1976

Pleistocene Local Glaciation In The Adirondack Mountains, New York

Jesse Leo Craft

Recommended Citation

Craft, Jesse Leo, "Pleistocene Local Glaciation In The Adirondack Mountains, New York" (1976). *Digitized Theses*. 902.
https://ir.lib.uwo.ca/digitizedtheses/902

PLEISTOCENE LOCAL GLACIATION IN THE ADIRONDACK MOUNTAINS, NEW YORK

by

Jesse Leo Craft

Submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Graduate Studies
The University of Western Ontario
London, Ontario
May, 1976

ABSTRACT

The purpose of the study was to find evidence for or against the hypothesis that local glaciation occurred in the High Peaks area of the Adirondack Mountains, New York, following recession of the Late Wisconsinan Laurentide ice sheet.

Field investigations consisted of: evaluating landforms using air photos, detailed mapping of glacially deposited materials, investigating landforms of possible glacial origin, measuring the orientation of pebbles in deposits of till and collecting till samples for laboratory analyses.

Laboratory methods comprised the identification of light minerals of the 0.044 mm to 0.125 mm sized fraction of all till samples; the identification of pebbles and the grain-size analysis in the sand, silt and clay fractions from selected sites throughout the study area.

The air photo and field studies identified 224 cirques in the High Peaks region. Detailed analysis of these features indicates that bedrock jointing and faulting are the primary controlling factors in the position and aspect of cirque development. Topographic position and elevation influences the degree of development of the glaciated valleys. Schrund elevations, a possible indication of snowlines, were determined for all cirques. The schrund elevation studies indicate two possible snowlines: one at 1700-2700 feet ASL, and another at 2400 to 3400 feet ASL. The lower values of schrund elevation for each possible snowline are associated with cirques which are located

on the west, north and east sides of mountain masses and open northward. Cirques located on the south sides of the mountains have higher minimum schrund elevations.

The distribution of erratics from north of the Adirondacks and striae in the main valleys demonstrate that the Laurentide ice sheet overrode the mountains. The most conclusive evidence of the time relationship between local glaciation and continental glaciation was obtained from the studies of the light mineral (quartz, orthoclase and plagioclase) fraction of the tills. Quantitative analysis demonstrates a correlation between sources of glaciation and till composition. Materials deposited from local ice sources within the Anorthosite Massif contain less than 20 percent quartz, less than 35 percent orthoclase and from 50 to 85 percent plagioclase. Continental tills contain less than 55 percent plagioclase with nearly equal amounts of orthoclase and quartz.

Striations on bedrock and elongate pebble orientation studies provide evidence of ice movement at nearly right angles to the Laurentide ice-flow direction in Roaring Brook on the west side of Giant Mountain, at the Coon Pit on Whiteface Mountain and at Newcomb. A northward flow of ice is recorded at the McIntyre Development, Tahawus, N. Y. Lithology distributions indicating ice flow in directions other than that expected by the Laurentide ice advance have been found in White Brook Valley.

End moraines formed by local glaciation have been identified at St. Huberts, below Giant Mountain; Cooperkill Pond; Weston Mountain Cirque; Blue Ridge; Boreas Mountain and Redfield Cirque. Lateral moraines were observed in White Brook Valley, Styles Brook, Johns Brook and Boreas Mountain.

The approximate time of the last episode of local glaciation has been established by the existence of an outwash delta into Glacial Lake Warrensburg at Blue Ridge, N. Y. Glacial Lake Warrensburg is correlated to the Luzerne Readvance of Connally and Sirkin (1971) at 13,200 years BP. The oldest glacial event is established by a date of greater than 53,000 years BP (Muller, 1969) for lacustrine sediments overlying till at Tahawus, N. Y.

A climatic model is proposed to explain the existence of local glacial activity south of the Laurentide ice sheet.

The history of local glaciation in the Adirondack Mountains is believed to comprise the following episodes:

During Early Wisconsinan time, the Adirondack Mountains probably became a local ice center. This early ice melted away and the lake deposits at the McIntyre Development were formed. A major Laurentide ice advance then completely overrode the High Peaks. The Laurentide ice mass melted from the High Peaks region possibly during the Erie Interstade. The local ice probably redeveloped during the Port Bruce Stade and receded to some extent during the Mackinaw Interstade. Deglaciation of local ice to recessional moraine positions is related to the Two Creeks Interstadial. Rapid valley deglaciation occurred with the draining of Lake Iroquois. All glacial ice was probably gone by the time of the completion of the Champlain Sea phase of deglaciation.

ACKNOWLEDGEMENTS

The writer wishes to acknowledge financial support for this field project from the Society of Sigma Xi, the Geological Society of America, The University of Western Ontario and the Atmospheric Science Research Center at Albany, N. Y. Air photos used in this study were loaned to the author by the New York State Science and Museum Service at Albany.

Special thanks are due to Professor A. Dreimanis, University of Western Ontario, Dr. F. Mayr, University of Quebec at Montreal, and G. H. Kelley of Syracuse University for many hours of discussion on the problems of glacial geology in mountainous regions. Special thanks are due to Shirley Pytlac, David Cuyler and Chester Howard for working with me on this project as my field assistants.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I INTRODUCTION

1-1 PURPOSE OF THE INVESTIGATION.

The existence of mountain glaciation in the Adirondack Mountains has been accepted in the literature since Taylor published a paper on this subject in 1897. However, the time that mountain glaciation occurred is not known. Goldthwait (1913) and Fairchild (1917) suggested that the valleys were occupied by local ice prior to continental glaciation and not reoccupied by ice following continental deglaciation. Cushing (1899), Ogilvie (1902a), Johnson (1917) and Alling (1919) believed that local glaciation occurred after continental deglaciation of the Adirondack Mountains.

Using modern understanding of Pleistocene history, field investigations and laboratory methodology, evidence which would establish the glacial history of the Adirondack Mountains was sought. A search was made for indications of both continental and local glaciation and for the sequence of these glacial events. The area was studied with the premise that the landforms and glacial deposits could have been formed either by continental or by local glaciation, or they could have been formed first by one, and then been modified by the other.

1.2 GEOGRAPHICAL SETTING

The Adirondack Highlands, a nearly circular, domical uplifted area of Precambrian rocks, is a southeasterly extension of the Grenville Province of the Canadian Shield and is connected to the Shield by a narrow arch known as the Frontenac Axis (Broughton <u>et al.</u>, 1962). This

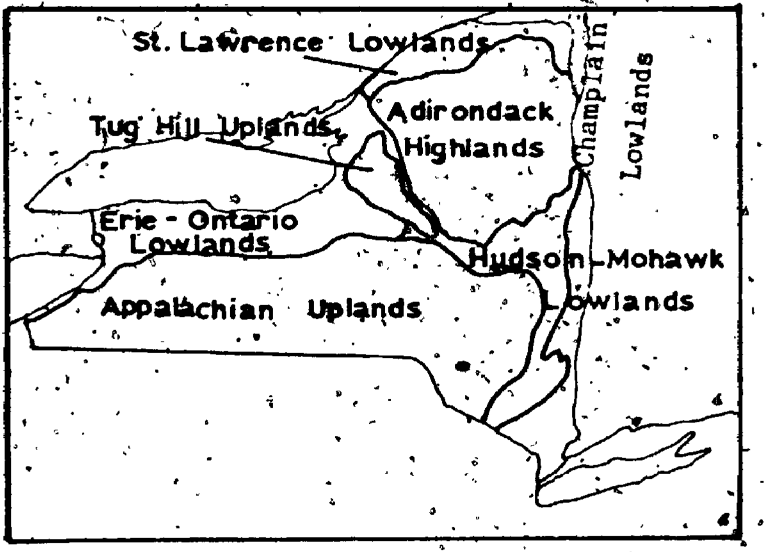


Figure 1. Physiographic subdivisions of New York State. (From New York State Geological Map, 1963).

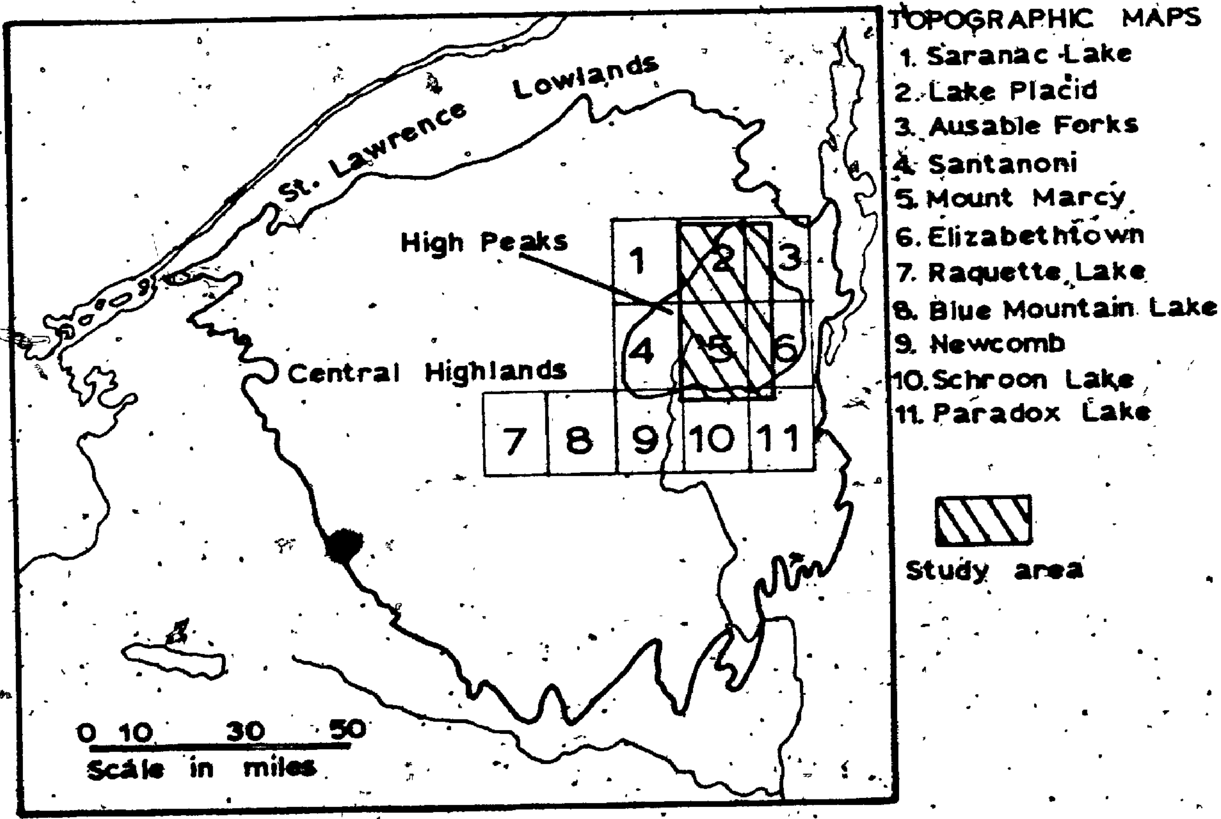


Figure 2. Physiographic divisions within the Adirondack Highlands physiographic province. Cross-lined area is the field region covered in this study.

mountainous area is located in the northeastern part of New York between 43° and 44°45' North latitude and between 73°30' and 75°45' West longitude (figure 1). This region is bounded on the north by the St. Lawrence Lowlands, on the east by the Champlain Lowlands, on the south by the Hudson-Mohawk Lowlands, and on the west by the Tug Hill Uplands (figure 1).

The study area can be divided into two geomorphic districts: the Central Highlands and the High Peaks (figure 2). These landform subdivisions are largely controlled by the bedrock lithology (see 1.3.2).

1.3 HIGH PEAKS REGION

1.3.1 TOPOGRAPHY

This study deals primarily with the High Peaks region. It lies within the boundaries of five fifteen-minute topographic quadrangles: Lake Placid, Santanoni, Mount Marcy, Ausable Forks, and Elizabethtown. The highest elevation in the area is Mount Marcy, (Mount Marcy Quadrangle) at 5344 feet ASL, next highest is Algonquin, 5114 feet ASL. In all there are forty-six prominent peaks in this region that stand above 4000 feet ASL (table 1, figure 3). The mountain ridges are arranged in a northeast-southwest line with extremely steep slopes (50° to 90°) along the sides of the ridges. The northeastern and southwestern ends of the mountain ridges are generally more gently sloping (30° to 50°) than the sides of the ridges. There are numerous low cols or passes through these ridges at the heads of tributary valleys, which give the skyline the appearance of an arête (figures 4 and 5). Armchair-shaped theaters, cut into the main ridge lines,

TABLE 1.

ELEVATIONS OF MOUNTAINS OF THE HIGH PEAKS REGION

(in order of height)

Elevations Based on 1953 Survey

	Name	Topographic Quadrangle Map	Elevation Feet
1.	Marcy (Tahawus)	Marcy	5344
2.	Algonquin	Marcy	5114
3.	Haystack	Marcy	4960
4.	Skylight	Marcy	4926
5.	Whiteface	Lake Placid	4867
6.	Dix	Marcy	4857
7.	Gray Peak	Marcy	4840
8.	Iroquois	Marcy	4840
9.	Basin	Marcy	4827
10.	Gothics	Marcy	4736
11.	Colden	Marcy	4714
12.	Giant	Elizabethtown	4627
13.	Nipple Top	Marcy	4620
14.	Santanoni	Santanoni	4607
15.	Redfield	Marcy	4606
16.	Wright	Marcy	4580
17.	Saddleback	Marcy	4515
18.	Panther	Santanoni	4442
19.	Table Top	Marcy	4427
20.	Rocky Peak	Elizabethtown	4420
21.	Macomb	Marcy	4405
22.	Armstrong	Marcy	4400
23.	Hough	Marcy	4400
24.	Seward	Santanoni	4361
25.	Marshall (Herbert, Clinton)	Santanoni	4360
26.	Allen	Marcy	4340
27.	Big Slide	Marcy	4240
28.	Esther	Lake Placid	4240
29.	Upper Wolf Jaw	Marcy	4185
30.	Lower Wolf Jaw	Marcy	4175
31.	Street	Santanoni	4166
32.	Phelps	Marcy	4161
33.	Donaldson	Santanoni	4140
34.	Seymour	Santanoni	4120
35.	Sawteeth	Marcy	4100
36.	Cascade	Marcy	4098
37.	South Dix	Marcy	4060
38.	Porter	Marcy	4059
39.	Colvin	Marcy	4057
40.	Emmons	Santanoni	4040
	Street--West Summit	Santanoni	4034
41.	Dial	Marcy	4020
	Yard	Marcy	4018
42.	East Dix	Marcy	4012
	MacNaughton	Santanoni	4000
43.	Blake	Marcy	3960
44.	Cliff	Marcy	3960
45.	Nye	Santanoni	3895
46.	Couchsachraga	Santanoni	3820

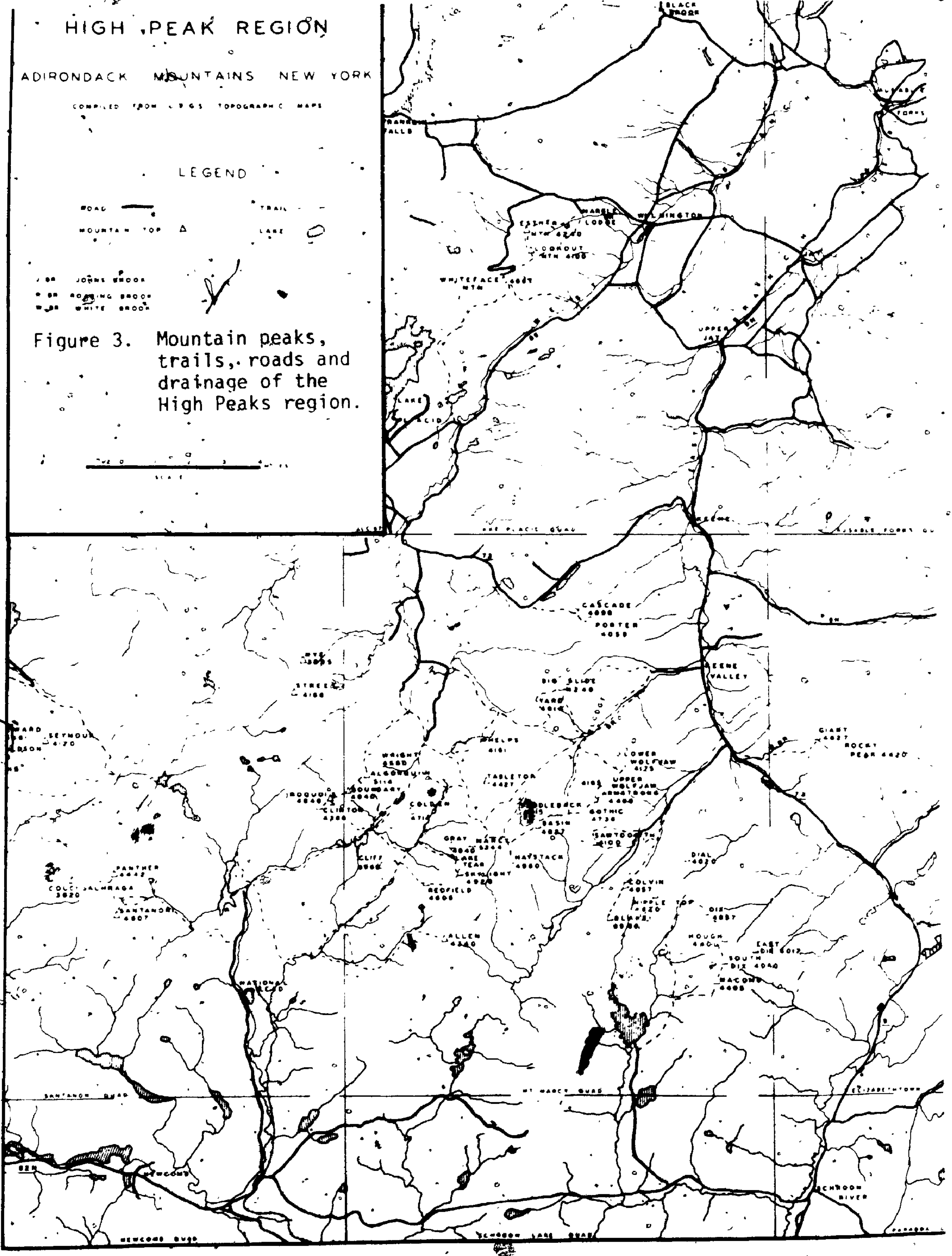


Figure 3. Mountain peaks, trails, roads and drainage of the High Peaks region.

Figure 4. View from Mount Marcy looking east. Large slide scars on the mountain in skyline center are developed on Giant Mountain.

Figure 5. View of the Range from Giant Mountain. Cone-shaped peak on center skyline is Mount Marcy.

constitute the cirque forms that are so common in the High Peaks region. The major features of bedrock relief are the results of interplay of several major factors such as composition, resistance to weathering and erosion, presence of foliation and linear structures of the rocks, and fault lines and major joint systems.

1.3.2 GEOLOGIC SETTING

The bedrock geology of the High Peaks region has been reported by Kemp (1898), Miller (1919), and Crosby (1966) for the Lake Placid Quadrangle; Cushing (1899), Kemp (1894), Kemp and Newland (1899), and Van Diver (1968) for the Santanoni Quadrangle; Kemp (1921) and Balk (1931) for the Mount Marcy Quadrangle and Kemp (1910) for the Elizabethtown Quadrangle. Buddington (1953, 1966) studied the bedrock geology in the northern part of the High Peaks region and the rocks of the Central Highlands to the north and east. Isachsen compiled all known information for the Geologic Map of New York State (Broughton et al., 1962).

In general the area is underlain by metamorphic rocks of Precambrian age composed mostly of anorthosite. Bordering the edge of the Anorthosite Massif is a complex sequence of granitic gneisses, syenite gneisses, charnockites and metasedimentary rocks of the amphibolite facies of metamorphism (Broughton et al., 1962). A generalized map compiled from the sources listed above is part of figure 6.

Resting unconformably on the Precambrian bedrock to the north and northeast of the High Peaks region is an extensive sequence of Lower Paleozoic sedimentary rocks. The most significant as a source for glacial deposits is the Upper Cambrian Potsdam sandstone. This easily recognized rock is a common constituent in the continental glacial deposits throughout the region.

LEGEND

Metasedimentary and Charnockite Rocks ▥

Anorthosite ○

Site Location and Number ⊙

Highway Number ⊙

Scale Contour interval 500 feet

0 1 2 miles

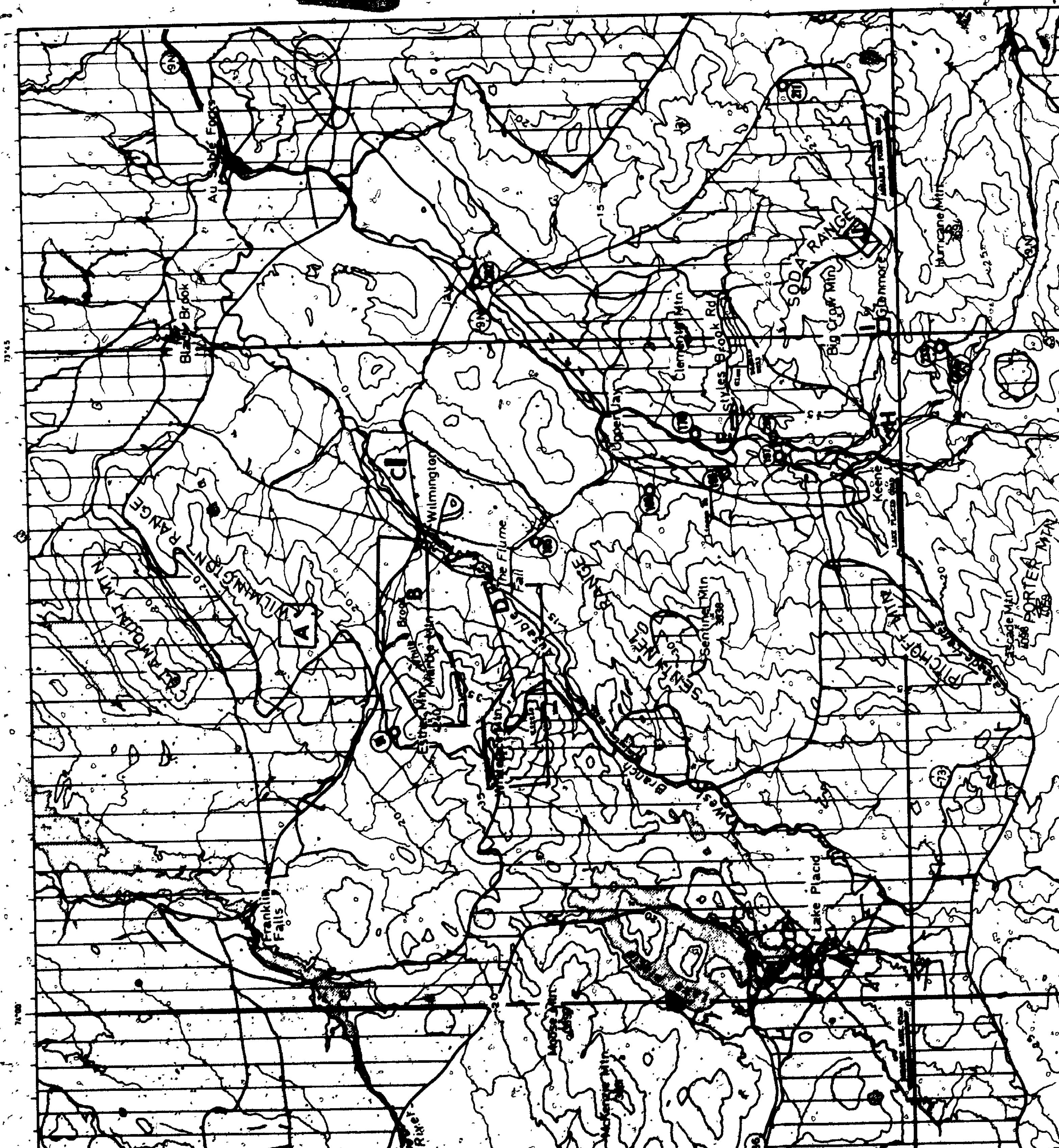
Base map compiled from U.S.G.S. Topographic Map

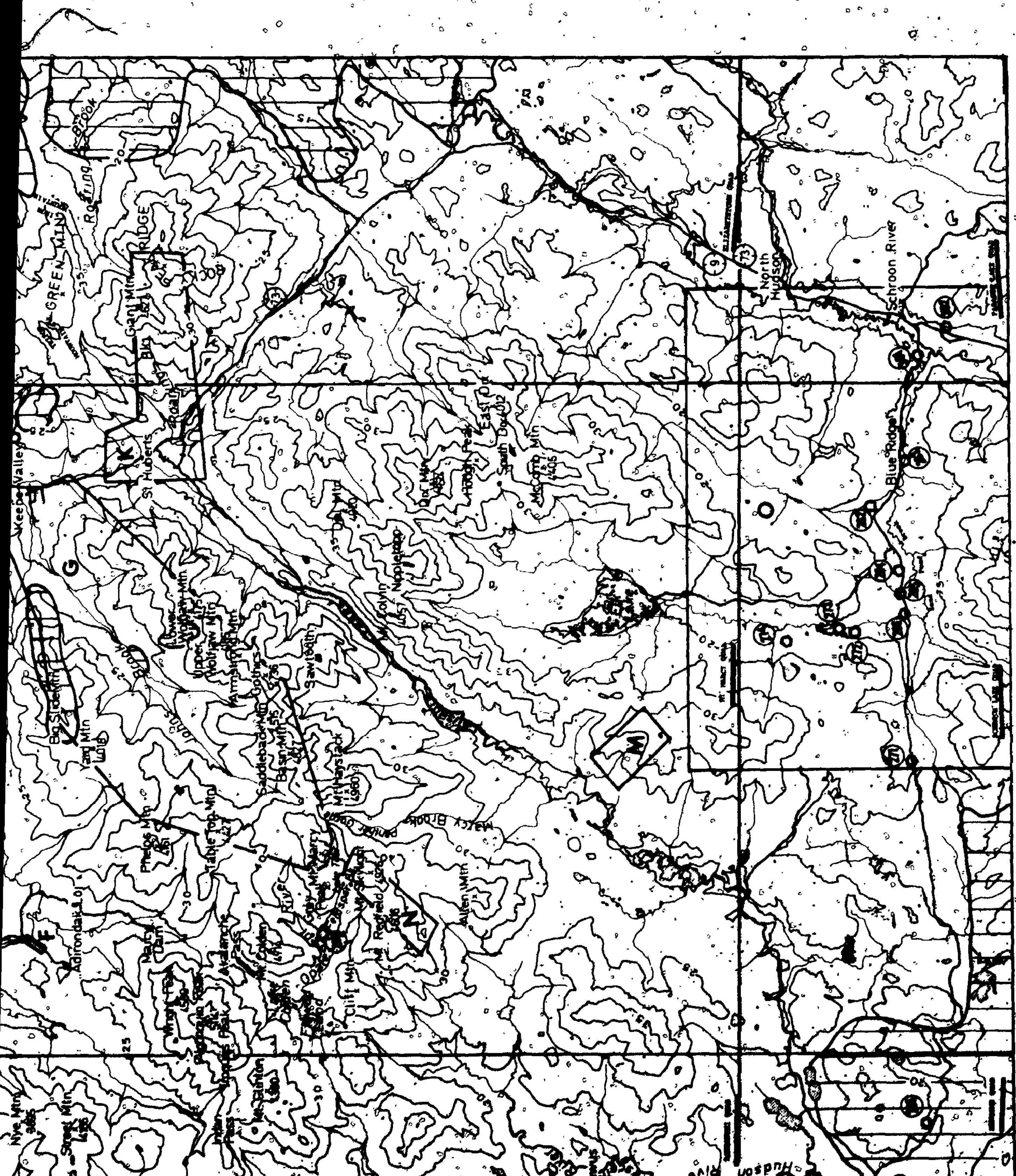
Geology from Balk (1931) and Broughton, et al., (1962)

DETAILED MAP IN TEXT B

A	Figure	12	
B	Figure	14	
C	Figure	66	
D	Figure	30	
E	Figure	67	
F	Appendix	D	Adirondack Loj Road
G	Figure	40	
H	Appendix	D	Keene Gravel Pit
I	Appendix	D	Hurricane Lodge
J	Figure	13	
K	Figure	21	
L	Figure	71	
M	Figure	28	
N	Figure	11	
O	Figure	69	
P	Figure	37	Dix Mountain

Figure 6. Geologic and Field Location Map, High Peaks Region, Adirondack Mountains, New York.


Au Sable Forks
Black Brook
Jay
Upper Jay
Wilmington
WILMINGTON RANGE
Clements Mtn
Styles Brook Rd
SODA RANGE
Big Crank Mtn
Hurricane Mtn
Keene
SENTINEL RANGE
Sentinel Mtn
3838
PITCHOFF MTN
PORTER MTN
Cascade Mtn
4098
The Flume
Franklin Falls
Lake Placid
Moose Mtn
McKenzie Mtn
Whiteface Mtn
Esther Mtn
West Branch
River
A
B
C1
D
H
9N
86
73


Roaring Brook
GREEN MTN
RIDGE
Giant Mtn
Keene Valley
St Huberts
K
G
Big Slide Mtn
Yard Mtn
4018
Lower Wolfjaw Mtn
Upper Wolfjaw Mtn
Armstrong Mtn
Gothics
Sawteeth
Saddleback Mtn
Basin Mtn
Mt Haystack
4960
Marcy Brook
Phelps Mtn
Table Top Mtn
Mt Marcy
Adirondak Lo
Marcy Dam
Avalanche Pass
Mt Colden
Wright Peak
Algonquin Peak
Iroquois Peak
Indian Pass
Mt Marshall
Nye Mtn
Street Mtn
Cliff Mtn
Redfield
Allen Mtn
N
Colvin
Nippletop
Dial Mtn
Dix Mtn
Hough Peak
East Dix
South Dix
McComb Mtn
4405
M
O
North Hudson
Schroon River
Blue Ridge
Hudson River
9
73

The major structural feature of the region is a series of northeast-southwest faults. Deep valleys have been eroded along them, and they also determine the location of the main passes through the mountain area. The most important fault passes in the High Peaks are: Wilmington Notch (Lake Placid Quadrangle), Cascade Pass, Avalanche Pass, Ausable Lakes Pass, Chapel Pond Pass (Mount Marcy Quadrangle) and Indian Falls Pass (Santanoni Quadrangle). Lake Placid is a large fault zone, blocked off at the south end by a massive moraine (Alling, 1919).

Buddington (1953) reported two major joint directions which are prevalent throughout the Northern Adirondacks: N 70° E and N 80° W. The northeast joint system is commonly slickensided and is related to the major faulting in the area. A third direction, between N 45° and 70° W is present in many places and has local structural significance. All of the joint systems have a steep dip.

The surficial geology of the region is dominated by Pleistocene glacial erosional landforms and deposits. Bedrock exposures in the valleys are scarce because of the drift blanket. It is only on the higher elevations in areas of very steep slope that bedrock is well exposed.

1.3.3 DRAINAGE

The individual streams exhibit rectangular drainage patterns, however, the regional drainage is radial (figure 3). Water flows into both the Hudson River system to the south and the St. Lawrence system to the north. In the south and southwest, the rivers flow directly to the Hudson River or into the Mohawk River which then joins the

Hudson River at Albany. In the north and east, the waters reach the St. Lawrence River via Lake George and Lake Champlain. In the northwest, the water flows either into Lake Ontario or directly to the St. Lawrence River.

The major rivers of the area are the Hudson and its tributaries flowing south; the Black River flowing directly into Lake Ontario to the north; the Oswegatchie, Grass, Raquette and Salmon Rivers which flow north to the St. Lawrence River; and the Saranac and Ausable Rivers which flow into Lake Champlain. The rivers follow pre-glacial valleys throughout much of their course but are locally diverted from these valleys by glacial drift. In many cases, this diversion of the stream from one valley to another is through very deep bedrock gorges.

The stream channels reflect the control of underlying bedrock structure related to the regional jointing of N 75° E to N 80° W and the major northeast to north trending faults. Wherever valleys have been filled by drift, streams tend to meander through swampy ground and the pattern becomes dendritic.

1.4 PREVIOUS WORK

A summary of previous investigators who have worked in the vicinity of the study area and the pertinence of their contributions to the present study is shown in table 2.

Table 2. Summary of Previous Workers, Their Contributions and Pertinence to the Present Study

Author	Contribution	Pertinence to Present Study
Taylor (1897)	Suggested possible local valley glaciation in the Adirondacks, recognized beach terraces, ice dammed lakes, importance of Potsdam sandstone erratics.	Recognition of local valley glaciers.
Hitchcock (1898)	Noted distribution of erratic materials high up on the slope of Whiteface and other high peaks.	Use of erratics from outside the Anorthosite Massif as indicator of continental glaciation.
Kemp (1898)	Described moraine at Lake Placid Village, observed large glacial erratics, recognized lake-bottom sediments, deltaic outwash and other related deposits. Recognized cirques on slopes of Whiteface, and Sentinel Range, Giant and Gothics.	Recognition of cirque-cutting as significant in the glacial history of the region.
Cushing (1899)	Mapped a morainic area on the north flanks of the Adirondacks that contained erratics deposited by a "northward flow of ice from an Adirondack Center".	Recognition of local glaciation.
Ogilvie (1902a)	Placed glacial events of the Adirondacks in chronological sequence, recognized ice-dammed lakes, beach deposits, local glaciers, moraines.	Recognition of a local glaciation following the melting away of the continental ice mass from the High Peaks.

Author	Contribution	Pertinence to Present Study
Cushing (1905)	Suggested the mass of the Adirondack Highlands blocked off the southward flow of the continental ice mass, forming two great ice streams. Also recognized the importance of local glacial erosion in making minor modifications of the landscape.	The role of local glacial erosion in minor landscape modification.
Kemp (1906)	Described cirques on flanks of mountain ridges; mentioned possibility of local glaciation.	Identification of cirques.
Cushing (1907)	Described cirques on flanks of mountain ridges; mentioned possibility of local glaciation.	Identification of cirques.
Miller (1910)	Described cirques on flanks of mountain ridges; mentioned possibility of local glaciation.	Identification of cirques.
Fairchild (1913)	Argued against the idea of local glaciation in the Adirondacks; envisioned the High Peaks as a bare rock area surrounded by the continental ice mass.	Established the controversy as to whether local glaciation played a role in the glacial history of the Adirondacks.
Goldthwait (1913)	Worked in the Presidential Range of New Hampshire; came to the conclusion that cirques were developed before continental glaciation and that cirque valleys were not reoccupied after the continental ice mass melted away. Same conclusions as Fairchild for the Adirondacks.	Helped establish the controversy by inference that if local glaciers could not exist in the Presidential Range, they could not exist in the Adirondacks.

Author	Contribution	Pertinence to Present Study
Johnson (1917, 1933)	Recognized lateral moraines in the Adirondacks as deposits from local glaciers; disagreed with Fairchild and Goldthwait on the interpretation of field evidence for local glaciation.	First to establish real field evidence of local glaciation.
Kemp (1921)	Wrote a generalized report on the Adirondacks; followed Goldthwait's idea of pre-continental local glaciation and used Fairchild's 1913 maps to illustrate the deglaciation of the Adirondacks.	Carried on the controversy.
Alling (1919, 1921)	Described in more detail the lateral moraine recognized by Johnson; described in detail a lake sequence in the Lake Placid region; recognized the late glacial origin of cirque glaciers.	Established more evidence of local glaciation after the melting away of the continental ice mass.
Miller (1925)	Described Glacial Lake Warrensburg extending from Luzerne, N. Y. to North Hudson.	Local glacial moraine at Blue Ridge, N. Y. has a delta built into this lake.
Balk (1932)	Recorded observation of glacial erratics; noted that highest peaks were free of erratics.	Substantiated by this author's observations on the lack of erratics on peaks higher than 4200 feet ASL.
Buddington (1937, 1953)	Briefly discussed the glacial history of the area and described specific valleys as being formed by local glaciation.	Identification of additional valleys of local glacial origin.

Author	Contribution	Pertinence to Present Study
Muller (1965a, 1965b)	Described a multiple till section at Tahawus, N. Y. with C^{14} date of greater than 55,000 B.P.	Demonstrates earlier period of glaciation.
Connally and Sirkin (1969)	Obtained C^{14} date from material in front of Luzerne Moraine that dates Glacial Lake Warrensburg at 12,400 B.P.	Established the time frame of reference for local glaciation in the High Peaks region.
Connally and Sirkin (1970b, and 1973)	Re-evaluated date of Luzerne Readvance to 13,200 B.P.	Established the time frame of reference for local glaciation in the High Peaks region.
Coates and Kirkland (1974)	Applied a theoretically derived ice model to the advance and retreat of the Laurentide ice sheet.	Suggested that ice surrounded the Adirondacks, overrode and melted leaving the High Peaks region ice free while surrounded by lobes of Laurentide ice.

CHAPTER II METHODS

2.1 PLANNING THE INVESTIGATION

Air photos and topographic maps were studied in detail in order to reduce the amount of field time in each area of study. The problem was to find evidence that would establish the glacial history of the Adirondack Mountains. Items of special interest were cirque-like landforms, moraines, and areas of possible glacial deposits exposed by erosion. The features identified in this preliminary study were then visited in the field. The cirque-like forms were checked for striations on the valley floor, streamlining of bedrock knobs and glacial deposits. Pebble orientation measurements were made in the tills found in these valleys. Till samples were collected for later laboratory study, and pebble identifications were made in the field and laboratory.

The light mineral fraction of the Adirondack tills was investigated as a means of establishing the source area of the glacier that formed the deposit. The author believes that if there was a period of local glaciation, this ice would originate, flow over and stop within the topographically high Anorthosite Massif, while the continental ice would have moved over the Paleozoic sedimentary rocks and a broad area of metasedimentary rocks before encountering the Anorthosite Massif. Since the mineralogy, especially the light mineral composition, of the sedimentary and metasedimentary rocks is distinctly different from the anorthosite mineralogy, the mineral composition of the glacial deposits would reflect the terrain over which the glacier had moved.

The metasedimentary rocks are composed of varying combinations of quartz, K-feldspar, and plagioclase feldspar with minor accessory minerals. The anorthosite is composed of almost 100 percent plagioclase feldspar with minor accessory minerals. Therefore the occurrence of quartz and K-feldspar in the tills indicates a metasedimentary source.

2.2 FIELD WORK

Field work was done during the summers of 1965, 1966 and 1967. The summer of 1965 was spent reconnaissance mapping the Raquette Lake district and checking the stratigraphy and geomorphology of cirque-like depressions containing lakes between 2000 and 3000 feet ASL. The second and third field seasons were spent in the High Peaks region of the Adirondacks. It was felt that there would be a greater probability of finding evidence to show the relationship between local and continental glaciers in this area of higher elevation where there is more mature development of cirque forms.

The interior part of the High Peaks region was studied during the summer of 1966. This field work included identification and distribution of erratics, mapping morainal topography and searching stream valleys for exposed sections of glacial deposits. During the summer of 1966 over 600 miles of trails were walked. All the mountain peaks over 4000 feet in elevation were inspected for the occurrence of erratics on their summits and on the slopes leading up to the summits.

Cirque depressions on Whiteface Mountain, Brothers, Big Slide, The Range, Giant and around Mount Marcy were examined for evidence of local ice accumulations as a source of mountain glaciation.

The summer of 1967 involved reconnaissance mapping along the roads throughout the High Peaks region. This field work comprised general mapping of glacial sediments at the scale of 1:62,500, locating and describing moraines and measuring exposed glacial deposits. Seventy-five till samples were collected for laboratory studies. Two-dimensional till pebble orientations were measured at seven sites in areas where local mountain valleys intersected the main valley system and twenty pebble samples were collected for quantitative investigation.

2.3 LABORATORY METHODS

2.3.1 GRAIN SIZE ANALYSIS

The sand, silt and clay fractions of ten till samples from the High Peaks region were determined using the standard pipette method of grain-size analysis of Krumbein and Pettijohn (1938). A cumulative granulometric curve was constructed for each sample, and the percentages of sand, silt, and clay were read from the curves using 2 mm as the upper sand boundary, 0.062 mm as the sand-silt boundary, and 0.002 mm as the silt-clay boundary.

2.3.2 PEBBLE ANALYSIS

The lithology of pebbles contained in tills was investigated in an attempt to determine the source area of the glacially transported material. Rocks identified were varieties of anorthosite, charnockite, amphibolite, gneiss, quartzite and Potsdam sandstone. Details of the method, the rock identification criteria and the results appear in Appendix B.

2.3.3. QUANTITATIVE MINERALOGIC ANALYSIS OF THE 0.044 mm to 0.125 mm LIGHT MINERAL FRACTION OF ADIRONDACK TILLS

Vagners (1969) found that minerals in tills are concentrated in grain-size fractions characteristic for each mineral. He (ibid., p. 124), suggested the size range 0.0039 mm to 0.50 mm for study of quartz and the feldspars. After consultation with Vagners, it was decided that the most workable size fraction for Adirondack till would be 0.044 mm to 0.125 mm.

Staining techniques were used to identify K-feldspar. Refractive Index Oil (R.I. 1.544) was used on the uncovered slides to aid in separating quartz from untwinned plagioclase feldspar. All counting was done on a petrographic microscope. Slide preparation and the staining method are described in Appendix C.

2.3.4 TILL PEBBLE ORIENTATION

A study of the two-dimensional orientation of elongate pebbles in till was made at eight sites. The method used and site locations appear in Appendix D and Appendix A respectively.

2.3.5 AIR PHOTO STUDY

Vertical air photographs at a scale of 1:10,000 were used to identify landform features and areas of glacial deposits for later field investigation. The air photographs were also used to identify cirques, which were then marked on the topographic map. The general characteristics of cirques in the High Peaks region are:

1. A sharp craggy rim separating the head of the valley from the uplands,
2. Cliffed head and/or side slopes cutting into the main ridge of the mountain mass,
3. Relatively flat valley floors in cross valley profiles,
4. A col through a mountain ridge at the head of the U-shaped

valley,

5. U-shaped valleys leading out from the mountain mass with one or more of the above mentioned characteristics.

Altogether, 224 cirque-like depressions were identified in the air photo study (figures 49, 51, 53, 55, 57 and 59). Various features were measured from the topographic maps including cirque position and aspect and schrund elevation.

Cirque aspect has been defined by Temple (1965) as the orientation of the cirque axis. The cirque axis is determined by tracing out the longest contour line within the cirque valley and bisecting this area with a line drawn normal to a line tangent to the curve of the contour at the back of the cirque.

Cirque position is the compass orientation of the center of the cirque bowl, measured from the highest point of the mountain mass. The center of the cirque bowl is defined as the geographic position of the schrund elevation.

The schrund elevation is defined by Goldthwait (1970) as the elevation of the intersection of the line of slope of the floor down the glacial trough with the line of slope of the steep central headwall (figure 7).

The schrund elevation was determined by two methods, either of which gives the same results:

1. Construction of longitudinal valley profiles and drawing on this profile the line of slope (figure 7).
2. By recording the elevation of the change in contour line spacing, where the contour lines are farthest apart, along the line of cirque axis. It was found that either method was

accurate on the 20 foot contour line spacing to within a limit of error of ± 100 feet.

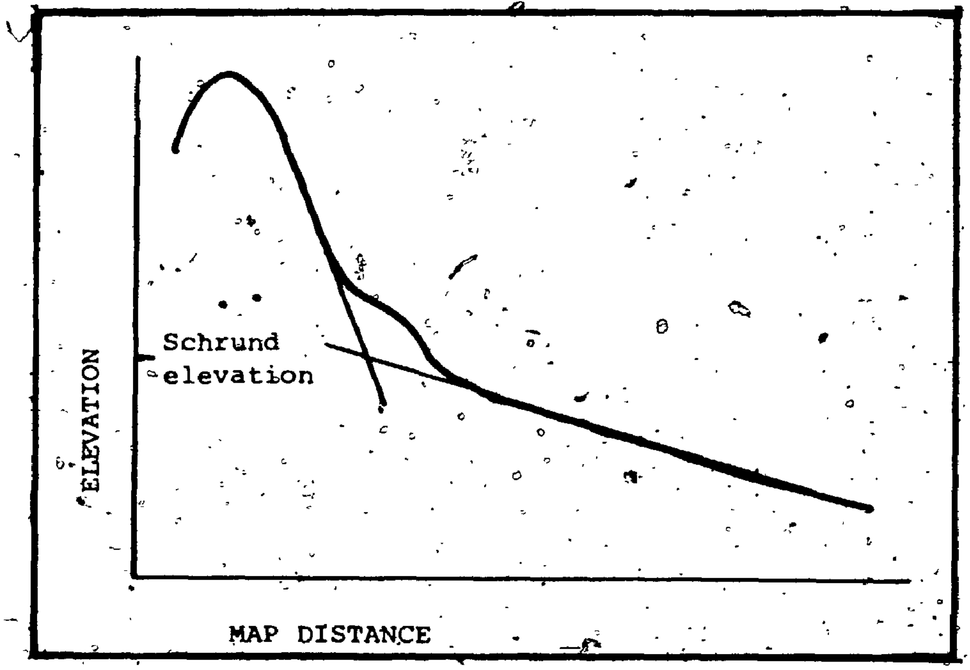


Figure 7. Determination of schrund elevation from a topographic profile.

CHAPTER III GLACIAL EROSION

Many glacial erosional landforms are found in the Adirondack Park: U-shaped valleys, cirques, truncated spurs, rounded and smoothed bedrock hills, hanging valleys and serrated skylines.

3.1 U-SHAPED VALLEYS

The region is characterized by broad, open, flat-floored valleys dividing the highlands into a series of isolated mountain masses. Each mountain mass has been dissected by valley glaciers with the upper part of these valleys ending in amphitheater-shaped cirques. The major valleys are oriented northeast-southwest. All of the main valleys start in the high mountains as steep-walled narrow passes which broaden to form U-shaped open valleys at lower elevations. Glacial erosion has steepened the valley sides to form typical glacial troughs. Many of the tributary valleys also exhibit U-shaped form (figure 8). Glacial drift deposited on the sides and in the bottoms of the main valleys partially obscures the U-shaped form; however, this form has been preserved in the fault-controlled mountain passes. The best examples of this preservation occur at Avalanche Pass, Chapel Pond (figure 8), Wilmington Notch, Cascade Lakes, and the Ausable Lakes Pass.

3.2 CIRQUES

This study has established three types of cirques based on size, position and relationship to the associated valleys:

1. Isolated cirque basins which are not connected to lower U-shaped valleys,

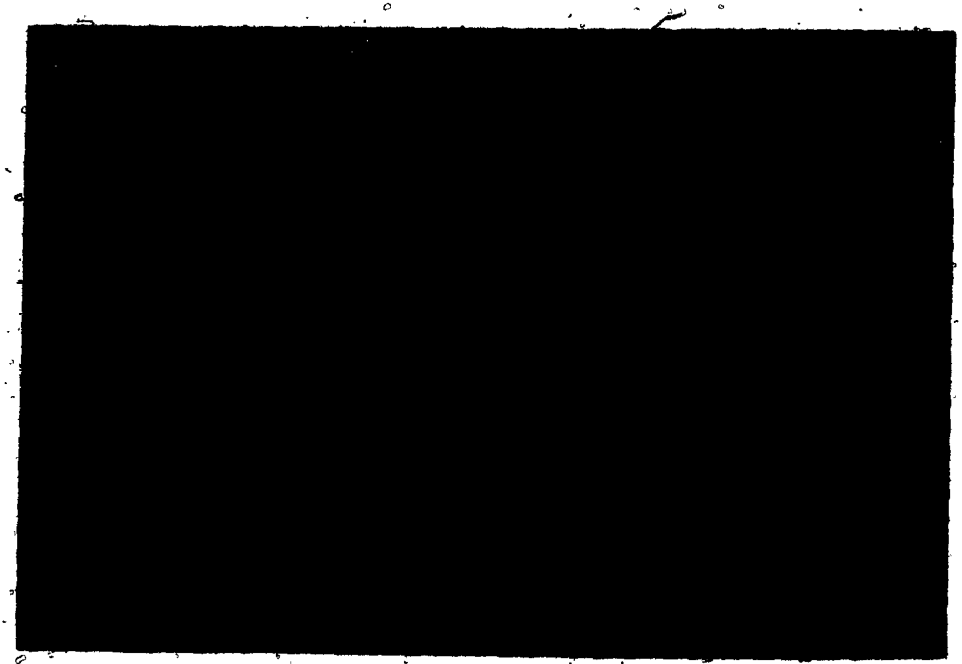


Figure 8. Giant Mountain - Chapel Pond Pass is the U-shaped valley to the right of Giant Mountain. Taken from First Brothers. Note the arm-chair cirque form of the Roaring Brook Cirque on Giant Mountain.

2. Single cirques at the heads of short U-shaped valleys which terminate abruptly on entering a main valley, and
3. A series of cirque amphitheaters all of which open into one large U-shaped valley which ends abruptly on entering a main valley.

The deposits directly related to these cirques (moraines, protalus ramparts, etc.) will be described together with the corresponding cirques.

3.2.1 ISOLATED CIRQUE BASINS

The nivation cirques which are not directly part of a U-shaped valley are relatively small. This type of cirque can also be referred to as a hanging cirque. These depressions are cut into bedrock and contain small tarn lakes. Morainal ridges extend from the sides of the cirque toward the middle of the valleys. These ridges have been breached by erosion and, in some cases, have been blocked by beaver dams. The outlet streams drop rapidly over a series of step-like waterfalls to the lower drift-filled valleys.

Four nivation cirque depressions in the High Peaks region were investigated. They are:

(a) Redfield Cirque, occupied by an unnamed lake, on the south side of Mount Redfield (figures 6; region N, and 9),

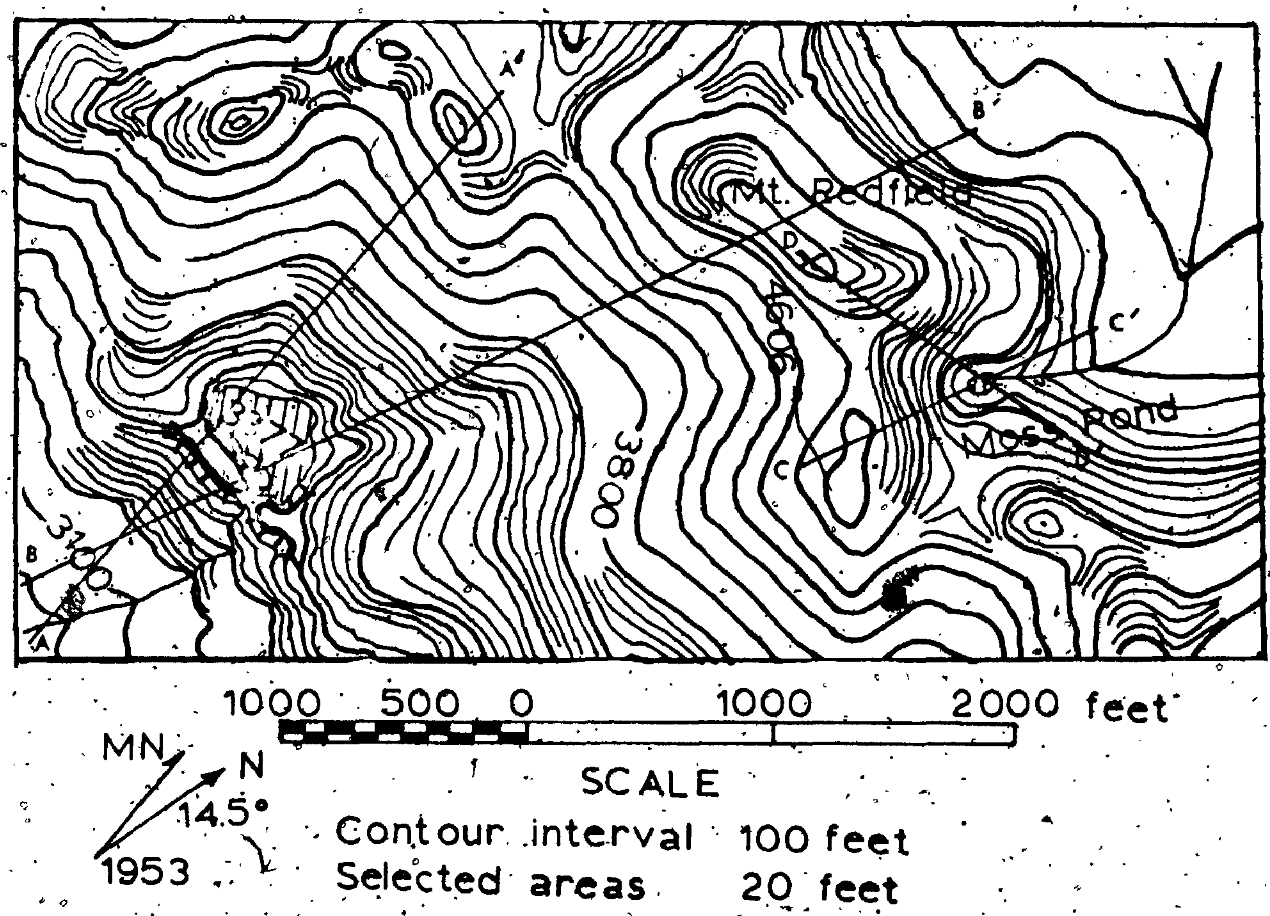
(b) Moss Pond Cirque on the north side of Mount Redfield (figures 6, region N; and 9),

(c) Cooperkill Pond Cirque on the south side of the Wilmington Range (figures 6; region A, and 12),

(d) Weston Mountain Cirque, located on the south side of Weston Mountain (figures 6, region J; and 13).

3.2.1.1 REDFIELD CIRQUE

The Redfield Cirque and its associated tarn lake are located on the south side of Mount Redfield, about 2000 feet from the mountain peak, left center Mount Marcy Quadrangle (figures 6, region N; and 9). Elevation of the tarn lake is 3377 feet ASL.



Moraine

Figure 9. Topographic map of Redfield and Moss Pond Cirque. For topographic profiles, see figure 11.

Figure 10. Aerial view of Redfield tarn looking north. Note the bog vegetation filling the lake.

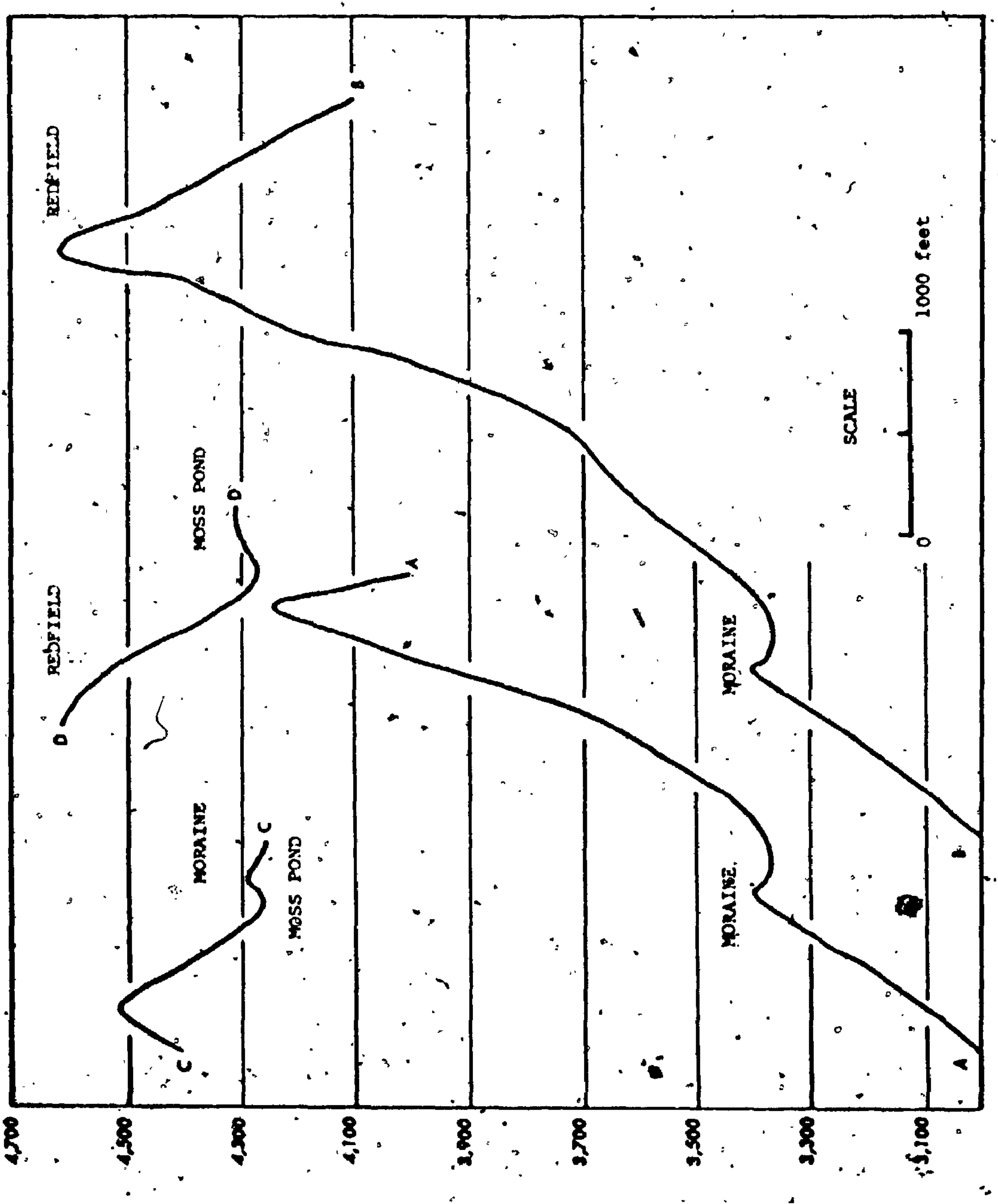


Figure 11. Topographic profiles of Redfield Cirque and Moss Pond.

Mount Redfield and the surrounding area are composed of Marcy anorthosite. The major joint directions in this area are 041° and 275°. The dip of the joint planes is nearly vertical (80° to 90°).

The backwall of the cirque extends from the lake surface to the top of Mount Redfield (4606 feet ASL), over a horizontal distance of 0.7 miles (figure 9). Thus the gradient of the backwall is 1755 feet per mile. The orientation of the cirque opening (figure 9) is 185°.

The flooded area within the cirque depression is approximately 500 feet long and 300 feet wide and is mostly filled with bog vegetation. The depth of the depression could not be measured because of lack of suitable probing rods; however, an eight foot probe did not reach the bottom of the depression in the center of the bog. The moraine blocking the outlet of the cirque depression stands 18 feet above the lake surface. This moraine has been breached to the bedrock surface by the outlet stream. An abandoned beaver dam partially blocks the present outlet. The outlet stream flows over a relatively level bedrock surface for approximately 300 feet then drops over a 35-foot cliff and cascades to the drift-filled valley below. The gradient of the stream to the junction of Skylight Brook is 123 feet per mile.

3.2.1.2 MOSS POND CIRQUE

Moss Pond, the true source of the Hudson River, is a small tarn lake located on the northeast side of Mount Redfield. The pond lies in an amphitheater-shaped depression 341 feet below the crest of the mountain (figures 6, region N; 9 and 11). The depression is eroded into the Marcy anorthosite. The major joint directions observed were 045° and 272°. The depression is oriented 019°. The elevation of the lake surface is 4265 ±.5 feet ASL. The backwall of the cirque extends from the lake surface to the top of Mount Redfield (elevation 4606 feet ASL) over a horizontal distance of 0.25 miles, which gives a slope gradient of 1364 feet per mile. The lake is contained in a depression cut into bedrock with an eroded moraine partially blocking the outlet. The undissected part of this moraine stands about six feet above the level of the lake. Much of the lake depression has been filled with bog vegetation. The depth of the lake is undetermined but is greater than six feet, the length of the probe available.

3.2.1.3 COOPERKILL POND CIRQUE

Cooperkill Pond is located on the southwest end of the Wilmington Range just north of Morgan Mountain in the Lake Placid Quadrangle (figures 6, region A; and 12). The backwall of the cirque extends from the lake surface (elevation 3002 feet ASL) to the high point on the Wilmington Range (elevation 3340 feet ASL) over a horizontal distance of 0.25 miles, which gives a slope gradient of 1352 feet per mile. Cooperkill Pond Cirque is different from the other nivation cirques in that it lies at the intersection of two mountain ridges, the Wilmington Range striking 037° and the Stephenson Range striking 086°. The outlet stream flows through a low pass to the east.

The outlet of the pond is partially blocked by a broad, flat surfaced, boulder strewn ridge, the lower part of which is cut by the outlet stream. The ridge is from 15 to 25 feet above the pond surface near the outlet stream and rises to the north. The top of the ridge is relatively level, with numerous boulders of Whiteface anorthosite scattered on the surface. The ridge is from 200 to 500 feet across and the slope

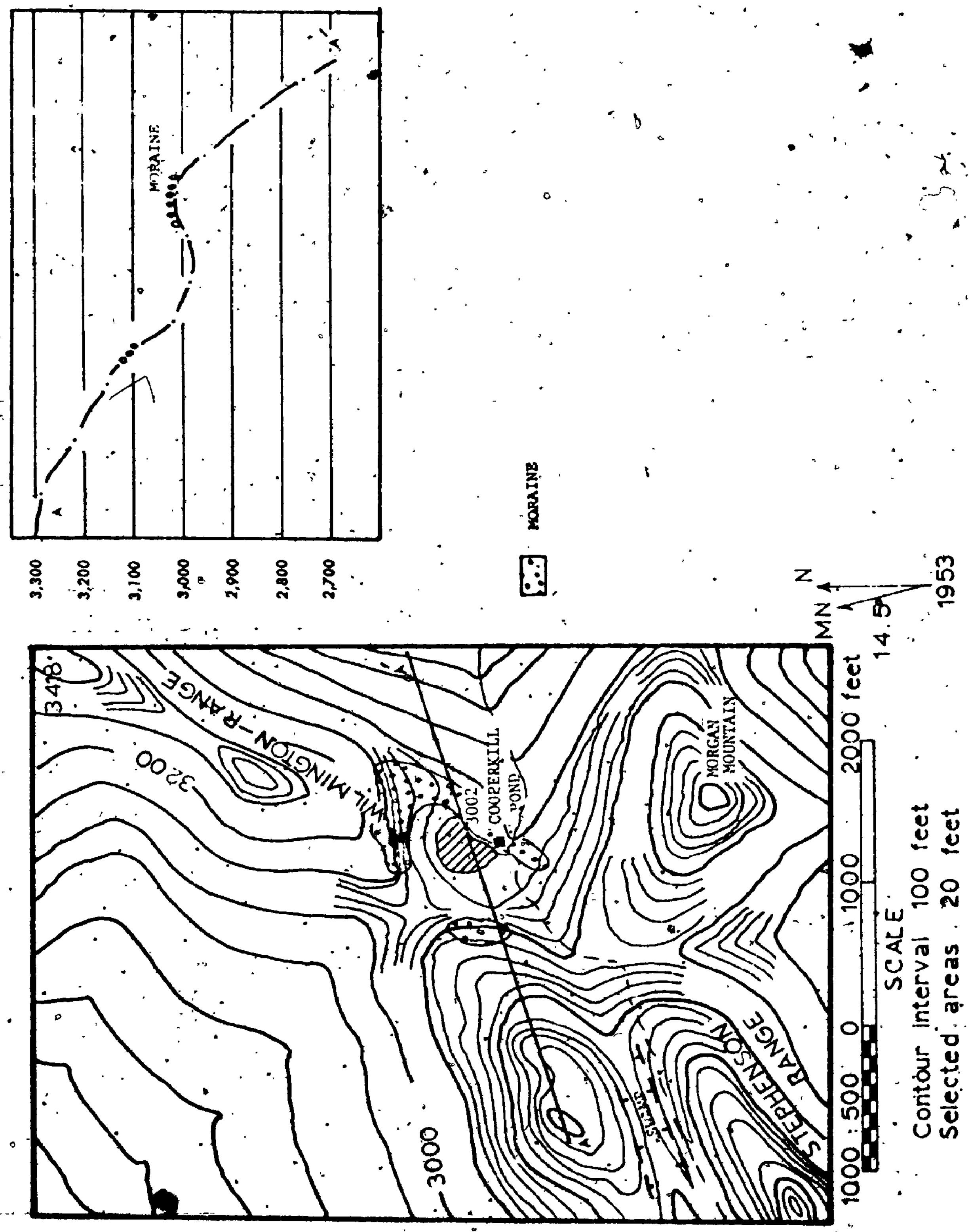


Figure 12. Topographic map and profiles of Cooperkill Cirque.

changes abruptly at the outer edge to approximately 30° and extends down into the lower valley.

The morainal ridge rises to the north with a slope of 10° to 15° to the elevation of approximately 3210 feet ASL where bedrock is exposed in a 40-foot cliff. Bedrock is exposed from this elevation to the top of the mountain.

Talus accumulations were observed all along the base of the bedrock cliff on the north and west sides of the cirque depression. The talus is composed of large two-to five-foot boulders of Whiteface anorthosite. This talus accumulation ends abruptly at an elevation of 3140 to 3180 feet ASL. No large boulders were observed between the boulder line and the water's edge. This boulder line marks the edge of a protalus rampart on the north side of the pond. The south shore contains numerous boulders both in the water and in the woods to the south of the shore.

The pass to the southwest is eroded into bedrock and is filled with glacial drift. An abandoned outlet channel cuts through the drift. This channel is flat-floored, 100 to 150 feet wide, with steep sides and is 20 to 50 feet deep. The bottom of the channel (elevation approximately 3210 feet ASL) ~~is~~ a swamp and is the headwater area for the stream flowing southwest off the mountain.

Cooperkill Pond Cirque is not a true cirque in the geomorphic sense of landform development. The cirque-like depression has three outlets and therefore might be better described as a saddle cirque or mountain crest cirque with ice flow in three directions simultaneously during ice occupation of the cirque basin. The existence of the protalus rampart configuration of the lake depression and morainal deposits are evidence of ice occupation and sculpture to form the present topography.

3.2.1.4 WESTON MOUNTAIN CIRQUE

The Weston Mountain Cirque and its associated tarn lake, Lost Pond, are located on the southeast side of Weston Mountain in the southeast corner of the Ausable Forks Quadrangle (figures 6, region J; and 13). Elevation of the pond surface is approximately 2850 feet ASL. The backwall of the cirque extends from the lake surface to the summit of Weston Mountain (elevation 3195 feet ASL) over a horizontal distance of 0.5 miles, which gives a slope gradient of 690 feet per mile. The pond is from two to four feet deep in the center and is elongated in the north-south direction. Bedrock is exposed along most of the shoreline except in the northernmost part where the pond is filled with bog vegetation. The geologic map shows a contact between charnockite and anorthosite in the southern part of the pond (figure 13). Weston Mountain is composed entirely of charnockite.

A well developed moraine swings across the opening of the depression from the west wall of the cirque and is breached by an outlet stream. The moraine is approximately 190 feet wide near the outlet stream and narrows to fifty feet as it rises toward the side of the valley at the base of a twenty-five-foot bedrock cliff.

The outlet stream flows over a relatively flat bedrock surface, then drops over a thirty-foot waterfall, then over a series of smaller falls to the lower valley.

3.2.2 SINGLE CIRQUES WHICH CONTINUE INTO SHORT U-SHAPED VALLEYS

This type of cirque originates on the side of a mountain and opens into a major valley. A U-shaped trough extends directly from the high area to the main valley bottom. The valleys are relatively short; from

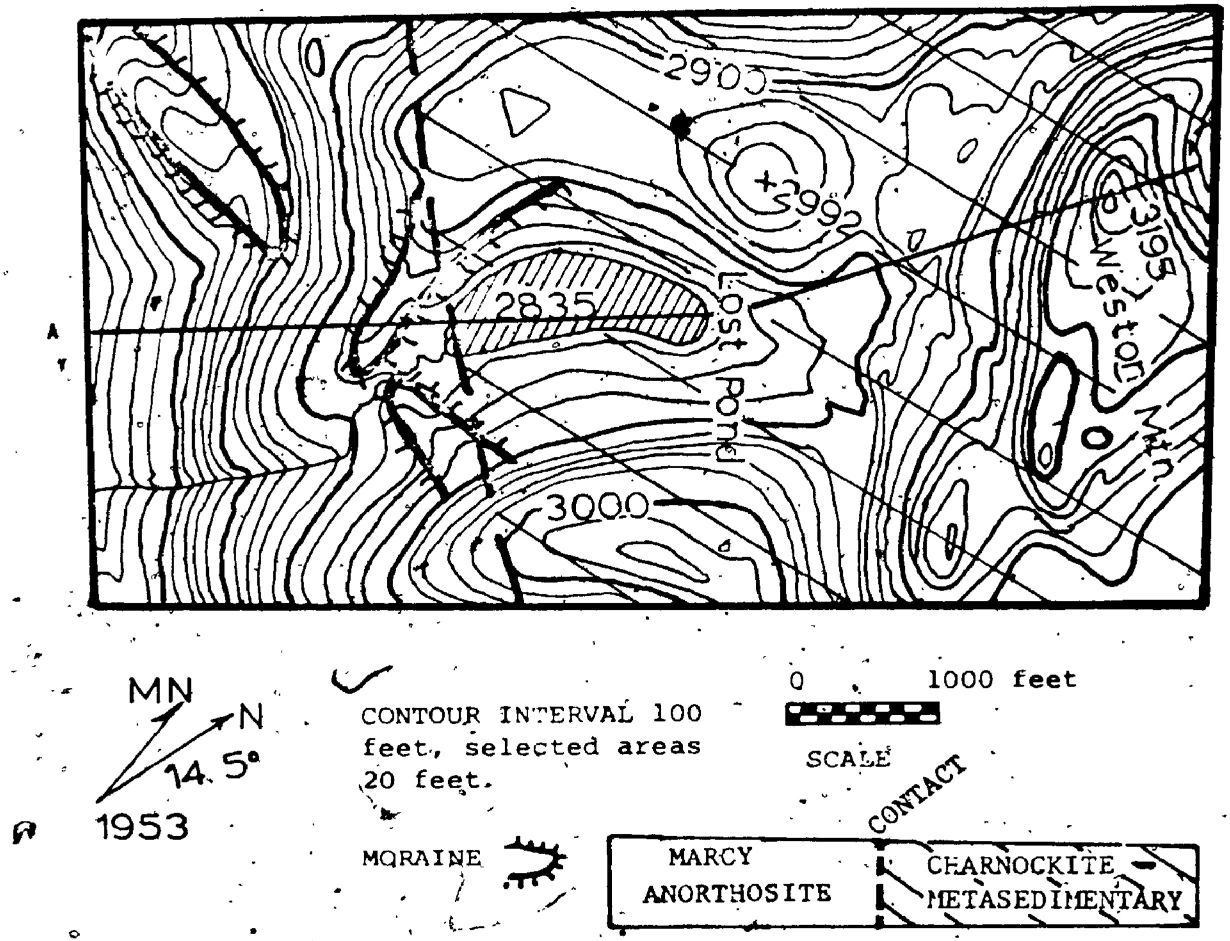
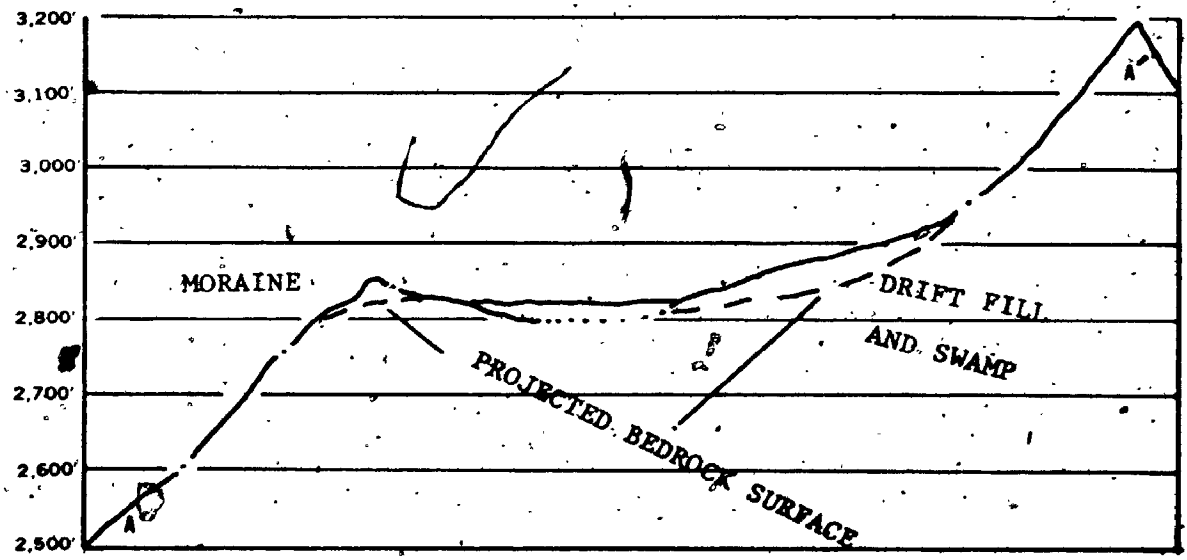


Figure 13. Topographic map and profile of Weston Mountain Cirque.



5,000 to 10,000 feet long from the horn at the head of the valley to the point where the sides of the valley terminate. The valley sides are very steep with many vertical cliffs, and the valley narrows toward the outlet. None of the single valley cirques contains a lake, although there is frequently swampy ground at the schrund elevation. Some of the valleys of this type have lateral moraine ridges along the valley sides. These ridges are subdued and difficult to identify because of forest cover and mass wasting of the slopes.

Map and field studies have identified twenty-nine single cirque valleys (figures 49, 51, 53, 55, 57 and 59). Three of these will be discussed in detail. They are:

(a) White Brook Valley Cirque (figures 6, region B; and 14),

(b) Giant Mountain Roaring Brook Valley Cirque (figures 6, region K; and 21), and

(c) Boreas Mountain Cirque (figures 6, region M; and 28).

3.2.2.1 WHITE BROOK VALLEY CIRQUE

White Brook Valley is located in the Lake Placid Quadrangle (figure 6, region B) on the northeast side of Whiteface Mountain between Esther Mountain (4240 feet ASL) and Lookout Mountain (4100 feet ASL). The valley is oriented 055° (figure 14). It is approximately 3000 feet wide and 9000 feet long. The northwest and south sides and the backwall are nearly vertical. The head of the valley forms a pass or col through the mountain mass at an elevation of 3860 feet ASL. White Brook flows on the bedrock surface from an elevation of 2900 feet ASL to 1820 feet ASL where it encounters the thick drift cover of the main valley. The stream has cut a deep V-shaped valley along the axis of

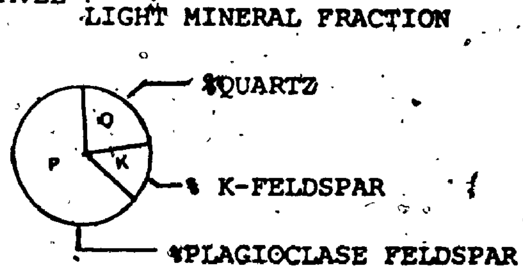
LEGEND

ROCK TYPE

- ☐ WHITEFACE ANORTHOSITE
- ▣ PINK ANORTHOSITE
- ▧ MARCY ANORTHOSITE
- S POTSDAM SANDSTONE ERRATICS
- ○ SITE AND SAMPLE NUMBER

GLACIAL DEPOSITS

- ▥ TILL
- ▤ LACUSTRINE SAND, SILT CLAY
- ▨ ALLUVIAL FAN DEPOSITS, SAND AND GRAVEL
- MORAINE
- DELTA
- BEACH



OTHER

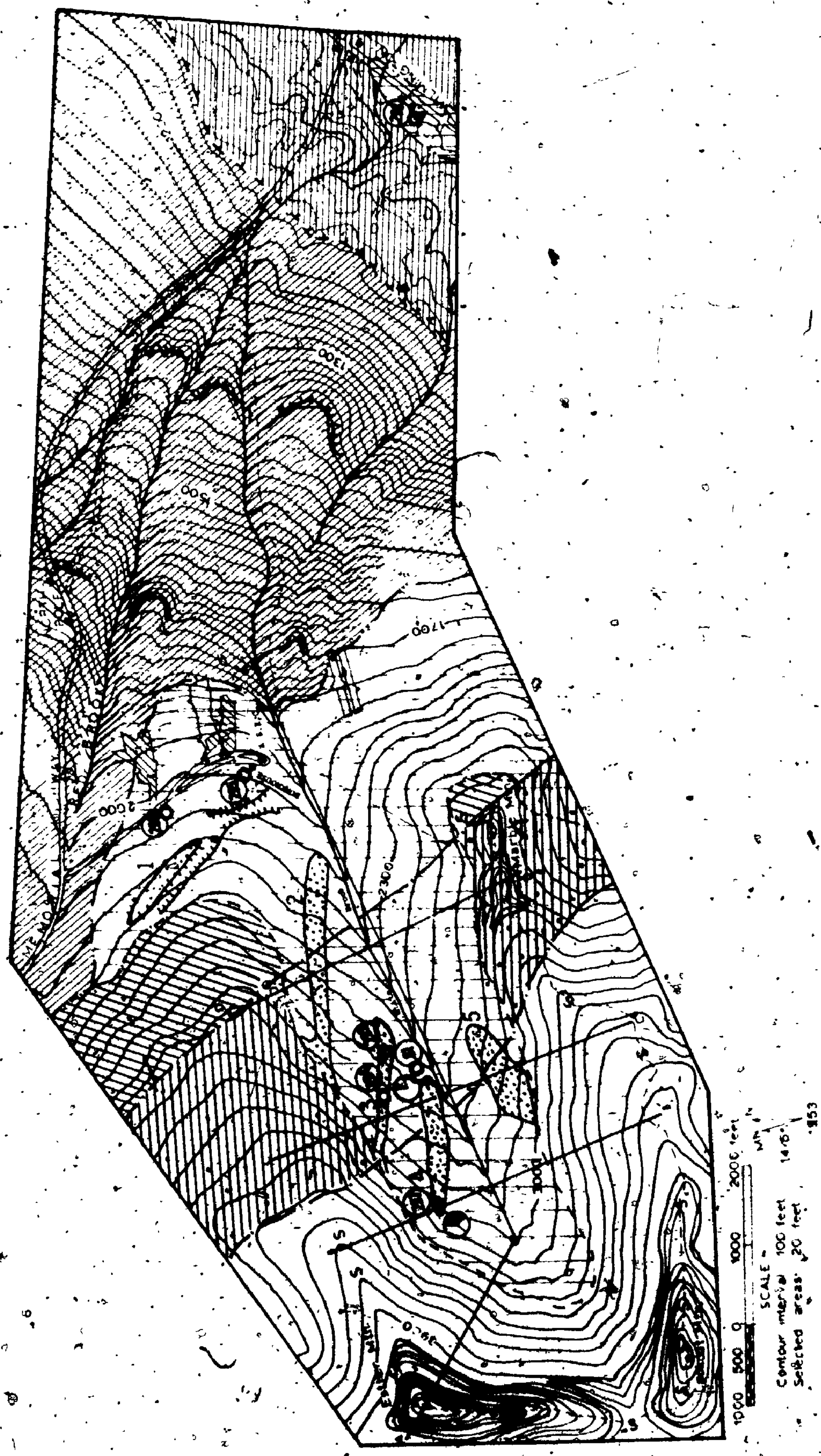
APPROXIMATE DRIFT BEDROCK CONTACT

APPROXIMATE CONTACT BETWEEN TWO ROCK TYPES

A-A' Topographic profile line (see figure 15)

Topographic data from U.S.G.S. manuscript map.

Figure 14. Topographic Map with Bedrock and Glacial Deposits, White Brook Valley.


1300
1500
1700
2000
2300
1000 500 0 1000 2000 feet
SCALE
Contour interval 100 feet
Selected areas 20 feet
MN
14½°
1953

the U-shaped drift-filled trough.

The bedrock of this part of the mountain consists of various types of anorthosite. The upper elevations show extensive exposures of Whiteface anorthosite. The middle portion of the valley is composed of a light green to pink anorthosite with one-quarter-to two-inch phenocrysts of pink plagioclase. The lower part of the valley floor and Marble Mountain are composed of Marcy anorthosite with one-to five-inch phenocrysts of labradorite.

The vertical distance from the back rim of the cirque amphitheater to the change of slope of the valley floor (schrund elevation) is 1240 feet. The horizontal distance from the top of Mount Esther to the schrund elevation is 0.55 miles which results in a gradient of 2254 feet per mile. The gradient of the valley below the schrund line is 614 feet per mile. Longitudinal and transverse profiles are shown in figure 15.

Esther Mountain can be classified as a horn in the youthful stage of erosional development. Cirque erosion has isolated the mountain peak from the rest of the mountain mass (figure 14). The three ridges radiating out from the peak are very narrow (thirty feet at one point on the northeast ridge) with nearly vertical sides. These ridges change to broad gently sloping bedrock surfaces at an elevation of between 3600 to 3700 feet ASL. This broad flattened surface is covered with numerous Potsdam sandstone erratics lying on the surface and caught in the open joints.

The occurrence of Potsdam sandstone pebbles lying on the surface is indicated by the letter "S" in figure 14. No Potsdam sandstone pebbles were observed on the top of Esther Mountain. The ridge below

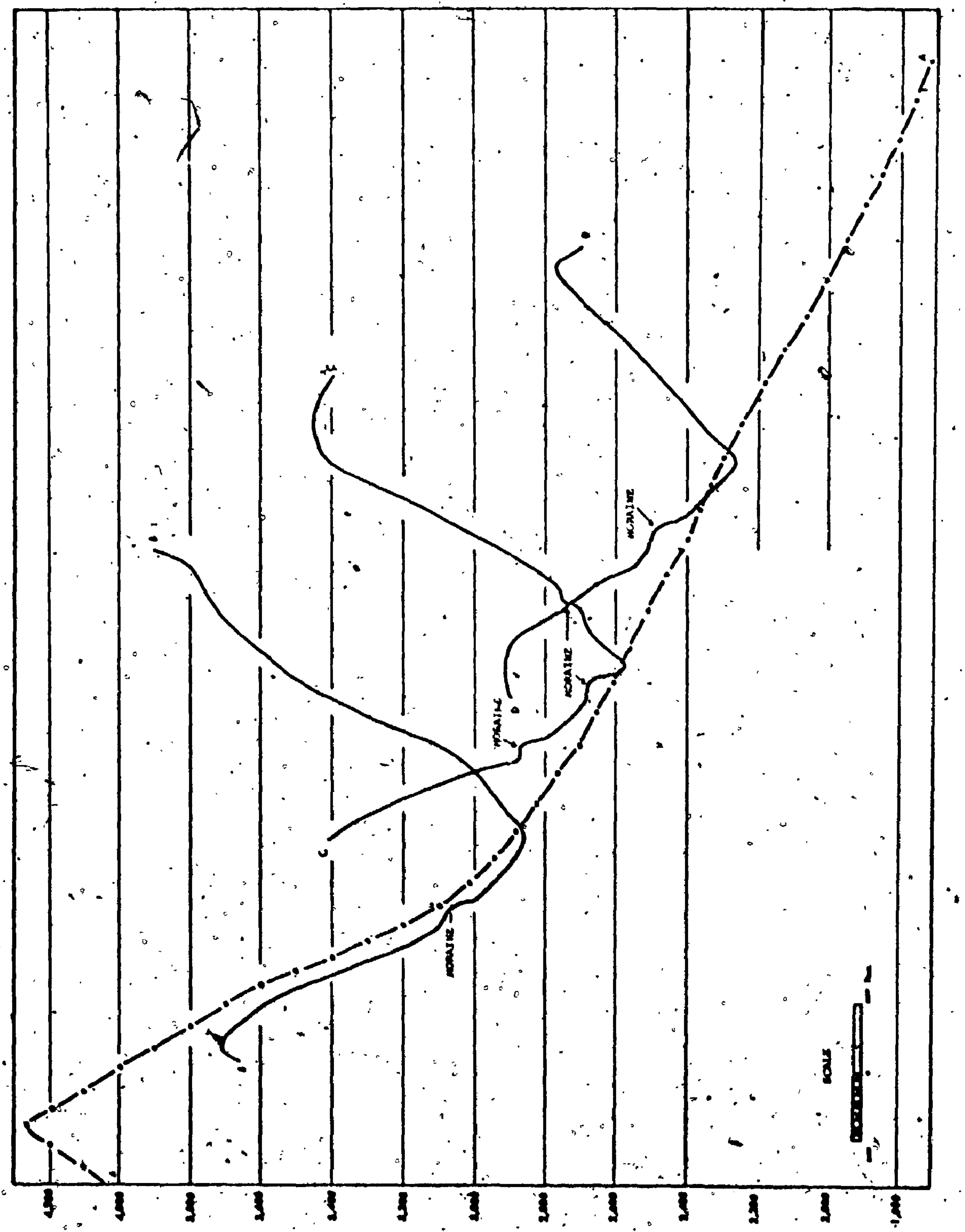


Figure 15. Longitudinal and cross valley topographic profiles of White Brook Valley.

Figure 16. Moraine four of White Brook Valley, south slope.

Figure 17. View of moraine four, White Brook Valley. Looking east from highest point on the moraine.

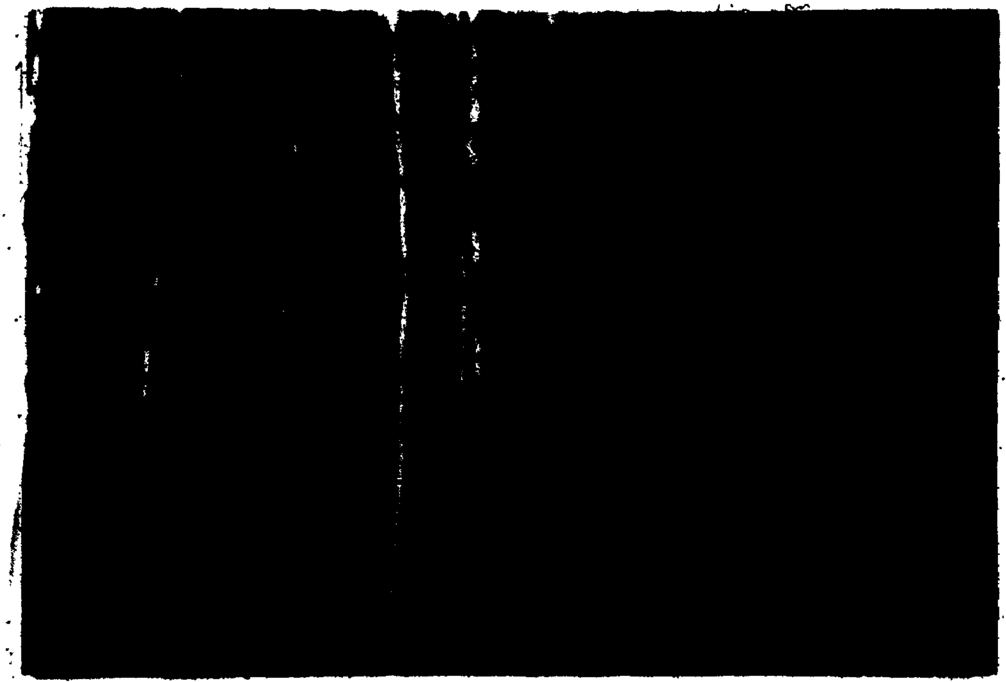


Figure 18. Large anorthosite erratic on distal slope of moraine two, White Brook Valley.

the peak of Esther Mountain, however, contained numerous Potsdam pebbles scattered over the bedrock surface and in the joint cracks.

Till-pebble orientations were measured at sites 295 and 296, and their rose diagrams are plotted on figure 14; the results of light mineral studies of two till samples are included in figure 14 adjacent to the sample locations. Nine pebble counts were made. The results are shown in table 3.

Five moraines have been identified in White Brook Valley: three on the northwest side of the valley, one on the southeast side and one above the A.S.R.C. access road: the moraines have been numbered 1-5 on figure 14.

Moraine number five is composed of boulders one to five feet in diameter which form a pronounced boulder terrace with the steepest side parallel to White Brook. The boulders become smaller up the slope and end abruptly at the base of a very steep slope.

Moraines two and three are very similar. These two ridges are composed of till with boulders lying on the surface. Most of the boulders are found on the crests of the ridges and on the north or open valley side of the ridges. Figure 18 is a photograph of the largest block seen on any of the moraines. It lies about twenty feet below the crest on the north slope of moraine two.

Moraines one and four are composed predominantly of sand and gravel, with boulders lying on their crests. Figure 19 is a measured section of moraine four. Figures 16 and 17 are photographs of moraine four. This is the only moraine where it was possible to study its internal composition.

Moraine number one is somewhat different in that the ridge runs

Table 3. Pebble Composition in White Brook Valley Drift

ROCK TYPE	SITE NUMBERS AND ELEVATIONS						
	61 2540' ASL	294 2780' ASL	295 2000' ASL	296 2060' ASL	297 3000' ASL	293 2520' ASL	298 1130' ASL
Pink Anorthosite %	-	10.4	38.5	30.5	2.0	22.2	23.3
Whiteface Anorthosite %	40.0	77.5	25.5	43.2	64.0	50.1	20.3
Marcy Anorthosite %	17.0	0.8	12.4	7.8	-	8.4	13.1
Potsdam Sandstone %	31.0	-	10.5	4.9	25.0	5.5	16.8
Charnockite %	7.0	9.6	3.7	9.8	5.0	10.2	14.0
Amphibolite %	5.0	1.7	4.7	1.9	0.9	12.5	1.9

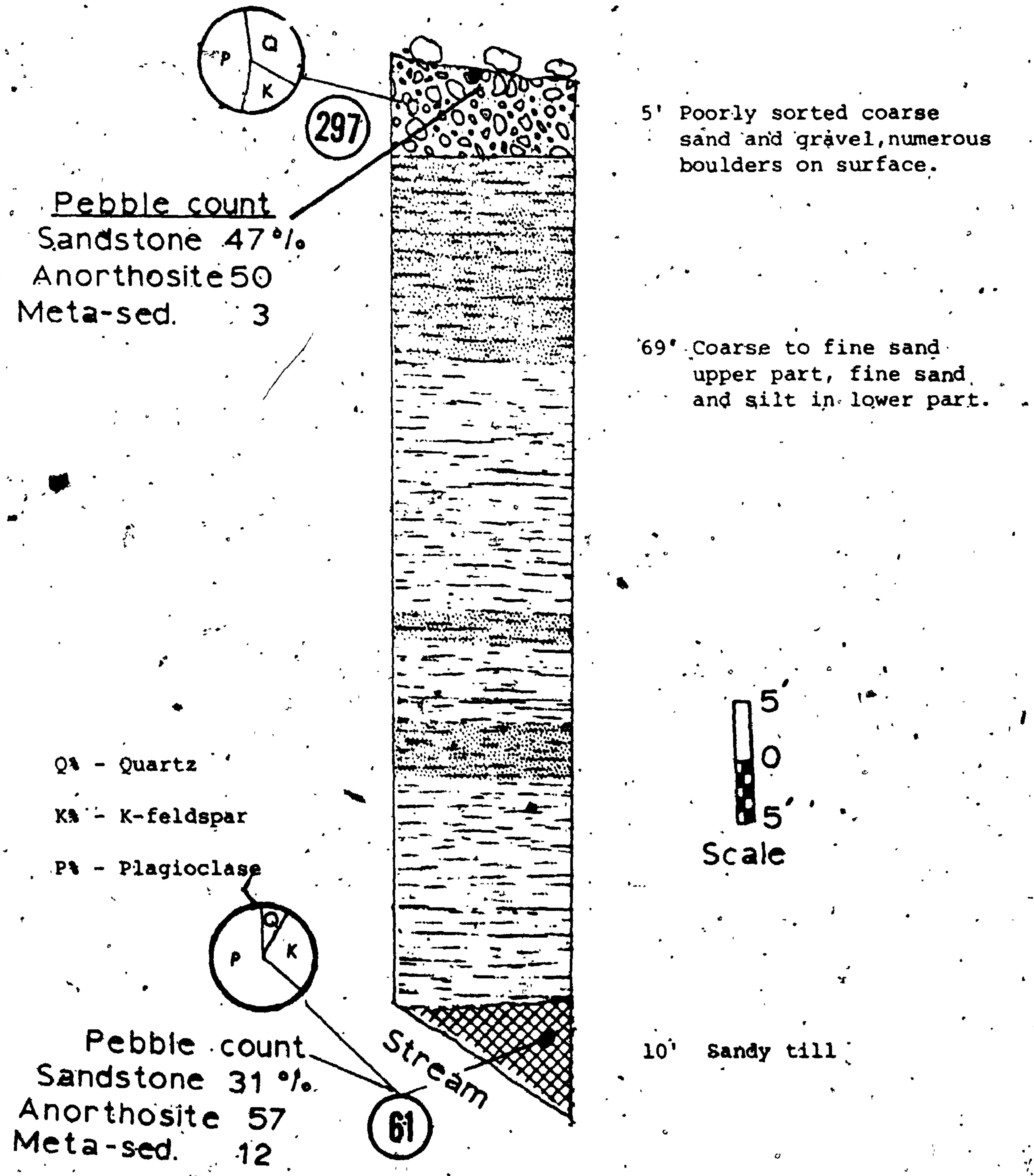


Figure 19. Measured section Moraine 4, White Brook Valley.

nearly parallel to the valley side. The morainal ridge stands from ten to thirty-five feet above the small valley formed between the moraine and the main valley side. The crest of the ridge is narrow. There are boulders lying on the crest and southwest slope of the moraine but the ridge appears to consist mainly of coarse sand and gravel. The northwestern end of the moraine starts at a bedrock cliff and continues to the southeast (figure 14). The ridge decreases in height but continues at approximately the same elevation until it disappears into a kame terrace just northwest of the first ski slope clearing north of the A.S.R.C. Headquarters. A meltwater channel starts on the south side of the kame terrace and continues to the north edge of White Brook Valley where it disappears into another kame terrace.

Seven till exposures were studied. The locations of these exposures are shown in figure 14. Potsdam erratics were identified in all of the pebble studies (table 3) except for the count made on moraine three, site 294. The highest percentage of Potsdam erratics was found in the upper part of moraine four, site 297. The next highest percentage occurred in the till exposed behind the A & W Root Beer stand (site 298) at the bottom of Wilmington Valley. The presence of Potsdam sandstone in the valley and along the ridges on each side of the valley indicates transportation and deposition by the continental ice sheet.

However, the composition of the light mineral fraction of the till (sample 61) and the distribution of locally derived rock fragments in the valley relative to the positions of the different types of bedrock exposed in the valley presents a different picture. Sample 61 was collected from an exposure of lodgement till in the lower part of moraine four (site 61). It contained 9% quartz, 28% K-feldspar and 64%

plagioclase feldspar. This composition indicates that ice overrode anorthosite bedrock. The anorthosite bedrock outcrops throughout the Wilmington Valley from White Brook Valley northward approximately ten miles to Black Brook. Therefore, this till could have been deposited by local ice moving northeast from White Brook Valley or by continental ice moving southwest into White Brook Valley. Sample 62 collected from ablation drift in the upper part of moraine four (site 297) contained 39% quartz, 19% K-feldspar and 46% plagioclase feldspar indicating a metasedimentary rock origin of the deposit, the nearest source of which is north of Black Brook.

Pebble lithologies of the White Brook Valley drift are particularly informative. Field work in the High Peaks area established that pink plagioclase anorthosite occurs only in White Brook Valley and on the ridges on either side of the valley. The northernmost exposure of pink plagioclase anorthosite was observed on the south side of the Lake Stevens Pass which separates Esther Mountain from the Wilmington Range. The southernmost exposure was observed on the south side of Marble Mountain, the south ridge of White Brook Valley. These findings were confirmed by Crosby in 1966 (personal communication).

Appendix B shows the percent of each pebble type identified throughout the High Peaks region. The pink anorthosite was found only in samples collected in White Brook Valley and at a single site on the Wilmington-Franklin Falls Road, west of Lake Stevens Pass (site 55). This road goes through the pass between Esther Mountain and the Wilmington Range.

The highest percentage (39%) of pink anorthosite pebbles occurred at site 295 (figure 13) and the next highest (31%) in the exposure north of the bunkhouse along the access road (site 296). The third highest percentage (23%) was at site 298 at the bottom of the valley. Table 3 is arranged to show the distribution of the pink plagioclase from the upper moraine (column one) to the lowest part of the valley (column 6) in descending order of elevation and valley position. These data show an increase in pink anorthosite composition across the outcrop belt in the down valley direction to a maximum at site 295, then a decrease at the bottom of the valley (site 298). Figure 20 shows pink anorthosite boulders excavated from the till at site 298. All of these boulders except the sixth from the left (Whiteface anorthosite) are pink anorthosite. Note the well developed flat surfaces cut on boulders 1, 3, 4, 7, 8, and 9. These flat faces are glacially ground facets with numerous striae clearly demonstrating glacial transport.

The abundance of Potsdam sandstone and metasedimentary fragments (table 3) suggests a continental glacial origin of the drift. If the deposits were formed by the southwest moving continental glacier only, the lowest elevation in White Brook Valley that the ice would encounter a pink anorthosite outcrop would be 2300 feet ASL. Since the continental glacier would be moving up the valley, no pink anorthosite fragments should be found below 2300 feet ASL. The pink anorthosite fragments occur in deposits below the outcrop with a decreasing concentration as the distance downslope from the outcrop increases. This distribution clearly indicates a northeast flow of ice at least as far as site 298. Ice flowing in this direction must have been of local origin. The Potsdam sandstone and metasedimentary rock fragments associated with the pink anorthosite fragments indicate a

Figure 20. Pink anorthosite erratics from excavation at A & W Root Beer Stand, site 298; numbering in text is from left to right.

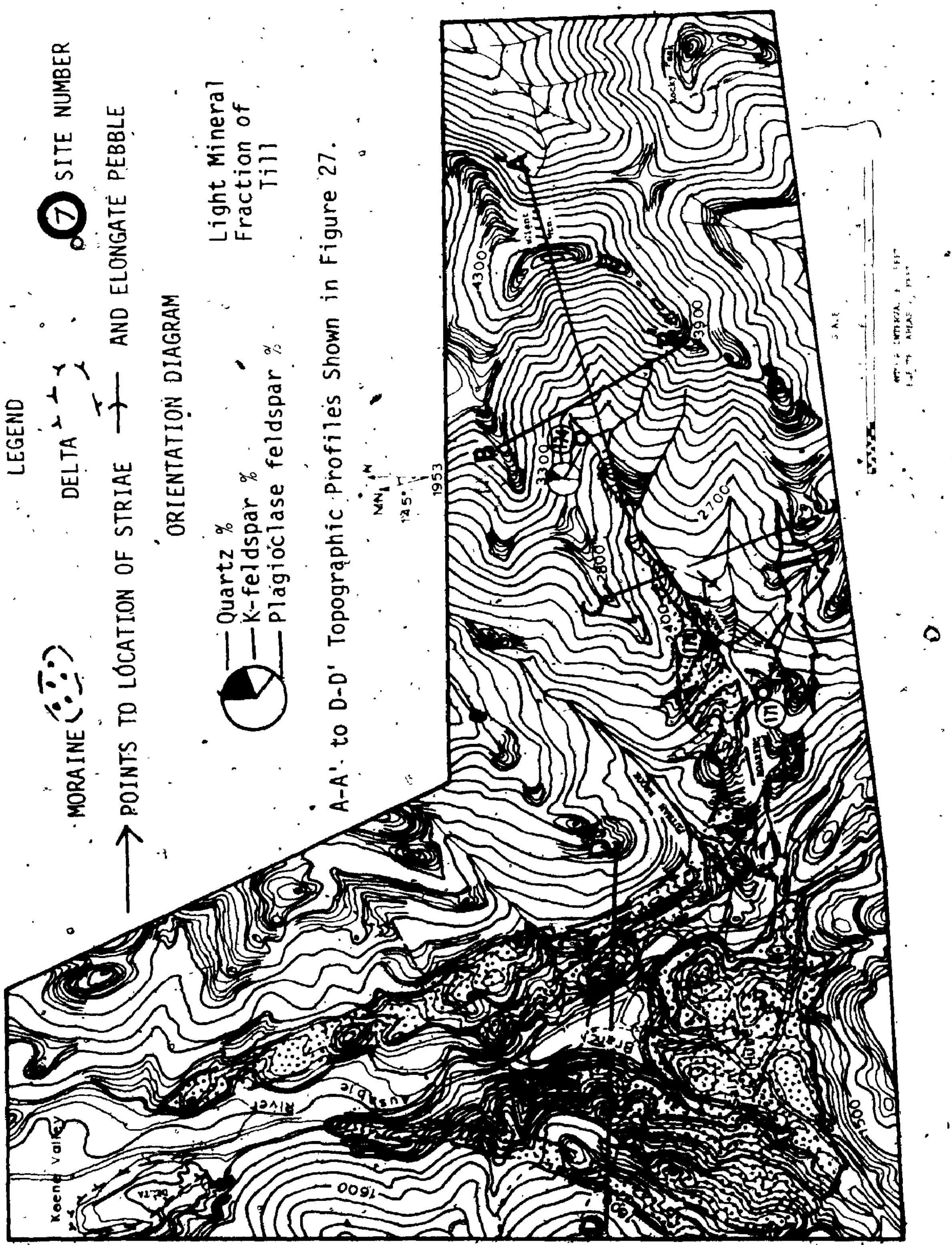


Figure 21. Topographic map Giant Mountain-Roaring Brook Cirque.

reworking of previously deposited continental drift.

The moraines in the upper part of the valley between site 298 and moraine four are recessional moraines. Moraine four (site 297) is an ice stagnation ablation moraine. The high concentration of Potsdam sandstone and metasedimentary rocks (table 3) which occurs on the surface of this moraine is believed to be due to surface sliding of debris from the ridge above the moraine. This ridge, composed of Whiteface and pink anorthosite, is covered with a thin veneer of Potsdam sandstone and metasedimentary erratics.

It could be argued that the distribution of pink anorthosite is not due to a local ice mass but has resulted from a massive landslide following deglaciation of the continental ice mass. However, sites 295, 296, and 298 have the appearance of lodgement tills, and the matrix is compressed tightly around larger fragments. The faceted surfaces on the boulders before excavation at site 298 were observed to be nearly parallel to the ground surface in the outcrop. Such uniformity of position could occur only by ice transport, not by landslide.

Summarizing all the evidence discussed, a conclusion is drawn from the White Brook Valley glacial deposits that they were deposited by local glacial ice moving northeast, out of the cirque at the foot of Esther and Lookout Mountains.

3.2.2.2 GIANT MOUNTAIN-ROARING BROOK CIRQUE

Roaring Brook Valley is located on the west side of Giant Mountain (4627 feet ASL) in the Elizabethtown-Mount Marcy Quadrangles

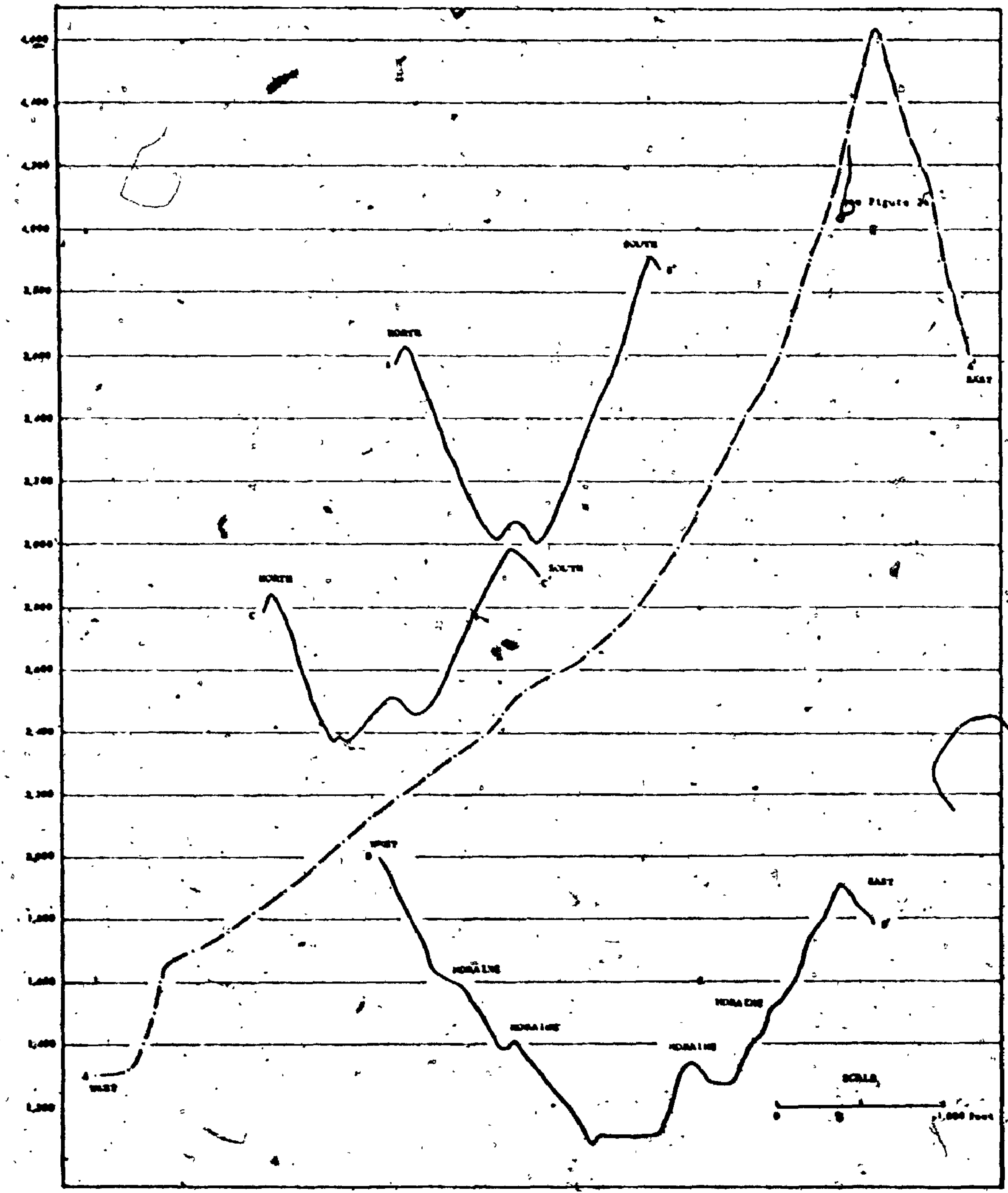


Figure 22. Longitudinal and cross valley topographic profiles of Giant Mountain and Roaring Brook.

Figure 23. Giant Mountain and the Roaring Brook Cirque from Sawtooth Mountain. White areas on mountain and stream valley are bedrock exposed by the 1963 slide.

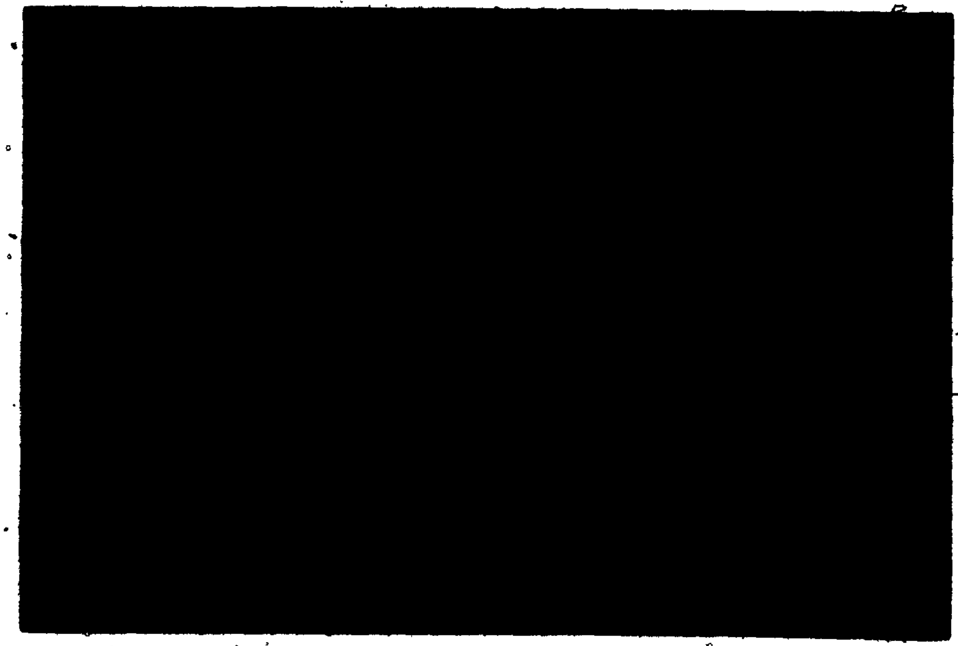


Figure 24. Striations (289°) in Roaring Brook at 2200 feet ASL. Site 179.

(figures 23 and 6, region K). The valley is oriented 250° with the opening to the west and is approximately 2500 feet wide and 9000 feet long (figure 21). Schrund elevation is 2980 feet ASL (figure 22) with a slope gradient above schrund elevation of 3540 feet per mile and the gradient below schrund elevation of 460 feet per mile. Landslide debris fills the valley bottom at an elevation of 2700 feet ASL and the stream has eroded through this mass to bedrock. The stream plunges over a nearly vertical 200-foot waterfall at 1500 feet ASL.

Glacial drift fills the sides of the valley below schrund elevation. Striations oriented 289° were observed at an elevation of 2200 feet ASL (figure 24). Till pebble orientation at an elevation of 1940 feet ASL shows an orientation maximum at 288°. (figure 21, site 171).

A well developed lateral moraine is visible along the north side of Roaring Brook Valley starting at an elevation of 2500 feet ASL ± 40 feet and extending as an almost continuous ridge approximately 1.5 miles north of the junction of Roaring Brook with the Ausable River. There is a less well developed moraine on the west side of the Ausable River Valley. This moraine extends along the side of the valley from about 1800 feet ASL to the valley floor. A delta with a surface elevation of 1100 feet ASL has been mapped north of this moraine. A second moraine complex has been mapped within the boundaries of these moraines. This inner moraine starts at approximately 1540 feet ASL on the south side of Putnam Brook and extends north to the junction of Roaring Brook with the Ausable River. This moraine complex is a kame moraine that has been dissected to bedrock by the Ausable River and Roaring Brook.

Light mineral studies of two till samples from Roaring Brook show low percentages of quartz, slightly higher percentages of K-feldspar and high percentages of plagioclase (table 4).

Table 4. Light Mineral Composition of Roaring Brook Till Samples.

Elevation	Quartz	K-feldspar	Plagioclase Feldspar
1940 feet ASL	12.1%	26.7%	61.2%
2900 feet ASL	15.3%	39.8%	44.9%

Striae were observed on the north side of the valley floor of Roaring Brook at 2200 feet ASL (figure 21, site 179). The striations have been carved into a large xenolith of fine grained mafic-rich anorthosite enclosed in Marcy anorthosite. The striated surface was exposed by the 1963 landslide. Fresh scars from the landslide were observed, superimposed upon the glacially striated surface. The glacial striae are closely spaced parallel grooves on the bedrock oriented N 85° W. The bedrock surface is inclined down the valley at approximately 20°. Joints oriented N 15° W cut across the surface. Plucking on the west (downstream edges) of the joints indicates a westward flow of ice at this point. The striation and the configuration of the grooves indicate active abrasion by ice flowing off the mountain in an east to west direction toward the main north-south valley below.

A till fabric measurement (figure 21, site 171) taken on the south side of the valley at 1940 feet ASL shows an east-west orientation of pebbles which agrees with the striation direction. Fifteen feet of till is exposed in this section. The base of the exposure is covered with colluvium, but the till appears to be resting on bedrock. The orientation measurements were taken at approximately nine feet above the bedrock surface in a freshly exposed face of the till. Valley orientation at this point is N 60° E.

The striations, pebble orientations, light mineral compositions, and distribution of moraines indicate a flow of local ice westward from Giant Mountain. This flow swung northward in the main valley system. The maximum advance stopped 1.5 miles north of the junction of Roaring Brook and Ausable River. A delta developed on the north side of the outer moraine indicates a lake occupied the Ausable River Valley north of this moraine. The inner kame moraine complex indicates a recession of the ice prior to final melting.

3.2.2.2.1 EAST SIDE OF GIANT MOUNTAIN

The east face of Giant Mountain has rock exposed from the crest of the mountain (4627 feet ASL) to the valley floor (approximately 3200 feet ASL). Most of this surface was stripped of forest cover by a series of landslides in the spring of 1963. Investigation of the landslide debris on both sides of Giant Mountain indicates that only a minor amount of rock material was removed by the slides.

On the east side of Giant Mountain there is an abrupt change of slope between 2900 feet ASL and 4100 feet ASL (figures 21, 25 and 26). Above this elevation the bedrock surfaces are smooth and show evidence of chemical weathering. Below this elevation the bedrock is fresh, showing very little evidence of weathering. The surface is irregular and broken as though large sheets of rock have been removed. There are many small 2-to 10-foot cliffs. This broken, irregular zone

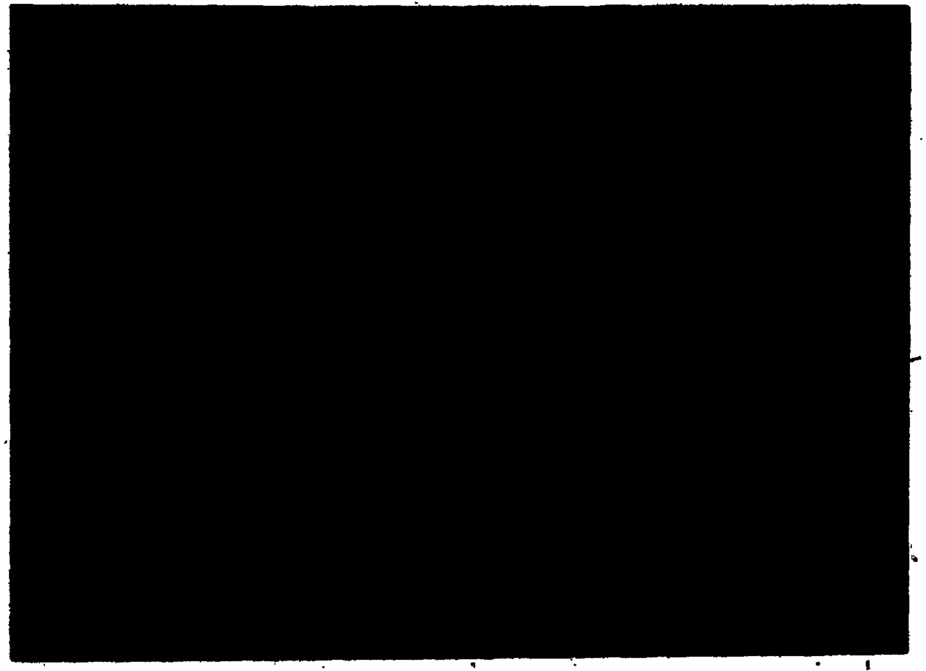


Figure 25. East side of Giant Mountain from the air. Note the quarried surface, indicated by arrow. Looking southwest.

Figure 26. East side of Giant Mountain taken from the pass between Giant and Rocky Peak. Looking north. This photo shows the change in slope and the effect of quarrying. Whiteface Mountain on center skyline.

extends across the backwall of the valley and along the side where it disappears under the forest cover.

It is believed that this surface developed in the following manner (figure 27).

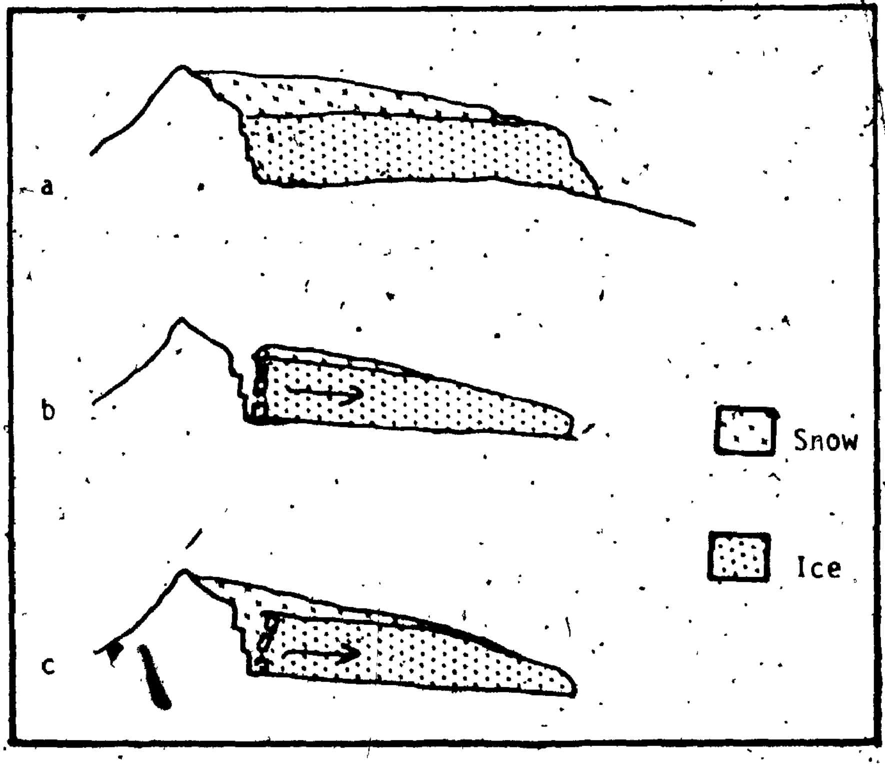


Figure 27. Cirque headwall steepening by ice plucking.

The valley was filled with glacial ice and during the colder periods (winter) the ice-rock contact was frozen solid (figure 27, a). During warmer times and/or under vertical load pressures, the glacier ice moved away from the headwall (figure 27, b) forming a bergschrund crevasse. The movement of the ice pulled large blocks of rock from the headwall. This was followed by filling of the crevasse with snow and/or meltwater from the mountain top (figure 27, c), refreezing and when movement occurred again additional plucking of the headwall occurred.

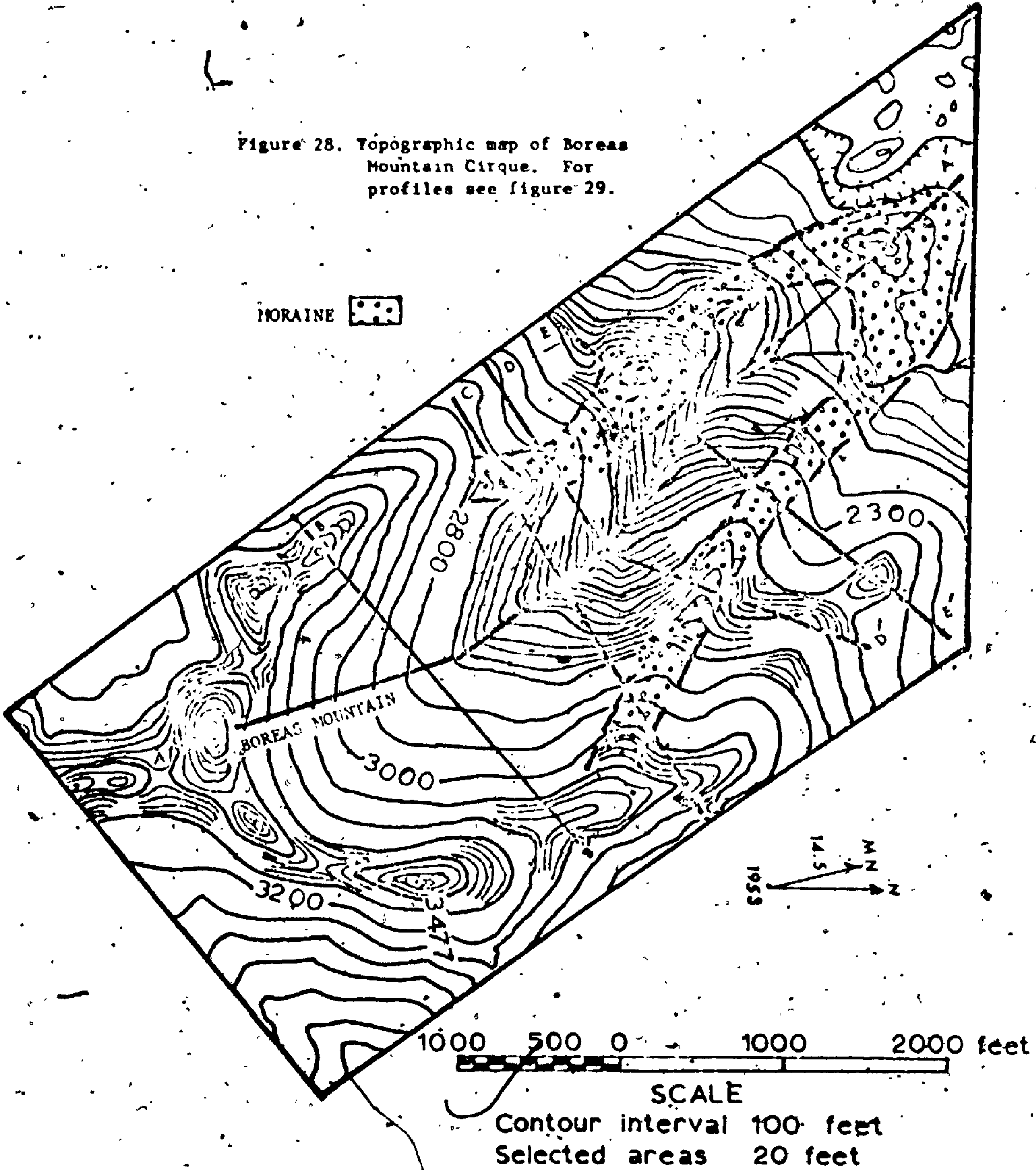
The upper limit of glacier-bedrock freezing and plucking marks the upper surface of glacial ice. The mountain slope above this line would be the snow field accumulation area.

3.2.2.3 BOREAS MOUNTAIN CIRQUE

Boreas Mountain is located in the south central portion of the Mount Marcy Quadrangle. It is the southern high point (figure 6, region M) on an eight mile long mountain ridge striking 032° which extends from Boreas Mountain to Mount Colvin. This high ridge has 15 cirques developed on its slopes. Three of these cirques are on the southeast side of the mountain ridge. The rest are on the northwest side of the ridge. The best developed cirque (figure 28) is located on the north side of the highest peak on Boreas Mountain and is oriented 315°. This cirque was chosen for discussion because it has a well developed amphitheater form, lateral moraines on both sides of the valley, and a terminal moraine blocking the outlet of the valley (figure 28).

The valley is 4000 feet wide in the cirque amphitheater and narrows to 1500 feet between the lateral moraine ridges near the outlet. Distance from the ridge at the back of the cirque to the terminal moraine is 8800 feet. Elevation of the mountain peak at the head of

Figure 28. Topographic map of Boreas Mountain Cirque. For profiles see figure 29.



this cirque is 3560 feet ASL ± 20 feet. Schrund elevation is 2560 feet ASL and is 0.25 miles from the high point. This gives a slope gradient of 3000 feet per mile above schrund elevation and 875 feet per mile below schrund elevation (figure 29).

The valley is eroded into the Marcy anorthosite with the stream flowing over bedrock throughout most of its course. Glacial drift and talus fill the sides of the valley in the upper part and lateral moraines are well developed in the lower part of the valley. These moraines form a pronounced ridge along the sides of the valley converging to the outlet (figure 28). These ridges are composed of sand and gravel, and numerous large boulders were observed on the surface. The lateral moraine on the north side of the valley is the better developed of the two. The stream is diverted from its westward course at the mouth of the valley by the terminal moraine situated across the valley opening extending out into the main valley.

The shape of the cirque valley and configuration of the lateral and end moraines indicate a west-northwest movement of a local glacier, which extended a short distance into the main valley.

3.2.2.4 WHITEFACE MOUNTAIN

Whiteface Mountain (elevation 4867 feet ASL) is located in the center portion of the Lake Placid 15' Quadrangle (figure 6, region D). Access to the summit is provided by the Whiteface Memorial Highway. The Whiteface Mountain Ski Center operates a chairlift during the summer which gives access to the east slopes of the mountain. There is also a Conservation Department foot trail from Lake Placid over the summit and on to Wilmington. Figure 30 is a detailed topographic

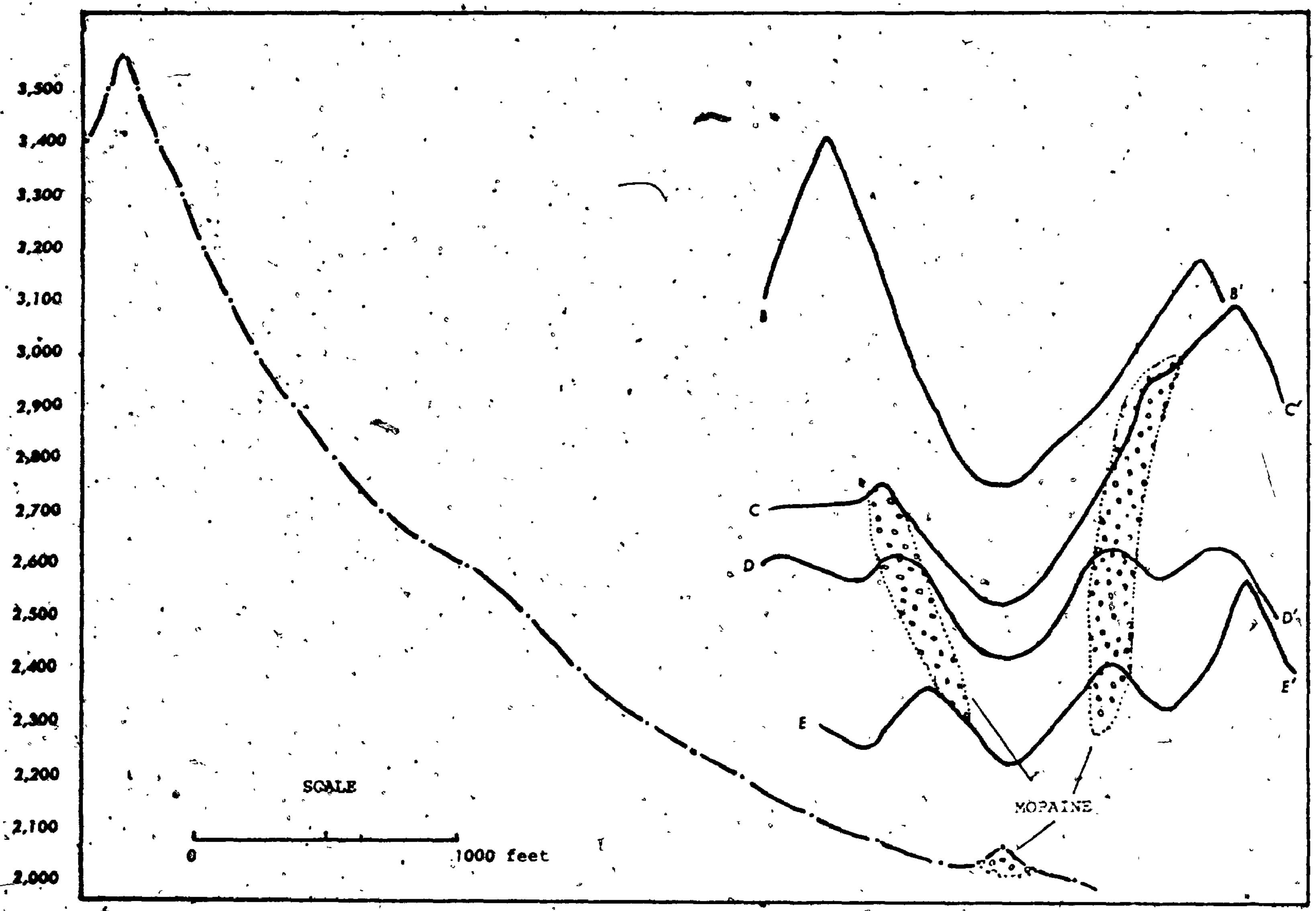


Figure 29. Topographic profiles of Boreas Mountain Cirque and moraines.

LEGEND

Metasedimentary / Anorthosite Approximate boundary of metasedimentary and anorthosite rocks

⑦ Site number and location

Striation and grooves

— — — Foot trail

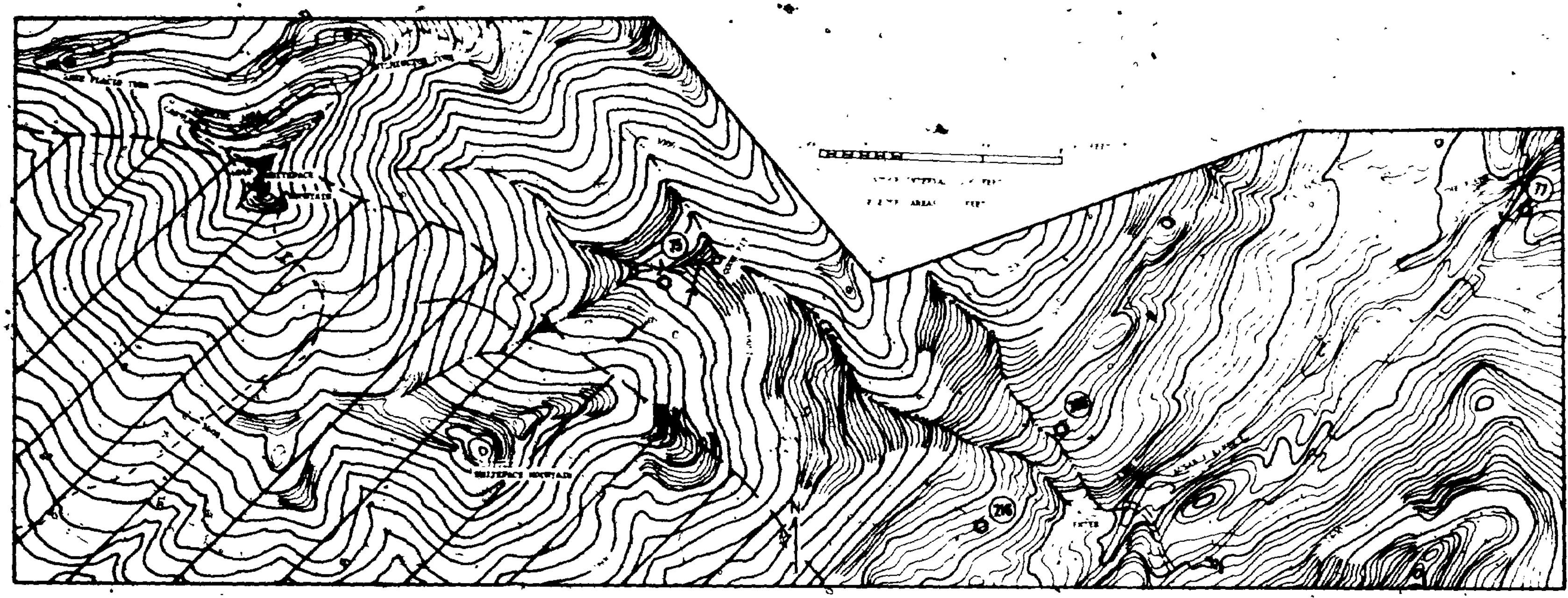


Figure 30. Topographic map of Whiteface Mountain and Ski Center.

map of the Whiteface Mountain and the Ski Center area.

The only evidence of continental glacial erosion on top of any of the mountains was observed on the summit of Whiteface Mountain (figure 31). The summit of Whiteface Mountain is relatively flat. On the south side of the summit area, the surface rises slightly and has a streamlined appearance. This apparently streamlined area has been smoothed and rounded to the point that it resembles the whale back glacial erosion commonly developed on a bedrock surface. The alignment of the whale back feature is N 35° E which is the approximate regional ice flow direction of the continental ice mass.

The shape and smoothness could, however, be related to lineation of mineral bands in the Whiteface anorthosite combined with removal of joint blocks by mass wasting on the summit. This surface is walked over by thousands of tourists each year, which would smooth and polish the rock surface giving an appearance of glacial polish. The evidence is really insufficient to determine the true origin of the feature.

The ridges leading up the summit from the Wilmington Turn on the Whiteface Memorial Highway and from the parking lot just below the summit (figure 30) exhibit erosional characteristics that are indicative of glacial activity in the amphitheater depression below. The ridge trending west from the summit (figure 32) towards the parking lot stands 200 feet high. The south side is nearly vertical and the north side slopes from 65° to 80°, approximately parallel to a surface of sheet jointing. This sloping surface has been excavated to a vertical face to build a parking lot.

The south face of this ridge is a vertical cliff for approximately 100 feet then slopes 70° to 80° to the elevation of 3500 feet

Figure 31. Whale back erosion on summit of Whiteface Mountain looking south. Feature oriented N 35° E.

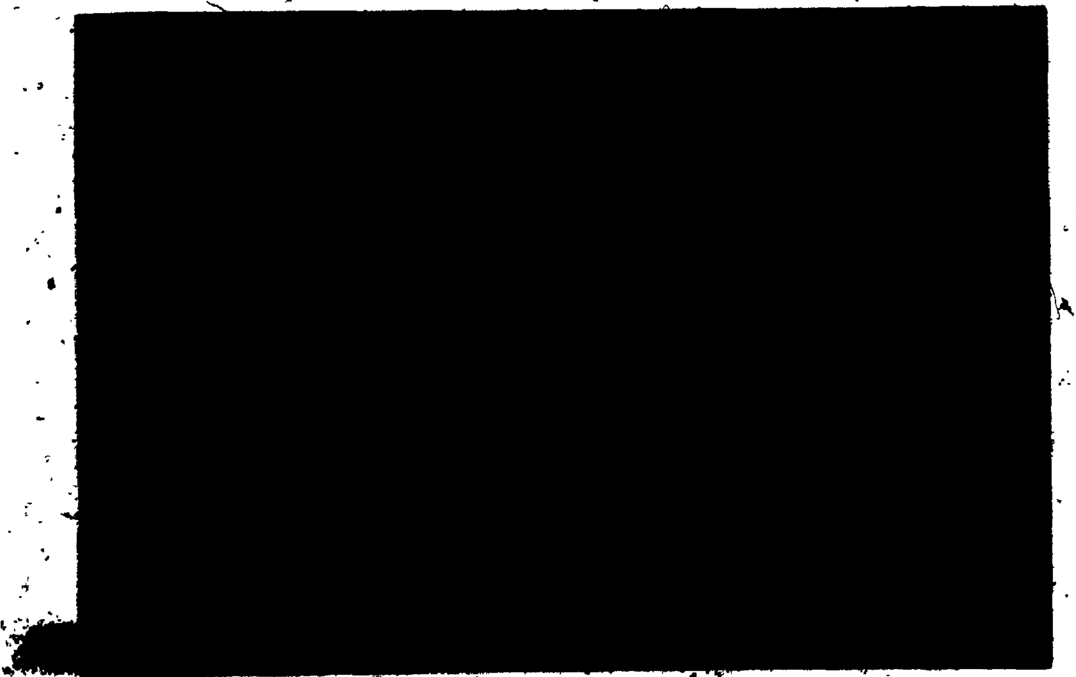


Figure 32. Castle trail from Summit of Whiteface Mountain to parking area looking west.

ASL. The ridge developed by the intersection of the two slopes is about 10 feet wide at its narrowest point and 50 feet wide close to the summit. The ridge runs 305° northwest to the Lake Placid turn where it swings around to the west then to the southwest. The north slope is slightly steeper than the sheet jointing and the present slope stability is controlled by this sheet jointing. The south-facing cliff owes its stability to the nearly vertical jointing in the rock. The joints run 352° to 043°. Joint spacing across the crest forms blocks from 2 to 5 feet across. This cliff is fairly stable with only a few blocks falling off in the spring.

The east-facing cliff along the Wilmington Turn summit trail is similar to the one just described. It also is the head of a cirque depression. The slope of the top of the ridge is controlled by sheet jointing (figure 33) which dips towards the west at 10° along the crest increasing to 40° below the crest to the west. The headwall face of the mountain slopes between 65° and 80° from the crest to an elevation of approximately 3700 feet ASL at the top of talus and drift accumulation. The Coon Pit Ski Lift is located in the bowl of this cirque (figure 34).

3.2.2.4.1 COON PIT, WHITEFACE MOUNTAIN

The Coon Pit (figure 30, site 75) is the local name for the buildings at the upper end of the first ski lift at Whiteface Mountain Ski Center. Glacial striae and a large glacial cut groove are located in the stream bed above the buildings at an elevation of 2520 feet ASL. Striae are oriented N 80° W and are best seen on a wet surface in reflected light looking towards the sun. The bedrock surface at this point is gently inclined down slope. Approximately 15 feet downstream from the striated surface, the stream bed increases its slope to about 70° and continues at this angle to an elevation of 2340 feet ASL.

At an elevation of approximately 2435 feet ASL a joint in the bedrock striking N 15° E has been enlarged by glacial abrasion to form a large groove (figure 35). The groove is narrower and more sharply defined at the south end, widens to the north and ends abruptly at the base of a 100-foot cliff.

The abrupt termination at this groove at the base of the cliff, in combination with the striae mentioned above, indicate that the ice was moving downslope within the confines of the valley, therefore indicating a west to east flow from Whiteface Mountain.

3.2.2.4.2 WHITEFACE MOUNTAIN SKI CENTER

The Whiteface Mountain Ski Center is located off Highway 86, between the Flume and the Wilmington Notch (figure 30) on the west side of the Ausable River at the base of Whiteface Mountain. The ski lodge is built at the edge of the river floodplain and into a stratified sand and gravel terrace. This terrace forms the level ground at the base of the ski slopes. Exposure of the terrace material was observed where roads had been constructed up the slope. Two of these exposures are of special interest; the first, 0.1 miles south of the ski center (figure 30, site 216); the second, 0.2 miles north (figure 30, site 300). The stratigraphic sections are shown in figure 36.

A bedrock ridge breaks the continuity of the terrace behind the maintenance building on the north side of the ski center building

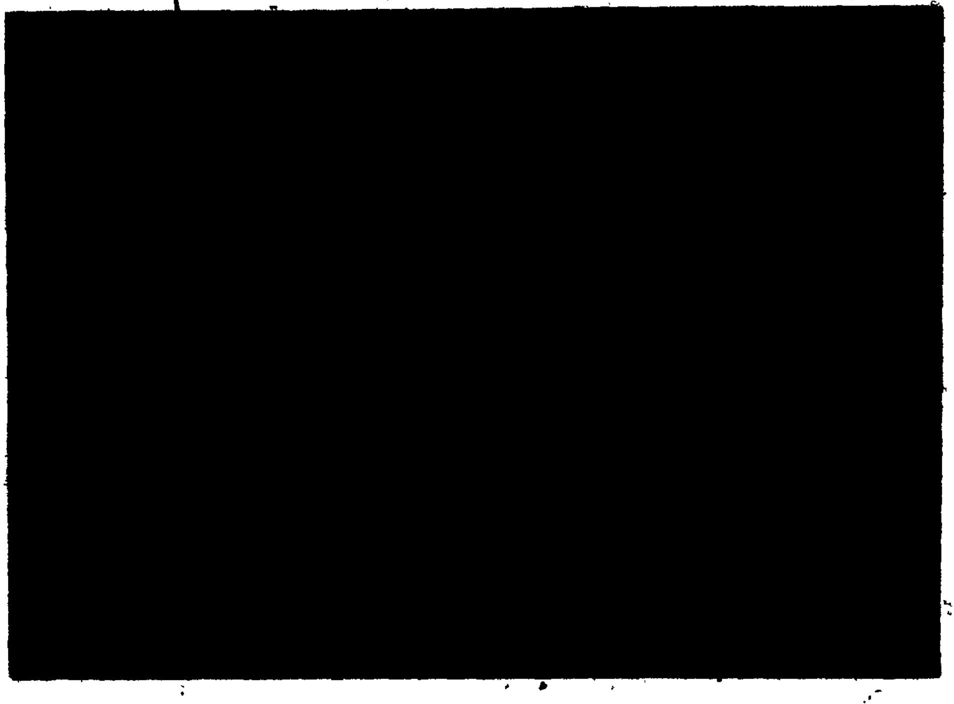


Figure 33. Headwall of Coon Pit Cirque - Summit-Wilmington Turn trail looking northeast. Foliation of bedrock dips to the left.

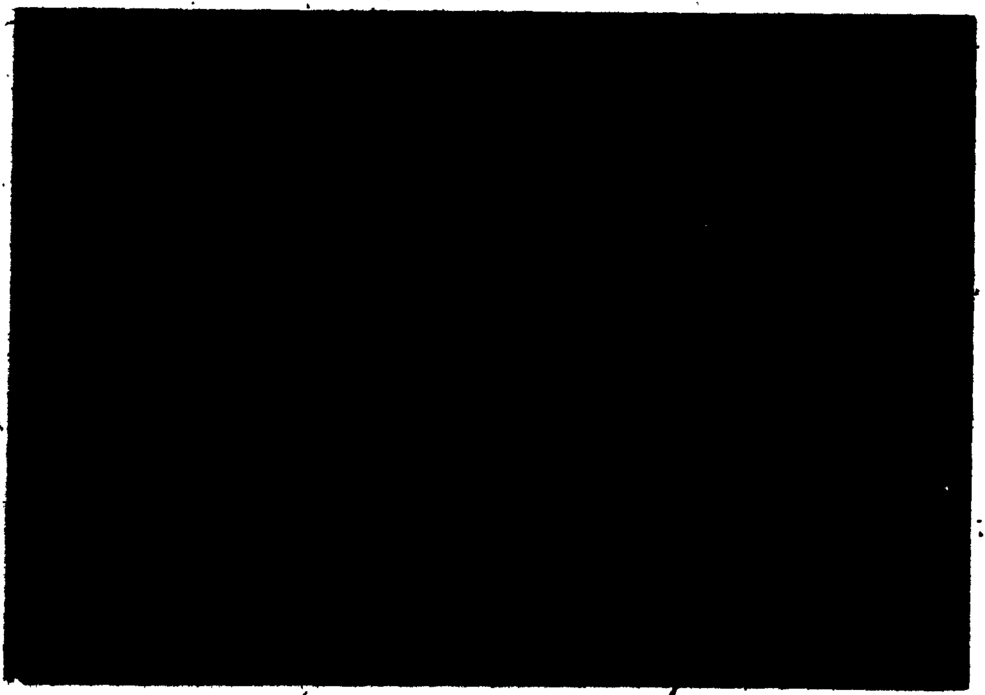


Figure 34. Looking east from Summit-Wilmington Turn trail. Coon Pit lift station is the cleared area in center of photograph.

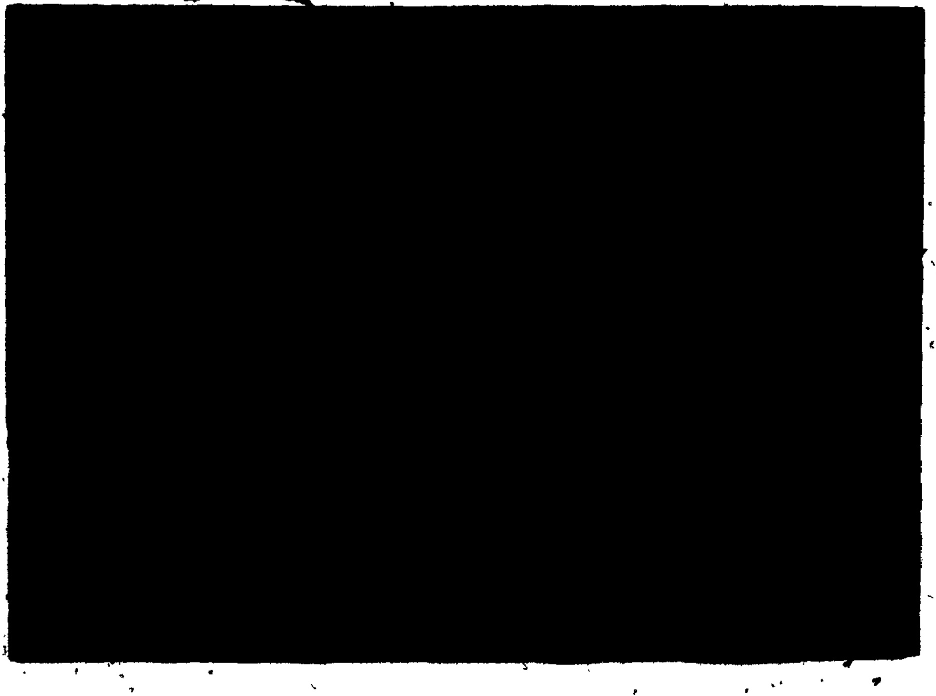


Figure 35. Enlarged joint by glacial grinding looking south in Marcy anorthosite in stream above Coon Pit, Whiteface Mountain.

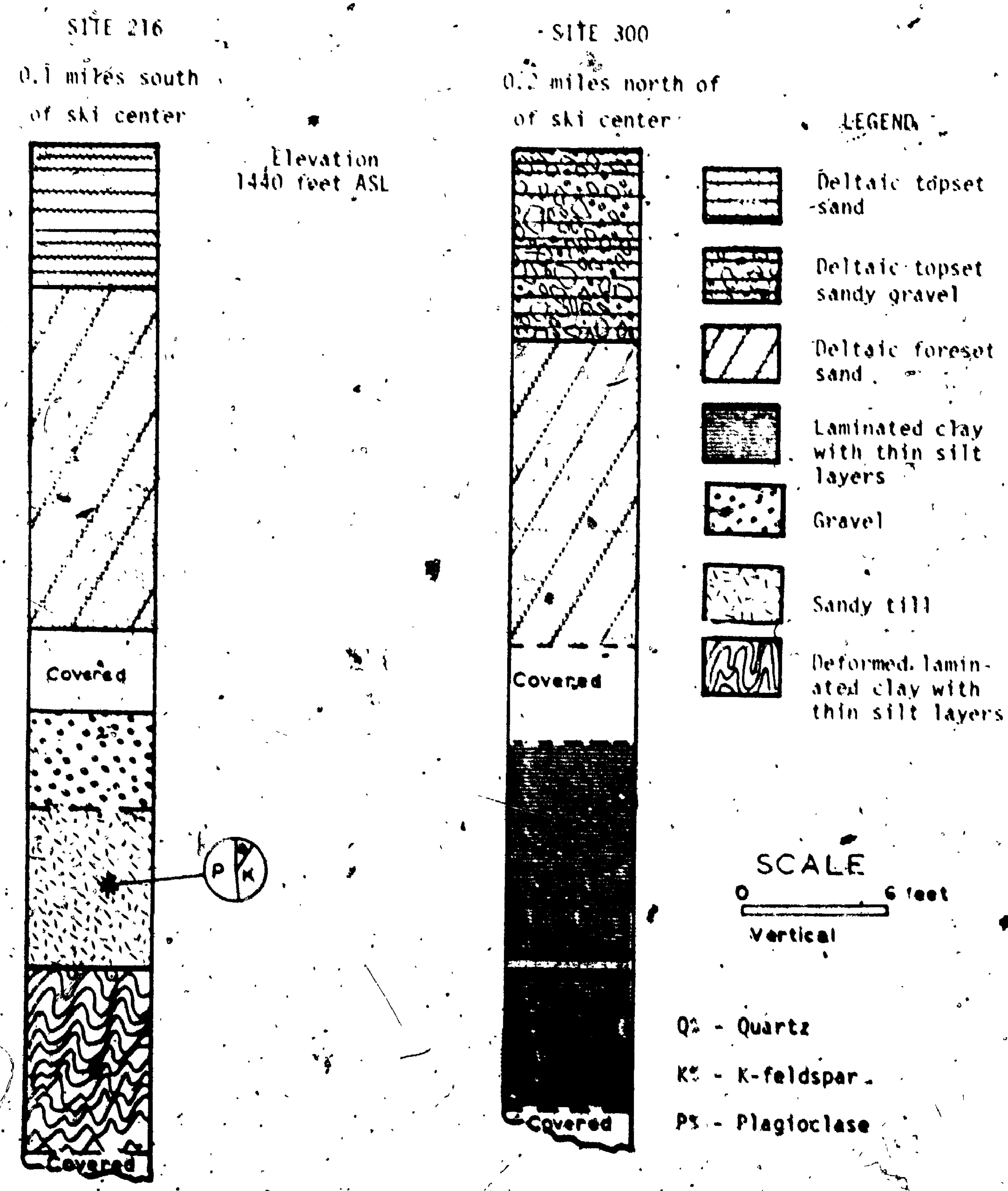


Figure 36. Stratigraphic sections of the 1440 foot terrace Whiteface Mountain Ski Center.

complex. This ridge extends up the slope to an approximate elevation of 2240 feet ASL.

The top surface of the two sections is at an elevation of 1440 feet ASL. The stratigraphic sections of the upper parts of both exposures are basically the same, consisting of deltaic sands and gravels. The northern exposure contains no till and shows no deformation. The southern exposure, however, contains a 4-foot thick layer of till lying on top of strongly deformed laminated clays in the lower part of the section. Light mineral analysis of this till shows a mineral composition of 18 percent quartz, 36 percent K-feldspar, and 42 percent plagioclase. A very small amount of perthite was observed in the light mineral counts. Potsdam sandstone pebbles were observed in both the till and the overlying gravels.

Bedrock of the mountain above the deposits is Whiteface and Marcy anorthosites with some metasedimentary rock exposed on the ridge around Little Whiteface Mountain (figure 30). Little Whiteface Mountain is located on the south side of the cirque valley that would feed ice to these deposits.

Tills formed by the erosion of the metasedimentary and anorthosite rocks of the mountains would contain perthite and a higher percentage of quartz and K-feldspar than would be found in till from erosion of only anorthosite rocks.

3.2.2.4.3 THE FLUME

Striae were observed at the Flume which is located on Route 86 between Wilmington, N. Y. and the Whiteface Mountain Ski Center, where the West Branch Ausable River passes under the road in a deep gorge cut into bedrock. The striae are located on the east side of the road at the north end of the exposure (figure 30, site 77). Bedrock at this location is Marcy anorthosite with a two-foot thick basalt dike cutting the anorthosite. The striae are cut into the nearly vertical side of the dike which strikes N 30° E. No striae were observed on the surrounding anorthosite.

3.2.2.4.4 INTERPRETATION OF THE WHITEFACE MOUNTAIN SITES

Striations and a glacial groove above the Coon Pit on the valley floor at an elevation of 2520 feet ASL indicate an eastward ice movement downslope toward the ski center. Till overlies deformed laminated clays and indicates that ice overrode the valley bottom sediments. The northern exposure of these thinly laminated clays are undisturbed and lack a till cover. The mineral composition of the till, quartz 18%, K-feldspar 36%, and plagioclase 47%, resembles the rocks of the east side of Whiteface Mountain.

This evidence of glaciation is undeniable. Is this local ice from the west or is this continental glaciation from the north? The path of least resistance to continental ice advance would be southward in the Wilmington Valley. The glacial groove and striations indicate an eastward flow of ice. If the glaciation was continental, the northern exposure of laminated clay probably would not escape deformation of clay and deposition of till.

The glacial groove and striations indicate an ice movement from the Coon Pit Cirque towards the ski center. The light mineral composition of the till can be explained by composition of the bedrock over which the ice would flow from the Coon Pit Cirque. The fact that the clay in the northern exposure shows no signs of overriding by ice supports the interpretation that the ski center till was deposited by local ice from Whiteface Mountain. The bedrock ridge behind the ski center maintenance building is believed to have acted as a "cleaver" directing the local ice tongue southward overriding the southern deposit and leaving the northern deposit undisturbed.

3.2.2.5 DIX MOUNTAIN

Dix Mountain Group is located on the southeast half of the Mount Marcy 15' Quadrangle (figure 6, region P). It is composed of five mountain peaks with elevations of greater than 4000 feet ASL and has the highest point in this part of the map area. The mountain peaks are Dix (4857 feet ASL), Hough Peak (4400 feet ASL), South Dix (4060 feet ASL), East Dix (4012 feet ASL), and McComb Mountain (4405 feet ASL). The peaks are separated from each other by cols or passes through the ridge (figure 37). Cirque erosion has cut into the ridge so that it is only a few feet wide in some places (figures 38 and 39). The cols are located at the apex of the amphitheater form, and the peaks of the mountains are along the sides of the amphitheaters. The narrow ridge of bedrock rises from each col curving in an amphitheater form. The foot trails connecting the peaks run along these sharp crests.

These very narrow ridges follow the curvature of the cirque amphitheaters dissecting the mountain mass. They have not been abraded as one would expect them to be if eroded by the southward flowing continental ice mass. The individual peaks are separated by deep passes or cols which lie at the heads of the cirque amphitheaters.

Figure 37. Dix from airplane looking west.

Figure 38. Dix peak from trail to top. Note narrow crest of the ridge.

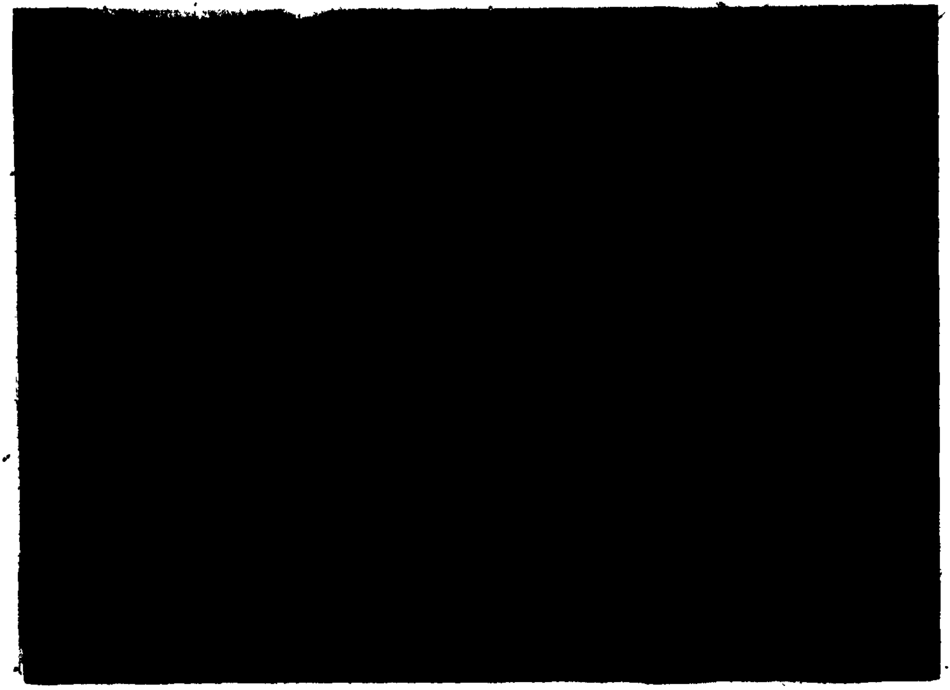


Figure 39. Note sharp crest of the ridge between Dix Mountain and Hough Peak. Looking south from Dix.

3.2.3 MANY CIRQUES FEEDING A TRIBUTARY VALLEY

The third type of valley glacier development is one in which there is a large valley tributary to the main valley system, with numerous cirque amphitheaters feeding into the tributary valley. Examples of this type of valley glacier are numerous: the Elk Lake system, the north and south forks of the Boquette River, the Mount Colden-Marcy system and the Johns Brook Valley system (figure 6; region G).

3.2.3.1 JOHNS BROOK VALLEY

The most accessible area for studying evidence of this type of valley glacier development is found in Johns Brook Valley (figures 6, region G, and 40) which has 19 cirques opening into the main tributary valley. Thirteen facing north are developed on the north slopes of The Range (figure 42), and the six facing south are on the south slopes of Table Top, Big Slide Mountain and Brothers Mountain (figures 43 and 44).

Johns Brook Valley is oriented 052° with Mount Marcy (5344 feet ASL) at the head of the valley. The valley is nine miles long and 2.1 miles wide at the lower end. The elevation at Keene Valley where Johns Brook enters the Ausable River is 1016 feet ASL, giving a total gradient of 470 feet per mile. Schrund elevation for the main valley is 3710 feet ASL (table 5 and figure 41). The gradient is 3000 feet per mile in the upper part of the valley, and 360 feet per mile in the lower part.

Elevation of the mountain peaks decreases from Gothic (4736 feet ASL) to Lower Wolfjaw (4175 feet ASL) on the west side, and Third

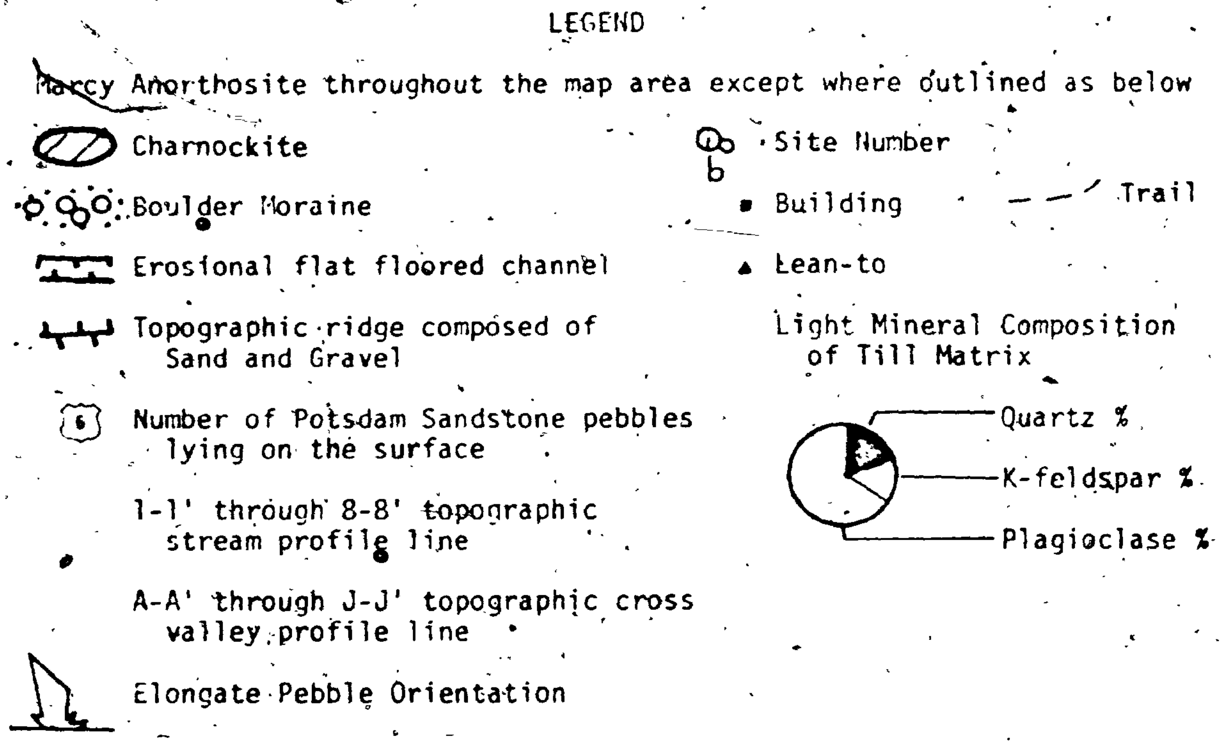
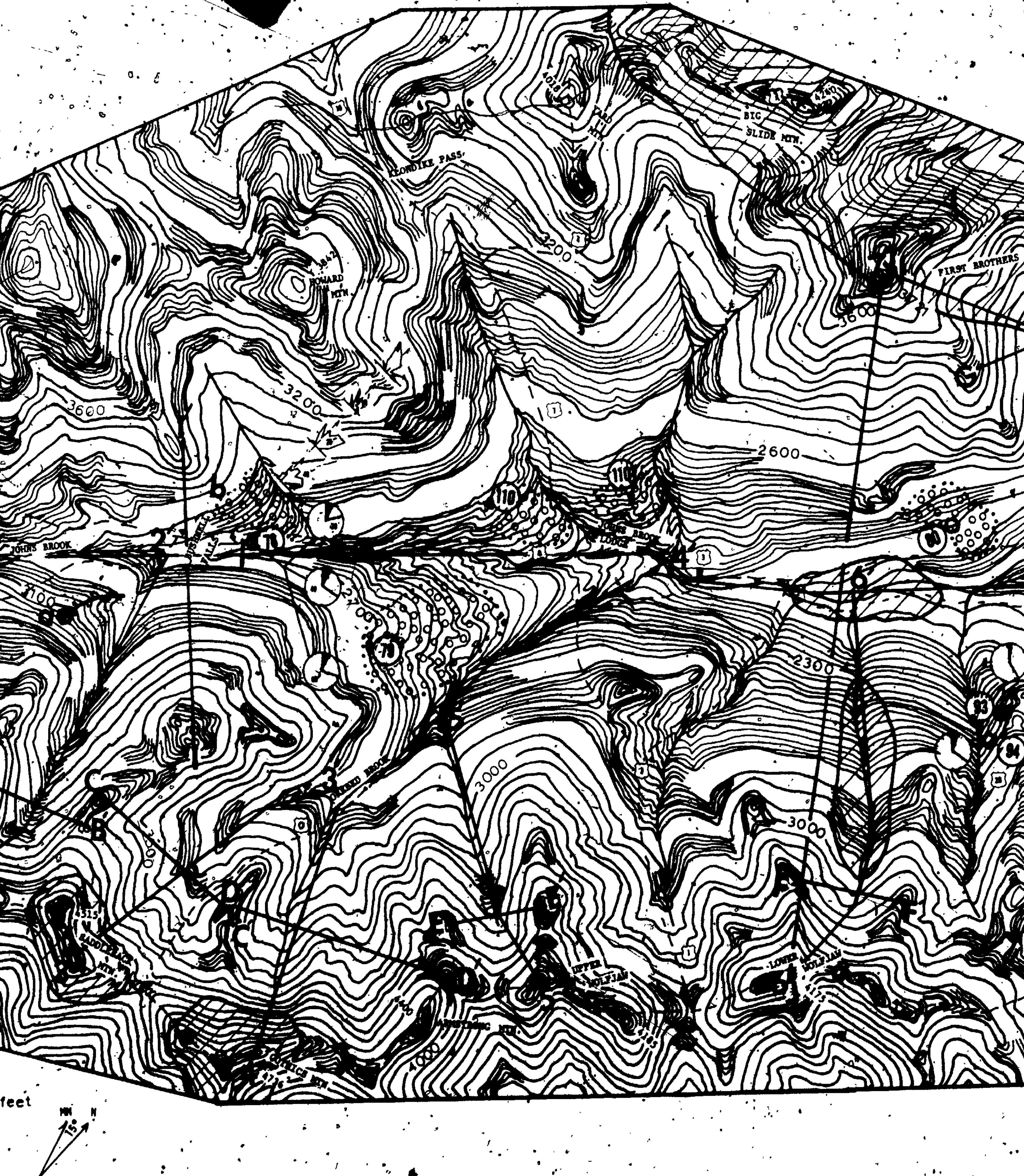


Figure 40. Topographic and geologic map of Johns Brook Valley.


MOUNT MARCY
5344
4700
LITTLE MARCY
4765
4300
4100
3800
3600
JOHNS BROOK
LITTLE HAYSTACK
3930
SADDLEBACK MTN.
4515
0
1,000'
2,000'
3,000'
4,000' feet
SCALE
Contour interval 100 feet
Selected areas 20 feet
MN
N
1953

[redacted]



KLONDIKE PASS
YARD MTN
4018
BIG SLIDE MTN
HOWARD MTN
FIRST BROTHERS
3600
3200
3200
3600
2600
JOHNS BROOK
FALLS
JOHNS BROOK LODGE
2100
2300
3000
3000
CROOKED BROOK
4515
SADDLEBACK MTN
ARMSTRONG MTN
UPPER WOLFJAW
LOWER WOLFJAW
4000
GOTHICS MTN
feet
MN
N
15°
1953

[redacted]

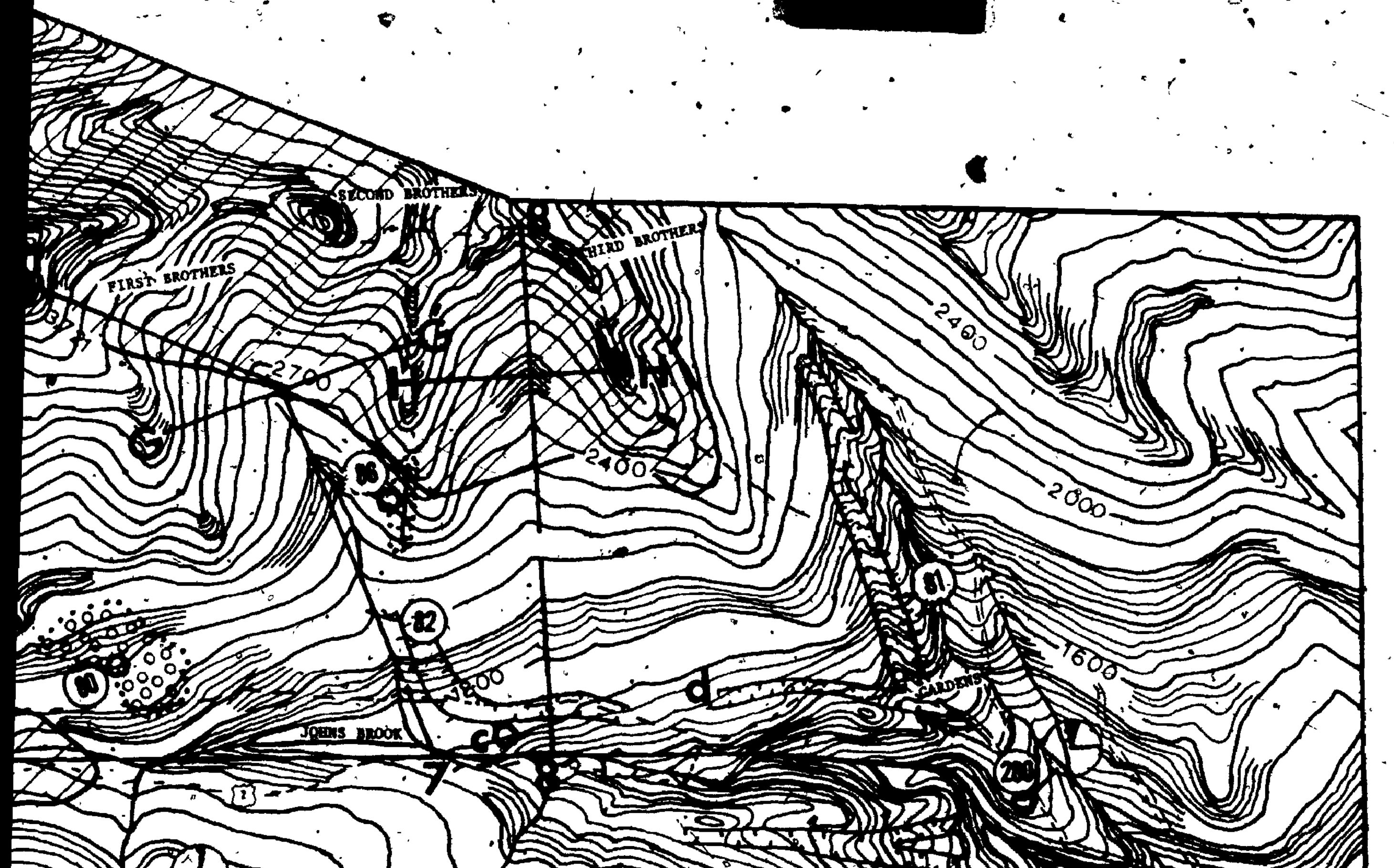

FIRST BROTHERS
SECOND BROTHERS
THIRD BROTHERS
2700
2400
2000
1600
1800
H
C
86
82
81
80
83
84
280
278
JOHNS BROOK
GARDENS
d
2400
2000
1600
KEENE VALLEY

Table 5. Valley Slope Gradient Data for Johns Brook Valley

Mountain Name	Elevation of Cirque Headwall	Schrund Elevation	Stream Junction	Headwall Schrund Distance	Schrund to Stream Junction Distance	Headwall Gradient	Valley Gradient
Gothics	4800' ASL	3040' ASL	2720	.39 mi.	.64 mi.	4480'/mi.	500'/mi.
Little Haystack	4640' ASL	3710' ASL	1300	.31 mi.	6.7 mi.	3000'/mi.	360'/mi.*
Basin	4500' ASL	3580' ASL	2760	.17 mi.	1.3 mi.	5420'/mi.	631'/mi.
Saddleback	4500' ASL	3200' ASL	2720	.37 mi.	.64 mi.	3570'/mi.	750'/mi.
Upper Wolfjaw	4200' ASL	3450' ASL	2520	.26 mi.	.76 mi.	2830'/mi.	1224'/mi.
Lower Wolfjaw	4000' ASL	3170' ASL	1910	.23 mi.	1.33 mi.	3610'/mi.	947'/mi.
Third Brothers	2900' ASL	2610' ASL	1710	.62 mi.	.92 mi.	2080'/mi.	978'/mi.
First Brothers	2900' ASL	2160' ASL	1410	.31 mi.	.90 mi.	2390'/mi.	834'/mi.

*360'/mi. is gradient of Johns Brook, all tributaries change to this on joining main stream.

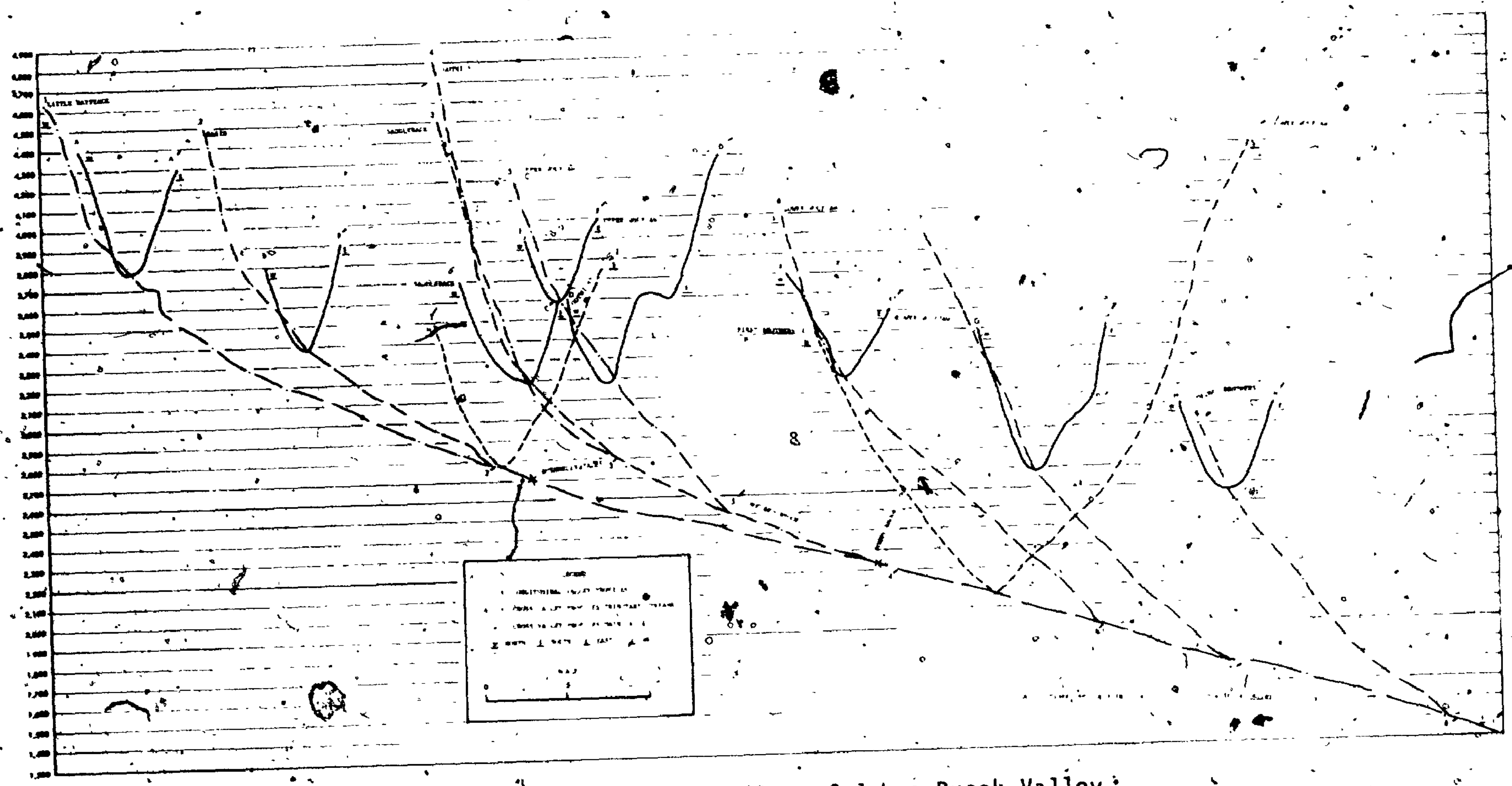


Figure 41. Topograhic profiles of Johns Brook Valley.

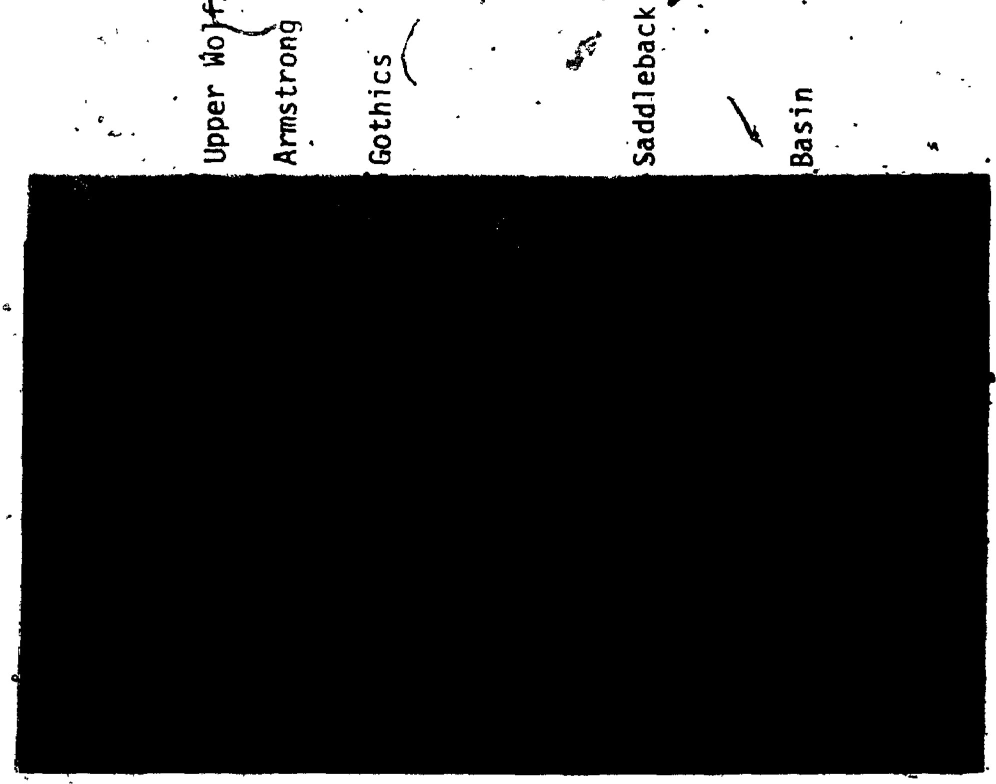


Figure 42. Gothics from Second Brothers looking south across Johns Brook Valley.

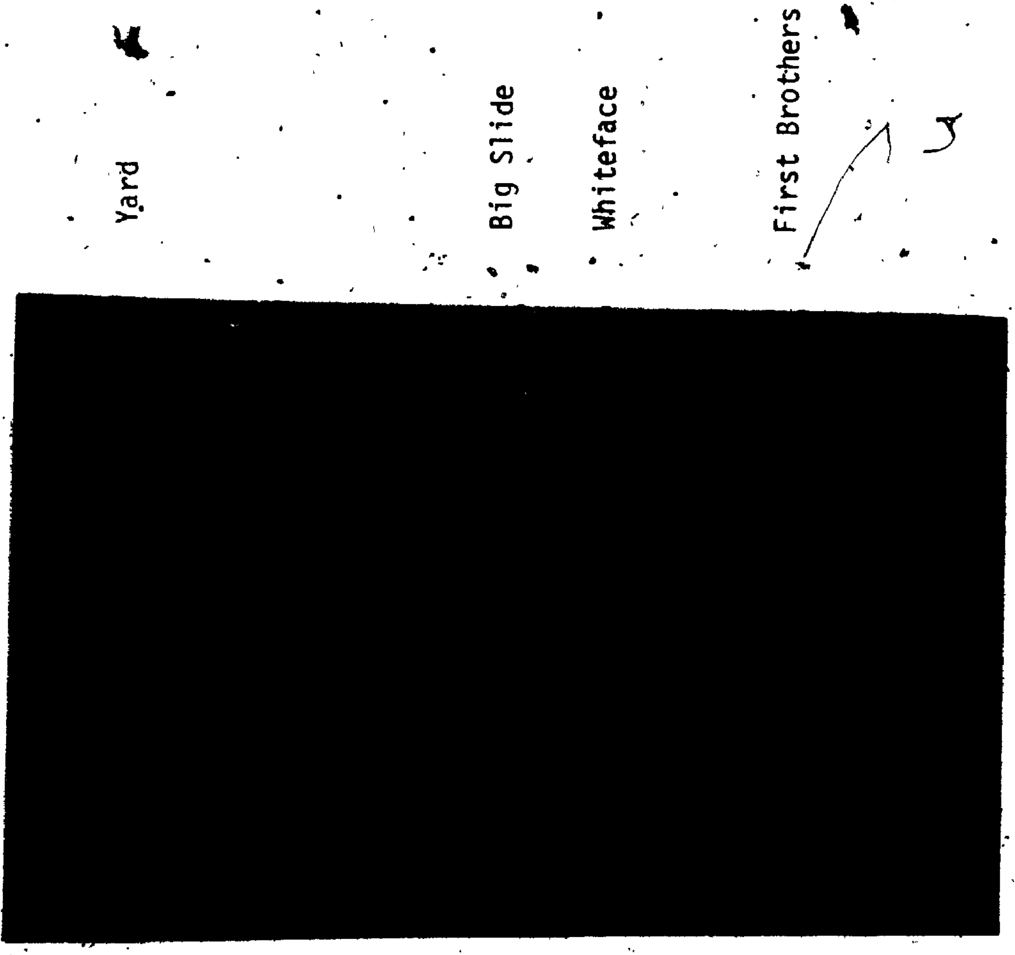


Figure 43. Johns Brook Valley and Big Slide Mountain from Gothics.

Figure 44. Cirque bowl between First and Second Brothers.

Brothers (3140 feet ASL) on the east side. Slope gradients above schrund elevations increase with higher elevations, ranging from 2080 feet per mile at Third Brothers to 5420 feet per mile at Basin Mountain. Slope gradients below schrund elevations are the reverse with higher gradients in the lower part of Johns Brook Valley (834 to 1224 feet per mile) than in the upper part of the main valley (360 to 750 feet per mile).

There are nineteen cirque valleys opening into Johns Brook Valley. Two of these valleys were studied in detail: Basin Mountain Cirque and Brothers Cirque.

3.2.3.1.1 BEDROCK OF JOHNS BROOK VALLEY

Johns Brook Valley and the surrounding ridges are composed predominantly of Marcy anorthosite. Saddleback Mountain, Gothics Mountain, Big Slide Mountain, the Brothers and Lower Wolfjaw are composed of charnockite (figure 40).

The Marcy anorthosite in the lower part of the valley contains large 4" to 8" phenocrysts of labradorite feldspar in a fine grain matrix. Mafic minerals such as hornblende, augite and garnet become more common at increased elevations.

One fault was observed below Bushnell Falls. In this area the anorthosite has been broken into six-to twelve-inch rectangular blocks along a zone approximately twenty-five feet wide. It is believed that this zone of fracturing represents faulting. No displacement of rock could be determined. Upstream from this fault zone an outcrop of clay was observed. The deposit is fifteen feet thick and ten feet wide. Unweathered anorthosite outcrops on both sides of the clay deposit and in the stream bed below the deposit. Three feet of weathered anorthosite is exposed at the base of the clay. This deposit has been formed by alteration of the anorthosite to clay in place. The clay is yellow brown at the surface, changing to white about five inches below the surface. A ghost outline of a labradorite crystal two inches thick and four inches long was observed in the clay. All of the original rock has been altered to clay in this narrow zone.

3.2.3.1.2 BASIN MOUNTAIN CIRQUE

This cirque is located on the north side of Basin Mountain (figure 40, profile line 2-2'). The cirque valley is oriented N 15° W. The stream enters Johns Brook above Bushnell Falls at an elevation of 2760 feet ASL.

The gradient of the valley bottom above schrund elevation (3580 feet ASL) is 5420 feet per mile and below schrund elevation 631 feet per mile. The cirque valley is bordered on both sides by nearly vertical cliffs standing over 500 feet above the valley floor. These cliffs terminate in narrow ridges that end at elevations of approximately 3700 feet ASL on the east side, and 3600 feet ASL on the west side. The bedrock ridge continues downslope as a boulder strewn moraine ridge on the west side. This moraine ridge is approximately 1300 feet long and drops 130 vertical feet, curving slightly down the axis of Johns Brook Valley (figure 40, site a).

The Basin Mountain cirque terminates on the south side of Johns Brook at Bushnell Falls. A boulder moraine has been mapped on the north side of Johns Brook (figure 40, site b). Ninety feet of glacial drift is exposed in the valley bottom (figure 40, site 79).

The main valley axis of Johns Brook is N 50° E and the tributary valley (Basin Mountain Cirque) just south of the till exposure is oriented N 15° W.

The light mineral composition of the till is high in plagioclase, low in quartz and K-feldspar. This composition is to be expected since the deposit is surrounded by anorthosite. The elongate pebble orientations are shown on figures 40, site 78; and 45. Four pebble orientation studies were made in this exposure, one at 40 feet, 20 feet, 10 feet and 5 feet from the top.

The lowest till fabric shows a preferred orientation of N 55° E with a secondary peak at N 16° E. This orientation is nearly parallel to the axis of Johns Brook Valley (N 50° E). The twenty-foot fabric shows a change in orientation more to the north with a preferred orientation of N 33° E and a secondary peak at N 20° W. The ten foot fabric has a preferred orientation of N 18° W with a secondary peak of N 8° E, and the five-foot fabric has a preferred orientation of N 20° W and no secondary peak. Basin Mountain Cirque is oriented N 15° W.

The source of the early ice movement was from the cirques on Basin Mountain, Little Haystack, Little Marcy, and Table Top (figure 40). This ice flowed from the source area down Johns Brook Valley to some point east of Bushnell Falls. Eventually the ice thinned and receded back up the main valley. The pebble orientation change from northeast to northwest is believed to indicate the influence of ice moving out of Basin Mountain Cirque into Johns Brook Valley. The uppermost fabric (N 20° W) is nearly parallel to the orientation of

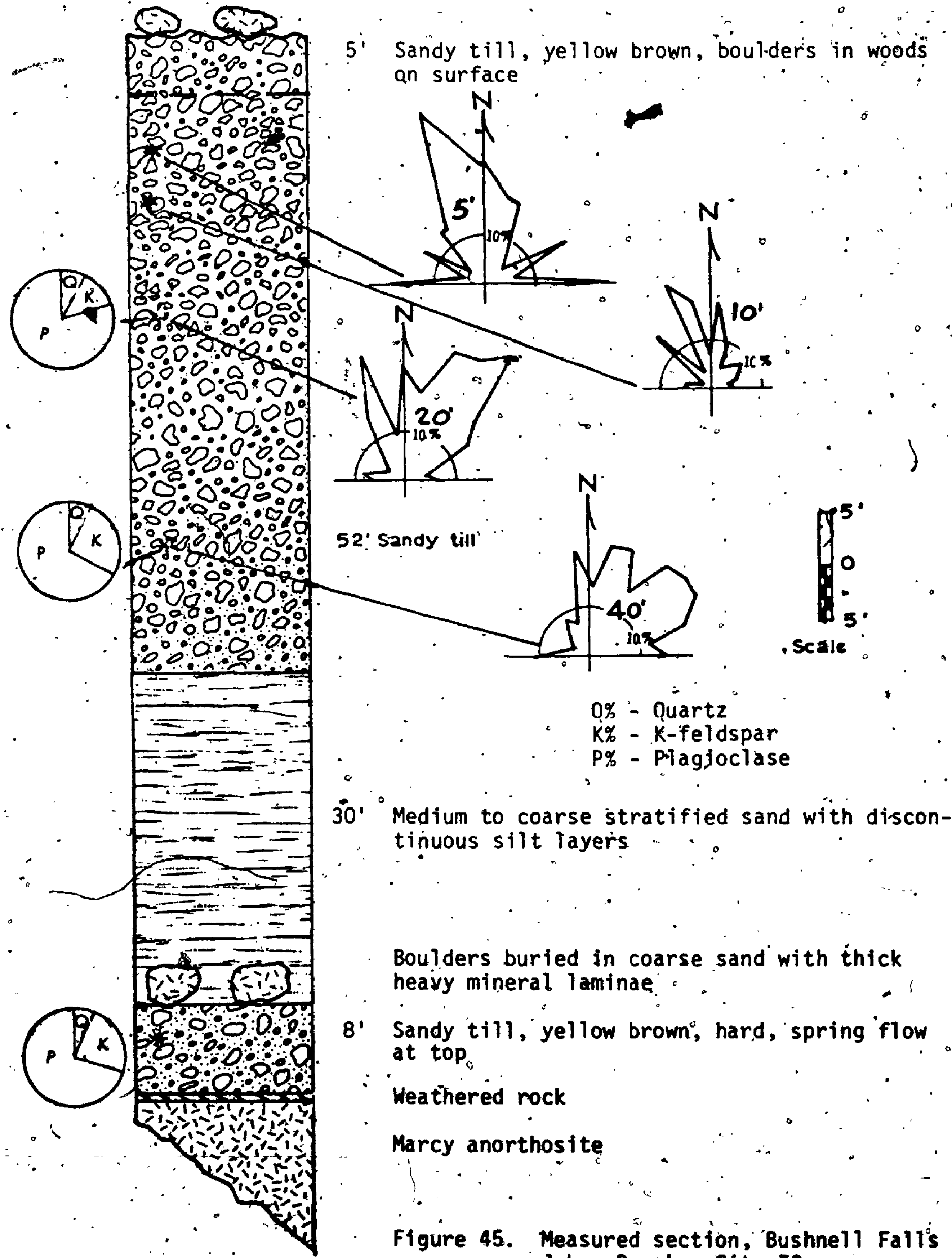


Figure 45. Measured section, Bushnell Falls Johns Brook. Site 79.

the axis of Basin Mountain Cirque (N 15° W).

The lateral moraine ridge on the west side of Basin Valley (figure 40, site a) at an elevation of 3100 feet ASL and the boulder moraine on the north side (figure 40, site b) of Johns Brook between 2700 feet and 2800 feet ASL are indicators of this local ice lobe from Basin Mountain Cirque.

3.2.3.1.3 BROTHERS CIRQUE

This cirque is located on the north side of Johns Brook (figure 40, profile line 7-7') between First Brothers and Second Brothers Mountains. The valley is oriented N 70° W and opens to the south. The stream from the cirque enters Johns Brook at the elevation of 1740 feet ASL.

The gradient of the valley bottom above schrund elevation (2160 feet ASL) is 2390 feet per mile and below schrund elevation is 834 feet per mile. The cirque basin is bordered along the sides and back by nearly vertical cliffs. These cliffs are in the form of steps ranging from 20 feet to over 100 feet high. The center portion of the cirque has a definite bowl shape as can be seen in the photograph (figure 44) taken from the east ridge of Second Brothers Mountain looking towards First Brothers. The bottom of this bowl is swampy ground; however, no moraine could be identified in the middle of the valley. A lateral moraine was found to border the cirque on the east side of the valley (figure 40, site 86). This moraine starts as a broad nearly level terrace at the base of a vertical cliff at an elevation of 2780 feet ASL. The moraine narrows to a sharp crested gravel ridge striking N 40° W and inclines down the valley to the southeast. The bedrock ridge strikes N 65° W. Two pebble counts were made at elevations of 2320 and 2680 feet ASL from the surface of this ridge from holes dug to a depth of 2 to 3 feet at the crest line of the moraine.

The lower elevation counts show a slightly higher composition of metasedimentary rock (28.6%) than the upper elevation count. Table 6 contains the pebble identifications. Bedrock of the upper part of the Brothers is metasedimentary (figure 40).

Table 6. Pebble Lithologies of Moraine on East Side of Brothers Cirque.

Rock Type	Elevation 2320 ft. ASL	Elevation 2680 ft. ASL
Marcy Anorthosite	36.0%	35.5%
Whiteface	34.9%	47.0%
Metasedimentary	17.9%	8.0%
Amphibolite	10.7%	8.8%
Potsdam Sandstone	0.8%	0.7%

This moraine disappears into a large gently sloping almost flat surface at an elevation of 2240 feet ASL. About 200 feet below the lower end of this moraine is another ridge (site 82) starting at an elevation of approximately 2020 feet ASL which extends down the slope and curves at the lower end until it is nearly parallel to Johns Brook. A well developed flat floored erosional channel occurs on the north and east side of this ridge.

This ridge form disappears at an elevation of approximately 1740 feet ASL and the south side of the channel becomes a smooth, broad gently sloping surface ending abruptly at the erosional channel of Johns Brook. A partially exposed section was located on the edge of this cut at an elevation of approximately 1700 feet ASL (figure 40, site c). The exposed portion of the surface is composed of coarse gravel on top of stratified sand and gravel (figure 46).

The erosional channel ends at an elevation of approximately 1660 feet ASL in a broad gently sloping surface. Approximately 1000 feet northeast (figure 40, side d) of the end of this channel another erosional channel starts at an approximate elevation of 1660 feet ASL. This channel is traceable from this point to the Gardens parking area where it merges with a channel from the north and disappears into the recent erosional development of Johns Brook.

3.2.3.1.4 OTHER DEPOSITS IN JOHNS BROOK VALLEY

3.2.3.1.4.1 BOULDER MORAINES

Five boulder fields have been mapped in Johns Brook Valley (figure 40). Site b has been discussed in relationship to the Basin Mountain Cirque. The other boulder moraines are shown on figure 40 by symbols and site numbers. They are the sites numbered 79, 80, 110 and 276.

Boulder field 79 occupies the slope area between Johns Brook and Orebed Brook. The boulder field starts at the base of a very steep bedrock surface at elevations of approximately 2720 feet ASL and extends downslope to an elevation of approximately 2460 feet ASL where it disappears into a sand plain. The topography within the boulder field is very irregular with numerous swampy areas present. Boulder field 110 has the same appearance and character as boulder field 79. Boulder field 110 starts at an elevation of 2520 feet ASL

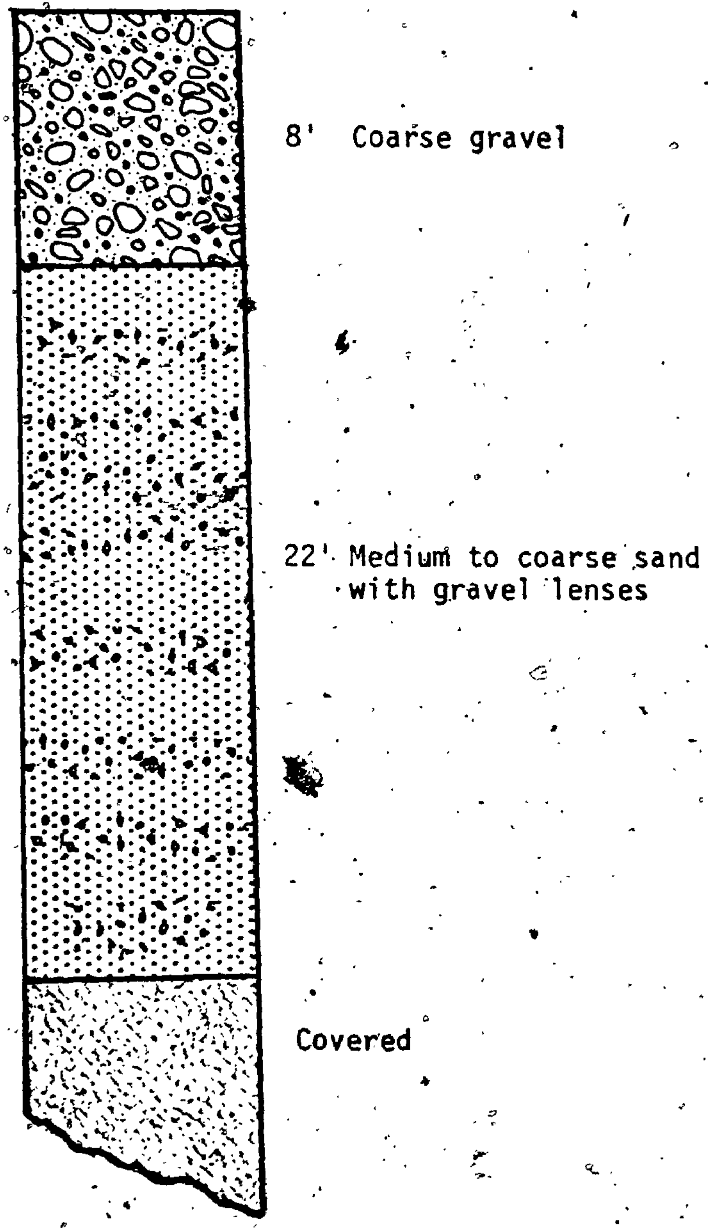


Figure 46. Measured section on north side of Johns Brook, site(c)on figure 40.

and extends approximately one hundred vertical feet downslope where it disappears under a sand plain.

Boulder fields 79 and 110 may have been originally one continuous deposit which have been separated by erosional downcutting of Johns Brook and its tributaries.

Boulder field 80 lying on the valley slope is different in that it has a down-valley elongation slope and does not have streams dissecting its margins. The boulder field starts at the base of a nearly vertical bedrock cliff and extends 260 vertical feet eastward to the erosional edge of Johns Brook where it ends. One boulder located on the Johns Brook trail stands 30 feet high.

Boulder field 276 is located at the lower end of Johns Brook. This boulder deposit has been cut into by the stream exposing a 25-foot section composed of boulders 1 to 5 feet in diameter with very little fine material.

3.2.3.1.4.2 JOHNS BROOK VALLEY TILL

The lower part of Johns Brook Valley from the Ranger Station (elevation 2220 feet ASL) to Keene Valley is mainly sand and gravel. Till has been identified in the tributary stream flowing north off Lower Wolfjaw Mountain (figure 40, sites 93 and 94) and along the access road to the Garden parking area (figure 40, site 280). Pebble identification counts and light mineral studies of the till matrix were performed on samples from the Wolfjaw sites. Table 7 is the pebble composition of these sites. Light mineral composition was determined from samples from site 280. The light mineral compositions are plotted on circular diagrams on figure 40 and are given in Table 8.

Table 7. Pebble Lithologies of Tills on the North Slope of Lower Wolfjaw Mountain.

Elevation	site 93 2460 ft. ASL	site 94 2480 ft. ASL
Lithology		
Marcy %	64	37.8
Whiteface %	32	32.4
Potsdam Sandstone %	4	22.5
Metasedimentary %	0	7.3

Table 8. Light Mineral Composition of Till Matrix, Johns Brook Valley.

	site 78			site 93	site 94	site 280
Depth from surface	20'	40'	65'	2'	2'	6'
Minerals						
Quartz %	6.5	7.3	7.7	7.4	5.3	8.35
K-feldspar %	12.4	27.6	23.6	28.8	39.2	20.15
Plagioclase %	64.1	64.1	68.7	63.8	55.5	71.5

The broad relatively flat terrace located just north of the village of Keene Valley appears to be an outwash alluvial fan overriding a delta built into the Ausable River Valley. The village of Keene Valley uses this deposit for its aggregate needs. Their excavations are located on opposite sides of a deep but narrow valley at an elevation of approximately 1180 feet ASL north of town (site 278). The excavation on the north side of the valley is in 25 to 30 feet of coarse sand and coarse gravel. Boulders ranging up to 3 feet in diameter are common. Directly across the narrow valley is a 24-foot exposure of sand with horizontal bedding at the base and cross bedding in the middle portion capped by gravel. The gravel layer is at the same elevation as the bottom of the pit on the north side of the valley.

Figure 47 is a compiled stratigraphic section of these two excavations.

3.2.3.1.4.3 DISTRIBUTION OF POTSDAM ERRATICS

The trails, stream beds and exposed areas where trees have been blown down wer[illegible]earched throughout Johns Brook Valley for the occurrence of Potsdam sandstone erratics. It was found that Potsdam sandstone erratics were common constituents in gravels everywhere in the valley below the junction of Klondike, Orebed and Johns Brook (figure 40, site 4). Potsdam erratics are very common on the trail from Johns Brook Loj to Klondike Pass between Yard Mountain and Howard Mountain. Potsdam erratics were observed on the Orebed Brook Trail up to an elevation of 3000 feet ASL and on the Upper Wolfjaw Trail to an elevation of 3260 feet ASL. Potsdam erratics were also observed on

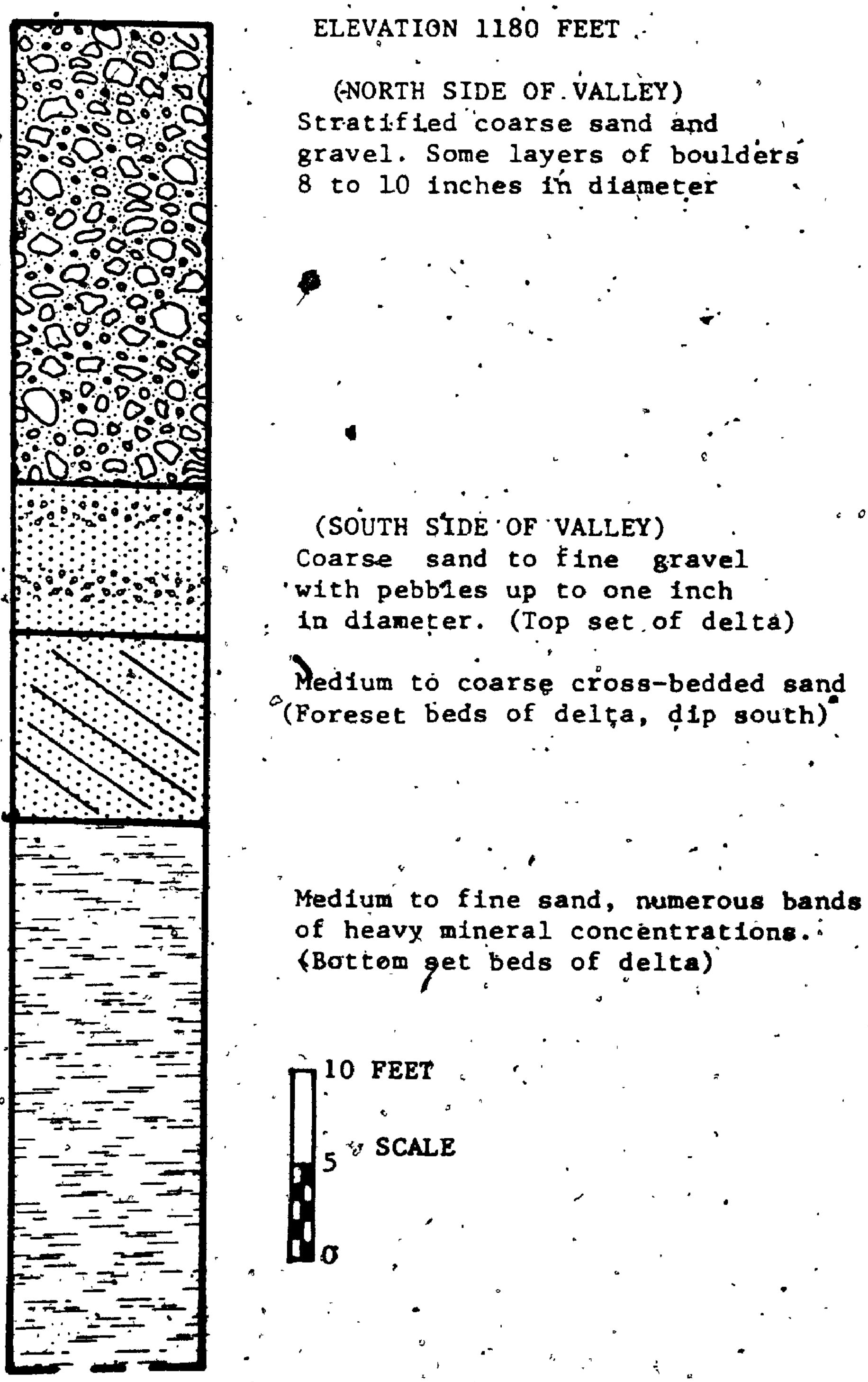


Figure 47 Compiled stratigraphic section Site 278, lower part of Johns Brook Valley

the slopes of Yard and Big Slide Mountain but not on the mountain peaks. No Potsdam erratics were seen in Johns Brook above Johns Brook Loj or along the trails leading to the upper part of the valley and to the mountain ridges. A line drawn from Yard Mountain on the north side of Johns Brook Valley to Armstrong Mountain on the south side separates the area of Potsdam erratics being common (down valley) from Potsdam erratics being rare (up valley). Potsdam erratics were observed in tills below Wolfjaw Mountain (sites 93 and 94) in a stream cut near site 80 and at site 280.

3.3 DISTRIBUTION OF CIRQUES

The High Peaks region can be divided into six distinct mountain masses. This division is based on the separation of a mountain mass from the surrounding area by a low elevation pass. Air photo studies of the High Peaks region show cirques in each of these six divisions. The outlines of these mountain masses and the positions of the cirques are shown in figures 49, 51, 53, 55, 57, and 59. The six mountain groups and the numbers of cirques and their schrund elevations appear in table 9.

Two hundred and twenty-four cirques were identified in the air photo studies of the High Peaks region. Figure 48 is a rose diagram of the cirque positions and aspects for the entire High Peaks area. Schrund elevations are shown as a histogram. Joint directions are plotted as a rose diagram from data compiled by Balk (1931).

Table 9. General Information on Cirques.

	Group	No. of Cirques	Lowest Schrund Elevation	Highest Schrund Elevation	Average Schrund Elevation
I.	Whiteface Mountain & Wilmington Range	19	2200' ASL	3500' ASL	2923' ASL
II.	Sentinel Mountain & Porter Range	20	2400' ASL	3300' ASL	2850' ASL
III.	Jay Mountain, Soda Range, & Hurricane Mountain	29	1800' ASL	3000' ASL	2400' ASL
IV.	Green Mountain & Giant Mountain	30	1700' ASL	3800' ASL	2750' ASL
V.	Boreas Mountain & Dix Range	49	2400' ASL	3700' ASL	3096' ASL
VI.	Marcy	77	2400' ASL	4300' ASL	3339' ASL
	TOTAL CIRQUES	224	1700' ASL	4300' ASL	2893' ASL

The rose diagrams show that cirque positions and aspects occur in all quadrants. When the information is analyzed by quadrants, a pattern emerges (table 10). With regard to cirque positions, a quadrant analysis reveals that 33% of the cirques fall in the northeast quadrant and only 18% in the northwest. Cirque aspect is somewhat similar with 29.5% of the cirques opening to the northeast; the lowest number (19.2%), open toward the southwest.

It is obvious from these data that there is no strong preference for any one quadrant in the distribution of cirques throughout the High Peaks area. There is an almost equal distribution of positions and aspects of cirques throughout the area with only a 15% difference between the quadrant with the greatest number of cirques (NE) and the

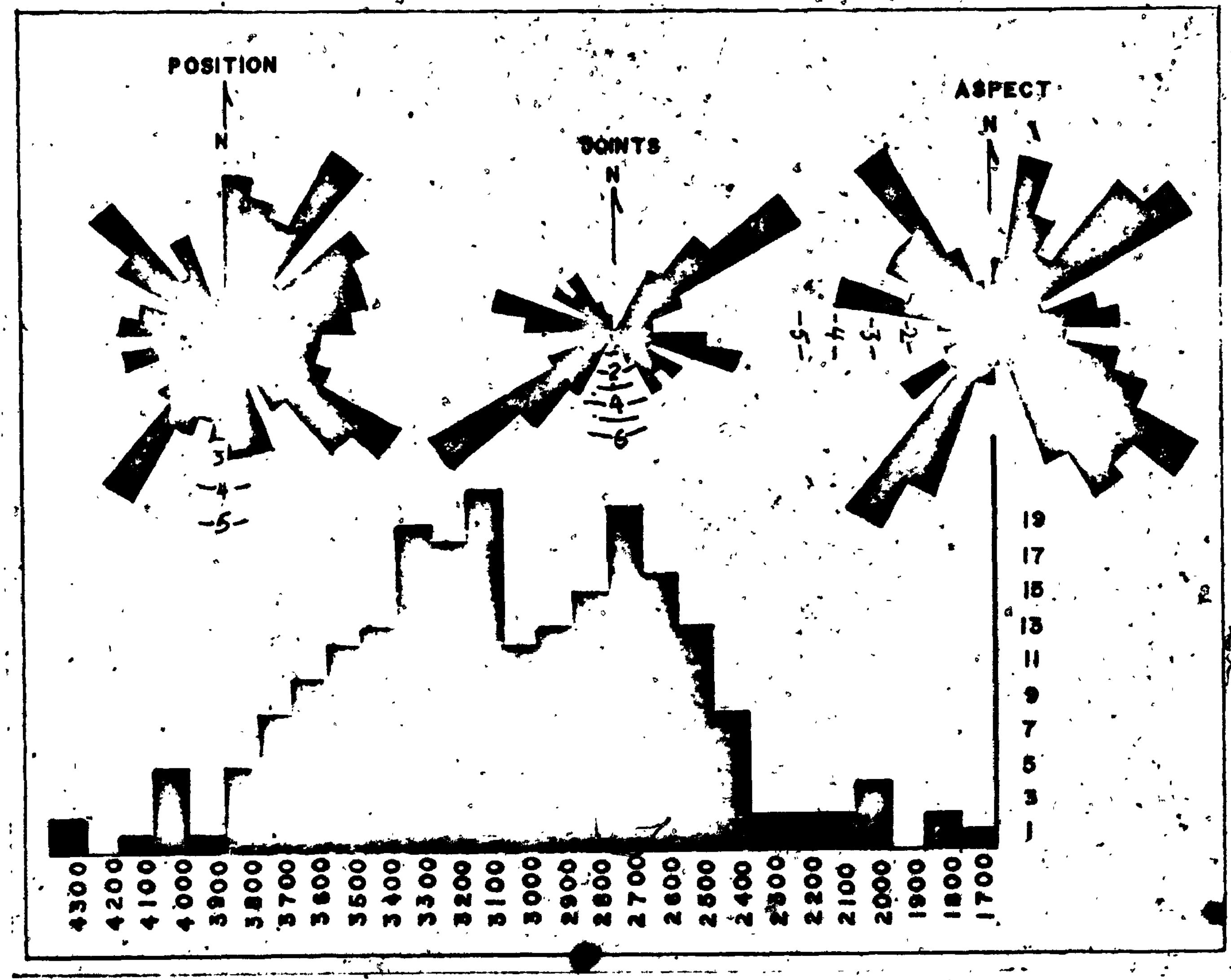


Figure 48. Rose diagrams of cirque position, joint direction, and cirque aspect for total study area. Histogram shows elevation of schrund lines.

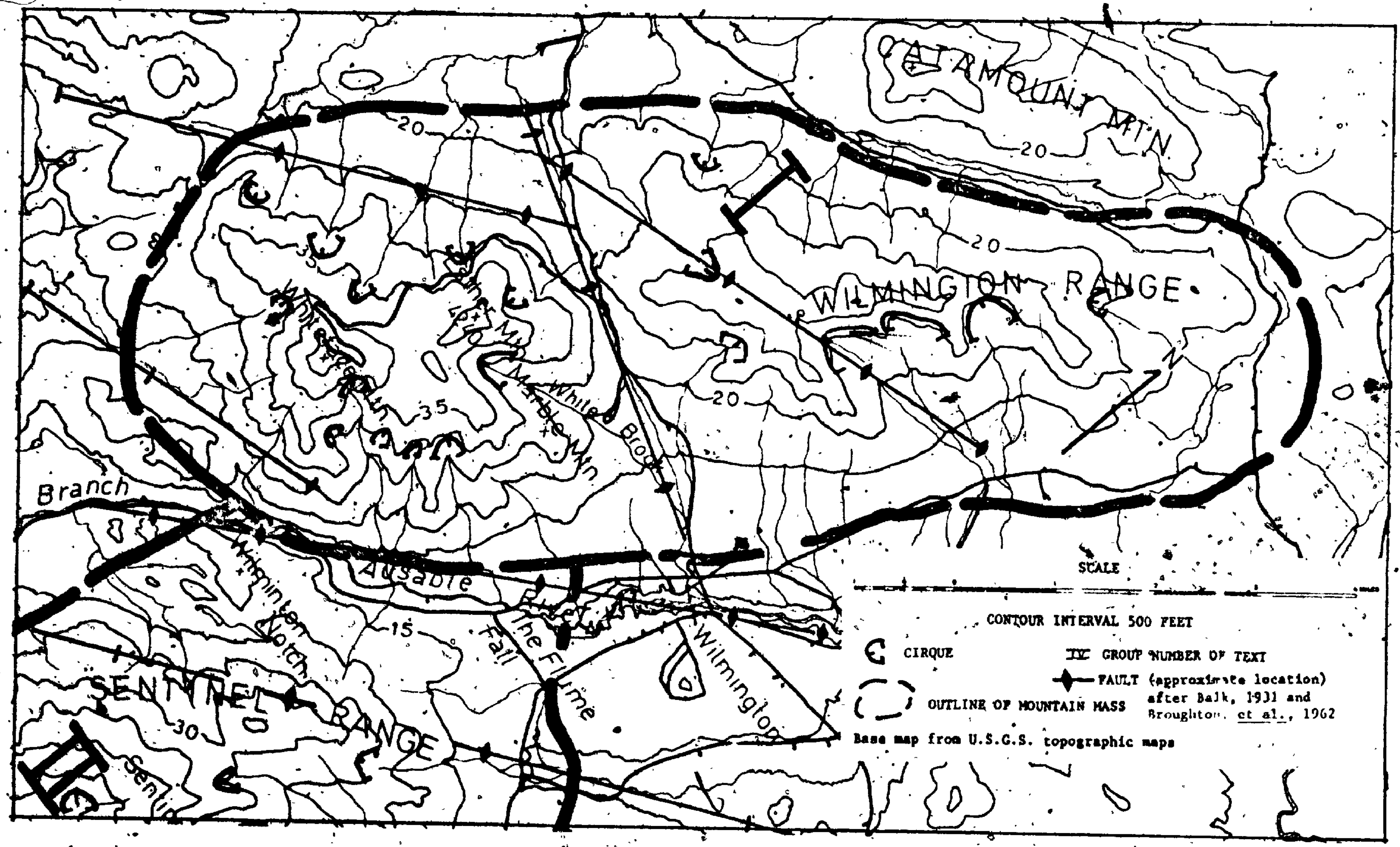


Figure 49. Cirque location map, Group I, Whiteface Mountain - Wilmington Range.

least number (SW).

Table 10. Position and Aspect of Cirques by Quadrants for High Peaks Region.

Quadrant	Cirque No.	Position %	Cirque No.	Aspect %
Northeast	74	33.0	66	29.5
Southeast	59	26.3	63	28.1
Southwest	50	22.3	43	19.2
Northwest	51	18.3	52	23.2
TOTAL	224	99.9	224	100.0

There occurs in each position quadrant a maximum. The maxima occur at 035°, 130°, 215° and 310°. Analysis of the data reveals that these maxima are the result of contributions from the individual mountain groups. Thirty-six percent of the cirques positioned at 035° are from Group IV, with the other five groups contributing from 0-27%. The maximum at 130° received a 35% contribution from Group III, compared with a range of 0 to 20% from the other groups. Forty-four percent of the cirques positioned at 215° are from Group II; the other groups contributing from 0 to 22%. The maximum at 310° is strongly influenced by a 58% contribution from Group IV, compared with 0 to 18% contributions from the remaining groups.

The maxima which occur in each cirque aspect quadrant also reflect the influence of individual mountain groups. The maximum which occurs at 055° receives a 30% contribution from Group II, compared with 0 to 20% from the other five groups. Thirty-eight percent of the cirque aspects at 125° are from Group VI with contributions of 0 to 23% from the other groups. Groups III and IV each influence the maximum at 215° by 31% with the range for the other groups 0 to 23%. Sixty-seven percent of the 325° maximum is due to Group IV cirques with the others contributing 0 to 17%.

The factors which influence the position and aspect of cirques are discussed in 3.3.1 to 3.3.6.

There is a strong relationship between joint direction and faulting to cirque aspect and position. Balk (1931) points out that the major joint and fault directions throughout the High Peaks area are nearly parallel to the individual mountain ridges, and that the secondary joint directions fall at nearly right angles to the major directions. Comparing cirque aspect and position to joint directions (figure 48) shows that most of the cirques fall on either side of the predominant joint direction. There are, however, cirques in each group whose orientations are similar to those of the predominant joint directions. These cirques occur either at the ends of mountain ridges (e.g. Group IV, Iron Mountain) or on either side of ridges cut by faults which are oriented in the direction of jointing (Group I, Cooperkill Pond).

3.3.1 GROUP I - WHITEFACE MOUNTAIN AND THE WILMINGTON RANGE (Lake Placid Quadrangle, figure 49)

This is the northernmost mountain group of the High Peaks region. It is elliptical with the long axis oriented northeast. Whiteface Mountain at the southwest end of the elliptical mass is a nearly circular dome-like mountain composed of Whiteface anorthosite at the top, grading downward into Marcy anorthosite. The Wilmington Range is separated from Whiteface Mountain by a pass at Stevens Lake. This pass is believed to mark the trace of a fault (Broughton et al., 1962). The Wilmington Range is a long relatively narrow ridge oriented northeast and is composed mostly of Whiteface anorthosite with some charnockite xenoliths grading downward into Marcy anorthosite.

This mountain group is believed by Alling (1921) and Broughton et.al. (1962) to be bounded by the Lake Placid fault on the west and Wilmington Notch fault on the east. The only evidence of faulting observed within the mass is the Lake Stevens Pass fault, which separates Whiteface Mountain from the Wilmington Range. The highest elevation is Whiteface Mountain (4867 feet ASL) on the southwest end of the mass. Elevation decreases to the northeast with Esther Mountain (4240 feet ASL) being next highest. The highest point on the Wilmington Range is 3418 feet ASL. The air photo study identified 19 cirques on this mountain group (figure 49).

Cirques appear to have been eroded across the mass with some structural or bedrock control. The faults cutting the mountain mass strike approximately N 53° E (Wilmington Notch fault) and N 70° W (Stevens Pass fault). Jointing in the area is nearly the same (N 80° W and N 60° E). The ridge line for the area is oriented N 35° E.

Particularly interesting here are the positions and aspects of the cirques. The greatest number (36.8%) is positioned in the northeast quadrant and is nearly in line with the northeast structural trend. The second greatest number (31.6%) falls in the southeast quadrant nearly in line with the northwest structural trend. Cirque aspects show the same relationship to structure with concentration of

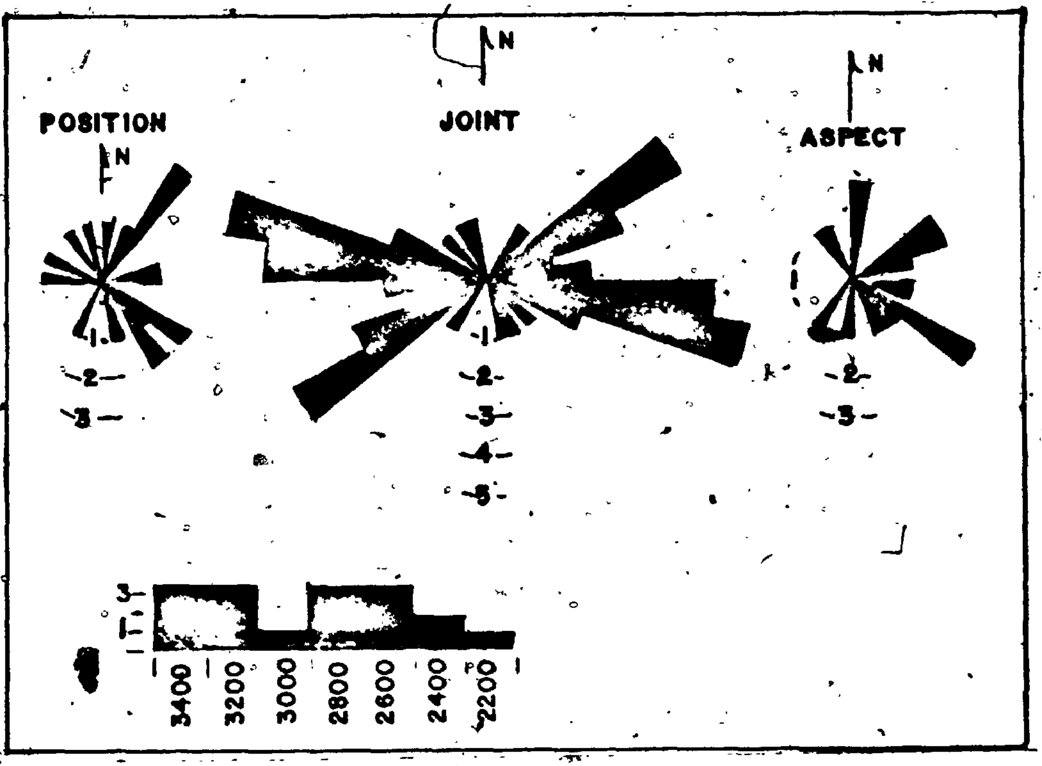


Figure 50. Rose diagrams of cirque position, cirque aspect, joint orientation and histogram of schrund elevations. Group I - Whiteface Mountain - Wilmington Range.

Table 11. Position and Aspect of Cirques by Quadrants. Group I - Whiteface Mountain - Wilmington Range.

Quadrant	Cirque No.	Position %	Cirque No.	Aspect %
Northeast	7	36.8	7	36.8
Southeast	6	31.6	8	42.2
Southwest	2	[illegible]0.5	2	10.5
Northwest	4	21.1	2	10.5
TOTAL	19	100.0	19	100.0

cirques opening in directions similar to the joint directions (figure 50).

Schrund elevations vary from 2100 to 3500 feet ASL with the lowest elevation on the north side of the mountain. Though individual position and aspect vary, the concentration of forms and degree of development indicate the most favorable micro-climatic conditions for continued preservation of localized ice masses existed on the east side of the mountain, since 68.4% of the cirques are positioned on the east side of the mountains and 79.0% open to the east.

3.3.2 GROUP II - SENTINEL RANGE AND PORTER MOUNTAIN (Lake Placid and Mount Marcy Quadrangles, figure 51)

The Sentinel Range and Porter Mountain are located south of the Whiteface Group and are separated from the Whiteface mass by the Wilmington Notch fault (Broughton et al., 1962). Porter Mountain is separated from the Sentinel Range by the Cascade Pass fault. These two faults strike N 53° E. Balk (1931) shows the jointing of this group to be the same as the Whiteface Mountain Group with joint directions of N 80° W and N 60° E.

The group is roughly rectangular in outline (figure 51) with the highest elevation in the southern part (Porter Mountain, 4059 feet ASL). Bedrock is essentially the same as for the Whiteface Mountain Group with Whiteface anorthosite containing charnockite xenoliths in the upper elevations of the Sentinel Range and changing to Marcy anorthosite downward. Porter Mountain is all Marcy anorthosite.

Twenty cirques were identified in the air photo study. Nine (45%) lie on the northeast side of the mountain mass and 7 (35%) on

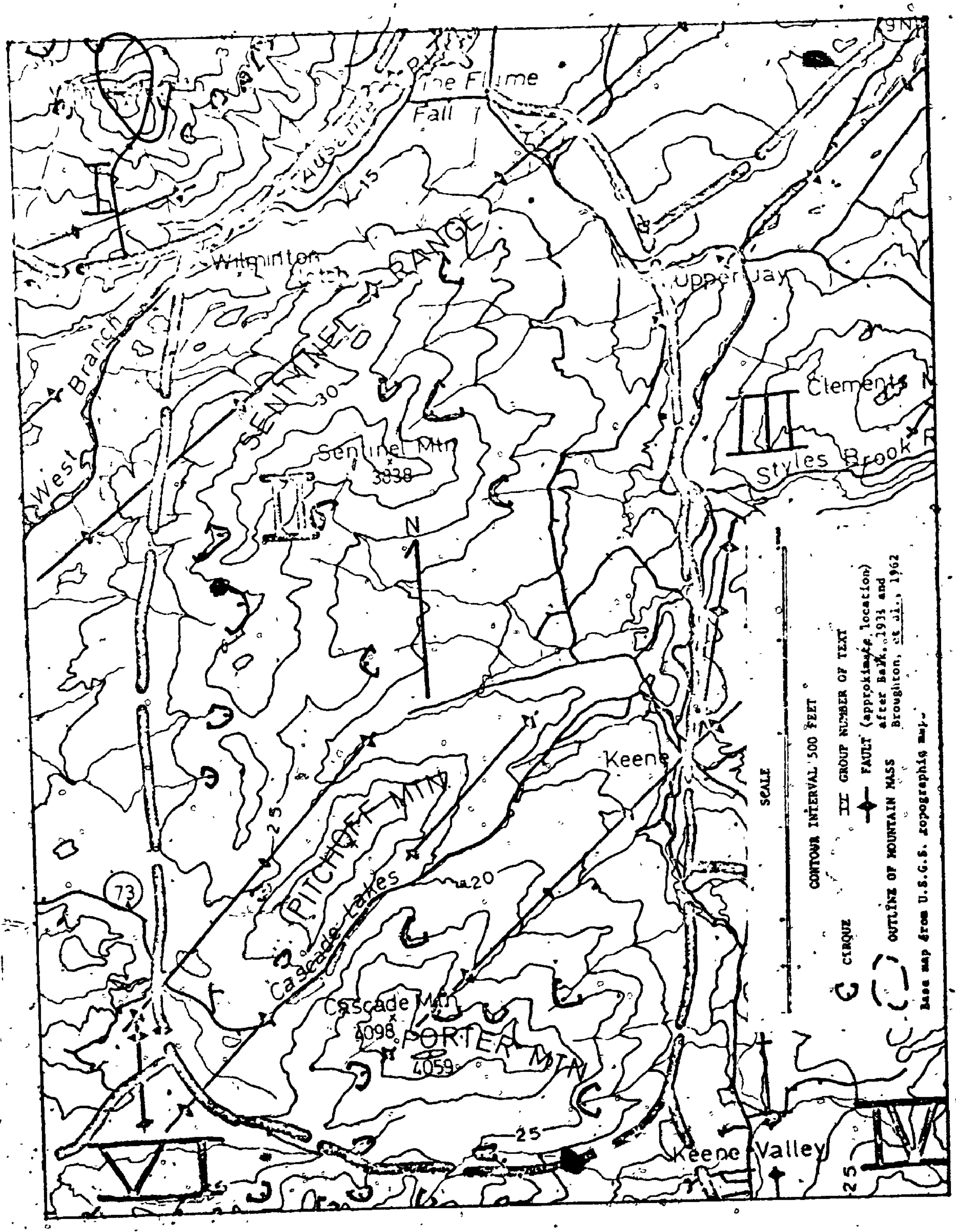


Figure 51. Cirque location map, Group II, Sentinel Range and Porter Mountain.

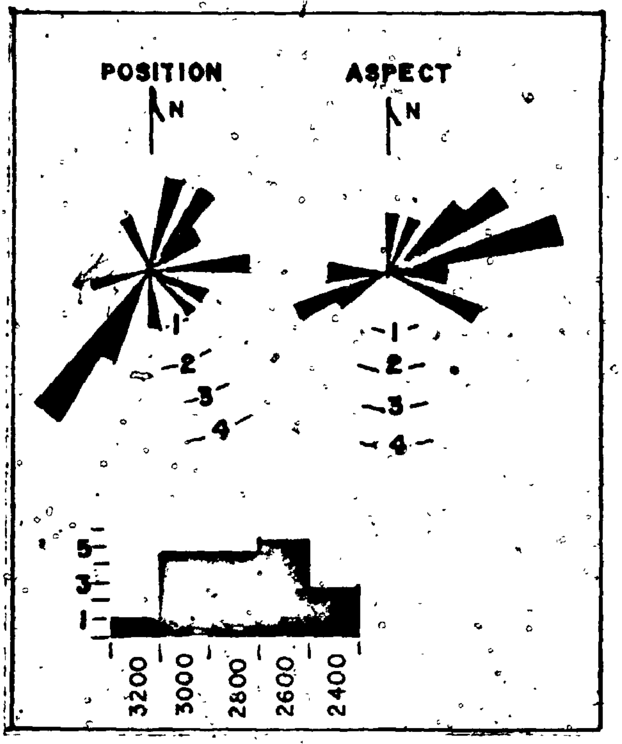


Figure 52. Rose diagram of cirque position, cirque aspect and histogram of schrund elevation. Group II - Sentinel Range and Porter Mountain.

Table 12. Position and Aspect of Cirques by Quadrants. Group II - Sentinel Range and Porter Mountain.

Quadrant	Cirque No.	Position %	Cirque No.	Aspect %
Northeast	9	45	12	60
Southeast	3	15	3	15
Southwest	7	35	4	20
Northwest	1	5	1	5
TOTAL	20	100	20	100

the southwest side. However, 12 or 60% of the cirques open toward the northeast (figure 52, table 12). This strong predominance of position and aspect is in close alignment with the direction of jointing and faulting in the area. Cirque positions (figure 52) are on either side of the joint-fault direction. Cirque aspects show a stronger orientation in the direction of major structural trends.

Schrund elevations are concentrated between 2400 feet and 3000 feet ASL with the lower elevations (one in each quadrant) in the Sentinel Range. The most completely developed cirques are those with northeast positions and aspects. Although individual aspect and position vary, the concentration of alignments and the degree of development indicate micro-climatic conditions favorable for preservation of localized ice masses on the east side of the mountain masses. It is believed that the development of cirques in the southeast quadrant (35% position) is related to a micro-climatic wind shadow from the higher mountains to the south and southwest of Porter Mountain.

3.3.3 GROUP III - JAY MOUNTAIN, SODA RANGE AND HURRICANE MOUNTAIN

The Group III mountain area is located due east of the Group II mass and is separated from it by the East Branch Ausable River (figure 53). This valley is one of the main northeast-southwest troughs through the high mountains. In this part of the High Peaks region the river valley lies, in part, on the contact between the anorthosite massif and the metasedimentary border rocks. Hurricane Mountain and most of the Soda Range are Marcy anorthosite (figure 6, region J). Clements and Jay Mountains are mixtures of anorthosite and metasedimentary rocks. Kemp and Alling (1925) mapped two faults within the outline of this group: one cutting through the Soda Range (figure 53) striking N 65° E, and the second in Styles Brook striking from N 60° E at the west end curving to N 30° E at the east end. Two major faults have been mapped outside the map limits (Kemp and Alling, 1925) striking N 35° W and N 50° E.

This area is the lowest part of the High Peaks region that has well developed cirques. The highest schrund elevation is only 3000 feet ASL with most of the schrund elevations approximately 2400 feet ASL (figure 54). The lowest schrund elevation is 1800 and lies in a west-northwest position. The highest peak in this mass is Hurricane Mountain, elevation 3694 feet ASL. Cirque positions are distributed around the mountain peaks (table 13). The highest percentage is in the southeast quadrant (34.5%), with the lowest percentage in the northeast quadrant (19.2%). Cirque aspect, however, shows a predominance in the northeast quadrant (38%) and the southwest quadrant (31%).

Structural influence on position and aspect is different in this group than those previously discussed.

Cirque position is concentrated to either side of the structural trend (figure 54) in the northwest-southeast direction; whereas cirque aspect is concentrated at nearly right angles to cirque position with the cirque openings oriented in the northeast-southwest directions. The orientation of positions and aspects seem to indicate a preference for position on the west and southeast sides of the mountain, with valley erosion taking advantage of the intersection of the two structural trends developing valleys oriented northeast-southwest. The best developed cirques lie in the northeast-southwest orientation. This is believed due to a combination of most favorable local climatic effect and the above mentioned structural weaknesses.

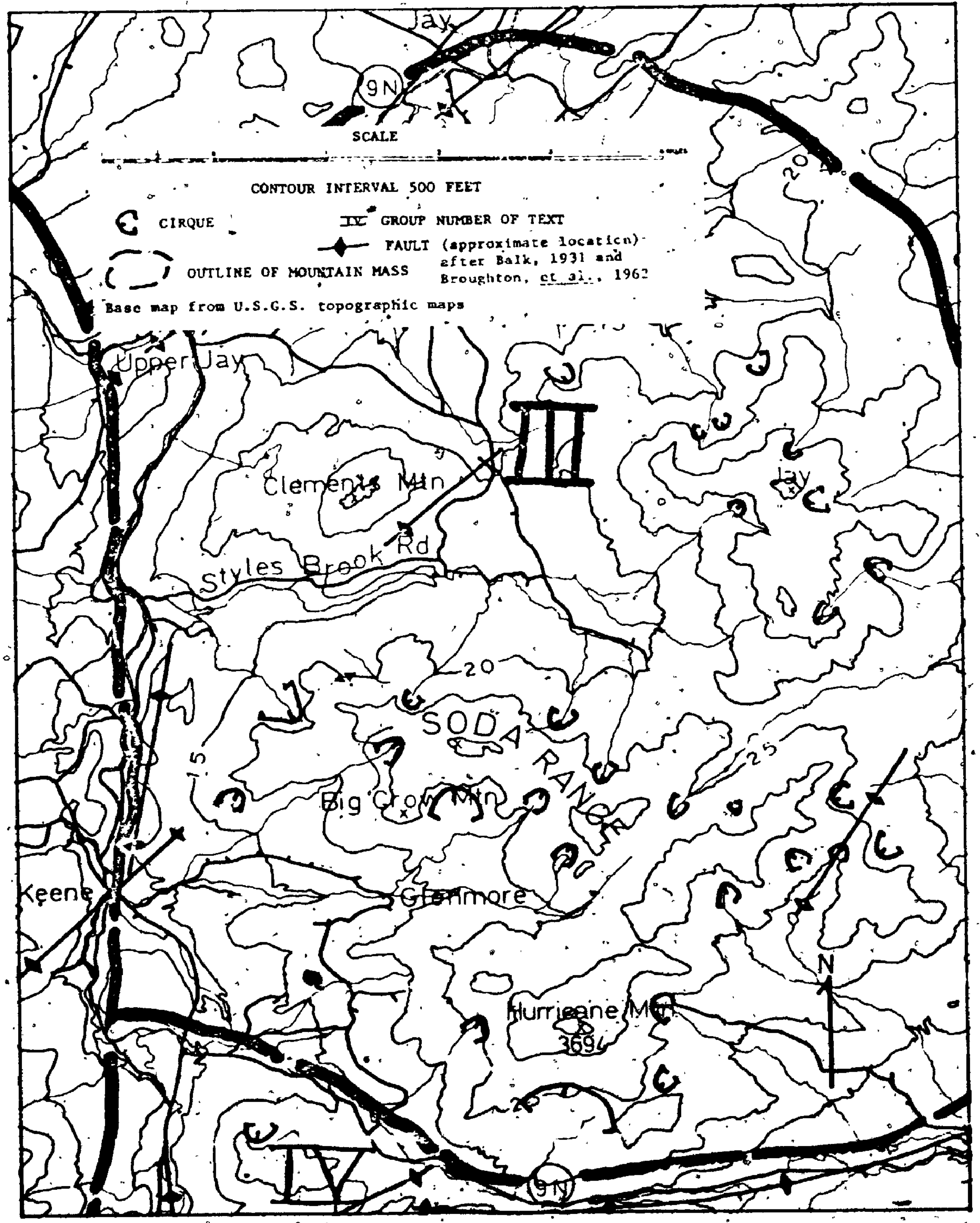


Figure 53. Cirque location map, Group III, Jay Mountain, Soda Range, and Hurricane Mountain.

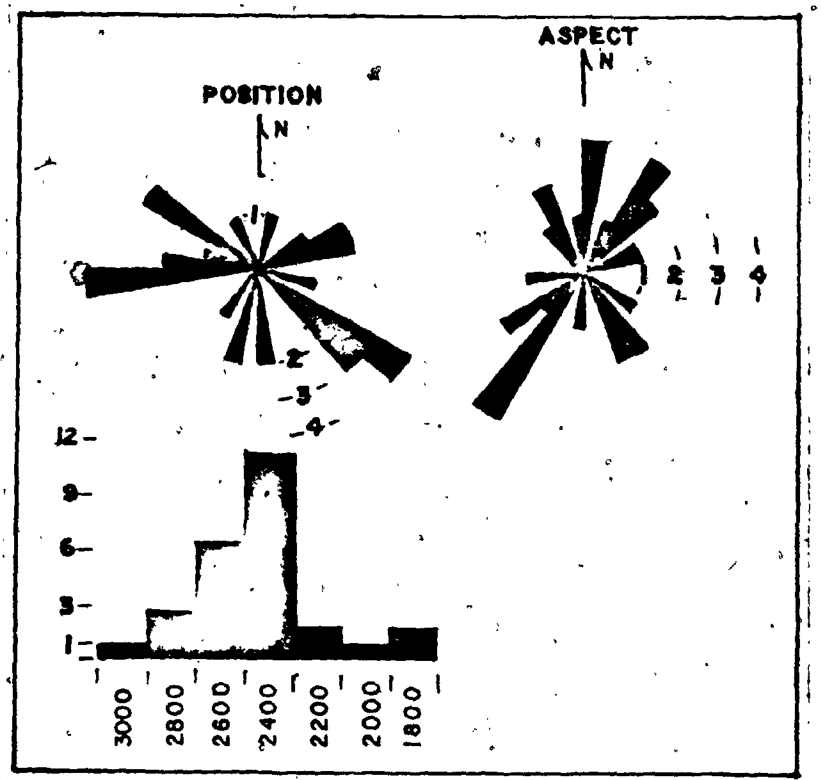


Figure 54. Rose diagram of cirque position, cirque aspect and histogram of schrund elevations. Group III - Jay Mountain, Soda Range, and Hurricane Mountain.

Table 13. Position and Aspect of Cirques by Quadrants. Group III - Jay Mountain, Soda Range, and Hurricane Mountain.

Quadrant	Cirque No.	Position %	Cirque No.	Aspect %
Northeast	5	17.2	11	38.0
Southeast	10	34.5	5	17.2
Southwest	7	24.1	9	31.0
Northwest	7	24.1	4	13.8
TOTAL	29	99.9	29	100.0

3.3.4 GREEN AND GIANT MOUNTAINS (Elizabethtown Quadrangle, figure 55).

The Green and Giant Mountains group is located on the eastern edge of the High Peaks region (figure 55). The area is bounded by the Bouquet River to the east and south, by Chapel Pond Pass to the southwest, by the East Branch Ausable River to the west, and by the Spruce Hill Road Pass to the north. Highest elevations are Giant Mountain (4627 feet ASL) and Rocky Peak (4420 feet ASL) located on the southern side of the mountain mass. Green Mountain is an elongate east-west ridge on the north side of the mass.

Kemp (1910) identified faults in the Bouquet River Valley striking N 50° E, in Chapel Pond Pass striking N 48° W, and Alling (1921) mapped the Ausable Lakes fault striking N 38° E. Balk (1931) shows the predominent joint direction in this group to be N 43° E with the secondary direction oriented N 35° W. Bedrock throughout this group is Marcy anorthosite with two small areas of metasedimentary rocks (figure 6, region K).

The air photo study identified 30 cirques in this group. The northeast quadrant contains 46.7% of the cirques; the southeast, 26.7%. Forty percent of the cirques open to the northeast, and 30% open to the southeast (figure 56, table 14). Thus, over 73% of the cirques are positioned on the east side of the mountain peaks and 70% open to the east.

Cirque position is clearly related to the structural trend of this group with fifteen of the thirty cirques located close to the N 43° E direction of the joint system and 17% close to the northwest-southeast joint system. In this group, the major orientations of cirque aspect are in the same directions as cirque position.

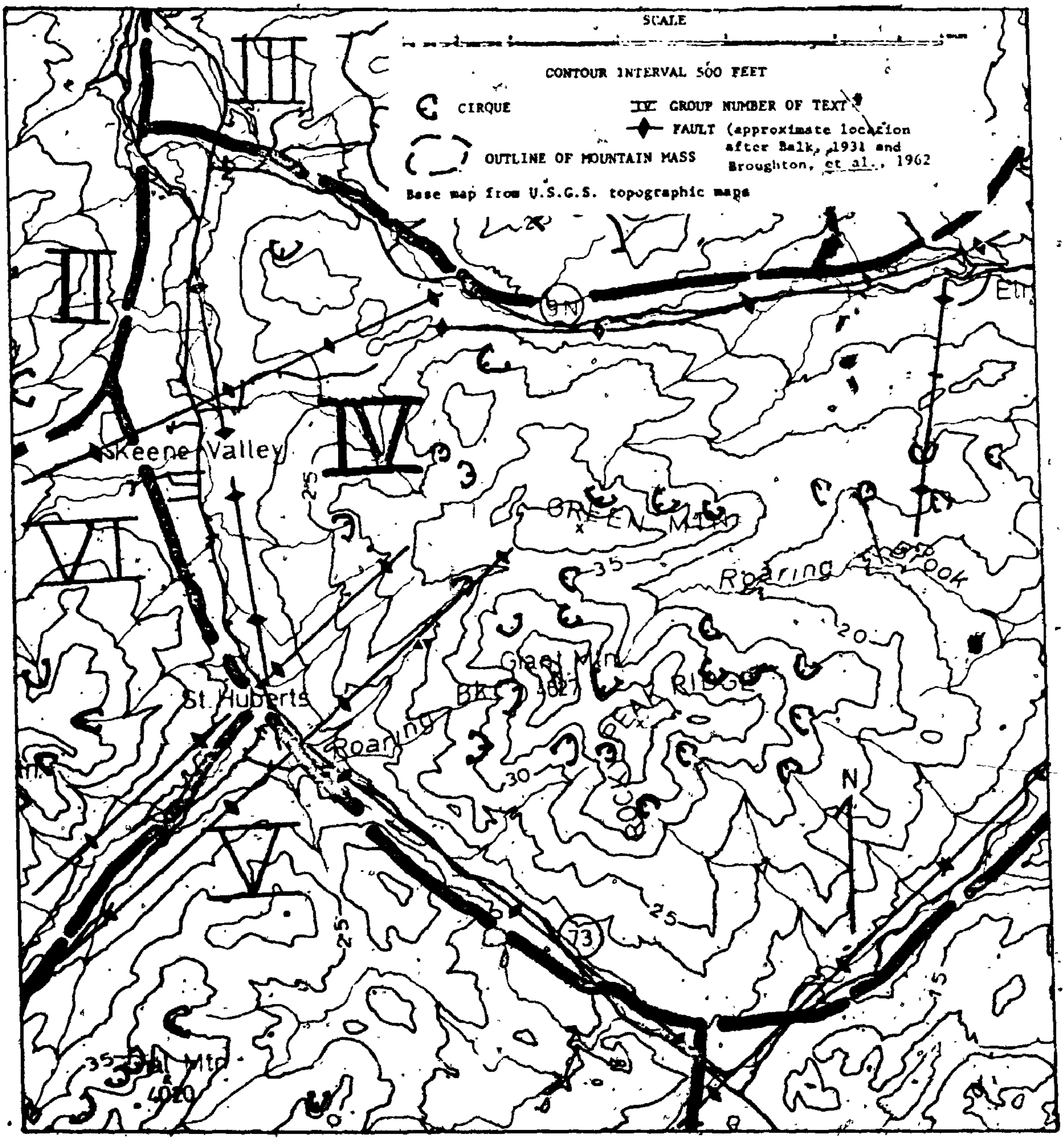


Figure 55: Cirque location map, Group IV, Green and Giant Mountains.

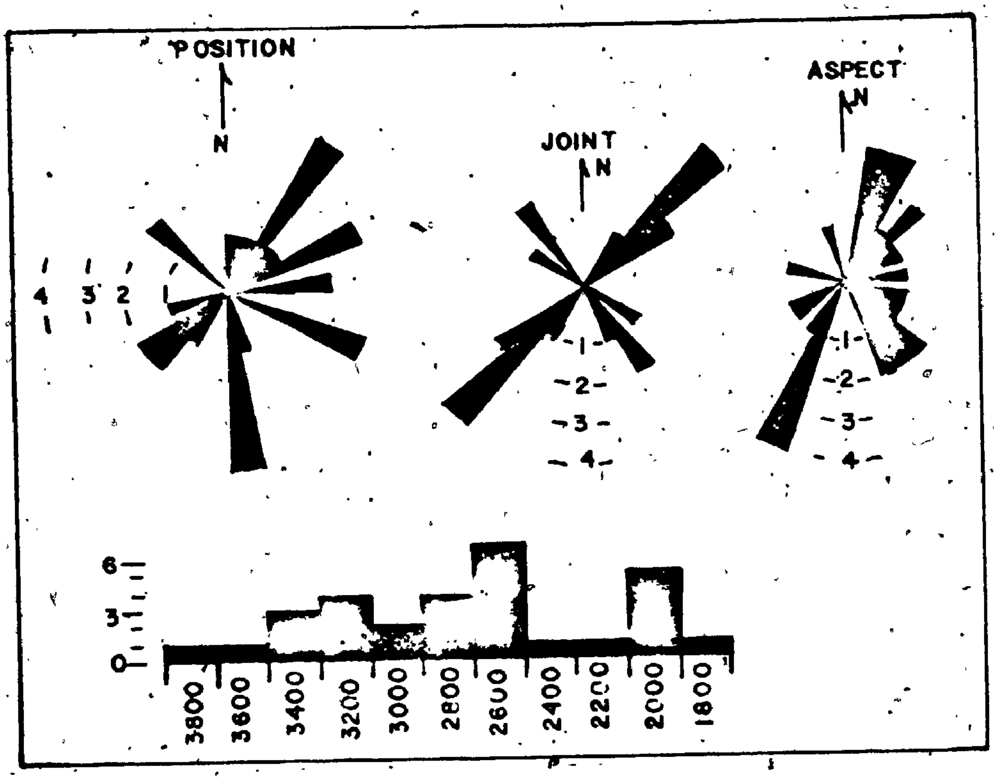


Figure 56. Rose diagram of cirque position, joint orientation, cirque aspect and histogram of schrund elevation. Group IV - Green and Giant Mountains.

Table 14. Position and Aspect of Cirques by Quadrants. Group IV - Green and Giant Mountains.

Quadrant	Cirque No.	Position %	Cirque No.	Aspect %
Northeast	14	46.7	12	40.0
Southeast	8	26.7	9	30.0
Southwest	6	20.0	7	23.3
Northwest	2	6.6	2	6.6
TOTAL	30	100.0	30	100.0

Schrund elevation ranges from 1800 to 3800 feet ASL with the lowest schrund elevation in a northeast position.

The distribution of cirques is also related to the location of the individual mountain to the adjacent mountains and the prevailing meteorological conditions. For example, Giant Mountain and Rocky Peak are ringed by cirques, but Green Mountain at a lower elevation just north and east of Giant has cirques only on the north-facing slope.

Green Mountain is separated from Giant Mountain by a glaciated valley opening eastward. If the prevailing winds were from the southwest, Green Mountain and the valley between Green Mountain and Giant would be in a wind shadow of Giant Mountain.

This valley downwind from the mountain mass would receive wind transported snow from Giant Mountain sufficient to form an eastward moving glacier. This glacier is believed to have filled the valley so that no individual cirques could develop on the valley sides. However, snow accumulating on the north side of Green Mountain did develop individual cirques. Iron Mountain on the east end of the Green Mountain chain and Tripod Mountain on the west end have cirques distributed around the mountain peak. These two areas, the east and west ends of the ridge, are far enough from the wind shadow effect of Giant Mountain and Rocky Peak that cirque development has occurred randomly around the peaks due to redistribution of snow into protected areas around the mountains.

3.3.5 GROUP V - BOREAS MOUNTAIN AND THE DIX RANGE (Mount Marcy Quadrangle, figure 57)

The Boreas Mountain and Dix Range is the southernmost mountain mass of the High Peaks area. This group is bounded by Chapel Pond Pass to the northeast (figure 57), by the East Branch Ausable River to the northwest and by Blue Ridge Road to the south. The Dix Range is composed of eight individual mountain peaks with elevations over 4000 feet ASL. Bedrock is Marcy anorthosite throughout. Kemp (1910) identified a fault in Chapel Pond Pass striking N 48° W and Alling (1921) mapped a fault in Ausable Lakes Pass striking N 38° E. Balk (1931) shows the joint system to be oriented approximately N 60° E and N 55° W. The Boreas Mountains are much lower in elevation with the highest point being Mt. Colvin (4057 feet ASL) on the northernmost end of the ridge.

The Boreas Mountains are part of an elongate northeast-southwest ridge rising in elevation from south to north. The southernmost part of this ridge has cirques developed only on the west side of the ridge. The most northern half of the ridge, which is higher in elevation, has cirques on both sides of the ridge. The west-facing cirques on the lower part of this ridge are the best developed, and one of these has an end moraine at the mouth of its valley (see 3.2.2.3 for detailed description of this feature). The Dix Range is the highest part of the group and cirques have cut the mass into a series of individual peaks. A review of the distribution of cirque position by quadrants shows a scatter with only 12% difference between the highest percentage, northeast and southwest (each 28.6%), and the lowest percentage, northwest (16.3%). Cirque aspect has a slightly larger difference among quadrants (22%), and the largest number (36.7%) are oriented in the northwest quadrant (figure 58, table 15).

In this group the structural trend has less influence on cirque

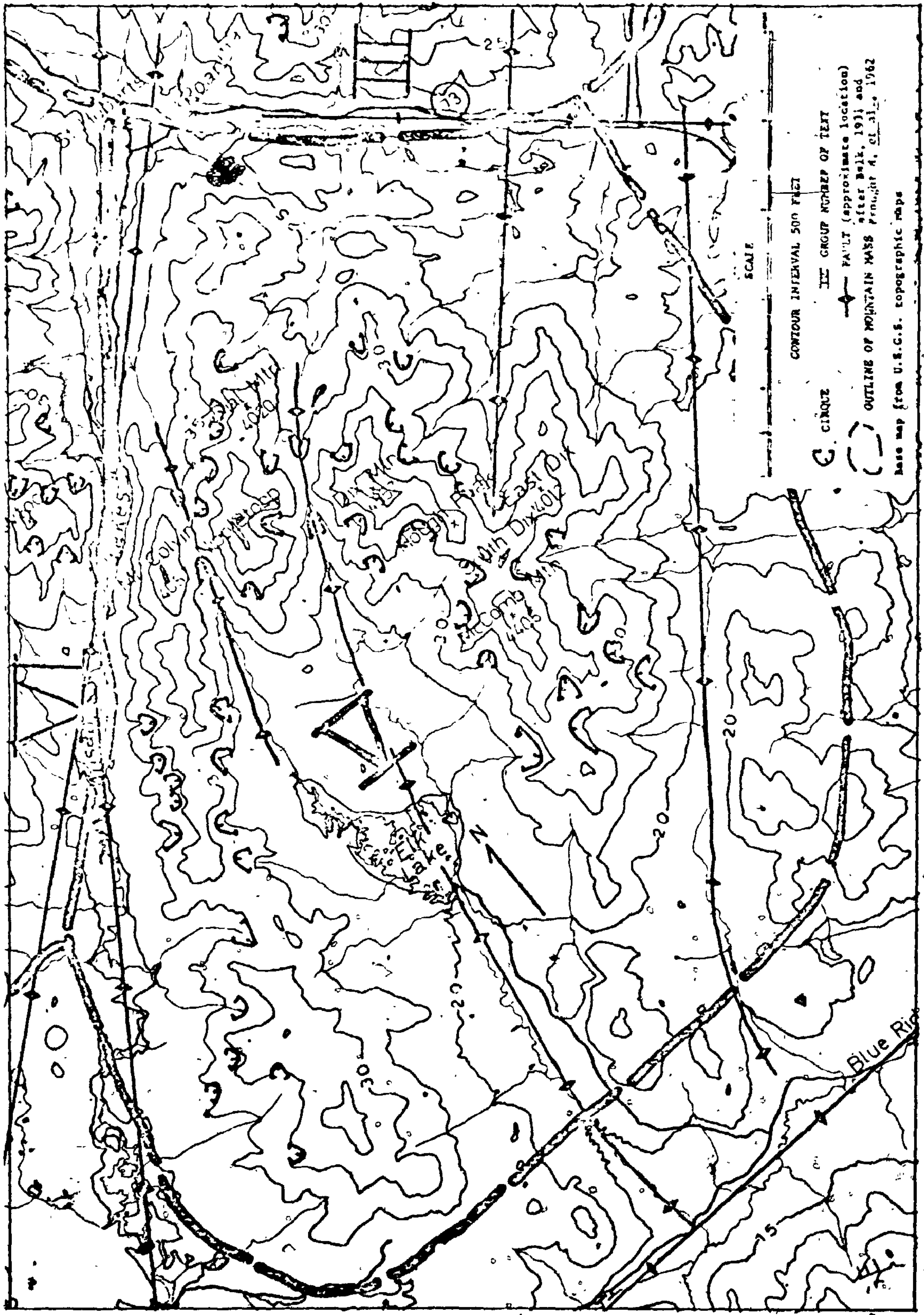


Figure 57. Cirque location map, Group V, Boreas Mountain and Dix Range.

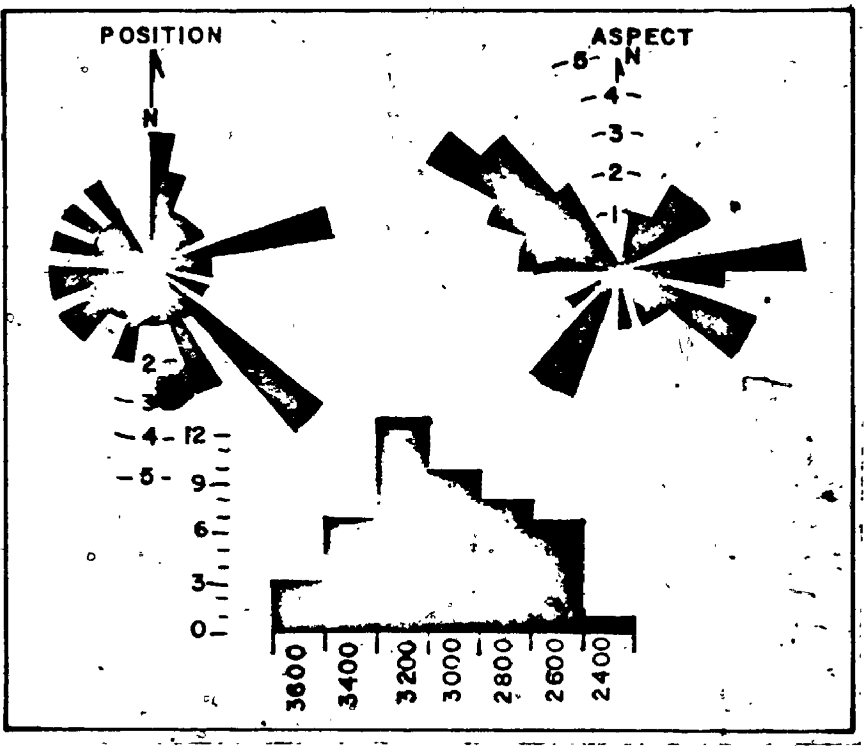


Figure 58. Rose diagram of cirque position, cirque aspect and histogram of schrund elevation. Group V - Boreas Mountain and Dix Range.

Table 15. Position and Aspect of Cirques by Quadrants. Group V - Boreas Mountain and Dix Range.

Quadrant	Cirque No.	Position %	Cirque No.	Aspect %
Northeast	14	28.6	12	24.5
Southeast	13	26.5	12	24.5
Southwest	14	28.6	7	14.3
Northwest	8	16.3	18	36.7
TOTAL	49	100.0	49	100.0

position. Table 15 shows a fairly equal distribution of position. Cirque aspect, however, is different. The influence of the major northwest joint direction is shown by the concentration of cirque openings oriented in the northwest-southeast direction (figure 58).

Schrund elevations range from 2400 to 3600 feet ASL with a maximum frequency at 3200 feet ASL scattered amongst all quadrants. The minimum schrund elevation occurs in a northwest position.

3.3.6 GROUP VI - MOUNT MARCY (Mount Marcy Quadrangle, figure 59)

The Mount Marcy Group of cirques are in the most southwesterly part of the High Peaks region (figure 59). Bedrock throughout the whole mass is Marcy anorthosite except for a few large xenoliths of metasedimentary rocks in the vicinity of Wolfjaw Mountain. The air photo study identified 77 cirques. The quadrant plots of the position of the cirques show a maximum position at N 45° W. The northeast quadrant contains 32.5%; the southwest, 18.7% (table 16).

Mount Marcy (5344 feet ASL), the highest mountain in the High Peaks region has the fewest number of cirques (11) developed on its slopes. Those that are developed ring the mountain mass. Thirteen cirques are developed on the mountain system to the north of Mount Marcy and 43 on the Range. The Range, with Johns Brook on the north side and Ausable Lakes on the south, is deeply dissected by cirque glaciation. There are eight peaks above 4000 feet ASL in elevation, each peak is isolated by a col from the adjacent peak. The most strongly developed cirque outline occurs on the north side of the ridge. The mountain system on the north side of Johns Brook Valley is lower in elevation and has less well defined cirques, and these

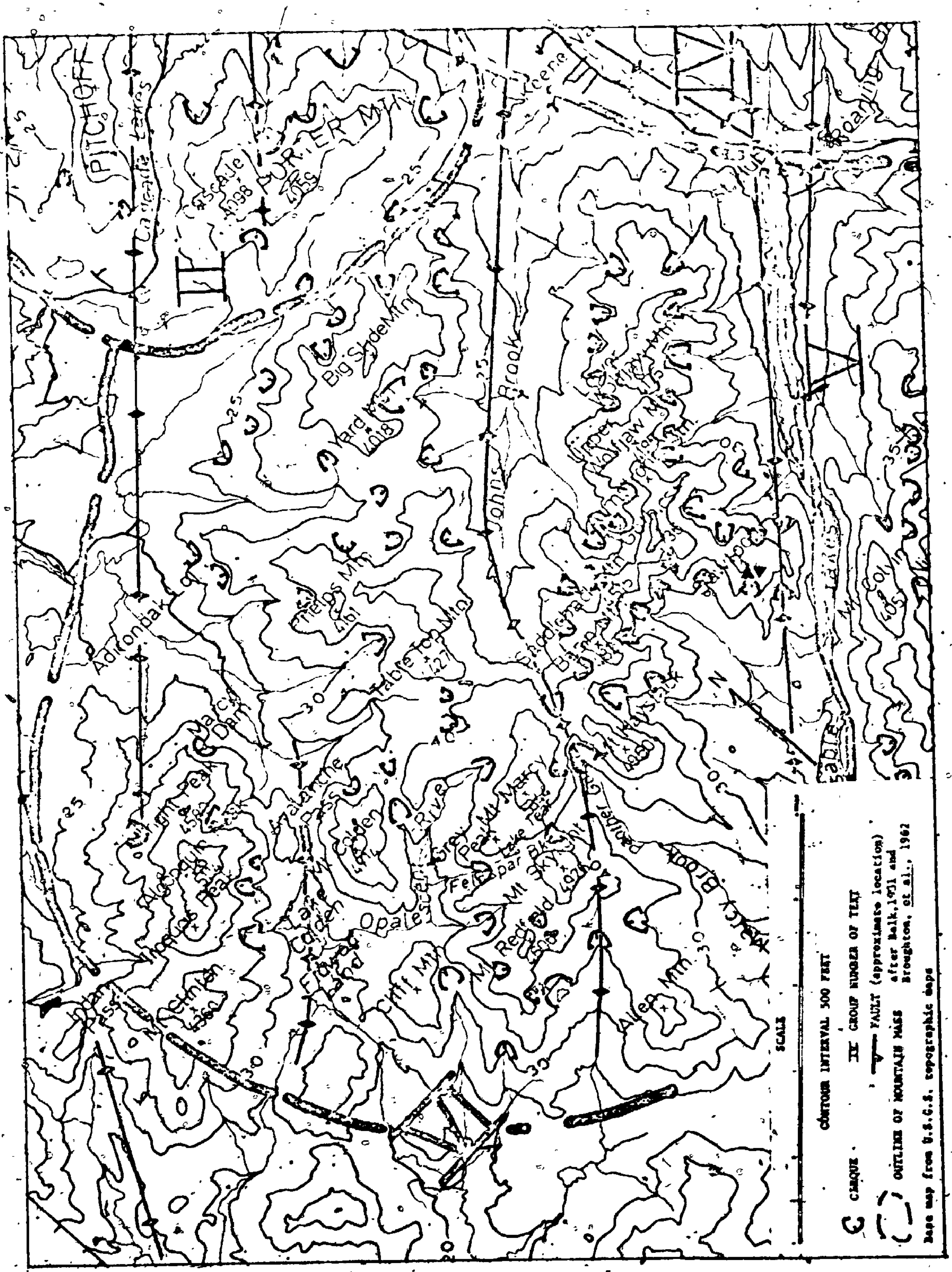


Figure 59. Cirque location map, Group VI, Mount Marcy.

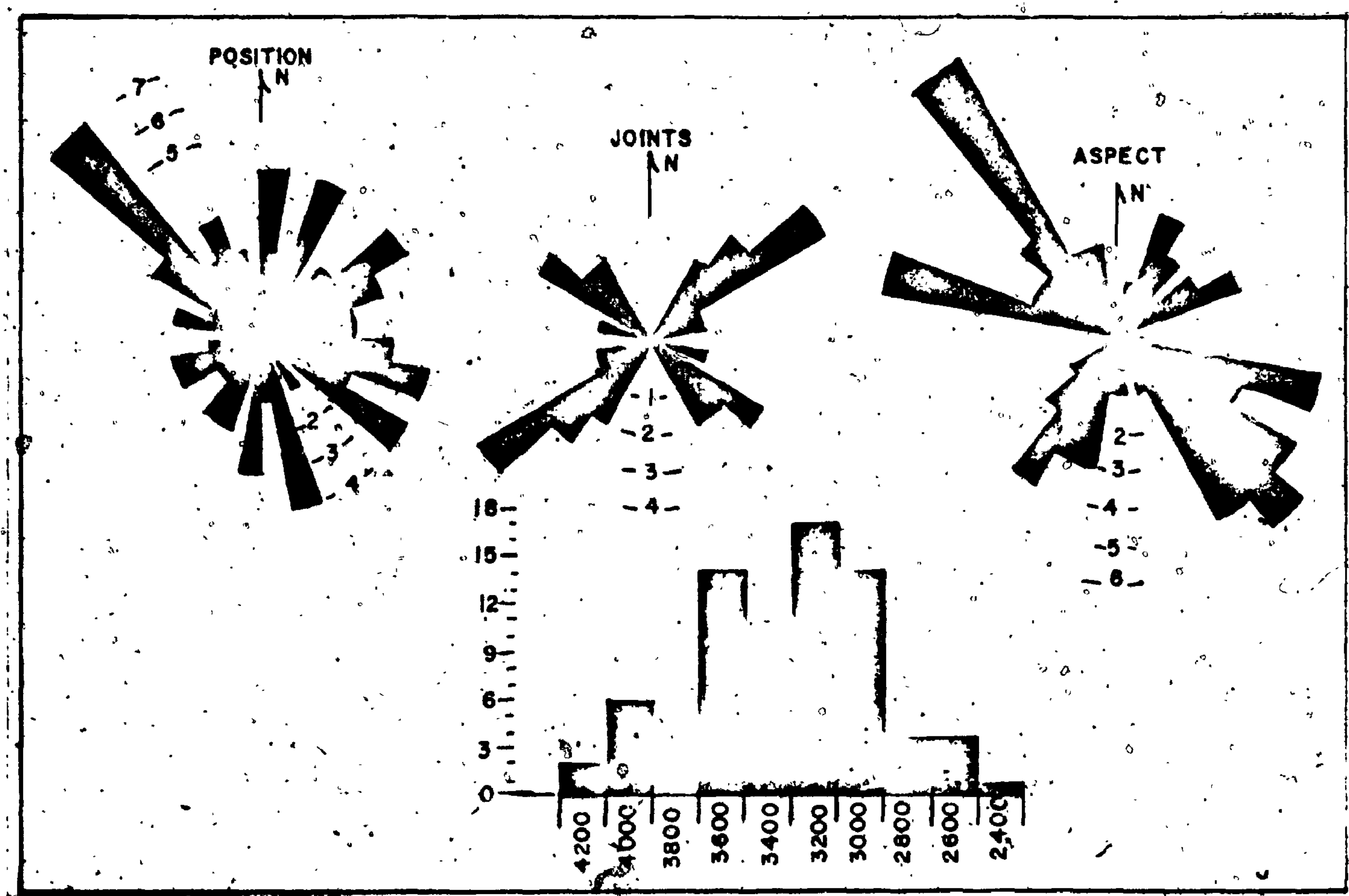


Figure 60. Rose diagram of cirque position, joint direction, cirque aspect and histogram of schrund elevation. Group VI - Mount Marcy.

are more scattered in position and aspect (figure 60, table 16).

Broughton et al. (1962), Balk (1931) and Kemp (1921) have identified major fault zones in Cascade Lake Pass striking N 45° E, Avalanche Pass (N 42° E) and Ausable Lakes Pass (N 42° E). The author identified a fault zone in Johns Brook Valley below Bushnell Falls that strikes N 8° W. The fault system defined by the above directions has produced a series of valleys trending northeast-southwest and corresponding ridges. The major jointing nearly parallels the direction of faulting (figure 60).

Cirque position and aspect are both closely associated with the topography established by these structural trends. Cirque aspects show a closer relationship to the structure than position.

Figure 60 shows that cirque aspect has a preferred orientation at nearly right angles to the major structural trend (N 55° E) and a secondary preferred orientation in the direction of the major structural trend. Cirque position is more random in distribution with only a slight predominance (32.5%) in the northeast quadrant.

Schrund elevation varies from 2400 to 4200 feet ASL with a maximum occurring at 3200 feet ASL (figure 60). The highest schrund elevations are associated with isolated cirque basins. The lowest schrund elevation occurs in a northwest position.

3.3.7 DISCUSSION OF CIRQUE DISTRIBUTION

The distributions of cirque position and aspect (figure 48, table 10) for the entire region shows no preferred position for cirques when evaluated on a quadrant basis. The fewest number of cirques occurs in the northwest quadrant, and the lowest frequency

Table 16. Position and Aspect of Cirques by Quadrants. Group VI - Mount Marcy.

Quadrant	Cirque No.	Position %	Cirque No.	Aspect %
Northeast	25	32.5	12	15.6
Southeast	19	24.7	26	33.8
Southwest	14	18.7	14	18.2
Northwest	19	24.7	25	32.5
TOTAL	77	100.6	77	100.1

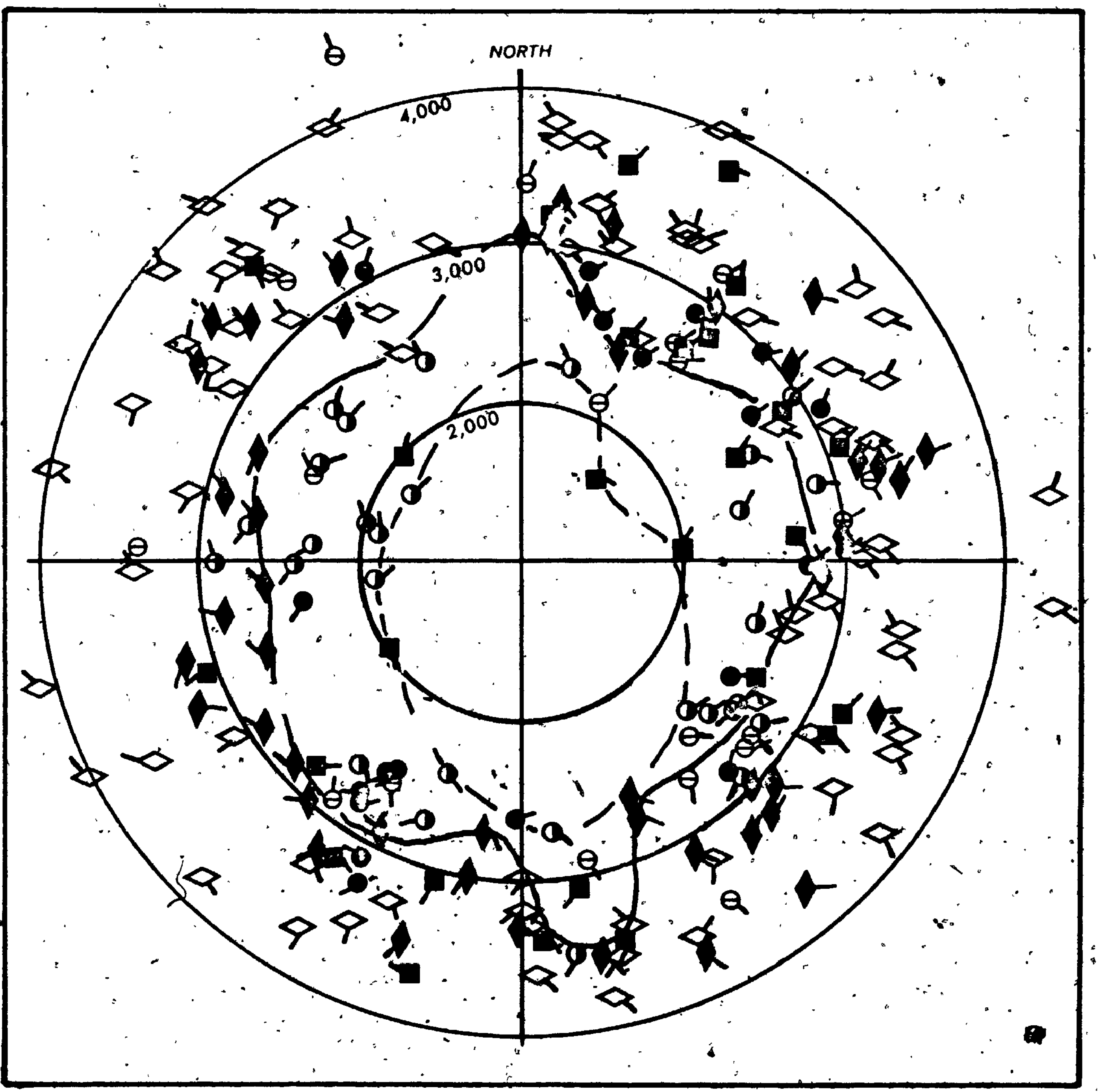
of cirque aspect occurs in the southwest quadrant (table 10). The most frequently occurring position and aspect are in the northeast quadrant. There is little difference between the first and second predominant positions. However, when each area is analyzed individually, the jointing and faulting influence cirque positions and aspects. In each group there is a predominance of cirques opening on either side of the major structural trends. Cirque positions appear to be more scattered around the mountain peaks with only a slight predominance on the more protected slopes.

Studies in England by Temple (1965) have indicated a strong northeast orientation of position and aspect in cirque development. Temple believed that the distribution of cirques on the northeast side of a mountain mass was due to climatic conditions, ~~that~~ is, southwest prevailing winds and protection from sun ablation. This author believes that the distribution of cirques throughout the High Peaks region is determined by climatic conditions which assisted glacier formation in combination with topography and structural trends which locally control cirque position, aspect and degree of development.

Goldthwait (1970) suggested that schrund elevation is a measurable topographic feature related to cirque formation which is directly dependent on micro-climatic conditions. The histogram of schrund elevation for all the cirques (figure 48) shows a bimodal distribution with the higher mode at 3100 feet ASL and the lower mode at 2700 feet ASL. The higher mode is primarily influenced by schrund elevation values of Group V and VI which contain 56% of the cirques and whose overall elevation and maximum elevations are greater than those of the other four groups. The lower mode contains values from all groups and is not biased by any particular group or groups.

Figure 61 is a polar diagram of cirque positions, aspects and schrund elevations. The inner line connects the minimum schrund elevations. The outer line connects the minimum schrund elevations of Groups V and VI. The shape and displacement of the inner line show that cirque positions are definitely related to micro-climatic controls. The south-facing slopes receive more energy from the sun because of duration and angle of incidence. Schrund elevations in the south reflect this because they are higher than those in the north. Data on cirque aspects are very significant. Figure 61 shows that all of the southern positioned cirques near the inner line open in directions other than south. This indicates that valley aspect is an important factor in cirque development as suggested by Temple (1965), Goldthwait (1970) and Garf (1976), especially at lower altitudes where the critical micro-climatic control is the duration and angle of incidence of the sun's energy (Goldthwait, 1970).

The outer line connecting the lowest schrund elevations of Groups V and VI shows that the higher values of minimum schrund elevation



⦶ Group I; ● Group II; ◐ Group III; ■ Group IV; ◆ Group V;
◇ Group VI

Line from cirque position is in the direction of aspect; schrund elevation is shown by distance from center in feet ASL. Dashed line connects minimum schrund elevations; solid line connects minimum schrund elevations of Groups V and VI.

Figure 61. Polar diagram showing cirque positions in relation to schrund elevation. Aspect is shown by line extending from cirque position.

also occur in the south.

These data may suggest two stages of local glacial activity in the area. During the first stage, a period of glacial maximum, all cirques were occupied by local glaciers to the lowest schrund elevation of 1700 feet ASL on the north side of the mountain to 2700 feet ASL on the south side. This stage may have been followed by a recession of ice to the higher schrund elevations with minimum schrund elevations of 2400 feet ASL and 3400 feet ASL on the north and south sides of the mountain mass respectively.

If these two stages occurred, they provide a possible explanation for the bimodal distribution of schrund elevations. Both the lower mode elevation of 2700 feet ASL and the upper mode elevation of 3100 feet ASL would be glaciated during each stage. The distribution could be expressing two overlapping unimodal schrund elevation distributions each of which was formed during two different periods of glacial activity.

Goldthwait (1970) suggested that the snowline for the Presidential Range occurred at 3500 ± 500 feet ASL during cirque occupancy. He reports that schrund elevations for this range are between 3100 and 4600 feet ASL. If this implies a relationship between snowline and minimum schrund elevation, then the minimum snowline in the Adirondacks during local glacial maximum would be at approximately 1700 feet ASL on the northern slopes, rising to 2700 feet ASL on the southern slopes. Similarly a recessional snowline of 2400 feet ASL on the northern slopes rising to 3400 feet ASL on the southern slopes is suggested.

CHAPTER IV. GLACIAL MOVEMENT

Evidence of direction of glacial movement in the Adirondack Mountains consists of striae and grooves in bedrock, the orientation of elongate pebbles in till deposits, and the lithologic composition of till.

The flow direction indicators mentioned above are the result of glacial erosion and transport or deposition of glacial debris at the base of the moving ice mass. These indicators of local glacial movement were strongly controlled by the existing bedrock topography. It is, therefore, no great surprise that, throughout the Adirondacks, indicators of glacial flow tend to follow the orientation of valleys.

All of the ice flow direction indicators reported in the literature (Buddington, 1953) are located in the main valleys and suggest a general flow of ice through the mountains from northeast to southwest with local variation determined by the controlling topography (figure 62) as it confined the ice within the valleys.

4.1 GLACIAL STRIAE AND GROOVES

Throughout the High Peaks region striae are scarce. Unreported striae were observed at nine locations. Of these, six coincide with the regional ice flow direction, and four indicate glacial movement in directions other than that of regional flow.

A survey of literature shows that many more striae have been measured throughout the Adirondack Mountains (Ogilvie, 1902a, 1902b; Alling, 1916, 1919, 1921; Miller, 1910, 1916, 1917, 1919, 1921, 1926; and

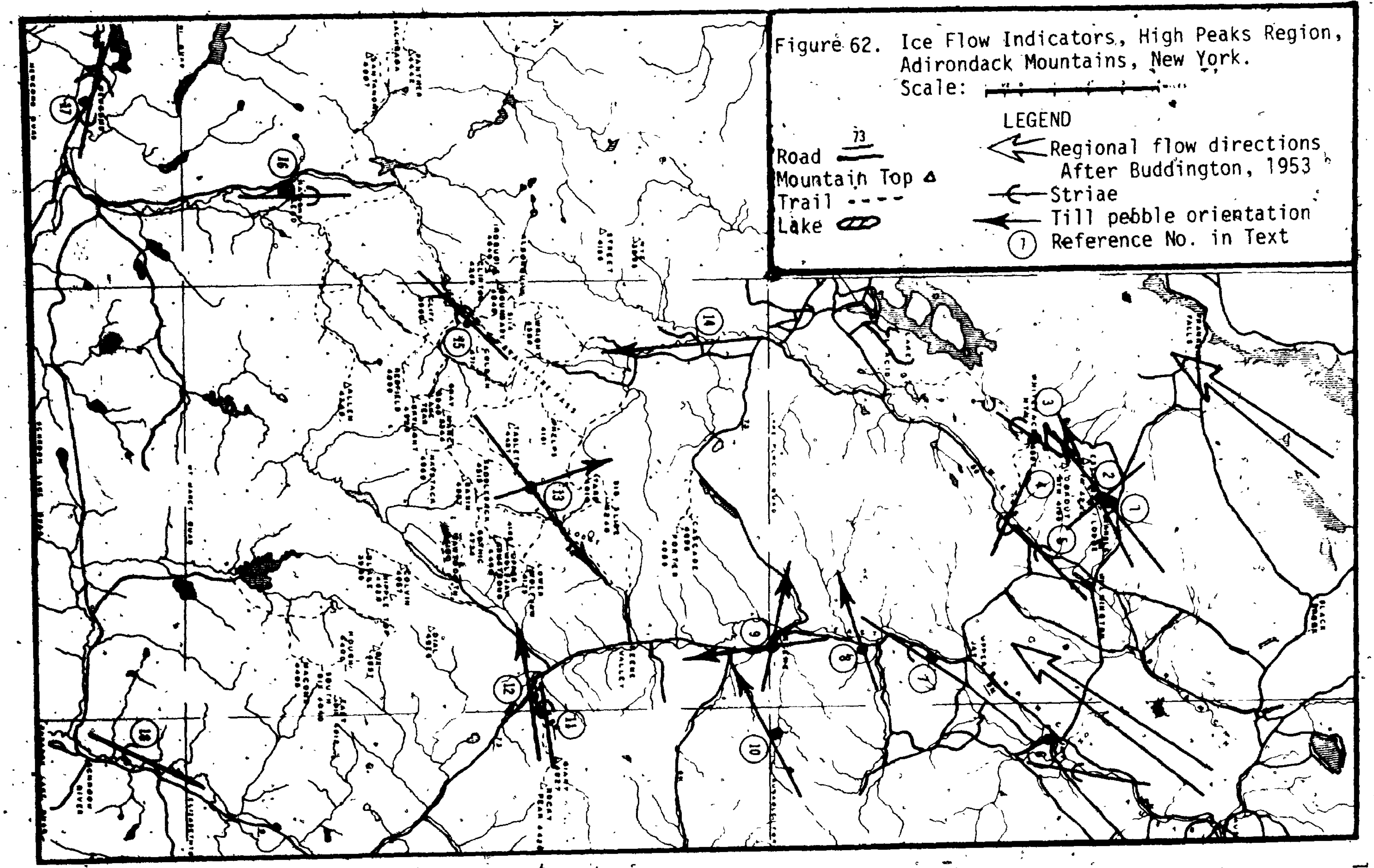


Figure 62. Ice Flow Indicators, High Peaks Region, Adirondack Mountains, New York.
Scale:

Buddington, 1953). Buddington (1953) compiled all of the information published on striae and plotted a regional flow map for the Adirondacks (figure 62). Buddington (1953) does not show any variation of flow direction through the High Peaks region. His arrows indicate the ice flowing towards and around the mountain mass, not through it. Striae have, however, been observed in the main valleys of the High Peaks and record the flow of the continental ice mass through the mountains. These striae have been recorded (figure 62) at Avalanche Pass (site 13), the Flume (site 5, and see 3.2.2.4.3), Jay N. Y. (site 6), between Upper Jay and Keene (site 7) and along Interstate 87 between the Route 73 junction and the North Hudson exit (site 18). Striae in directions other than that of continental flow have been recorded on Giant Mountain (site 12, and see 3.2.2.2), Whiteface Mountain (site 4, and see 3.2.2.4.1), in the Newcomb Blue Ridge Valley (site 17) and at the National Lead Co. McIntyre Development at Tahawus, N. Y. (site 16, and see 5.4). Details of sites 6, 7, 13, 17 and 18 are in Appendix E.

4.2 ALIGNMENT OF ELONGATE PEBBLES

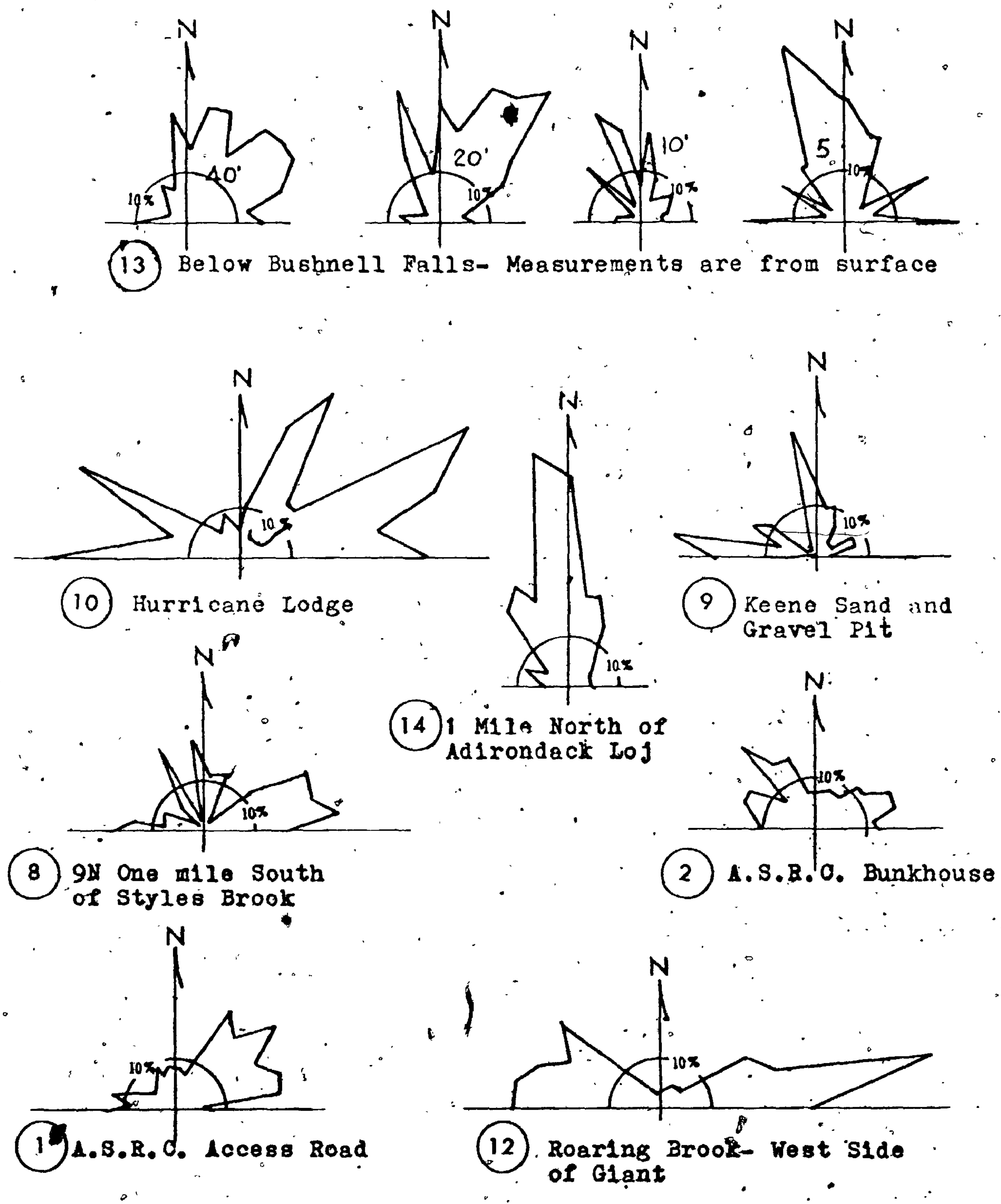
Measurements of alignment of elongate pebbles were made throughout the High Peaks region in valleys tributary to the main north-south drainage valleys. Measurements were made wherever an exposure of till could be cleared below the winter freeze line. Eleven sets of measurements were made at eight localities (figure 62). The results of these measurements are shown in figure 63.

All of the pebble orientations bear a strong relationship to the orientation of the valleys, with pebbles oriented in the long valley direction. Site 14, one mile north of Adirondack Loj, is the exception to this. This site is located in the center of a broad, flat valley and there would be little if any topographic control of ice flow in the immediate vicinity.

Sites 1, 2, 9, and 14 have elongate pebble orientations near to that of regional ice flow direction (figure 62) and nearly parallel to the main valley orientation. Sites 8 and 12 are located along the edges of main valleys at the mouths of tributary valleys. They show a strong correlation to the orientation of the tributary valley. Sites 2 and 9 show two peak orientations possibly indicating a reorientation of an earlier direction of ice flow. Site 13 includes a series of measurements at different depths which show a change in ice flow direction from top to bottom (see 3.2.3.1.2 for detailed discussion).

4.3 RECOGNITION OF GLACIAL TILL IN THE HIGH PEAKS REGION

The early workers (Ogilvie, 1902a; Taylor, 1897; Kemp, 1898; Alling, 1916, 1919, 1921) in reporting their observations of glacial deposits in the High Peaks region describe poorly sorted and well stratified glacio-fluvial deposits, ice contact stratified drift, and outwash sand and gravels. Nowhere do they describe or identify till as a typical ice deposited material. This non-recognition of glacial till is understandable as most work on glacial deposits at that time in New York had been done in glacial deposits associated with fine grained sedimentary rock and the tills were quite silty in composition. The role of bedrock in till texture and composition had not at this time been recognized. Adirondack tills are quite sandy



⑬ Below Bushnell Falls- Measurements are from surface

⑩ Hurricane Lodge

⑭ 1 Mile North of Adirondack Loj

⑨ Keene Sand and Gravel Pit

⑧ 9N One mile South of Styles Brook

② A.S.R.C. Bunkhouse

① A.S.R.C. Access Road

⑫ Roaring Brook- West Side of Giant

Figure 63. Pebble orientations rose diagrams. All plots are to true north. Numbers refer to locations on Figure 62.

(figure 64) due to the character of bedrock from which they were derived. These tills do not resemble the classical silty tills of central New York with which the early field researchers were familiar.

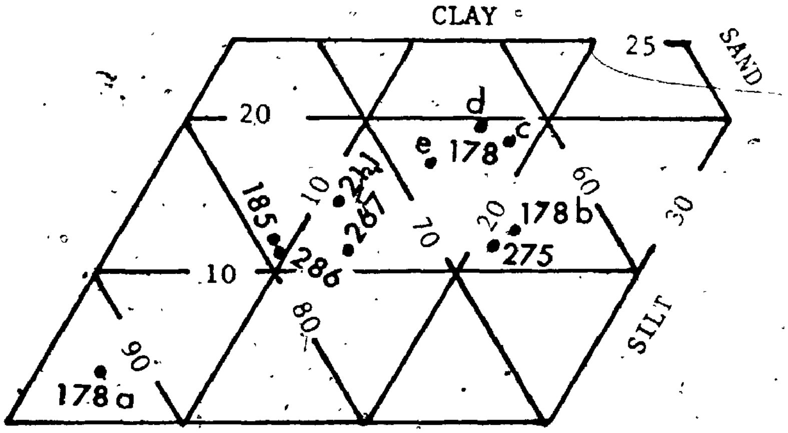


Figure 64. Ternary diagram plot of sand, silt and clay of ten Adirondack till samples (for sample locations see Appendix A)

When the author first started field work in the Adirondacks, many of the deposits described in the literature were visited. In most cases, the reported poorly sorted sands and gravels were found to be sandy and silty tills. This recognition of till within the High Peaks region, combined with the detailed studies of the light mineral composition of these tills, has played a significant role in establishing the glacial sequence within the High Peaks region.

4.3.1 CHARACTERISTICS OF HIGH PEAKS TILLS

Undisturbed Adirondack till deposits have the appearance of poorly sorted sand and gravel. In some deposits where large boulders are not present and the surface has been weathered, it is almost impossible to identify the origin of the deposit. However, excavation into the deposit beyond the freeze-thaw zone will reveal evidence of their origin. The following are criteria used for recognition of tills in the High Peaks region:

(1) Apparent lack of sorting and stratification of the deposit, and the presence of considerably more silt-clay sized particles than in glacio-fluvial sands and gravels.

(2) Compacted nature of the deposit. In active gravel pits, the till will hold a vertical face. When the till is excavated, it comes out in chunks. However, these chunks break apart easily in the hand. It is difficult to collect a block of till and keep it intact.

(3) Occurrences of striated and faceted pebbles combined with

(4) Silt coating on pebbles and boulders.

Two deposits of silt-clay rich till were located; one on the Styles Brook Road (5.2) and one just each of Wilmington (5.1). In each case, ice moved across lacustrine deposits prior to the deposition of till.

4.3.1.1 LITHOLOGIC COMPOSITION OF ADIRONDACK TILLS

A survey of the geologic literature on the Adirondacks and the area to the north and northeast of the Adirondacks shows three distinctive rock assemblages and associated mineral compositions: Precambrian anorthosite, Precambrian metasedimentary rocks, and Paleozoic sedimentary rocks (figure 6). These distinctive assemblages are extremely useful in determining whether a deposit was formed by local or by continental glacial action.

4.3.1.1.1 PRECAMBRIAN ANORTHOSITE

The central core of the High Peaks region is composed almost exclusively of anorthosite. According to Buddington (1966), the anorthosite series have an average mineral composition ranging from 62% to 94% plagioclase, 0% to 2% orthoclase, and 0% to 3% quartz; with small percentages of other minerals particularly hornblende, biotite, garnet and augite. Buddington (1966) gives data on mineral compositions of gabbroic differentiates, pegmatites and satellitic intrusives of the anorthosite series. In these rocks, plagioclase ranges from 39% to 55%, orthoclase from 2% to 6%, and quartz from 0% to 2%. There is a marked increase in amounts of ferro-magnesian minerals in these rocks.

Anorthosites are easily identified in the pebble size fractions and larger, and it is possible to separate the anorthosite into three distinctive types--the Marcy facies, the Whiteface facies, and the pink plagioclase facies.

Marcy Facies

The Marcy facies is characterized by being light blue-green to white with a fine matrix of plagioclase feldspar containing phenocrysts of labradorite feldspar. The matrix is commonly so fine that individual crystals cannot been seen without magnification. Some mafic minerals are present, especially in the higher elevations of the mountain and in areas close to exposures of the Whiteface facies type of anorthosite. A complete range of the changes in the Marcy anorthosite can be seen on a traverse from the lower end of Johns Brook to the top of Mount Marcy.

Whiteface Facies

This facies is named after exposures on Whiteface Mountain. This rock is characterized by a crystalline equigranular texture composed mostly of white plagioclase feldspar crystals with more than 25% mafic minerals present. Numerous large inclusions of charnockite have been observed in Whiteface anorthosite.

Pink Plagioclase Facies

The pink plagioclase facies has been observed only along the ridges of White Brook Valley (Lake Placid Quadrangle) below Esther Mountain where it makes up most of the ridges on both sides of the valley. The rock is not exposed in the bottom of the valley where it is believed to be buried under a blanket of glacial drift. This rock is very similar in appearance to the Marcy anorthosite, i.e. fine grained matrix with phenocrysts, but the matrix is pale pink. The phenocrysts resemble salmon microcline in color but exhibit well developed albite twinning. The importance of this rock in understanding the glacial history was discussed in the section on the deposits of White Brook Valley (3.2.2.1). Bedrock exposures of the Wilmington Range, north of White Brook, were investigated for pink anorthosite but none was observed.

4.3.1.1.2 PRECAMBRIAN METASEDIMENTARY ROCK

The anorthosite core of the Adirondacks is completely surrounded by a complex sequence of metasedimentary rocks. Rock types are charnockites, amphibolites, granitic gneisses, marble, and quartzite of varying mineral compositions and appearances.

The metasedimentary rocks are so variable locally that there are no significant rock or mineral variations within the metasedimentary sequence to permit identification of directions of ice movements. However, these rocks are significantly different from the anorthosite both in appearance and in mineralogy.

The quartz, K-feldspar, and plagioclase compositions of these rocks are distinctly different from those occurring in anorthosite. In metasedimentary rocks, the quartz content ranges from 16 to 60 percent; K-feldspar content varies from less than 5 percent in amphibolites to 40 percent in granitic gneisses; and plagioclase content ranges from 16 to 50 percent. Presence of a considerable amount of perthite made separation of plagioclase and K-feldspar difficult in the mineral counts. For the purposes of this study, if the perthite was stained as K-feldspar even though albite twinning was present, it was counted as K-feldspar. This is justified because perthite is associated only with the metasedimentary sequence and the purpose of the li[illegible] mineral counts was to determine whether the till originated from anorthosite or metasedimentary terrains.

Pebbles and boulders from the metasedimentary rocks are easily identified as to their source. The only confusion in identification is in distinguishing the Whiteface anorthosite from amphibolite and weathered charnockite.

Charnockites weather to a brown sugar color and close investigation with a hand lens will usually allow identification of some quartz. Amphibolites are rich in mafic minerals with white plagioclase feldspar. The plagioclase forms bands separated by mafic minerals in the amphibolites whereas it is dispersed as individual grains in the Whiteface anorthosite. If the rock fragment is very large, it will usually show mineral banding in the amphibolites and a salt and pepper appearance in the anorthosite.

4.3.1.1.3 PALEOZOIC SEDIMENTARY ROCKS

Surrounding the metasedimentary rocks on the outer edge of the Adirondack Mountain area is a sequence of Paleozoic sedimentary rocks. In this study, the author is interested in those sedimentary rocks that have been transported by glaciers and that are found in tills. This is primarily the Cambrian Potsdam sandstone. A few pebbles of completely weathered Ordovician Chazy limestone were observed in the till at the north end of Wilmington Valley.

The Potsdam sandstone outcrops all around the north and northeast edge of the Adirondacks and any continental glacier moving out of the St. Lawrence Valley into the mountains had to override these rocks. Since the Potsdam is a very pure quartz sandstone bound together by quartz cement, it weathers very slowly. The combination of stability and sedimentary characteristics of the Potsdam sandstone makes it easily recognized as rock fragments in the till. It was first thought that the presence of Potsdam sandstone erratics was positive evidence of continental glaciation and unrelated to local glaciation; however, in some cases, local ice movement has reworked previous continental deposits containing Potsdam sandstone erratics (see discussion on deposits on White Brook Valley, 5.4).

4.3.1.1.4 LIGHT MINERAL COMPOSITION OF ADIRONDACK TILLS

Due to the distinctive mineralogical character of the rocks of the High Peaks region, light mineral determinations were made of all till samples collected during the field work. Methods used for light mineral identification are discussed in 2.3.3 and Appendix C.

Light mineral studies were conducted on 13 till samples from the Raquette Lake area (figure 2). These results are shown in Appendix C and in figures 65 and 66. The Raquette Lake samples contain nearly equal percentages of quartz, K-feldspar and plagioclase feldspar. The mean values and the standard deviations of quartz, K-feldspar and plagioclase are respectively: 30.9% ± 6.65, 39.2% ± 13.33, and 29.9% ± 5.48. Figure 66 shows the frequency distributions of these light mineral fractions as histograms with crossline patterns.

In metasedimentary rocks the light mineral composition ranges are: quartz, 16 to 60%; K-feldspar, 5 to 40%; and plagioclase feldspar, 16 to 50% (Buddington, 1966). The light mineral contents of the Raquette Lake tills fall within these ranges. Since the nearest exposure of anorthosite is 25 miles to the north, there would be some anorthosite effect on the Raquette Lake tills. Therefore, the Raquette

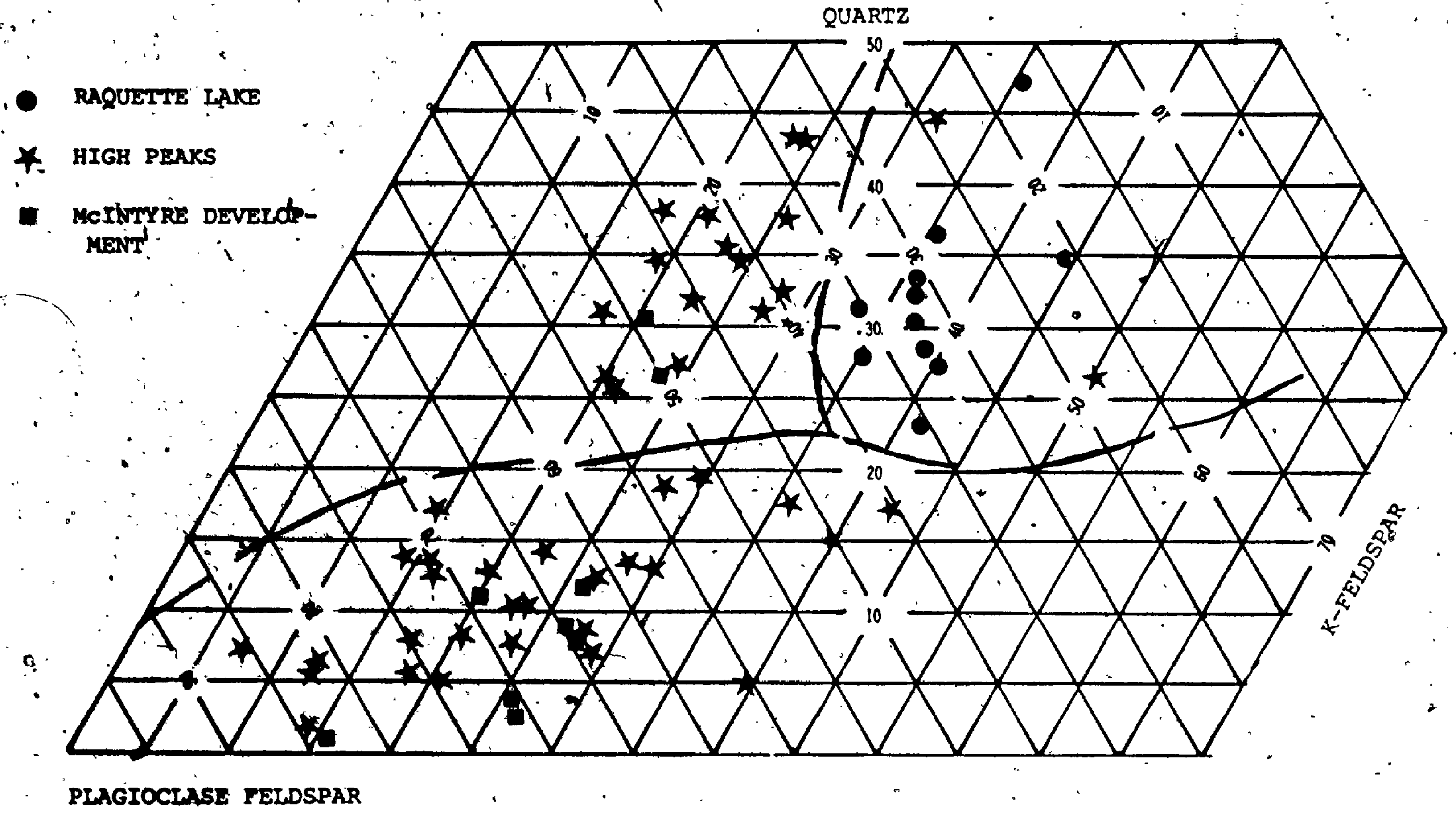


Figure 65. Triangle diagram of the light mineral fraction of Adirondack Tills.

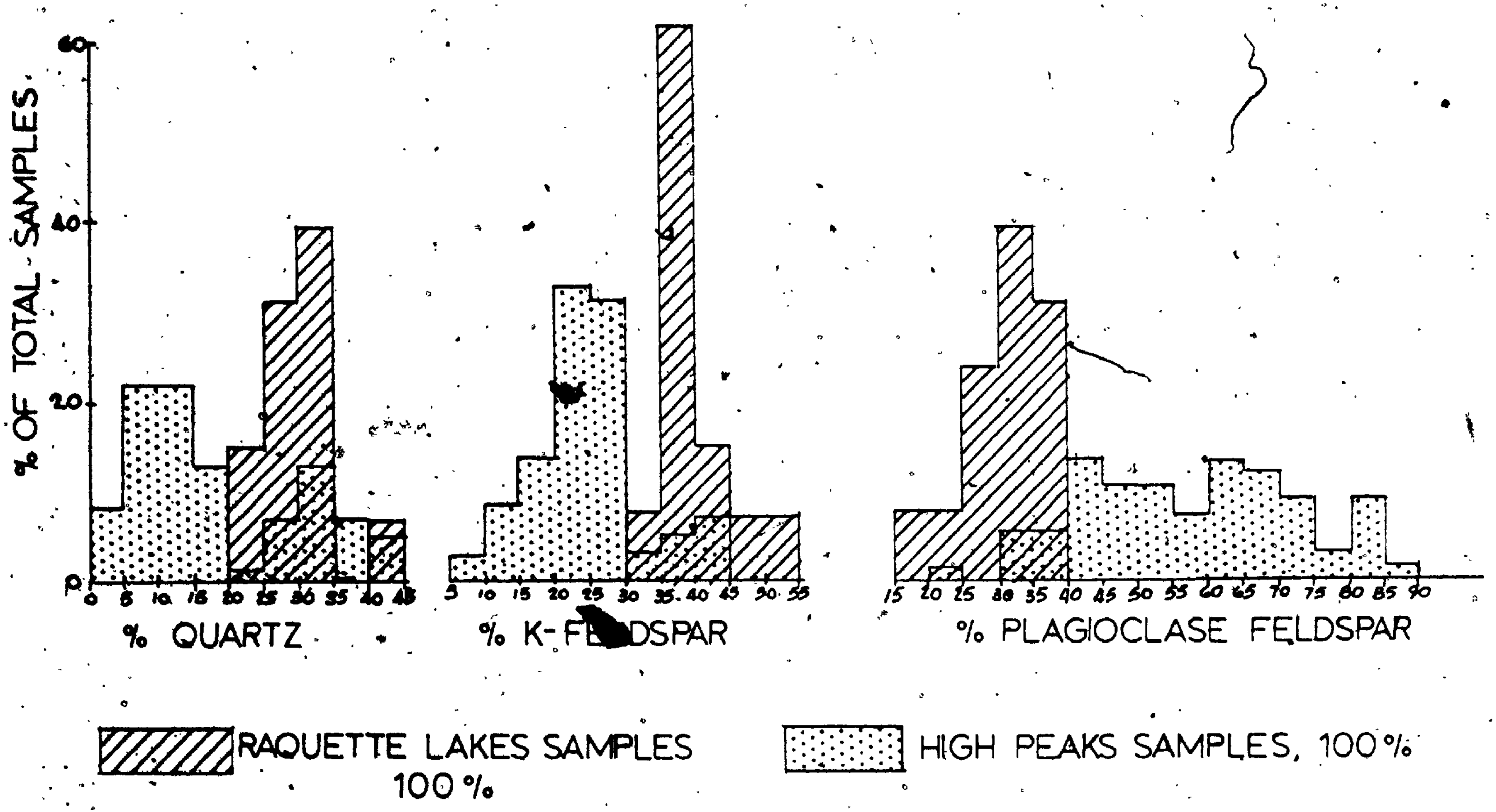


Figure 66. Histogram of quartz, K-feldspar, plagioclase feldspar in matrix of Adirondack Tills.

Lake till samples are believed to be representative of the mineralogic composition in tills derived mainly from metasedimentary rocks.

The light mineral compositions of 59 till samples from the High Peaks area were determined and appear in Appendix C and in figures 65 and 66. The mean values and standard deviations for quartz, K-feldspar, and plagioclase are respectively: 18.1% ± 12.33, 24.6% ± 8.05, and 57.4% ± 15.32.

Comparison of the light mineral frequency distributions of the High Peaks area tills and the Raquette Lake tills (figures 65 and 66) shows that these are different though overlapping distributions. The frequency distribution of quartz in the High Peaks area tills is bimodal indicating two populations with the second mode falling within the range of the Raquette Lake till quartz values. K-feldspar values for the High Peaks area tills are lower than the K-feldspar values for the Raquette Lake area tills and again a suggestion of a second mode in the High Peaks region falls under the mode of the Raquette Lake samples. Plagioclase frequency distributions of tills from the two areas are definitely different, with the values for the Raquette Lake tills being much lower showing only a small overlap of the distributions in the tills from the two regions.

The light mineral composition of a till is indicative of the rocks overriden and eroded by the ice which deposited the till. Anorthosite is a readily identifiable rock because of its high plagioclase, low quartz and low K-feldspar composition. If ice originated on an anorthosite terrain and stopped on the anorthosite terrain, the light mineral composition of the deposited till would be high in plagioclase and low in K-feldspar and quartz. If, however, the ice traversed a metasedimentary terrain and overrode an anorthosite terrain, the plagioclase content of the deposited material would increase as a direct function of the erodability of the anorthosite and the distance over the anorthosite that the original metasedimentary material had been transported. As the plagioclase content increased, the quartz and K-feldspar fractions would be correspondingly reduced.

This relationship is clearly shown on the ternary diagram of the light mineral composition (figure 65). There are three distinctive groupings of values: the Raquette Lake samples, high in quartz and K-feldspar; a middle group, higher in plagioclase and lower in quartz and K-feldspar; and a third group, very high in plagioclase. The middle group is believed to represent a dilution effect in composition which occurs as the ice moves from a metasedimentary terrain onto an anorthosite terrain.

In some cases, it can be shown that local xenoliths of quartz and K-feldspar-rich bedrock cause an increase in these minerals in the till samples (see Johns Brook Valley discussion, 3.2.3.1). In other cases, local ice originating in the contact area of metasedimentary rock with anorthosite gives high quartz and K-feldspar values in their deposited tills (see Styles Brook, 5.2; Whiteface Mountain Ski Center, 3.2.2.4.2; and the Blue Ridge area, 5.3).

The McIntyre mine tills at Tahawus are very significant (figure 65). Two samples fall in the middle group indicating that the ice has overridden a metasedimentary terrain prior to deposition of the till. In this case, the metasedimentary terrain is south of the deposit, indicating a northward flow of ice to deposit the till (see 5.4 for more details).

There is a marked variation in the plagioclase content of the High Peaks tills. Although light mineral content of the tills can be used as an indication of the history of the deposits, the plagioclase content alone does not define the history of the till. Other evidence in the individual deposits such as till fabrics, pebble lithology, striations and sediment deformation must be considered before the total relationship of the deposit to the glacial history can be established.

CHAPTER V. STRATIGRAPHIC SECTIONS OF SPECIAL INTEREST

5.1 WILMINGTON WATER PIPE DITCH

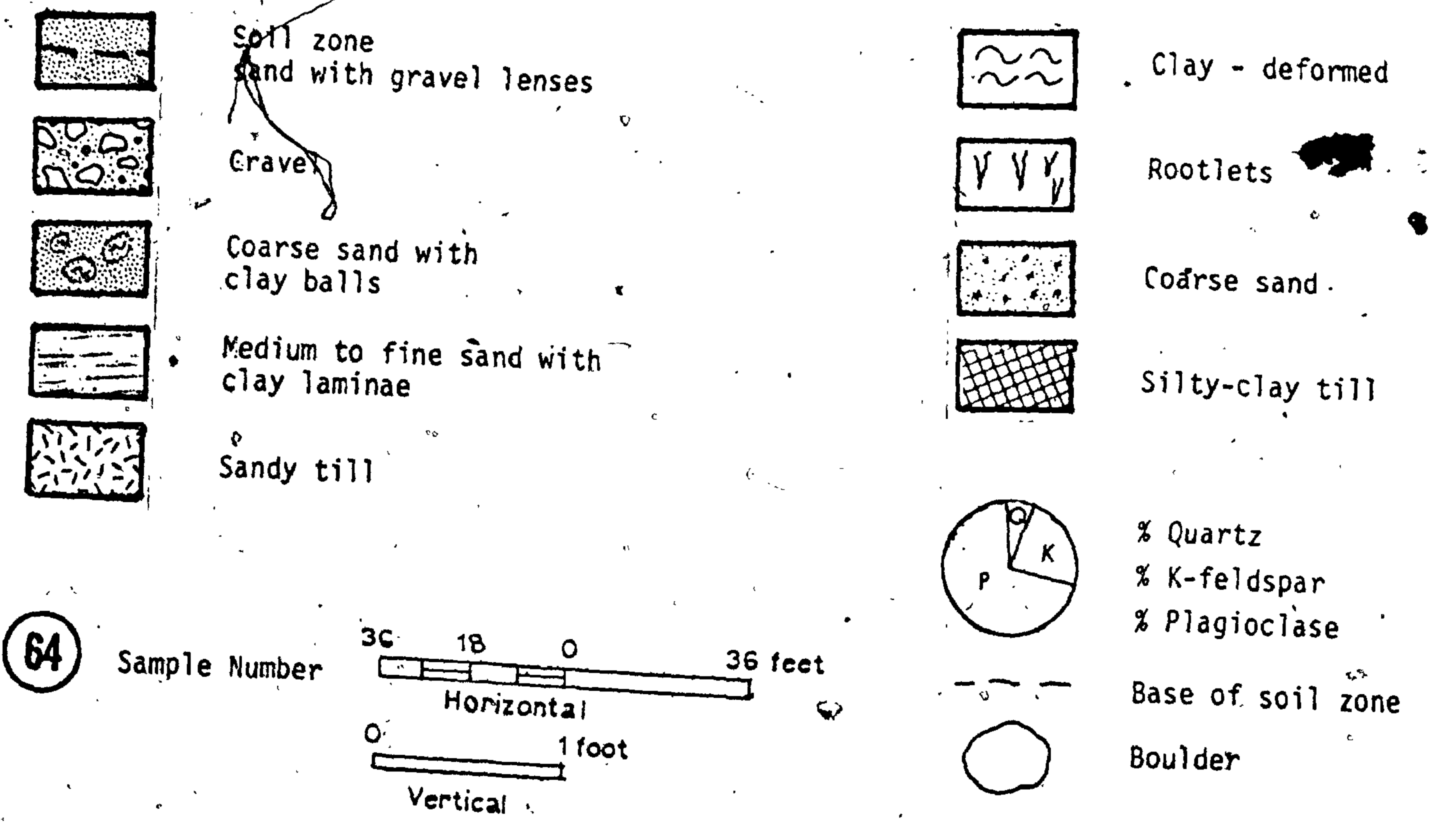
A series of measured sections were made in a ditch excavation one mile east of Wilmington, N. Y., on the north side of Route 86, (figure 6, region C). The ditch runs north from the road for approximately 600 feet. Figure 67 is a compilation of the individual measured sections.

This ditch is located almost at the middle of the broad open Wilmington Valley. Bedrock outcrops in the vicinity of the ditch are Whiteface anorthosite. The nearest metasedimentary rock outcrops are located approximately five miles north near Black Brook (figure 6).

Excavation of the ditch exposed till at the south end and from station 3 (figure 67) to the north end of the ditch. Figure 67 shows the stratigraphic relationship of these two tills to the stratified drift exposed in the ditch.

The till exposed at the south end of the ditch is a deep reddish-brown, silty-clay till with yellow-brown sand inclusions. This is one of two silty-clay tills found in the field study. Very few pebbles were observed in this till. Laboratory analysis of the sand fraction shows a composition of 45% quartz, 31% K-feldspar, and 24% plagioclase feldspar. This is a fairly typical representation of light mineral composition found in till formed by ice overriding the metasedimentary bedrock and then depositing on an anorthosite terrain. A sand sample collected from the layer directly on top of this till was found to have a composition of 30% quartz, 30% K-feldspar, and 40% plagioclase

LEGEND


Soil zone
Sand with gravel lenses
Gravel
Coarse sand with clay balls
Medium to fine sand with clay laminae
Sandy till
64
Sample Number
3C
18
0
36 feet
Horizontal
0
1 foot
Vertical
Clay - deformed
Rootlets
Coarse sand
Silty-clay till
Q
K
P
% Quartz
% K-feldspar
% Plagioclase
Base of soil zone
Boulder

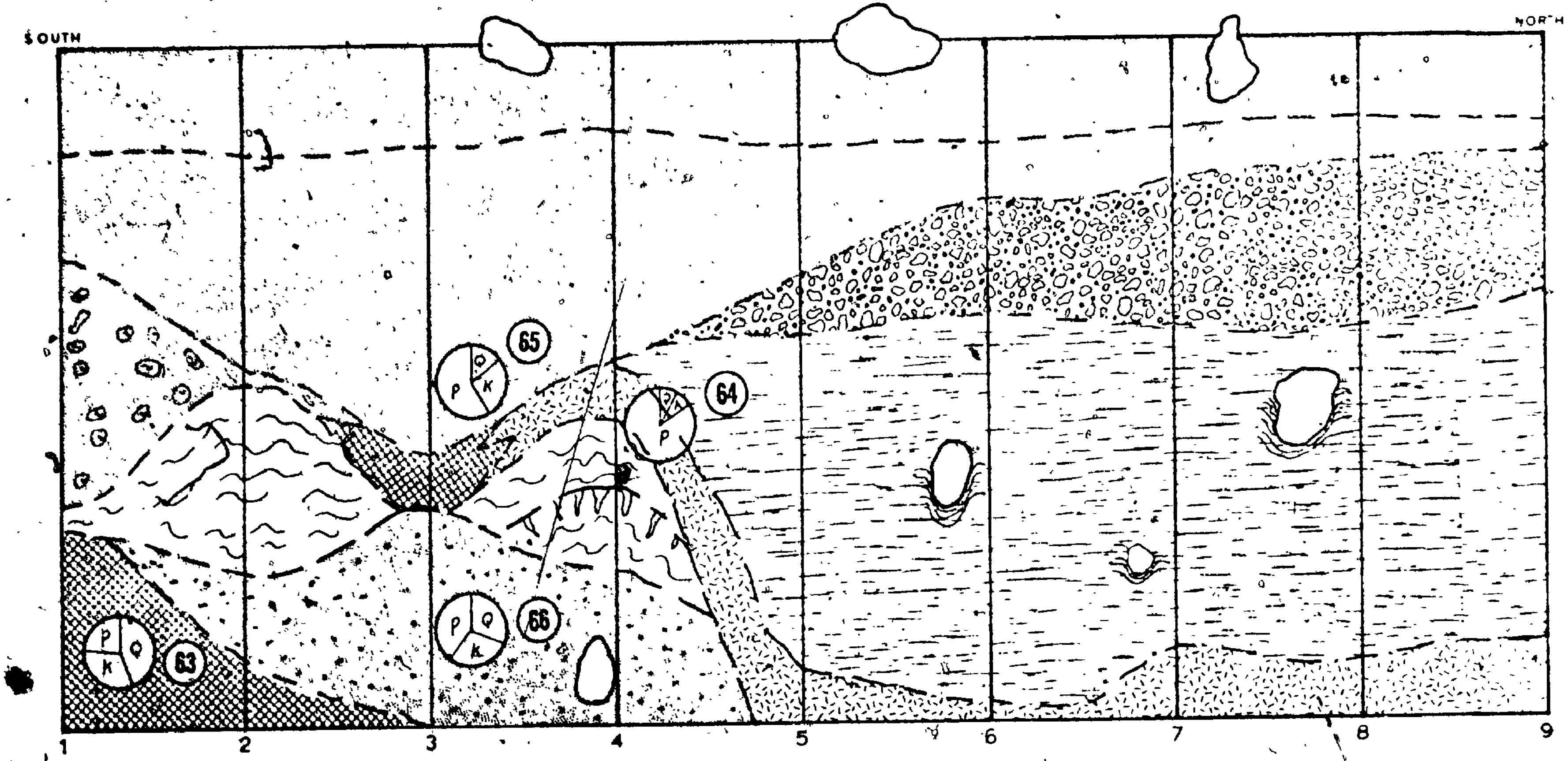


Figure 67. Stratigraphic section, water ditch, one mile east of Wilmington.

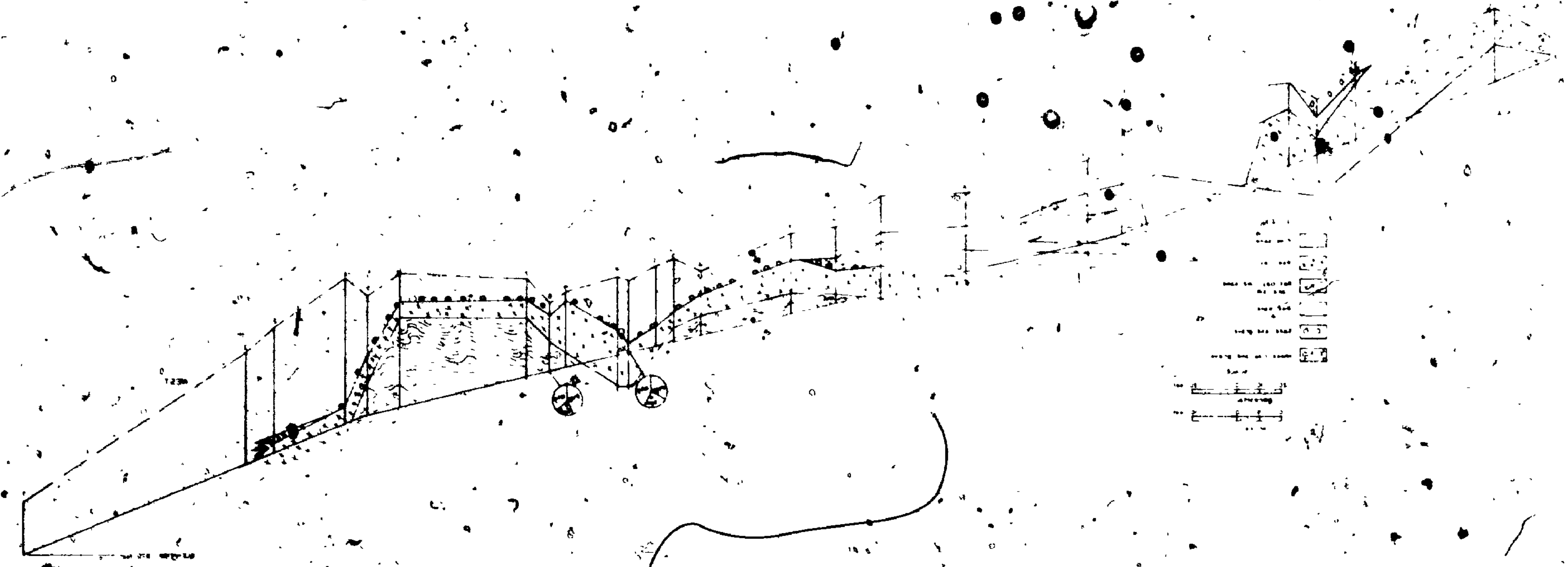


Figure 68. Stratigraphic section Styles Brook Road, for location see figure 6, region E.

This has been printed backwards - it is being corrected.

feldspar. Overlying this sand is a deformed clay sequence (figure 67) capped by a sandy-silt till. This till increases in clay content at the south end of the exposure where it incorporates a portion of the deformed clay forming a silty-clay till.

Laboratory analysis of this till (sample 64) shows 7% quartz, 8% K-feldspar, and 85% plagioclase feldspar, a composition indicating an anorthosite source area. Sample 65 collected from the sand overlying this till shows 14% quartz, 28% K-feldspar and 59% plagioclase feldspar.

5.1.1 INTERPRETATION OF SECTION

A glacier moving across the metasedimentary rock advanced into a lake bed incorporating clay into its base leaving behind a silty-clay till rich in metasedimentary minerals. The nearest source of metasedimentary rock is 5 miles north of the deposit. As this glacier melted away, sand with a mineral composition similar to the till was deposited on top of the till. This sand deposition was followed by deposition of lake clays. Rootlet channels were observed in these clays, which could indicate plant growth before the next glacial event, or could be due to modern root penetration. A second ice advance occurred and the upper till layer was deposited. This till has an anorthositic composition. Bedrock of the valley floor and the ridges on each side of the valley is anorthosite. The Wilmington Range on the west side of the valley has four cirques cut into its east face and White Brook Valley (figure 6, region B) also opens toward this deposit. Ice originating from any of these cirques would form a till with a matrix composition similar to the mineralogy of the anorthosites, that is, high in plagioclase content and low in K-feldspar and quartz contents. This is the composition of the upper till found in the ditch. Deposition of the upper till was followed by formation of a lake and deposition of its associated sedimentary materials. The sands deposited in this lake sequence are high in plagioclase and low in quartz and K-feldspar, indicating a source from glacial deposits originating from an anorthosite terrain. Some ice rafting occurred during this lake phase, as large boulders were found in the lake sediments. Deformation structures under the boulders indicate that they were emplaced vertically.

5.2 STYLES BROOK ROAD

Styles Brook Road is located 2.75 miles south of Upper Jay (figure 6, region L). Highway repairs in 1966 exposed a stratigraphic section at the west end of the road (figure 68). The section starts at an elevation of 870 feet ASL and continues upward along the road to an elevation of 980 feet ASL.

The section consists of laminated and deformed silt and clay overlain by a thin layer of silty-clay till which, in turn, is overlain by sand and gravel. The total exposure is blanketed by a fine sand layer. The top surface of the deposit forms a well defined terrace at an elevation of 980 feet ASL. This terrace is traceable as a distinct geomorphic feature along both sides of the East Branch Ausable River from Keene, 3 miles south, to Upper Jay, 2.75 miles north. This is the terrace identified by Alling (1916) as "Lower Lake".

Two till samples were collected for light mineral analysis, one at station 8, the second at station 11. Light mineral analyses are shown in table 17.

Table 17. Light mineral analysis of Styles Brook Road till.

	Quartz	K-feldspar	Plagioclase feldspar
Station 8	43%	24%	33%
Station 10	38%	18%	44%

5.2.1 DISCUSSION OF SECTION

Reference to the geologic map (figure 6) shows that any glacier moving into Styles Brook Valley, regardless of direction, would have overridden an extensive area of metasedimentary rock. This would have resulted in the approximate light mineral composition found in this till. Therefore, it is not possible to determine the direction of ice movement from the till composition in this case.

Information from other parts of the Ausable Valley indicates that the glacier moved into Styles Brook from the east. Exposures in the "Lower Lake" terrace on Lacy Road (figure 6, site 197) and in Liscomb Brook (figure 6, site 196), both located on the west side of Ausable Valley, show 30 feet of laminated silt and clay capped by coarse sand and gravel. No evidence of deformation of clay or presence of till was observed in either cut. The measured sections are shown in figure 69. A third exposure (figure 6, site 290) was located approximately one mile south of the intersection of Styles Brook Road with Route 9 N. This section is located on the east side of the Ausable River Valley at the south edge of Styles Brook Valley. The exposed stratigraphic section (figure 69) consists of compacted sand with thin

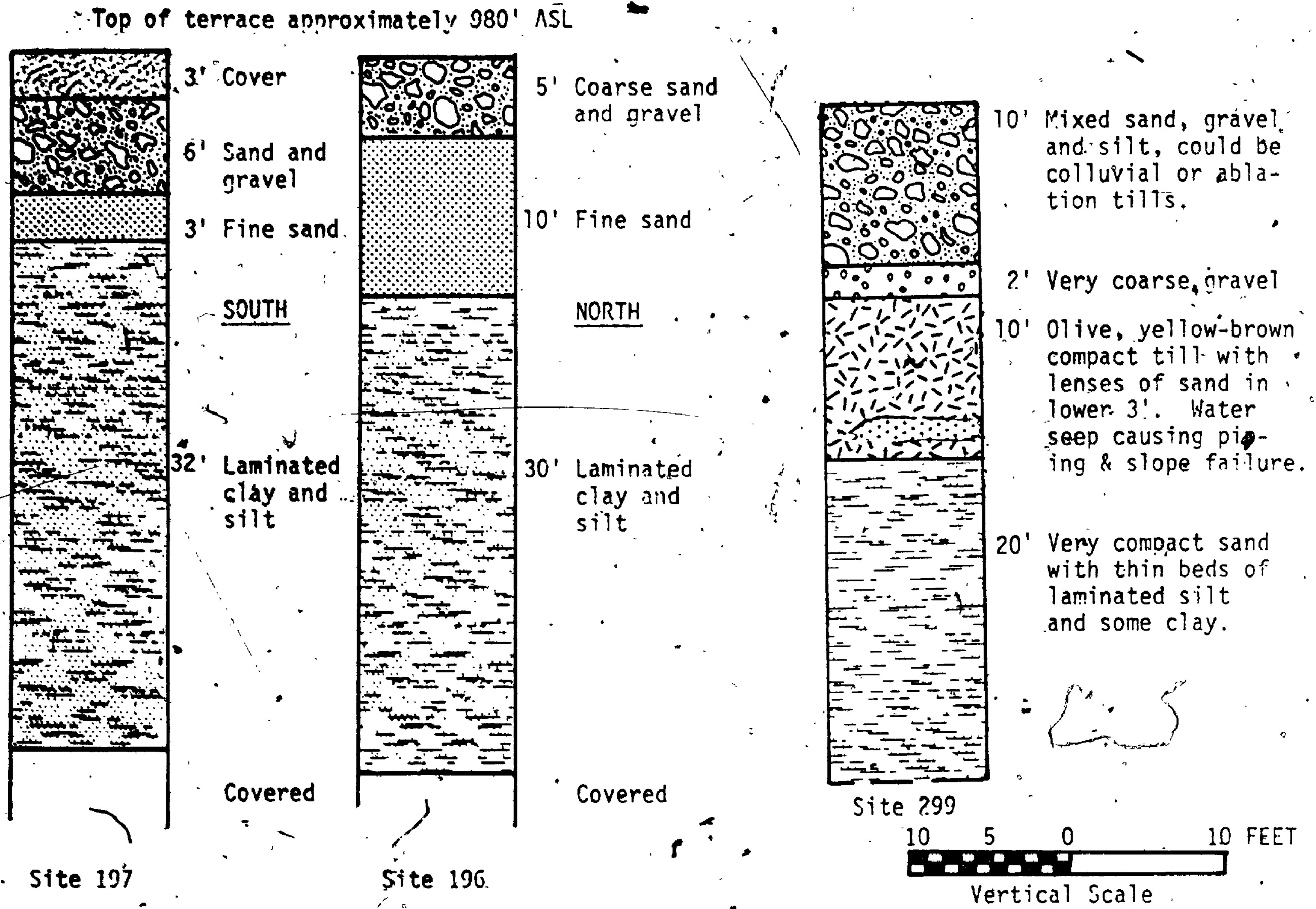


Figure 69. Stratigraphic sections associated with Styles Brook.

beds of laminated silt and clay overlain by till. Elongate pebble orientations measured five feet above the base of this till show a strong ENE-WSW preferred orientation indicating flow from the upper part of Styles Brook Valley.

Site 196 is directly west of the mouth of Styles Brook and site 197 is one mile south. Therefore, any ice moving into this area from the north, causing the till deposition and clay deformation observed along Styles Brook Road, would have overridden site 196 even though the ice might have stopped before reaching site 197. Therefore, the till in the Styles Brook exposures must have been deposited by a lobe of ice moving westward from the upper reaches of Styles Brook Valley and terminating on the eastern side of the Ausable River Valley.

Five cirque forms were identified in the air photo studies, (one on Jay Mountain, one on Spruce Hill and three on the Soda Range) that could have been feeder sources for a localized tongue of ice flowing out of the Glen and down Styles Brook Valley. Field work identified the existence of a well developed outwash alluvial fan at the top of Styles Brook Road. Alluvial remnants of a lateral moraine were observed at an elevation of 1800 feet ASL on the north side of Bissle Hill. The surface of this moraine slopes to the west into Styles Brook Valley, losing its ridge form at an elevation of approximately 1580 feet ASL. The surface of this ridge is gravel. The internal composition of the ridge is unknown because it is not exposed.

Although conclusive evidence was not found that the ice which moved down Styles Brook Valley was local in origin, there is definite evidence that the valley was occupied by an ice mass moving east to west and that it stopped on the east edge of the Ausable River. There are well developed cirque forms that could have fed a local ice mass in the upper part of Styles Brook Valley.

5.3 BLUE RIDGE MORAINE AND GLACIAL LAKE WARRENSBURG DELTA

The Blue Ridge Moraine is located at Blue Ridge, N. Y., 2.5 miles west of Schroon River, N. Y., on the Newcomb-Blue Ridge Road. The features discussed are in the Schroon Lake and Paradox Lake Quadrangles (figure 6, region 0).

The Blue Ridge Moraine is one of the few valley-blocking moraines identified in the field area. It is especially significant because of the association of this moraine and its valley train deposits with a delta constructed into Glacial Lake Warrensburg (Miller, 1925).

Miller (1925) traced the shoreline of Glacial Lake Warrensburg from Corinth, N. Y., near Luzerne, N. Y., northward up the Schroon River Valley to Deadwater Pond, 8.5 miles north of Schroon River, N. Y., in the Elizabethtown Quadrangle, a total north to south distance of seventy miles. Miller (ibid., page 516) identified a sand plain at Schroon Lake Village (900 + feet ASL) and at North Hudson (960 feet ASL). The terrace development along the sides of the Schroon River Valley is nearly continuous between these two points. The elevation of the terrace at Schroon River is approximately 940 feet ASL. A burrow pit located one half mile south of the junction of the Newcomb-Blue Ridge Road and Route 9 exposed deltaic foreset beds dipping eastward towards the east valley wall of the Schroon River (figure 70, site 302). This terrace is also exposed on the west side of the valley (figure 70, site 301) in a cut made during the construction of Interstate Highway 87, Schroon River-North Hudson Interchange.

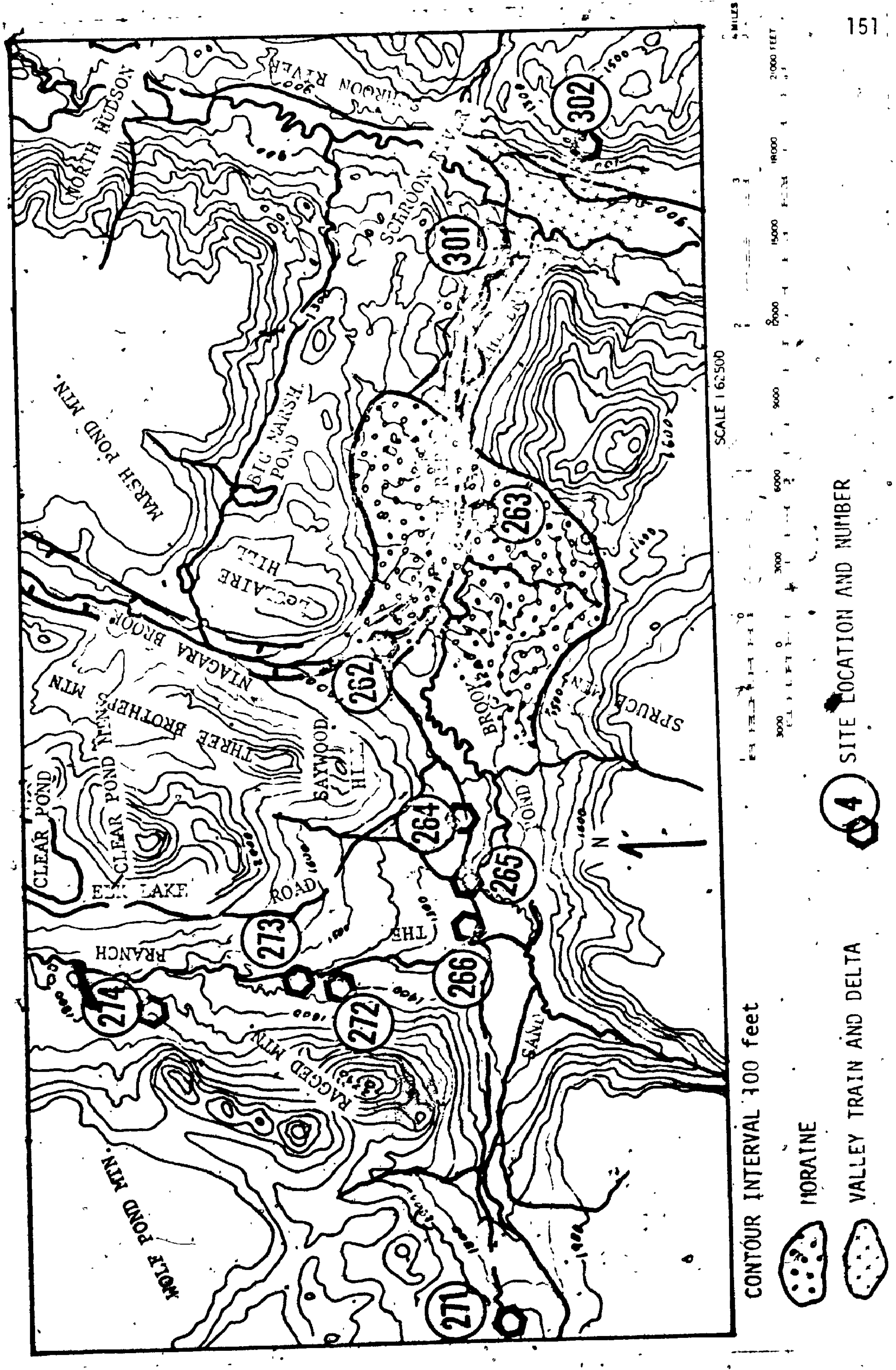


Figure 70. Topographic map of the Blue Ridge area.

Deltaic foreset beds at this site also dip eastward. The 940 foot terrace surface has been traced westward for about one half mile up Sand Pond Brook where it merges with an outwash valley train deposit. This deposit rises from the 940 feet ASL elevation of Glacial Lake Warrensburg to approximately 1100 feet ASL, where the valley train disappears into a valley-blocking end moraine. A meltwater erosional channel is located along the north side of the moraine. This channel has been traced northward up Niagara Brook. The Blue Ridge Moraine completely blocks the valley. The west side of the moraine has very steep slopes, ending abruptly in a swampy plain. The moraine is composed mostly of till with a variable thickness of sand and gravel covering the surface. The surface expression of the moraine is extremely irregular with a well developed knob and kettle appearance. The highest elevation is on the west side of the moraine. The eastward extension of the morainal topography merges with the valley train deposits.

Figure 71 shows the stratigraphic sections of eleven sites measured at Sand Pond Brook and The Branch.

Light mineral analyses were done on samples of till from sites 263, 271, and 274 (figure 70). The results of these analyses are shown in table 18.

5.3.1 INTERPRETATION OF BLUE RIDGE MORAINE

The most significant aspect of these deposits is the relationship of the Blue Ridge Moraine and the associated outwash valley train to Glacial Lake Warrensburg. The distribution of glacial fluvial sediments from the Blue Ridge Moraine to the Glacial Lake Warrensburg

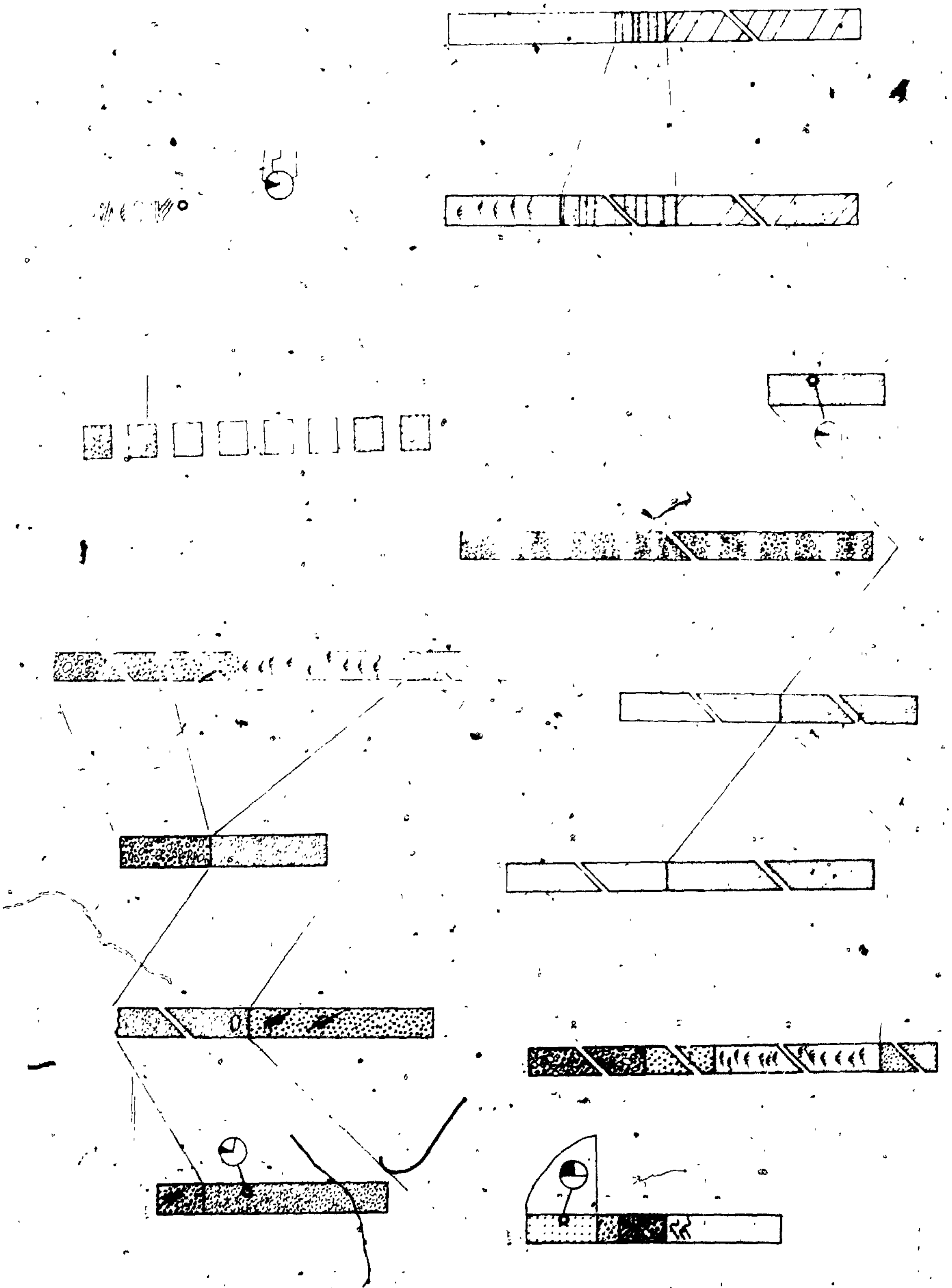


Figure 71. Stratigraphic sections of the Blue Ridge area.

Table 18. Light Mineral Composition of Tills Associated with the Blue Ridge Moraine.

Site Number	Quartz	K-feldspar	Plagioclase feldspar
263	5.5%	12.5%	82.0%
271	26.1%	20.5%	53.4%
274	8.0%	22.0%	70.0%

delta at the mouth of Sand Pond Brook indicates ice occupancy of the moraine during the time of Glacial Lake Warrensburg. The eastward-dipping foreset beds of the delta on the east side of the Schroon River are believed to indicate a complete filling of the valley by this delta. The middle portion of the delta was later removed during the formation of the Schroon River Valley. Since this delta was constructed into Glacial Lake Warrensburg, the age of Glacial Lake Warrensburg defines the time of ice occupation of the Blue Ridge Moraine.

Miller (1925) described the ice dam that formed Glacial Lake Warrensburg as located at Corinth, N. Y. Connally and Sirkin (1971) identified this ice dam as the Luzerne readvance and provided the only absolute date for glacial events in the interior of the Adirondack Mountains. A C^{14} date obtained from the base of a bog in the outwash plain of this readvance was 13,150 ± 200 BP. This, therefore, gives the minimum date for the tongue of ice at Blue Ridge as 13,150 ± 200 BP.

Light mineral composition of the till in Blue Ridge Moraine, site 263, indicates an anorthosite terrain origin. The light mineral composition of the till at site 274 also indicates an anorthosite origin of the till. However, the light mineral composition at site 271 indicates some addition of metasedimentary rocks. Bedrock west of site 271 is a combination of metasedimentary and anorthosite rocks (figure 6). The bedrock north of Sand Pond Brook is anorthosite. The composition of the till in the Blue Ridge Moraine[1] indicates either that this west to east flow of ice stopped in the vicinity of site 271 or the transported material is buried under the till analysed from the Blue Ridge Moraine, site 263, or is mixed in the moraine in areas not exposed for analysis. The light mineral composition of the till at sites 263 and 274 indicates that the glacial tongue which deposited the Blue Ridge Moraine advanced southward from the Dix Mountain complex to the north of Clear Pond.

A summary of events related to the Blue Ridge Moraine is:

1. A local tongue of ice moved south from the Dix-Mount Colvin Cirque complex into the Newcomb-Blue Ridge Valley and swung eastward stopping 13,000 + years ago at the present site of the village of Blue Ridge.
2. A second tongue of ice moving east in the Newcomb-Blue Ridge Valley encountered this tongue of ice and probably merged with it.
3. The valley train developed from the Blue Ridge Moraine built a delta into Glacial Lake Warrensburg. This delta completely filled the Schroon River Valley.
4. The dam at Luzerne opened, draining Glacial Lake Warrensburg and the deposits associated with the Blue Ridge Moraine were dissected by erosion.
5. The ice retreated northward leaving a blanket of outwash

gravel filling the center portion of The Branch.

6. A large block of ice was probably buried in the valley behind the Blue Ridge Moraine and the meltwater-transported material was carried across the buried ice block eastward into the Schroon River system.

5.4 TAHAWUS, McINTYRE DEVELOPMENT, INTERNATIONAL LEAD CO.

The McIntyre Development of the International Lead Co. is located approximately eight miles north of Route 82 on the Newcomb-Tahawus Road. The present working pit occupies the area of Tahawus and Sanford Lake in the Santanoni 15 minute quadrangle (figure 6, region L).

The McIntyre Development is located in a major north-south trending fault. The present operation is in the southward extension of the ore-bearing zone of this fault. The original mine operation was developed one-half mile north of the present active pit. Bedrock to the north, east and west of the fault zone is Marcy anorthosite (figure 6). Detailed field work by the International Lead Co., has not located any additional ore bodies south of the McIntyre Development. Metasedimentary rocks outcrop approximately six miles south of the mine.

The overburden from the area formerly under Tahawus and Sanford Lake was cleared in 1961 to reach the ilmenite ore. Excavation through the overburden exposed a multiple till section with interglacial lake sediments between two tills. Muller (1965a, 1965b) described two tills separated by an interglacial lake deposit containing wood fragments which were C^{14} dated, giving an age of greater than 40,000 years BP (W-1520) and greater than 55,000 years BP (Muller, E., 1969, Y-1715). Detailed measurements in the pit, made during an expansion phase of quarry operations established the existence of a third till layer (Craft, 1969).

Figure 72 is an oblique aerial photograph of the McIntyre Development taken during the summer of 1969. The locations of the measured glacial drift sections are shown on this photograph. Figure 73 is a compiled stratigraphic section of the total drift deposit exposed in the pit. Descriptions of the layers are included in this figure. Figures 74 to 76 are detailed stratigraphic sections showing the relationships of each of the tills to its underlying and overlying glacial fluvial and lacustrine sediments. The light mineral compositions of the tills are shown in table 19 and are plotted in their appropriate stratigraphic positions on the sections.

Table 19. Light Mineral Compositions of Tahawus Mine Tills

Till	Site	Quartz	K-feldspar	Plagioclase feldspar
C	3	30.4%	20.6%	49.0%
C	2	26.8%	23.2%	50.5%
B	2 a	2.6%	26.6%	70.8%
B	2 b	8.8%	26.7%	64.5%
B	2 c	11.4%	26.4%	62.1%
B	3 a	11.0%	20.0%	69.0%
B	3 b	10.2%	24.1%	65.7%
B	5 a	5.2%	20.6%	74.2%
B	5 b	10.3%	22.6%	67.1%
A	1 a	3.6%	25.6%	70.8%
A	1 b	1.0%	15.2%	83.8%

Pebble orientation studies were not possible in the pit due to the magnetic properties of the ilmenite ore. However, stripping operations have exposed striated bedrock surfaces throughout the mine

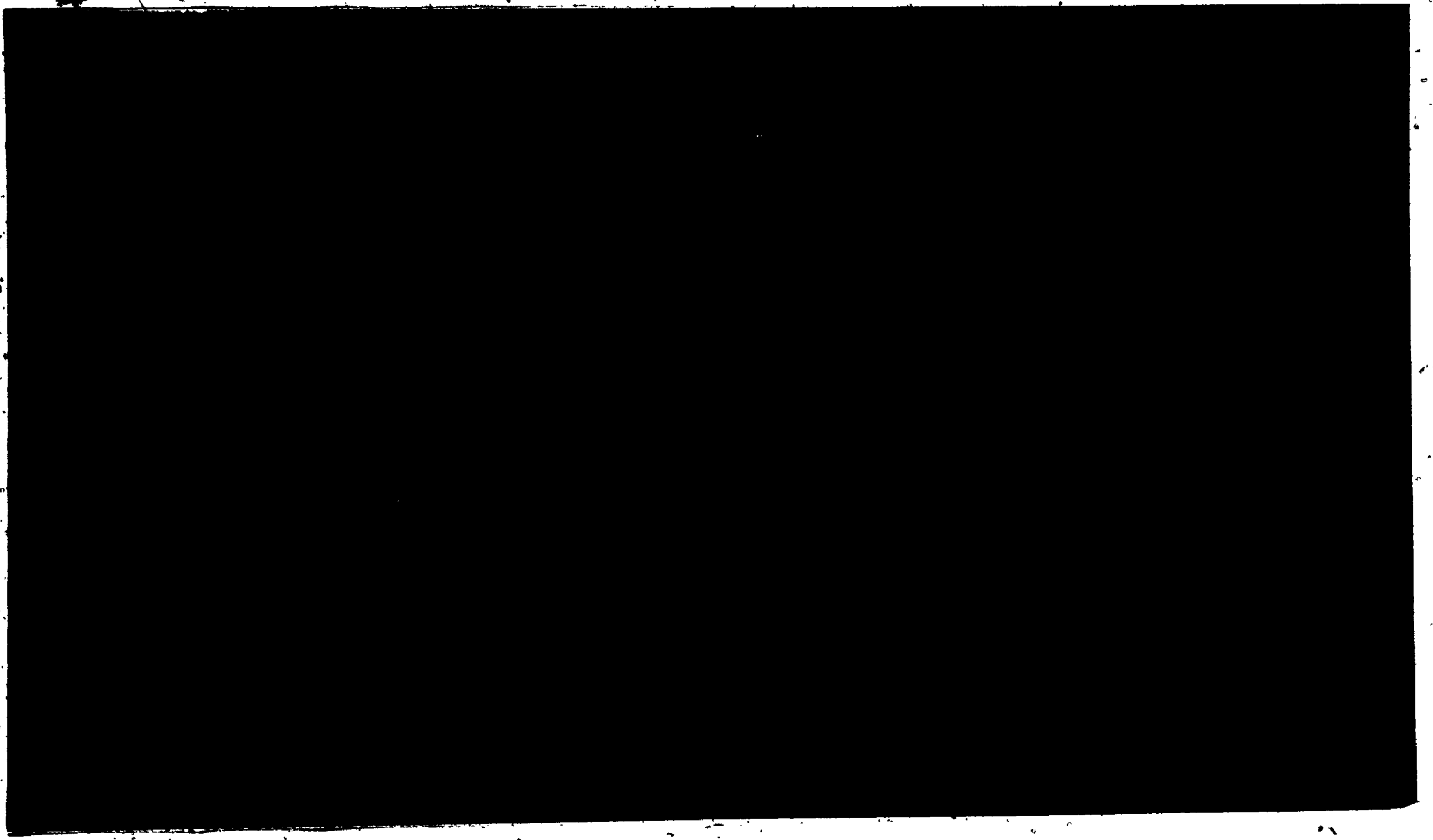
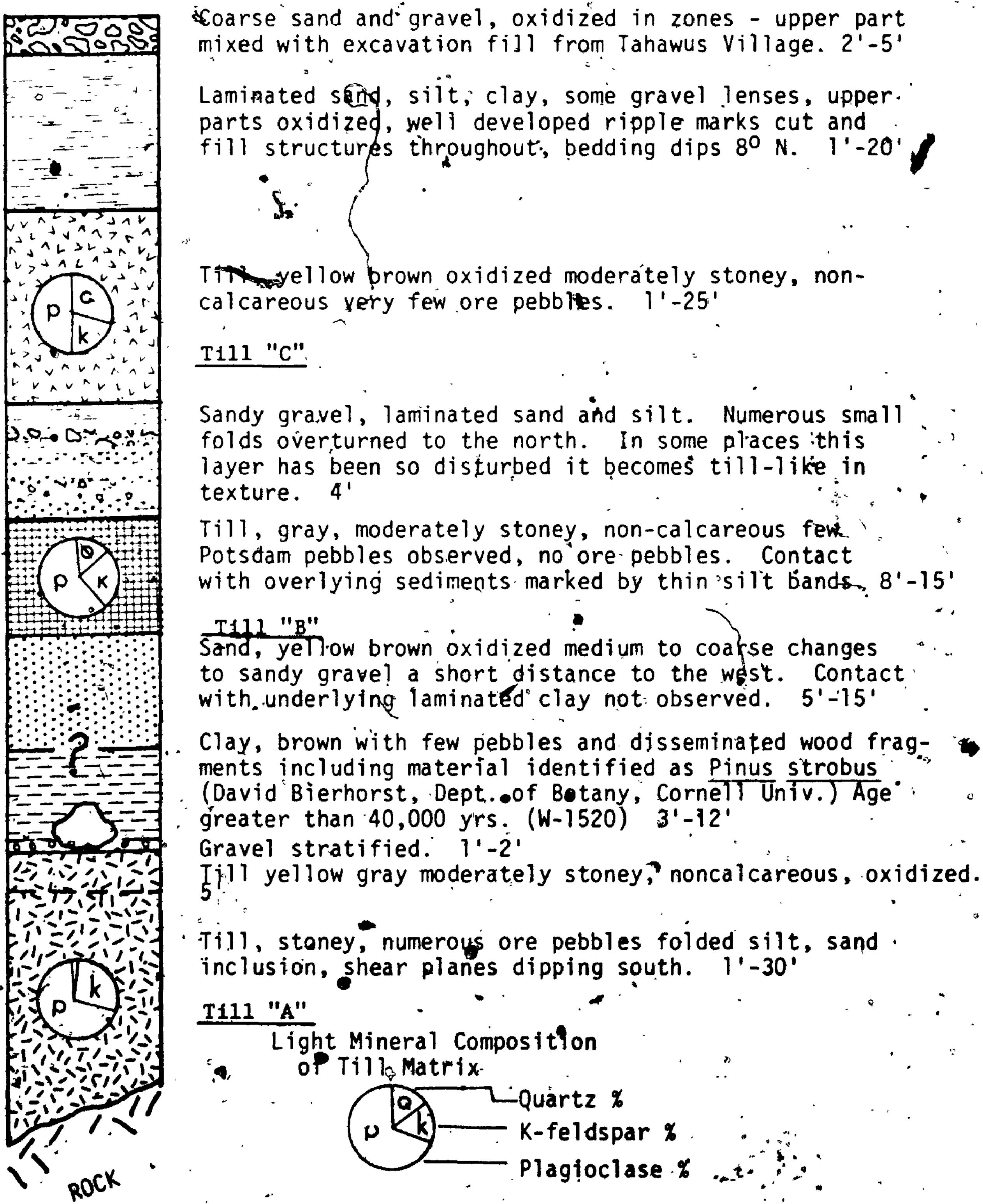


Figure 72. Oblique aerial photograph of McIntyre Development looking southwest.



Coarse sand and gravel, oxidized in zones - upper part mixed with excavation fill from Tahawus Village. 2'-5'

Laminated sand, silt, clay, some gravel lenses, upper parts oxidized, well developed ripple marks cut and fill structures throughout, bedding dips 8° N. 1'-20'

Till yellow brown oxidized moderately stoney, non-calcareous very few ore pebbles. 1'-25'

Till "C"

Sandy gravel, laminated sand and silt. Numerous small folds overturned to the north. In some places this layer has been so disturbed it becomes till-like in texture. 4'

Till, gray, moderately stoney, non-calcareous few Potsdam pebbles observed, no ore pebbles. Contact with overlying sediments marked by thin silt bands. 8'-15'

Till "B"

Sand, yellow brown oxidized medium to coarse changes to sandy gravel a short distance to the west. Contact with underlying laminated clay not observed. 5'-15'

Clay, brown with few pebbles and disseminated wood fragments including material identified as Pinus strobus (David Bierhorst, Dept. of Botany, Cornell Univ.) Age greater than 40,000 yrs. (W-1520) 3'-12'

Gravel stratified. 1'-2'

Till yellow gray moderately stoney, noncalcareous, oxidized. 5'

Till, stoney, numerous ore pebbles folded silt, sand inclusion, shear planes dipping south. 1'-30'

Till "A"

Light Mineral Composition of Till Matrix

Figure 73. Generalized stratigraphic section of Tahawus, McIntyre development drift deposits. Scale: 1" = 20'

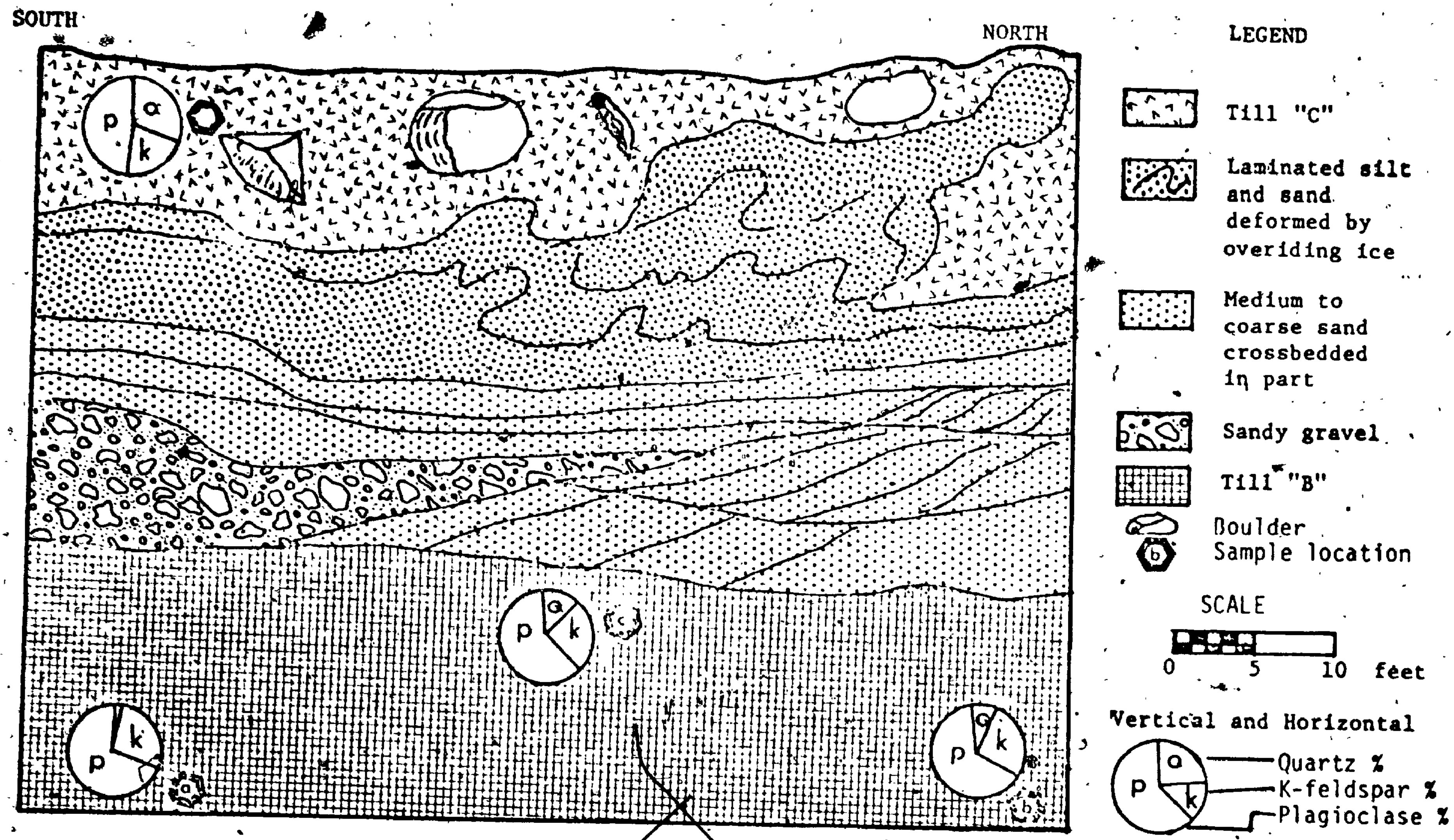


Figure 74. Stratigraphic section McIntyre Development. West face of excavation at site 2.

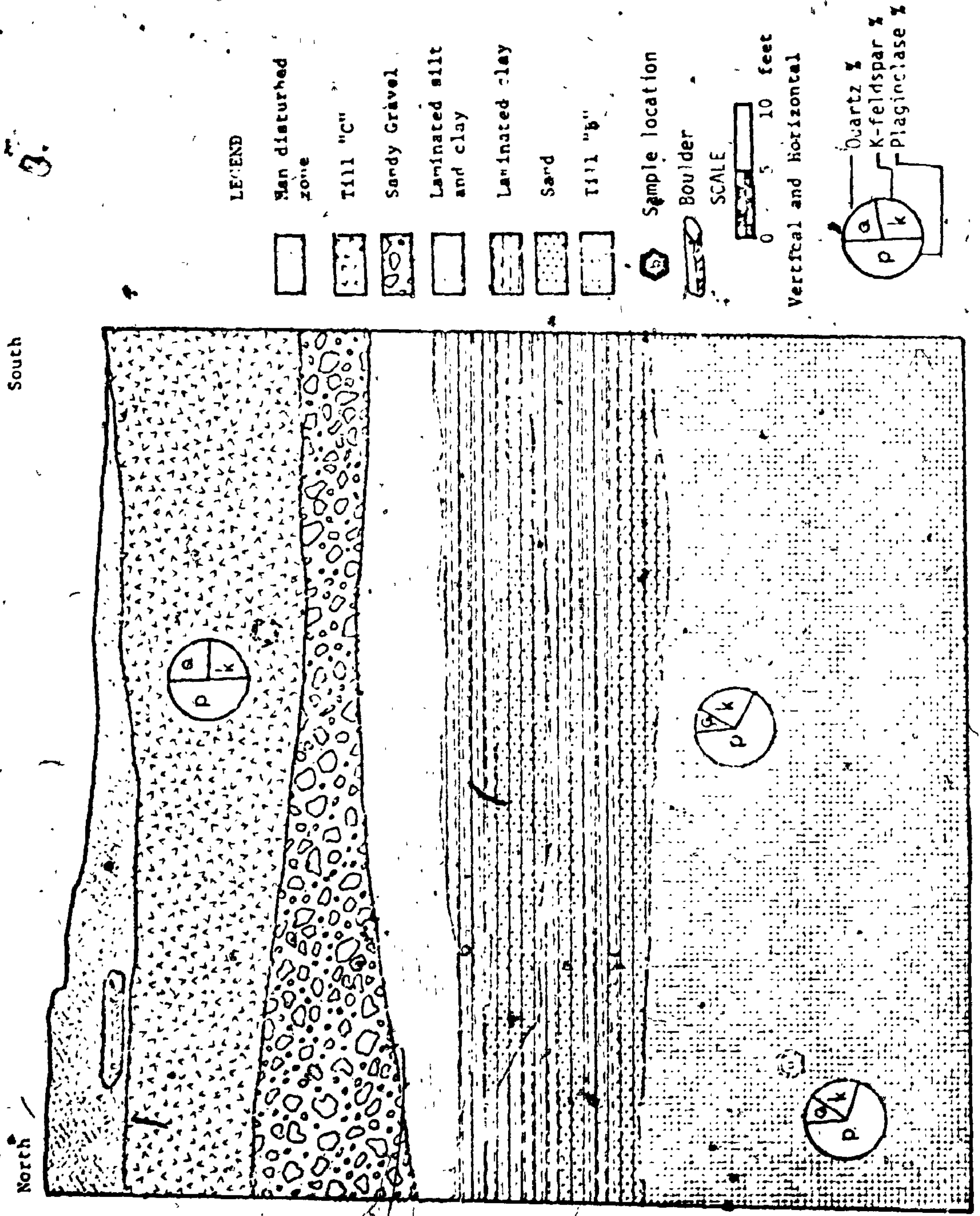


Figure 75. Stratigraphic section McIntyre Development, site 3, looking east.

113

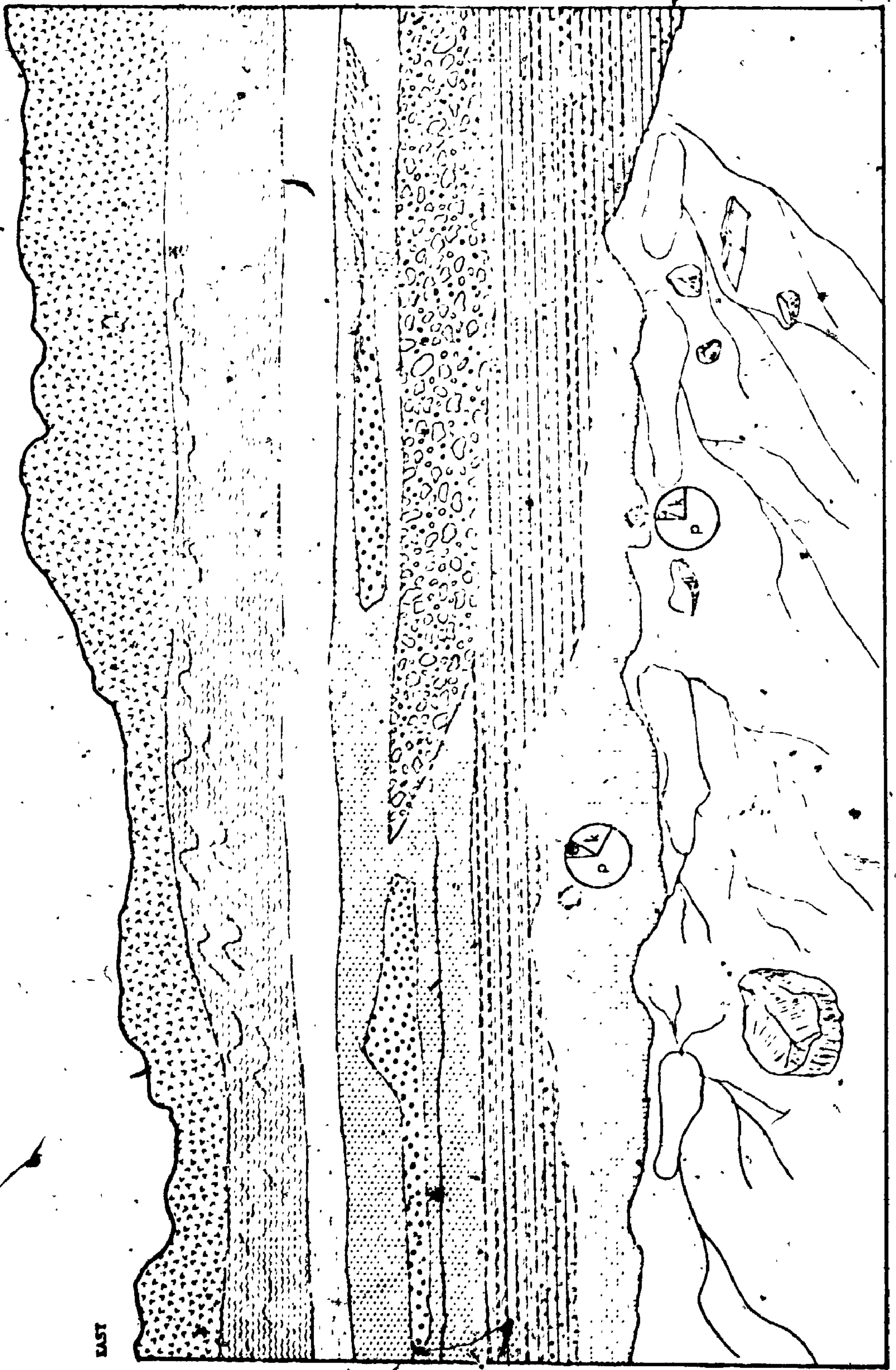


Figure 76. Stratigraphic section McIntyre Development, Site 5, looking south.

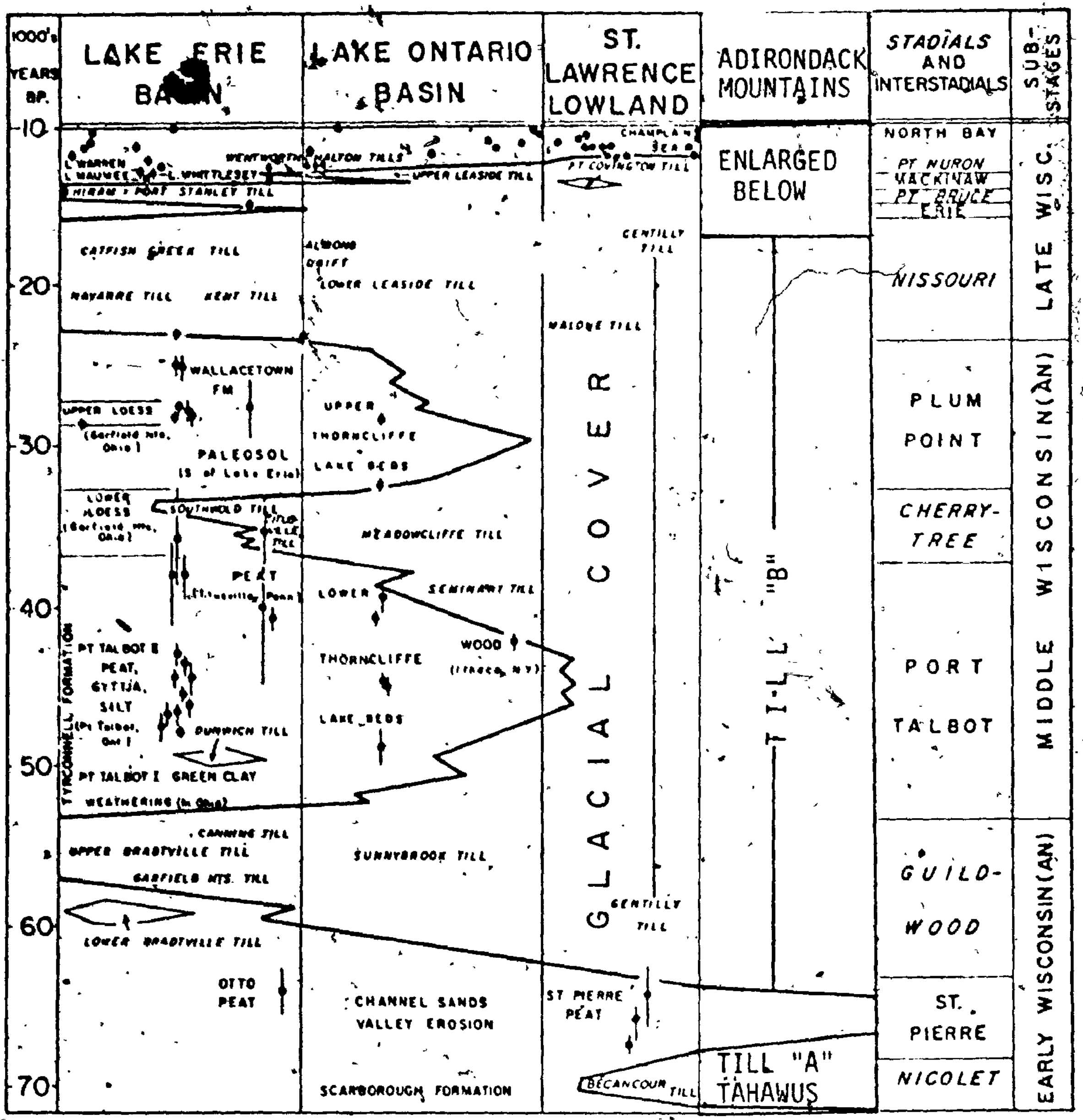
area. The most significant of these surfaces is located on the southeast side of the pit at the highest part of the exposed bedrock surface (figure 72, site 4). The surface at this point is relatively flat, rising slightly to the north. At the northern end of the exposure, the surface slopes steeply to the north at about 35°. The striations on the top of this surface are oriented north-south. The north end of the surface is also striated, but it has numerous breaks and irregularities on the surface, suggesting that numerous pieces of rock have been broken off and carried away. The author believes that if the ice had been moving southward, this north-facing slope would have received the full force of abrasion by the ice load and would have been worn to a smooth surface, very similar to the present south face of this knob. The quarrying action described probably indicates a northward flow of ice.

The first glaciation which is recorded in these deposits (till "A") occurred prior to 55,000 BP (Muller, E., 1969, Y-1715). Light mineral composition of the till deposited by this glaciation, and ore fragments in the till indicate that the ice movement was from the north. Investigations by the mine geologist (personal communication) have shown that no ore occurs south of the mine. This period of glaciation was followed by deposition of the lacustrine sequence from which C^{14} datable material was obtained. This was followed by a second glaciation, the till from which (till "B") has a light mineral composition typical of an anorthosite source, indicating that ice flow was from the north, east or west. This till also contains ilmenite ore pebbles so that the ice source was probably from the north.

This second glaciation was followed by deposition of fluvial and lacustrine sediments. These sediments were overridden by a third ice mass to produce till "C". The till deposited by this ice advance has a light mineral composition typical of a metasedimentary source with some enrichment by anorthosite. No ore pebbles were observed in this till. Metasedimentary rock outcrops six miles to the south, indicating that the ice flow was from that direction. The lacustrine sediments underlying this till have been deformed by the ice advancing over them. Deformation structures within the base of the till and these deformed lacustrine sediments indicate a northward flow of ice (figure 74). Striations in the mine also indicate a northward flow of ice.

CHAPTER VI GLACIAL HISTORY AND CLIMATIC MODEL OF LOCAL GLACIATION

Cirque development in the Adirondacks must have started very early in Pleistocene time. The oldest till at the McIntyre Development (figure 73, till A) clearly demonstrates a glaciation prior to 55,000 years BP, the age of the overlying lake sediments. These sediments could represent either an Early Port Talbot Interstade or the St. Pierre Interstade. The presence of continuous deposition of the Gentilly Till (Gadd, et al., 1972) in the St. Lawrence Valley from Late St. Pierre Interstade to Early Erie Interstade (figure 77) indicates that the lacustrine sediments were deposited during the St. Pierre Interstade. Till "A" represents the first glacial advance of the Wisconsinan Stage. Evidence indicates that the source of the ice that deposited this lower till was from the north (5.4). Two other areas of old weathered till were observed in the field study; one in Johns Brook Valley at the base of the Bushnell Falls exposure (figure 45), the other in the bank of West Branch Ausable River where the Adirondack Loj Road crosses the river (figure 86). There is no way of establishing an age for these tills except that they are more intensely weathered than the overlying tills. The Johns Brook Valley till, however, does show that the valley bottom existed in this present configuration sometime prior to the glaciation that deposited the older till. Goldthwait (1970) cited evidence of local glaciation and cirque-cutting at this time in the White Mountains. Cushing (1899) described a moraine on the north side of the Adirondacks near Malone, N. Y., composed entirely of Adirondack rocks. Cushing (1899, p. 8) interpreted this moraine as evidence of a late glacial flow



Time-space diagram showing glacial deposits (slant letters), non-glacial events, deposits and lake phases (vertical letters), the glacial margin as a heavy line, and radiocarbon dates (heavy dots with standard deviations as vertical lines). Time-stratigraphic divisons are listed in the two right-hand columns (from Dreimanis and Karrow, 1972).

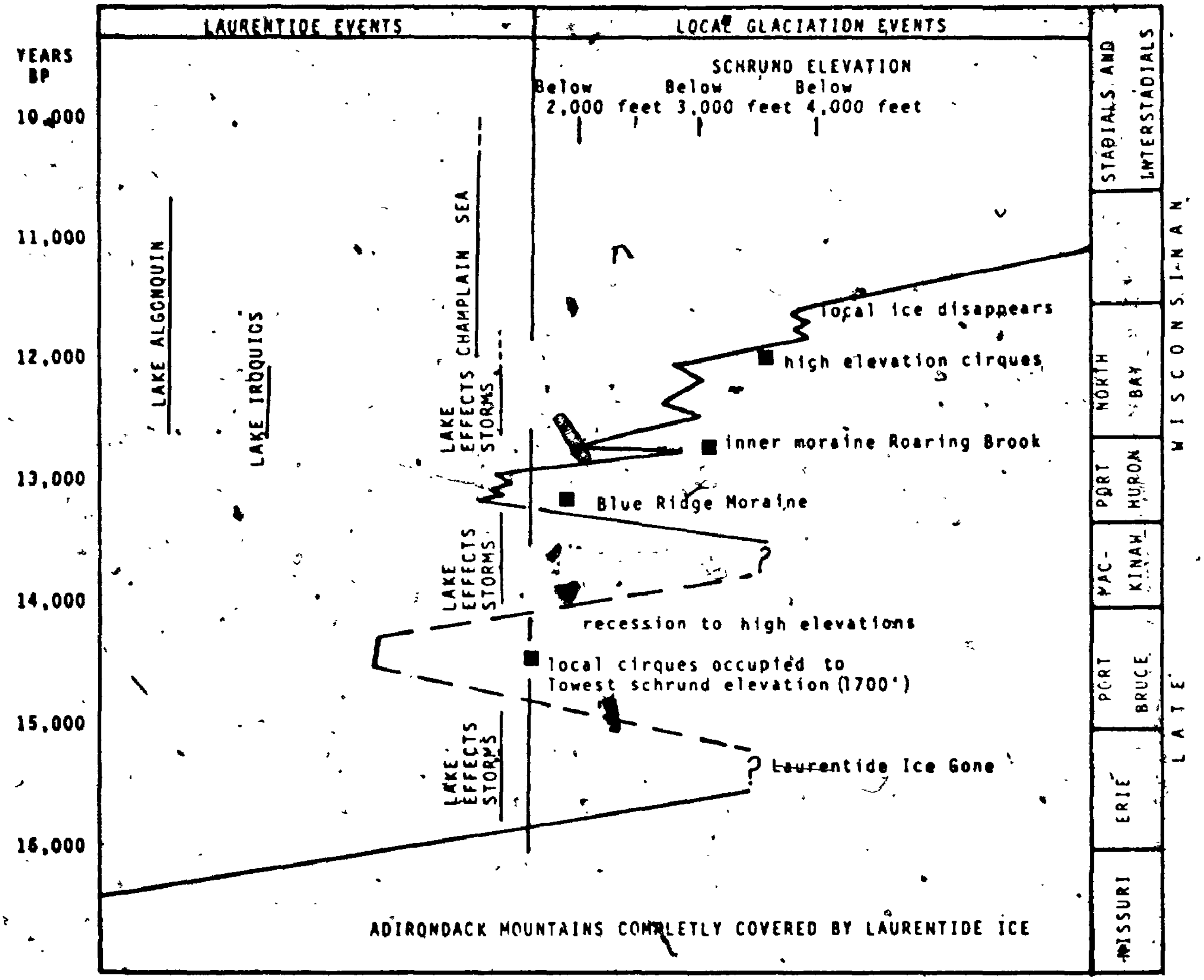


Figure 77. Diagrammatic stratigraphy of the Wisconsinan deposits, Adirondack Mountains, St. Lawrence Lowlands to Ohio.

of ice northwest from the Adirondacks. Field work in the High Peaks region, however, clearly indicates that the late glacial activity extended ice tongues only to the lower elevations of the main valleys. If, in fact, the moraine described by Cushing was actually older and had been exposed by late glacial erosional activity, a different story can be developed.

Using this sketchy evidence, the following working hypothesis for the time of initial local glaciation and cirque-cutting is proposed (figure 77).

The first glacial advance of the Laurentide ice sheet during Wisconsinan time in the St. Lawrence Valley has been reported by Gadd, McDonald and Shilts (1972). This advance blocked the outlet of the Ontario Basin, causing a rise in lake level to form Lake Scarborough (Dreimanis and Goldthwait, 1973). Goldthwait (1970) cited evidence of local glaciation and cirque-cutting in the White Mountains at this time. The existence of Lake Scarborough in the Ontario Basin establishes the criteria for "Lake Effect Storms". The presence of the Laurentide ice front would have created a glacial climate over the High Peaks region. Terasmae (1960) concluded from palynologic studies of the Scarborough Formation that the mean annual temperature at Toronto was 6° C. cooler at that time than at the present time. Goldthwait (1970) suggests that the average summer temperature in the White Mountains of New Hampshire was 9.3° C. cooler than at present. The present mean annual temperature of the Adirondacks at Lake Placid is 3.3° C.; at Burlington, Vermont, 4.4° C.; and at Albany, N. Y., 7° C. (Falconer, R., personal communication, 1969). Mean July temperature at Lake Placid is 18.9° C.; at Albany, N. Y., 22.8° C.; and at Toronto, 23.3° C.

Mordoff (1925) showed the mean annual growing temperature, April to September (interpreted as average summer temperature), to be 13.3° C. for the Adirondacks at the present time. Since snowline occurs where the average summer temperature is at 0° C. or slightly above, it is possible to predict snowline elevations for different annual mean summer temperatures (table 20).

Table 20. Mean Summer Temperature Variation with Elevation.

Mean Temperature Decrease from Present	6° C.[1]	10° C.[2]	11° C.[3]	0° C.[4]
Elevation	Mean Summer Temperature			
2000' ASL	7° C.	4° C.	2° C.	13° C.
3000' ASL	5° C.	2° C.	0° C.	11° C.
4000' ASL	3° C.	0° C.	-2° C.	9° C.
5000' ASL	1° C.	-2° C.	-4° C.	8° C.
6000' ASL	0° C.	-	-	-
9000' ASL	-	-	-	0° C.
Toronto	11° C.	7° C.	6° C.	17° C.

1. Annual mean temperature decrease for Lake Scarborough (Terasmae (1970).
2. Mean summer temperature decrease for White Mountains (Goldthwait, 1970).
3. Suggested mean summer temperature decrease for Adirondacks by author.
4. Present mean summer temperature at Wilmington, New York.

Snowline in the Adirondack Mountains during the existence of Lake Scarborough would occur slightly below 6000 feet ASL. This was determined by decreasing the mean annual growing time temperature of 13.3° C. at 2000 feet ASL by 6° C. as suggested by Terasmae (1960) and applying the normal lapse rate of 1.94° C. per 1000 feet elevation.

The influence of the proximity of the Laurentide ice sheet has not been considered in this calculation. Using the temperature decrease of 9.3° C. suggested by Goldthwait for the White Mountains, the snowline would be at 4000 feet ASL. A mean annual summer temperature decrease of 20° F. (11.1° C.) would place the snowline at 3000 feet ASL. Average schrund elevation in the High Peaks is 3036 feet ASL with a range from 1700 feet to 4300 feet ASL. These values suggest local glacial development was possible. It is conceivable, that, given time for ice accumulation and the additional cooling effect of the nearby Laurentide ice sheet, an ice cap glacier could have developed over the Adirondack Mountains and flowed northward to deposit the moraine described by Cushing (1899), south over the McIntyre Development to deposit till "A" and out of Johns Brook Valley.

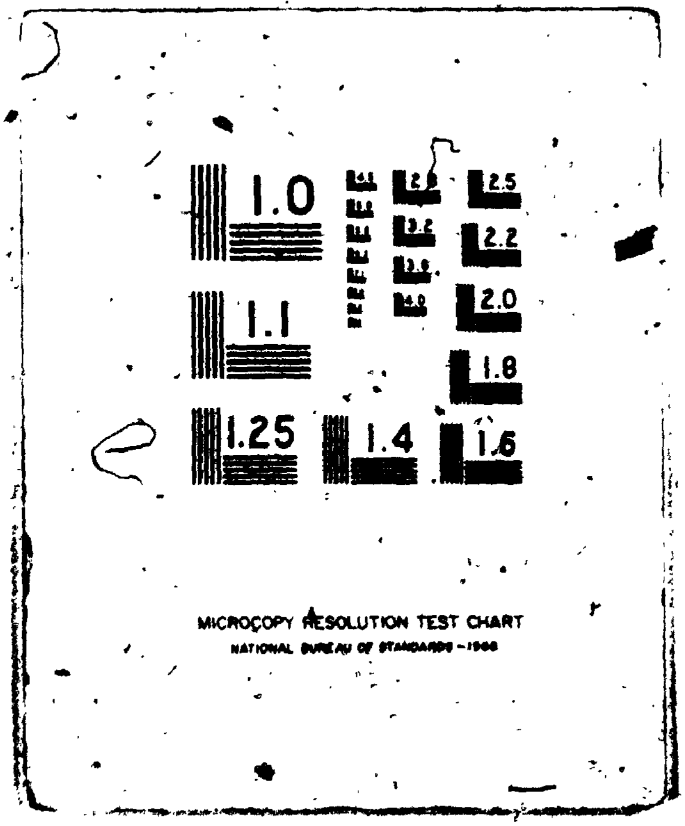
This could have been the stage of glaciation referred to in 3.3.7 when the low elevation cirques were occupied. When the early Laurentide ice melted from the St. Lawrence Valley, this local ice cap disappeared and the lacustrine sediments overlying the oldest till (figure 73, till "A") were deposited. These sediments are older than 55,000 years BP (Muller, 1969) and may record the St. Pierre Interstadial in the Adirondacks. This interstade was followed by the main Wisconsinan Advance, the Guildwood Stade of Dreimanis and Karrow (1972), which eventually extended south to Long Island and to Olean, New York. Coates and Kirkland (1974) suggest that this main Wisconsinan ice advance first flowed around the Adirondacks and that the Adirondacks eventually became an outflow center influencing the directions of flow of the Laurentide ice sheet. Field evidence in the High Peaks area indicates that the main Laurentide ice advance moved through the main valleys and continued southward. This is indicated by the presence of Potsdam sandstone erratics in the main valleys of the Adirondack Mountains and in the distribution of metasedimentary rocks in the tills deposited on the Anorthosite terrain of the High Peaks (Chapters III and IV). This main Laurentide Advance is also recorded in the Tahawus section (figure 73) by the deposition of till "B". The Adirondacks remained buried beneath this ice mass until Late Wisconsinan time. Deglaciation from the glacial maximum position began about 17,000 years BP (Connally and Sirkin, 1973). Deglaciation of the region appears almost continuous with some readvance of the continental ice mass reported by Connally and Sirkin (1973), the Walkill Readvance, until 13,200 years BP, the date of the Luzerne Readvance (Connally and Sirkin, 1973).

The exact time of Laurentide deglaciation from the High Peaks area is not known. However, a reasonable time frame can be established in relationship to the deglaciation history of the Late Wisconsinan ice mass.

Dreimanis and Goldthwait (1973) describe two Late Wisconsinan interstades, the Erie and the Mackinaw, that relate to the Adirondacks.

The Erie Interstade, approximately 15,500 years BP (Dreimanis and Goldthwait, 1973), is probably the earliest that the Laurentide ice would have melted from the High Peaks region (figure 77). At this time, the area would be surrounded by the Laurentide ice mass with the High Peaks standing as a bedrock island through the ice mass (Fairchild, 1913; and Coates and Kirkland, 1974). Dreimanis (1969) and Dreimanis and Goldthwait (1973) indicate an eastward flow of

3 OF/DE 3



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963

ARC - 374

water from the Erie Basin to the Hudson River Valley during the Erie Interstadial. This implies that the continental ice margin had to be north of the Onondaga Escarpment for the water to reach the Hudson River system. If this were true, then the High Peaks area could have been free of direct influence of the continental ice flow and the Hudson Valley would have been ice-free south of Albany, N. Y.

The Erie Interstade closed with ice advancing to the Lake Escarpment Moraine (Calkin, 1970; White, 1960), to the Valley Heads Moraine (Calkin, 1970; Muller, 1965b; MacClintock and Apfel, 1944) and to the Walkill Valley Moraine (Connally and Sirkin, 1970 a & b and 1973). This ice readvance has been dated by Calkin (1970) at 14,900 ± 450 years BP (I-4216) for the Lake Escarpment Moraine and by Connally and Sirkin (1973) at 15,000 years BP. This readvance is the Port Bruce Stade of Dreimanis and Karrow (1972) and probably represents Phase E suggested by Coates and Kirkland (1974).

The Port Bruce Stade was followed by stagnation and melting back of the ice front during the Mackinaw Interstade (Dreimanis and Goldthwait, 1973) to a line 50 to 150 km. north of the Port Huron Moraine complex in the Erie Basin (Karrow, 1969; Dreimanis, 1967; Dreimanis and Goldthwait, 1973) and receded to a line somewhere north of the south shore of Lake Ontario (Karrow, 1969; Calkin, 1970) and north of Luzerne, New York in the Hudson-Champlain Valley. During this interstade, the High Peaks area would have open drainage into the Hudson system southward. It is not known if there was a period of open drainage northward into the St. Lawrence Lowlands. MacClintock and Stewart (1965) reported lacustrine sediments between the Malone Till and the Fort Covington Till in the St. Lawrence Valley, and correlated the Fort

Covington Advance with the Port Huron. If this correlation is correct, then a partially open drainage to the north was possible during the Mackinaw Interstadial.

The Mackinaw Interstade was followed by the Port Huron Readvance (Dreimanis and Karrow, 1972) in the Erie Basin and the Bridport Readvance (Connally and Sirkin, 1970a, 1970b, 1973) in the Hudson-Champlain Valley. Calkin (1970) believes the morainal complex between Lake Ontario and the Onondaga Escarpment is probably related to the Port Huron Readvance. Dreimanis and Evenson (1976) suggest that the Bridport and Luzerne Readvances both belong to the Port Huron Stade.

The Luzerne Readvance (Early Port Huron Stade) caused ice to move down the Hudson-Champlain Valley to south of Glens Falls, New York (Connally and Sirkin, 1971, 1973). This advance blocked the Hudson River drainage from the Adirondacks and created Glacial Lake Warrensburg (Miller, 1925; Craft, 1970). Drainage northward was also blocked by ice, creating Glacial Lake Wilmington in the Ausable drainage system and Glacial Lake Saranac in the Saranac system.

The Port Huron Stade was followed by ice retreat and the development of a complex series of proglacial lakes. This lake series has been reported in detail by Hough (1958, 1963); Lewis (1969); Calkin (1970); Karrow <u>et al.</u> (1961, 1975); Dreimanis and Goldthwait (1973); and Prest (1970). The development of the proglacial lakes played an important role in local glacial activity in the High Peaks region.

The return of the Laurentide ice mass to the border of the High Peaks region during the Port Huron Stade brought a return of glacial climatic conditions to the higher elevations of the mountains.

Pre-existing depressions were filled with snow, which became thick enough to form ice and, finally, started flowing from the higher elevations as local glaciers. A permanent Arctic high pressure system would develop over the continental ice sheet.

Climatic conditions to the south and southwest were much warmer than to the north. Storm systems probably moved across the area from west to east, just as they do today (Manley, 1955; Wright, 1961; Fairbridge, 1970, 1972) but storm tracks would be pushed farther south. Air masses from the south and west would be relatively warm and moist, similar to those of today. When these warm air masses encountered the cold air from the ice mass, precipitation would occur. This precipitation would be rain in the south at lower elevations, and snow in the north at higher elevations. The rise in surface elevation from south and west to the High Peaks region to the northeast would create an orographic effect on the moving air masses, intensifying precipitation. In the early phase of this sequence, most of the accumulation would be from regional storms moving from the southwest and west towards the east.

With this in mind, let us consider a special type of storm development that may have played a very important role in events in the Adirondack Mountains following the Port Huron Stade of the Laurentide ice sheet, especially during late Port Huron and early North Bay time. This special storm situation is known as the "Great Lakes Snow Storms" or "Lake Effect Storms" (Jiusto et al., 1970; Lansing, 1965; Peace and Sykes, 1966; Falconer, Lansing and Sykes, 1964).

Basically "Lake Effect Storms" are presently generated over the open water surface of the Great Lakes during the winter months, when the air mass over the lakes is colder than the water. The difference in temperature between the air and water causes an unstable air mass condition to develop. Warm moist air rises into the cold air above to generate meso-scale storms with dimensions of about 2 to 20 miles in width and 50 to 100 miles in length (Lansing, 1965). These storms originate over the open water of the lake and then drift over the land, causing precipitation of either rain or snow depending on the air temperature over the land. The land surface rises east of Lake Ontario, causing an orographic lifting of the meso-scale storm and intensifying precipitation. These storms often reach the High Peaks region and because it is colder in this mountain area, precipitation is in the form of snow. For example, in November 1969 a meso-scale storm developed over Lake Ontario and extended eastward. Temperature at Oswego, N. Y., on the lake shore, was 40° F. and precipitation was in the form of rain and sleet. The temperature at Whiteface Mountain, approximately 120 miles east, was 8° F. and precipitation was in the form of snow (Falconer, R., personal communication). Figure 78 is a map showing mean seasonal snowfall in northern New York State. The impact of these "Lake Effect Storms" is readily shown by the amount of snowfall recorded at the east end of Lake Ontario. The greatest mean seasonal snowfall occurs at the highest point on the Tug Hill Plateau with over 220 inches recorded. This is due to a combination of meso-scale storms and orographic lifting of the air masses. The next greatest snowfall area is the High Peaks region of the Adirondack Mountains, with over 190 inches annually. Precipitation from this type of storm is intense. One single snow squall in 1964 dropped 48

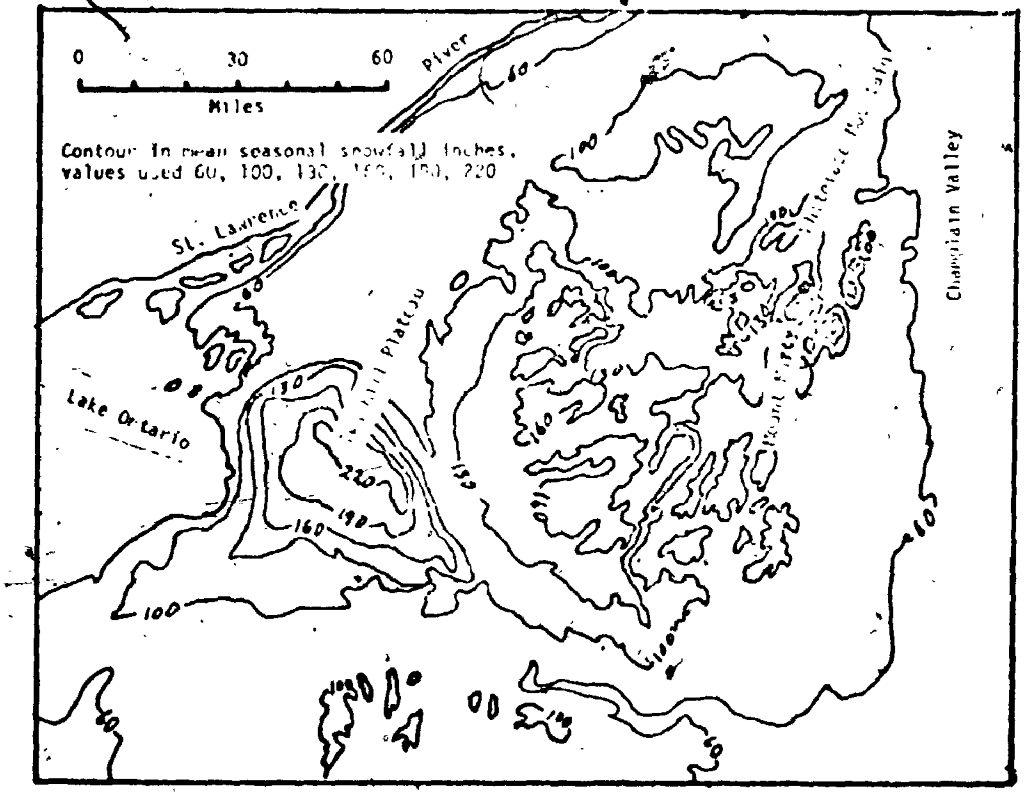


Figure 78. Mean seasonal snowfall map Tug Hill Plateau and Adirondack Mountains (after Muller, 1960). Pattern shading used to delineate area of snow accumulation 100 130 and 160 190 for ease of reading.

inches of snow on Boonville, N. Y. in 24 hours (Lansing, 1965).

The storms begin to develop in the fall as soon as surface air temperature is lower than surface water temperature, and continue until the lake freezes over or until spring, when the surface air temperature becomes higher than water temperature (Falconer et al., 1964). These storms generate large amount of snowfall. They are caused by a specific combination of conditions, i.e. warm water bodies overlain by cold air masses. These are the conditions that would have existed over the surface of proglacial lakes due to the nearby Laurentide ice field. Conditions would be most favorable for "Lake Effect Storms" following spring break-up of the frozen lakes and in the fall prior to the lakes freezing over. This would shorten the period of summer ablation and provide a source of large amounts of snow.

The conditions for "Lake Effect Storms" existed from the time of deglaciation of the Adirondack Mountains, possibly as early as the Erie Interstade (approximately 15,500 years BP) and lasted with lengthy interruptions and varying degrees of intensity until the retreat of the Laurentide ice north of the St. Lawrence Valley. Between the Erie Interstade and the opening of the Champlain Sea, large bodies of water of varying sizes and geographic positions existed at the edge of the Laurentide ice sheet. Cold polar air existed over the ice mass with warmer air to the south. The proglacial lakes were partially ice free at least during the warmer period of the year. The normal wind circulation was probably from west to east.

Figure 79 is a map showing the maximum possible ice recession position during the Mackinaw Interstade prior to the beginning of the Port Huron Stade. The High Peaks cirques were fully occupied by glaciers at this time. Figure 80 shows the approximate ice position reached by the Port Huron-Luzerne Readvance (Early Port Huron Stade). A very large body of water existed in the Erie Basin i.e. Glacial Lake Whittlesey. Small lakes existed in New York in the Finger Lakes region. The Adirondacks were surrounded on three sides by the continental ice sheet, establishing a cold glacial climate in this highland region. During this time, a delta from the Blue Ridge Moraine was deposited into Glacial Lake Warrensburg. This appears to be the time of local glacial maximum as indicated by the Blue Ridge Moraine and associated deposits. The outer Roaring Brook Moraine, the youngest till (till "C") at the McIntyre Development and Boreas Mountain Moraine were probably deposited at this time. At this period, it is doubtful that any "Lake Effect Storms" generated over Glacial Lake Whittelsey would have reached the Adirondack Highlands. However, regional cyclones from the west and southwest would have reached the mountains, and continued snow accumulation would have taken place.

As the continental ice melted back from this maximum position, the lake system expanded eastward (figure 81) forming Glacial Lake Warren.

The Laurentide ice receded and readvanced to the Bridport position of Connally and Sirkin at about 12,900 BP (1973) and Lake Warrensburg drained. Within the Adirondacks, the valley glaciers receded from their maximum positions. The inner moraine of Roaring Brook was formed. The glaciers flowing into Lake Wilmington and Keene were calving off into the lakes.

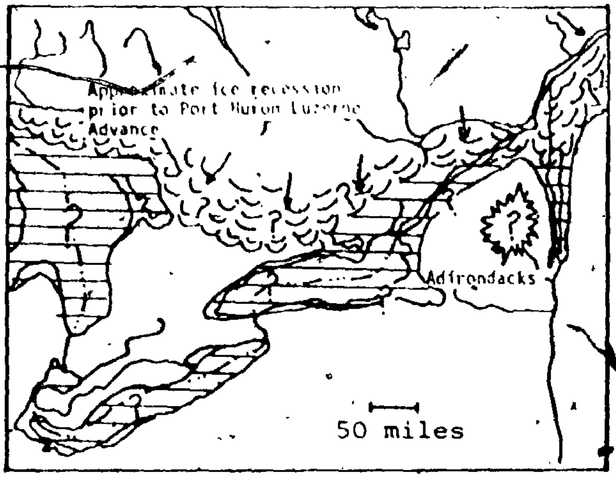


Figure 79. Approximate ice recession during Mackinaw Interstade. Early "Lake Effect Storms" caused snow accumulation in the Adirondacks building local ice masses.

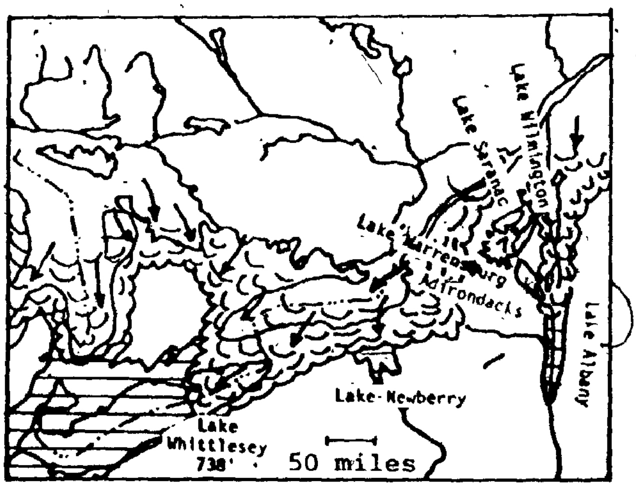


Figure 80. Approximate ice margin during Port Huron Stade. Note Adirondack High Peaks glaciation and presence of Glacial Lakes Warrensburg, Wilmington and Saranac. Local glacial maximum to Blue Ridge and outer Giant Moraines.

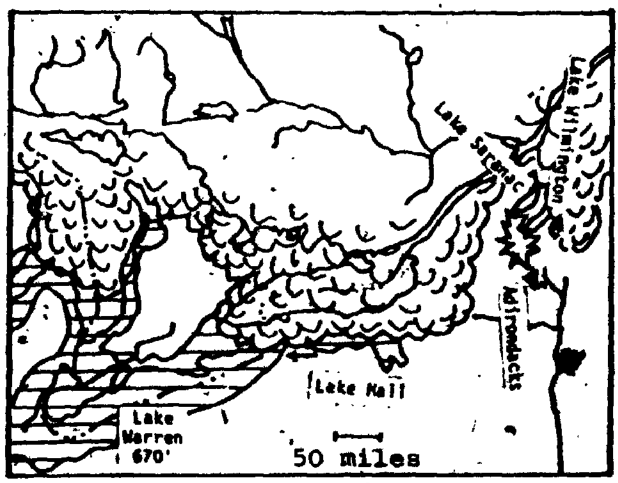


Figure 81. Approximate ice margin Late Port Huron Stade. Glacial Lakes Warren and Hall and the Adirondack lakes at approximately 12,900 BP. Local ice has receded to inner moraine at Giant Mountain. Lake Warrensburg drained. Maps modified from Prest (1970).

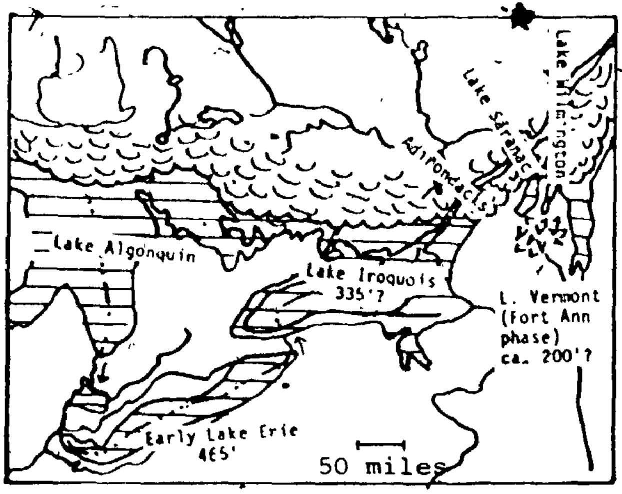


Figure 82. Glacial Lakes Algonquin, Iroquois and Vermont[1]. Note Lake Warrensburg has drained and presence of Lakes Saranac and Wilmington. Time of maximum "Lake Effect Storms". Local recessional lateral moraines developed in Johns Brook and White Brook (approximately 12,000 to 12,600 BP).

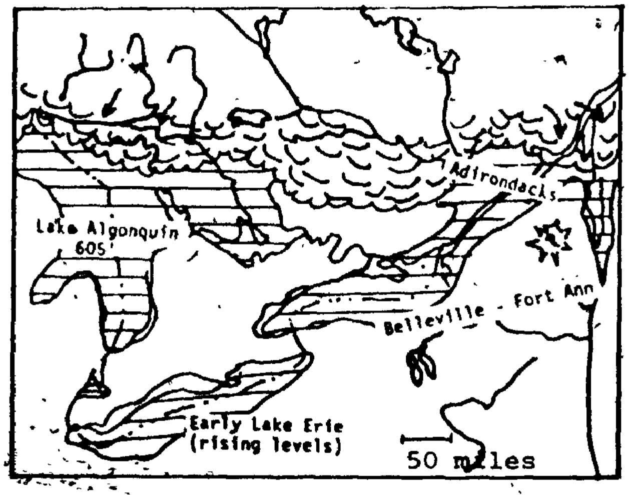


Figure 83. Glacial Lake Algonquin, Belleville-Fort Ann Stage[1] approximately 11,800 to 12,000 BP. Adirondack Lakes have now drained, mountain glacial activity waning. Rapid melting to higher elevations. Ice dammed lakes rapidly drained.

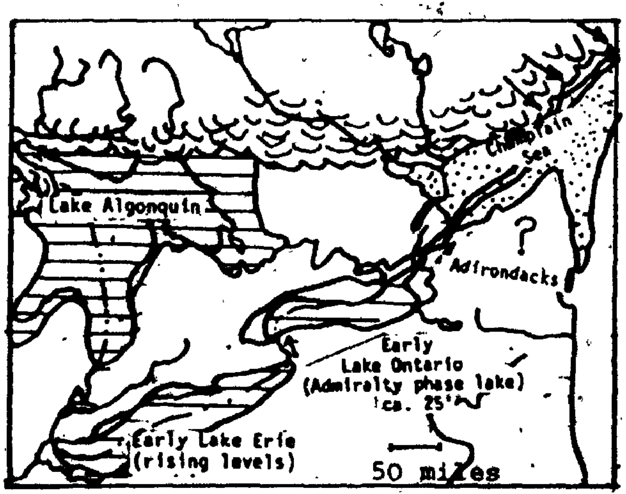


Figure 84. Glacial Lake Algonquin, Champlain Sea[1] approximately 10,200 to 11,800 BP. Early Lake Champlain, high elevation valley glaciers and isolated cirque glaciers e.g. Moss Pond. Probably all Adirondack ice had disappeared by 11,000 BP. Maps modified from Prest (1970).

The connection of Lake Warren between the Ontario and Erie Basins was short lived. Once the Utica outlet was opened by the retreat of the ice from the south side of the Tug Hill Plateau, the two basins separated and Glacial Lake Iroquois was formed. Karrow et al. (1975) placed this event at about 12,600 years BP. The creation of this large body of water in New York would have caused the return of the "Lake Effect Storms" affecting the Adirondack Mountains. There would have been a warming trend in the Highland area as the Lake Champlain Basin was freed of ice except at the northern end. Temperature in the mountain area, however, would still have been cold enough to maintain a positive balance of snow accumulation at higher elevations, primarily because of the high snowfall and elevations of the mountains. In the Adirondacks there appears to have been a delicate balance between accumulation in the higher elevations and ablation in the lower elevations. Major valleys were occupied by deep lakes. Local ice tongues advanced into these interior lakes and ice calving occurred.

Snowfall and accumulation rates at higher elevations would have been very high, ablation in the lower elevations would also have been high, as shown by the recession of the continental ice mass around the west and east sides of the mountain area and the rapid expansion of Glacial Lake Iroquois. The "Lake Effect Storm System" would have had its greatest effect when Glacial Lake Iroquois reached its maximum extent (figure 82), and the Laurentide ice mass was still resting against the north edge of the mountains. It was probably during this period that the ice was most active. Accumulation rates would have been high, but ablation rates at lower elevations would also have been high. Therefore, recession probably occurred. It was during this time interval that the recessional moraines of Johns Brook and White Brook were formed.

When the ice retreated to the north side of the St. Lawrence River (figure 83), the Adirondack proglacial lakes drained. The tongues of local valley ice rapidly melted back to higher elevations, leaving only small higher elevation valley glaciers and isolated cirque glaciers. This was probably the time of formation of the moraine in Moss Pond and Redfield Cirques and the upper moraine of White Brook Valley. Lake Belleville would still act as a source for generating "Lake Effect Storms" but ablation would be greater than accumulation. The interior Adirondack lakes would be rapidly draining and the Adirondack region would be warming.

With the beginning of the Champlain Sea at approximately 11,800 years BP (Karrow et al., 1975), the High Peaks climate would be much warmer. The most protected high elevation areas could still contain glaciers; however, they were probably stagnant melting ice masses. It is not possible to determine exactly when the last glacial ice disappeared from the Adirondacks, but all ice was probably gone by 11,000 years BP.

CHAPTER VII CONCLUSIONS

The purpose of the study was to find evidence for or against the hypothesis that local glaciation occurred in the High Peaks area of the Adirondacks after the recession of the Late Wisconsinan Laurentide ice sheet from the mountain mass.

Analysis of cirque schrund elevations in relationship to the positions and aspects of the cirques indicates a possible snowline at 1700 to 2700 feet ASL and a second possible snowline at 2400 feet to 3400 feet ASL. The lowest schrund elevations may relate to the development of an Early Wisconsinan ice cap and to the deposition of Till "A" at Tahawus, N. Y. The higher snowline may be related to the Late Wisconsinan events.

The most conclusive evidence of the time relationship between mountain glaciation and continental glaciation is derived from light mineral studies of the matrix of Adirondack tills. The best example of the stratigraphic relationships between tills deposited by the continental ice advance and local ice activity as defined by light mineral composition of the till matrix is in the Wilmington Ditch section (5.1). In this exposure, a till with a matrix composed of 85% plagioclase feldspar stratigraphically overlies a till composed of 40% plagioclase feldspar indicating a local ice advance from the anorthosite bedrock mountains on the west side of Wilmington Valley following the recession of the continental ice. The light mineral composition of the High Peaks tills provides evidence of local ice activity; however, light mineral composition by itself cannot be considered conclusive proof of local glaciation. Other factors such as striations, elongate pebble orientations, pebble lithology distributions, and sediment deformations must be considered and evaluated in relationship to the evidence of light mineral composition of the tills. For example, Laurentide ice flow indicators have been identified in all of the main northeast-southwest trending valleys; however, striations and elongate pebble orientation studies show ice movement at nearly right angles to this continental flow in Roaring Brook Cirque, on the west side of Giant Mountain (3.2.2.2); at the Coon Pit Cirque on Whiteface Mountain (3.2.2.4.1); and at Newcomb (4.1). A northward flow of ice is indicated at the McIntyre Development (5.4). Lithology distributions indicating flow in directions other than that expected by Laurentide ice advance have been found in White Brook Valley (3.2.2.1).

Deformation of unconsolidated lacustrine deposits by overriding glacial ice also indicates ice movement after Laurentide deglaciation. This was found at the Whiteface Mountain Ski Center (3.2.2.4.2) and at Styles Brook Road (5.2).

Goldthwait (1913, 1916a, 1916b) and Fairchild (1913) argue that the lack of end moraines at the lower elevations of the mountain valleys is evidence that local glacial activity did not follow Laurentide glaciation in the Adirondacks. Johnson (1917, 1933) observed that many modern glaciers are not developing end moraines; he concluded that the absence of end moraines does not negate the hypothesis of local glaciation. Another possible explanation for the scarcity of end moraines in the Adirondacks is that local ice tongues advanced into deep lakes. The ice "calved-off" and floated away, consequently no end moraines could develop. Tills resting on lacustrine sediments and large isolated boulders resting in fine-grained lacustrine sediments have been observed throughout the main valleys and support this explanation for the absence of end moraines. These are described at Whiteface Ski Center (3.2.2.4.2), the Wilmington Ditch (5.1), and Styles Brook Road (5.2).

Three end moraines exist within the interior of the High Peaks region. These are located at St. Huberts, below Giant Mountain (3.2.2.2); Cooperkill Pond Cirque (3.2.1.3) and Weston Mountain Cirque (3.2.1.4). Other end moraines were observed south of the High Peaks region at Blue Ridge (5.3), Boreas Mountain (3.2.2.3) and Redfield Cirque (3.2.1.1). Lateral moraines were observed in White Brook Valley (3.2.2.1), Johns Brook Valley (3.2.3.1) and Styles Brook Valley (5.2). The existence of these morainal deposits in the High Peaks area is another indication that local glaciation occurred after Laurentide glaciation.

In summary, the history of local glaciation in the Adirondack Mountains is believed to comprise the following episodes:

1. The first Laurentide glaciation occurred during Early Wisconsinan time and the Adirondack Mountains probably became a local ice center (Till "A", McIntyre Development, 5.4; Cushing's (1899) moraine and other older till deposits).
2. This early ice melted away and the lake deposits at the McIntyre Development were formed (dated material in silt and clay over Till "A", McIntyre Development).
3. A major Laurentide ice advance from the north moved over the High Peaks area, depositing Till "B" at the McIntyre Development. The mountains were completely overridden by this Late

Wisconsinan advance.

4. The Laurentide ice mass melted from the High Peaks region possibly during the Erie Interstade (15,500 years BP).
5. The local ice probably redeveloped during the Port Bruce Stade and receded to some extent during the Mackinaw Interstade. However, sufficient ice accumulated in Late Mackinaw time for ice to advance to the lowest preserved moraine position at Blue Ridge at approximately the same time as the early ice advance of the Port Huron Stade. The Adirondack High Peaks local glaciation is identified in a time relationship to the Luzerne Readvance by the Blue Ridge Moraine and the associated deposits into Glacial Lake Warrensburg, about 13,200 years BP.
6. Deglaciation of local ice to recessional moraine positions can be related to the Two Creeks Interstadial.
7. Rapid valley deglaciation occurred with the draining of Lake Iroquois with only remnants of cirque glaciers left during the Belleville-Fort Ann lake stages (approximately 11,900 years BP).
8. All glacial ice was probably gone by the time of the completion of the Champlain Sea phase of deglaciation, shortly after 12,000 years BP.

CHAPTER VIII · SUGGESTIONS FOR FURTHER STUDIES

A framework of Adirondack glacial history for the Wisconsinan Glaciation has been proposed. Additional field work needs to be done to establish more detailed information concerning the relationship of the High Peaks deposits to the deposits outside of the High Peaks area. The following are some suggestions for further investigation:

1. Paleontological and sedimentological studies of the old lake deposits at the McIntyre Development. Additional paleontological studies should also be done on the Adirondack lakes at different elevations and geographic locations.
2. Proglacial lake shore lines, lake outlet channels and drainage history should be established in detail for the interior valleys. These could then be related to events outside the High Peaks.
3. The area described by Cushing (1899) should be located and the sources of the rocks in the moraine should be identified.
4. Field work in the Raquette Lake area has indicated a complex but decipherable history of glacial activity. This area needs to be mapped in detail and its history related to the surrounding regions.

There are abundant opportunities for further studies in the Adirondacks. It is the area of New York of which we know the least about the glacial history. It is a difficult area in which to work, but at the same time, all new information from the area will make a definite contribution to the understanding of the glacial history of the Late Wisconsinan Stage.

APPENDIX A

LIST AND DESCRIPTIONS OF SAMPLE LOCATIONS

APPENDIX A SITE LOCATIONS

Locations are measured in inches from the side of the specified U.S.G.S. topographic map using the appropriate corner for direction reference. Example: Raquette Lake Quadrangle, NE-4.1", S-5.3" W means, measure south from the northeast corner of the Raquette Lake map 4.1" and west from the east edge of the map 5.3".

RAQUETTE LAKE AREA

Site No.	Quadrangle	Location	Description
6	Old Forge	NW-3.2" S-4.2" E	Twelve feet till over 12 feet fine sand. Sample collected 4.5 feet above sand-till contact.
17	Old Forge	NW-3.0" S-1.9" E	18-feet till sample collected near base.
18	Raquette Lake	SE-4.1" E-0.8" N	Till sample collected 3 feet above base of exposure.
20	Blue Mountain Lake	SE-8.1" N-3.2" E	8-foot till sample, 7 feet below top.
21	Blue Mountain Lake	SW-8.5" N-2.6" E	7 feet gravel over 5 feet till sample from near bottom of exposure.
25	Raquette Lake	NE-5.2" N-6.1" E	Weathered till on bedrock sample collected at bedrock contact.
26	Raquette Lake	SE-4.2" N-5.0" W	4 feet till over 2 feet sand. Sample 26 collected 5 inches above sand-till contact, and 27, 2.5 feet above contact.
32	Raquette Lake	SW-4.4" N-3.5" E	Twenty feet till sample, 10 feet below top.
35	West Canada Lakes	NW-0.95"-0.25" E	8 feet till sample collected 6 feet below top.

Site No.	Quadrangle	Location	Description
37.	West Canada Lakes	NW-1.3" E-0.3" S	6 feet till sample, 5 feet from top.
38	Raquette Lake	SE-9.3" N-2.2" W	10 feet till sample near base of exposure.
42	Raquette Lake	SW-8.5" N-5.5" E	Till collected from base of excavation 5 feet below surface.

HIGH PEAKS REGION

Site Number	Quadrangle	Location	Description
White Brook (Moraine 5)	see figure		
Blue Ridge Rd. (1 m. west of Elk Lake)	see figure	, site 264	
Blue Ridge Rd. (2 m. west of Elk Lake)	see figure	, site 266	
Whiteface elev. 4260'	Whiteface Mountain	NW-9.1" S-4.9" E	Five feet ablation till in road cut. Sample collected 3 feet from top.
Whiteface #2 elev. 3950'	Whiteface Mountain	NW-9.0" S-3.5" E	6 feet ablation till. Sample from base.
Whiteface #3 ele. 3168'	Whiteface Mountain	NW-7.2" S 5.3" E	30 feet lodgement till. Sample collected 15 feet from top.

SANTANONI QUADRANGLE, TAHAWUS, N. Y., McINTYRE DEVELOPMENT

T-1	see figure 76, upper till
T-2	see figure 76, 3a and figure 64, 178e
T-3	see figure 74, 2a
T-4	see figure 74, 2c and figure 64, 178b
T-5	see figure 73, 1b and figure 64, 178c

Site No.	Quadrangle	Location	Description
T-6	see figure 74, 2a and figure 64, [illegible]8d		
T-7	see figure 74, 2b and figure 64, 178a		
T-8	see figure 76, 3a		
74	see figure 14, pebble count on lower part moraine 5		
76	Whiteface Mountain	NW-10.3" S-6.65" E	10 feet sand over 15 feet till. Sample from lower 5 feet.
170	Whiteface Mountain	SE-4.2" N-1.8" W	Striation on bedrock 224° MN.
179	Whiteface Mountain	NE-10.05" S-3.75" W	15' till - sample from lower 5'.
188	Whiteface Mountain	NE-11.85" S-2.3" W	10' till - sample 5' below top.
202	Whiteface Mountain	SE-4.6" N-1.9" E	Striated bedrock 040° MN.
211	Ausable Forks	SW-2.2" N-4.8" E	12 feet sand and gravel over 5 feet till. Sample collected 4 feet below contact with overlying sand.
230	Marcy	NE-1.0" S-0.9" W	Mixed till and stratified sand sample a & b, collected 5 feet apart on poorly exposed surface.
233	Marcy	NE-0.9" S-0.2" W	5 feet sandy gravel overlain by 6 feet till and 7 feet sand and gravel. Sample a & b 2 feet below top of till, c & d 5 feet below top of till.
244	Ausable Forks	SW-.025" N-0.3' E	shown on figure 85
272	Schroon Lake	NW-2.1" S-7.75" E	8 feet gravel over 5 feet till. Sample 2 feet below contact.
273	Schroon Lake	NW-1.9" S-8.0" E	5 feet till over ice contact gravels. Sample 2 feet below top.

Site No.	Quadrangle	Location	Description
274	Schroon Lake	NW-0.9" S-7.8" E	5 feet gravel over 10 feet till, sample 3 feet below till gravel contact.
275	see figure 76, sample a		
280	Marcy	NE-4.0" S-3.0" W	10 feet till in road cut. Sample collected from base of section.
286	Marcy	NE-3.8" S-1.0" W	3 feet till exposed in ditch. Sample from bottom of ditch.
290	Whiteface Mountain	SE-2.6" N-1.9" W	6 feet till in natural cut. Sample 3 feet below top.

APPENDIX B

PEBBLE ANALYSIS - METHOD AND RESULTS

APPENDIX B LABORATORY METHODS - PEBBLE ANALYSIS

Pebbles were collected by marking off an area 12" by 12" digging out the till within the square and sieving this material through a 4 mm sieve. Pebble analysis was usually done on the 8-16 mm sized material, but in several cases pebbles from the 4-8 mm size were included because of an/insufficient number in the 8-16 mm range. All pebbles were broken to identify the minerals as an aid to distinguishing the different rock types.

The following rock types were identified:

1. Pink anorthosite--pink plagioclase phenocrysts in an aphanitic to phaneritic matrix; very few mafic minerals present.
2. Whiteface anorthosite--phaneritic plagioclase with hornblende, augite and garnet; appears yellow-brown on weathered surfaces and white on unweathered surfaces. When weathering has penetrated through the pebble, it will crumble when struck with a hammer.
3. Marcy anorthosite--phenocrysts of blue labradorite in an aphanitic to phaneritic matrix; locally high accumulation of mafic minerals may occur associated with the larger laboradorite phenocrysts. Pebbles have the same appearance on weathered surfaces and when broken. Many of the 4-8 mm pebbles are single crystals of labradorite.
4. Charnockite--composed mainly of quartz, potassium feldspar, sodic plagioclase, hypersthene and garnet; weathers yellow-brown, and on fresh surfaces the rock is olive-green. The

brown weathered surface and green interior combined with the presence of quartz is used to identify the charnockite pebbles.

5. Amphibolite--foliated hornblende and white plagioclase, commonly crumbles when being dug out of an exposure.
6. Gneiss--any crystalline rock that shows well-developed bands of different minerals.
7. Quartzite--foliated metamorphic rock composed of predominantly quartz and potassium feldspar.
8. Potsdam sandstone--a pure quartz sandstone and conglomerate. Some of the pebbles are yellow-brown and some are pure white. Many show cross-bedding and other sedimentary structures. The conglomerate pebbles consist of quartz grains up to 6 mm in diameter in a quartz sandstone matrix which varies in color from white to reddish brown. Sedimentary structures are common in the larger pebbles.

Table 21. Pebble Content of High Peak Tills

	White Brook									Johns Brook						Styles Brook		Railroad Gut Tahawus	Marcy Dam Road	Franklin Falls Road
Location Figure	14									40						6		6	6	6
Sample Number	61	62	74	293	294	295	296	297	298	78	79	86	87	93	94	204 a	204 b	267	102	55
Whiteface Anorthosite %	40	27	52	50	76	26	43	64	26	-	-	35	47	32	32	20	26	9	25	26
Marcy Anorthosite %	17	20	22	9	1	12	8	-	13	-	-	36	36	64	38	13	12	51	35	5
Pink Anorthosite %	-	4	-	22	10	39	31	2	23	-	-	-	-	-	-	-	-	-	-	4
Charnockite %	7	1	-	10	-	4	10	5	14	-	-	-	-	-	-	19	9	18	15	9
Amphibolite %	-	-	-	1	2	5	2	2	2	-	-	10	9	-	9	13	19	6	3	19
Metasedimentary %	5	2	13	3	-	5	2	2	5	-	-	18	8	-	4	10	16	6	12	9
Quartzite %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Sandstone %	31	47	13	6	10	10	5	25	17	-	-	1	1	4	23	27	18	9	11	30

APPENDIX C

QUANTITATIVE LIGHT MINERAL ANALYSIS
METHODS AND RESULTS

APPENDIX C

QUANTITATIVE LIGHT MINERAL ANALYSIS METHODS AND RESULTS

SLIDE PREPARATION

A 100-200 g. sample of till was soaked for 24 hours in a 5 percent solution of sodium hexametaphosphate to aid in the disaggregation of the sample. After soaking, the sample was stirred in a milkshake stirrer for 5 minutes. The sample was then wet-sieved through a [illegible]4 micron sieve and dried at 100° C. After drying, the sample was resieved through a sieve stack containing the 0.125 mm, 0.044 mm sieves and pan. The material caught on the 0.044 mm sieve was then transferred to a separatory funnel for heavy mineral separation. The material caught on the 0.125 mm sieve and the pan was discarded.

Heavy mineral separation was done in tetrabromoethane (sp. gr. 2.94). The heavy minerals obtained in this separation were washed in alcohol and placed in vials.

The light mineral fraction was washed in alcohol, dried and mounted in Shell 828 epoxy resin (R.I. 1.56) mounting medium. A thin section was cut from the block and ground to 0.03 mm thickness. The K-feldspar staining procedure of Laniz <u>et al</u>. (1964) was used.

The thin sections were left uncovered. The final step in preparing the slide for identification and counting of the minerals was placing a drop of refractive index oil (R.I. 1.544) on the slide and applying a cover slip. This oil gives quartz a low relief, plagioclase feldspar a high relief. The potassium feldspars were stained yellow. Over 300 grains were counted on each slide.

Table 22. Light Mineral Composition of Tills in the Raquette Lake Area.

Sample Number	Quartz	K-feldspar	Plagioclase
18-6	26.4%	50.5%	23.1%
5	47.2%	35.8%	17.0%
17	31.2%	33.2%	35.6%
20	20.8%	49.9%	29.3%
21	28.7%	38.8%	32.5%
25	27.6%	40.0%	32.4%
26	34.7%	39.4%	25.9%
27	23.1%	41.3%	35.6%
32	32.1%	36.5%	31.4%
35	33.6%	36.0%	30.4%
37	28.0%	35.3%	36.7%
38	31.8%	37.5%	30.7%
42	36.7%	35.5%	27.8%
Mean	30.9%	39.2%	29.9%
Standard Deviation	± 6.65	± 13.33	± 5.48

Table 23. Light mineral composition of tills in the High Peaks area.

Sample Number	Quartz	K-feldspar	Plagioclase
Whitebrook Valley	11.8%	25.4%	62.8%
Blue Ridge Road (1 mi. W Elk Lake)	1.2%	34.2%	64.6%
Blue Ridge Road (2 mi. W Elk Lake)	8.4%	9.6%	82.0%
Whiteface 4260	1.6%	14.3%	84.1%
Whiteface #2	5.4%	18.1%	76.5%
Whiteface #3	32.0%	22.6%	45.4%
T1	26.8%	23.2%	50.0%
T2	30.4%	20.6%	49.0%
T3	2.6%	26.6%	70.8%
T4	11.5%	26.4%	62.1%
T5	1.0%	15.2%	83.8%
T6	3.6%	25.6%	70.8%
T7	8.8%	26.7%	64.5%
T8	11.0%	20.0%	69.0%
60	8.9%	27.5%	63.6%
61	7.2%	7.5%	85.3%
62	34.4%	19.4%	46.2%
64	44.9%	31.3%	23.8%
65	13.7%	27.8%	58.5%
66	30.4%	29.8%	39.8%
76	17.5%	36.0%	46.5%
78	7.7%	23.6%	68.7%
93	7.4%	28.8%	63.8%
94	5.3%	39.2%	55.5%
101	19.6%	29.4%	51.0%
169	17.8%	27.7%	54.5%
172	12.1%	26.7%	61.2%
174	15.3%	39.8%	44.9%
177	6.5%	12.4%	81.1%
183	32.4%	28.0%	39.5%
188	31.1%	17.6%	51.3%
204-1a	43.2%	24.0%	32.8%
204-1b	38.0%	18.0%	44.0%
211a	27.3%	24.2%	48.5%
211b	37.9%	20.9%	41.2%
230a	35.5%	23.0%	41.5%
230b	34.8%	24.1%	41.1%
233a	27.8%	25.6%	36.6%
233b	25.5%	21.3%	53.2%
233c	43.1%	2[illegible].6%	33.3%
233d	26.1%	20.5%	53.4%
244-1	31.3%	27.5%	41.2%
244	17.6%	42.3%	40.1%
260-1	12.6%	19.7%	67.7%
260-2	13.7%	14.2%	72.1%
261-1	8.0%	22.2%	69.8%
261-2	12.5%	16.5%	71.0%
263	5.5%	12.5%	82.0%
267	13.2%	29.8%	57.0%
275	10.3%	22.7%	67.1%
275-2	10.2%	24.1%	65.7%
275-3	5.2%	20.6%	74.2%
280	8.4%	20.2%	75.5%
286	14.4%	22.2%	63.4%
290	17.2%	14.4%	68.4%
2571-2	23.9%	43.3%	32.8%
23571-1	15.5%	38.3%	56.2%
71466-1	18.0%	41.8%	40.2%
7571-1	12.1%	42.1%	57.4%
Mean Values	18.1%	24.6%	57.4%
Standard Deviation	± 12.33	± 8.05	± 15.32

APPENDIX D

TILL PEBBLE ORIENTATION - METHODS AND RESULTS

APPENDIX D

TILL PEBBLE ORIENTATION - METHOD AND RESULTS

PROCEDURE

The surface of the exposure was cleared of loose debris and a pit was dug approximately two feet across and eighteen inches into the sloping face. The bottom of this excavation was at least three feet below the base of the "A" zone of the soil profile. Field-work during the winter of 1965 indicated that surface freezing penetrates at least 10 inches into an exposed surface. Therefore, an attempt was made to gather all pebbles from the excavation at least 10 inches in from the surface. Even with this precaution, the randomness of some of the orientation diagrams may have been caused by reorientation of pebbles due to winter freezing and spring thawing.

Directional measurements were made with compass. Only pebbles with an elongation ratio of at least two were measured. The main difficulty in doing pebble orientation studies in Adirondack tills is the scarcity of elongate pebbles. For this reason, all of the analyses consist of between 50 and 100 pebbles. Pebble orientations were plotted in rose diagrams in figure 63.

HURRICANE LODGE SECTION (AUSABLE FORKS QUADRANGLE, figures 62 and 63, site 10)

The Hurricane Lodge exposure is located 2.7 miles east of Keene, N. Y. on the Hurricane Mountain Road where the road cuts across the head of the valley towards the Elizabethtown Highway. The exposure is the result of road construction. The cut at this point is 55 feet high at the south end and extends in the north-south direction for over 400 feet. The exposure is interrupted near the center by a small stream cutting through the section. The alignments of elongate pebbles were measured at ten feet above the contact of the till (figure 85) with the underlying sand and gravel in the southern portion of the exposure. These measurements are found in figure 63, site 10. The till in this exposure forms a vertical face making it impossible to do measurements higher up in the section.

The valley in which this till was found is oriented east-west (090°).

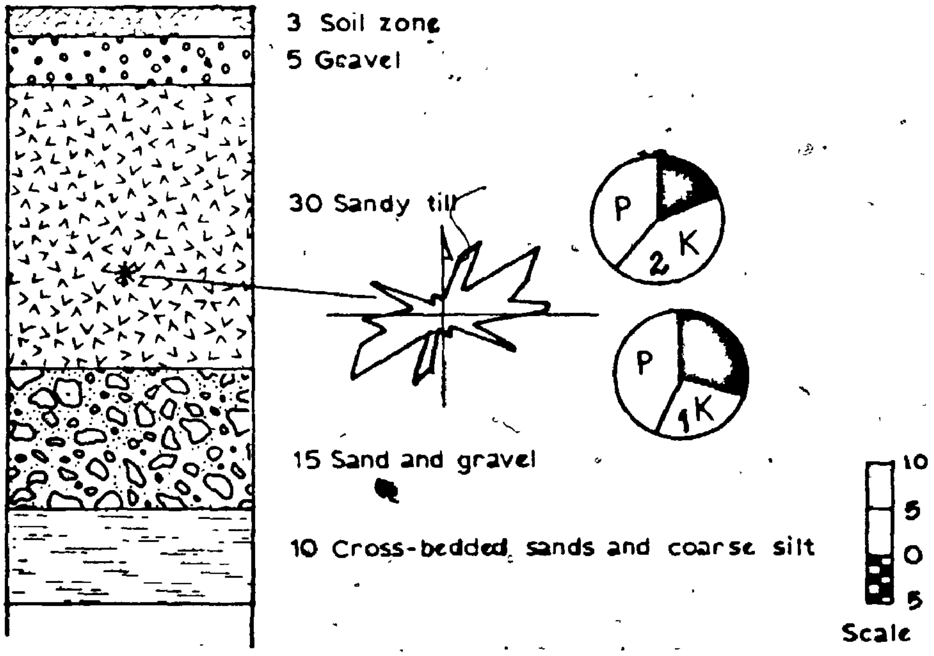


Figure 85. Stratigraphic section, Hurricane Mountain Road, site 244.

ADIRONDACK LOJ ROAD CUT (figure 62 and 63, site 14)

This section is exposed in the road cut starting approximately one mile north of the entrance to the Adirondack Loj parking area extending to the north bank of the East Branch Ausable River. The elongated pebble orientations were measured about 30 feet above the floor of a large gravel pit on the north side of the river. The deposit is located in approximately the middle of the large open valley locally known as South Meadow. There is no definable valley orientation.

This section is one of three areas in the High Peaks region in which an old till is exposed. Figure 86 is a topographic map and a compiled stratigraphic section of this exposure. Much of the surface is covered with vegetation and the areas between measurable sections are interpolated.

The elongate pebbles are strongly oriented in a north-south alignment (figure 63, site 14).

KEENE SAND AND GRAVEL PIT (figure 87, site 9; figure 6, region H)

The Keene Sand and Gravel Pit is located south of Keene on Route 9 N past the firehouse. The pit has been extensively worked. The deposit is mostly sand and gravel. Till caps the deposit on the north and south sides and is absent in the middle (figure 87). Elongate pebble orientations were measured on the vertical face of the north till exposure and are shown in figure 63, site 14. The deposit is located in the main valley oriented north-south and is at the mouth of a tributary valley oriented 090°.

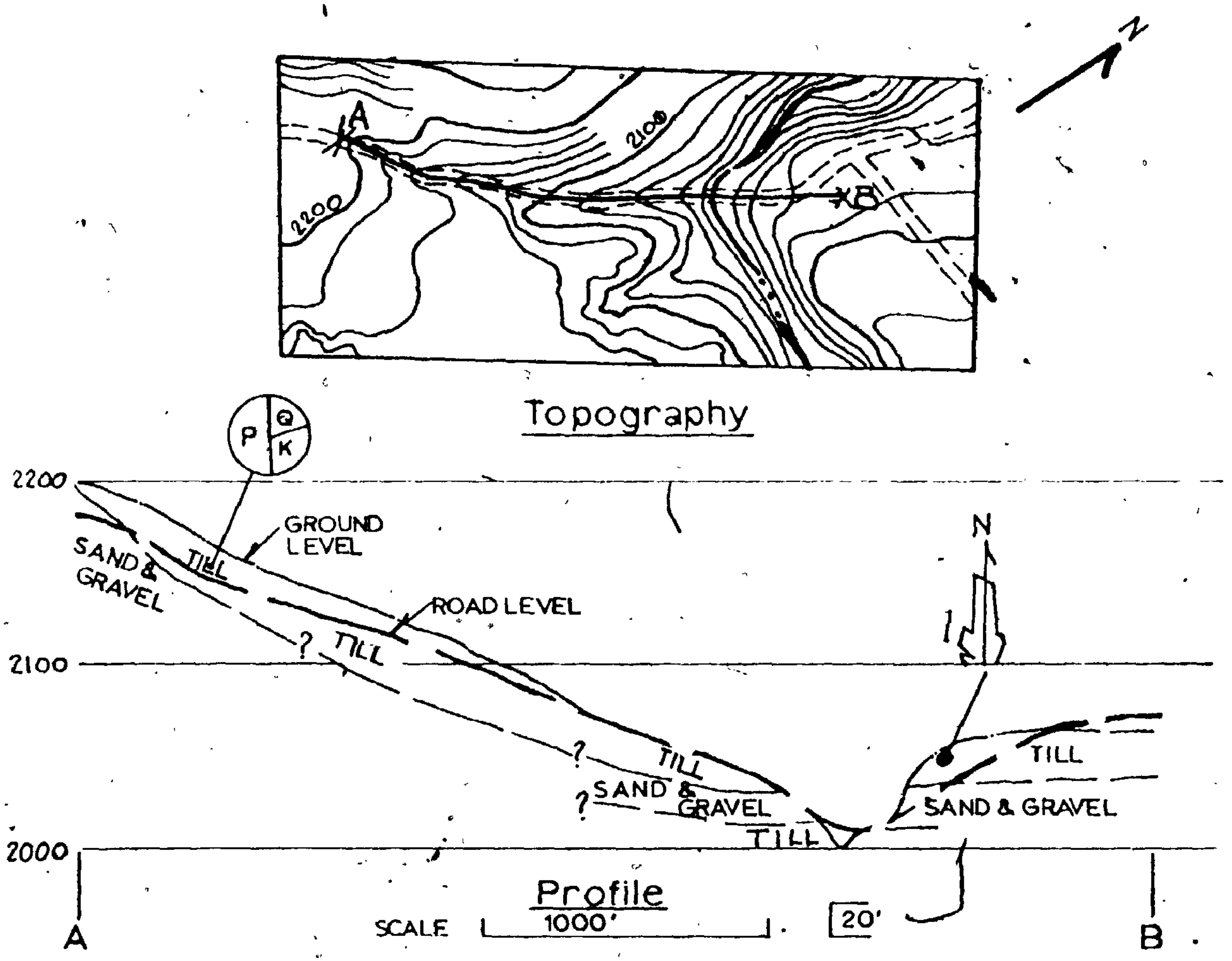


Figure 86. Topographic map and profile showing stratigraphic relationship of deposits exposed in road cuts and stream bank one mile northeast of Adirondack Loj, West Branch AuSable River, Mount Marcy Quadrangle.

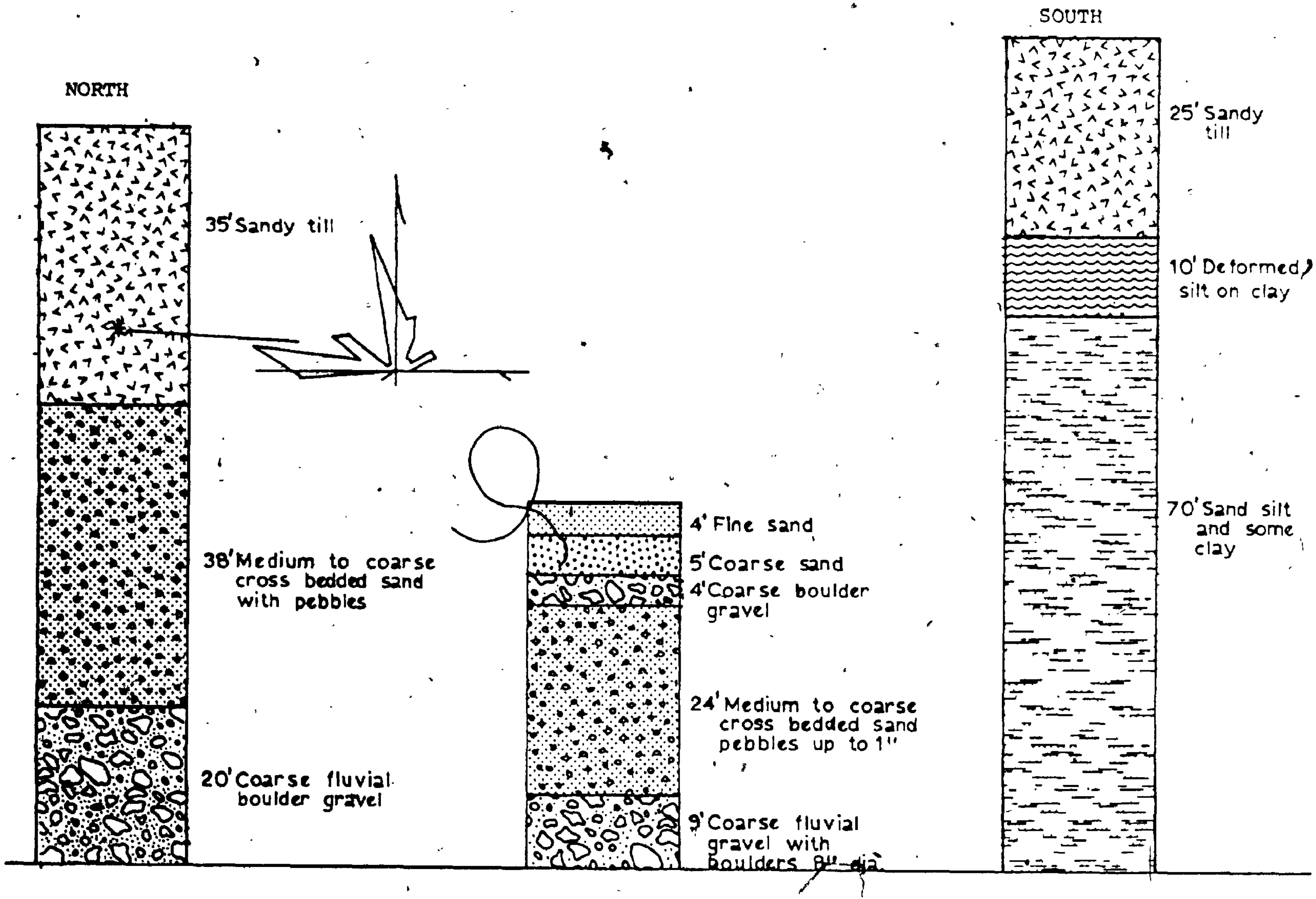


Figure 87. Stratigraphic sections Keene Sand and Gravel Co.

APPENDIX E

STRIATIONS ON BEDROCK

APPENDIX E STRIATIONS ON BEDROCK

AVALANCHE PASS

Avalanche Pass (figure 62, site 15) is located in the Mount Marcy Quadrangle between Lake Placid and Tahawus, N. Y. The pass is believed to occupy the position of a fault (Buddington, 1953). The highest point on the floor of the pass is 2883 feet ASL. This pass separates the two highest points in New York, Mount Marcy (5344 feet ASL) and Algonquin (5114 feet ASL) giving a total relief of 2461 feet in the pass.

The east wall of the pass above Avalanche Lake is striated and polished by glacial flow through the pass. The striae are located on a nearly vertical surface, and rise up the slope from north to south, an indication of a southward movement of ice through the pass.

JAY, N. Y.

Striae are located on the east side of the East Branch Ausable River 75 feet south of the covered bridge (figure 62, site 6). Bedrock is Marcy anorthosite with very large phenocrysts of labradorite present. The bedrock surface along the roadway has been highly polished and striated. Striae are oriented N 10° E.

INTERSTATE 87 BETWEEN JUNCTION WITH ROUTE 73 AND NORTH HUDSON

There are numerous striated bedrock surfaces recently exposed by highway construction along this route (figure 62, site 18). All striae measured were between N 27°-31° E and are best developed on the northward-sloping bedrock surfaces.

BETWEEN UPPER JAY AND KEENE

Striae were observed four miles south of Upper Jay on Route 73 (figure 62, site 7) approximately 200 yards north of the entrance to the Keene campgrounds on the east side of the road. A well developed, polished and striated surface has been cut onto a large exposure of amphibolite (figure 88). Striae are oriented N 33° E parallel to the valley axis.

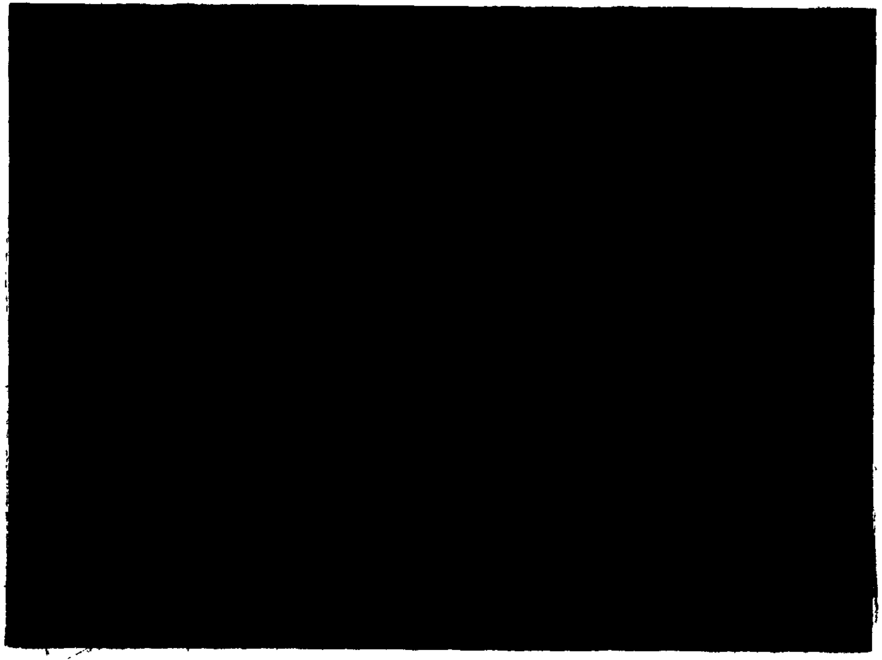


Figure 88. Striae on amphibolite mass between Upper Jay and Keene, Mount Marcy Quadrangle.

NEWCOMB VALLEY AT RICH LAKE

Newcomb Valley (figure 62, site 17) is an east-west valley system that extends from Long Lake to the Schroon River at North Hudson, N. Y., a distance of approximately 35 miles. Newcomb is located at about the halfway point. Striations were observed on the south side of Highway 28 at Rich Lake, on a nearly vertical face of metasedimentary rock (figure 89). The exposed bedrock face strikes N 90° E and dips 80° N. Direction of ice flow was west to east as established by the following observations:

1. Micro-faceted surfaces with an abrupt change of slope of the facet on the east end.
2. Striations rise on the bedrock face from west to east and maintain a west-east orientation where the bedrock surface becomes horizontal on the east end of the exposure.
3. Plucking on the west side of the joint fractures and striation on the east side of the fracture.

Figure 89. Striae on vertical face of bedrock cliff at Newcomb. Photo looking southeast.

REFERENCES

ALLING, H. L., 1916, Glacial lakes and other glacial features of the central Adirondacks: Geol. Soc. Am. Bull. 27, pp. 645-672.

_______, 1919, Pleistocene geology of the Lake Placid Quadrangle; N. Y. State Museum Bull. 211, 212, pp. 71-95.

_______, 1921, Glacial geology of the Mount Marcy Quadrangle: N. Y. State Museum Bull. 229, 230, pp. 62-84.

BALK, Robert, 1931, Structural geology of the Adirondack anorthosite: Mineralogische und Petrographisch Mitteilungen Bd. 41, pp. 308-434.

_______, 1932, Geology of the Newcomb Quadrangle: N. Y. State Museum Bull. 290, 106 pp.

BROUGHTON, J. B., FISHER, D. W., ISACHSEN, C. W., RICKARD, L. V., 1962, The geology of New York State: N. Y. State Museum & Science Service Map and Chart Ser. No. 5 (text).

BUDDINGTON, A. F., 1937, Geology of the Santa Clara Quadrangle: N. Y. State Museum Bull. 309.

_______, 1953, Geology of the Saranac Quadrangle: N. Y. State Museum Bull. 346.

_______, 1966, Adirondack anorthosite series in the George H. Hudson Symposium, Origin of Anorthosite: 1966 at Plattsburg, New York, pp. 3-5.

CALKIN, P. E., 1970, Strand lines and chronology of the glacial Great Lakes in northwestern New York: Ohio Jour. Sci., v. 70, pp. 78-96.

COATES, D. R. and KIRKLAND, J. T., 1974, Application of glacial models for large-scale terrain derangements; in Quaternary Environments: Proceedings of a Symposium; edited by Wahaney, W. C., Geographic Monographs, no. 5, York University, Atkinson College.

CONNALLY, G. Gordon and SIRKIN, Leslie A., 1969, Deglacial events in the Hudson-Champlain Valley and their possible equivalents in New England [abs.]: Geol. Soc. Am. Abstracts, Pt. 1, Northeast Section, p. 9.

_______, 1970a, Late glacial history of the upper Wallkill Valley, New York: Geol. Soc. Am. Bull. 81, pp. 3297-3306.

_______, 1970b, The Wisconsinan history of the Huron-Champlain Lobe [abs.]: Geol. Soc. Am., abstracts with programs (annual meeting), v. 2, no. 7, pp. 524-525.

_______, 1971, Luzerne readvance near Glens Falls, New York: Geol. Soc. Am. Bull., v. 82, no. 4., pp. 989-1008.

_______, 1973, Wisconsinan history of the Hudson-Champlain Lobe, in The Wisconsinan Stage; Black, R. F., Goldthwait, R. P., and Willman, H. B., eds.: Geol. Soc. Am. Memoir 136, pp. 47-70.

CRAFT, J. L., 1969, Evidence of Late Pleistocene local glaciation in the High Peaks region, Adirondack Mountains: Field trip guide for New York State Geological Association annual meeting, 1969, Plattsburg, N. Y.

_______, 1970, Late Pleistocene local glaciation and glacial climate in the High Peaks region, Adirondack Park, N. Y.: Am. Quaternary Association, first meeting, Bozeman, Montana, p. 23.

CROSBY, Percy, 1966, Field conference on anorthosite and associated rock of the Lake Placid region: George H. Hudson Symposium, Origin of Anorthosite, Plattsburg, N. Y., pp. 26-44.

CUSHING, H. P., 1899, Report on the boundary between the Potsdam and Precambrian rock north of the Adirondacks: N. Y. Museum 50th Annual Report, v. 2, pp. 5-8.

_______, 1905, Geology of the northern Adirondack region: N. Y. State Museum Bull. 95, pp. 292-294, 416-443.

_______, 1907, Geology of the Long Lake Quadrangle: N. Y. State Museum, Bull. 115, pp. 495-502.

DREIMANIS, A., 1967, Cary-Port Huron Interstade in eastern North America and its correlatives: Geol. Soc. Am. Special Paper 115, p. 259.

_______, 1969, Late Pleistocene lakes in the Ontario and Erie basins: Proc. 12th conf. Great Lakes Research, 1969, pp. 170-180. Internat. Assoc. Great Lakes Research.

DREIMANIS, A., and EVENSON E. B., 1976 (in press), Late glacial (14,000-10,000 years BP) history of the Great Lakes region and possible correlations: From IGCP Project 73/1/24 Quaternary glaciation in the Northern Hemisphere, Report no. 3, Prague, 1976.

DREIMANIS, A., and GOLDTHWAIT, R. P., 1973, Wisconsinan glaciation in the Huron, Erie, and Ontario Lobes, in The Wisconsinan Stage; Black, R. F., Goldthwait, R. P., and Willman, H. B., eds.: Geol. Soc. Am. Memoir 136, pp. 71-106.

DREIMANIS, A., and KARROW, P. F., 1972, Glacial geology of the Great Lakes-St. Lawrence Region, the classification of the Wisconsinan Stage, and its correlatives: Inter. Geol. Congr., 24th Session, Sect. 12, p. 5-15.

FAIRBRIDGE, Rhodes, W., 1970, World Paleoclimatology of the Quaternary:

Revue de Geographie Physique et de Geologie Dynamique (2), vo. XII, fasc. 2, pp. 97-104, Paris, 1970.

_______, 1972, Quaternary sedimentation in the Mediterranean region controlled by tectonics, paleoclimates and sea level: The Mediterranean Sea, edited by Daniel J. Stanley, Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pa.

FAIRCHILD, H. L., 1913, Pleistocene geology of New York State: Geol. Soc. Am. Bull. 24, pp. 133-162, also Science 37, pp. 237-249.

_______, 1917, Postglacial features of the upper Hudson Valley: N. Y. State Museum Bull. 195, 22 pp.

FALCONER, R., LANSING, L. and SYKES, R., 1964, Studies of weather phenomena to the lee of the eastern Great Lakes: Weatherwise, v. 17, pp. 256-302.

GADD, N. R., McDONALD, B. C., and SHILTS, W. W., 1972, Deglaciation of southern Quebec: Geol. Sur. Can. Paper 71-43, 19 p.

GARF, W. L., 1976, Cirques as glacier locations: Arctic and Alpine Research, v. 8, no. 1, pp. 79-90.

GOLDTHWAIT, J. W., 1913, Glacial cirques near Mount Washington: Am. Jour. Science, 4th Ser., v. 35, no. 205, pp. 1-19.

_______, 1916a, Evidence for and against the former existence of local glaciers in Vermont: Report of the Vermont State Geologist 1915-1916, pp. 42-73.

_______, 1916b, Glaciation in the White Mountains of New Hampshire: Geol. Soc. Am. Bull., v. 27, pp. 263-294.

GOLDTHWAIT, Richard P., 1970, Mountain glaciers of the Presidential Range in New Hampshire: Arctic Alp. Res., v. 2, no. 2, pp. 85-102.

HITCHCOCK, Charles H., 1898, The Hudson River lobe of the Laurentian ice sheet: Science v. 8, p. 467.

HOUGH, J. L., 1958, Geology of the Great Lakes: Urbana, Univ. Illinois Press, 313 pp.

_______, 1963, The prehistoric Great Lakes of North America: Am. Scientist, v. 51, pp. 84-109.

JIUSTO, J. E., HOLROYD, E. W., III, PAINE, D. A., and KAPLAN, M. L., 1970, Great Lake snowstorms, Part 1, cloud physics aspects; Part 2, synoptic and climatological aspects: for Environmental Science Service Adm., U. S. Dept. of Commerce, Boulder, CO, Grant No. E22-49-70.

JOHNSON, D. W., 1917, Date of local glaciation in the White, Adirondack, and Catskill Mountains: Geol. Soc. Am. Bull. 28, pp. 543-553; also abstract with discussion by J. W. Goldthwait in Geol. Soc. Am. Bull. 28, p. 136.

_______, 1933, Date of local glaciation in the White Mountains: Am. Jour. Sci. 5th Ser., v. 25, no. 149, pp. 399-405.

KARROW, P. F., 1969, Stratigraphic studies in the Toronto Pleistocene: Geol. Assoc. Can., Proc. 20, p. 4-16.

KARROW, P. F., CLARK, J. R., and TERASMAE, J., 1961, The age of Lake Iroquois and Lake Ontario: Jour. Geol., v. 69, p. 659-667.

KARROW, P. F., ANDERSON, T. W., CLARKE, A. H., DELORME, L. D. and SREENWASA, M. R., 1975, Stratigraphy, paleontology, and age of Lake Algonquin sediments in southwestern Ontario, Canada: Quaternary Research, v. 5, no. 1, pp. 49-87.

KEMP, J. F., 1894, Preliminary report on the geology of Essex County, N. Y.: N. Y. State Geologist Annual Report 13, pp. 431-472, with maps.

_______, 1898, The geology of the Lake Placid region: N. Y. State Museum Bull. 21, p. 21.

KEMP, J. F., 1906, The physiography of the Adirondacks: Pop. Sci. Monthly v. 68, pp. 195-210.

_______, 1910, Geology of the Elizabethtown and Port Henry Quadrangles, N. Y.: N. Y. State Museum Bull. 138, 173 pp.

_______, 1921, Geology of the Mount Marcy Quadrangle, Essex County, N. Y.: N. Y. State Museum Bull. 229-230, 86 pp.

KEMP, J. F., and ALLING H. L., 1925, Geology of the Ausable Quadrangle: N. Y. State Museum Bull. 21, 126 pp., esp. pp. 71-94.

KEMP, J. F., and NEWLAND, D. H., 1899, Preliminary report on the geology of Washington, Warren, and parts of Essex and Hamilton Counties, N. Y.: N. Y. State Geologist Annual Report 17, pp. 499-533.

KRUMBEIN, W. C, and PETTIJOHN, F. J., 1938, Manual of sedimentary petrography: Appleton-Century-Crofts, Inc. 549 pp.

LANIZ, R. V., STEVENS, R. E., and NORMAN, M. B., 1964, Staining of plagioclase feldspar and other minerals with F. D. and C. Red no. 2: U. S. Geol. Sur. Prof. Paper 501-B, pp. 152-153.

LANSING, Livingston, 1965, Air mass modification by Lake Ontario during the April-November period: Great Lakes Research Division, pub. no. 13, pp. 257-261, Univ. of Michigan.

LEWIS, C. F. M., 1969, Late Quaternary history of lake levels in the Huron and Erie basins: Proc. 12th conf., Great Lakes Research, 1969, pp. 250-270, Internat. Assoc. Great Lakes Res.

MacCLINTOCK, Paul, and APFEL, Earl T., 1944, Correlation of drifts of the Salamanca re-entrant, New York: Geol. Soc. Am. Bull.

v. 55, pp. 1143-1164.

MacCLINTOCK, Paul, and STEWART, David P., 1965, Pleistocene geology of the St. Lawrence Lowlands: N. Y. State Museum and Science Service Bull. 394, 152 pp.

MANLEY, Gordon, 1955, A climatological survey of the retreat of the Laurentide ice sheet: Am. Jour. Sci., v. 253, pp. 256-273.

MILLER, William J., 1910, Geology of the Port Leyden Quadrangle, Lewis County, N. Y.: N. Y. State Museum Bull. 135, 61 pp., esp. pp. 44-45.

_______, 1916, Geology of the Lake Pleasant Quadrangle, Hamilton County, N. Y.: N. Y. State Museum Bull. 182, 75 pp., esp. pp. 63-70.

_______, 1917, The Adirondack Mountains: N. Y. State Museum Bull. 193, 97 pp.

_______, 1919, Geology of the Schroon Lake Quadrangle: N. Y. State Museum Bull. 213, 214, 102 pp.

_______, 1921, Wilmington Notch: The Conservationist, Conservation Comm., N. Y., 4; pp. 99-101.

_______, 1925, Remarkable Adirondack glacial lake: Geol. Soc. Am. Bull. 36, pp. 513-520.

_______, 1926, Lyon Mountain Quadrangle: N. Y. State Museum Bull. 271, 101 pp., esp. pp. 68-74.

MORDOFF, R. A, 1925, The climate of New York State: Cornell Univ. Agr. Experiment Station, Bull. 444, p. 33.

MULLER, E. H., 1965a, Adirondack Mountains, INQUA Field Conference A., Guidebook, New England: N. Y. State Museum, INQUA VII Congress, 52 pp.

_______, 1965b, Quaternary geology of New York, in Wright, H. E., Jr. and Frey, D. B., eds., The Quaternary of the United States: Princeton, N. J., Princeton Univ. Press, pp. 99-112.

_______, 1969, Tahawus Y-1715; Radiocarbon, v. 11, no. 2, p. 569.

MULLER, R. L., 1960, Distribution of snow in New York: Masters Thesis, Syracuse Univ., Syracuse, N. Y.

OGILVIE, I. H., 1902a, Glacial phenomena in the Adirondacks and Champlain Valley: Jour. Geol. 10, pp. 397-412.

_______, 1902b, The geology of the Paradox Lake Quadrangle: N. Y. State Museum Bull. 96, pp. 461-506.

PEACE, R. L., Jr., and SYKES, R. B., Jr., 1966, Meso-scale study of a lake effect snowstorm: Monthly Weather Review, v. 94, pp. 495-507.

PREST, V. K., 1970, Quaternary geology of Canada in Douglas, R. J. W., ed., Geology and economic minerals of Canada: Geol. Survey Can. Econ. Geol. Rept. no. 1, pp. 677-764.

TAYLOR, F. B., 1897, Lake Adirondack: Am. Geol. 19, pp. 392-396.

TEMPLE, P. H., 1965, Some aspects of cirque distribution in the west central lake district. Northern England: Geografiska Annaler, v. 47A, pp. 185-193.

TERASMAE, J., 1960, A palynological study of the Pleistocene interglacial beds at Toronto, Ontario: Canada Geol. Sur. Bull. 121, 54 pp.

VAGNERS, V. J., 1969, Mineral distribution in tills in central and southern-Ontario: Ph.D. Thesis, Univ. of Western Ontario, London, Ontario, Canada, 277 pp.

VAN DIVER, Bradford, 1969, Adirondack meta-anorthosite; N. Y. State

Geological Guidebook, 41st annual meeting, field trip H.

WHITE, G. W., 1960, Classification of Wisconsinan glacial deposits in northeastern Ohio, U. S. Geol. Survey Bull. 1121-A.

WRIGHT, H. E., Jr., 1961, Late Pleistocene climate of Europe; a review: Geol. Soc. Am. Bull. v. 72, pp. 933-984.