PROVINCE OF NOVA SCOTIA

DEPARTMENT OF MINES

MEMOIR NO. 5

Pleistocene Geology of the Central Annapolis Valley Nova Scotia

BY

Charles F. Hickox Jr.

HALIFAX, NOVA SCOTIA
1962

HON. DONALD M. SMITH
Minister

J. P. NOWLAN, Ph.D.
Deputy Minister

PROVINCE OF NOVA SCOTIA

DEPARTMENT OF MINES

MEMOIR NO. 5

Pleistocene Geology of the Central Annapolis Valley Nova Scotia

BY

Charles F. Hickox Jr.

HALIFAX, NOVA SCOTIA
1962

HON. DONALD M. SMITH
Minister

J. P. NOWLAN, Ph.D.
Deputy Minister

CONTENTS

Introduction

PURPOSE OF INVESTIGATION

In 1896 L. W. Bailey (1898), a Nova Scotian geologist, noticed erratic boulders of granite lying on top of the basaltic sea cliffs that flank the Bay of Fundy. These boulders lie as much as 15 miles north of the nearest granite outcropping. From their distribution Bailey inferred that the erratics had been transported northward by glacier ice flowing radially outward from a center located along the axis of the Nova Scotian Peninsula.

Geologists who have worked in the area since Bailey's time have been divided in their opinion. Some have agreed with Bailey; some have felt that the granite erratics were of New Brunswick provenance that had been carried southward by continental ice; some believed that the erratics were of southern provenance but had been transported northward by agents other than glacier ice.

In an effort to solve this controversy, field work was undertaken in the summer of 1955.

The preliminary report of the investigation was submitted to Yale University in 1958 as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

ACKNOWLEDGMENTS

The author appreciates the material and financial aid furnished by the Nova Scotia Research Foundation, the advice and constructive criticism of Dr. R. F. Flint of Yale University, and the Laboratory facilities offered by the geological staff of Acadia University. Charles V. Guidotti, field assistant during the 1956 season, contributed notably to the successful completion of the field work. The field party worked out of Margaretsville throughout the field investigation. We wish to thank the inhabitants of this village for their fidelity, understanding and friendly co-operation.

LOCATION OF MAP AREA

The area selected for study lies about 70 miles west northwest from Halifax. It is bounded on the north by the Bay of Fundy and on the south by the Nova Scotian batholith. Furthermore it lies midway between the Minas Basin and the Annapolis Basin — the submerged extremities of the Annapolis Valley, Nova Scotia. The area, therefore, is here referred to as the Central Annapolis Valley. It covers approximately 275 square miles (fig. 1).

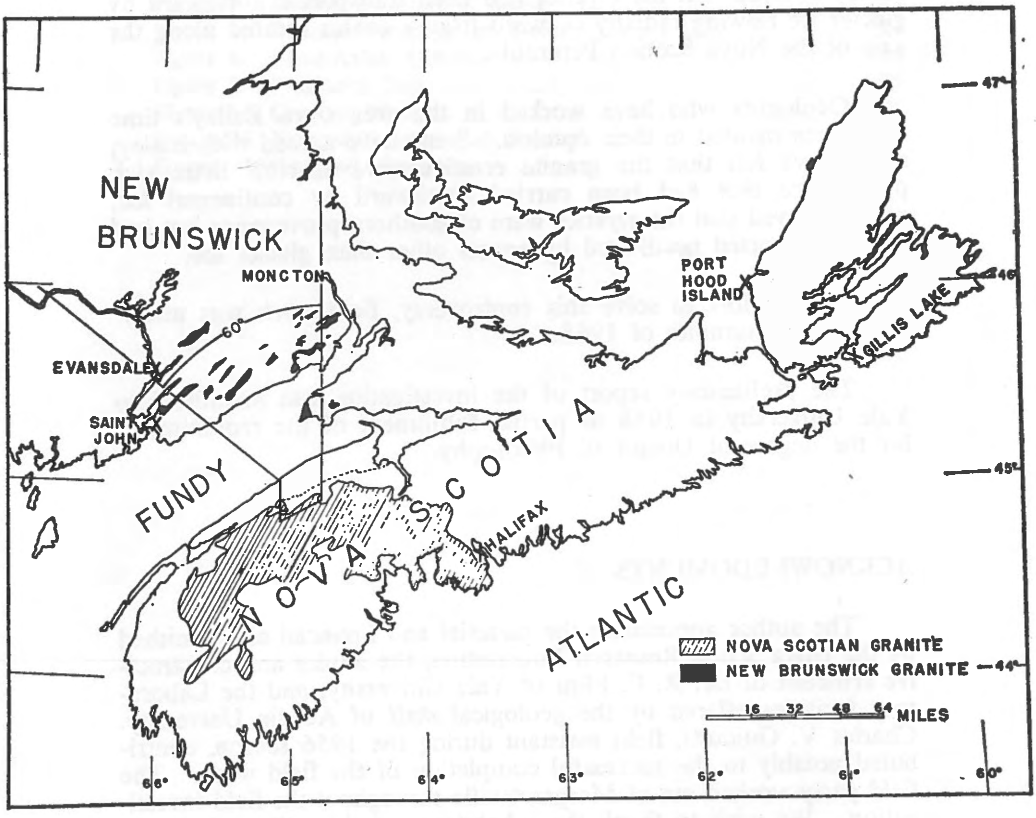

Figure 1. — Index Map Showing Location of Map Area and Radius of Sampling of New Brunswick Granites.

Bedrock Geology and Topographic Subdivisions

Some understanding of the bedrock geology of the Central Annapolis Valley is necessary in interpreting the sequence of glacial events; particularly so when glacial sequence has been worked out from studies of provenance and distribution of erratics and indicator stones.

Within the past 10 years several investigators have done bedrock mapping in the Central Annapolis Valley. The author made a preliminary map of the bedrock geology of the entire area (Hickox, 1958); G. deV. Klein (1959a; 1959b) did detailed work on the Triassic formations; and W. G. Smitheringale (1961) worked out the stratigraphic and structural problems of the Paleozoic sediments that underlie the south-eastern flank of the Annapolis Valley.

The area is divided into three structurally controlled, topographic subdivisions all of which trend east-northeast parallel to the Bay of Fundy and to the axis of the Nova Scotian peninsula. The relief of the area results from differential erosion of these three lithologic units (fig. 2).

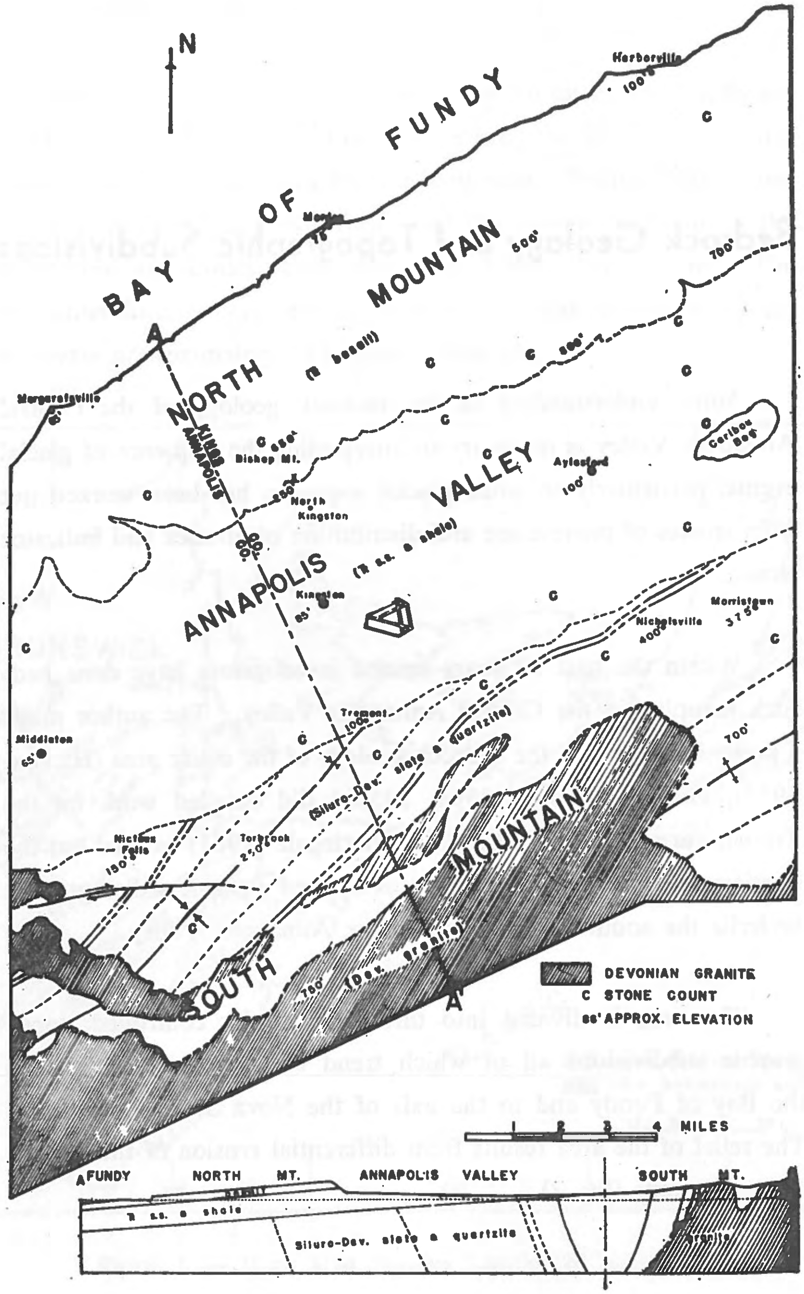

Figure 2.—Structural Geology and Topographic Subdivisions of the Central Annapolis Valley.

North Mountain:

This upland, approximately 175 miles long, forms the Nova Scotian shore of the Bay of Fundy; it extends from Brier Island on the southwest to Cape Split on the northeast. North Mountain, 3.5 to 5 miles wide, is capped by a series of Triassic lava flows having a total thickness of 550 feet. These flows dip northwestward at 4° to 10° into the Bay of Fundy. Thus North Mountain is a cuesta, the southeast face of which forms a prominent escarpment along the flank of the Annapolis Valley. The crestline of the escarpment ranges between 750 and 850 feet above sealevel. The till-covered, gently sloping surface of the upland has low relief, but because of the high boulder concentration and thin soil, agriculture is impractical. North Mountain, therefore, is sparsely populated and second growth forests cover most of the area.

The North Mountain lava flows are basaltic; some flows are massive; about two-thirds of the flows, however, contain zeolitic amygdules.

Annapolis Valley:

The Annapolis Valley forms the southeastern, inland flank of North Mountain. It is a subsequent valley eroded into Triassic shale and friable sandstone. These strata, lying conformably beneath the lava flows of North Mountain, also dip gently northwestward. Within the map area the Valley is about five miles wide, the central trough of which reaches maximum elevation of 125 feet above mean sea level at Caribou Bog. From this marshy divide the Annapolis River, 43 miles long, flows westward to the Annapolis Basin, and the Cornwallis River, 19 miles long, flows eastward to the Minas Basin. The two rivers, therefore, have gradients of 3 ft./mile and 6.5 ft./mile respectively. The Annapolis Valley, mantled in large part by stratified glacial drift, is agricultural land and therefore heavily populated relative to the adjacent uplands.

South Mountain:

This southern upland has a granite core, a batholith 125 miles long and up to 50 miles wide, which forms the axis of the Nova Scotian peninsula. Within the map area the northwest flank of this southern highland is underlain by tightly folded Paleozoic sediments into which the granite intruded in late Devonian time. The contact between the granite and the Paleozoic sediments is locally discordant, but the general trend is NE-SW parallel to the Annapolis Valley, to the axis of North Mountain, and to the shore of the Bay of Fundy. Along the base of South Mountain the Paleozoic formations pass under the Triassic sediments of the Annapolis Valley with angular unconformity.

The crestline of South Mountain, included within the southern boundary of the map area, is about 800 feet above sealevel. From the crestline the undulating, till-covered surface, dotted with shallow glacial lakes, slopes gently southeastward toward the Atlantic Ocean, 55 miles away. The northwest flank of South Mountain, underlain by the Paleozoic sediments, is arable and hence populated. The till-covered upland, however, with thin soil and heavy concentrations of granite boulders, is covered with uninhabited, second-growth forest.

Glacial Chronology

CONTINENTAL ICE SHEET

Nova Scotia was overridden by continental ice at least twice during the Pleistocene Epoch (Wilson, 1952). In the Central Annapolis Valley, however, no evidence has been found to support multiple continental glaciation, probably because deposits, left by earlier advances, were plowed up and incorporated in the overriding ice of later advances.

The last continental ice advanced across the Central Annapolis Valley from slightly west of north. This direction is established on: (1) orientation of striations, (2) orientation of stoss-and-lee topography, (3) till fabric analysis, (4) distribution of indicator stones.

Two consistent sets of crossed striations occur on the Paleozoic rocks exposed on the southeast flank of the Valley. The older set, determined by cross-cutting relations, trends between N 65/W and N 80 W. The younger set trends between N 20 W and N 35 W (plate I). Within the map area no striations have been found on the vesicular and amygdaloidal basalt of North Mountain, probably because they have been destroyed by weathering. Outside the area, however, crossed striations with angular relations similar to those on the Paleozoic rocks, have been found on the basalt (Goldthwait, 1924, p. 64). The consistent trends of the two sets suggest that the striations resulted from two separate glacial advances, rather than from local variations in direction of flow within a single advance. It is suggested that the older set was cut by the last advance of continental ice and that the younger set was cut by the later, local advance which flowed radially outward from a center located on the axis of the Nova Scotian Peninsula.

Stross-and-lee topography results from glacial quarrying and abrasion of jointed bedrock surfaces. Advancing ice abrades the upstream (stoss) side of a pre-existing bedrock boss and quarries the downstream (lee) side along joints. Thus streamline hillocks are formed with a step, quarried lee slope and a gentle, abraded stoss slope. Stoss-and-lee topography has been developed on the granite upland of South Mountain and on the metamorphic rocks along Jones Brook, in the southwest corner of the map area. The trend of the long axes of the streamline hillocks varies between N 25W and N 40 W, similar to the trend of the older striations. The steep lee slopes are invariably located at the southeastern ends of the hillocks. Therefore, the continental ice must have advanced from about N 30 W.

Erratics of the amygdaloidal North Mountain basalt are quickly recognized and, therefore, make ideal indicators (erratics of known provenance). Erratics of amygdaloidal basalt are found in high concentration on the floor of the Annapolis Valley. Both size and frequency of these indicators, however, decrease toward the southeast (table 1), but they do occur along the Atlantic shore from Cape Sable Island to Dartmouth (Goldthwait, 1924, insert map). Thus the distribution of indicators shows that the continental ice sheet advanced out of the northwest quadrant, overrode the Nova Scotian Peninsula, and terminated off the Atlantic shore.

A till fabric analysis was made in a road-cut 2 miles west of Margaretsville and 0.2 miles from the shore of the Bay of Fundy. The location was chosen because the till is thick and was probably deposited as lodgment till as the continental ice overrode North Mountain. The method of analysis, developed by Holmes (1941), consists of recording the attitudes of elongate stones included within the till. The rose diagram below (fig. 3), compiled from the statistical results of the analysis, shows a concentration of long axes of stones about S 20 E. The inference, therefore, is that the ice which deposited the till flowed across the area from N 20 W.

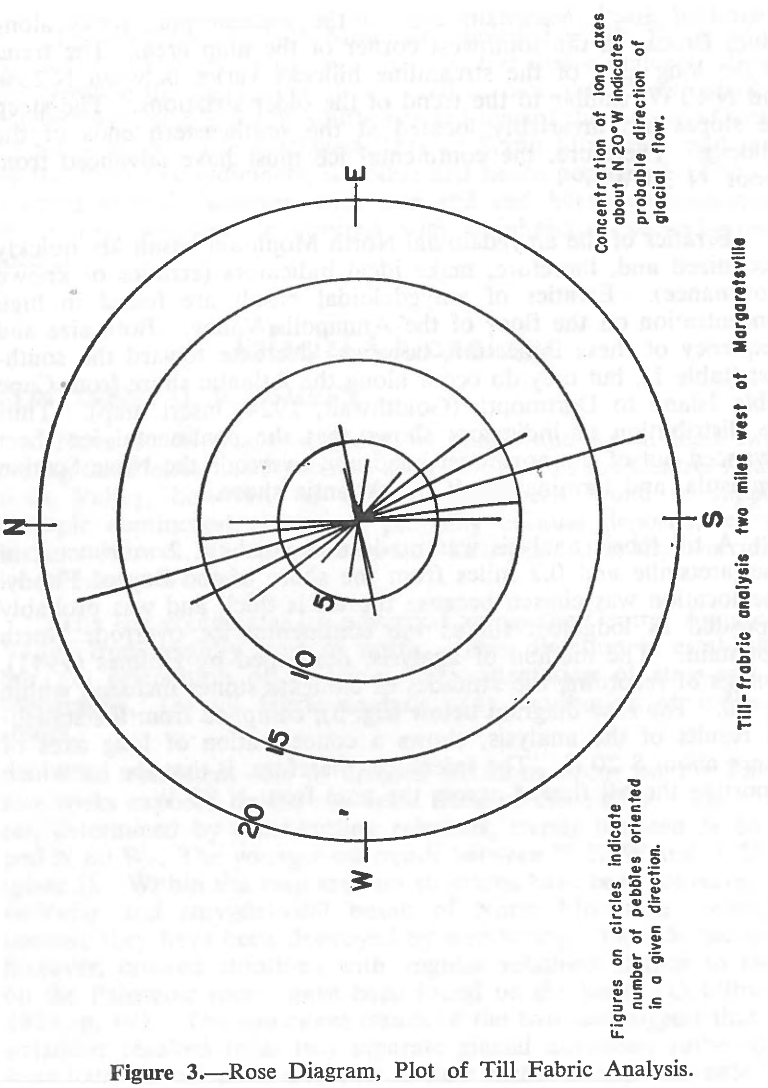

Figure 3.—Rose Diagram, Plot of Till Fabric Analysis.

The four independent lines of evidence, discussed above, all lead to the conclusion that the last continental ice advanced across the map area from N 20 - 40 W.

The age of this most recent advance of Laurentide ice across northern New England and the Maritime Provinces has been approximately dated by several investigators, using pollen analysis with supporting radiocarbon dating. Deevel (1951), in northern Maine, and Livingstone and Livingstone (1957) on Cape Breton Island, both found that the lake sediments with which they were working dated back to the warm Two Creeks interval (12,200 - 11,400 years B. P.). It is inferred that the drift, underlying the lake sediments, was deposited by an ice advance immediately preceeding Two Creeks time. The advance, therefore, was certainly of the Wisconsin Stage and was probably contemporaneous with the Port Huron sub-Stage of central North America (13,600 - 12,200 years B. P.).

RADICAL OUTFLOW FROM A LOCAL CENTER

As early as 1893 J. W. Dawson (1893, p. 169) noticed erratic boulders of granite on top of North Mountain. Dawson believed that these boulders, which lie as much as 15 miles north of the Nova Scotian batholith, and separated from it by the Annapolis Valley, had been transported northward by glacier ice. Three years later L. W. Bailey (1896, p. 26M) recognized that the erratics were megascopically similar to the granites of South Mountain and inferred that they had been moved into position, following the last continental glaciation, by ice moving radially outward from a center located somewhere along the axis of the Nova Scotian peninsula. Later Prest (1896, p. 108), Faribault (1920, p. 8E), and Walker and Parsons (1923, p. 7) came to much the same conclusions. Goldthwait (1924, p. 81-85) opposed the idea of radial outflow from a local center. He argued that the granite erratics on North Mountain were of New Brunswick provenance that had been carried southward by overriding continental ice.

In order to prove or disprove the theory of radial outflow, two steps seemed indicated: (1) to establish the provenance of the granite erratics and, if they proved of southern origin, (2) to establish the agent of transport.

Provenance of Granite Erratics:

It has been shown, above, that the last continental ice advanced across Nova Scotia from slightly west of north. Even allowing for major deviations in direction of flow the zone of transport of the continental ice must have lain somewhere between N 0° W and N 60° W from the Central Annapolis Valley. Two reconnaissance trips were made into New Brunswick to sample all known bodies of granite within this 60° arc and within a radius of 120 miles from the map area (fig. 1). The New Brunswick samples were then compared megascopically and microscopically with samples collected from the northwestern flank of the Nova Scotian batholith.

Except for one small body of the fine-grained, biotite granite, exposed at Evansdale, all New Brunswick granites within the zone of transport are meta-igneous, nonporphyritic, and biotite-free.

Furthermore, amphiboles and pyroxenes, comprising 5-20% of the volume, are almost entirely altered to chlorite.

The granite along the northwestern flank of the Nova Scotian batholith, on the other hand, is porphyritic with phenocrysts of feldspar up to 28mm. long; biotite constitutes 5 - 20% of the volume; and the rock contains neither amphiboles nor pyroxenes. Thus, the Nova Scotian granite can be distinguished from New Brunswick granites by its porphyritic texture, by its biotite content, and by its lack of chloritized amphiboles and pyroxenes. Erratics in the Annapolis Valley and on North Mountain are both types of granite. The larger boulders, however, are of Nova Scotian origin and must, therefore, have been transported northward.

In order to establish the distribution of erratics, stone counts were made on 19 stations across the map area (fig. 2). These counts were made on stone piles, placed along the margins of most fields by generations of farmers during spring clearing. The piles contain particles ranging from large pebbles to boulders 8 feet in diameter.

To avoid subjective sampling a wooden frame three feet square was placed on the stone pile and 250 cobbles and pebbles within the frame were counted and described. To establish the validity of the method, stone counts were made on two exposures of till. The statistical results of the till counts compare closely with counts made on stone piles in adjacent fields; thus the size-range and lithologic distribution within a single pile is fairly representative sampling of an area the size of the field, and to a depth reached by the plowshare.

In addition to the counts on pebbles and cobbles, 50 boulders were also counted and described at each of the 19 stations. This two-fold counting — of boulders and of smaller stones — was made to determine variations in size as well as variations in frequency of the lithologic types.

In the initial counts each lithologic type was recorded. However, only the basaltic stones of North Mountain provenance and the granitic stones, most of which are of South Mountain provenance, are here considered as indicators of directions of ice movement. Thus, the ratio of granitic to bsaltic stones is the significant factor.

TABLE I

Stone Counts — Ratio of Granite to Basalt

(50 boulders and 250 similar stones were counted at each of 19 stations)

SE ↓ NW	Pebbles & Cobbles gr/bas	Boulders gr/bas
Paleozoic slope of S. Mt. (Avg. of three counts)	7/4	5/1
South Flank of Valley (Avg. of five counts)	2/15	13/8
Center of Valley (Avg. of four counts)	1/22	1/6
North Flank of Valley (Avg. of four counts)	1/15	1/1000
N. Mt. Upland (Avg. of five counts)	1/60	1/1000

These counts indicate that both size and frequency of the granite erratics decrease northward. Granite cobbles and pebbles occur across the entire map area and in sufficient numbers to make statistical counting practical. Granite boulders of southern origin also occur across the entire map area; on the North Mountain upland, however, their frequency is so low that they can not be treated statistically.

The northward decrease in size and frequency of the granite erratics suggest strongly that their source area lies to the south.

Agent of Transport:

The granite erratics may have been transported northward by any one of three possible agents: (1) mass-wasting, (2) ice-rafting or (3) glacier ice.

Granite erratics lying north of the batholith could have been emplaced by mass-wasting only if they lie downhill from the outcrop area. All erratics on the northwestern slope of South Mountain and on the floor of the Annapolis Valley could have been thus emplaced; but those on the upland surface of North Mountain, separated from the outcrop area by the Valley, five miles wide and 700 feet deep, could not.

Estuarine clays in the Annapolis Valley and raised beaches along the Bay of Fundy indicate a late-glacial or post-glacial stand of sealevel of 65 feet. No evidence of greater inundation has been found. Thus those erratics at elevations of greater than 65 feet, particularly those lying near the 800 foot crestline of North Mountain, could not have been rafted into position.

By process of elimination glacier ice remains the only possible mode of transport for the erratic boulders.

Till, containing granite erratics from the South Mountain batholith, presents more positive evidence of glacial transport. On the northwestern slope of South Mountain, north of the batholith, granite erratics occur in high concentration both surficially and incorporated in till (fig. 4). On the floor of the Annapolis Valley, 1.5 to 6 miles north of the batholith, the till contains granite boulders to depth of at least five feet. The most significant exposure, however, is located on the north flank of Annapolis Valley where a till-filled obsequent stream valley is now being re-excavated. This exposure, located mid-way between North Kingston and Bishop Mountain, is 250 feet above sealevel; it lies 6.5 miles north of the nearest outcropping of granite and is separated from the outcropping by the Annapolis Valley (fig. 5). Here till contains small boulders of granite unquestionably of South Mountain provenance; therefore the ice that deposited the till must have flowed from south to north.

Surficial boulders of South Mountain granite are distributed sparsely, across the upland surface of North Mountain and along the shore of the Bay of Fundy, indicating that the ice advanced from the south at least 15 miles to the present shoreline.

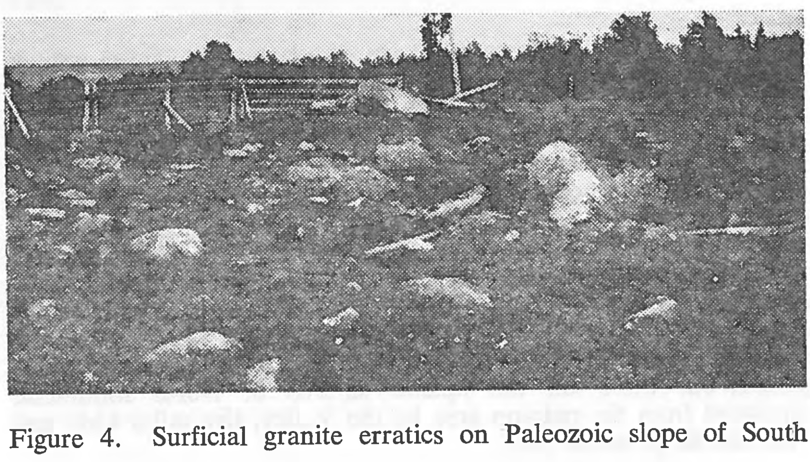

Figure 4. Surficial granite erratics on Paleozoic slope of South Mountain, 1.2 miles north of nearest exposure.

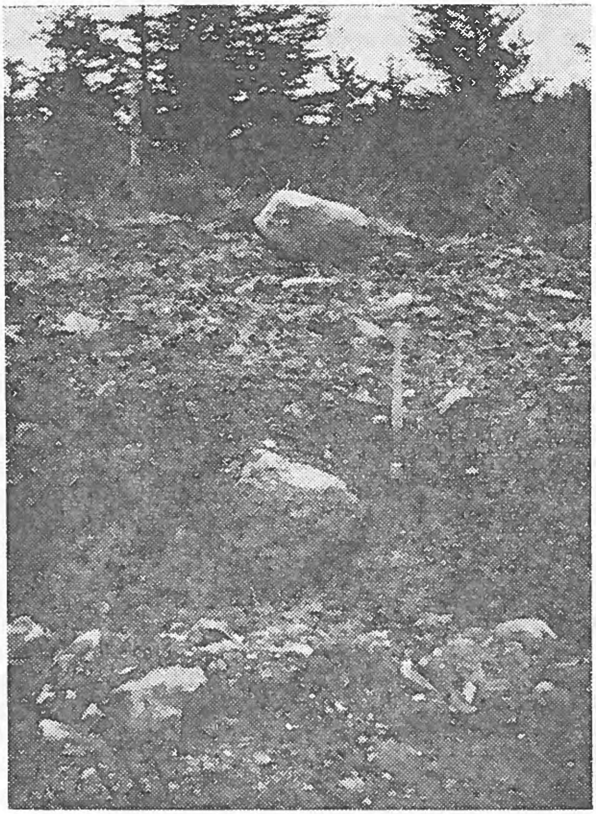

Figure 5. Erratic boulders of South Mountain granite in till, at 250-foot contour of Bishop Mountain, and 7.5 miles north of nearest exposure of granite.

Reconstructon of Local Movement and Late-Glacial Sequency:

The surficial position of so many of the granite erratics indicates that the flow of ice which transported them northward postdated the last continental advance across the area. Apparently the local ice, centered along the axis of the peninsula, thickened sufficiently to flow radially outward. It flowed northward to fill the Annapolis Valley, reworking the older till as it went, and incorporating granite boulders quarried from the batholith. After filling the Valley, the ice overrode North Mountain as a thin sheet with little basal till to deposit. The passage of ice across North Mountain is indicated by scattered surficial boulders of South Mountain granite, probably deposited during ablation, and by a small kame field on the shore of the Bay of Fundy two miles west of the village of Margaretsville.

Thus the relative age of the local advance is established by stratigraphy; it was the last advance of glacier ice across the Central Annapolis Valley.

The absolute date of the local advance, however, is uncertain. Livingstone and Livingstone (1958) suggest that the last continental ice to override Nova Scotia was of Wisconsin age probably immediately preceeding the Two Creeks interval (ca. 11,300 years B. P.). Their evidence, based on pollen analyses with substantiating radiocarbon dates, comes from Gillis Lake, Richmond County, which lies about 210 miles east of the Central Annapolis Valley.

Peat, recently collected by the author from between two tills on Port Hood Island — 190 miles east of the map area — has been dated at 10,250 — 240 years B.P. (Y-762; R. F. Flint, personal communication). This date is puzzling because the peat, presumably representing a period of deglaciation, is approximately time-equivalent with the Valders maximum in the Great Lakes region. However, the till, overlying the dated peat, must indicate glacial activity in Nova Scotia more recent than the Two Creeks interval.

The older till on Port Hood Island was presumably deposited by the last advance of continental ice, preceeding the Two Creeks interval. The younger till may, therefore, have been deposited by ice advancing from a center located, perhaps, on the Cape Breton Highlands. The Cape Breton outflow, if it existed, was probably contemporaneous with the local advance across the Central Annapolis Valley. The two bodies of ice, however, did not coalesce, their terminii were at least 150 miles apart.

Similar conclusions are inferred from Ogden's (1960) pollen profile of Caribou Bog; a raised bog, developed on outwash, near the eastern margin of the map area. Ogden, correlating his profile with Livingstone's profile from Gillis Lake, found that the lowest zones, representing Two Creeks, and Valders equivalents are absent from the Caribou core. If it is assumed that the Caribou core penetrated the oldest sediments of the bog, and that the bog began forming immediately following deglaciation, then the oldest pollen zone in the Central Annapolis Valley must post-date Valders time. Thus, the local glaciation may have ben contemporaneous with the Valders sub-stage in central North America.

These uncertain correlations suggest that: (1) the last continental ice to override the Central Annapolis Valley was probably contemporaneous with the Port Huron advance (13,600 - 12,200 years B.P.) and (2) the radial outflow, northward across the Central Annapolis Valley probably post-dated the Two Creeks interval, and may have been contemporaneous with the Valders advance in central North America (11,000 - 10,500 years B.P.).

Pleistocene Sediments and Drainage Patterns

With the exception of modern alluvium along the Annapolis River system, the entire map area is mantled by glacial and proglacial sediments. Most of this drift was deposited by the last ice which flowed radially outward from the local center. The only drift, known to have been deposited by continental ice, are the thick till deposits along the shore of the Bay of Fundy. Elsewhere the older drift was plowed up and incorporated in the ice of the radial outflow, or was buried under younger sediments deposited by the outflow. The distribution of the several types of drift is shown on the insert map (plate I).

TILL

Lodgement Till:

Lodgment till is the surficial deposit on the upland surface of South Mountain and on both flanks of the Annapolis Valley. On the floor of the Valley till "islands" protrude through the overlying cover of stratified drift, indicating that a continuous till sheet extends from North Mountain southward, beyond the southern limit of the map.

Lodgment till, deposited by accretion of drift from the sole of an overriding glacier, is characteristically unsorted and unstratified. The lithology of the included boulders and cobbles and the grain size of the matrix materials reflect the character of the underlying bedrock from which most of the drift was derived. Within the map area, therefore, the till ranges from boulder-rich over the igneous bedrock of South Mountain, to clay-rich over the shale of the Annapolis Valley. p

Ablation Till:

The bedrock surface of North Mountain and the lodgment till of South Mountain and the Annapolis Valley are thinly veneered by surficial cobbles and boulders. These stones were probably deposited as ablation till during melting and final retreat of the local glacier (fig. 4). As mentioned above, the discovery of erratic boulders of South Mountain granite in the ablation till of North Mountain lead geologists to the concept of ice flowing radially outward from a center located south of the map area.

ICE-CONTACT STRATIFIED DRIFT

This term includes all bodies of sediment deposited by glacial meltwater, in contact with stagnant blocks of ice. It includes: (1) crevasse filling (kames), (2) deposits of glacier-margin streams (kame terraces), (3) deposits of streams flowing on, or within glacier ice (eskers), (4) deposits built in standing water on, or against glacier ice ice-contact deltas and lacustrine deposits). The relative position or orientation of each of these features are used to determine the direction of flow of late-glacial drainage systems.

The hills or ridges of i.-c.s.d. that remain today must have been deposited during ablation of the last glaciation, otherwise they would have been destroyed by overriding ice. The concentration of i.-c.s.d. in the Annapolis Valley indicates that the ice stagnated longer here than on the surface of the two uplands. It lingered in the lowland for three reasons: (1) in order to override North Mountain the ice first had to fill the Valley; hence it was 700 feet thicker here than on the adjacent highlands; (2) the flanks of the Valley partially protected the ice from the direct rays of the sun; (3) meltwater from the adjacent uplands flowed into the Valley, depositing a thick, insulating mantle of sediments about the stagnant blocks.

The insert map (plate I) shows that the i.-c.s.d. is concentrated along the flanks of the Annapolis Valley, and that the central portion of the Valley is mantled by overlapping outwash. Four types of i.-c.s.d. occur within the map area.

Kame Terrace:

A low kame terrace extends for 7.5 miles along the south flank of the Valley, from Millville to Tremont. This terrace slopes southwestward at about 7 feet per mile, a gradient similar to that of the modern Annapolis River. The terrace sediments were deposited by meltwater flowing between the bedrock flank of South Mountain and the mass of ice lying stagnant in the Valley.

A channel, along the axis of the terrace, marks the position of the glacier-margin stream that first aggraded, and later channelled the terrace. Channeling resulted when the ice, down-valley, had melted sufficiently to lower the base-level of the stream. Along the south flank of the Annapolis Valley, therefore, the late glacial drainage pattern was similar in direction and gradient to the modern pattern.

Kames:

Within the map area three major kame fields mark former positions of large masses of stagnant ice. The western kame field is centered about Nictaux Falls; the eastern kame field is located in the Valley along the eastern margin of the map; the northern kame field extends along the shore of the Bay of Fundy from McNeily to Port George. In addition to the three major areas there are several smaller ones, which developed in protected cross-axial valleys of North Mountain. A small but significant kame field is located in the west central portion of the area, 1 mile north of Wilmot Station.

Internally the kames are cross-bedded, having chaotic cut-and-fill stratification. Individual lenses are well-sorted, ranging in grain size from medium sand to cobble gravel. Grain size, however, changes abruptly from lens to lens, a result of abrupt change in velocity and discharge of the depositing meltwater. Characteristically the stratification, along the steep flanks of the kames, dips radially outward subparallel to the surface. The steep marginal dips developed when the retaining walls of stagnant ice finally melted and the crevasse-filling slumped into the voids formerly occupied by ice. (fig. 6).

Kames probably covered the floor of the Annapolis Valley in late-glacial time, but were later buried under the overlapping outwash or were destroyed by erosion of proglacial streams.

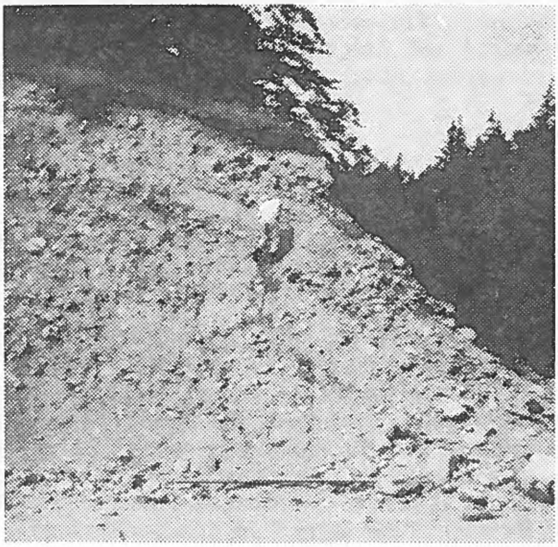

Figure 6. Internal structure of kame, near McNeily, showing well-sorted beds, wide range of grain size between beds, and marginal slumping sub-parallel to surface.

Eskers:

Eskers, located in the valleys of Fales River and the east branch of the South Annapolis, are oriented with their long axes parallel to the modern streams. The relations suggest that late-glacial drainage flowed northward from South Mountain parallel to the trend of pre-glacial valleys, that the modern streams flow in re-excavated pre-glacial valleys, and that the late-glacial drainage system was parallel to the modern system on South Mountain. Furthermore, the orientations of these eskers suggest that the glacial streams were tributaries to the glacier-margin stream that deposited the kame terrace.

The long axis of a third esker, located on the south flank of the Annapolis Valley 0.5 miles north of Nictaux Falls, trends S 80° W. It is parallel to the Valley and to the drainage of the Annapolis River; and lies in line with the kame terrace. Thus the drainage, represented by the esker, flowed parallel to the modern system, and may have been a continuation of the glacier-margin stream.

Along the northern flank of the Annapolis Valley the glacial drainage system is represented by an esker—delta—lacustrine complex 16.5 miles long. The upstream, eastern, end of this drainage complex is represented by an esker, the head of which rises in the eastern kame field. The esker trends westward from the kame field through Aylesford and Auburn. The size of sediments within the esker decreases from cobble gravel near the source to well-sorted medium sand west of Aylesford. The sorting and decrease in grain size suggests a downstream decrease in velocity of the glacier stream, perhaps a result of decrease in gradient. Conversely the width and height of the ridge increases westward from the source indicating that both discharge and load increased downstream, a result of tributary streams of meltwater pouring into the main drainage channel from adjacent areas of stagnant ice and from the highland to the north.

At Aylesford the esker is 400 feet wide at its base; it has steep flanks, and it rises about 20 feet above the surface of the onlapping outwash. Beds of medium and coarse sand in cut-and-fill stratification account for the bulk of the sediments, although lenses of pebble and cobble gravel occur throughout the section.

Ice-Contact Delta:

At Hudgin's sand pit, 6 miles farther west, the ridge is 0.8 miles wide and rises about 40 feet above the surface of the outwash. Here the top of the ridge is flat and the flanks slope gently. The ridge at Aylesford has an eskerlike form; at Hudgin's pit it has a delta-like form; between the two sites the form is transitional.

Stratification in Hudgin's pit is very regular; the courses dip west at angles ranging from 2° to 12° and are 5 to 30 feet long (fig. 7). The sediments are well-sorted coarse and medium sand with rare interbeds of pebbles; no cobbles are present. These relations suggest deposition by running water of moderate velocity, and having constant discharge and direction of flow. The long, regular cross-laminae are interpreted as delta foresets.

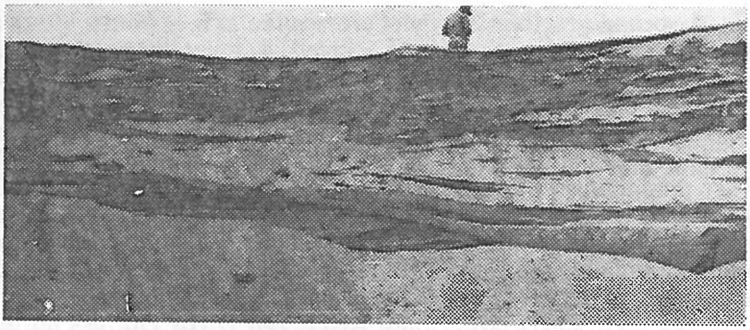

Figure 7. Internal structure of ice-contact delta at Hudgin's sand pit showing uniform grain size and long, delta-type foreset beds.

Ice-Margin Lacustrine Deposit:

Between Hudgin's pit and Melvern Square the coarse deltaic sand interfingers with fine and very fine lacustrine sand. This body, centered about Melvern Square, mantles an area of approximately 3.5 square miles. It extends into the deep re-entrant in the North Mountain cuesta north of Melvern Square.

The sand is very well-sorted; coarse sand, pebbles, and cobbles are absent. However, rare boulders, probably ice-rafted into position, have been found in the deposit. Fresh cuts in this sediment show no bedding. After several days of drying, however, faint laminations appear, ranging in thickness from 0.25 to 2 inches.

The lake, in which the fine sand was deposited, was trapped between the flank of North Mountain and the main body of stagnant ice standing in the Annapolis Valley. The kame field that should mark the position of the former ice dam was almost totally destroyed by erosion of proglacial streams or by burial under overlapping outwash. The kames, north of Wilmot Station are all that remain of the dam.

CROSS-AXIAL DRAINAGE

Overflow from the ice-margin lake did not drain westward down the Annapolis Valley, but northward across the axis of North Mountain. The cross-axial channel has a bed-rock threshold approximately 325 feet above sea level. This elevation is in contrast to the average crestline of North Mountain that ranges between 750 and 850 feet above sealevel. Today Wiswal Brook flows southeastward from the threshold, into the re-entrant containing the lacustrine sediments, to join the Annapolis River. McNeily Brook flows northward from the threshold, crosses a proglacial delta, and enters the Bay of Fundy.

A second proglacial channel crosses the axis of North Mountain from the apex of a re-entrant located 4 miles west of Melvern Square. This channel trends northward from Spa Springs, passes through Victoria Vale, and enters the Bay of Fundy within several hundred feet of the mouth of the Wiswal channel. The bedrock threshold of this channel is 270 feet above mean sealevel, 55 feet lower than that of Wiswal Channel (fig. 8). Ernest Haycock (1900) noted that wind gaps cross the axis of North Mountain opposite most of the major consequent streams that flow northward from South Mountain to join the Annapolis River. For example: the gap at Parker's Cove lies north of the Lequille River, the gap at Sandy Cove lies north of the Weymouth River, and Digby Gut lies north of Bear River. He inferred that passes across North Mountain represnet former extensions of these consequent streams that were beheaded by headward erosion of the subsequent Annapolis River. The pass at Victoria Vale, therefore, is probably such a wind gap resulting from capture of the Nictaux River. Thus the gap was eroded by pre-glacial streams, but the fresh bedrock of the channel, from which all drift has been stripped, indicates that the pass was reoccupied by a pro-glacial stream.

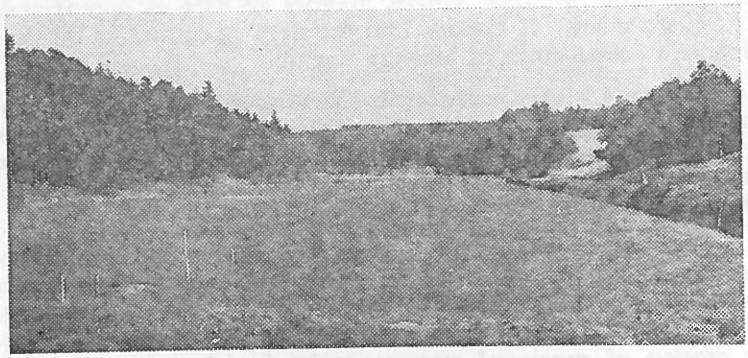

Figure 8. Cross-axial channel viewed southward from McNeily toward Victoria Vale.

PROGLACIAL DELTA

Along 1.8 miles of shore between Margaretsville and Port George the seacliffs, 110 feet high, are cut into unconsolidated, cross-laminated sediments that fill an embayment in North Mountain basalt (fig. 9). The surface of the deposit is 0.5 miles wide and slopes seaward at about 50 ft./mile. At McNeily the landward margin of the deposit extends into, and is at grade with the mouth of the Victoria Vale channel. Sediment of the McNeily deposit is well-sorted medium and medium-coarse sand with rare lenses of pebble gravel. Even though granite pebbles compose less than 0.1% of the volume of the gravel some are clearly of South Mountain provenance. The deposit must have had access to sediments of southern source and is, therefore, probably related to the advance of ice from South Mountain.

The courses of the cross-bedded sediments dip north at 5° to 20°, indicating that the sand was deposited by water flowing from the south. The size of the body demands deposition from a stream of large discharge. No such stream exists today and waves and tide are rapidly eroding the sediments. However, the large size of the Victoria Vale channel indicates that such a stream once existed, and the deposit of cross-laminated sand is, therefore, probably a delta, deposited by the proglacial, cross-axial stream. A Kame field, superposed on the delta, indicates that cross-axial drainage and delta-building occurred during advance of the local glacier. The advancing ice must have dammed the Annapolis Valley to a depth of 270 feet. Proglacial meltwater then spilt over the bedrock threshold of the Victoria Vale pass and deposited the delta in the Bay of Fundy. This cross-axial drainage continued until the ice thickened sufficiently to flow first through the pass, and later to over-ride North Mountain. The kame field, superposed on the delta, indicates that the delta too was overridden. During ablation, cross-axial drainage through the Victoria Vale pass was re-established long enough to clear the channel of glacial drift.

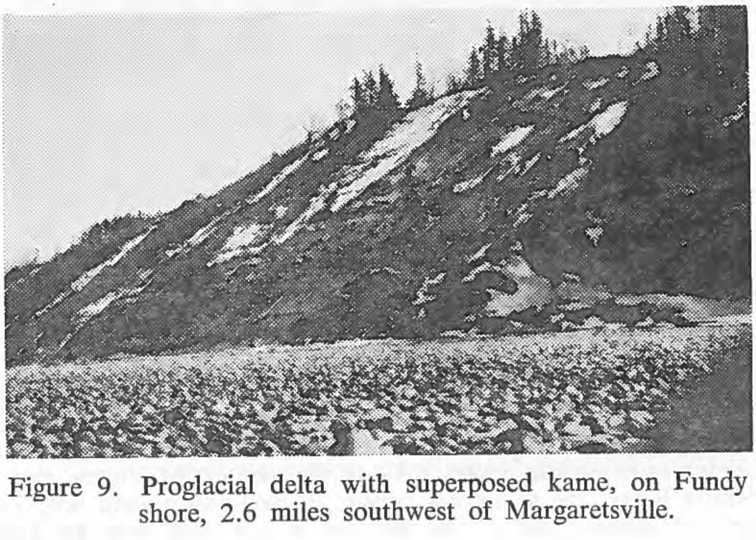

Figure 9. Proglacial delta with superposed kame, on Fundy shore, 2.6 miles southwest of Margaretsville.

OUTWASH

The central trough of the Annapolis Valley is mantled by an outwash plain, the surface of which reaches maximum elevation of 125 feet at Caribou Bog. This bog, accumulating on the outwash, is both the source and the divide separating the Annapolis River watershed from the Cornwallis River watershed. Thus the outwash, sloping gently eastward and westward away from the divide, is not a typical valley train because the proglacial meltwater and sediments did not originate in a valley, headed by an active alpine glacier. The initial flow of ice was not down-valley, but perpendicular to the valley trough. Meltwater and sediments, therefore, were derived partly from a valleyful of stagnant ice and partly from ice ablating on the adjacent uplands.

Within the map area the outwash plain decreases in elevation from 175 feet at the divide to 74 feet at Middleton. Logs of water wells indicate that the thickness is variable, ranging from 32 feet at Auburn to 120 feet at Greenwood Airbase. The outwash overlaps till and ice-contact stratified drift along both flanks of the valley. Near the eastern limit of the map area kames, eskers, and "islands" of till protrude through the overlying outwash. Further west, however, all pre-existing bodies of drift were destroyed by erosion of proglacial streams or were buried under the outwash. The western plain, therefore, is featureless except for shallow valleys made by modern stream erosion. (fig. 10).

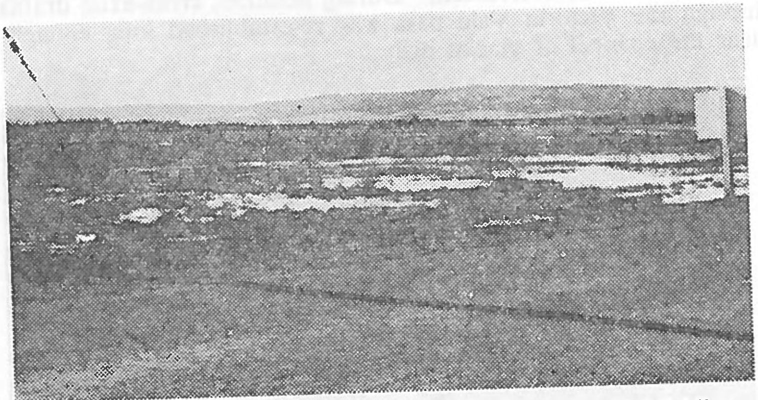

Figure 10. Outwash plain viewed northward toward Middleton and the North Mountain cuesta.

Internally the outwash has cut-and-fill stratification. Along the flanks of the Valley pebble gravel alternates with coarse sand and rare lenses of cobble gravel. Along the axis of the Valley, east of Nictaux River, the sediments consist of well-sorted sand with rare lenses of pebble gravel. The decrease in grain size from the flanks toward the center of the outwash plain, together with the fact that the valley has no outwash head, indicate that most of the sediments were carried into the valley from the adjacent highlands.

West from the Nictaux River the well-sorted sand is overlain by a wedge of poorly-sorted cobble gravel, also having cut-and-fill stratification (fig. 11). The wedge, 10 to 15 feet thick north of Nictaux Falls, thins to a knife edge along the Annapolis River. As shown on the insert map (plate I) the eastern limit of the cobble gravel parallels the course of the lower Nictaux River. The areal relations suggest that proglacial drainage was established in the Nictaux Valley during late phases of the last deglaciation, after the bulk of the outwash had been deposited in the Annapolis Valley. The proglacial Nictaux had greater discharge than the modern stream, and carried a heavy load of glacial debris. It flowed from South Mountain onto the flat surface of the main outwash where it lost velocity, because of decrease in gradient, and deposited the coarse sediments as a surficial wedge that thins toward the north and east.

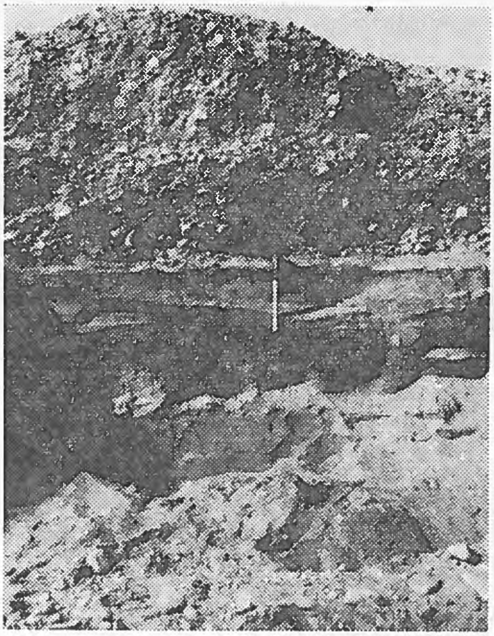

Figure 11. Internal structure of outwash, 2 miles north of Nictaux Falls, showing medium outwash sand underlying cobble gravel of the proglacial Nictaux River.

Fluctuation of Sea Level

Emerged beaches, benches and wave-cut cliffs along the shore of the Bay of Fundy, and estuarine clay in the Annapolis Valley indicate that sealevel is 65 feet lower, relative to the land, than it was in late-glacial time.

EMERGED SHORE

A veneer of beach shingle mantles the shore of the Bay of Fundy wherever the sea cliffs are less than 65 feet high. However, the best morphologic development of the emerged shore occurs where the basalt sea cliffs are not only low but are also plastered over with thick deposits of till. Within the map area remnants of a wave-cut bench and cliff, eroded in till, are found at Port George, at Margaretsville, 0.4 miles west of the mouth of Turner Brook (fig. 12), and at Harborville.

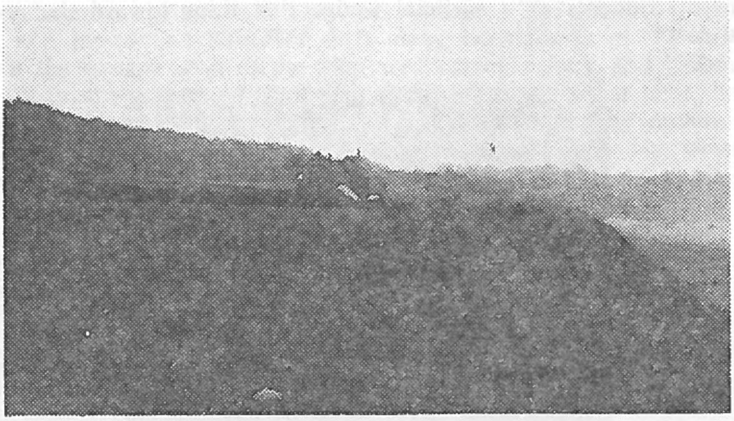

Figure 12. Emerged strandline, 0.4 miles west of mouth of Turner Brook, showing modern seacliff in right foreground, emerged wave-cut bench in middle distance, and emerged wave-cut cliff in background.

At each of these four sites the emerged shore and the modern shore are parallel and have the following morphologic similarities: The wave-cut benches slope seaward at 3° to 7°; they are mantled with a thin veneer of shingle; and they terminate landward in abrupt wave-cut cliffs. Because of these similarities it is believed that the regimen of waves and tide has not changed appreciably since the emerged shore was formed.

Modern sea cliffs, developed on glacial drift, are undercut only during storms or spring tides. Thus the break in slope between wave-cut bench and cliff represents the level of spring high tide. Because of the morphologic similarities the break in slope between emerged bench and cliff probably represents the level of spring tide during stillstand. To determine the elevation of the emerged shoreline the vertical distance between the two breaks in slope were measured by hand-level and steel tape. Measurements made at the four localities ranged from 62 feet at Harborville to 66 feet at Margaretsville. The deviations probably resulted from errors in handleveling and in locating the precise break in slope between emerged bench and cliff.

The emerged shore has been cut in till, and no glacial drift overlies it. The shore, therefore, must have been formed after deglaciation and at a time when eustatic change of sealevel was in equilibrium with the isostatic uplift of the land. Because the emerged bench and cliff are cut in till rather than in the more resistent basalt of North Mountain, the period of equilibrium need not have been long.

Along an emerging shore a horizontal strandline is possible only if the shore parallels the hinge line of isostatic uplift. Both Goldthwait (1924, p. 150, fig. 17) and Flint (1957, p. 251, fig. 14-6) diagramed post-glacial upwarping along the southeastern section of the North American ice sheet. Although their diagrams differ in other details, both show the isobases (contours of equal upwarping) parallel to the axis of the Bay of Fundy. The unwarped strandline between Harborville and Port George is consistent with their interpretation; it represents the 65-foot isobase.

No erosional or depositional features have been found in the map area to suggest a stand of sealevel higher than 65 feet. It is believed, therefore, that this strandline represents the maximum post-glacial marine overlap. Earlier reports of strandlines at 115 or 120 feet should be viewed with caution.

ESTUARINE DEPOSITS

West of Wilmot Station the Annapolis Valley outwash is underlain by sediments ranging in size from silty clay to silty sand, and in color from grayish red to moderate reddish brown. Because clay is the dominant grain size, the deposit is here referred to as clay. The clay appears structureless when wet. When dry, however, it is finely laminated. The laminations result from alternations in grain-size rather than from color differences.

The approximate eastern limit of the clay is shown on the insert map (plate I). At Wilmot Station, where it is exposed in the banks of the Annapolis Valley, the clay is 2 feet thick, it overlies Triassic bedrock, and is overlain by outwash. From this eastern limit the body thickens and widens down-valley. Along the western margin of the map it is about 2 miles wide and at least 12 feet thick. The clay can be traced, discontinuously, down the Annapolis River to Bridgetown, 10 miles west of the map area, where it merges with, and is indistinguishable from the modern tidal sediments of the Annapolis Basin.

In spite of extensive search neither megascopic nor microscopic marine fossils have been found in the clay. In the latter part of the 19th Century, however, several brickyards were active in the Middleton area. Bailey (1898, p. 20m) reported tha "brick clays of Middleton contain layers filled with marine shells, together with remains of star-fishes (Ophiopholis)." The brickyard from which these fossils were taken is 47 feet above mean sealevel. It was located just west of the Middleton hospital on a site now occupied by a sawmill. There is little doubt that the clay underlying the outwash is estuarine.

At the railroad station in Middleton the interface between the clay and the overlying outwash is 57 feet above mean tide. It is unlikely that this level marks the upper marine limit but it is sufficiently high to represent an eroded remnant of the 65-foot strand that is preserved along the shore of the Bay of Fundy.

Within the Annapolis Valley the marine clay is overlain by outwash; the emerged features along the Bay of Fundy, however, are not overlain by drift. It is inferred that, as the ice melted from the shore of the Bay of Fundy and from the trough of the Annapolis Valley, the sea invaded the deglaciated areas to a depth of 65 feet. The sea eroded the features of emergence along the Bay of Fundy and deposited estuarine clay in the valley. The outwash, overlying the estuarine clay, however, indicates that ice lingered on the uplands or in the eastern portion of the Valley throughout this period of inundation. Meltwater, flowing from the areas of stagnant ice into the Annapolis estuary, deposited outwash over the clay. These stratigraphic relations suggest that marine invasion was contemporaneous with deglaciations, and that isostatic uplift of the land began to exceed eustatic rise of sealevel immediately following deglaciation.

Eolian Sediments

DUNES

A field of dunes overlies the outwash east of Fales River. Some of the dunes are asymetrically parabolic with wings pointing westward, into the prevailing wind. Most of them, however, are longitudinal with long axes trending between N 70° W and S 65° W. The orientation of the long axes and the concentration of dunes near the eastern end of the outwash body indicate that the dune sand, derived from the outwash and the ice-contact delta, was transported and redeposited by effective westerly winds.

About two-thirds of the dunes are now fixed by a cover of pine forest, blueberry, or heath plants. However, some of the dunes are still active and small deflation basins are developing on the less vegetated areas. According to Flint (1957, p. 179) the only condition needed to stimulate growth of dunes is abundant supply of dry, unvegetated sediment. This condition has been brought about in the Annapolis Valley by extreme permeability of outwash and deltaic sediments, and by lowering of the water table that must have accompanied the shift in stream regimen from proglacial cut-and-fill to post-glacial stream entrenchment. Therefore, no significant change in precipitation or prevailing wind need be postulated to explain the formation of dunes in the Annapolis Valley. The anchoring of dunes by an increase in vegetation may, however, suggest some slight increase in precipitation.

LOESS

Loess of varying thickness overlies the southeastern portion of the Annapolis Valley outwash; it overlaps the kame terrace along the south flank of the Valley, and can be traced up to the 400-foot contour of South Mountain at Nicholsville. The deposit thickens toward the southeast, from a knife edge along the Annapolis River south of Middleton, to a maximum of six feet at Millville. The distribution of loess indicates that silt-size particles were winnowed from the outwash by the prevailing westerly wind. The fine sediment was transported downwind in suspension and was deposited along the southeast flank of the Valley where the wind is deflected upward with loss of velocity and competence. Although most of the loess was probably deposited shortly after deglaciation, while the outwash was unvegetated, slow deposition probably continues today. The silt is structureless, buff-colored, and homogeneous. It is slightly thicker in depressions and on the eastern flanks of ridges than on hilltops. It therefore modifies, very slightly, the topographic irregularities of the underlying drift.

VENTIFACTS

Pebbles, left as lag concentrate on the deflated surface of the ice-contact delta, are being abraded by the wind. Evidence from Hudgin's sand pit indicate that some of these ventifacts have been faceted within the last ten years. (Hickox, 1959).

Summary of Late-Glacial Events

Although the Annapolis Valley was probably over-ridden several times by continental ice, evidence of only one such advance has been found within the map area. It is assumed that this advance was the one that also overrode Gillis Lake, Cape Breton Island immediately preceeding the Two Creeks interval; it was probably contemporaneous with the Port Huron sub-Stage (ca. 13,600 - 12,200 years B. P.). The continental ice invaded the Central Annapolis Valley from the northwest. Till, deposited by this advance, is identified by included erratics of northern provenance only.

The last glacier advanced across the Central Annapolis Valley from a center located on the axis of the Nova Scotian peninsula. Alhough the ice must have flowed radially outward from the center, evidence from the map idea indicates only that it flowed northward. It is not known whether the local ice was left as a residual cap on the southern highland when the continental ice retreated or whether toal ablation occurred before reaccumulation. Pollen studies suggest that the local advance was contemporaneous with the Valders sub-Stage in Central North America (11,000-10,500 years B. P.).

Ice from the local center flowed down the north flank of South Mountain reworking older drift of the continental glaciation to a depth of at least 6 feet. The reworked drift contains granite erratics that the ice quarried as it flowed northward across the South Mountain batholith.

When the ice had filled the Valley to a depth of 270 feet cross-northward across the axis of North Mountain through the Wiswal axial drainage was established in the Victoria Vale channel and the delta developed at its mouth. The ice eventually filled the Valley and overrode North Mountain. Kames superposed on the delta indicate that the delta, too, was over-ridden by this advance from the south. The lack of lodgment till and ice-contact stratified drift on the North Mountain upland suggest that the overriding ice must have been thin, and that both advance and retreat must have been rapid. Surficial boulders, some of which are granite of southern provenance, were deposited as ablation till during rapid melting of the upland ice.

During ablation cross-axial drainage was re-established in the Victoria Vale pass long enough to clear the channel of drift.

The main drainage, along the north flank of the Annapolis Valley, originated in the eastern kame field. A glacial stream flowed westward from the stagnant ice of the kame field through Aylesford and Auburn. West from Auburn the coarse esker sediments, deposited by the glacial stream, interfinger with deltaic sand. This delta was deposited in an ice-margin lake, the lacustrine sediments of which center about Melvern Square and extend northward into the Wiswal re-entrant. As long as the imponding ice remained thicker than 370 feet overflow from the ice-margin lake drained channel. When the ice dam thinned to less than 370 feet, drainage down the Annapolis Valley was presumably re-established.

The orientation of eskers and of the kame terrace along the south flank of the Annapolis Valley indicate that, here, late glacial drainage paralleled the modern system. Glacial streams flowed down the slope of South Mountain along flanks of pre-glacial valleys. These consequent streams, supplemented by meltwater from ice stagnating in the Valley, coalesced to form an ice-margin stream which flowed down-valley from Millville to Tremont. The orientation of the esker, 1 mile north of Nictaux Falls, suggests that ice-marginal drainage may have extended beyond the western limit of the map.

The emerging shore along the Bay of Fundy and the estuarine clay in the Annapolis Valley indicates a late-glacial stand of sealevel 65 feet higher than present. The emerged shore is not mantled with drift, but the estuarine clay is overlain by outwash. These stratigraphic relations suggest that marine inundation was contemporaneous with deglaciation, and that isostatic uplift began to exceed eustatic rise of sealevel immediately following deglaciation.

Dunes and loess, located in the eastern portion of the Annapolis Valley, indicate erosion, transport, and deposition by wind similar in direction and velocity to the prevailing westerlies of today.

Economic Applications

AGGREGATE

The Central Annapolis Valley and adjacent highlands have unlimited supply of diverse materials that have been, or can be used as aggregate in the manufacture of concrete, or as road metal. Furthermore these materials are favorably located in relation to transportation by road, rail, or water. They occur in economic concentration in the following localities:

Fine and Very Fine Sand: centered about Melvern Square. This deposit, covering an area of 3.5 square miles, is well sorted; it would need no screening, but is probably too fine to be used as aggregate.

Coarse Sand: Most of the deposits listed below are well-sorted and would need little screening.

1. Delta front — between Margaretsville and Port George.
2. Ice-contact delta — a ridge extending from Auburn west to Hudgin's sand pit.
3. Outwash — anywhere in the center of the Annapolis Valley from Greenwood west to Middleton.
4. Esker — the ridge 1 mile north of Nictaux Falls.
5. Kame terrace — between Millville and Tremont.

Cobble Gravel: The deposits listed below are poorly sorted and need screening. Furthermore the larger particles are water-rounded and would need crushing before they could be used as concrete aggregate.

1. Outwash — surficial 5 to 15 feet west of the Nictaux River.
2. Eastern kame field.

Trap Rock: The North Mountain basalt, particularly the more massive flows, represent an unlimited supply of high quality aggregate or road metal. However, the local demand for such material is probably insufficient to justify the initial cost of a crushing plant.

CLAY

West of Wilmot Station the Annapolis Valley outwash is underlain by thick deposits of sediment that range from silty clay to silty sand. In Middleton, during the latter part of the last century, clay-rich lenses were worked and used in the manufacture of bricks. Clay of brick-making quality can still be found in economic concentration. Even in the clay-rich lenses, however, the high percentage of silt and fine sand makes it unfit for manufacture of fine pottery.

AGRICULTURE

Publication 752 of the Dominion of Canada — Department of Agriculture (Harlow and Whiteside, 1943) covers the agricultural possibilities of the Annapolis Valley in detail. Detailed soils maps are included in this publication.

In summary, however, the upland surfaces of both North and South Mountains have thin, bouldery soil that makes farming marginal. Lumbering and pulping are the principal industries of these two areas, although sheep and cattle are raised on the northern upland. The till-mantled flanks of the Annapolis Valley are arable after the glacial erratics have been cleared from the fields. The central portion of the Valley, covered by outwash, has excessive subsurface drainage because of the high permeability of the sediments. Natural vegetation is sparse and shifting sands are in constant motion across the unvegetated areas. Here farming is practical only with extensive irrigation.

WATER SUPPLY

Perennial streams on the uplands of North and South Mountains could furnish adequate water for the sparse population. However most of the isolated farms have their own wells, drilled into bedrock, and producing water from fracture and joint systems.

The Annapolis Valley has unlimited water supply that has not yet been exploited because of poor drilling technique. The Valley, mantled by thick deposits of permeable sand and gravel, receives sub-surface flow from both north and south highlands and the water table, even during drought, is less than 25 feet below the surface of the outwash plain. To exploit this supply wells need not penetrate bedrock. Wells hand-dug or drilled, should be cased with screens or perforated pipe to hold back the sand while permitting the groundwater to circulate into the hold. At present most wells in the Valley are drilled haphazardly into bedrock in the blind hope that they will penetrate a porous, water-bearing horizon or a fracture system.

References Cited

Bailey, L. W., 1898
Geology of southwest Nova Scotia; Geol. Surv., Canada, Ann. Rept., 1896, vol. 9, p. 1M - 154M.

Dawson, J. W., 1893
The Canadian ice age, being notes on the Pleistocene geology of Canada, with especial reference to the life of the period and its climatic conditions; privately published, Montreal, 301 pages.

Deevey, E. S., Jr., 1951
Late-glacial and postglacial pollen diagrams from Maine; Amer. Jour. Sci., vol. 249, p. 177-207.

Faribault, E. R., 1920
Kings and Annapolis Counties, Nova Scotia; Geol. Surv., Canada, Summary Rept., pt. E, p. 6-16.

Flint, R. F., 1957
Glacial and Pleistocene geology; John Wiley & Sons, Inc., New York, 553 pages.

Goldthwait, J. W., 1924
Physiography of Nova Scotia; Geol. Surv., Canada, memoir 140, 179 pages.

Harlow, L. C. and Whiteside, G. B., 1943
Soil survey of the Annapolis Valley fruit growing area;; Dom. of Canada, Dept. of Agri., pub. 752, tech. bull. 47, Ottawa, 92 pages.

Haycock, Ernest, 1900
Records of post-Triassic changes in Kings County, Nova Scotia; Proceedings and Trans., Nova Scotia Inst. of Sci., p. 287-302.

Hickox, C. F., Jr., 1958
Geology of the Central Annapolis Valley, Nova Scotia; Ph. D. thesis, Yale University, unpublished.

1959
Formation of ventifacts in a moist, temperate climate; Geol. Soc. Amer. Bull., vol. 70, p. 1489-1490.

Holmes, C. D., 1935
Till fabric; Geol. Soc. Amer. Bull,, vol. 52, p. 1299-1354.

Klein, G. DeV., 1959a
Sedimentary structures in the Blomidon formation, a Triassic lake deposit, Nova Scotia; Geol. Soc. Amer. Bull. vol. 70, p. 1630 (abstract).

—1959b
Stratigraphy of the Triassic rocks of Nova Scotia; Geol. Soc. Amer. Bull., vol. 70, p. 1631.

Livingstone, D. A. and Livingstone, B. G. R., 1958
Late-glacial and post-glacial vegetation from Gillis Lake in Richmond County, Cape Breton Island, Nova Scotia; Amer. Jour. Sci., vol. 256, p. 341-359.

Ogden, J. G., III, 1960
Recurrence surfaces and pollen stratigraphy of a postglacial raised bog, Kings County, Nova Scotia; Amer. Jour. Sci., vol. 258, p. 341-353.

Prest, W. H., 1896
Glacial succession in central Lunenburg; Trans. of the Nova Scotia Inst. Sci., vol. 9, p. 158-170.

Smitheringale, W. G., 1960
Geology of Nictaux-Torbrook map-area, Annapolis and Kings Counties, Nova Scotia; Geol. Surv., Canada, paper 60-13, 32 pages.

Walker, T. L. and Parsons, A. L., 1923
The North Mountain basalt of Nova Scotia; glaciation, tubular amygdaloid, mordonite and lonisite, Univ. of Toronto studies, Geol. Ser., no. 16, p. 5-12.

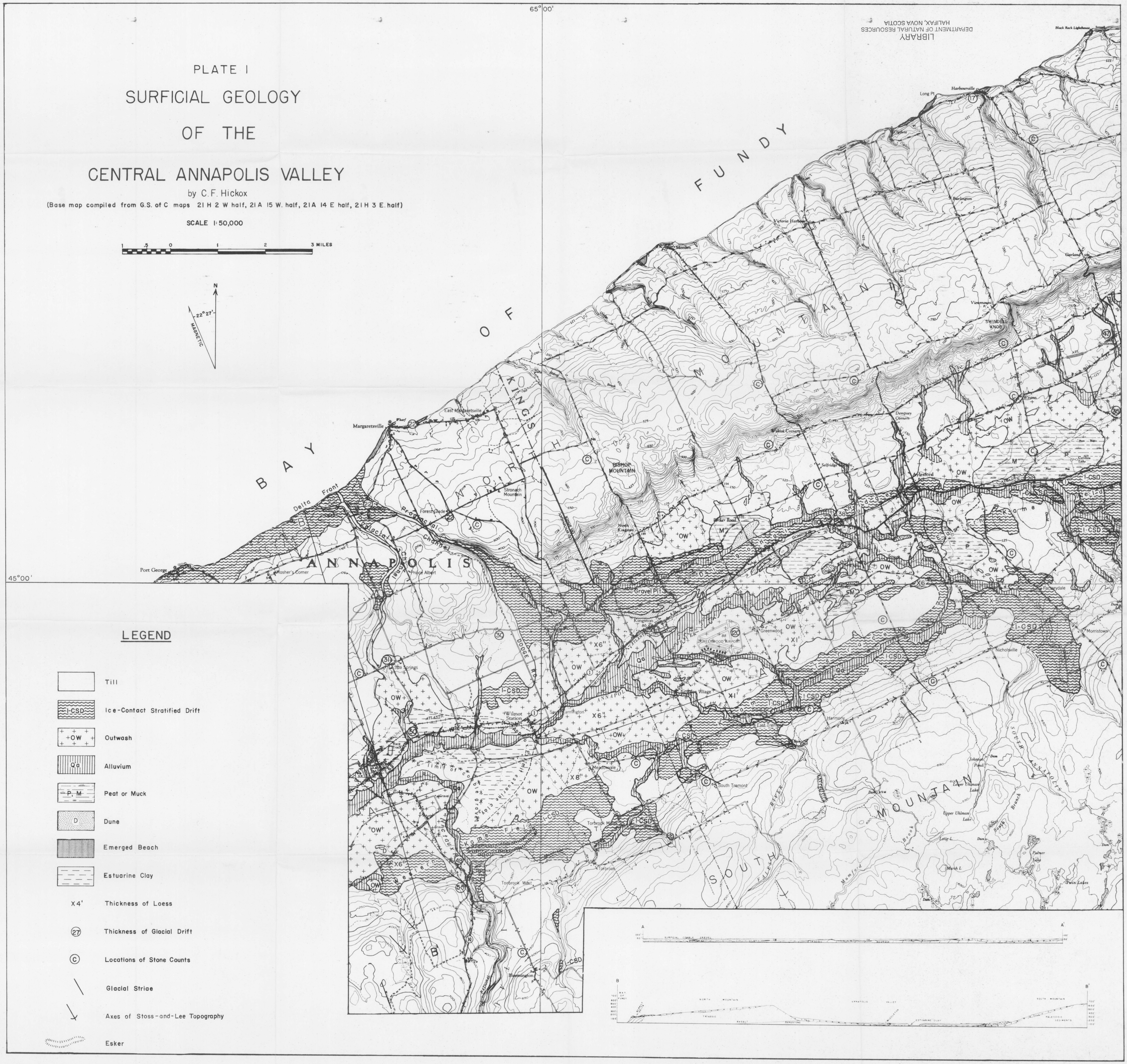

PLATE I
SURFICIAL GEOLOGY
OF THE
CENTRAL ANNAPOLIS VALLEY
by C.F. Hickox
(Base map compiled from G.S. of C maps 21 H 2 W half, 21 A 15 W. half, 21 A 14 E half, 21 H 3 E. half)
SCALE 1:50,000
3 MILES
N
22°27'
MAGNETIC
65°00'
45°00'
LIBRARY
DEPARTMENT OF NATURAL RESOURCES
HALIFAX, NOVA SCOTIA
BAY OF FUNDY
NORTH MOUNTAIN
ANNAPOLIS
SOUTH MOUNTAIN
BISHOP MOUNTAIN
SWINDELL KNOB
Delta Front
Proglacial Channel
Margaretsville
Port George
Harbourville
Long Pt
Victoria Harbour
Morden
Aylesford
Kingston
Greenwood
Wilmot Station
Meadowvale
Torbrook
Torbrook West
Nictaux
Bloomington
Middleton
Spa Springs
Prince Albert
Mosher's Corner
Forest Glade
Stronach Mountain
North Kingston
Gravel Pit
South Tremont
Harmony
Nicholsville
Morristown
Factorydale
Dempsey Corners
Burlington
Garland
Viewmount
Black Rock Lighthouse
Lower Uhlman Lake
Upper Uhlman Lake
Long L.
Marsh L.
Palmer Lake
Twin Lakes
Kame Field
LEGEND
Till
I-CSD Ice-Contact Stratified Drift
OW Outwash
Qa Alluvium
P, M Peat or Muck
D Dune
Emerged Beach
Estuarine Clay
X4' Thickness of Loess
27 Thickness of Glacial Drift
C Locations of Stone Counts
Glacial Striae
Axes of Stoss-and-Lee Topography
Esker
A
A'
B
B'
NORTH MOUNTAIN
ANNAPOLIS VALLEY
SOUTH MOUNTAIN
ESTUARINE CLAY