RECONNAISSANCE OF THE FORESTS OF OXFORD COUNTY, MAINE, WITH SPECIAL REFERENCE TO THE EFFECTS OF FIRE, WIND, SOILS, AND GLACIATION

by

Herschel G. Abbott

Submitted in partial fulfillment of the requirements
for a degree of Master of Forestry at
Harvard University

Harvard Forest
Petersham, Massachusetts

August 15, 1951

ILLUSTRATIONS

Plates: (In pocket back cover.)

Plate I. Preliminary Geologic Map of Maine
Plate II. Map of Glacial Deposits in Maine

Tables:

Table I. Geologic Time Scale for Maine 33a
Table II. Classification of the Pleistocene Period 54a

Figures:

Fig. 1. Dominant red oak occupying crest of a granitic ridge 8a

Fig. 2. Mature basswood growing on a rock-fragment slope 8b

Fig. 3. View showing the relationship between the type boundary of white pine and the approximate limits of a kame terrace 9a

Fig. 4. Soil profile along old logging road showing compact till 9a

Fig. 5. Topographic development in the Swift River Valley believed to be the result of periglacial frost action 10a

Fig. 6. Evidence of periglacial frost action in the Androscoggin River Valley 10a

Fig. 7. Old blowdown mounds and pits in a pastured area cleared over 100 years ago 20a

Fig. 8. Typical blowdown mound resulting from the storm of 1883 .... 20a

Fig. 9. Decayed remains of a yellow birch which originated on a blowdown mound since removed by erosion 21a

Fig. 10. Cross-section through blowdown mound showing profile development 21a

Fig. 11. Direction of glacial striae in the State of Maine ... 41a

Fig. 12. View of esker delta at Augusta, Maine 47a

Fig. 13. Kame near North Woodstock, Maine 47a

Fig. 14. Section of esker, Bryant Pond, Maine 48a

Fig. 15. Preliminary map showing the extent of marine clays in Maine 50a

TABLE OF CONTENTS

INTRODUCTION 1

DESCRIPTION OF AREA OF OBSERVATIONS 4

RELATIONSHIP BETWEEN TIMBER TYPES AND GLACIAL DEPOSITS 7

EVIDENCE OF FROST ACTION 10

LAND USE HISTORY 12

THE PREVALENCE OF FIRES 16

OCCURRENCE OF WINDS 20

SUMMARY 26

CONCLUSIONS 28

APPENDIX: THE GEOLOGY OF MAINE

Previous Geologic Work in Maine 30

Bedrock Geology of Maine 33

Shaping of the Preglacial Surface 38

Glacial Erosion 41

Glacial Deposits 44

Marine Clays 50

Aeolian Deposits 51

Historical Summary of the Late Pleistocene in Maine 53

The Glacial Period in Maine 54

LITERATURE CITED 55

The section of Maine examined was limited in extent because of time and travel facilities available. Field work was conducted largely in Oxford County in the townships of Woodstock, Milton, Rumford, Bethel, Roxbury, and Andover. This area is often referred to as the "hilly western section" or as the "foothills of the White Mountains." It is included in the Androscoggin River drainage area which is that part of the state between the region tributary to the Saco River on the south and the Kennebec River on the east.

The field work was carried on during a three week period in May, 1951. A general reconnaissance was made of exposures of glacial deposits along logging roads and highways. Cross-sections of blowdown mounds were exposed and the ages of trees growing upon them determined by increment borings. Shallow pits were dug to discover the remains of old fires, and historical records and old personal diaries were searched for recorded evidence of occurrences of both wind and fire. Efforts were concentrated on observation rather than the accumulation of tabulated data. The observations were made more through the eyes of a practical forester than those of the experienced geologist or ecologist.

This report will first present a somewhat detailed description of the area in which the investigations were made. This description is followed by an attempt to show relationship between the glacial deposits and timber types with the observed fossil frost forms receiving brief attention. A generalized statement as to land use history and a discussion of the evidence of fire and wind as observed on the ground and in historical records constitute the remaining body of the text. Following a summary of the results obtained from the investigation, conclusions are stated regarding the relationship of glacial

INTRODUCTION

Fire and wind are two well recognized agencies causing extensive destruction to forest lands. The importance of fire as a factor in the development of vegetation has for some time received attention by foresters and plant ecologists. The effect of wind upon forest vegetation has not been as fully appreciated. Oxford County, Maine, has been relatively free from recent forest fires and with the exception of the hurricane of 1938, wind damage has not been of a serious nature. Past occurrences of fire and wind have not been considered in the light of their influence upon the vegetational development of this forested area.

Although the geology of the State of Maine has been studied extensively over the past 115 years and rather intensively since 1942, there is no published literature giving evidence of any attempt to relate the geological formations of the state with its forest vegetation. Jackson (1839) indicated his appreciation of the implications of geology to agriculture when he wrote "agriculture draws most largely from the science of geology for the elucidation of the origin, distribution, and composition of soils." Had the word "forestry" been a part of the vocabulary he would have done well to have included it in his statement.

This paper reports the results of two types of studies, the first ecological and the second geological. Its purpose is three-fold: (1) to discover the prevalence of fire and wind in a specified area and to speculate on their ecological significance, (2) to determine the relationship between the timber types and the glacial deposits in the above area, (3) to describe briefly the geology of the state as a whole.

deposits to the timber types and the significance of the ecological factors of fire and wind.

A section of this paper has been devoted to the geology of Maine. It is to be found in the appendix and is offered as descriptive background material. Previous geologic work in Maine is first mentioned with a brief account of the Maine Geological Survey and its functions. The bedrock geology, shaping of the preglacial surface, and the glacial geology in general is discussed. Such subjects as marine clay and aeolian deposits are also included.

The following library facilities were used: Whitman Memorial Library, Bryant Pond, Maine; Maine State Library, Augusta, Maine; University of Maine Library, Orono, Maine; Gray Herbarium, Harvard University; and the Harvard Forest Library, Petersham, Massachusetts.

The writer wishes to express his sincere appreciation to Dr. Hugh M. Raup and Earl P. Stephens for their patient guidance and many helpful discussions relative to the preparation of this paper.

DESCRIPTION OF AREA OF OBSERVATION

The Androscoggin River drainage area, as previously mentioned, includes that part of Maine between the region tributary to the Saco River on the south and the Kennebec River on the east. The Androscoggin has had a very complex history and according to Crosby (1922) has altered its course several times during the late Tertiary and post-Pleistocene periods. It is believed to have formerly been a tributary of the Connecticut River in New Hampshire. The Umbagog Lake and the Magalloway River are the sources of the Androscoggin which swings south and then east passing into Maine and becoming a tributary to the Kennebec River and Merrymeeting Bay. At Rumford the Androscoggin alters its northeasterly course to the north, then turns at right angles and flows southeasterly toward Dixfield. This sudden change in course over rock ledges furnishes the water power for Rumford and is due to the blocking of the valley to the south by glacial deposits. The glacial deposits extending southward through Milton, Bethel, and Woodstock are joined by the main series of gravel and sand deposits in the form of eskers and kame terraces which extend northward from Bryant Pond into the valley of Meadow Brook at North Woodstock. From this place, the deposits continue down the valley as a well-defined ridge of stratified gravel and sand into the valley of the Androscoggin.

Northward from Rumford, through Roxbury and Byron, is the Swift River valley which drains the mountainous country south of the Rangeley Lakes. Kame terraces border the walls of this valley and local detached kames occur in the valley floor. Above Frye, the valley narrows and the wash plains are reduced to a narrow fringe between the stream and the bordering terraces which are largely of till. Just above Roxbury village the valley widens once more and is occupied by a sand plain. This widened valley extends northward to Byron where it is once more filled with till forcing the stream from its preglacial course.

The next valley westward from Rumford is that occupied by the Ellis River which drains Andover and the region to the north. It joins the Androscoggin near Rumford Point and is followed by that river to Abbot's Mills while the broad valley of Meadow Brook, believed to be a continuation of the Ellis River valley, extends southward to Bryant Pond into Paris and Norway. From Abbot's Mills, the esker gravels may be traced into the sand plain of the Androscoggin and along the valley to Rumford Point. Northward from the village, the esker extends up the valley of the Ellis River into the sand-floored Andover Basin. At places these gravels rest against the valley walls as kame terraces, while in other places they swing into the valley as a distinct two-sided ridge. The basin in which Andover village stands is one of the broad, mountain encircled basins which are occasionally found in the higher areas of Maine. The basin is covered with sand carved into terraces by the Ellis River. At the upper end of the basin the mountains again close in, and the west branch of the Ellis extends westward through Andover West Surplus. The east branch of this river rises in Roxbury Pond, formerly known as Ellis Pond, which occupies a sand plain 200 feet above the Andover Basin. Northwestward from this basin, Black Brook follows a narrow valley through Black Brook Notch northwestward to the South Arm of Richardson Lake. At South Arm an esker runs south through the lake as a series of islands and a long narrow point west of

the Landing. These gravels extend southeastward down the valley to Black Brook and form a dam which prevents Richardson Lake from flowing directly south through the Notch into the Ellis and Androscoggin Rivers. The esker gravels are believed to extend down the valley into the Andover sand plain and so form a part of the system extending from the Ellis River valley southward through Bryant Pond and into the valley of the Little Androscoggin.

Portions of these four valleys, the Androscoggin, Meadow Brook, Swift River and Ellis River and the surrounding territory represent in general the area in which investigations were conducted to determine, if possible, any relationships between the timber types and glacial deposits and to discover evidence of fire and wind storms of the past.

Altitudes vary from about 700 feet in the valleys to 3062 feet on Long Mountain in Andover. The relief is often accentuated by the presence of high cliffs, talus slopes, and exposed knobs of bedrock. There are many slight surface irregularities which may be bedrock controlled, remnants of ground moraine or the product of periglacial frost action. The surfaces of most of the slopes are dissected by numerous streams which have in many cases carved out V-shaped ravines.

The forest soils in this area are strongly podsolized and fall within the Great Soil Group classification of "podsol soils." Most of the soils have a sandy or gravelly loam texture in the upper layers which vary in thickness from a few inches on the outwash deposits to as much as 30 inches mantling the granitic tills. Conspicuous zones of podsolization accompany other well developed soil characteristics reflecting the dominating influence of climate and vegetation.

RELATIONSHIP BETWEEN TIMBER TYPES AND GLACIAL DEPOSITS

The till mantled mountain slopes in this section of the Androscoggin drainage area are for the most part now covered with a second-growth[1] forest of mixed hardwoods of the following species: sugar maple (*Acer saccharium*), yellow birch (*Betula lutea*), beech (*Fagus grandifolia*), red maple (*Acer rubrum*), and paper birch (*Betula papyrifera*). White ash (*Fraxinus americana*), red oak (*Quercus borealis*), basswood (*Tilia americana*), and aspen (*Populus tremuloides* and *P. grandidentata*) are also represented as scattered individuals and in small local concentrations. A few remains of the red spruce slopes (*Picea rubrum*) described by Westveld (1931) may still be seen. Spruce is also present throughout the hardwood and may occupy old fields and be found in association with hemlock (*Tsuga canadensis*) and balsam fir (*Abies balsamea*) bordering streams and in the ravines. White pine (*Pinus strobus*), with an occasional representation of red pine (*Pinus resinosa*), inhabits the outwash deposits in the valleys and extends up the valley sides on some of the westerly and southwesterly slopes to adjoin the hardwoods. Pine is largely confined within these limits with the exception of those stands occupying old fields and the flats above ledges of lower elevation (800-900 feet) overlooking the outwash areas and linked to them by kame terraces. A few swamp areas border the meadow lands and contain northern white cedar (*Thuja occidentalis*), tamarack (*Larix laricina*), balsam fir and red maple.

The red oaks found in these forests probably represent an extension of the transition hardwood type into this northern hardwood region.

---

1. The term "second-growth" is used throughout this paper to indicate forest stands that have followed the removal of the primeval forests.

This species, although occasionally present in admixtures of other hardwoods, assumes a position of dominance (Fig. 1) only on elevations of 1000-2000 feet where the till is very thin and bedrock exposures are prevalent.

Basswood holds a position comparable in importance to red oak in this vicinity. Confined almost entirely to rock-fragment slopes and their accompanying granitic ledges, this species apparently satisfies its growth requirements and attains proportions suitable for sawtimber material (Fig. 2).

White pine, although largely distributed as previously described, also may be found growing on the more moist, well-drained soils in association with hardwoods and other conifers. There seems to be, on the other hand, a definite relationship between the extent of the outwash deposits and the general distribution of the larger pine areas. The writer also believes that the upper limits of the pine growth along the sides of the valleys are in many cases very closely related to the kame terrace boundaries (Fig. 3).

There seems to be little apparent relationship between the glacial deposits and the type boundaries of the spruce-hardwood, northern hardwood, and spruce slope types. The remaining spruce slopes and areas which previously supported this type are characterized by shallow tills and rocky outcrops. Some of these spruce slopes now support excellent hardwood growth and it is believed that the distribution of the spruce slope type was influenced mainly by some factor other than the glacial origin of the soils.

Glacial deposits along logging roads and in old borrow pits show relationship between the quality of the hardwood growth and the depth

Fig. 2. Mature basswood growing on a rock-fragment slope.

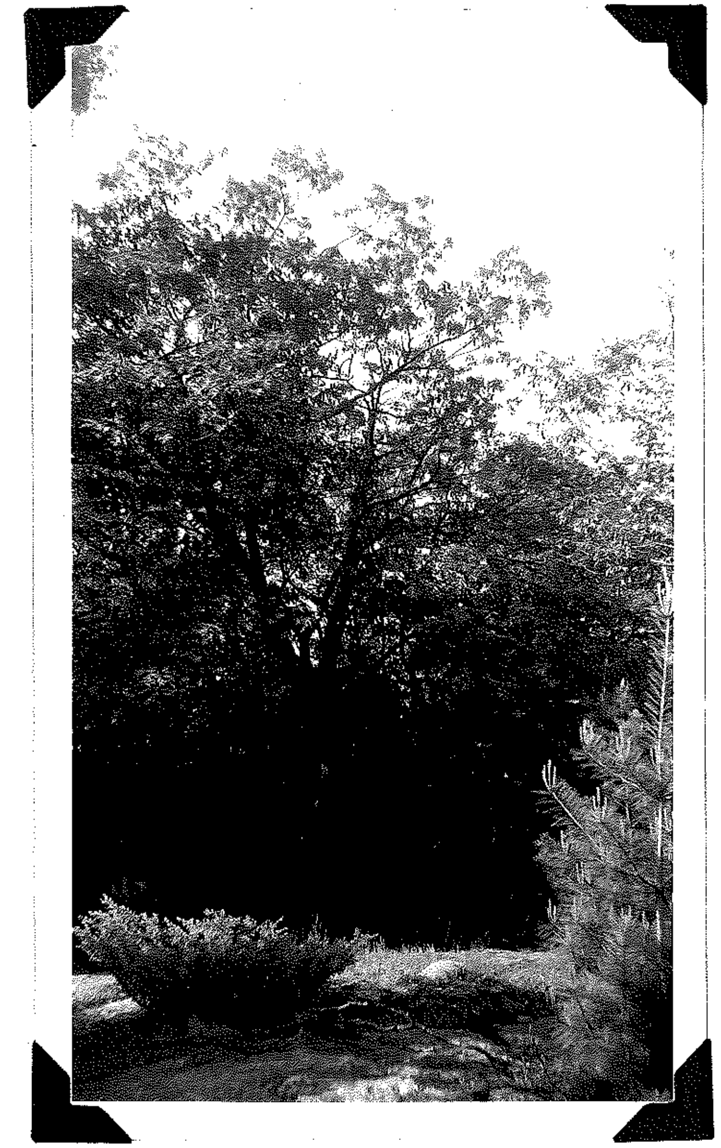

Fig. 1. Dominant red oak occupying the crest of a granitic ledge.

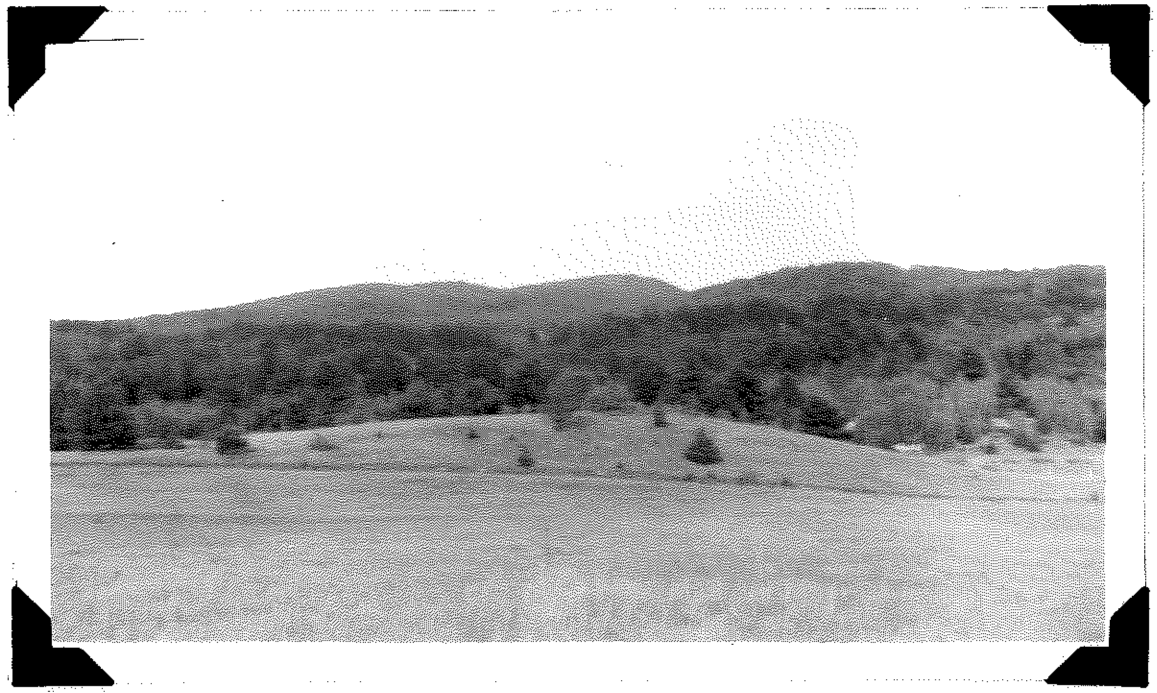

Fig. 3. View showing the relationship between the type boundary of white pine and the approximate upper limits of a kame terrace. Note typical kame in the foreground.

Fig. 4. Soil profile along old logging road showing exposed, compact clay till.

and water-holding capacity of the till. One particular tract in Andover township was investigated. This area is well known locally for its "good growing" qualities and the writer is personally familiar with it. A superior growth of mixed hardwoods and fir, cut in 1947, grew on a fine sandy loam underlain at a depth of 24-30 inches by a sandy clay till of unknown depth. Soil profiles (Fig. 4) examined along old logging roads showed this till to be very compact, and capable of perching the water table during the driest periods. The bottom of two eight-foot pits remained very moist throughout the critically dry summers of 1947 and 1948, indicating that the compact till is capable of perching the water table during dry periods.

This is in sharp contrast to the moisture-holding capacity of the gravelly tills more common in this locality. A detailed study in this area of the permeability of tills, their thickness, and depth below the forest floor might give rise to a valuable indicator of site quality.

Stout (1950), on the Harvard Forest in western Massachusetts, found that there were relationships between the local distribution of red oak and white ash and the depth of the modified soil layer or solum down to a tight till. This was kept in mind by the writer during the course of his investigations but observations of the vegetation surrounding the few profiles exposed did not produce any comparable conclusions in this area.

Fig. 5. Topographic development in the Swift River Valley described by Perkins as "till terraces," believed by the writer to be the result of periglacial frost action.

Fig. 6. Evidence of periglacial frost action in the Androscoggin Valley.

EVIDENCE OF FROST ACTION

Evidence of current frost action has been found on the higher mountains in Maine and reported by Nichols and Nichols (1906), Butler and Ray (1946), and others. The fact that stones work to the surface on agricultural land, and the occurrence of occasional avalanches, such as the slide on Old Speck Mountain at Grafton in 1927, offer additional proof of the effects of rapid temperature changes on land surfaces.

Many anomolous surface features were observed and believed by the writer to have been developed by frost action during a periglacial climate. The surface irregularities in the Androscoggin and Swift River valleys classified by Perkins (1935) as "till terraces" (Fig. 5 and 6) are probably the result of solifluction, a term proposed by Anderson (1906) for the flowing from higher to lower ground of masses of waste saturated with water. Bryan (1946) proposed the term "congeliturbation" for all varities of frost heaving and solifluction induced by a cold climate. These topographical features have a rather definite lobular shape and have been referred to as "congeliturbate lobes." These lobes, although not always well defined, are found throughout much of the subject area beyond the limits of the outwash deposits.

Previous mention has been made of the existence of rock-fragment slopes formed by the accumulation of frost-shattered blocks at the foot of cliffs or ledges. The observed relationship between these slopes and the distribution of basswood has also been discussed. This relationship seems to be the only very evident one between frost action and forest vegetation in this area.

Although these cursory observations revealed little if any interrelationship between the present vegetation and the apparent frost forms, further detailed investigations might well result in the attributing of local differences in the distribution of forest vegetation to the periglacial frost action in this area.

LAND USE HISTORY

An attempt to write a comprehensive land use history of an area including portions of several townships would be futile and of little value in fulfilling the objective of this study. However, a few brief statements as to time of settlement, original timber types encountered, and early development of local wood-using industries will help portray the extent of forest exploitation in this particular section of Maine since colonization.

The first ten townships to be settled in Oxford County and their dates of settlement are listed below:

Bethel	1773
Waterford	1775
Buckfield	1777
Paris	1779
Rumford	1780
Sumner	1783
Norway	1786
Andover	1789
Peru	1793
Woodstock	1797

From this list it is apparent that the period of 1773 to 1797 represents the advent of the white man with his axe as an ecological factor of the forest environment. Only a small mark was made at this time upon the forests which stood as the main barrier to the establishment of homesteads and the subsequent growth of community life. Except for the small amounts of timber necessary for fuel consumption and the construc-

The subsistance of the early settlers depended largely upon the fruits of the land and of personal labor. The lower and middle slopes of the mountains were grazed by sheep and cattle. The richer hillsides and lowlands were cultivated immediately following clearing and were for the most part planted to corn. The harvesting of this crop brought about the construction of the first grist mills for grinding the corn into meal. These were followed by the first sawmills, and pine and spruce was manufactured into boards and dimension stock to be used in the construction of new buildings and the replacement of the original log dwellings. Water power sawmills on the rivers and larger streams became numerous and active in the middle of the 1800's and constituted the nucleus of the forest industry of this section.

The arrival of the railroad in 1851 gave access to wood product markets. The value of the second growth paper and yellow birch became appreciated about 1880 with the construction of the first bobbin, spool, dowel, clothespin, and handle mills. It was not until 1892, when the International Paper Company established its mill at Rumford that the spruce slopes offered promise of real value to the landowners, and the economy of many communities shifted from agriculture to lumbering. During the last half century, the better quality second growth hardwoods, especially paper and yellow birch, have furnished the basic raw materials for many small industries throughout the area.

As a result of repeated cutting of immature stands, loss from birch die-back, and attacks by the bronzed birch borer (<u>Agrilus anxius</u>), stands of timber have become so depleted that some industries are now using other hardwoods of poorer quality. Birch is also being imported from Canada and one corporation now imports its wood from South America.

tion of log shelters, trees were cut and burned to form clearings for tillage and pasture land in like manner to all other early colonization. Historical records offer little evidence of any preference being shown for the qualities of soil and site, with perhaps the exception of the rich alluvium intervales along the Androscoggin and Little Androscoggin Rivers. It was not until the early 1800's with the arrival of the land surveyors, the granting of large sections of land and the assessing of taxes that these early settlers appreciated their wisdom or folly in locating their farms. The burden of taxation and the occurrence of fires were sufficient causes for the mortgaging of many farms to the "capitalists" residing in the shire town of Paris. As early as 1816 the influence of the settler upon the natural succession of the forest vegetation became paramount and the "second growth" forest has since predominated.

The timber types encountered during the settlement of this area are described by early local historians. Whitman (1891), in his history of Bethel, writes the following:

> "The natural growth of wood was white pine on the intervals and upland swells; maple, yellow birch, and beech on the highlands and spruce and hemlock on the mountains. There was also to be found a scattering of Norway and pitch pine."

Lapham (1890) described the forest composition of Rumford as follows:

> "The flora of Rumford presents no peculiarities. White pine was quite abundant when the first settlers came here. There was also an abundance of spruce, hemlock, and fir. Of the hardwoods, yellow birch, beech, and rock maple were the principal varieties. Elms were found on the rivers and an occasional basswood in the forests."

Other statements in town histories and personal diaries add little to these meager descriptions which furnish a glimpse of the timber types which constituted the primeval forests in this part of Maine.

During the last two decades, a demand for the poorer quality hardwoods by the paper manufacturing plants has resulted in the development of this market as the main outlet of wood production in this area at the present time. The demand for veneer stock during World War II made possible the salvage of a great volume of old growth hardwoods, mostly yellow birch, beech, and sugar maple which were overmature and decadent. These operations have continued to the present time and the culls from this high-grading type of cutting are gradually being accepted by the pulpwood industry.

The natural pineland area has been supplemented by the succession of old field white pine on many farms which have gradually been abandoned over the past eighty years. However, during the recent war years and the subsequent expansion period of housing construction, the demand for eastern white pine lumber has brought about the birth of additional sawmills and keener competition between the mill operators. The estimated production of 100 million b. f. of pine lumber in the past five years by small mills in only one township indicates somewhat the depletion of the second growth pine. This has recently led to the realization by some pineland owners of the necessity of better logging practices. "Selective cutting," now in its embryo stage, represents the attempt by local industry to practice "silviculture."

THE PREVALENCE OF FIRES

In 1825, a fire occurred in Maine which burned nearly one-half of the forest land of the state. This fire was repeated on a more local scale but with a far greater financial loss in 1947 when approximately 130,000 acres of forest land burned. This is nearly 1% of the total 16,783,000 acres of forest land in the state. The catastrophes of these two years did not reach into central and northern Oxford County which has been nearly immune from extensive fire damage over the last several generations.

During the course of this study, charcoal was found several inches below the surface of the ground while investigating blowdown mounds and soil profiles. This led to further search for such evidence and the eventual disclosure that much of the area in question had been burned at some time in the past. A review of the available literature brought to light written accounts of at least one major fire which had burned over much of the area studied. This fire occurred in the fall of 1816 following the coldest summer which has ever been experienced in New England. Whitman (1915) writes the following of the origin of the fire in this locality:

> "In the fall fires raged in this section. One, starting in Woodstock, ignited some brush, spread through the forests in a southeasterly course and entered the town of Buckfield. Acres upon acres of fine timber were burned over and destroyed. The vegetable covering of thin soils was consumed and lands which before were called good never recovered from the fearful ravage of flames."

A more colorful account of this fire is given by Lapham (1882) when he writes the following:

> "The year 1816 was exceptionally cold for this latitude. There was frost every month of the year and nothing but the hardier cereal grains ripened. Another cause of serious

> discomfort and great loss this year was the unusual prevalence of fires. The season, though cold, was exceptionally dry, and much of the wood and nearly all of the timber in the town was destroyed. So extensive were these fires that ordinary print could be read by their light in almost any part of town at midnight, and the summits of the blazing mountains could be seen far away. These fires not only destroyed the wood and timber, but in many places the surface soil was charred and greatly damaged by intense heat."

Perley (1891) does not mention the damage in this locality but regarding other affected areas states that "devastating fires swept through the woods of Vermont, New Hampshire, and Maine.... In Maine, along the Kennebec River, and as far east as Frenchman's Bay, they were burning as late as October 11."

The fire of 1816 is apparently the only one on record in this vicinity which resulted in widespread devastation. Other smaller fires have occurred since this date, such as the Bemis fire of 1909, and one case is cited of an extensive fire as early as 1717. It is quite probable that the pre-settlement forests were often burned by relatively small fires caused by lightning or ignited by the Anasagunticook and Rokomekos Indians who inhabited this section prior to the arrival of the white man. The important fact is that there are written accounts substantiating the evidence in the field that the forests of this part of the state, which have been relatively free from fires for many years, were burned over at least once.

The effect of fire, now long forgotten, upon the forest vegetation may well be of major significance. It has been an important influence in establishing extensive stands of second growth paper birch. Numerous wood-using industries dependent on this birch have grown up to be important segments of the local economy.

Shirley (1941) observed that paper birch was the only local species in the Lake States to approach aspen in its capacity to colonize burns. Pinchot (1908) was of the opinion that the local occurrence of paper birch was very largely determined by fire. Some of the older residents of Woodstock recall the cutting of small, pure stands of this species which had seeded in on fields known as "burnt pieces." These fields were usually located on small flats along the sides of mountains which had been cleared and cultivated. After being abandoned for cultivation purposes they were occasionally burned and used for pastures or hayland.

Cary (1936) after many years of observations, came to the conclusion that a large part of the pine timber in Maine came through the agency of fire, and associated his observations with the historic burn of 1825. Maessurrow (1935) also adds that in his opinion the white pine in Canada did not reproduce under the canopy of the virgin forest, and being only a temporary element of the forest association, perpetuated itself primarily through the medium of fire.

The distribution of other species could well have been influenced similarly. The fact that hardwoods now occupy areas that previously supported the spruce slope type may be due, at least in part, to the absence of fire. According to Bloomberg (1950), fire has a positive and causative effect on the establishment of spruce as a climax type in the Canadian Rockies. He states, "in Alberta, at least, forest fire is such a constant bed-fellow that there is no precedent to show what might happen when virgin stands of spruce are protected from fire for more than a rotation. It may not be too fantastic to consider the day when we shall wonder whether fire, in some form at least, has not been a friend masquerading as a foe."

While fire, more than any other agency, has played havoc with Maine forest lands, if properly used as a silvicultural tool, it may be a means of perpetuating natural growth of certain preferred species.

OCCURRENCE OF WINDS

Recent consideration has been given at the Harvard Forest, Petersham, Massachusetts, to the effect of strong winds upon the forests, not only by the destruction of standing timber, but also by the disturbance of the soils upon which they grow. A detailed study has been made by Goodlett (1951) of the relationship of the uprooting of trees by wind to the distribution of the vegetation and the disturbance of soils in Potter County, Pennsylvania. Results of previous studies by Shaler (1891), Lutz and Griswold (1939), and Lutz (1940) were published on the effect of the upheaval of trees upon soil characteristics.

Wind storms of the past have left their mark upon the forested areas in the form of mounds of mineral soil and their accompanying pits which dot the landscape accentuating the features of microrelief (Fig. 7). Evidence of such phenomena is visible throughout that part of the State of Maine covered by this study. In many cases these "blowdown mounds" can readily be seen from an automobile while riding along wooded roads. Several days of travel through the woods in this area is sufficient to convince one that these forests, at least since settlement, have been subjected to the force of winds of damaging intensity.

Most of the blowdown mounds in this area are relatively small (Fig. 8) compared to those observed at Harvard Forest and the mounds described by Goodlett (1951) in Pennsylvania. They average approximately 6 to 14 feet in length, 3 to 8 feet in width, and rarely over 3 feet in height, being usually oval shaped to circular in outline. The general orientation of the mounds is in a north-south direction with many of the associated crescent-shaped pits lying to the east. Exceptions to this may be found depending upon the local topography, since pits ordinarily occupy the upslope side of the mounds.

The older mounds have a definite flattened upper surface caused largely by weathering. In most cases their size indicates that they resulted from the uprooting of large live trees.

In a few isolated cases where mounds are found located in deep ravines or in small intermittent stream beds, erosion seems to have been very active in reducing the size of mounds. One such case is pictured in Figure 9 where the mound is almost entirely eliminated. This is the most striking example located and is probably exceptional.

Most mounds are covered with a thin layer of organic material with practically all of the older ones having partially developed profiles containing leached material. Buried profiles are easily identified by their still conspicuous zones of podsolization (Fig. 10). Identifiable remains of stumps on these mounds are generally lacking. Mounds resulting from the upheaval of pines still contain some remnants of these trees, a fact due largely to the resinous quality of the stumps. Nearly all species represented in the area were found growing upon mounds. Few mounds are found to be unoccupied, and for the most part, tolerant, as well as light-demanding species, are equally represented.

One very interesting fact was observed on a 1600 acre tract in Roxbury township. This tract contained an estimated 2 million b. f. of exceptionally fine pine timber consisting of tall, mature trees, widely scattered throughout a mixed hardwood and fir composition. Over two hundred trees were inspected and approximately 80% were found to be growing on old blowdown mounds. It is the writer's opinion that the greater part of the pine on this tract has gained its present position

Fig. 7. Old blowdown mounds and pits in pastured area cleared over 100 years ago.

Fig. 8. Typical blowdown mound resulting from the storm of 1883.

through the occupancy of small forest openings caused by wind. Its origin in other areas in admixtures with hemlock and hardwoods is also believed due to such cataclysmic events. Pinchot and Graves (1896) wrote the following account regarding the influence of such catastrophes on the distribution of pine and other species:

> "That bodies of Pine occur on land which the Hemlock would tend to occupy to its exclusion is often to be explained by the fact that, although it may once have been driven out, the Pine has returned in windfall clearing made by a storm. The same result would follow a devastating fire. Such accidents exert an undoubted influence on the mixtures and topographic distribution of species."

Although Maine suffered severely from the damage to its forests by the 1938 hurricane, the resulting blowdown mounds in this vicinity are relatively few compared to the number of older mounds of previous storms. The ages of trees growing upon these mounds showed that the majority of them germinated following two major storms, one occurring in the 80's, and the other falling very closely to the year of the "Great Fire" in 1816. An old copy of a local newspaper, the Oxford County Democrat, established the later of these two winds to have occurred in 1883. Bailey (1883), of Andover, Maine, has written the following account of this storm:

> "The storm came on in the evening of November 11, 1883, and raged all night, being a violent gale of wind with but little rain, the sky being clear part of the time. Owing probably to the hour, no lives were lost, though many barns were unroofed and chimneys blown down. But few cared to leave their houses, and many people put their fires out altogether. The tremendous unbroken roar of the wind filled the ears so completely that no sound could be heard and the largest trees were not heard to fall. The roads in all directions were so blocked up by them that several days were required to clear them for travel. The ground was not frozen so that in most cases the trees blew over, tearing the roots completely out of the ground. In some cases, however, they broke short off ... in the heart of the forest acres of great trees were carried over and lay as flat as grain after reaping."

Fig. 9. Decayed remains of a yellow birch which originated on a blowdown mound removed by erosion.

Fig. 10. Cross-section through blowdown mound showing the presence of leached materials in the partially developed profile and the definite zone of podsolization in the old buried profile.

A search for written evidence of similar storms in the earlier part of the nineteenth century met with little success. However, Perley (1891) has described a hurricane in 1815 as reaching into Maine. Brooks and Conrad (1945) mapped the courses of four New England hurricanes which included storms in 1821 and 1944 as well as the better known hurricanes of 1815 and 1938. The 1815 gale is the only one of these storms whose plotted path passes directly into this area. Although local writers have not recorded the effect of the wind damage on the forests of Oxford County in 1815, blowdown mounds and their associated vegetation indicate the probability of its presence.

Other mounds occupied by trees whose ages do not fall within these two previous classifications, imply the occurrence of local gales of damaging intensity which have received no publicity. Chase (1882) mentioned "severe gales" as having occurred in Woodstock on August 1, 1802 and October 9, 1804, the latter of these two being the same storm described by Perley (1891) as causing destruction to much of the forested area of New England. He writes the following regarding the damage:

> "The gale was very injurious to the pine and oak timber trees of the forests, destroying the larger portion of the best oaks that were useful in ship building. It has been said that so many of the great oaks were destroyed that the building of vessels declined in Massachusetts, and that the great gale of 1815 brought about its entire abandonment in several places. At Thomaston, Maine, a sixty-acre timber lot was almost entirely blown down. Such great sections of the woods were leveled that new landscapes and prospects were brought into view to the surprise of many people."

Many other storms in New England are acknowledged by Perley, including the oldest recorded wind of hurricane intensity, occurring in 1635, and described by Bradford (1901) in the following words:

> "This year, ye 14. or 15. of August (being Saturday) was such a mighty storm of wind & raine, as none living in these parts, either English or Indeans, ever saw. Being like (for ye time it continued) to those Haurricanes and Tuffins that writers make mention of in ye Indeas. It began in ye morning, a little before day, & grue not by degrees, but came with violence in ye begining, to ye amasmente of many. It blew downe sundry (211) houses, & uncovered others; diverce vessells were lost at sea, and many more in extreme danger. It caused ye sea to swell (to ye southward of this place) above 20. foote, right up & downe, and made many of ye Indeans to climb into trees for their saftie; it tooke of ye borded roofs of a house which belonged to the plantation at Manamet, and floted it to another place, the posts still standing in ye ground; and if it had continued long without ye shifting of ye wind, it is like it would have drouned some parte of ye country. It blew downe many hundered thowsands of trees, turning up the stronger by the roots, and breaking the hiegher pine trees of in the midle, and ye tall yonge oaks & walnut trees of good biggnes were wound like a withe, very strang & fearfull to behould. It begane in ye southeast, and parted toward ye south & east, and vered sundry ways; but ye greatest force of it here was from ye former quarters. It continued not (in ye extremitie) above 5. or 6. houers, but ye violence begane to abate. The signes and marks of it will remain this 100. years in these parts wher it was sorest; the moone suffered a great eclips the 2. night after it."

Winds comparable to that which occurred in November, 1950, would probably have received but little attention in the days of early settlement. However, the effect upon the forests in the path of such storms was probably of great significance from an ecological viewpoint. The young, second growth stands in New England today offer less resistance, thus being less vulnerable to attack, than were the trees of pre-settlement forests. Size alone aids in escape from the damage of winds. Had the mature timber blown down by the 1938 hurricane been exposed to the 1950 storm, probably much of it would have been similarly destroyed.

Many such storms have exerted their power upon the forests of eastern United States over the past 300 years. It is suggested that the accumulated force of these minor storms must be added to that of well known hurricanes to realize full appreciation of the overall influence of wind as an ecological factor affecting the forest vegetation.

SUMMARY

Evidence has been provided by previous geologic work that the State of Maine was completely glaciated during the Wisconsin stage of the Pleistocene Period. Most of the present microtopography of the state resulted from this glaciation and its associated periglacial climate. The 16,783,000 acres of Maine forests are growing upon soils originating from the surficial deposits on this modified topography. This study has shown that there is some relationship between these glacial deposits and the aeral extent of white pine. It has also implied a relationship between the quality of site and the underlying till or parent material.

Maine has experienced extensive fires causing serious devastation to its forests at least once during each of the last two centuries. The area covered by this study was not affected by these two major conflagrations, but it has been shown that fires of less spectacular nature have caused these forests to have been burned at least once since the arrival of the white man. The effect of these fires upon the succession, ecology and silviculture of certain forest types has far-reaching implications.

These investigations have brought to light the fact that the forests in this area and the soils that support them have been continually disturbed by wind. Blowdown mounds, resulting from the uprooting of trees, have been described and their influence upon the forest distribution discussed.

An attempt also has been made to describe the history of land use in order to acquaint the reader with what has happened to the forest lands of this section of Maine since early settlement.

Five factors have been touched upon by this study, namely: glacial origin of the soils, land use history, fire, wind, and the successional development of vegetation. An attempt has been made to draw attention to these factors, an acquaintance with which is deemed necessary to the success of applied silviculture in Maine forests.

CONCLUSIONS

This study has shown that a relationship exists between the glacial outwash deposits and the general distribution of the larger pine areas. Observations have also indicated a possible relationship between the type boundaries of white pine and the upper limits of kame terraces. Basswood in this area is entirely confined to rock-fragment slopes, and red oak assumes a position of dominance only on elevations of 1000-2000 feet where the till is thin and bedrock exposures are prevalent. The area within the scope of these investigations has been exposed at least once to extensive fires. It is suggested that this is the influential factor responsible for the origin of the heavily exploited pure stands of paper birch. Both the forests and the soils upon which they grow have been continually disturbed by wind for the past 300 years and possibly since the retreat of the continental ice sheet and the subsequent occupation of the glaciated region by forests. It is believed that many of the changes in the forest vegetation are due to this factor.

APPENDIX

THE GEOLOGY OF MAINE

PREVIOUS GEOLOGIC WORK IN MAINE

The first geological survey of the State of Maine was conducted by Charles T. Jackson in 1836, '37 and '38. This survey was rather comprehensive and covered much of the state. The results were published as 1st, 2nd, and 3rd Reports and 1st, 2nd, and 3rd Annual Reports of the State Geologist. These reports are written in travelog form depicting many observations, some of which are of value today.

In 1861, a second survey directed by C. H. Hitchcock was authorized by the Maine legislature. The results of this survey were included in the Sixth and Seventh Annual Reports of the Maine Board of Agriculture. According to Trefethen (1947), the most notable contribution of Hitchcock, resulting from his work as State Geologist, was the publishing of the first geological map of the state. This is found in the Colby Atlas of Maine, 1885 edition.

The Hitchcock survey was not continued and the office of State Geologist was vacant until 1910. At this time, Freeman Burr was appointed State Geologist and carried on geological work in this capacity until 1920.

Nine years later, Lucius Merrill was named State Geologist and E. H. Perkins, Assistant State Geologist. In 1931, J. C. Twinem replaced Merrill and Burr again served for the period 1933-42. Merrill and Perkins, also Twinem and Perkins, issued reports. In 1932, the Bibliography of Maine Geology compiled by Twinem was published, and a year later Arthur Keith and Perkins completed a preliminary geologic map of the state. (See Plate I.)

Burr retired in 1942 and the present State Geologist, Joseph M. Trefethen, was appointed. The State Legislature subsequently enacted a bill placing the State Geological Survey under the Development Commission, thus removing it from politics.

The function of the Survey today is fundamentally to collect information on the rocks, minerals, ores, and scenery of the state and to make this information available to the public. It is hoped that the Pleistocene studies will be expanded in the future. The results of these studies in the past have been of particular value in construction projects, especially highway construction, reconstruction, and maintenance . In this connection, the work of Perkins and Leavitt is outstanding. Construction engineers, geologists, and laymen have realized for years the need of more geological surveys in Maine so that the location of suitable materials for the building of highways and structures might be known. The Maine Technology Experiment Station at the University of Maine, in cooperation with the Maine State Highway Commission, drew up a plan which would in this respect render service to the State. The plan was to make a survey of the glacial road materials within the state which might also be useful in building construction. Field work was begun in June, 1930, under the direction of Prof. Walter Leavitt, Secretary and Engineer of the Maine Technology Experiment Station, and was completed in July, 1933. Dr. Edward H. Perkins, Assistant State Geologist and Professor of Geology at Colby College, was given charge of the geological work of the survey.

The results of this survey were published as a Maine Technology Experiment Station Bulletin entitled "A Survey of Road Material and Glacial Geology of Maine." This is the Experiment Station's thirtieth bulletin and consists of two volumes, namely:

Vol. I,	Part I	A Survey of Road Materials of Maine; Their Occurrence and Quality
Vol. I,	Part II	Maps showing Location of Road Materials
Vol. II		Glacial Geology of Maine
Vol. II,	Supplement	Map of Glacial Deposits of the State of Maine (See Plate II.)

To the best of the writer's knowledge, Vol. II is the only existing publication dealing entirely with the glacial geology of Maine. It is from this bulletin that much of the descriptive background of this thesis is drawn.

Table I. Geologic Time Scale for Maine[2]

Era	Period	Important Features	Events in Maine
Cenozoic	Recent	Development of man	Slight erosion; uplift to present coastline
	Pleistocene	Glaciation	Submergence and glaciation
	Tertiary: Pliocene	Age of Mammals	High elevation and rapid erosion
	Miocene	Age of Mammals	Erosion and uplift
	Oligocene	Age of Mammals	Erosion of higher levels; uplift
	Eocene	Development of mammals	Erosion and uplift
Mesozoic	Cretaceous	Coming of modern plants Climax of reptiles	Plane completed and uplifted
	Jurassic	Age of Reptiles	Long erosion
	Triassic	Coming of dinosaurs Formation of Conn. and Fundy Basins	Formation of trap dikes
Paleozoic	Permian	Glaciation Appalachian Revolution	Folding; granite intrusions
	Pennsylvanian	Coal Age	Sediments in York County
	Mississippian	Age of Sharks	Perry and Mapleton sandstones
	Devonian	Age of Fish First amphibians	Mountain folding Granite intrusion Moose River and Chapman sandstones Volcanics
	Silurian	First air-breathing animals	Shale and limestone depositions; volcanics
	Ordovician	Age of Invertebrates	Shale; Rockland and Lewiston limestone
	Cambrian	First good fossils	Quartzites and shales
Pre-Cambrian			Highly altered rocks; gneisses and schists

2. Perkins, E. H. 1935. Glacial Geology of Maine.

BEDROCK GEOLOGY OF MAINE

In order to establish a background for the research of this paper, the bedrock as well as the glacial geology of the area should be considered. Although it is with the unconsolidated materials of the earth's crust which were deposited by glaciers and their associated streams that this paper largely deals, it must be kept in mind that these materials were derived, directly or indirectly, from the bedrock and are in many instances today bedrock controlled.

The three classes of bedrock material, segregated according to their method of formation, are igneous, sedimentary, and metamorphic. Rocks are also classified according to their age. Table I shows the principal divisions of geologic time together with some of the more significant geological events that are recorded in Maine.

Keith's "Preliminary Geologic Map of Maine" (Plate I), although lacking in detail, furnishes a generalized knowledge of the different periods and the types of rock in each period. This information is probably sufficient for this paper. However, a brief outline will be given of the present knowledge of the bedrock geology of the state as indicated on the map. Only the igneous and sedimentary rocks will be discussed, the metamorphic being a derivative from one or both of these types.

Igneous Rocks

The common igneous rocks of Maine may be divided according to their chemical and physical characteristics into four types: diabase, rhyolite, granite and basalt.

Diabase. In the northern and western sections of Maine there are a series of flows and ash beds which are mapped as diabase and amygdaloid.

These rocks have been altered largely into chlorite schists and most of their original structure has been destroyed. In Quebec on the north, a series of similar rocks are considered to be of Ordovician age. The schist in the region of Chain Lakes between Eustis, Maine, and Woburn, Quebec, greatly resemble the Canadian rock and may also be of Ordovician age. Other altered diabase rocks are associated with Devonian and Silurian sediments and were probably formed during these periods.

Rhyolite. Rhyolite flows and intrusions associated with breccia and tuff are found in three areas of Maine. The first follows the coast from the Penobscot Bay to Eastport where it is associated with rocks of Silurian period. The second area is associated with the Devonian sandstone of central Aroostook County and is of late Devonian age. The third and largest belt follows the Devonian syncline from Franklin County northeastward to northern Aroostook. These are intruded in Devonian sandstone and are probably of late Devonian or Carboniferous age. Mt. Kineo on the shore of Moosehead Lake is an example of this mass.

Granite. The exact age of the granite intrusions in Maine is not known. In the Eastport region the granites cut rocks of Silurian age, while the Perry conglomerates, believed to be of Mississippian age, contain pebbles of similar granites. Throughout the remainder of the state where age can be determined, the granites which appear older are associated with rocks mapped by Keith as pre-Cambrian. Also, some granites cut rocks of Pennsylvanian age and the appearance of other masses indicate intrusions in the late stages of the Appalachian Revolution.

Basalt. Basalt occurs in Maine only as dikes which are all too small to be shown on a map of the scale of Keith's. These dikes

resemble the Triassic flows and it is believed that most of them, particularly those along the coast, were formed during the Triassic period. To the best of the writer's knowledge, no rocks younger than Triassic have been found in Maine.

Sedimentary Rocks

Perkins (1935) states that all of the sedimentary rocks in Maine are of the Paleozoic era with the exception of the pre-Cambrian. They may be classified according to their geologic age as follows: pre-Cambrian, Cambrian, Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian.

Pre-Cambrian. The western and southern parts of Maine are composed of highly metamorphosed rocks classified on the map as pre-Cambrian. They consist of schists, gneisses, slates, and limestone representing sedimentary rocks altered by heat and pressure.

Cambrian and Ordovician. Bands of quartzites and argillites with imbedded black and grey slates trend southwest and northeast. These appear to be older than Silurian and are mapped as Cambrian and Ordovician. Age has been determined largely by structural relations, few fossils of either Cambrian or Ordovician having been found in the state. According to Perkins (1935), evidence provided by the Quebec Survey now indicates the presence of Ordovician rocks in the northern part of the state which is mapped as Silurian. Undoubtedly other sections of northern and western Maine contain Ordovician slates but fossil evidence is lacking.

Silurian. Most of central and northern Maine is covered with slates, shales and sandstone which pass into quartzites and impure, shaly limestone. Fossil evidence establishes the age of these sediments as Silurian.

__Devonian__. Most of the Devonian rocks in the state are found in the synclinal basin entering Maine in northern Aroostook County and passing southwestward through the Moosehead Lake region, ending in the granite intrusions in northern Franklin and Oxford Counties. Some shales and slates are found in this area but most of the formations are brown and gray sandstone of Lower Devonian age. The beds in the Moosehead Lake region are called Moose River Sandstone, and fragments of these rocks have been carried south and east by the glacier. Another area of Devonian in Aroostook County near Presque Isle is fossiliferous and is called the Chapman Sandstone.

__Mississippian__. There are two areas of red conglomerate and sandstone in Maine: the Perry Sandstone, northwest of Presque Isle, and a smaller area located in Mapleton. The Perry Sandstone rests upon Silurian rock and contains granite pebbles of Devonian age. It has been placed in the Upper Devonian because of the evidence provided by plant fossils. Areas of similar rock occur in New Brunswick and have been considered to be of Mississippian age. Because of the period of earth movement in the late Devonian, followed by the erosion and deposition of red sandstone in the maritime provinces in the Mississippian time, the Perry conglomerate is considered to be of the same age. The Mapleton Sandstone classification is somewhat comparable. Earth movement occurred between the sandstone and Devonian sediments upon which it rests, thus causing it to be considered as an outlier of the red sandstone in New Brunswick which is of Mississippian age and rests similarly upon folded Paleozoic sediments.

__Pennsylvanian__. A series of slates, phyllites, quartzites, and impure limestones have been mapped in York County. The age has been

determined by the tracings of quartzites and phyllites into similar formations in the neighborhood of Worcester, Massachusetts, which contain Pennsylvanian fossils.

SHAPING OF THE PREGLACIAL SURFACE

No sediments were laid down in the State of Maine after the deposition of the Perry and Mapleton sandstones until the deposition by the glacier in the Pleistocene period. The period of time, estimated as 140,000,000 years of the Mesozoic or medieval life, and 60,000,000 years of the Cenozoic era or modern life, is recorded in rock structure and surface topography rather than in sediments.

The Paleozoic era ended in a great mountain-making movement known as the Appalachian Revolution. Mountains were folded up in a belt extending from the southern states across southern Maine and eastward through Nova Scotia and New Brunswick.

This period of earth movement was followed by erosion during which the mountains and land were reduced to a plain dotted with hills. Faulting occurred and the Connecticut Valley was formed to the west of Maine, and the Fundy Valley to the east. During the Triassic period, volcanic activity occurred, pouring out floods of lava into these basins. If such lava flows occurred in Maine, they have been eliminated by erosion. The basalt dikes occurring along the Maine coast are similar to those in the above mentioned basins and may have been feeders for lava flows long since removed. These dikes cut all other formations and are the youngest bedrock in the state. Late in Triassic and early in Jurassic time, movements again occurred in the earth's crust to the east and west of Maine, resulting in the formation of mountains comparable to those existing in the southwest at the present time. It is quite possible that similar faulting occurred in Maine but up to the present time it has not been recognized.

A long period of stability followed this movement during which New England was reduced to a great peneplain with many low hills. Erosion continued throughout the Purassic period and was practically completed by early Cretaceous time. No evidence of Cretaceous sediments have been found in Maine. It is possible that Mt. Katahdin represents an unreduced remnant of the great New England plains formed in Jurassic and Cretaceous time. As the Cretaceous and younger sediments were stripped from the plain, ridges were developed with steep slopes facing inland and gentle slopes facing seaward. These ridges have been called cuestas. Cuesta banks covered with glacial drift have been identified off the coast of Maine. The Cretaceous peneplain may slope from an elevation of approximately 5000 feet in the White Mountains to the base of the cuesta banks in the Gulf of Maine, with the Cretaceous surface at one time passing above the present Maine topography.

At the end of the Cretaceous period, crustal stability ended and a renewed uplift tilted the Cretaceous peneplain to the east and west and renewed the streams. The Cretaceous erosion was thereby renewed along the eastern margin of the deposits and materials were redeposited seaward. These deposits are buried beneath the sea at the edge of the continental shelf.

Intermittent uplift continued through the Tertiary period and probably reached a climax in the early Pleistocene prior to glaciation. Maine probably stood higher than it does today and extended out on the continental platform several miles east of the now existing coastline. Buried gorges extending below sea level give evidence of this high stand. At the time of the last uplift, the topography of the State of Maine is considered to have reached a stage of maturity. The mature stage in the cycle of geographical development described by Davis (1909) assists in the portrayal of the drainage system of Maine at this time.

> "In maturity, the relief retains much of the intensity of adolescence and adds thereto a great variety of features. The valley lines are closely adjusted to the structure of the region, this condition having been gained by a delicate and thorough process of natural selection, in which the most suitable drainage lines survive, and the less suitable ones are shortened or extinguished. The impetuosity of youth has disappeared; all the larger streams have developed grades on which their ability to do work is nicely adjusted to the work which they have to do; the lower courses already show signs of age, while the upper twig-like branches are relatively youthful. The whole drainage system is earnestly at work in it's task of base-leveling the region, and the forms that the region has assumed bear witness to the close search made by the streams for every available line of effective work."

This maturity is evidenced today by the gently rolling hills and broad valleys, the bottoms of which are filled with glacial outwash and marine clays. Deep and narrow gorges indicate rapid uplift and erosion for a short time previous to the ice advance.

Studies have shown the existence of canyons on the edge of the continental shelf off the coast of Maine. These are believed to be several thousand feet deep and appear to have been carved by rivers. If these canyons were rivers carved above the level of the sea, then it is logical to assume that the elevation of Katahdin and the Moosehead Plateau were several thousand feet higher in the past than they are today. This great uplift undoubtedly influenced the climate and was instrumental in introducing the ice age to New England. Maine could very well have had glaciers in the valleys of the higher mountains prior to the main ice advance from Labrador. Fenneman (1938) states that the Katahdin region contained outmoving valley glaciers whose direction of movement was unrelated to that of the general ice sheet.

GLACIAL EROSION

Dutton (1881) describes glacial erosion as the result of two complex processes. "The first group comprises those which accomplish the disintegration of the rocks, reducing them to fragments, pebbles, sand and clay. The second comprises those processes which remove the debris and carry it away to another part of the world. The first is called disintegration; the second, transportation."

The advancing ice of the continental glacier exerted an erosive force which is evidenced by a comparison of rocks south of the glacial limits with those in the glaciated area. In Maine, the surface rock is solid and undecomposed while the ledges in the southern states are weathered and decomposed for a depth of several feet. During the Tertiary period when the present topography was being formed, Maine probably became covered with a residual, decomposed rock similar to that present today south of the glaciated area. This was removed by the advance of the ice sheet and today the bedrock below the glacial deposits is largely solid with little indication of weathering. There is little or no evidence of preserved preglacial soils in Maine.

The scouring and plucking action of the glacier removed the weathered rocks and cut into the solid rock beneath. Rocks and sand in the bottom of the glacier left parallel scratches on the bedrock known as striae. The best striae in Maine are found on slate and shale. However, quartz veins carry striae when marks have disappeared from surrounding rocks. As striae offer the best evidence of direction of ice movement, a map showing the direction of the marks (Fig. 11) indicates the direction of the latest movement of the ice over the state.

Glaciated ledges often have a characteristic slope. The side facing the ice movement is apt to be smoothed to a gentle slope, while on the opposite side, where plucking is more active, the slope is steeper and may be cliffed. Such ledges of "roche moutonnée" form are common in Maine and are useful in determining the direction of ice movement where striae are lacking. Von Engeln (1948) states that "the roche moutonnée unit is representative, in miniature, of all the phenomena of glacial erosion." Mountains which have been glaciated often take on this form. Such examples in Maine are Mount Kineo, near Moosehead Lake; The Bubbles, on Mount Desert Island; Mount Blue, in Avon; and De Boulie Mountain in Northern Arroostook.

The erosive power of glaciers is increased by being forced through valleys and between mountains. A glacier moving down a valley erodes the side walls as well as the bottom and gives a U-shaped profile to the valley. These valleys are characterized by flat floors, steep side walls and truncated spurs. Although Maine is not rugged enough for the most characteristic development, many may be found in the state. The Little Black River valley in the Allegash region is an example of a characteristic glaciated valley and is undoubtedly preglacial. Others may be found in the Katahdin region, on Mount Desert Island, and in the hilly western part of the state.

Fjords are glaciated valleys submerged by the sea. Although the Maine coast has been called a fjord coast, investigations of the submerged valleys indicate that very few of them have distinct glacial features and are probably drowned rivers rather than glacial valleys.

Formation of certain features by valley glaciers are distinguishable from those formed by continental ice sheets. Cirques, the most

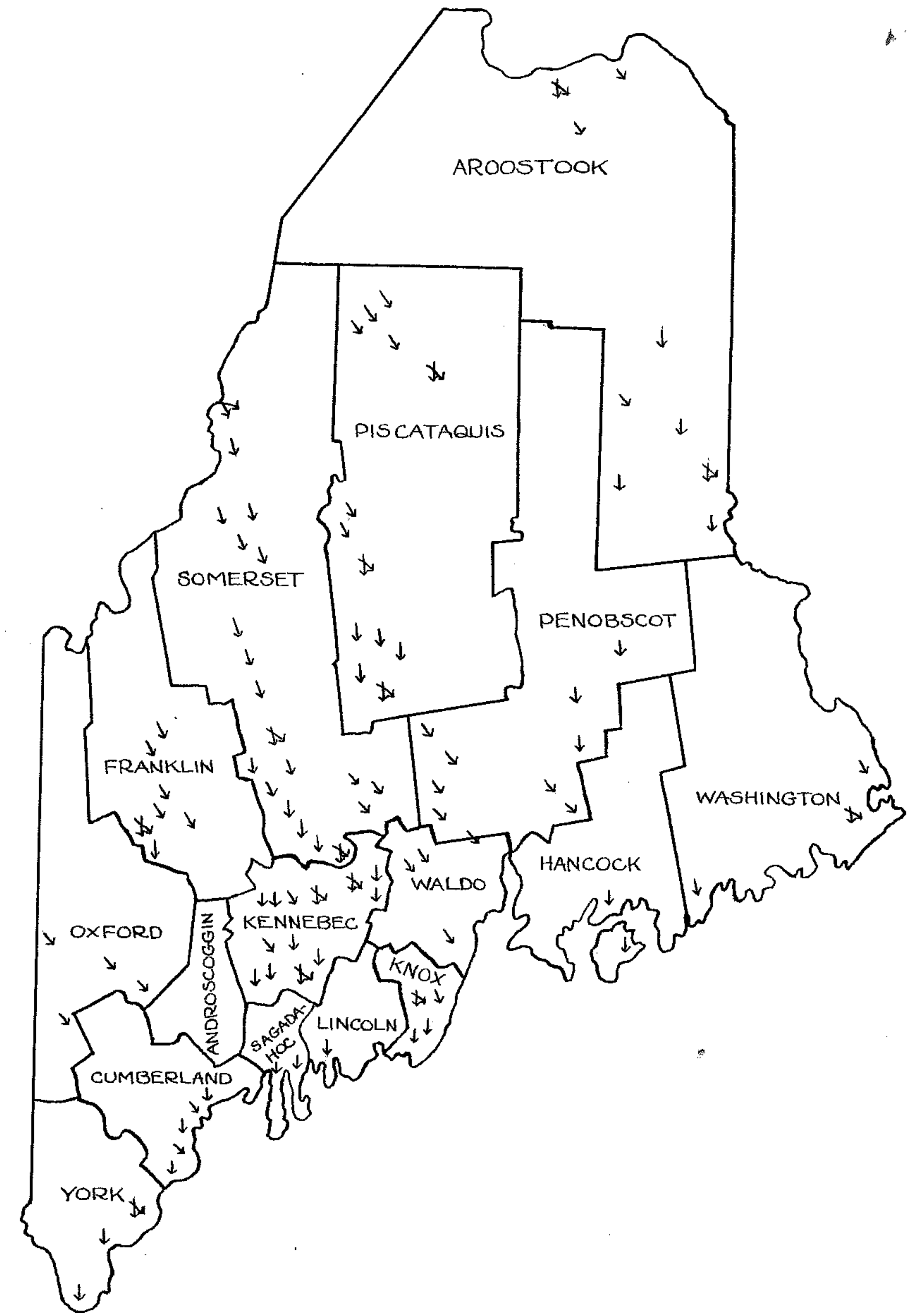

Fig. 11. Direction of glacial striae in the State of Maine as mapped by Perkins.

characteristic of these forms, are amphitheater-shaped valleys with steep head and side walls and flat floors eroded into a series of steps. The best developed cirques in Maine are those of the Katahdin region and of the mountains in the western part.

It is believed that glacial erosion played a minor role in shaping the present topography of Maine. Glacial valleys follow former river valleys; mountains have been smoothed and a few cirques have been formed. Perkins (1935) has classified the microtopography as glacial and the macrotopography as preglacial.

GLACIAL DEPOSITS

It has been estimated that at least 90% of the present surface of Maine is covered with glacial drift. This drift has been divided into two types, unstratified drift or "till" and stratified drift or "wash."

Till

Till, which is characterized by the lack of bedding or sorting, is composed of whatever material the glacier happened to obtain at the time of deposition. The distribution of till in Maine is related to the topography, being very thin on the upland and as deep as fifty feet in the valleys. It is entirely lacking on many of the higher mountains and on the ledges near the coast. Till is characterized in the shale regions by its heavy clay content and in granitic regions by boulder field formation. The material in most Maine tills is largely local. Perkins (1935), in his count of till composition in southern Maine, found an average of 70% strictly local material. Eskers in the same region showed a representation of local material of only 30%.

Stones and boulders of different character from that of the rocks upon which they rest have been called "erratics." Many large erratics have been found throughout the state, and erratic stones and pebbles have been found by Tarr (1900), Smith (1928), and Antevs (1932) on the summit of Mt. Katahdin. From the evidence provided by these men, it has been concluded that this peak, the highest in the state, was completely overridden by the last ice sheet.

Bands of boulders which have been named "boulder trains" are often carried by glaciers and deposited over a region in the general direction of ice movement. Many such boulder trains are found in

Maine and they are of interest in indicating the direction of glacial movement.

Till, which has been modified by the ice traveling over it, often has a hummocky appearance and is known as "ground moraine." Special forms of ground moraine such as drumlins and till terraces are of particular interest.

Drumlins are elongated masses of till smoothed by ice and having a streamlined appearance. Drumlins consisting of bedrock veneered with a thin layer of till have been referred to as "rock drumlins." Most drumlins in Maine are of the true type consisting only of till and are found largely in two areas, one being in the extreme southwestern part of York County and the other in the northeast corner of Aroostook County.

Perkins (1935) has classified another topographic development of Maine tills as "till terraces." These occur along the sides of higher valleys above the kame and river terraces. In the Androscoggin and Swift River valleys, in the vicinity of Rumford, all three kinds of the above terraces are represented.

End moraine, also known as terminal moraine, has been defined by Flint (1947) as a ridge-like accumulation of drift along the terminal margin of a glacier or the margin of an ice sheet. It is typically built of till but as in the case of ground moraine, may contain stratified material. Typical end moraines of till are said to be lacking in Maine.

Wash

Much of the glacial drift in Maine, especially that in the valleys, was worked over by melt-water from the glacier. The water-laid material was deposited in swift streams or quiet water and may have been disturbed

by drifting ice masses. Drift material was deposited in deep valleys and open plains, in deep or shallow water. Because stratified drift was deposited by water action, most of it is to be found in the valleys, whereas the till or unstratified material covers the hills. The lowlands of the south-central part of Maine were covered by the sea in Pleistocene time; therefore most of the stratified deposits there are covered by marine clays. Inland, in the hilly portion of the state, stratified drift is confined to the valleys in which it was deposited around gradually melting tongues of ice.

Moraine Banks. The frontal glacial deposits in Maine have the form of smooth, hummocky ridges with contact slopes on one side and gentle sloping wash plains on the other. These deposits have been named "moraine banks." The best sample of these in Maine is a series of moraine banks in the southwestern part of the state known as the Newington Moraine.

Outwash. In Maine extensive areas of wash plains were formed by the discharge of the finer materials from the ice front by melt-water. The largest wash plains in the state are found in Washington County. Other extensive plains of sand and gravel in York County merge with and are covered with marine clays.

Depressions in outwash plains caused by the melting out of buried ice blocks are known as "kettles." Most of the small ponds in Maine, and some of the larger lakes, are believed to have originated in this manner. Kettles may in time become filled with vegetation and pass into the bog stage. The plain in front of the terminal moraine in the Sebago Lake region is pitted with these depressions.

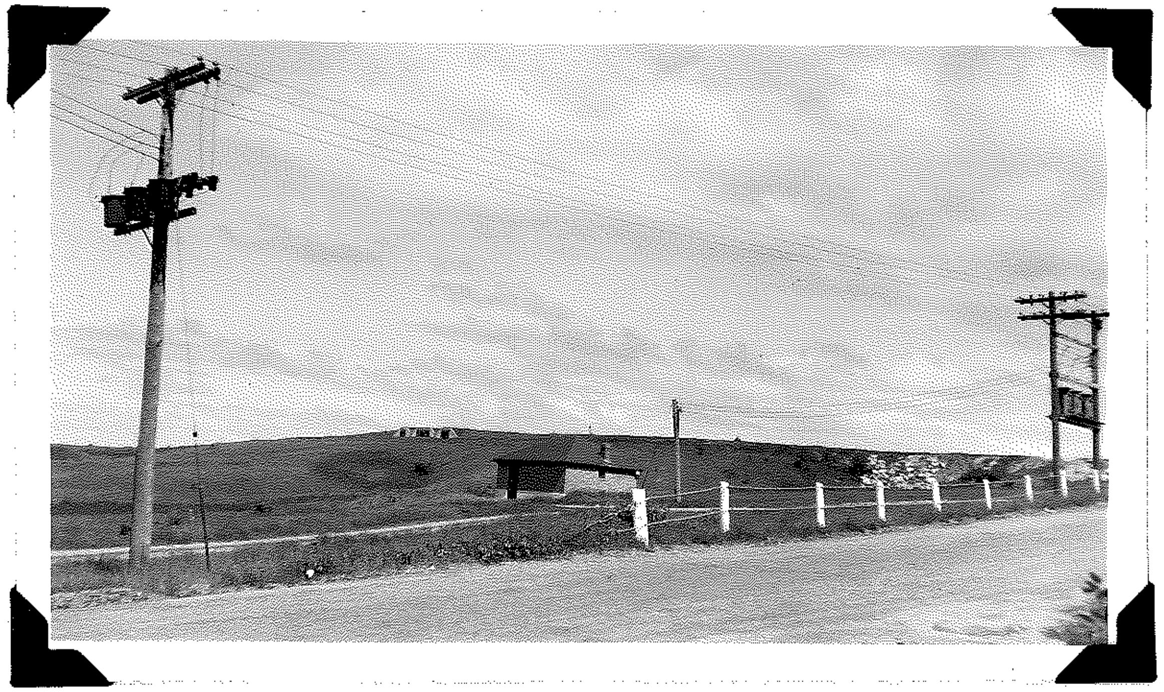

Fig. 12. View of esker delta at Augusta, Maine, looking north from U. S. Highway 202.

Fig. 13. Wooded kame near North Woodstock, Oxford County, Maine.

After the outwash sediments were deposited, the plains were elevated above their original formation level and streams began to flow over their surfaces. Rivers entrenched themselves toward their present level, and stream terraces were formed along the sides of the valleys. These terraces may be distinguished from kame terraces by their more regular stratification and the curved meander scars along their fronts. All of the larger and many of the smaller rivers of the state have terraced valleys of this type.

Deltas. Deltas are deposited where a stream loaded with sediments discharges into a large body of water. "Glacial deltas" are formed by streams discharging from a glacier into a lake or sea. "Stream deltas" are formed where land streams enter a body of water. A third type, "esker deltas," (Fig. 12) is probably the most common in Maine. The upstream parts of these deltas were built against the glacier terminus and with the melting of the ice, the sediments slumped away, altering the delta form. Aside from this, esker deltas differ little from stream or glacial deltas. Deltas are common in Maine, ranging in size from small forms to large massive deposits.

Kames. Kames are low, steep-sided hills of detached ice-contact stratified drift appearing as knolls, mesas, or ridges. (Fig. 13) Those with ridge-like appearance have been termed "crevasse fillings," and when sufficiently elongated pass into eskers. Kames are often closely related to eskers and may form a part of an esker system. Maine is dotted with several sizable kame fields. (See Plate II.)

Kame Terraces. Kame terraces have been defined by Flint (1947) as accumulations of stratified drift laid down chiefly by streams between a glacier and an adjacent valley wall and left as a construc-

Fig. 14. Section of esker, Bryant Pond, Maine.

tional terrace after the disappearance of the glacier. These terraces often resemble eskers which have swung against valley walls. Well developed kame terraces have been found in the upper Androscoggin and Kennebec River valleys.

Eskers. The most characteristic glacial feature of the state is the esker, known locally as "whaleback" or "horseback." No other place in the world can boast of better eskers than the State of Maine. Bowman (1900) gives a colorful description of Maine eskers in saying:

> "... they represent channel deposits of subglacial and englacial streams that discharged across the zone of wastage of the continental ice sheet. They form a not inconsiderable part of the total area and are conspicuous relief features, often extending for miles without a break of any sort and with even summits, again crossing hills and valleys, the level undulating in sympathy with the general topography."

The typical esker form is a narrow-topped ridge with steep sides and may be continuous for miles, with few gaps and more erratic stones present as it is traced upstream. Mountains are crossed by esker systems at lod saddles, gaps, or cols, and at these crossings eskers are very apt to be discontinuous. A typical esker structure (Fig. 14) consists of irregular bedding of fine and coarse materials. Eskers were probably formed during the late stages of ice recession after all movement in the region of esker deposition had ceased. This seems to be the most logical explanation of the presence of long ridges of undisturbed stratified gravel that cross the direction of ice movement. In western Maine, the relation of the kames to the eskers shows this same thing.

Much of the southern part of the state was beneath the sea and the lowlands filled with clay during the later part of the glaciation period. In this region the glacial deposits of the esker systems of the larger valleys became mantled with clay. In many cases it is evident that these eskers are pre-marine and have been subjected to wave erosion.

In the extreme southwestern part of Maine, in York County, eskers are almost entirely lacking, only an occasional ridge projecting through the marine clay. Farther inland, in the hilly region, eskers are more common and are associated with kame terraces. In the coastal region, in eastern Maine, eskers have the appearance of discontinuous kame-like ridges in the river valley sand plains. As one progresses farther north, eskers appear to be more continuous following the north-south valleys. Some of the longest eskers in the world are found in the southern part of Aroostook County.

MARINE CLAYS

Glacial erosion produced not only sand and gravel but also large quantities of rock flour. Because of its fineness, much of this rock flour was carried out into the sea and deposited as marine clay. Most of the clay that covers the southern and central regions of Maine was deposited in the sea that covered that part of the state in post-glacial time. Marine clays are identified by their contents of marine fossils and by lack of varves or banding. Marine clays in Maine have also been divided into two types according to their color. Both of these types, brown and blue-gray, are underlain by sand, bedrock or till, and in many places the blue-gray underlies the brown clay. Marine clays occur at elevations as low as ten feet along the present shore. Inland from the shore the clays are found in the valleys at increasing elevations to the north, the highest being over 400 feet. The clays do not cover the entire coastal area but are restricted to the valleys. In 1948 Goldthwait (1949) attempted a more exact location of the northerly limits of the marine clay area (Fig. 15). This limit is still considered unsatisfactory as much of the clay is covered with other deposits.

AEOLIAN DEPOSITS

Dunes. Toward the end of the marine invasion period uplift of the land occurred, resulting in the retreat of the sea to beyond its present shoreline. Sand deposits were washed out by rivers over the mud flats and formed the great sand plains of the larger river valleys. Little seems to be known of the Penobscot sand plain as most of it is covered with forests. The Kennebec sand plain covers marine clays from Bingham south to Norridgewock, from which point the main mass extends southward and an eastern arm continues nearly to Augusta. The great sand plain of the Androscoggin extends south and east, covering all of the area now drained by the lower Androscoggin and Kennebec Rivers. Exposure of these great sand areas to wind action resulted in dune formation. Wind is still active in several parts of the state, the Desert of Maine at Freeport being the most widely known.

Loess. Loess has been referred to by Smith and Fraser (1935) as fine-grained, non-stratified deposits formed by the settling of dust particles from the atmosphere. The bulk of the loess is regarded by most geologists to have been transported and deposited by wind.

According to Bryan (1950), our knowledge of loess dates back to Richthafen's (1877) study of dust storms in China. Where the loess of glaciated regions has been closely studied it has been found that it becomes finer textured and thinner with increasing distance from its source. It has also been found that the mineral content of the loess resembles that of the corresponding size-grade fraction of till in the same region.

Active outwash plains provided a source of fine sediments for the

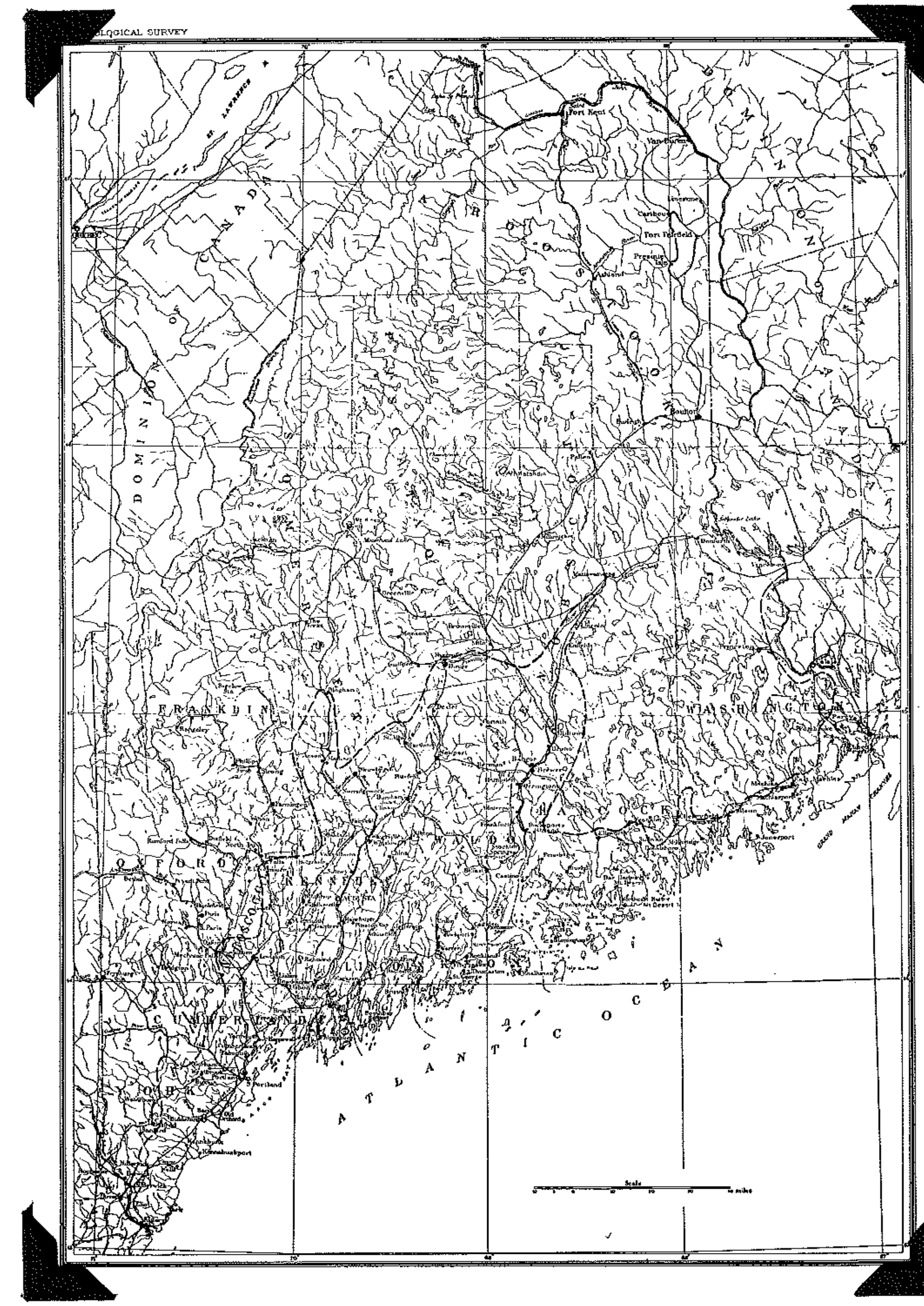

Fig. 15. Preliminary map showing the extent of marine clays in Maine.

accumulation of loessal deposits during the Pleistocene epoch. Although these deposits are not known to be common in Maine, certainly the large areas of glacial outwash could have provided sufficient source material for extensive loess deposits over much of the state. Up to the present time, these deposits have been found only in York County capping the drumlins, till deposits, and gravel plains.

****

The following brief historical summary of the late Pleistocene of the Androscoggin, Kennebec, and Penobscot valleys by Trefethen (1947) is of assistance in visualizing the order of deposition of the glacial deposits previously discussed.

HISTORICAL SUMMARY OF THE LATE PLEISTOCENE OF THE ANDROSCOGGIN, KENNEBEC, AND PENOBSCOT VALLEYS

1. Advance of the major ice sheet, burying all of Maine and extending beyond the state limits, accompanied by a lowering of the sea level. At this time most of the glacial erosion and deposition took place.

2. Retreat of the ice -- deposition of outwash sediments.

3. Advance of the sea inland to an elevation of 400 feet or more above the present sea level.

4. Deposition of the marine clays in sheltered and quiet waters of the embayments fed by melt water of the ice containing rock flour.

5. Occupancy of clay bottoms and flats by marine organisms.

6. Readvance of relatively thin and weak ice sheet. Erosion slight and till deposits thin. Stagnation and dissipation of the ice tongues; formation of principal esker system. In part, the reworked marine clays of the earlier marine stages form a very clayey till easily mistaken for marine clay.

7. As the ice melted back, as well as downwards, a second marine invasion inundated the land and locally washed the ice front; esker deltas were built, and on the tidal flats the brown clays formed, while in the estuaries of deeper water, a second marine clay was deposited.

8. Withdrawal of the seas, accompanied by wave action, wind, and stream work, modifying and removing parts of earlier deposits.

Table II. Classification of the Pleistocene Period
Modified from Perkins (1935)

Stage	Substage	Duration of time in years
Recent		25,000
Wisconsin Glacial	Mankato	25,000
	Cary	
	Tazewell	
	Iowan	3,000
Sangamon Interglacial		120,000
Illinoian Glacial		9,000
Yarmouth Interglacial		300,000
Kansan Glacial		7,500
Aftonian Interglacial		200,000
Nebraskan Glacial		7,500

THE GLACIAL PERIOD IN MAINE

The Pleistocene represents a period of glaciation and refrigeration not only in Maine but throughout most of the world. The glaciers covering Maine were only a part of a series of continental glaciers. The glacial period consisted of several stages of glaciation separated by stages of deglaciation. Table II shows one classification of these stages. Maine glaciers probably all belonged to the last or Wisconsin stage. There is little evidence of pre-Wisconsin glaciation, although Sayles and Antevs (1927) reported the presence of three tills in southern Maine suggesting an age older than Wisconsin, possibly Illinoian.

There were probably two ice advances in Maine as was noted in the previous summary from Trefethen. Distribution of gravels, direction of striae and the relationship of marine clays to gravels in eskers lead to this conclusion. According to Perkins (1935), there is not enough difference in age to place these two movements in two separate stages, and they may have occurred in the same substage. Goldthwait (1951) considers all surficial deposits in Maine to be Mankato.

LITERATURE CITED

Anderson, J. G. 1906. Solifluction, a component of subaerial denudation. J. of Geo., Vol. 14, pp. 91-112.

Antevs, Ernst. 1932. Alpine Zone of Mt. Washington Range. Merrill and Webber Co., Auburn, Maine.

Bloomberg, W. J. 1950. Fire and Spruce. Forestry Chronicle, Vol. 26, No. 2, pp. 157-161.

Bowman, Isaiah. 1911. Forest Physiography. John Wiley & Sons, N. Y.

Bradford, William. 1901. Bradford's History "of Plymouth Colony." (from the original manuscript) 555 pp.

Brooks, C. F. and C. Chapman. 1945. The New England Hurricane of 1944. Reprinted from the Smithsonian Report for 1945. Pub. No. 3825, pp. 235-246.

Bryan, Kirk. 1946. Cryopedology, the study of frozen ground and intensive frost action with suggestions on nomenclature. Am. J. of Science, Vol. 244, pp. 622-642.

" 1950. Annals of the Assn. of Amer. Geographers, Vol. XL, No. 3.

Butler, A. P. and L. L. Ray. 1946. Modern Polygonboden formation in Maine. Abstract, Bul. Geo. Soc. of Amer., Vol. 57, pp. 1183-1184.

Cary, Austin. 1936. White Pine and Fire. J. of F., Vol. 34, pp. 62-65.

Chase, Stephen. 1882. Excerpts from personal diary covering period 1801-1806. Published in Lapham's History of Woodstock, Maine.

Crosby, I. B. 1922. Former Courses of the Androscoggin River. J. of G., Vol. 35, pp. 232-247.

Davis, W. M. 1909. Geographical Essays. Ginn & Co., Boston, Mass.

Dutton, C. E. 1881. United States Geological Survey, Second Annual Report.

von Engeln, O. D. 1948. Geomorphology, systematic and regional. The Macmillan Co., N. Y.

Fenneman, N. M. 1938. Physiography of the Eastern United States. McGraw-Hill Book Co., Inc., N. Y.

Flint, R. F. 1947. Glacial Geology and the Pleistocene Epoch. John Wiley & Sons, Inc., N. Y.

Goldthwait, L. 1949. Report of the State Geologist, 1947-48. Maine Development Commission, Augusta, Maine.

" 1951. Personal correspondence.

Goodlett, John C. 1951. The Vegetation of Potter County, Pennsylvania. Unpublished doctoral thesis, Harvard Univ., Cambridge, Mass.

Jackson, Charles T. 1839. Third Annual Report on the Geology of Maine.

Lapham, W. P. 1882. History of Woodstock, Maine.

" 1890. History of Rumford, Maine.

Lutz, H. J. 1940. Disturbance of Forest Soils Resulting from the Uprooting of Trees. Yale Univ. School of Forestry Bul. No. 45.

Lutz, H. J. and F. S. Griswold. 1939. The Influence of Tree Roots on Soil Morphology. Am. J. of Science 237 pp. 389-400.

Maissurow, D. K. 1935. Fire as a Necessary Factor in the Perpetuation of White Pine. J. of F., Vol. 33, pp. 373-378.

Nichols, R. L. and F. Nichols. 1936. Polygonboden on Mt. Desert Island, Maine. Science, Vol. 83, p. 161.

Perkins, E. H. and H. W. Leavitt. 1935. Glacial Geology of Maine. Maine Technology Experiment Station Bul. No. 30.

Perley, Sidney. 1891. Historic Storms of New England. Salem Press, Salem, Mass.

Pinchot, Gifford and H. S. Graves. 1896. The White Pine. The Century Co., N. Y.

Pinchot, Gifford. 1908. Paper Birch. USDA Forest Ser. Silvical Leaflet No. 38.

Richthafen, Franz von. 1877. China, Vol. I.

Sayles, R. W. and E. Antevs. 1927. Three Pleistocene Tills in Southern Maine. Abstract, Geological Soc. of Amer. Bul., Vol. 38, p. 142.

Shaler, N. S. 1891. The origin and nature of soils. 12th Annual Report of the Geological Survey; Part I, Geology, pp. 213-235.

Shirley, Hardy L. 1941. Restoring Conifers to Aspen Lands in the Lake States. Lake States Forest Experiment Station Technical Bul. No. 763.

Smith, E. S. C. 1928. The Cambrian of Northern Maine. Am. J. of Science, Vol. 15.

Smith, H. T. U. and H. J. Fraser. 1935. Loess in the Vicinity of Boston, Massachusetts. Am. J. of Science, Vol. 30.

Stout, Benjamin B. 1950. Species Distribution, Surficial Geology, and Soils in the Harvard Forest. Unpublished master's thesis.

Tarr, R. S. 1900. Glaciation of Mt. Katahdin. Bul. of the Geo. Soc. of Amer., Vol. 11.

Trefethen, J. M. 1947. Report of the State Geologist, 1945-46. Maine Development Commission, Augusta, Maine.

Westveld, Marinus. 1931. Reproduction of Pulpwood Lands in the Northeast. USDA Technical Bul. No. 223.

Whitman, C. A. 1915. History of Buckfield, Maine. 341 pp.

Whitman, W. B. 1891. History of Bethel, Maine. Press of the Maine Farmer. 688 pp.