate of the preglacial valley profile.

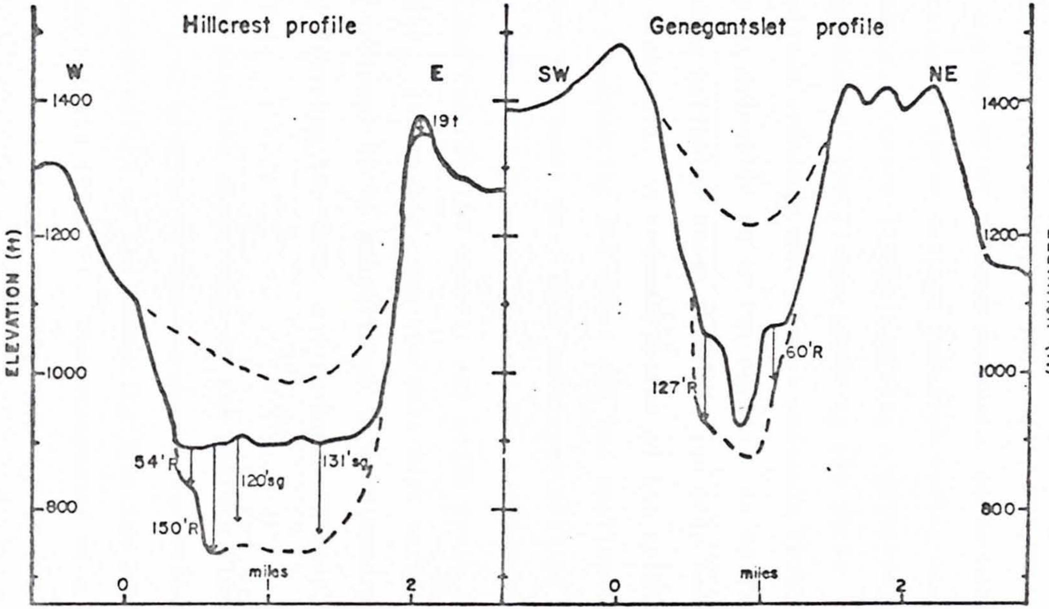


Figure 6. a. Cross profile of the Chenango River valley at Hillcrest; well data suggests valley bottom configuration. Dashed line above present valley bottom represents estimation of preglacial valley profile.

b. Cross profile of the Genegantslet Creek near Fetonia Lake.

the Chenango River valley at Hillcrest, respectively, with 340 ft and 260 ft of bedrock removed. It is not known whether the erosion of these valleys resulted during one or multiple glaciations. Coates (1966b)suggests a multicyclic theory for evolution of the Finger Lakes in New York.

Outflow channels and lateral channels result from the erosion by meltwater at an ice margin. An outflow channel forms when meltwater flows from the ice onto bedrock, and carves a channel. A reconstruction of the relationship between a retreating ice sheet and the outflow channel is presented in Figure 7a. With continued melting of the ice sheet a lake will develop between the ice and the bedrock walls, and the outflow channel may still drain the lake (Fig. 7b). Eventually, the ice will melt sufficiently to permit drainage to be established in a tributary channel thereby draining the lake, and forming a lateral channel (Fig. 7c).

The steplike appearance of the bedrock floor in the longitudinal profile of the Chenango River valley suggests the erosive effect of the advancing ice; the steps are known as riegels (Fig. 8). The steepening of a river valley into riegels and basins results either from the constriction of the bedrock walls of the valley, or from the confluence of the glacier ice at the junction of two stream valleys.

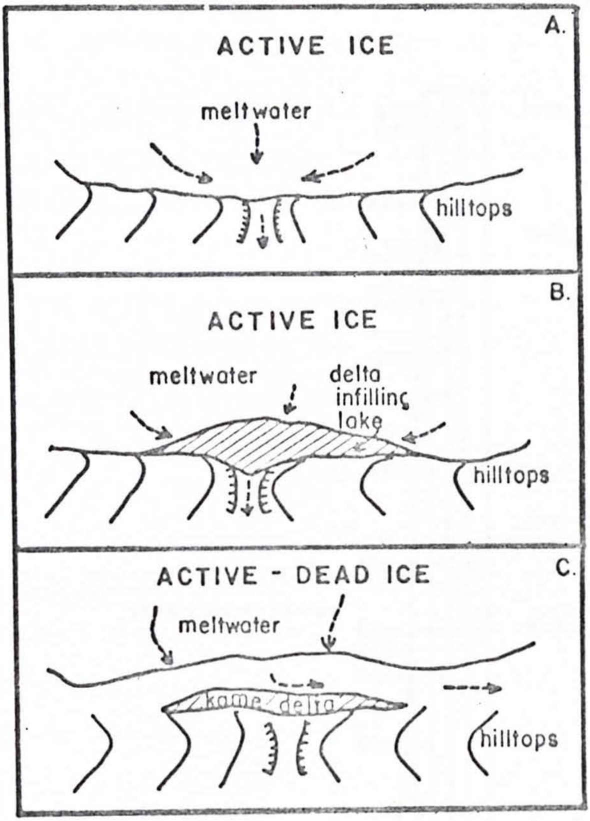


Figure 7. Plan diagram of upland ice retreat.
a. Ice against mountain, with meltwater flowing through outflor channel.
b. Shaded area represents deglaciated part with proglacial lake and delta. Meltwater flows through outflow channel.
c. Continuing ice margin retreat with lake drains; outflow channel abandoned; and incisement of lateral channel.

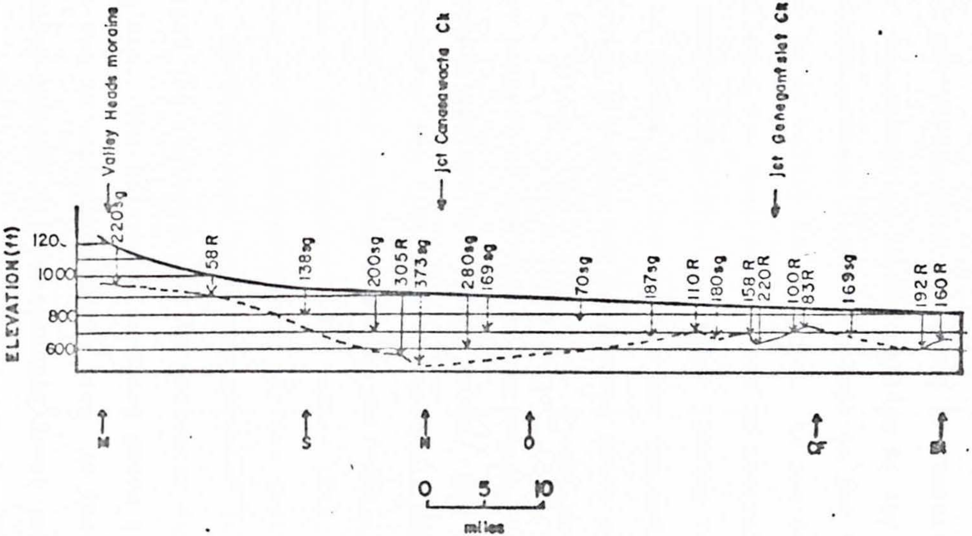


Figure 8. Longitudinal profile of the Chenango River valley. Well data suggests the bedrock configuration printed on the profile. The step like areas are carved by the advancing ice and are referred to as riegels.

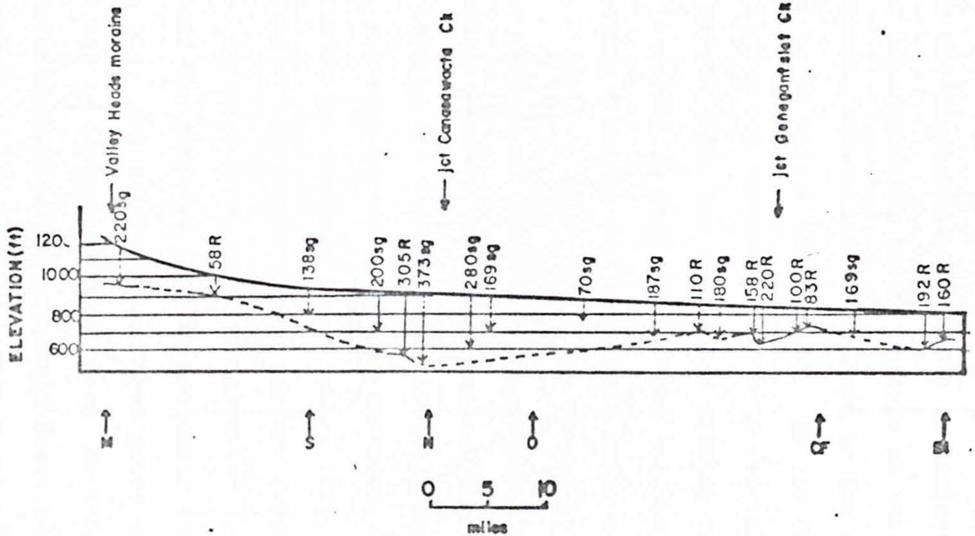


Figure 8. Longitudinal profile of the Chenango River valley. Well data suggests the bedrock configuration printed on the profile. The step like areas are carved by the advancing ice and are referred to as riegels.

RETREATAL ICE MARGINS

The Valley Ice Tongue

The retreat of the Wisconsinan ice sheet is characterized by protuberances of ice remaining in the valleys as the ice retreats in the uplands. These ice masses left in the valleys are herein referred to as valley ice tongues. An ice tongue may extend down valley a few hundreds of feet to several miles beyond the upland margin (Fig. 9). Meltwater flowing from the upland margin is forced to flow between the ice and the bedrock walls, creating a unique and diagnostic suite of deposits.

With continued retreat of the valley ice tongue, sedimentary deposits remain against the valley walls. The upper surface of these features are flat to subhorizontal, commonly areally extensive, and will be termed planar surfaces. A longitudinal profile of the Chenango River valley (Fig. 10) contains the location of all mapped planar surface features within the valley. Surfaces have been reconstructed (center diagram) to represent the surfaces used by meltwater during the retreat of the ice. The meltwater surfaces grade upward to a position that was in contact with the ice. As the margin retreats the meltwater assumes a progressively lower position for that particular margin. Thus lower surfaces are of younger age. There is a valley tongue sequence of retreat for each

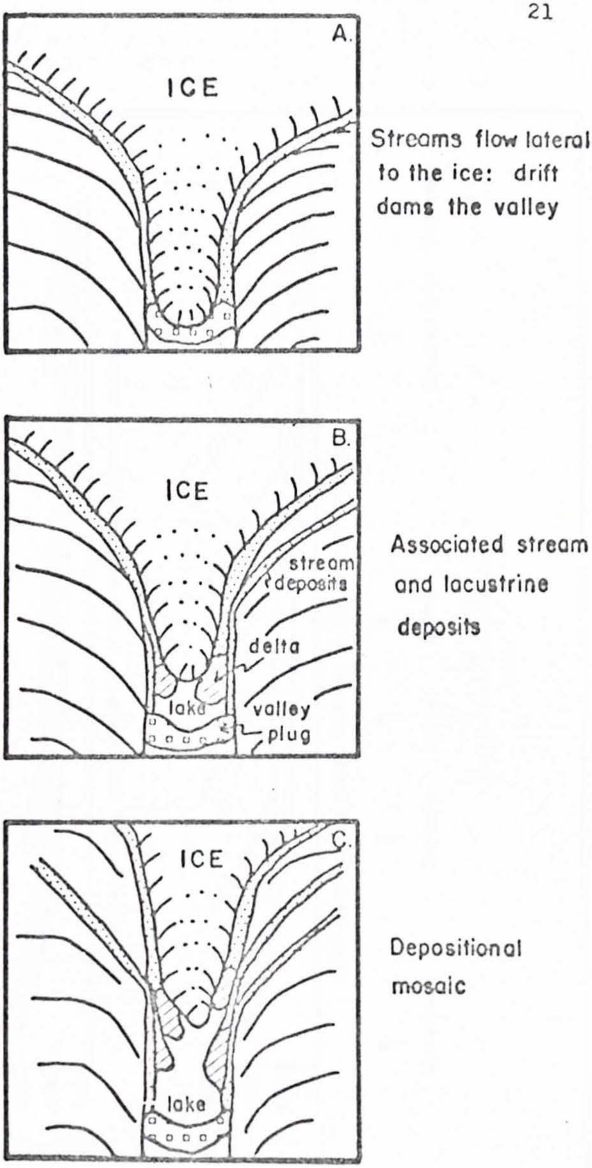


Figure 9. Diagram of a retreating ice tongue margin and the depositional mosaic associated with the retreat.

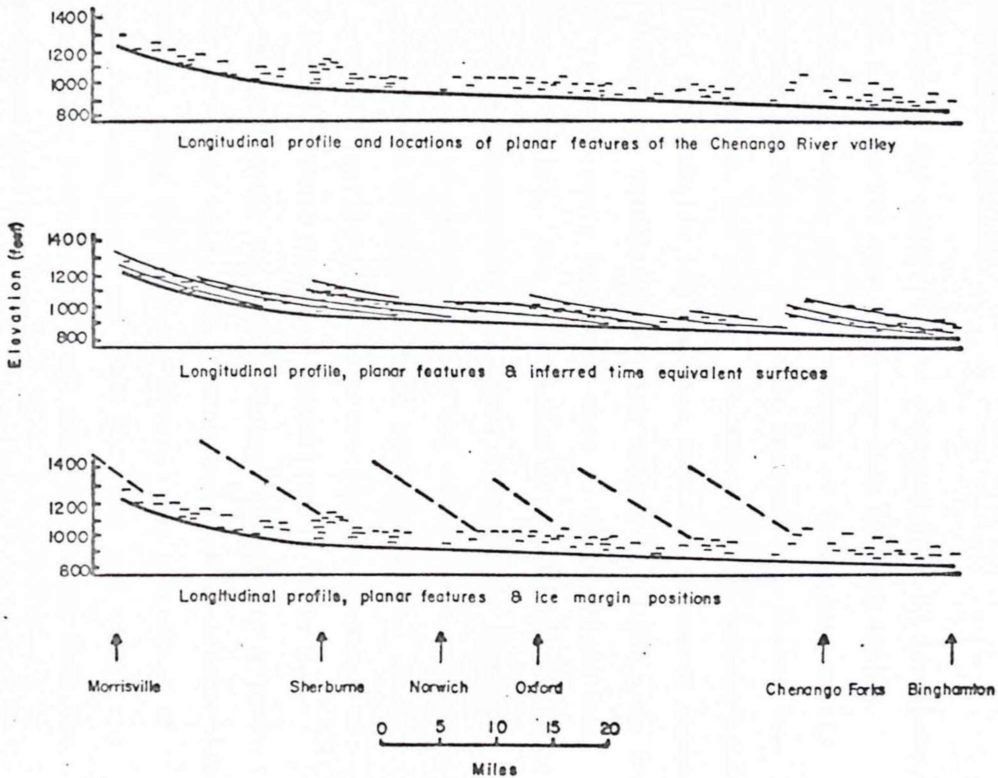


Figure 10. General location of planar surfaces, inferred times equivalent surfaces, and retreatal ice margin zone locations (shown by heavy dashed lines) with respect to the longitudinal profile of the Chenango River valley.

of the ice margin positions.

Sedimentary Parameters

Samples for analysis were obtained from 63 locations. A rock count of 100 specimens was made on each sample, specifically noting the percentages of limestone, locals (sandstone, siltstone, and shale derived from within the drainage basin), and exotics (metamorphic and igneous rocks derived from outside the drainage basin). Figure 11 summarizes the lithologic percentages and the sample locations. On the basis of rock counts the study area is divided into four lithologic facies. The differences are based on the percentages of representative rock types (limestone, locals, exotics, and red sandstone). A chi square test was conducted and significant differences were obtained at the .01 or 99% level of confidence, substantiating the presence of four facies. These data are summarized in Table 3.

The percentage of each lithology changes in a downstream direction (Fig. 12). Percentages of limestone decrease downstream along the Chenango River. The percentage of exotics decrease along the Unadilla River and there is a corresponding increase of local materials along both the Chenango and Unadilla Rivers.

A summary of Ø values from the cumulative wieght-percent distribution curves and the calculations of mean, sorting, skewness, kurtosis, and median are summarized in Appendix C.

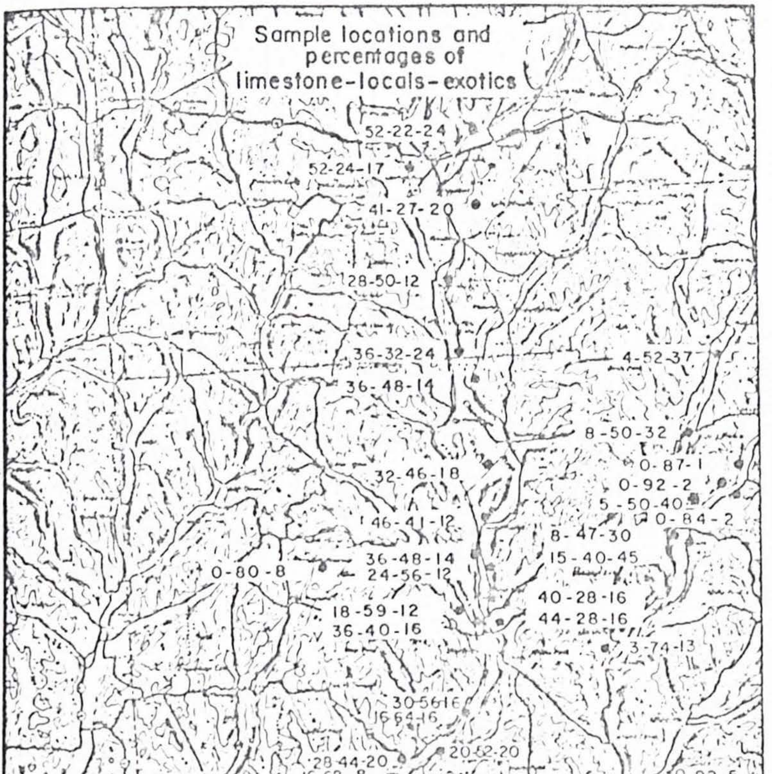


Figure 11. Sample locations and the percentages of limestone-locals-exotics (0-88-4) within the coarse fraction of samples. Sample locations by number are shown in Appendix D.

Table 3. Facies and their percentage by composition.

LOCATION	LITHOLOGY limestone	locals	exotics	red ss	no. stations
Chenango	25.88	48.47	18.23	8.82	34
Tributary	.28	85.71	4.28	9.71	7
Susquehanna	1.09	82.81	5.54	10.54	11
Unadilla	5.36	59.81	24.00	10.91	11

DATA FOR CHI SQUARED TEST

LOCATION	LITHOLOGY limestone	locals	exotics	red ss	Total (O)	
Chenango	850	1632	612	306	3400	O = observed
	494.35	2054.57	517.56	333.52		E = expected
	255.8	86.9	17.23	2.02		$(O-E)^2/E$
Tributary	2	602	28	70	700	(O)
	101.78	423.00	106.56	68.67		(E)
	97.8	74.1	57.9	.0257		$(O-E)^2/E$
Susquehanna	11	913	66	121	1100	(O)
	159.94	664.71	167.44	107.90		(E)
	39.6	92.7	75.5	1.59		$(O-E)^2/E$
Unadilla	55	660	264	121	1100	(O)
	159.94	664.71	167.44	107.90		(E)
	68.9	.0334	55.7	1.59		$(O-E)^2/E$
Total (O)	918	3807	959	618	6300	

Std. 9df = ${}_{\text{cells}}\,(O-E)^2/E$ - 926.49

Table 3. - cont.

There is a marked statistical difference between location of individual lithologies
= 16.92 (.05 level) = 21.67 (.01 level)

C (Contingency Coefficient) = $\frac{X^2}{N + X^2}$ = .358

The upper limit of a 4 x 4 = .8, therefore there is a low measure of extent of association between location and type.

Ho: The samples in the 4 different locations are the same in all classes.

Ha: The samples in different locations differ from class to class.

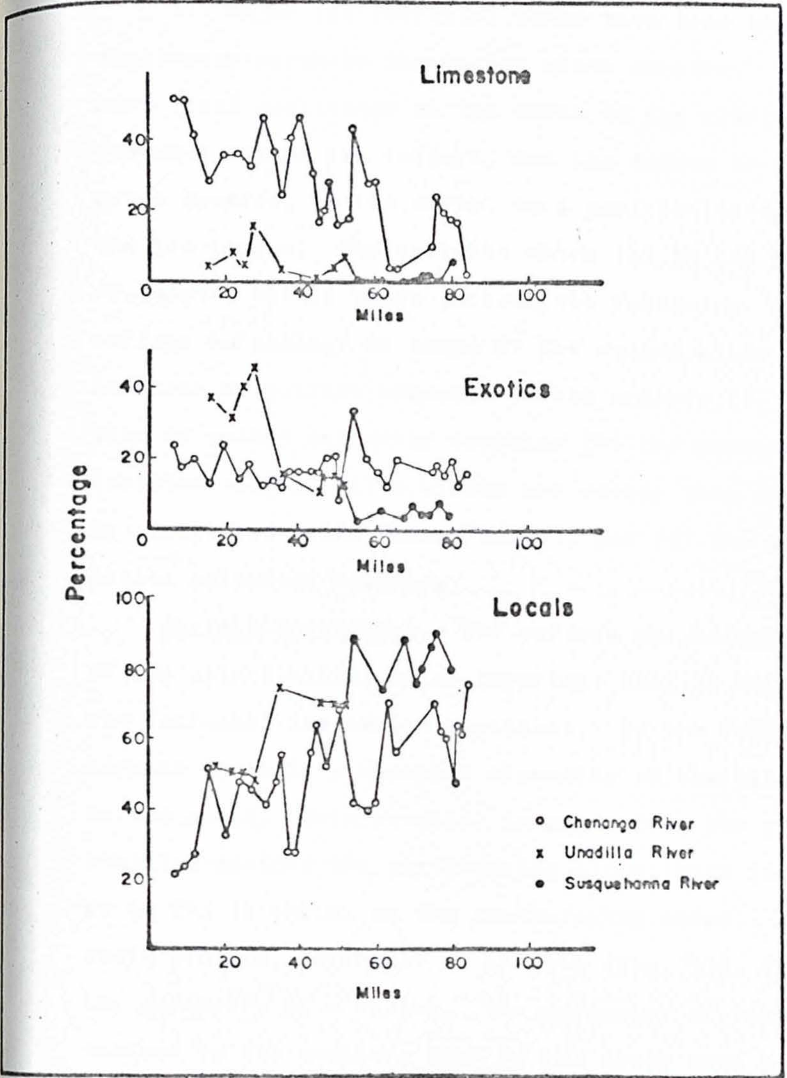


Figure 12. Changes in the percentages of limestone, exotics, and local materials, in miles downstream from the headwater.

Criteria for the Location of Margins

Six major ice retreatal zones have been located from Binghamton north to the Valley Heads moraine. These zones were first positioned on the basis of the glaciofluvial features within the valleys, and the manner in which they grade upwards, to the north, to a position in contact with the ice tongue. The criteria which led to the identification of margins within zones include the following: (1) the surface morphology or shape of the upland hills (2) the location of outflow channels in the uplands (3) the association of upland meltwater deposits (4) the presence of isolated bedrock hills within the valley that are surrounded by stratified drift (umlaufbergs), and (5) the sequence of valley meltwater deposits.

Surface Morphology. The surface morphology, or shape of the upland hills, is an important tool in delineating the retreatal ice margin positions. In the region north of Norwich there is pronounced asymmetry of the hills, steeper to the north. This results, in part, from the glacier ice abutting against the north-facing slope, with lodgment till up to 245 ft thick, on the south-facing slope. A north-south profile, northwest of Norwich (Fig. 13), illustrates the asymmetry of a valley. The asymmetry of valleys is more subdued in the southern half of the study area and many of the streams are flowing in anomolously large valleys.

Outflow Channels. Outflow channels are formed at an

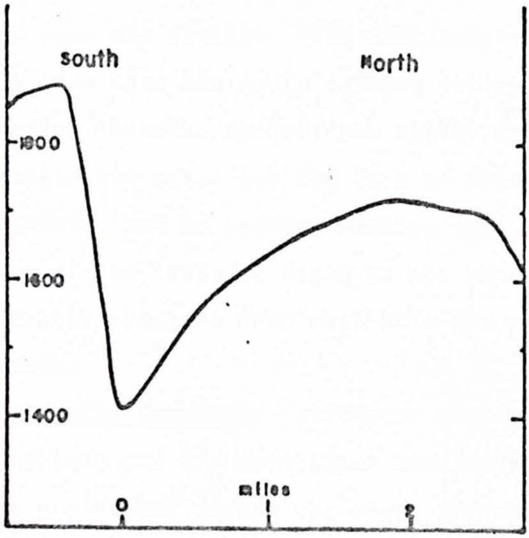


Figure 13. Cross profile of the East Branch of the Canasawacta Creek at Beaver Meadow, illustrating the asymmetry of valleys. The slope on the north side of the valley is masked with a thick deposit of till (till shadow). (See also Fig. 18).

ice margin position when meltwater flows from the ice directly onto till and/or bedrock. As glacier ice retreats the channels are used for short periods and then abandoned because of their location at or near the divide. With continued retreat, meltwater will flow into the newly exposed valley (Fig. 7), and create lateral channels against the valley walls.

Many channels are noted for the lack of associated meltwater sediments, but do contain massive till deposits. The composition of the tills at depth is not known as their presence is largely obtained from well data and very few surface exposures.

Upland Meltwater Deposits. Meltwater deposits locally occur in the uplands and are associated with outflow channels. These deposits are formed during the short periods that water flowed through an outflow channel. Most of the upland meltwater deposits are located north of Norwich.

Umlaufbergs. The presence of isolated bedrock hills within the valleys, surrounded by stratified glaciofluvial sands and gravels, and with wind gaps in their uplands, help substantiate the retreatal margin positions. The sand and gravel is not necessarily of uniform thickness or extent on all sides.

Valley Sequence. Four types of valley deposits are associated with a retreating ice margin. Downstream from ice margin these deposits are as follows. (1) Till units are preserved in the area where the valley tongue changes

into an upland margin. The till may be a flowtill, lodgment till, or ablation till. (2) Lateral to the ice tongue, at the valley wall, meltwater will flow commonly as a braided stream, depositing finely cross-stratified sediments. A temporary lake is formed if there is a dam down valley and deltas generally develop. Ice contact slopes are associated with the deposits near the valley bottom. If the dam that served as the temporary base level for the lake is removed, incision commonly occurs in both the deltaic and braided stream sediments. (3) Stagnant ice, kame moraine topography, or a kamefield may be preserved at the margin of the valley tongue. These sediments are composed of stratified sand and gravel, and kettles or other large depressions are common on the surface. The features may resemble kettled outwash. (4) Proglacial meltwater flowing within the valley, commonly as a large braided stream, deposits sand and gravel, and fills the valley to form a relatively flat valley floor. These features are frequently incised by the present river.

Components of a Margin

There are three major areas of an ice margin: (1) the unstratified drift area (2) the stratified drift area, and (3) the periglacial zone (Fig. 14). The unstratified drift area is that region covered with glacial till. The till generally exhibits no stratification and sorting is poor. The color of the till in the study area ranges from yellowish

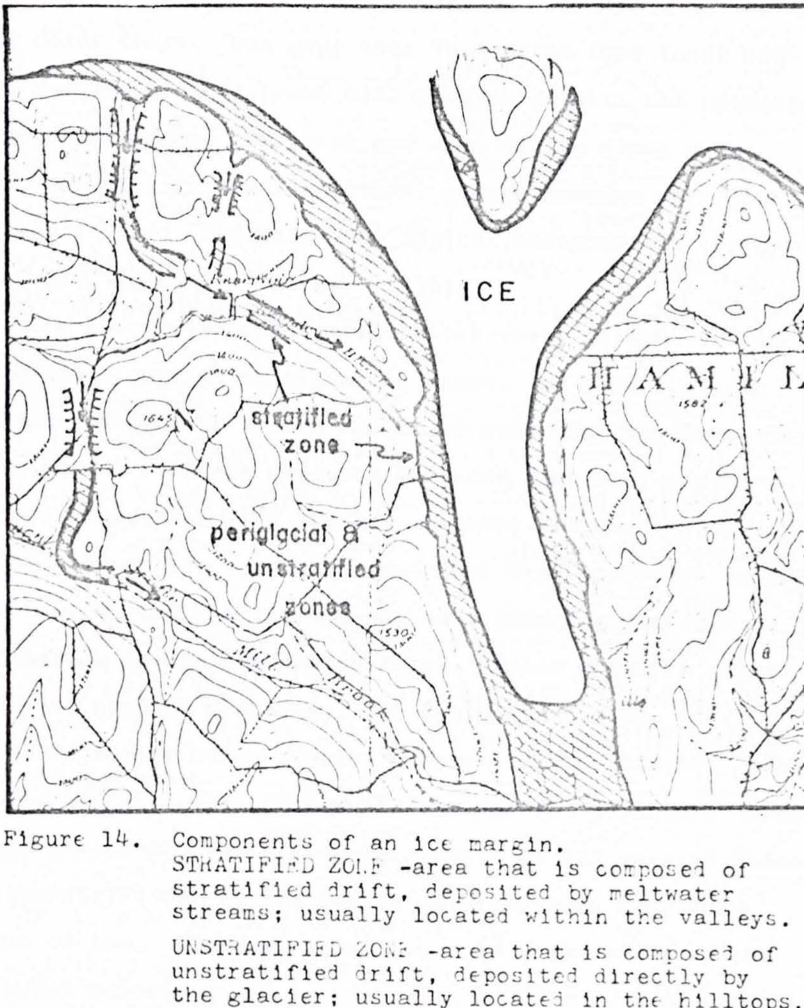


Figure 14. Components of an ice margin.
STRATIFIED ZONE -area that is composed of stratified drift, deposited by meltwater streams; usually located within the valleys.

UNSTRATIFIED ZONE -area that is composed of unstratified drift, deposited directly by the glacier; usually located in the hilltops, and on the south-facing slopes of hills.

PERIGLACIAL ZONE -area of deglaciated, exposed till or bedrock, that is subjected to a severe climatic regime prevalent under periglacial conditions.

gray (5Y7/2) to reddish brown (10R5/4) - (10R6/2), on the Rock Color Chart. The gray till is derived from local bedrock whereas the red-brown till originated with the Devonian redbeds located to the north and east of the study area. Two types of till are identified, ground moraine and flowtill, and are defined, together with typical examples and characteristics, in Table 4 (after p. 34).

The stratified drift area occurs where glacial debris is sorted according to the size, shape, and weight of its component fragments by the action of meltwater streams. The distribution of these deposits indicate that many are deposited in contact with blocks, tabular masses, or tongues of ice. These ice masses may not have been connected to the main body of the glacier and may have been remnants of downwasting ice in stagnation zones. These deposits illustrate ice contact features. The ice contact slope is formed by active sedimentation adjacent to ice blocks. As the ice melts slumping occurs in the contact position. Some of the gently sloping sedimentary units at the edge of kames and kamefields may be the result of deposition over thin wedges of ice. Slumping also occurs in these units as the ice wedge melts.

Stratified drift deposits include kames, kamefields, ice channel fillings (eskers, crevasse filling), valley train, kame terrace, kame delta, valley plug, undifferentiated stratified drift, and lacustrine units (Table 4). These

features are located near the ice tongue within the valleys during active sedimentation. The location of all of these features in the study area is presented in Plate 1.

The area of periglacial activity is in the uplands near the ice margin. Periglacial features result from climatic conditions more rigorous than the present, that are common to a recently deglaciated area. The features may have initiated development during the most recent periglacial period or persisted for an unknown length of time.

The composite model of an ice margin (Fig. 14) represents an ideal situation. Individual margins in the study area do not satisfy every criteria. Frequently only one or two of the criteria could be used for the delineation of the margin. The location of all retreatal ice margins formed during the deglaciation of the study area are summarized in Figure 15.

Table 4. Components of an ice margin.

Feature	Definition	Examples	Characteristics
UNSTRATIFIED			
ground moraine	moraine with low relief devoid of transverse linear elements; deposition beneath glacier; word selected to include ablation and lodgment tills which are generally indistinguishable	till generally covering hillslopes; photo, p. 79	unsorted, unstratified, till composed of clay, silt, sand, pebbles, cobbles and boulders; lacks topographic expression of its own; reflects bedrock topography on all but S and SW facing slopes
terminal moraine	an end moraine built along the downstream or terminal margin of a glacier lobe occupying a valley	8 mi NNW of Hamilton at Pratts Hollow	massive sand, silt, clay, and till; both in the valleys & uplands; upland sand & gravel at least 220 ft thick; many ice contact features (zone 2)
flowtill	supraglacial till that flowed from glacier onto a stratified sand and gravel deposit (Hartshorn, 1958)	1) in kame terrace just north of Sidney E wall of Unadilla R. photo, p. 80	poorly sorted, poor to unstratified lens in kame terrace (zone 2)
		2) Chenango R. valley 0.5 mi N of confluence with Tioughnioga R, W bank photo, p. 79	poorly sorted, poorly stratified lens unconformable above/ or below stratified sed (zone 1)
STRATIFIED			
Kame	moundlike hill of ice contact stratified drift of any size	1.5 to 3 mi NE of Oxford, 2 kames one on either side of valley photo, p. 80	stratified gravel, sand, silt, and clay with ice contact features (faulting, slumping) (zone 3)

Table 4. - cont.

Feature	Definition	Examples	Characteristics
kamefield	group of kames or large areas of knob and kettle (hummocky) topography	1) 1 mi E of Brisben, near Warn Lake Photo p. 81	stratified sands & gravels with ice contact features (zone 3)
		2) 1 mi NE of Afton, N.Y., near Afton Lake	stratified sands & gravels with ice contact features (zone 2)
kame terrace	moderately flat-topped terraces of stratified sands & gravels formed by meltwater streams in temporary valleys between glacier ice and valley wall	1) 1 mi E of Oxford along E wall	generally horizontally stratified sands & gravels; 1500 ft wide, 1.5 mi long; gradient 18 ft/mi; 100 ft relief; shows ice contact (zone 3)
		2) 1 mi S of Smyrna, S to Sherburne Four Corners	2000 ft wide; >5 mi long; 32 ft/mi gradient; horizontally stratified sand & gravel with ice contact features (zone 4)
		3) 1.5 mi S of N. Norwich, E valley wall, photo p. 81	600 ft wide; 1000 ft long; no exposures (zone 4)
kame delta	moderately flat-topped forms similar to kame terrace but containing foreset beds	1) 1.5 mi N of Chenango Bridge W of Kattel Cr, Photo p. 82	well stratified sands & gravels with foresets dipping 10-27°W; exhibits some ice contact features (zone 1)
		2) E of Chenango R at Greene	same as 1 (zone 2)
		3) 3.5 mi S of Afton, S of Vallonia Springs	stratified sand & gravel, perhaps more than 350 ft thick; upper surface is about 450 ft above present river level (zone 1)

Table 4. - cont.

Feature	Definition	Examples	Characteristics
kame delta-cont.		4) 2 mi N of Norwich, W side of valley	same as 1 (zone 4)
		5) 4 mi S of Norwich, W side of valley, photo p. 82, 83	same as 1 (zone 3)
ice channel filling	phrase representing eskers & crevasse fillings; term chosen because of difficulty in distinguishing en, sub, & supraglacially formed features	1) 2 mi S of Chenango Forks, in Chenango Valley State Park, between the lakes, photo, p. 84	area of high relief between two lakes (zone 1)
		2) esker 2.5 mi E of Greene, along Wheeler Ck, photo p. 83	semicontinuous ridge 1.5 mi long, of poorly stratified sand & gravel (zone 2)
valley train	long, narrow body of outwash confined to a valley, with or without ice contact drift in headward zone	1) 1 mi SW of Brisben near confluence of Chenango R and Tillotson Cr, photo p. 84,85	planar bedded, stratified sediments from braided streams infilling the valley; thickness perhaps greater than 140 ft (zone 3)
		2) from Hamilton N toward Madison, photo p. 85	horizontally stratified sand & gravel; greater than 300 ft thick (zones 5 & 6)
valley plug	massive accumulation of sand, gravel, and till that plugs the valley with NO continuation into the uplands	1) Chenango Valley State Park, near Chenango Forks, photo p.86	well-stratified sand & gravel and till; upper surface pitted as kettled outwash; ice contact features (zone 1)

Table 4. - cont.

Feature	Definition	Examples	Characteristics
valley plug-cont.		2) Genegantslet Cr, near confluence with the Chenango R.	ice-contact stratified drift (zone 2)
		3) 2 mi S of Oxford	kettled topography, composed of sand & gravel (zone 3)
		3) N of Upper Lisle, on the Otselic River	ice-contact stratified drift (zone 2)
undifferentiated stratified drift	stratified drift, undifferentiated by origin	1 mi N of Norwich	stratified drift with poor exposures & unusual morphology (zone 4)
lake bottom units	fine silts and clays that accumulated in a lake bottom position	1) 0.25 mi N of Norwich, photo p.A9	rippled silts & clays, finely stratified (zone 4)
		2) well data indicates lake bottom sediments are common in the valley bottoms	
PERIGLACIAL			
patterned ground	term given to a group of features including polygons, circles, and stripes that form distinct designs on ground	0.5 mi E of Genegantslet Cr on S. Echo Lake Rd.	polygons 8 ft in diameter with relief of 6 to 10 in (zone 2)
frost wedges	cracks & upwarping of rock resulting from thermal contraction of frozen ground and/or the expansion of water freezing within the cracks	3.5 mi E of N. Norwich & 1 mi NW of Burwell Corners, photo, p. 86	separation and upwarping of bedrock, as a wedge, along planes similar to joing planes (zone 4)

Table 4. - cont.

Feature	Definition	Example	Characteristics
rock city	isolated bedrock towers, separated from a cliff, during periglacial conditions	3.5 mi S of Hamilton	45 ft cliff with rock tower separated 5 ft from the cliff (zone 5)
tors	bedrock tower or remnant left isolated at the crest of a hill	3 mi SW of Binghamton at the crest of Ingraham Hill	solitary bedrock block or tower remaining at the crest of the hill, with no other rock exposed (zone 1)

Figure 15. Retreatal ice margin locations within the study area. For detailed examination see Plate 1.

PROBLEMS

The Binghamton Problem

MacClintock and Apfel (1944) located the southern boundary of bright, exotic rich gravel in south-central New York. This boundary was drawn to represent the terminal zone of the Binghamton ice advance, with a type locality at Binghamton, New York (Fig. 16).

A problem developed from attempts to delineate between the Binghamton materials, and those of the next older ice advance, the Olean. Table 5 contains a summary of the lithologic percentages in these drift sheets. Denny (1956) could not find the Binghamton drift in the Elmira region. He concluded there was either a complete change in the character of the materials between Binghamton and Elmira or the Binghamton materials had been buried beneath, or incorporated within, the Valley Heads moraine (the next younger ice advance). Moss and Ritter (1962), on the basis of work between the Finger Lakes and the Catskills, suggested that the Binghamton materials are a phase of the Olean advance. Coates (1963) indicated that the Binghamton materials represent a valley facies and the Olean an upland facies of the same ice sheet. Connally (1960, 1964) related the Binghamton to the Valley Heads in western New York.

My study in the Chenango River valley and vicinity supports the idea that the Binghamton drift was not deposited

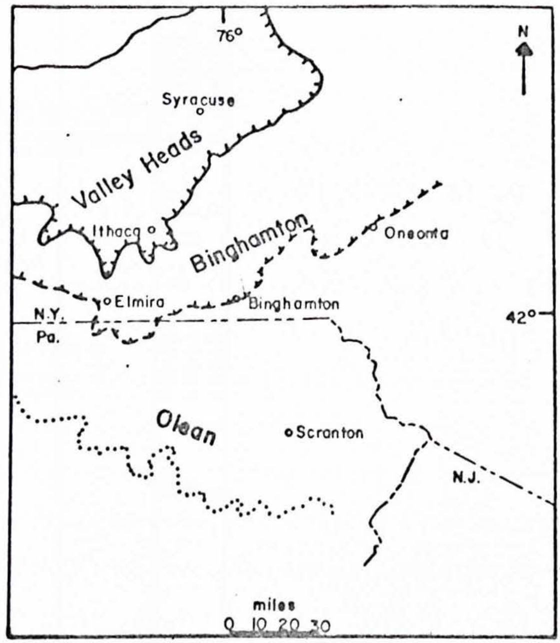


Figure 16. Wisconsin glacial boundaries, after MacClintock and Apfel (1944).

Table 5. Percentages of lithologies in the Valley Heads, Binghamton, and Olean type drifts.

	MacClintock and Apfel 1944		Moss and Ritter 1962		Present study
Valley Heads (VH)			local	66.5	22.0
			ls	24.0	52.0
			exotics	9.5	24.0
Binghamton (B)	local	67.7		58.0	48.5
	red ss	4.25		8.4	8.8
	ls	14.2		21.5	25.7
	exotics	8.56		12.1	18.2
Olean (O)	local	85.2		96.0	85.7
	red ss	2.5		4.0	9.7
	ls	6.66			0.3
	exotics	6.57			4.3
	B	23 samples	VH	1 sample	VH 1 sample
	O	15 samples	B	1 sample	B 34 samples
			O	1 sample	O 7 samples

by a separate ice advance. The Binghamton and Olean materials were deposited by the same Woodfordian ice sheet, retreating from the study area at least 16,650 ± 1800 yrs B.P. (BGS86). The premise that the Olean is an upland deposit and the Binghamton a valley deposit cannot statistically be accepted, as there are many locations with "Binghamton-type" deposits in the uplands and "Olean-type" in the valleys.

A provenance study of the sediments in the Binghamton drift suggests that the material is principally derived from the Helderberg escarpment, Adirondacks, and Canada. The material was incorporated within an advancing pre-Woodfordian ice sheet, and deposited during the retreatal stages. The sediment was probably deposited over the entire area, not only in the valleys. The large concentrations of drift presently found in the valleys (corresponding to Binghamton drift) result from (1) large amounts of pre-Woodfordian meltwater flushing the tributary valleys clean of the material, with deposition in the main valleys (2) a veneer of ablation till (the Olean till of older usage), rich in local bedrock, was deposited during the waning stages of retreat in the uplands, masking the hillside and any other drift deposits, and (3) the pre-Woodfordian gravel and debris in the valleys was not brought high enough to carry over the valley walls, by shear planes at the terminus of the Woodfordian valley tongues. The sediments were therefore confined to the major valleys.

Four facies are recognized in this study. The terms

"Olean" and "Binghamton" have not been retained for describing these deposits, thus reducing additional confusion in terminology. More local terms are used that delineate the region of occurrence. The four facies are distinguished largely on the basis of sediment composition, and location, and are referred to as the Chenango, Unadilla, Susquehanna, and Tributary facies. The characteristics of the four facies are summarized in Table 3 (p. 25). The Chenango, Unadilla, and Susquehanna facies are those primarily located along the valley bottom in the respective drainage basin. The Tributary facies is located generally in tributary valleys to the major rivers.

The Planar Surface/Terrace Problem

A problem exists about the origin of depositional features that are level and subhorizontal on the upper surface, are areally extensive, and occur generally within the confines of a valley. Five working hypotheses for the origin of planar features have been proposed. (1) The features are cut and fill type terraces, remnants from a time when the valley was filled with glaciofluvial materials. (2) The features were formed by glacial erosion at the base of the ice, carved into previously deposited materials. (3) The features are remnants of braided stream deposits, and located between an ice tongue and the valley wall. (4) The features are deltaic remnants from materials deposited in long narrow lakes between an ice

tongue and the valley wall. (5) The features are erosional and were planed smooth by the high discharges associated with a retreating ice margin.

The interpretation of the mode of formation of planar features depends upon internal structures, and may be the result of a combination of the previously mentioned hypotheses. All mechanisms may have contributed to the formation, but inclined (foreset) bedding and current cross bedding within the terraces indicate that ice margin deltas and braided streams were the major cause.

The Problem of Ice Retreat

In central New York delineating the number of glaciations recorded in the drift deposits has been a problem. Denny and Lyford (1963) indicated that the earlier Wisconsin (Olean) ice did not build a prominant moraine at the drift border, or construct any significant moraine south of the Valley Heads moraine, nor deposit prominent features of glaciofluvial materials within about 15-20 mi of the drift border. Hence, there is a problem of the manner of retreat of the Woodfordian ice sheet.

Two main thermal categories of glaciers are recognized, polar (cold), and temperate (warm). An individual glacier can be cold in one part and warm in another. A temperate glacier is one that is relatively warm; at or near, the pressure melting point, except during the winter when the

upper surfaces are frozen. Water can accumulate freely in surface lakes, crevasses, and englacial tunnels. Polar ice is cold, with the temperature well below the pressure melting point. These glaciers lack englacial and subglacial drainage except during brief melting periods.

If the terminal zone of the Woodfordian ice sheet in the study area is indeed the same as the Olean boundary in Pennsylvania, then the Woodfordian ice sheet at its maximum extent was a polar ice mass. This is evidenced by the lack of a prominent moraine at the edge of the drift border and also by the paucity of glaciofluvial deposits within 15-20 mi of that border. As a cold ice mass, water was locked in as ice and melting occurred only in the marginal positions. During recession the style of deglaciation changed because the ice sheet became more temporate, resulting in the deposition of much thicker amounts of glaciofluvial materials within the valleys near Binghamton.

The manner of retreat of an ice margin is usually a function of backwasting vs downwasting. Bloom (1971) suggested models of deglaciation for the interaction between backwasting and downwasting (Fig. 17). Backwasting occurs when melting is limited to the margin position as in a polar ice sheet. Downwasting, in contrast, occurs when climatic conditions are such that melting is in a marginal zone, perhaps within miles of the drift border, as in a more temperate glacier.

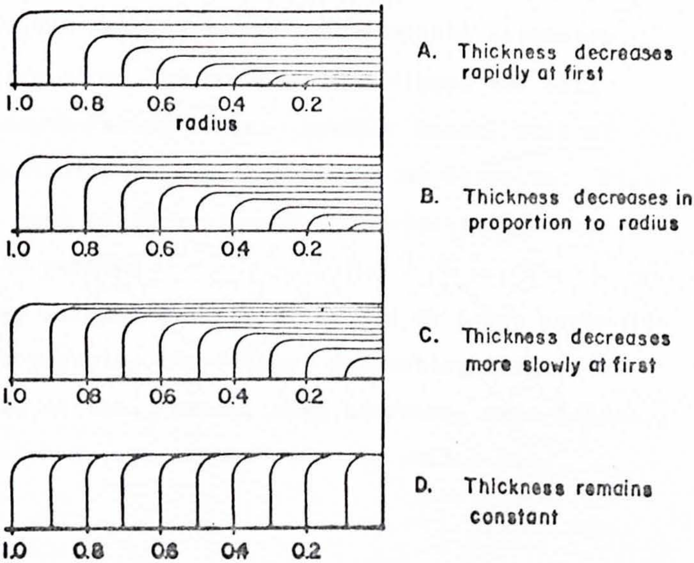


Figure 17. Profiles of an ice cap in various modes of deglaciation. Circular plan view is assumed (after Bloom, 1971).

A distinction is made between the manner of retreat of the Woodfordian ice sheet in the uplands and the valleys. The upland margins are characterized by marked asymmetry, stratified drift along the north-facing slope, and till cover on the south-facing slope. Bradley Brook, west of Hamilton, illustrates this configuration of deposits. Figure 18 suggests a mode of formation of the deposits associated with the upland margin.

The valley margins are characterized by large assumulations of drift plugging the valley, delimiting the toe of a valley tongue of ice. Kames, kame terraces, kame deltas, and valley train are associated with the valley plug.

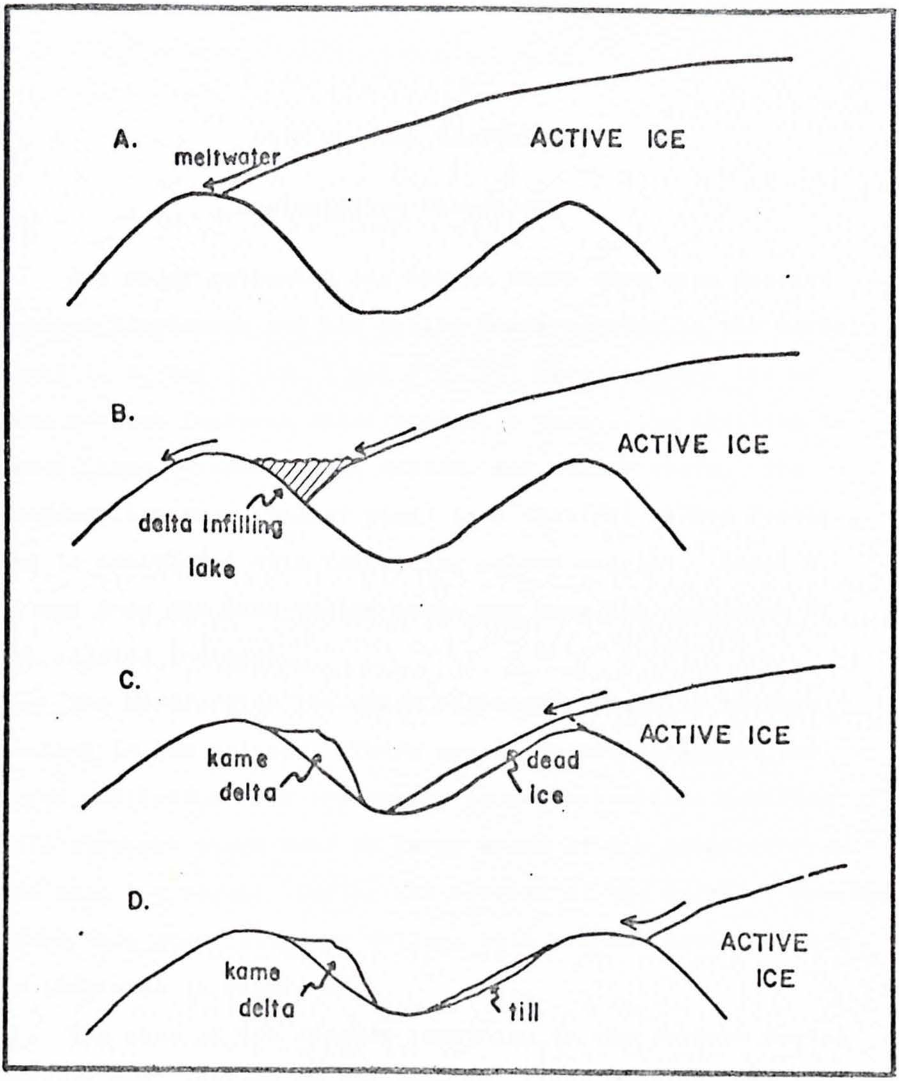


Figure 18. Diagram of upland ice retreat, with associated upland deposits. Margin locations in the uplands are governed by topography, which preceded the ice.

LATE GLACIAL HISTORY

Deglaciation Chronology

Six major retreatal ice margin zones have been located between Binghamton and the Valley Heads moraine to the north. Zones 1, 2, and 3 (Pl. 1 and Fig. 15) have stagnant ice or kame moraine features associated with them....in addition to kames, kame terraces, kame deltas, and valley train. The stagnant ice area (valley plug) is a distinct valley feature and is correlated with retreating upland margins. Zones 4, 5, and 6 do not have valley plugs but have the remainder of the related features.

The Woodfordian ice sheet retreated primarily by backwasting in the uplands. There are no massive stagnant ice areas continuous from one valley to another across a divide. This suggests there were no large areas of ice detached from the main ice sheet. During the retreat of the uplands, however, there were some tributary valleys with remnant masses of ice as indicated in Figure 18.

The size of ice tongues remaining in the valleys during retreat was governed by the rate of upland retreat, and by valley ice melting. In the areas of rapid upland ice retreat long tongues of ice could have remained in the valleys behaving in some ways similar to a valley glacier. The valley tongues retreated by both downwasting and backwasting; the downwasted areas are characterized by hummocky, knob and kettle, stagnant

ice topography, and valley plug locations.

Zone 1: Chenango River Valley

Zone 1 traces the retreat of the ice sheet from Binghamton, north in the Chenango River valley to Chenango Forks (Pl. 1). During individual margin positions, isolated bedrock hills to the north of the margin became deglaciated and formed nunataks.

Margin A. When the upland ice margin was at position A, an ice tongue remained in the main Chenango River valley extending south at least to Binghamton. The umlaufberg at Kattelville was exposed through the ice as a nunatak and meltwater carved the wind gap in the upland (marked as an outflow channel on Plate 1). Periglacial conditions existed south of the ice front, as revealed by the tor locality at the top of Ingraham Hill. Meltwater also flowed lateral to the ice tongue and as the tongue diminished in size conspicuous kames and kame terraces were deposited by the streams.

The high level overflow channels south of Port Crane facilitated drainage during the early stages of this margin. When the margin retreated slightly to the north, meltwater flowing from the eastern margin was able to flow westward along the bedrock wall. A high level sand and gravel deposit 100-150 ft above the present river level was deposited during this time. With continued melting, ice tongues remained in the valleys surrounding the umlaufberg, and braided streams

were flowing lateral to the ice.

Margin B. During this margin streams continued to flow lateral to the ice tongues. With the continued retreat of Margin B meltwater could not flow south of the umlaufberg because of an ice dam located in the vicinity of Port Crane. Meltwater was forced to flow to the north of the hill, in the Kattelville valley. The ice dam remained south of the umlaufberg through Margins C and D.

Margin C. During Margin C, ice tongues remained in the main Chenango Valley, and remnant tongues were located west of the umlaufberg, and perhaps south to Binghamton. Most of the sedimentation of the kame terraces and deltas occurred during this time. Beginning, approximately, with Margin C the retreat of the upland ice changed from dominant back-wasting to downwasting. Amounts of both meltwater and debris increased. During the waning stages of this margin the valley train was deposited. Examples of the transition from deltaic deposition to valley train can be seen in two extensively operated sand and gravel pits northwest of the umlaufberg.

Margin D. In the early stages of the development of this margin large amounts of sand and gravel were being deposited in the main valley at the junction of the Tioughnioga and Chenango Rivers. The change in the melting of the ice to a downwasting regime was responsible for the increase in amounts of water and debris. With changes in stream gradient

from about 100 ft/mi on the ice, to about 25 ft/mi in front of the ice, the streams were not able to transport the materials and the valley became choked with debris. This debris (valley plug) served to control the local base level of deposits lateral to ice within the valley to the north. Meltwater continued to flow through an outflow channel at Fenton, into Page Brook.

During the sedimentation of the valley plug, blocks of ice remained in the Chenango Valley especially at the south end of the plug. Two large blocks resulted in the formation of Lily and Chenango Lakes. An ice channel filling is preserved where the debris was deposited between the blocks. Numerous other kettles are preserved to the north, similar perhaps to pitted outwash.

Analysis of the structure of the valley plug indicates there are massive sections of horizontally stratified sands and gravels and a separate till zone. A 45 ft exposure near the bridge over the Chenango River at Chenango Forks (at B, Fig. 19) displays a poorly-sorted, well-stratified zone capped by 10 ft of bouldery till. Another exposure in the same feature, 3500 ft to the northeast (at C), exhibits the same type of till, but at an elevation 50 ft lower than the previous till unit. This is either an ablation till deposited during the melting of the last vestiges of the ice tongue while it was still in contact with the valley plug or an originally englacial stratified drift deposit--esker. A

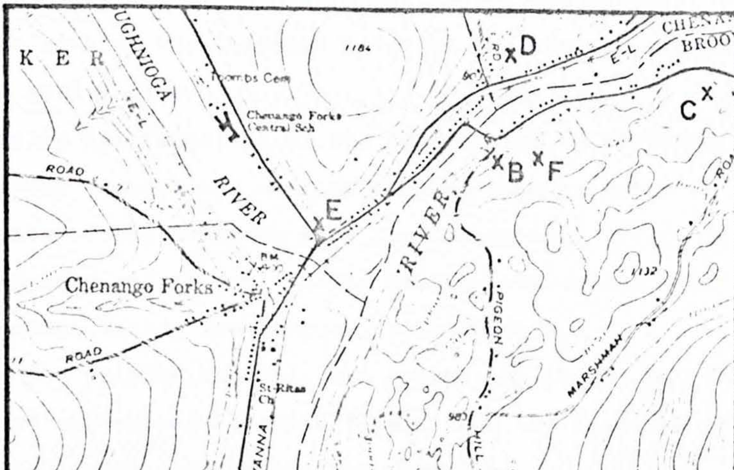


Figure 19. Topographic map of the Chenango Valley State Park and vicinity. Part of the Chenango Forks 7.5' U.S.G.S. topographic map (1:24,000).
A. ice channel filling (crevasse fill);
B. exposure of horizontally stratified drift, capped by till; C. till exposure;
D. stratified drift capped by till (flowtill); E. exposure of flowtill within stratified drift; F. kettle hole bog, location of radiocarbon date 16,650±1800B.P.

third exposure (D) of both sand and gravel and flowtill is on the west side of the Chenango River at the western extension of this valley plug.

During the formation of the features at D, meltwater was flowing through the outflow channel that is north of the confluence of the Chenango with the Tioughnioga River, into a ponded area and formed a delta between the valley wall and the Chenango Valley ice tongue. With cessation of meltwater flow in the outflow channel, and before the tongue retreated, saturated supraglacial debris flowed from the ice onto the stratified sands and gravels, as flowtill.

At E there is a 90 ft exposure with stratified gravel, sand, clay, and flowtill. Interpretation of well data suggests the thickness of the valley plug is greater than 202 ft, or 70 ft below river level. Deposition of the valley plug ceased when deglaciation of the Tioughnioga River eroded through the valley plug, and the ice dam at Port Crane broke free. Meltwater flow was then established in the present path of the Chenango River. F is the location of the kettle hole bog where a radiocarbon age date of 16,650 ± 1800 yrs was obtained.

The stratified sands and gravels in this valley plug were deposited during zone 1 (Pl.1). The decrease in stream gradient, together with the ice margin remaining at this same location for a long period of time, might explain the preponderance of stratified materials. There is the

possibility that with a change of gradient from 100 ft/mi on the ice to about 25 ft/mi in front of the ice, there would have been great turbulence which may have initiated a scouring action, and thus, perhaps, formed some of the kettles in the area.

Zone 1: Susquehanna River Valley

Retreatal zone 1 continues across the drainage divide to the east into the Susquehanna River at Harpursville. Here an ice tongue extended almost to Windsor, and kame terraces and deltas were deposited between the ice tongue and the valley wall. Another ice tongue extended at least to Howes in the Cornell Creek valley 5 mi west of Harpursville. With the retreat of this ice tongue two high level features formed: a kame delta and a kame terrace with elevations 1450 ft and 1500 ft respectively, about 500 ft above the level of the Susquehanna River. The thickness of the delta is greater than 350 ft as substantiated by exposures along the Cornell Creek valley walls. During the sedimentation of this deltaic sequence the outflow channel may have been south near Howes. During the deposition of the kame terrace the outflow was to the southwest, toward Doraville on the Susquehanna River. Sand and gravel was not deposited along the Doraville outflow channel until the meltwater reached the Susquehanna River where kame terraces formed adjacent to the Susquehanna ice tongue.

With the retreat of this margin, to approximately Bettsburg, meltwater could no longer flow out Cornell Creek. With ice tongues remaining in the main Susquehanna River valley meltwater flowed lateral to the ice and deposited the massive kame terrace sequence south of Pickerel Pond.

Zone 2: Chenango River Valley

Margin A. During the retreat of the ice margin to A, an ice tongue remained in the Chenango Valley extending almost to the valley plug at the Chenango Valley State Park. The ice margin to the east of the Chenango River retreated and exposed Curtis-Wheeler Creek valleys. Valley train materials were deposited filling the valley westward toward the valley tongue that occupied the main Chenango Valley. Meltwater then flowed as a braided stream lateral to the ice and deposited the kame terraces along the valley walls of the Chenango Valley.

Downwasting of the ice was still dominant, and as the ice thinned hilltops east of Greene were exposed as nunataks. Englacial or subglacial streams flowed south in Wheeler Creek and became confluent with the braided stream depositing the valley train. The en- or subglacial stream created the ice channel filling (esker) present in the center of the Wheeler Creek valley. The esker is 2.5 mi east of Greene along the Wheeler Creek. The feature is 1.5 mi long and 50 ft high, forming a semi-continuous ridge. At the time of the formation

of the esker a large mass of ice in the main valley diverted the flow south through Wheeler Creek. This channel served as a tributary to the then westward-flowing Wheeler Creek. With continued melting, the ice margin retreated toward B with an ice tongue remaining in the main valley. Meltwater resumed flowing in the Chenango Valley and sedimentation continued lateral to the ice tongue and formed the kame terraces and deltas at Greene.

Margin B. During the retreat from Margin A to B, two valley plugs were formed. These features resulted from the deposition of large amounts of sand and gravel onto stagnating ice tongues. Large quantities of meltwater, still being derived from the ice during downwasting, carried vast quantities of debris, and deposition occurred onto the stagnating ice. The valley plug in the Genegantslet Creek valley is 4 mi long and has a relief greater than 200 ft (see also Fig. 6, p. 16). The Otselic River valley plug formed in much the same manner, with stratified drift deposited upon stagnating ice. The size of some of the stagnant ice blocks is suggested by the large kettled areas.

During the downwasting of the upland ice many of the hilltops became exposed as nunataks. These areas were subjected to intense freeze-thaw conditions. Evidence of this periglacial action is preserved in a patterned ground location 0.5 mi east of Genegantslet Creek on South Echo Lake Road, at the junction of the Old Turk Road.

The increase in the numbers of upland undrained depressions in this zone, in comparison with zone 1, reflects small blocks of ice in these headwater positions that become isolated during downwasting. These small blocks may not have remained intact much longer than the ice sheet, but they remained active long enough to create an impermeable layer of ablation till.

Zone 2: Susquehanna River Valley

The two margins, A and B, are traced eastward into the Susquahanna River valley to the north of the outflow channels. Margin A extends east and southeast through North Afton and Afton. An ice tongue remained in the Susquehanna River valley extending approximately to Harpursville. The tongue remained in the valley during the retreat of the upland margin towards B. Sedimentation occurred onto stagnating blocks of the ice tongue north of Afton at Afton Lake. The kame terraces were deposited lateral to the ice tongue and the valley wall. At the transition between zones 2 and 3, the ice tongue was backwasting,and the valley train south of Bainbridge may have been deposited.

Zone 3: Chenango River Valley

Margin A. An ice tongue occurred in the main Chenango River valley extending from A to at least Brisben, and perhaps Greene. At this time the kamefield and kame terraces northeast (Brisben were being formed.

When the margin of the ice tongue was at Brisben the horizontally stratified valley train to the west was formed. The photographs(Appendix A, Pls. 17 and 18) represent a 40 ft vertical section. Well data suggests that sand and gravel are present for more than 90 ft below the present river level, a total thickness of at least 130 ft.

Margin B. At margin B the ice tongue extended to approximately Warn Lake and sedimentation occurred on the stagnating ice tongue, forming the hummocky topography. Where exposed, these features illustrate ice contact structures.

Margin C. During recession from B to C, the ice tongue retreated from Warn Lake to the valley plug 1.5 mi southwest of Oxford. The terminus of the valley tongue remained in this position during the retreat of the upland margin through the remainder of zone 3. Stratified drift and till began accumulating at the terminus of the tongue both lateral to and above the ice. The plug served as a dam and control of local base level for deposition of kame terraces and deltas between Oxford and Norwich. Well data suggest there is more than 68 ft of sediments below river level.

Margins D, E, F, and G. During backwasting of the margin from C to D and E, kame terraces and deltas northwest of Oxford were deposited. The kame terrace east of the Chenango River is 1.5 mi long, 1500 ft wide, has a surface gradient of about 18 ft/mi, and an average relief of 100 ft above river

level. This kame terrace formed when the ice tongue was in the main valley and meltwater was supplied from both the main valley to the north and Lyon Brook to the east. The terrace is composed of braided stream deposits, with some cross stratification, and lake clays. Ice contact slumping and collapse resulted in local dips in the clays and stream deposits. The clay units were deposited in ponded areas formed during changes in channel location and the ponding of water in depressions.

Ice remained at the Margin F location for a substantial period of time, evidenced by the meltwater molded forms in the uplands and the very clearly delineated margin position. The kame terraces along the Canasawacta Creek were deposited during the transition through Margins E, F, and G. These terraces are composed, lithologically, of the Chenango facies. The upland kame, located to the south of the western end of Margin F, is composed, however, of tributary facies materials.

Zone 3: Unadilla River Valley

Two ice retreatal margins in zone 3 can be traced across the drainage divide to the east into the Unadilla River valley. Margin C continues near the outflow channels across Shumway Hill, to Mt. Upton, and along the south wall of Butternut Creek. An ice tongue was present in the valley,and extended south to at least Sidney. Kame terraces were formed lateral to the ice tongue with meltwater flowing in both the main

valley and the tributaries Guilford Creek and Kent Brook. The kame terrace just north of Sidney, on the east valley wall has a flowtill deposit near the upper surface. The flowtill began as supraglacial debris on the ice tongue when the braided stream was flowing between the ice and the valley wall. The debris became saturated with water, derived from the melting ice surface, and began to flow onto the braided stream. The till temporarily damned the stream, but the till was subsequently mantled with 3 ft of stratified sand and gravel prior to the complete melting of the ice tongue.

Ice margin F extended east of Norwich through South New Berlin to Homesville, and to the east near the outflow channels. These outflow channels facilitated flow to the south into Butternut Creek. The ice tongue continued south to at least Latham Corners during the deposition of the kame terraces near Holmesville.

Zone 4: Chenango River Valley

During the retreat of the ice through zone 4, the valley plug south of Oxford was still damming the valley, creating a large lake and serving as the temporary base level for the streams lateral to the ice. The ice tongue, however, only extended to Norwich and the lake extended south of Norwich to the valley plug. The presence of this lake is substantiated by well data, indicating greater than 300 ft

of clay with sand and gravel. A well for the Norwich Pharmaceutical Company suggests gravel between 0 and 20 ft, and clay to bedrock at 305 ft.

Margin A. At this margin location the ice tongue extended to only Norwich, and the kame delta deposits were beginning to form. The kame terraces along the eastern valley wall may also have been deposited.

Margin B. During the retreat to Margin B, ice remained in all of the valleys around the umlaufbergs at North Norwich, and meltwater began to flow lateral to the ice. Meltwater deposited sediments primarily in the western channel lateral to the ice. At this time meltwater was flowing across the nunataks, eroding notches in the uplands. No ice existed in the uplands east of North Norwich, but periglacial conditions were intense. This is evidenced by frost wedges located 3.5 mi east of North Norwich and 1 mi northwest of Burwell Corners. At this locality are at least two well preserved wedges (Plate 3). The orientation of the wall is N 20 E along one of the sets of joint planes. The wedge is formed along N 75 W, and persists along that joint plane for at least 3 ft (Plate 4).

Margin C. During the transition between margins B and C, meltwater was still flowing in the westerr channel, lateral to the ice tongue to form the largest kame terrace in the study area. The terrace is located between Smyrna and Sherburne Four Corners. It is more than 5 mi long, 2000 ft wide, and has a surface gradient about 32 ft/mi. This gradient may be exaggerated

Plate 3. Closeup photo of the frost wedge. Orientation of this 9 ft wall is N 20 E.

Plate 4. Plan view of the frost wedge-the upper surface of the resistant layer on the top of the crack. Shovel is 2 ft long.

due to ice contact slumping. At Margin C, meltwater began to flow between the two umlaufbergs. Ice remained in the easternmost valley diverting flow from that channel. At this time meltwater flow ceased in the western channel.

Margins D and E. During the retreat of the ice through these margins, meltwater flow became established in the easternmost valley around the two umlaufbergs as the ice plug began to melt. The melting was slow and the ice served as a dam enabling deposition of lake units in zone 5.

Zone 4: Unadilla River Valley

Two margins continue across the divide into the Unadilla River valley. Margin B extends east into New Berlin and along the south valley wall of Wharton Creek. Margin E can be traced east, north of Sherburne, along Handsome Creek into South Edmeston, and up the valley wall to the east. Valley tongues were present during the sedimentation of the kame terraces and kame deltas along both the Unadilla River and Wharton Creek valleys.

Zone 5: Chenango River Valley

Margins A and B. Through the development of Margins A and B, and ice tongue remained in the main river valley to about Sherburne. Kame terraces and deltas were deposited lateral to the ice tongue. At Margin B the ice tongue may have retreated to about Earlville, permitting lake sediments

to fill in the valley north from Sherburne.

Margins C and D. During the retreat from Margin C to D the hilltop west of Hamilton became exposed through the ice as a nunatak, and meltwater carved the outflow channel to the north of the hill. Ice tongues remained in both the main Chenango River valley and the Hamilton-Madison valley. As the ice was retreating and the hilltops east of Hamilton became exposed a large mass of ice remained in the Moraine Lake valley. This ice retreated northeastward away from the tongue of ice in the Hamilton valley, and a large lake was formed between the retreating Moraine Lake ice and the Hamilton valley ice (Plate 5). The lake was filled with a large delta, the foresets of which are exposed southwest of the lake.

The uplands southwest of Hamilton were deglaciated, and subjected to intense periglacial conditions, forming a rock city 3 mi south of Hamilton along the west-facing bedrock wall. This is a rock cliff 45 ft high with at least one isolated bedrock remnant separated from the cliff. The bedrock cliff was initially carved by ice advancing down the Chenango Valley during the Woodfordian advance.

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

Plate 5. Photograph to the east toward Moraine Lake. The sloping surface between the observer and the lake is composed of foreset beds of a delta, as indicated in the pit in the left foreground. The delta formed between ice that was at Moraine Lake and ice that was present in the main valley (directly beneath the observer).

Zone 6: Chenango River Valley

The ice margin at zone 6 is the terminal moraine of the Valley Heads advance, and represents a readvance of the Lake Woodfordian ice sheet. This moraine contains a series of margin positions associated with the readvance, instead of a single stand. Associated with this margin are the massive valley train deposits infilling the Chenango Valley area, especially in the vicinity of Pratts Hollow and Madison. This valley train is traced semi-continuously to Sherburne, 19 mi south of the terminal moraine.

POST GLACIAL HISTORY

Glacial-Isostatic Rebound

A large ice mass is believed to constitute a significant stress that exceeds the strength of materials in the upper mantle. The crust, therefore, subsides beneath the ice in a basin like manner. With deglaciation flow restores the crust to nearly its preglacial level. The isostatic recovery is more intense in the areas of thickest accumulation of the ice. After, recovery may be measured by tilting of originally horizontal lake units.

An important question is the thickness of ice that is required to deform the crust of the earth. There is no precise answer to this, except that in the areas of small valley glaciers and ice caps, crustal deformation does not occur. The relief of the land does not appear to have a significant effect as isoclines constructed on warped surfaces appear to follow regional trends regardless of local topography (Flint, 1971). Many of the measurements within the study area (Table 6) cannot be used to interpret isostatic adjustment, as deposition was in small lakes. The kame delta north of Norwich, however, formed in a larger lake and suggests a rebound of approximately 1 ft/mi.

Vegetation

The first postglacial vegetation was the tundra- or

Table 6. Planar surface gradients.

Location	Gradient (ft/mi)	Remarks
Chenango River		
Binghamton to Earlville	2.8	
Earlville to Morrisville	14.0	Represents Valley Heads valley train.
Overall	5.4	
Unadilla-Susquehanna River system		
NY-Pa line to Mt. Upton	2.64	
Mt. Upton to S.Brookfiled	6.35	This is not to the headwaters.
Overall	4.0	
Kame deltas		
Norwich	0-1	Too small an area: may, however, suggest 1 ft/mi rebound.
Kame terraces		
Harpursville	10-16	These represent original depositional surfaces.
Oxford	18	
Smyrna	20	
Composite planar surfaces in zones		
Zone 1 - Chenango River	27	The similarity is due in part to rebound which began even prior to the retreat of the ice. There is insufficient data to detect rebound on a regional scale, within the study area.
Zone 2 - Unadilla River	33	
Zone 3 - Unadilla River	20	
Zone 4 - Chenango River	27	
- Unadilla River	25	
Zone 5 - Chenango River	26-30	

tundra-like grassland that migrated rapidly on poor soil. The tundra was followed by spruce, which was more stable and migrated at slower rates. In southern New England pollen studies indicate that the tundra zone persisted until 14,000 BP, and the spruce to 11,500 BP. Between 9500 and 7500 BP the spruce was gradually replaced by pine, and this was followed by hemlock and deciduous trees (Flint, 1971, p.590).

From the sampling of the bog in the study area, vegetation had begun to populate the area marginal to the ice sheet, at least 16,500 ± 1800 yr BP. An identification of the organic materials used for the radiocarbon date could not be made as there was only sufficient material for the date.

Cementation

Many of the sand and gravel deposits with high percentages of limestone, contain zones or layers with a calcareous cement. Cementation occurs only in local layers or zones (Plate 6). The calcite probably was derived from the limestone pebbles located within the deposits. When groundwater flowed through the area the calcite was dissolved and then precipitated as the cement. Cementation is not present in every deposit, and, therefore, suggests the possibility that the dissolving of calcite was influenced by the acidity of the groundwater.

An undetermined amount of limestone has been removed from

Plate 6. Photograph of a tower of cemented sand and gravel in a pit southwest of Sherburne. This is a vertically cemented zone; there are also horizontally cemented layers.

the cemented deposits. It is suggested that only the outermost rims of limestone pebbles were dissolved, thereby not changing the percentage of composition of any of the deposits.

Incision

The kame terraces and deltas deposited along the valley walls lateral to an ice tongue undergo modification by streams with changes in local base level. The terraces may also be incised immediately after deposition if meltwater is able to flow in a lower level escape route.

Much of the incision, however, began after the melting of the ice. Tributary streams to the main valley flowed onto a terrace and cut channels through the recently deposited material. Some of the notches were caused by the melting of large ice blocks incorporated within the terrace. The overlying material is slumped and resembles an eroded valley.

Alluvial fans began to develop during the postglacial period. These fans are constructed of sand and gravel with perhaps a colluvium cover.

Swamp Deposits

The swamps in the study area occur primarily in the uplands in the vicinity of ice retreatal zones 2 and 3. The upland swamps were formed during the melting and retreat of the upland ice margin. Ablation till was not eroded from these areas, and when the ice melted an impermeable layer

created a perched water table forming the upland swamps.

Swamps within the major valleys were not formed in the same manner as in the uplands. Most of the valley swamp areas were formed when large masses of the valley ice tongue melted and created collapse features.

Holocene

The swamp deposits previously described were formed immediately after the retreat of the ice. These features may or may not have formed in the Holocene, depending upon where the boundary is placed.

The alluvial fans began to develop during the immediately postglacial period. They are constructed of sand and gravel with perhaps a colluvium cover. The fans continued to develop during the Holocene.

The flood plains of present river courses that are flooded by modern streams, constitute the most recent deposits. These are indicated in Plate 2 by Qal.

CONCLUSIONS

1. A style of deglaciation has been established in south-central New York State. Backwasting of the ice sheet was dominant with downwasting occurring in zones 2 and 3. With the retreat of the upland ice, protuberances of ice were left within the valleys, referred to in the study as valley ice tongues.

2. A depositional mosaic has been established for a retreating ice tongue of a large ice sheet. Backwasting and downwasting of the ice yield sundry deposits.

3. Criteria have been established for the recognition of retreatal ice margins, noting particularly the interpretation of planar surfaces and the sequence of valley meltwater deposits.

4. Twenty-five retreatal ice margins have been grouped into six zones between Binghamton and the Valley Heads terminal moraine. This is a region that had not previously been examined for retreatal margins.

5. Four of the retreatal zones are traced eastward into the Susquehanna and Unadilla River valleys, and one zone is traced westward into the Otselic River valley.

6. The drift in the study area is all from the same late Woodfordian ice sheet except for the Valley Heads terminal moraine. Lithologically, the Valley Heads drift is the same as the material in the Chenango River valley, but

resulted from a readvance of the Woodfordian ice sheet.

7. A radiocarbon age determination of 16,650 ± 1800 BP (BGS 86) has been obtained from a kettle hole bog in the Chenango River valley near the Chenango Valley State Park. This is the basis of the Woodfordian correlation. The date suggests vegetation became established at least 16,650 yr BP.

8. The term "Binghamton" should be used only as a rock stratigraphic term, as in references to the bright valley facies located in the Chenango River valley.

9. Four drift facies have been identified and are named for the drainage basins where they are found: Chenango, Susquehanna, Unadilla, and Tributary facies.

Appendix A: Plates illustrating those
features described in
Table 4.

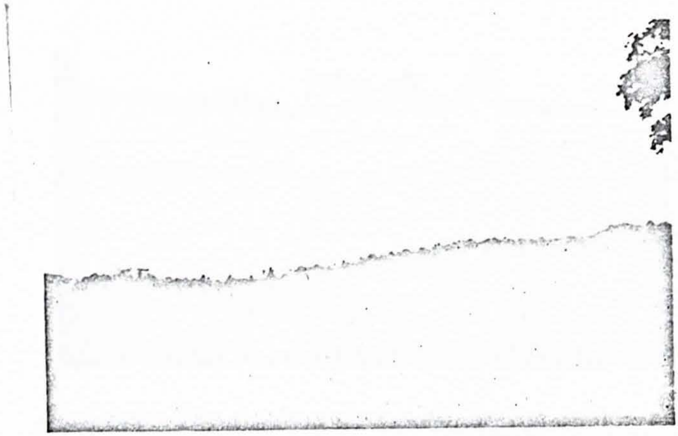


Plate 7. Ground moraine- View is to the west on the hills to the west of Norwich, illustrating typical ground moraine topography.

Plate 8. View is looking to the west at an exposure along the west side of the Chenango River valley, opposite the Chenango Valley State Park. The upper unit is till which is resting on a deltaic unit.

Plate 9. Flowtill-The view is to the north in the exposure along the east side of the Unadilla River valley just north of Sidney. The exposure is in a kame terrace of stratified sands and gravels. The flowtill is outlired, in the photo, and is capped with 5 ft of additional sediments.

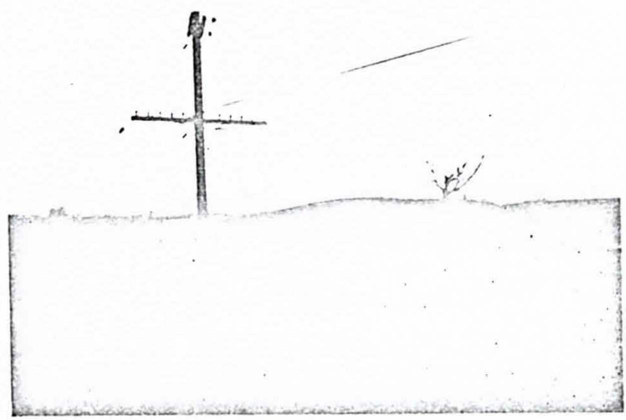


Plate 10. Kame-The view is to the east towards an isolated kame located to the northeast of Oxford.

Plate 11. Kamefield-The view is looking to the northeast from above the Chenango River valley at Brisben, over Warn Lake. The small hills surrounding the lake, and between the west valley wall and the river, are kames and collectively are referred to as a kamefield.

Plate 12. Kame terrace-The view is looking to the north at a kame terrace located 5 mi north of Norwich along the east valley wall. Notice the terracettes along the steep ice contact slopes.

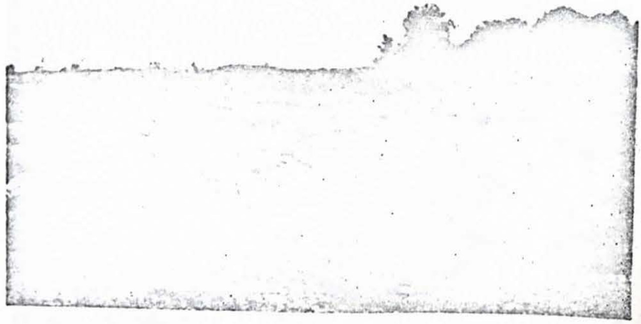


Plate 13. Kame delta-View is looking to the northwest in an extensively operated locality. The resistant cap above the foreset beds is 8 ft of horizontally stratified sands and gravels.

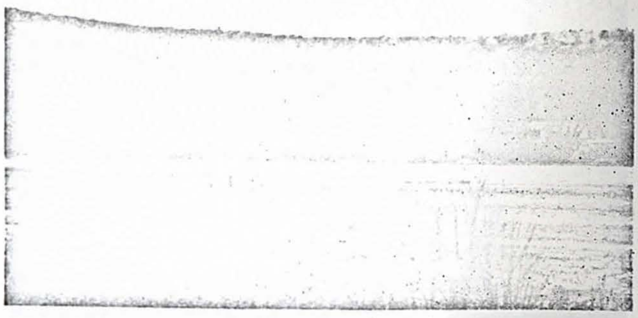


Plate 14. Kame delta-View is looking to the west toward a kame delta. Note the planar nature of the upper surface. The foresets are dipping to the left (south). The exposure is located 4 mi south of Norwich along the west valley wall of the Chenango River.

Plate 15. Kame delta-This is a closer photograph of the same delta in the previous photo.

Plate 16. Ice channel filling (esker)-The view is looking to the south along the crest of the esker that is located 3 mi east of Greene in the Wheeler Creek valley. The road follows the crest of the esker for about a mile.

Plate 17. Ice channel filling (crevasse filling)- The view is looking to the northeast above the Chenango Valley State Park, specifically over the golf course. The two lakes, Lily and Chenengo, were large blocks of ice and the land between the lakes formed when sediments were deposited between the ice.

Plate 18. Valley train-The view is to the northwest over Brisben. The broad flat area is the valley train; the exposure at the arrow is 0.5 mi long and 40 ft high, and is horizontally stratified sands and gravels.

Plate 19. Valley train-This is a closer view of the same valley train in the previous photograph. These are horizontally stratified sands and gravels.

Plate 20. Valley train-The view is looking to the east over Leland Pond towards Madison (5 mi north of Hamilton). The valley train, the flat valley bottom, was mostly deposited during the Valley Heads readvance.

Plate 21. Valley plug-The view is looking to the north along the Chenango River valley near Port Crane. The valley plug is located within the valley walls, and is indicated by the arrows. Note the two lakes, Lily and Chenango, and the ice channel filling (crevasse filling).

Plate 22. Frost wedge-View is to the east toward the bedrock wall in a shale quarry east of Norwich. Note the two frost wedge features, with the one to the right better developed. Closeup photos of these are in the text(p. 65).

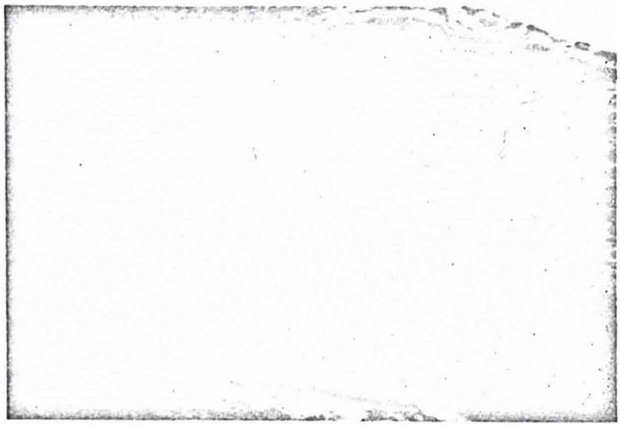
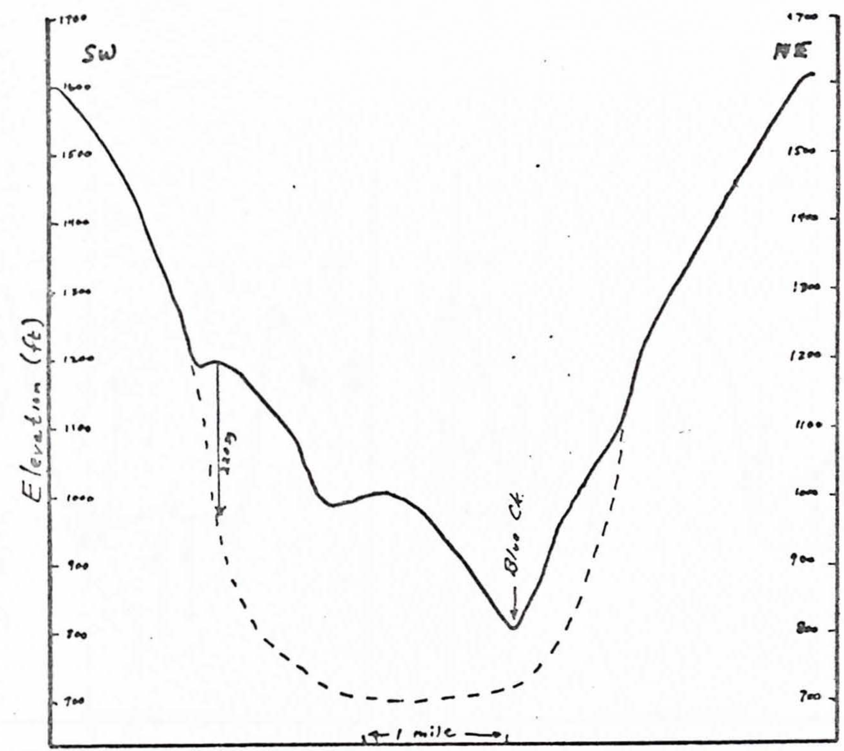
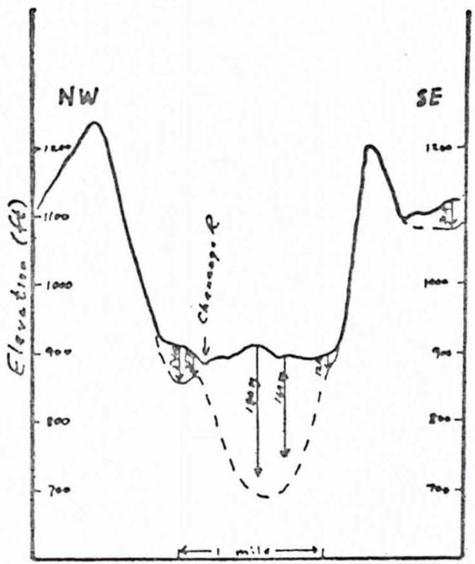


Plate 23. Lake bottom sediments-The view is to the east in a sand pit located just to the north of North Norwich. Note the ripple drift laminations, and what appears to represent rapid changes in the current directions, at the arrow.

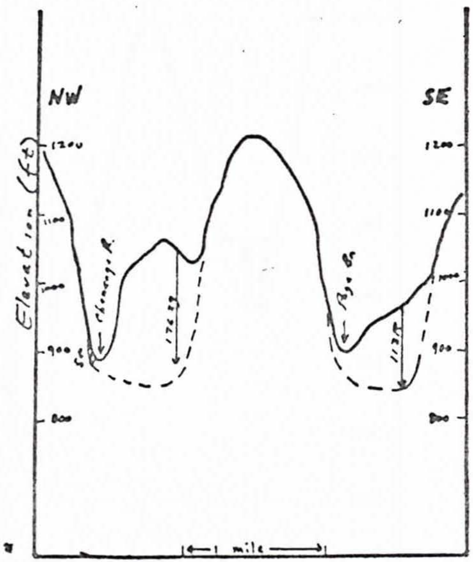
Appendix B: Supplementary cross profiles of valleys within the study area.



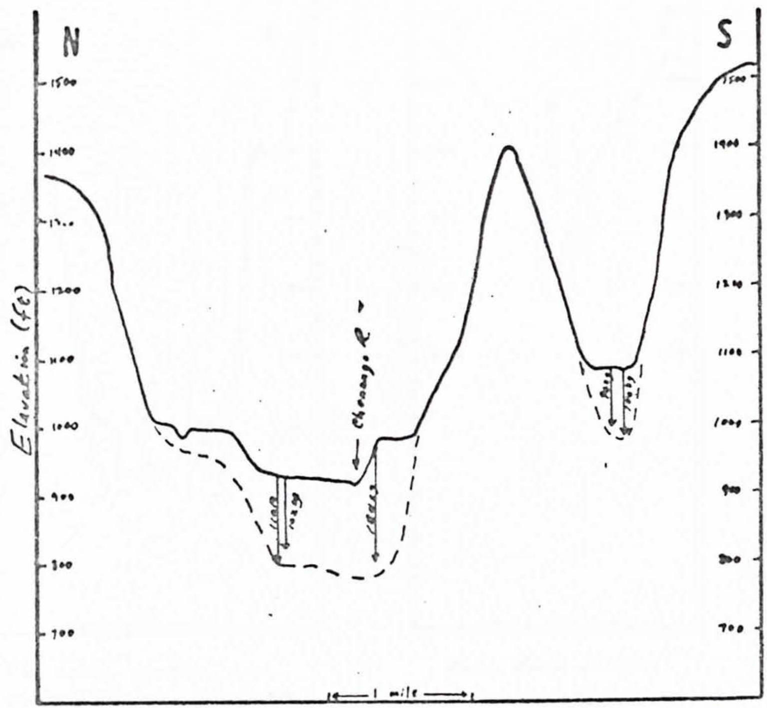
Blue Creek profile of Valley Heads Moraine, in Stockbridge Valley; 1 mi North of Pratts Hollow



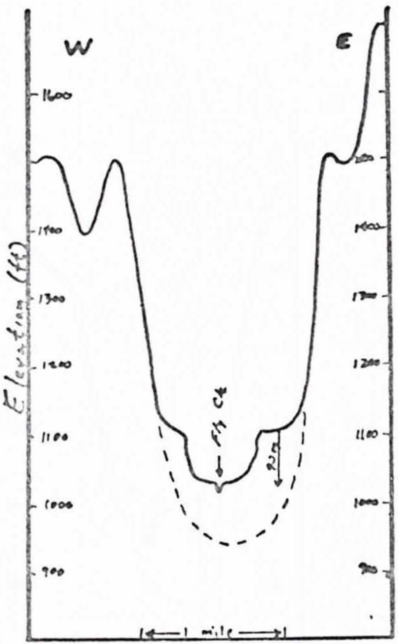
2 mi North of Port Crane



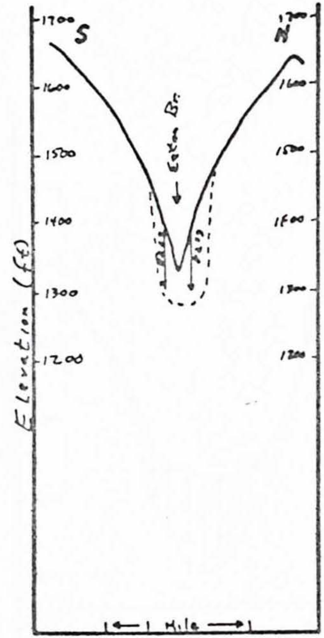
Chenango Forks - Page Brook



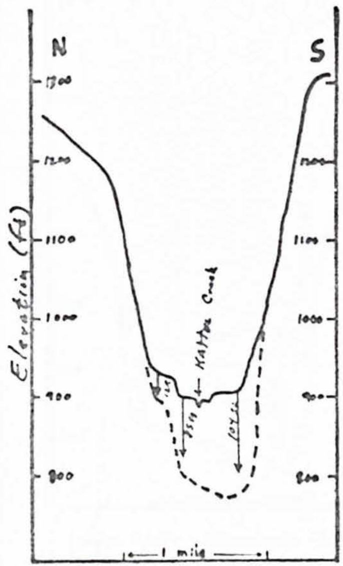
2 mi East of Greene across Chenango River valley and Wheeler Creek valley



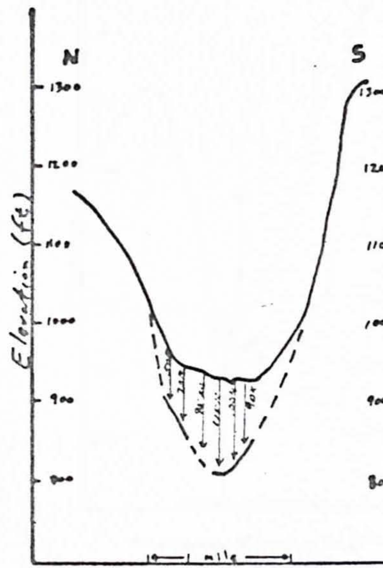
Fly Creek profile, 1 mi south of Sherburne Four Corners



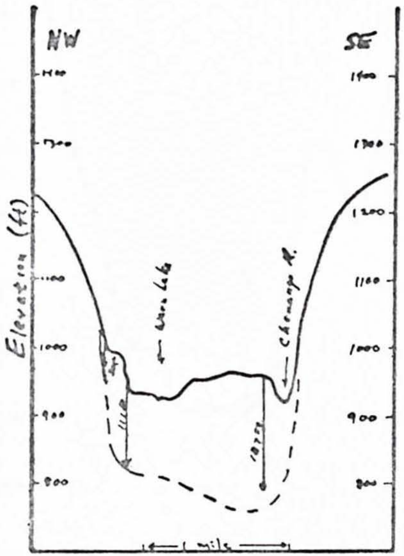
Eaton Brook profile, 2.5 mi West of Eaton



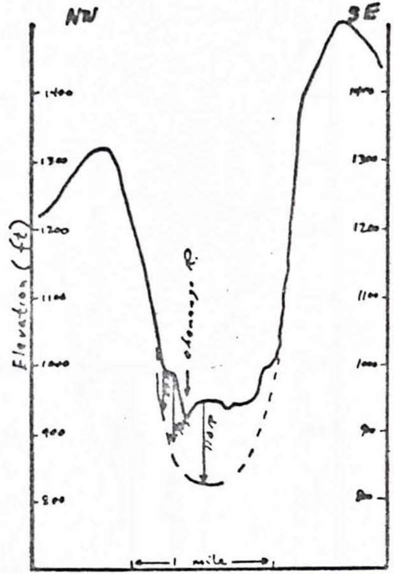
0.5 mi W of Kattelville



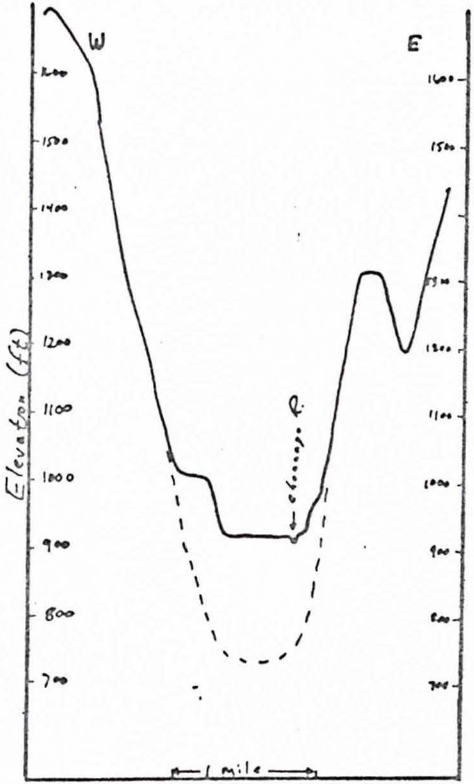
0.5 mi East of Kattelville



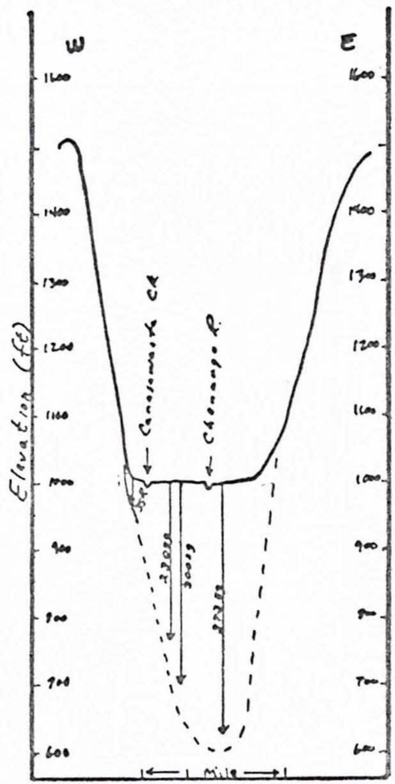
Warn Lake - Chenango River profile, 2 mi NE of Brisben



Chenango River profile at Brisben



Chenango River valley 1.5 mi South of North Norwich

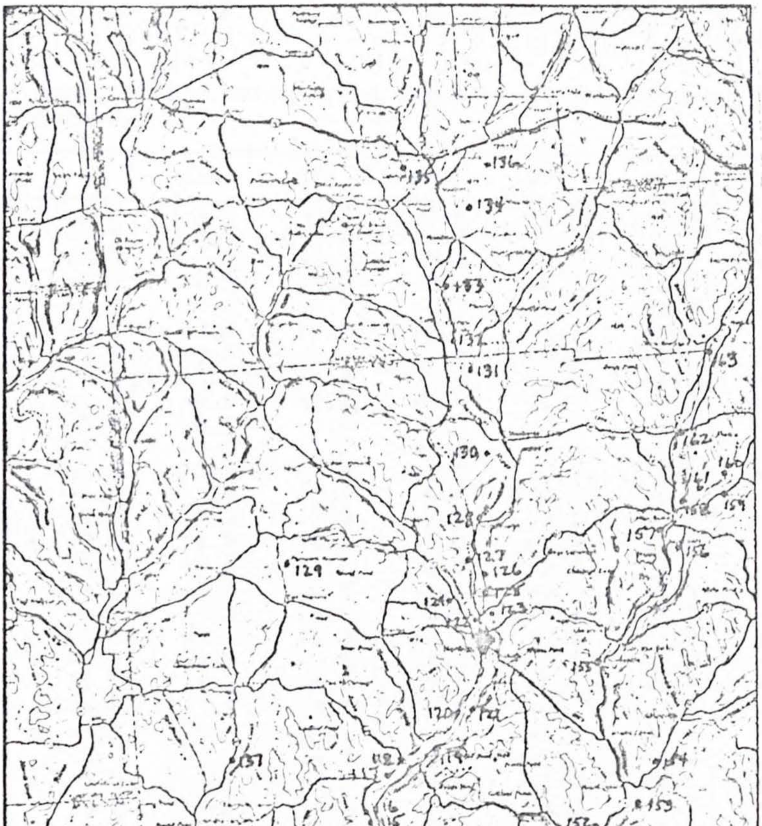


Chenango River valley at Norwich

Appendix C: - Map of sample locations and station numbers.

- Summary of Ø values.

- Summary of sedimentary parameters.



Map of sample locations and station numbers.

Summary of Ø values from cumulative percent frequency curves.

Sample #	Ø5	Ø16	Ø25	Ø50	Ø75	Ø84	Ø95
101	-5.5	-5.0	-4.5	-3.4	-2.2	-1.2	+0.8
102	-6.5	-6.1	-5.7	-4.8	-4.0	-2.0	+2.1
103	-6.5	-6.1	-5.7	-4.9	-4.1	-2.2	+2.2
104	-5.0	-4.3	-3.7	-2.7	-0.8	-0.3	-0.5
104	-0.9	+0.2	+0.7	+1.3	+1.6	+2.2	+3.1
104	-1.1	+0.2	+0.8	+1.3	+1.7	+2.2	+3.1
104	-5.9	-5.3	-5.0	-4.0	-0.2	+1.2	+2.8
106	-6.2	-5.8	-5.3	-4.2	-3.0	-1.0	+2.0
107	-4.8	-4.0	-1.2	+0.8	+1.5	+1.8	+2.8
107	-5.0	-4.5	-4.0	-3.2	-2.0	-1.0	+0.6
107	-3.0	+0.8	+1.2	+1.8	+2.5	+2.8	+3.1
107	-5.2	-4.9	-4.3	-3.3	-1.7	-0.6	+1.4
108	-6.0	-5.6	-5.1	-4.1	-2.3	-1.3	+1.2
108	-4.9	-4.1	-3.4	-1.7	+0.2	+0.8	+2.0
108	-3.1	-1.4	-0.5	-0.8	+1.5	+1.8	+3.0
109	-5.7	-4.8	-3.9	-1.9	+0.3	+1.0	+2.5
109	-4.2	-3.4	-2.8	-1.0	+0.5	+1.3	+2.4
110	-6.1	-5.7	-5.2	-4.2	-3.1	-2.7	+2.2
110	+0.8	+1.2	+1.3	+1.7	+2.2	+2.4	+3.1
111	-5.5	-4.7	-3.9	-2.3	0.0	+1.0	+3.9
113	-6.2	-5.1	-4.0	-1.0	+0.7	+1.5	+2.5
116	-4.5	-3.6	-3.0	-0.2	+1.1	+1.4	+2.9
117	-5.3	-3.9	-3.1	-0.2	+1.2	+1.6	+2.3
118	-5.8	-5.2	-4.7	-3.6	-1.1	-0.2	+1.3
119	-6.0	-5.7	-5.5	-4.6	-2.2	+0.1	+2.5
120	-4.7	-3.9	-3.5	-2.7	-1.7	-1.0	-0.1
121	-5.7	-5.0	-4.4	-2.2	0.0	+1.1	+3.2
122	-5.0	-3.8	-2.7	-0.5	+1.5	+2.3	+4.2
123	-4.2	-2.2	-1.5	+0.1	+1.0	+1.2	+1.4
125	-2.9	-1.8	-1.0	+0.7	+1.7	+2.3	+5.2
126	-4.8	-4.0	-3.4	-1.8	0.0	+0.8	+1.5
127	-5.9	-5.2	-4.8	-3.3	-1.3	-0.6	+0.7
128	-1.9	+1.1	+1.3	+1.9	+2.5	+2.8	+3.6
138	-6.1	-5.6	-5.4	-4.8	-3.8	-3.1	-1.6
139	-5.3	-4.9	-4.5	-3.0	-0.3	+3.0	+4.1
140	+1.1	+1.5	+1.6	+2.1	+2.6	+3.1	+4.4
140	-5.6	-5.1	-4.5	-2.3	-0.6	-0.1	+1.0
141	-5.2	-3.7	-2.9	-1.8	-0.3	+0.1	+1.3
141	-0.1	+1.5	+1.7	+2.1	+2.8	+3.1	+4.2
143	-6.2	-5.6	-5.0	-3.8	-1.4	-0.9	-0.2
145	-2.0	-0.4	-0.1	+1.1	+1.9	+2.5	+3.9
145	-5.3	-4.8	-4.1	-3.1	-1.3	-0.2	+3.0
147	-5.9	-5.4	-4.9	-2.4	+0.1	+1.7	+4.2
148	-5.9	-5.3	-4.8	-3.0	-0.5	+1.1	+3.8
149	+1.1	+1.4	+1.6	+3.1	+4.2	+4.5	+4.8
149	-4.0	-3.5	-3.1	-2.1	-1.0	-1.4	+0.5
150	-4.0	-3.7	-3.4	-2.8	-1.8	-1.0	-0.1
151	-4.5	-1.2	-0.5	0.0	+1.1	+1.6	+3.1
164	-5.5	-5.2	-4.6	-3.8	-2.3	-1.3	+3.2

Summary of sedimentary parameters.

Inclusive graphic standard deviation (σ) =

$$\frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

Inclusive graphic skewness (Sk_I) =

$$\frac{\phi 16 + \phi 84 - 2\phi 50}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - 2\phi 50}{2(\phi 95 - \phi 5)}$$

Kurtosis (K_G) =

$$\frac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25)}$$

Median (Md) = $\phi 50$

Graphic mean (M_Z) =

$$\frac{\phi 16 + \phi 50 + \phi 84}{3}$$

Sample	σ	Sk_I	K_G	Md	M_Z
101	1.91	0.244	1.12	-3.4	-3.20
102	3.32	.482	2.07	+4.8	-4.30
103	2.30	.508	2.23	-4.9	-4.40
104	1.84	.183	0.78	-2.7	-2.43
104	1.11	.591	1.82	+1.3	+1.23
104	1.14	.121	0.19	+1.3	+1.23
104	2.94	.581	0.74	-4.0	-2.70
106	2.44	.417	1.46	-4.2	-3.66
107	2.60	.091	1.15	+0.8	-0.47
107	1.72	.308	1.15	-3.2	-2.90
107	1.42	.287	1.92	+1.8	+1.80
107	2.07	.339	1.04	-3.3	-2.93
108	2.17	.387	1.05	-4.1	-3.66
108	2.26	.046	0.79	-1.7	-2.66
108	1.73	.327	1.25	+0.8	+0.40
109	2.69	.037	0.78	-1.9	-1.90
109	2.17	.026	1.11	-1.0	-1.03
110	2.01	.271	1.62	-4.2	-4.20
110	0.65	.191	0.12	+1.7	+1.76
111	2.85	.242	0.99	-2.3	-2.00
113	2.97	.024	0.76	-1.0	-1.53
116	2.37	.261	0.30	-0.2	-0.80
117	2.52	-0.343	0.95	-0.2	-0.83
118	2.33	0.370	0.81	-3.6	-3.00

Summary- cont.

Sample	σ	Sk_I	K_G	Md	M_z
119	2.74	0.645	1.06	-4.6	-3.40
120	1.39	.151	1.05	-2.7	-2.53
121	2.85	.147	0.83	-2.2	-2.03
122	2.92	.053	0.90	-0.5	-0.66
123	1.70	-0.092	0.92	+0.1	-0.30
125	2.24	0.165	1.23	+0.7	+0.73
126	2.15	.065	0.76	-1.8	-1.66
127	2.15	.193	0.78	-3.3	-3.03
128	1.25	.529	1.88	+1.9	+1.93
138	1.45	.391	1.15	-4.8	-4.50
139	3.40	.514	2.55	-3.0	-1.63
140	0.90	.322	1.35	+2.1	+2.23
140	2.25	.060	0.70	-2.3	-2.50
141	2.15	.023	1.04	-1.8	-1.80
141	1.05	.113	0.16	+2.1	+2.23
143	2.08	.217	0.69	-3.8	-3.43
145	1.61	-0.008	1.21	+1.1	+1.06
145	2.41	0.365	1.23	-3.1	-2.70
147	3.30	.230	0.83	-2.4	-2.03
148	3.07	.341	0.91	-3.0	-2.40
149	1.31	.008	0.58	+3.1	+3.00
149	1.20	.245	0.88	-2.1	-2.33
150	1.26	.358	1.01	-2.8	-2.50
151	1.85	-0.021	1.97	0.0	+0.13
164	2.29	.445	1.56	-3.8	-3.43

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EXPLANATION

Holocene

Qs — Swamp deposit

Qal — Alluvium
Gravel, sand, silt and clay; found chiefly in areas flooded by modern streams; Alluvial fans.

QUATERNARY — Pleistocene — Wisconsinan — Woodfordian

GLACIOFLUVIAL AND GLACIOLACUSTRINE DEPOSITS

Ice margin positions indicated by numbers; 1 is oldest, 6 is youngest.

		1	2	3	4	5	6
Kame or kamefield	Qk			Qk	Qk		
Ice-channel filling	Qic				Qic		
Kame terrace	Qkt			Qkt	Qkt		
Valley train	Qv		Qv	Qv			

Kame or kamefield
Knobby hills of moderate relief and irregular lower knobby masses of sand and gravel.

Ice-channel filling
Narrow ridges of sand and gravel deposited as eskers or crevasse filling.

Kame terrace
Originally flat topped terrace forms composed of sand and gravel.

Valley train
Generally flat valley bottom composed of sand and gravel.

chiefly
ms;

gravel.

PLATE I

RETREATAL ICE MARGIN MAP
OF THE
CHENANGO RIVER VALLEY, NEW YORK

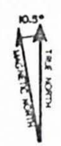
AND PORTIONS OF THE
SUSQUEHANNA AND UNADILLA RIVER VALLEYS, N.Y.

By

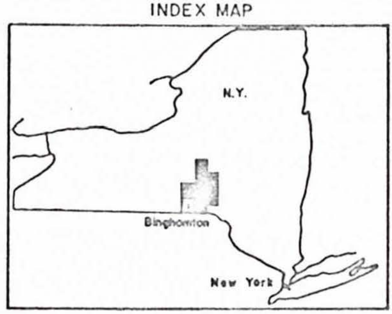
Donald H. Cadwell

0 1 2

scale in miles



INDEX MAP



Location of study area

PLATE I

RETREATAL ICE MARGIN MAP
OF THE
CHENANGO RIVER VALLEY, NEW YORK

AND PORTIONS OF THE
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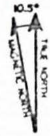

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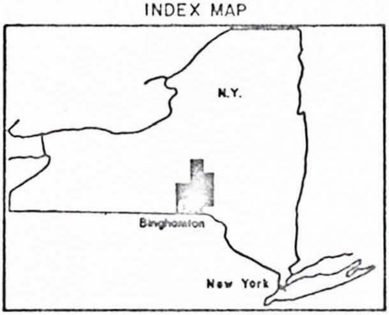
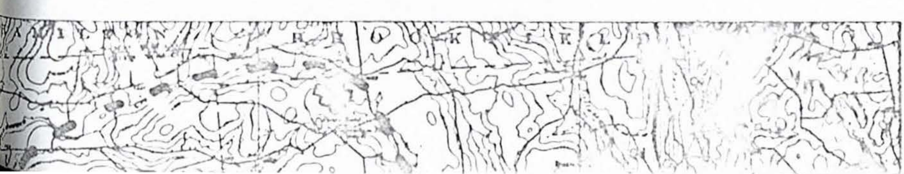


Location of study area



QUATERNARY

Pleistocene

Wisconsinan

Woodfordian

Kame terrace

Originally flat topped terrace forms composed of sand and gravel.

Qv Qv

Valley train

Generally flat valley bottom composed of sand and gravel.

Qkd Qkd Qkd

Kame delta

Flat topped hills with deltaic structures built into open lakes composed of sand and gravel.

Qvp Qvp

Valley plug

Stratified sand and gravel and till choking the river valley.

Ql — Lake deposits
Bottom sand, silt and clay of temporary glacial lakes.

Undifferentiated stratified drift
Sand and gravel deposits not distinct enough to separate by origin.

Qt — Till; Qtt, thick till.

DEVONIAN

D — Devonian bedrock
Exposure of sandstone, siltstone or shale.

Contact
Dashed where approximately located.

Outflow channel
Gap through which glacial meltwater flowed.

...d and gravel.

..., gravel.

...n lakes composed of sand and gravel.

... valley.

...a
... sand, silt and clay of temporary
... lakes.

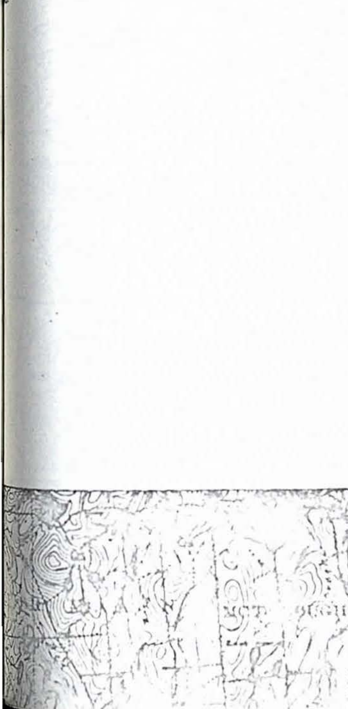
...ed stratified drift
...nd gravel deposits not distinct
... to separate by origin.

...ck till.

...edrock
...re of sandstone, siltstone or shale.

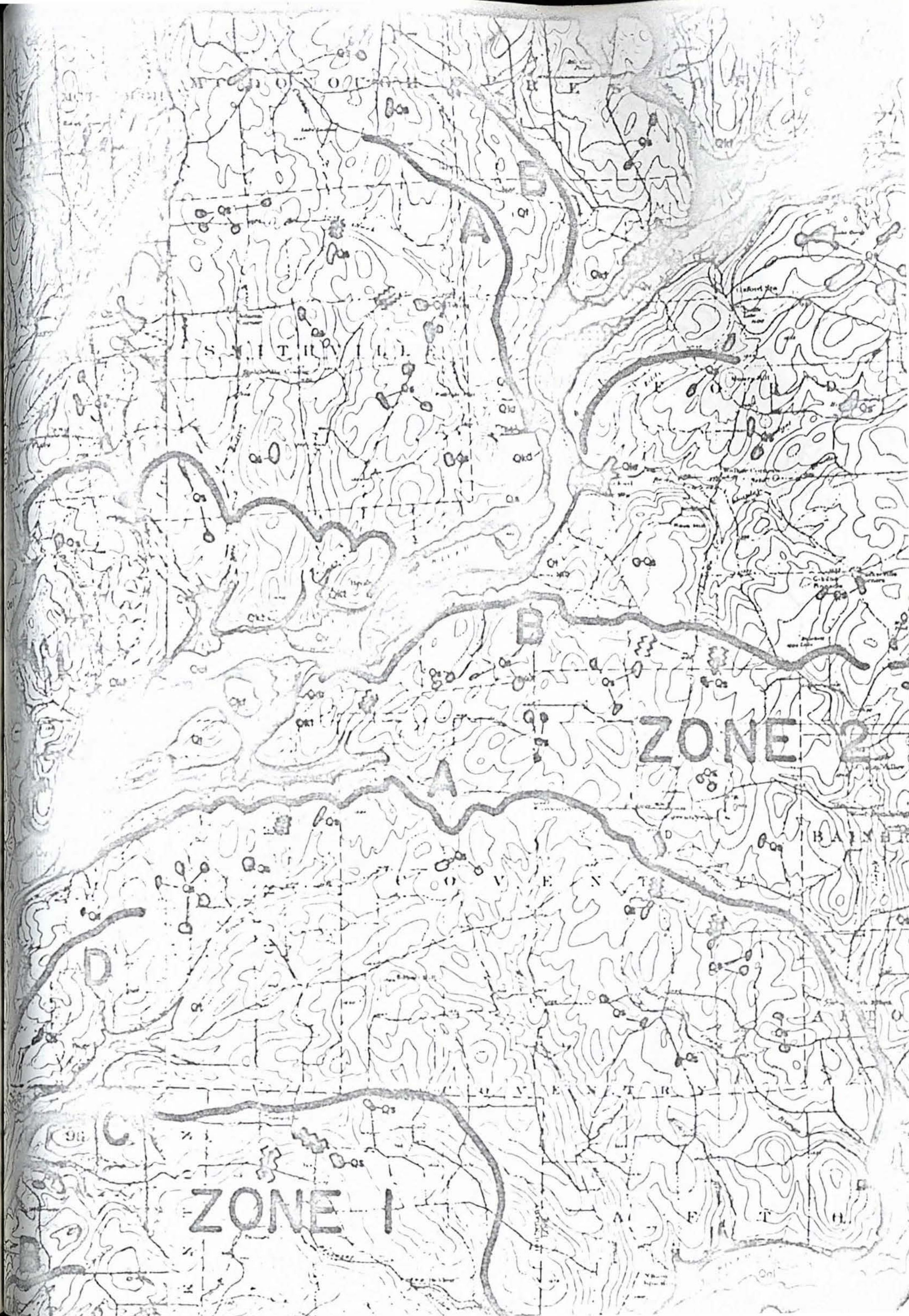
...d where approximately located.

...hannel
...rough which glacial meltwater
...d.

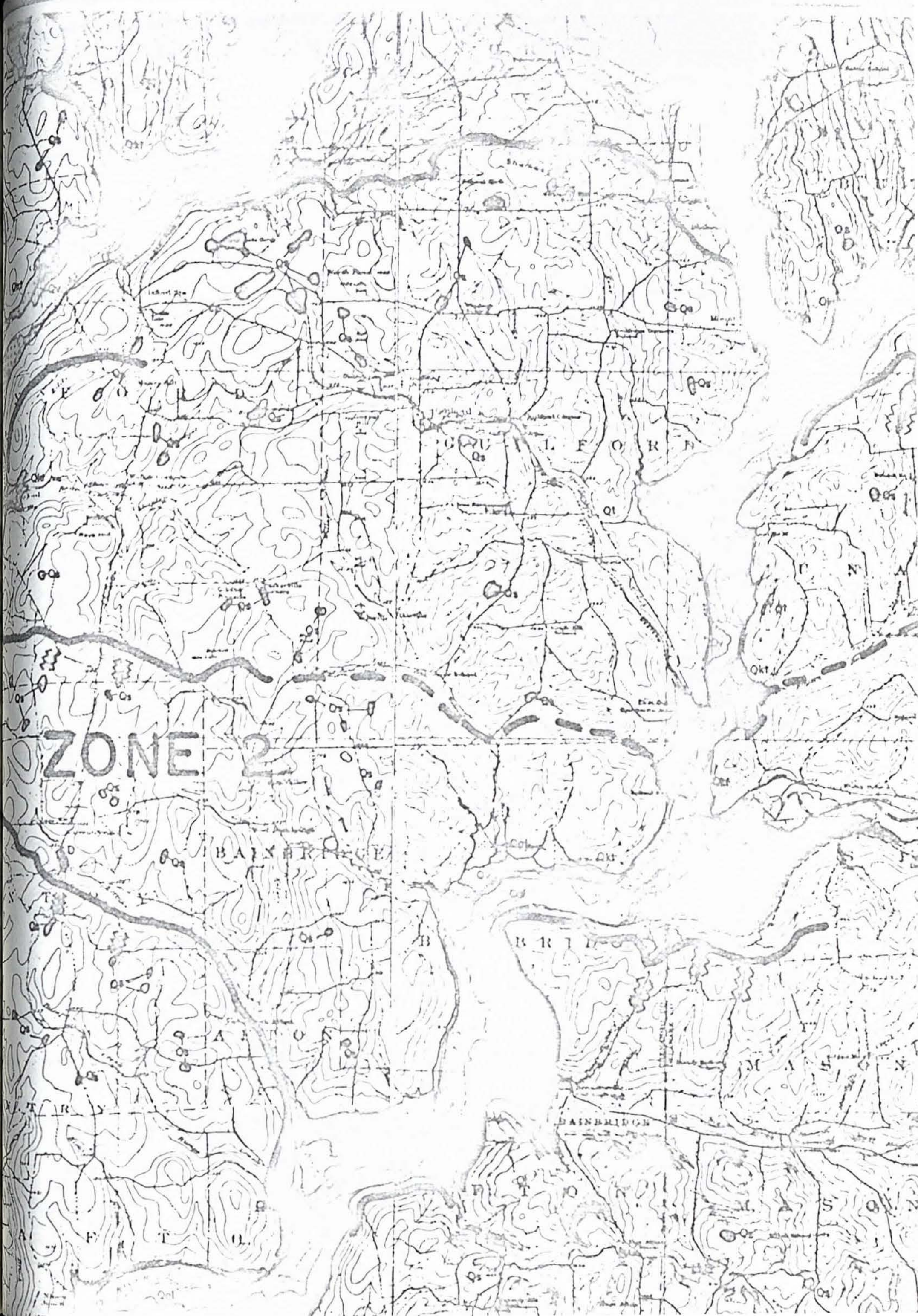


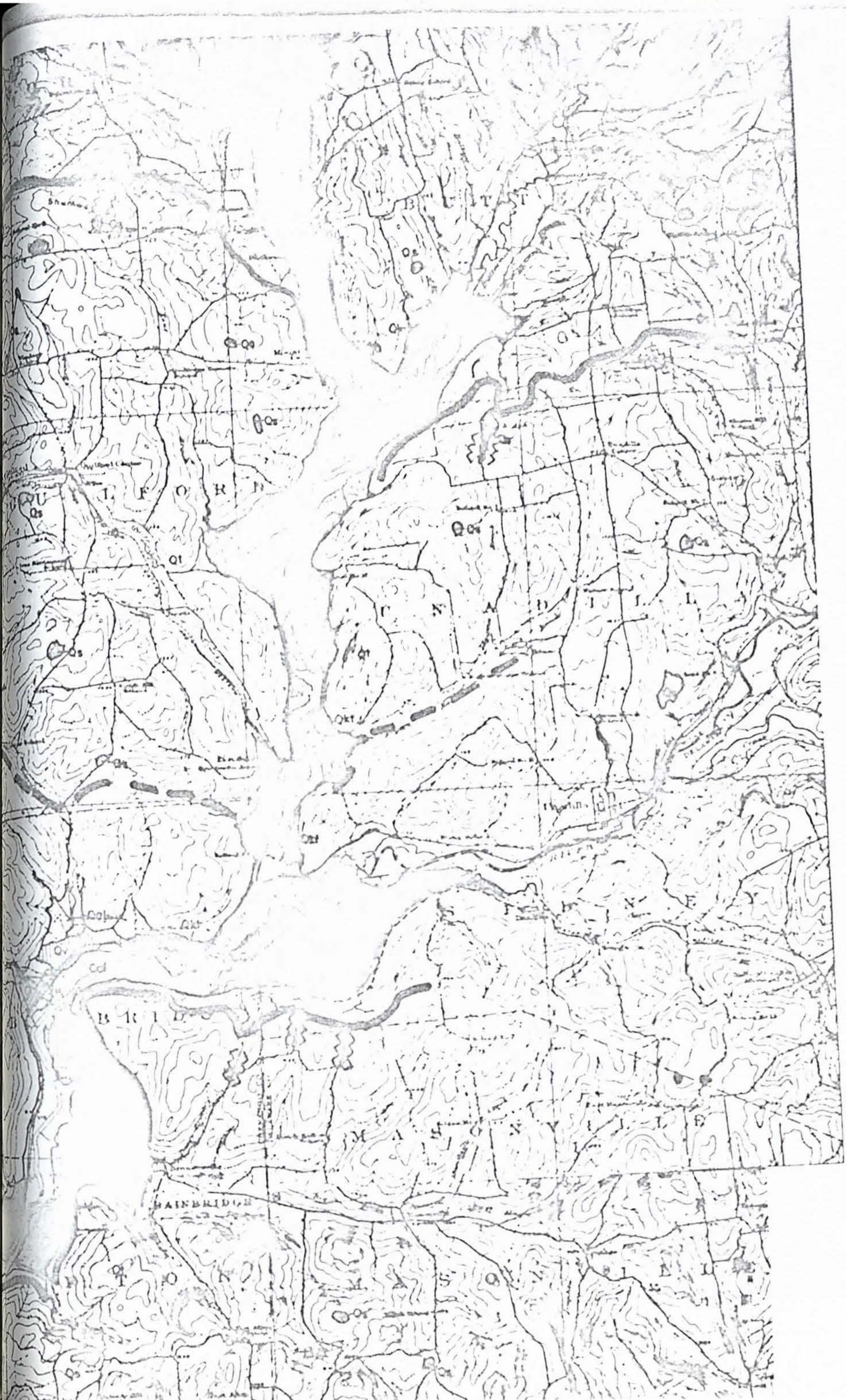

ERBURNE
G
F
D


C O L U M B U S



B
A
B
ZONE 2
A
D
C
ZONE 1


ZONE 2
BAINBRIDGE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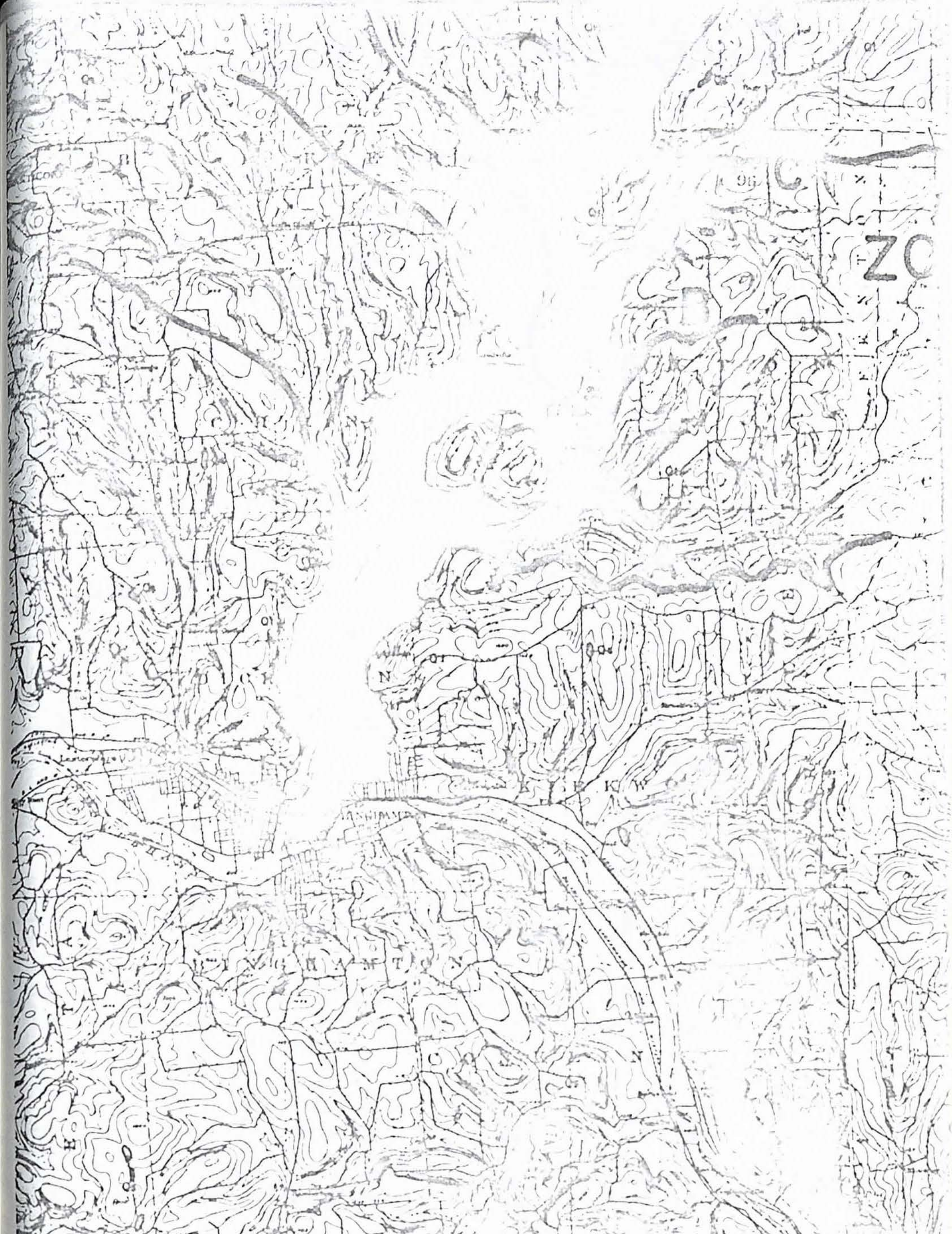
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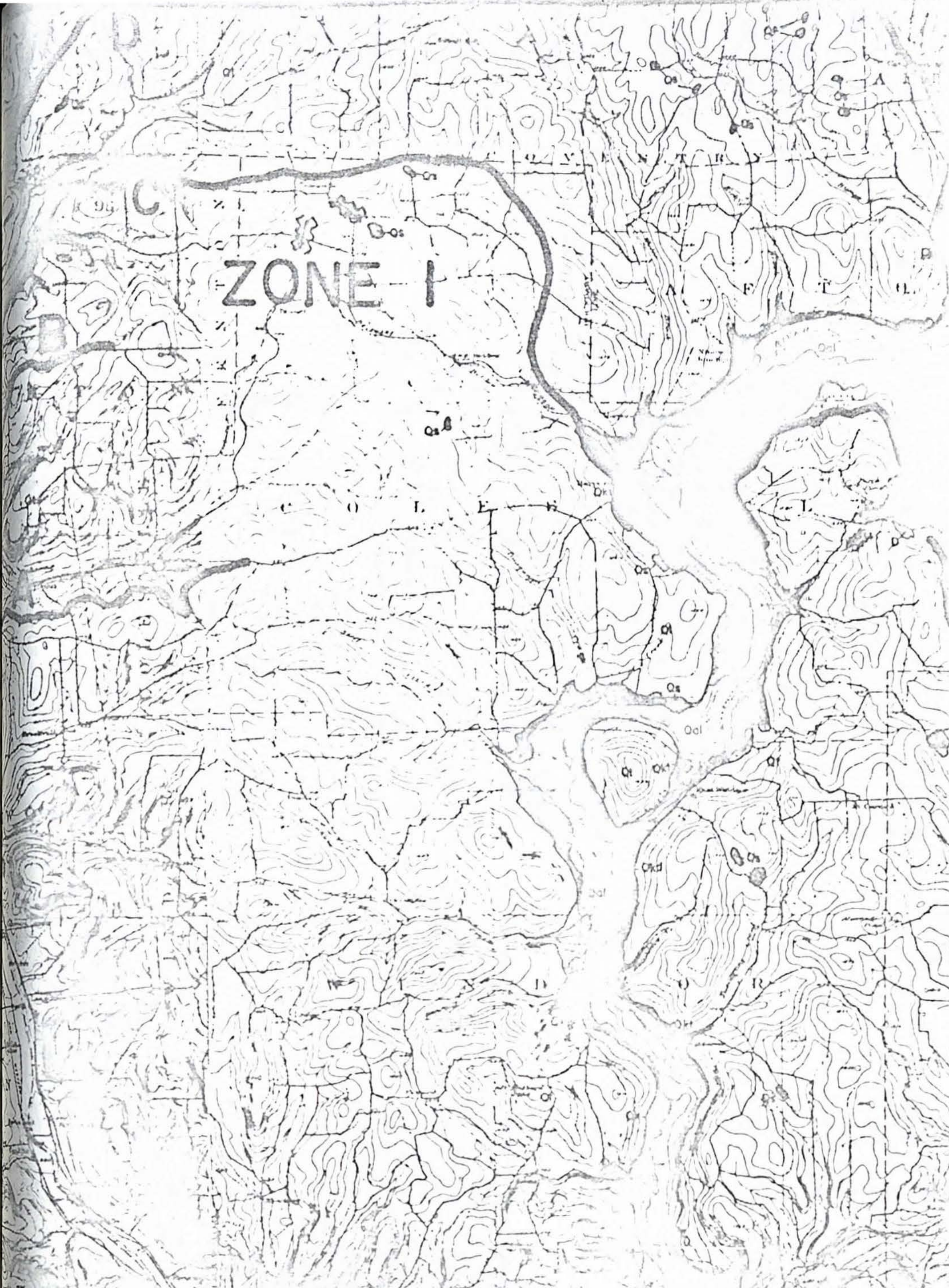
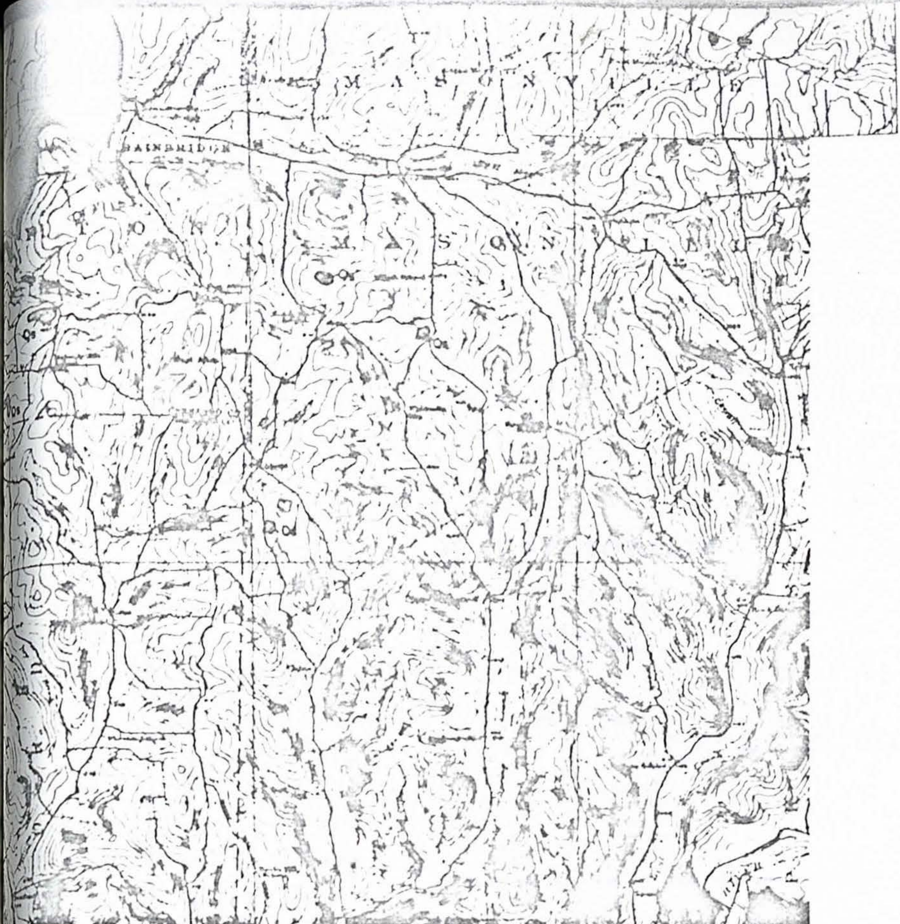
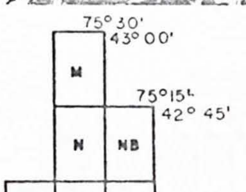


ZONE I
C O L E
Qal
Qs

Mapped during the summe





15' U.S.G.S. QUADRANGLE MAPS

M - Morrisville
N - Norwich
NB - New Berlin
G - Greene
O - Oxford
U - Unadilla
B - Binghamton
H - Ninevah
D - Deposit

Mapped during the summers 1969, 1970, 1971.

EXPLANATION

QUATERNARY

Holocene

Qs — Swamp deposit

Qal — Alluvium
Gravel, sand, silt and clay; found chiefly in areas flooded by modern streams; Alluvial fans.

Pleistocene — Wisconsinan — Woodfordian

GLACIOFLUVIAL AND GLACIOLACUSTRINE DEPOSITS

Ice margin positions indicated by numbers; 1 is oldest, 6 is youngest.

	1	2	3	4	5	6
Qk	Qk	Qk	Qk	Qk	Qk	
Qic	Qic	Qic		Qic		
Qkt	Qkt	Qkt	Qkt	Qkt	Qkt	Qkt
Qv	Qv	Qv	Qv	Qv	Qv	Qv
Qkd	Qkd	Qkd	Qkd	Qkd	Qkd	

Kame or kamefield
Knobby hills of moderate relief and irregular lower knobby masses of sand and gravel.

Ice-channel filling
Narrow ridges of sand and gravel deposited as eskers or crevasse filling.

Kame terrace
Originally flat topped terrace forms composed of sand and gravel.

Valley train
Generally flat valley bottom composed of sand and gravel.

Kame delta

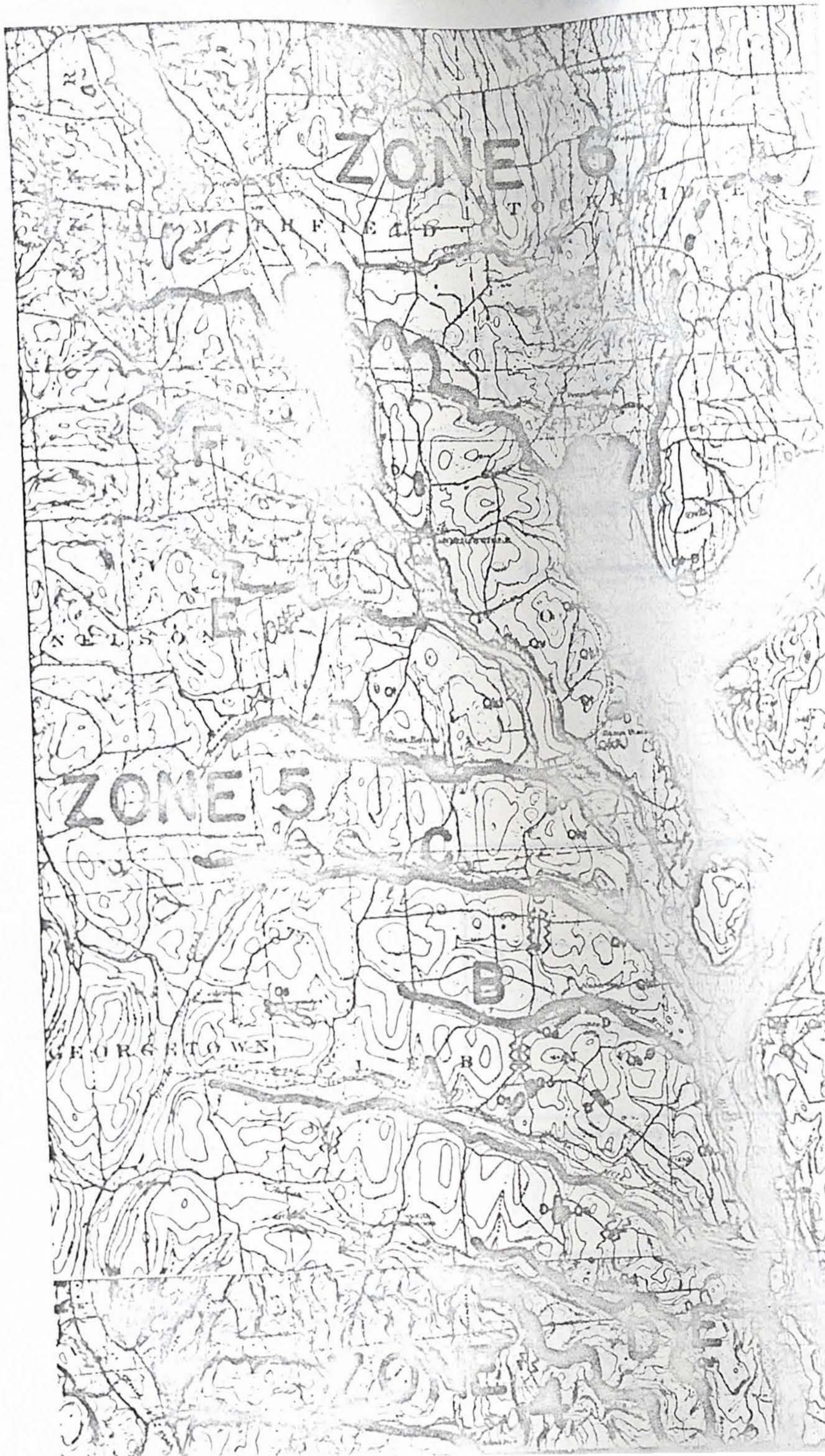
...ay; found chiefly
...odern streams;

...DEPOSITS

...of sand and gravel.

...us filling.

...avel.



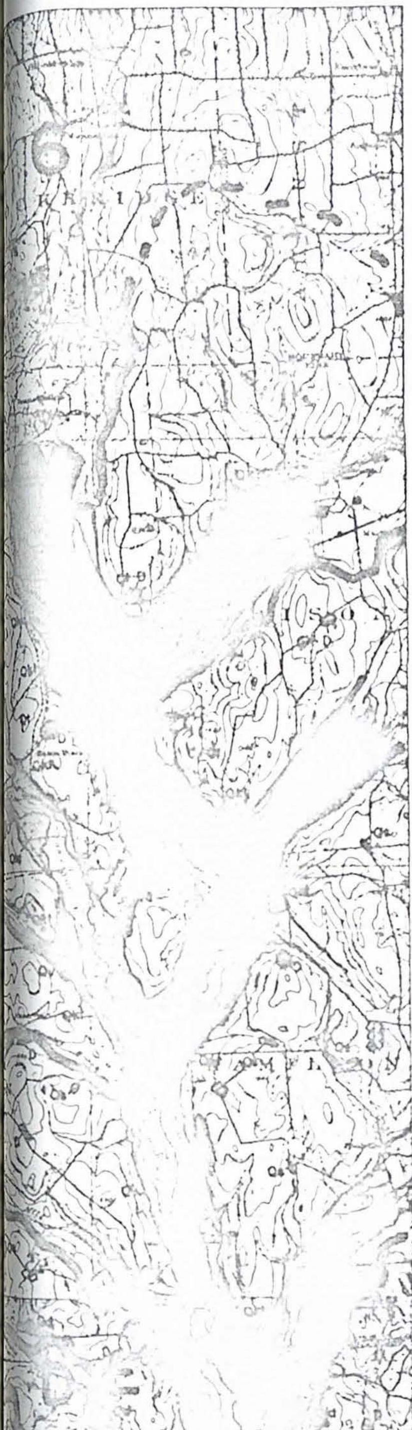


PLATE 2

SURFICIAL GEOLOGIC M

OF THE

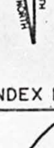
CHENANGO RIVER VALL NEW YORK

AND PORTIONS OF THE

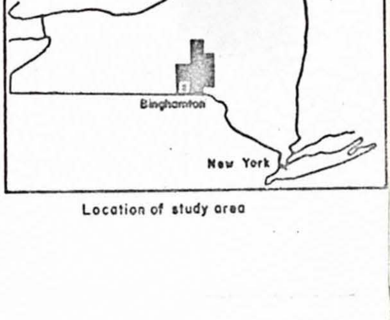
SUSQUEHANNA AND UNADILL RIVER VALLEYS, N.Y.

By

Donald H. Cadwell



INDEX MAP



Location of study area

PLATE 2

SURFICIAL GEOLOGIC MAP
OF THE
CHENANGO RIVER VALLEY, NEW YORK

AND PORTIONS OF THE
SUSQUEHANNA AND UNADILLA RIVER VALLEYS, N.Y.

By

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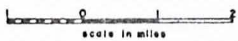
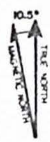
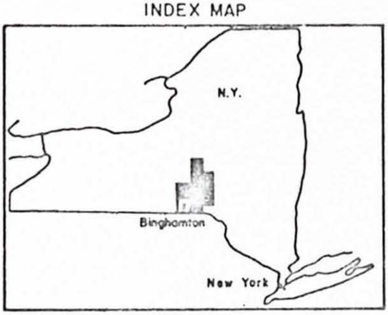




INDEX MAP



Location of study area

QUATERNARY
Pleistocene
Wisconsinan
Woodfordian

Kame terrace

Originally flat topped terrace forms composed of sand and gravel.

Qv | Qv | Qv | Qv | Qv | Qv | Qv

Valley train

Generally flat valley bottom composed of sand and gravel.

Qkd | Qkd | Qkd | Qkd | Qkd | Qkd

Kame delta

Flat topped hills with deltaic structures built into open lakes composed of sand and gravel.

Qvp | Qvp | Qvp

Valley plug

Stratified sand and gravel and till choking the river valley.

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Contact
Dashed where approximately located.

Outflow channel
Gap through which glacial meltwater flowed.

sand and gravel.

Ov

d gravel.

open lakes composed of sand and gravel.

er valley.

its
n sand, silt and clay of temporary
l lakes.

ated stratified drift
and gravel deposits not distinct
h to separate by origin.

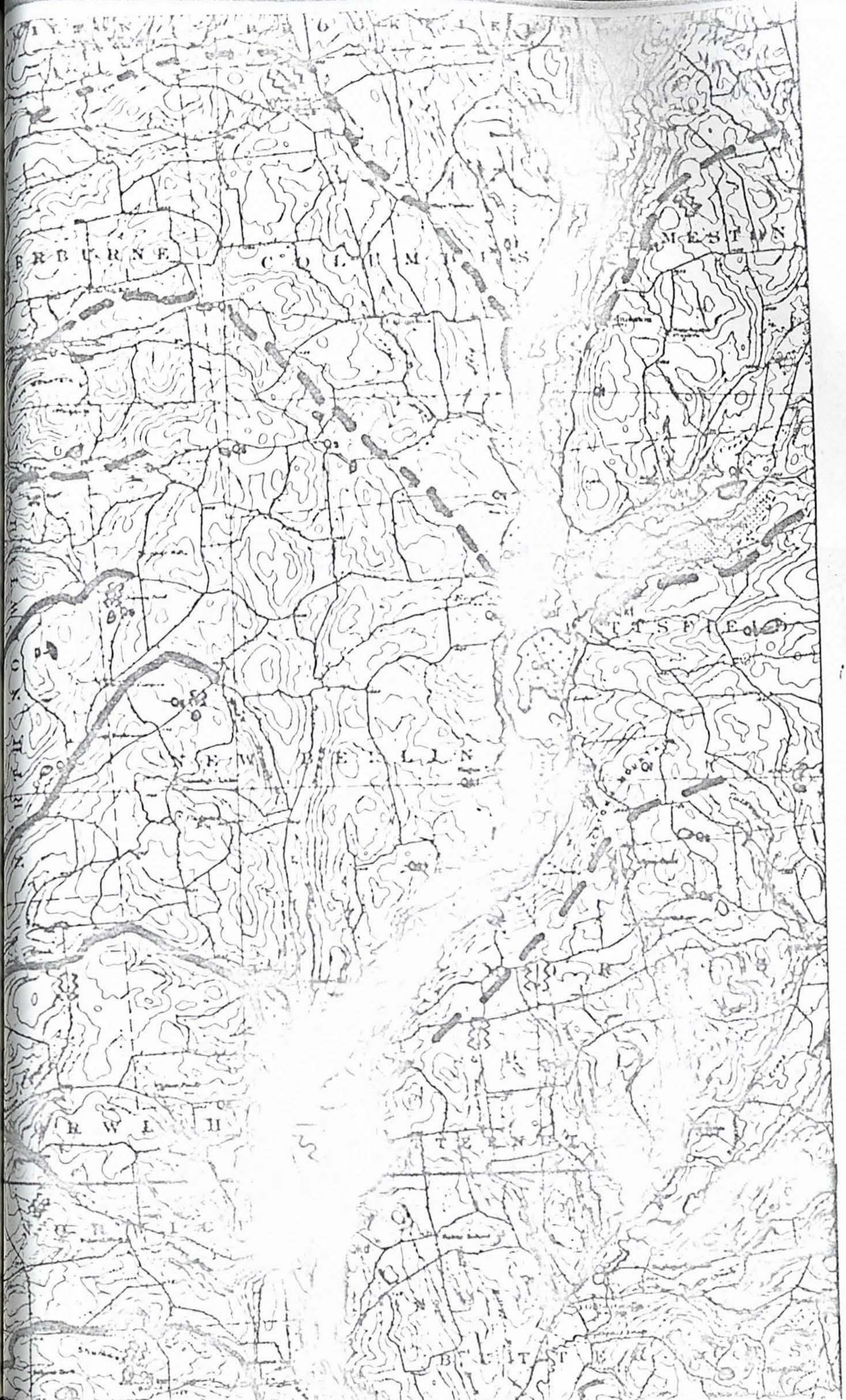
ick till.

bedrock
ure of sandstone, siltstone or shale.

d where approximately located.

channel
hrough which glacial meltwater
d.


E R B U R N E



Contact
Dashed where approximately located.

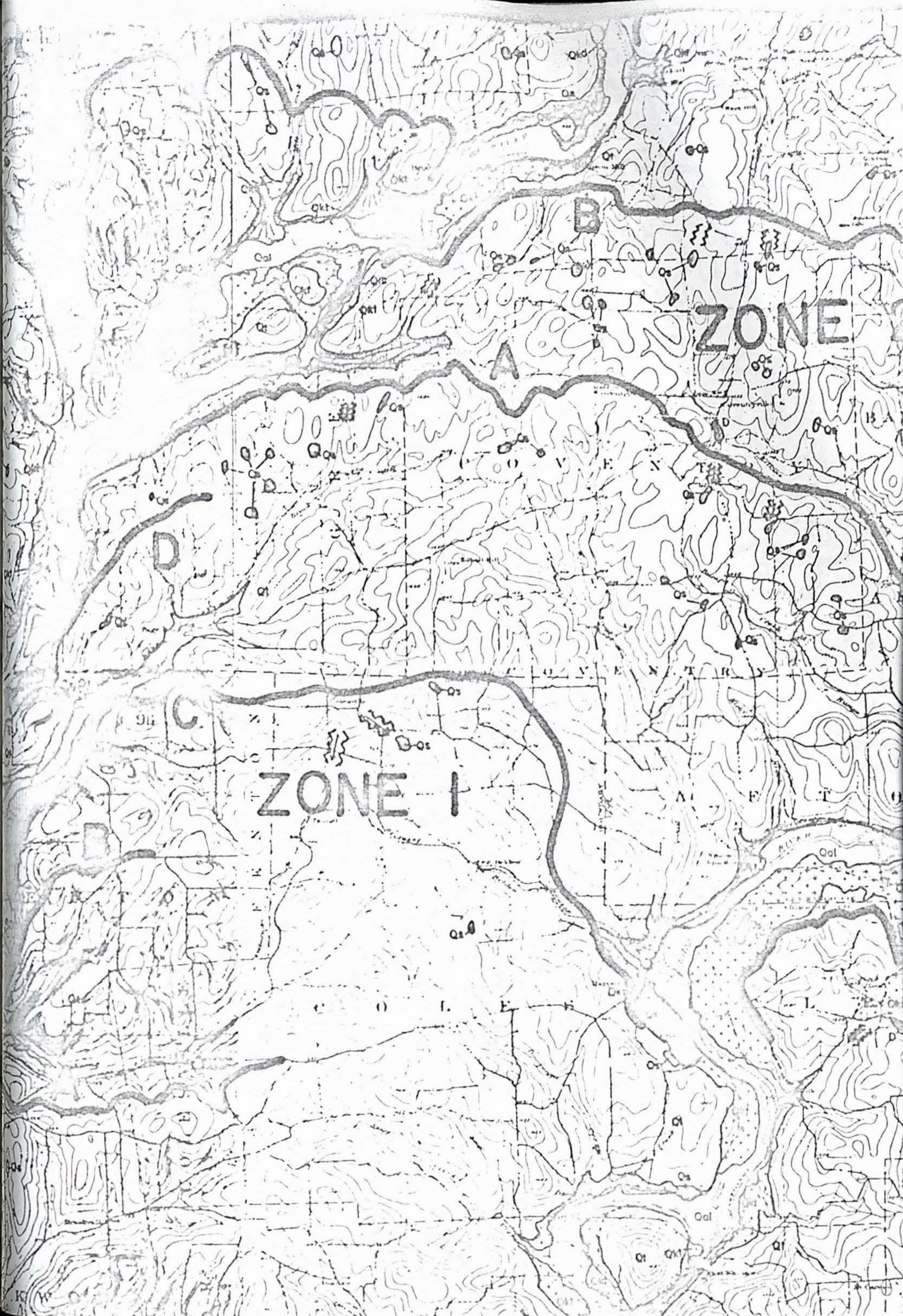
Outflow channel
Gap through which glacial meltwater flowed.

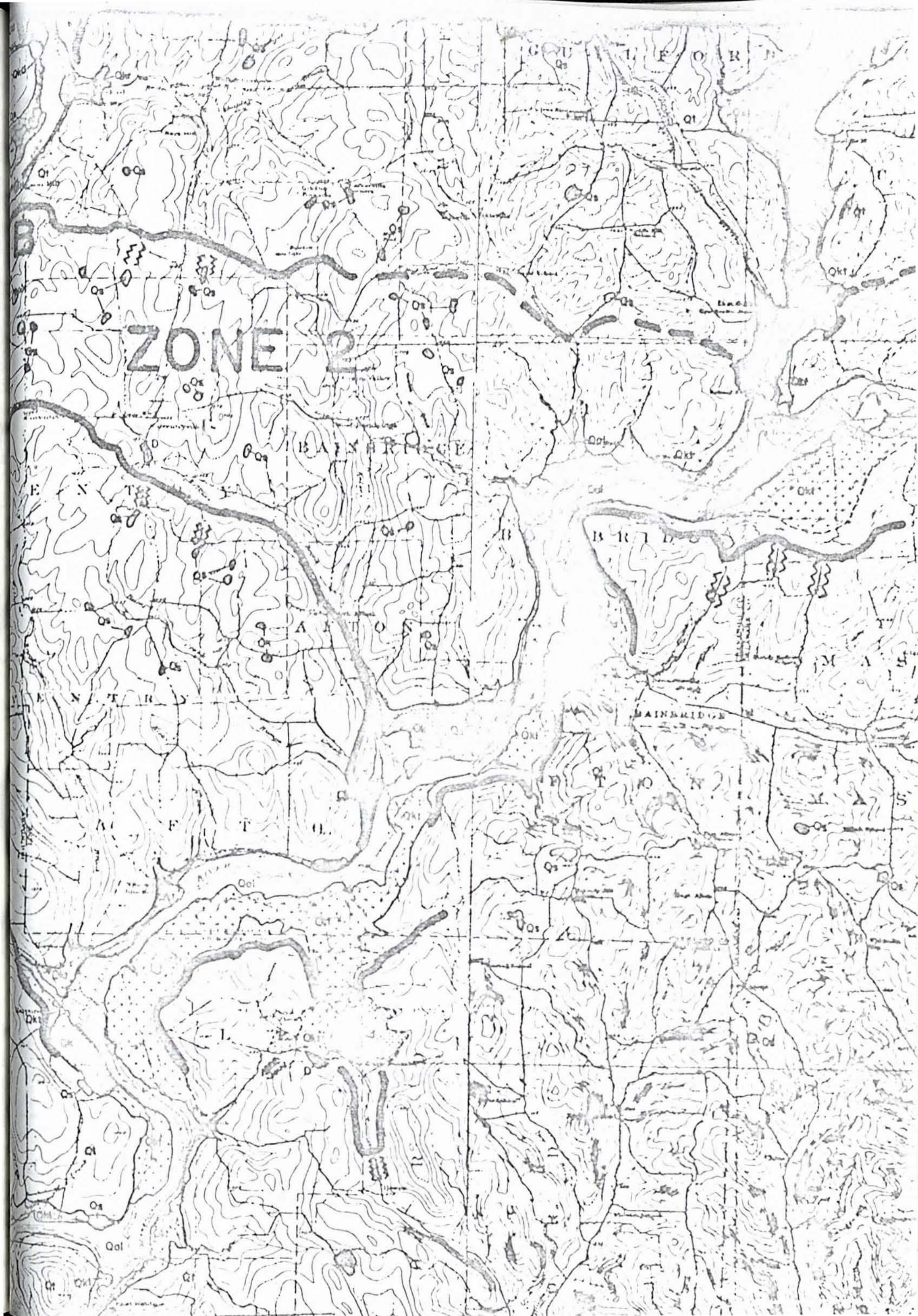
shed where approximately located.

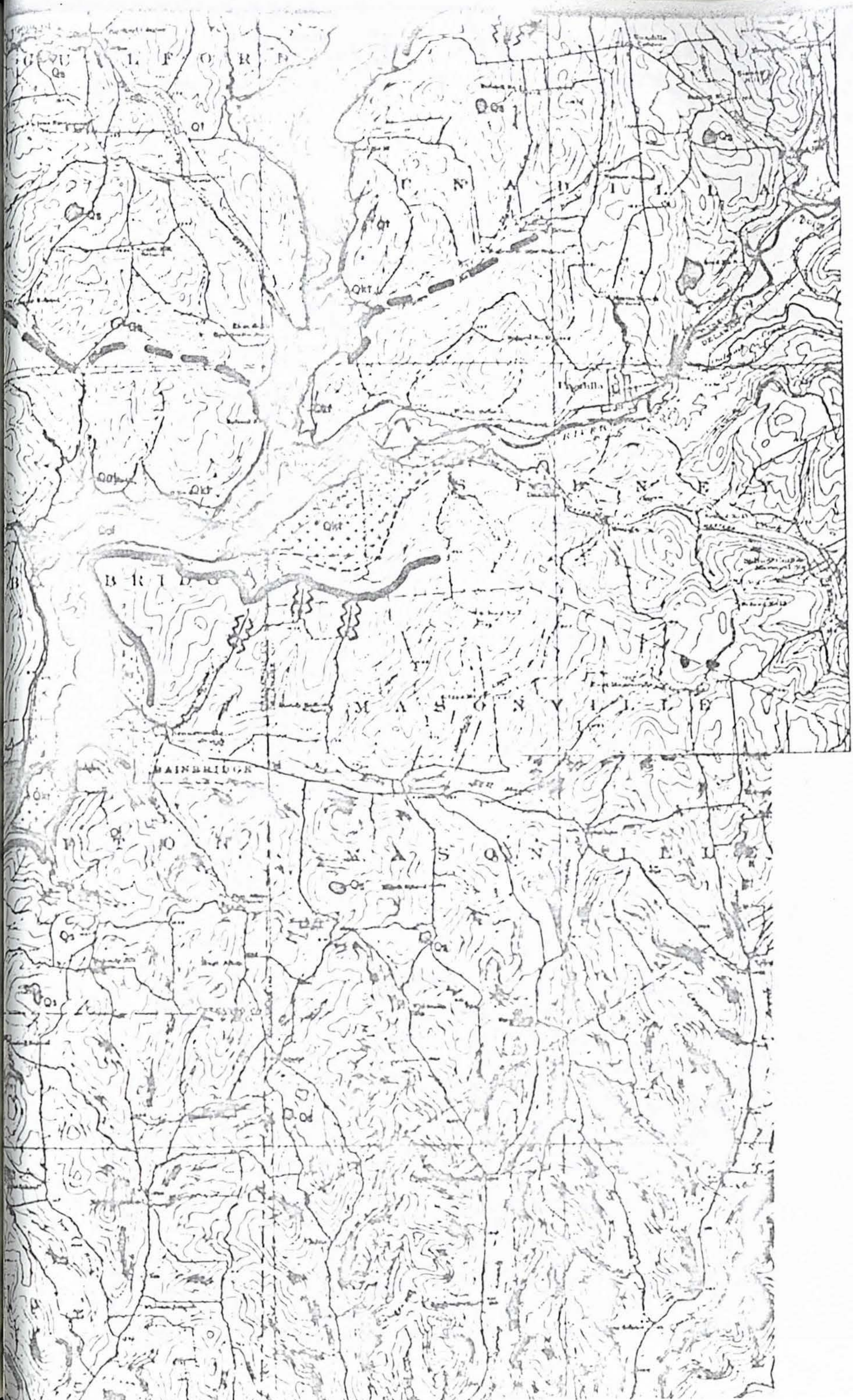
channel
through which glacial meltwater
ored.


E
D
B
B
ZONE
Qs
Qt
Qkt


D
C
95
B

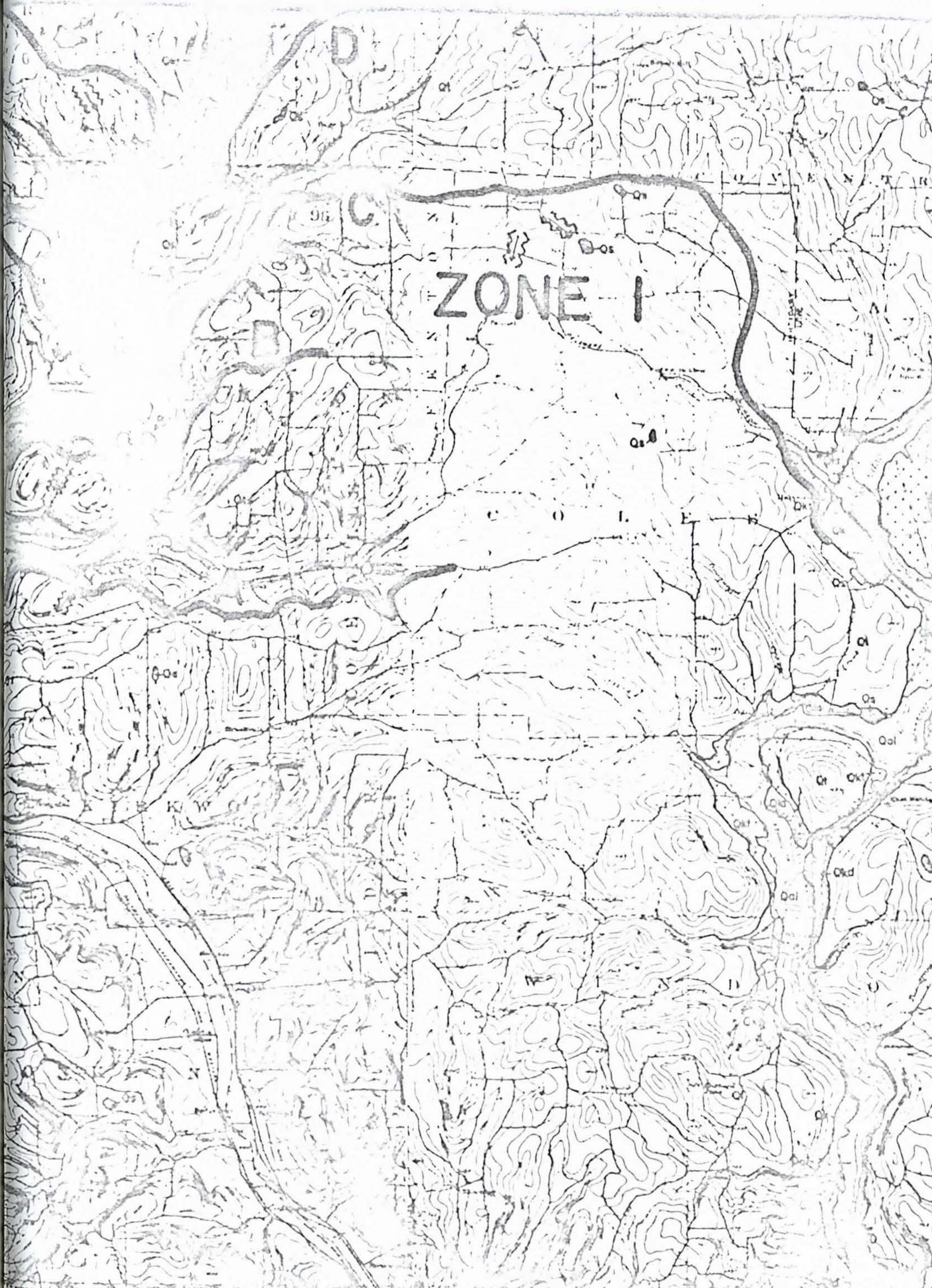

ZONE I
ZONE
A
B
C
D
Qal
Qs
Qkt
Qt

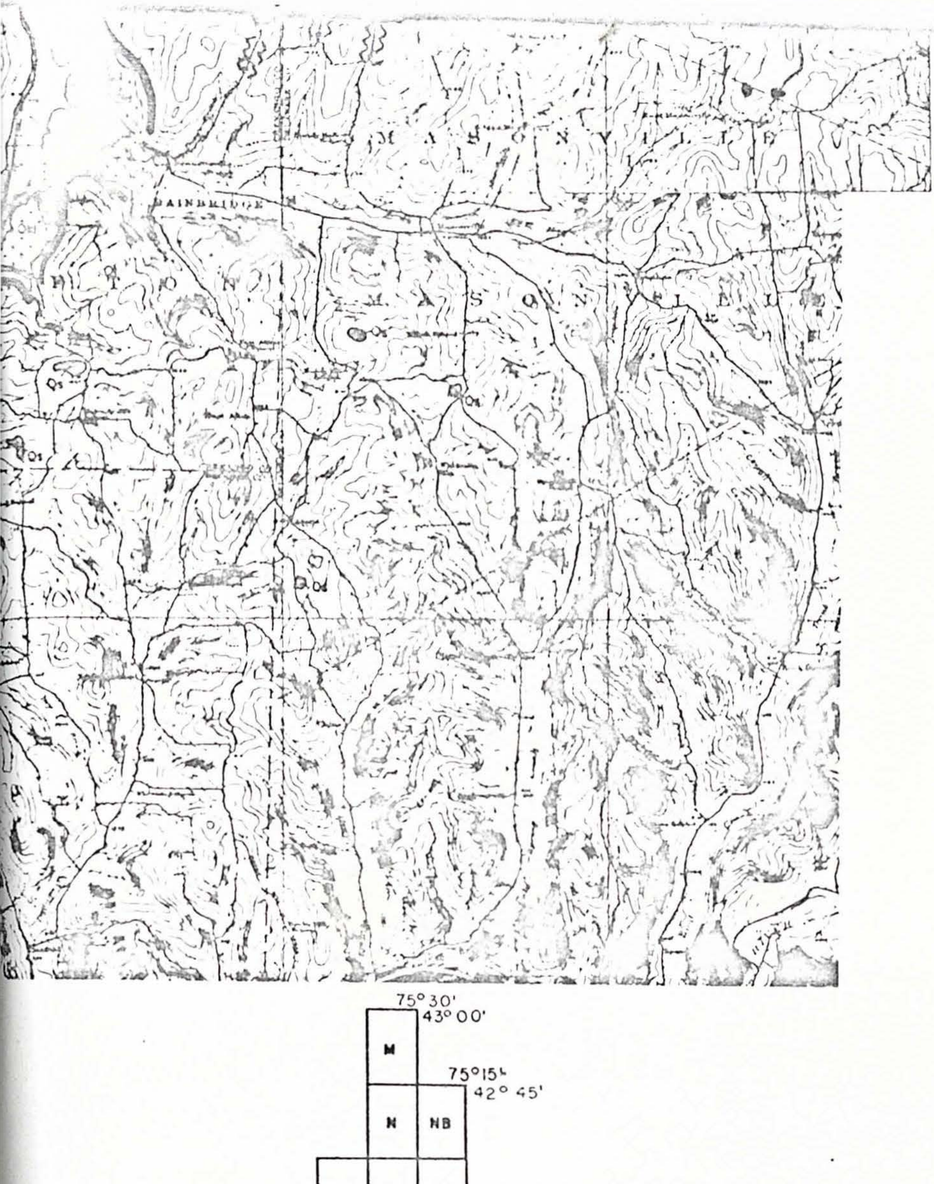

ZONE 2
BAINBRIDGE

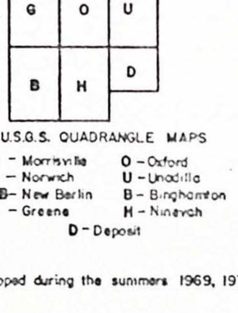


G U I L F O R D
U N A D I L L A
S I D N E Y
M A S O N V I L L E
BAINBRIDGE


B I N G H A M T O N


ZONE I
D
C
B
C O L E
Qs
Qt
Qal
Qkd
Qkt





15' U.S.G.S. QUADRANGLE MAPS

M – Morrisville   O – Oxford
N – Norwich   U – Unadilla
NB – New Berlin   B – Binghamton
G – Greene   H – Nineveh
D – Deposit

Mapped during the summers 1969, 1970, 1971.