GEOLOGY
OF
MORRIS COUNTY
IN BRIEF

NEW JERSEY GEOLOGICAL SURVEY

The sketch on the front cover shows the workings of the Mt. Hope Iron Mine before the turn of the century. Mt. Hope is the oldest continuously operating iron mine in the United States. The magnetite ore was taken out by colonists beginning in 1710 and continued until 1958 when the mine was closed. In 1977, the mine was reopened and over 1000 tons of iron ore per day is being removed from the workings.

STATE OF NEW JERSEY

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GEOLOGY OF MORRIS COUNTY IN BRIEF

by

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GEOLOGY OF MORRIS COUNTY IN BRIEF

Topography

Morris County lies within two physiographic provinces; the Piedmont Province and the Highlands Province. The Piedmont Province in New Jersey is a rolling plain underlain by soft shale and sandstone interrupted to the east by Towakhow Mountain and to the south by Mount Kemble and Long Hill. These basaltic ridges average approximately 500 feet above sea level.

The general level of the plain and crests of the ridges gently slopes toward the southeast. Between Montville and Dover the plain averages 300 feet above sea level. At the southern tip of the county at the Great Swamp the average elevation is 200 feet above sea level.

The New Jersey Highlands are a portion of the Reading Prong of the New England Physiographic Province. The Highlands consist of a series of flat-topped ridges, separated by narrow deep valleys. The mountains are composed of hard, crystalline, resistant Precambrian igneous and metamorphic rocks and the valleys are underlain by easily eroded shale and limestone. The highest elevation of the county is found in this region on Bowling Green Mountain, 1,391 feet above sea level.

Geologic History

Proterozoic Era

Precambrian Period - In Morris County, the earliest geologic event, for which there is evidence preserved in rock, is the deposition of thousands of feet of sediments. After deep burial, these rocks were subjected to folding and faulting, coupled with increased heat and pressure metamorphosing the rocks. Molten igneous rock then intruded and metamorphosed

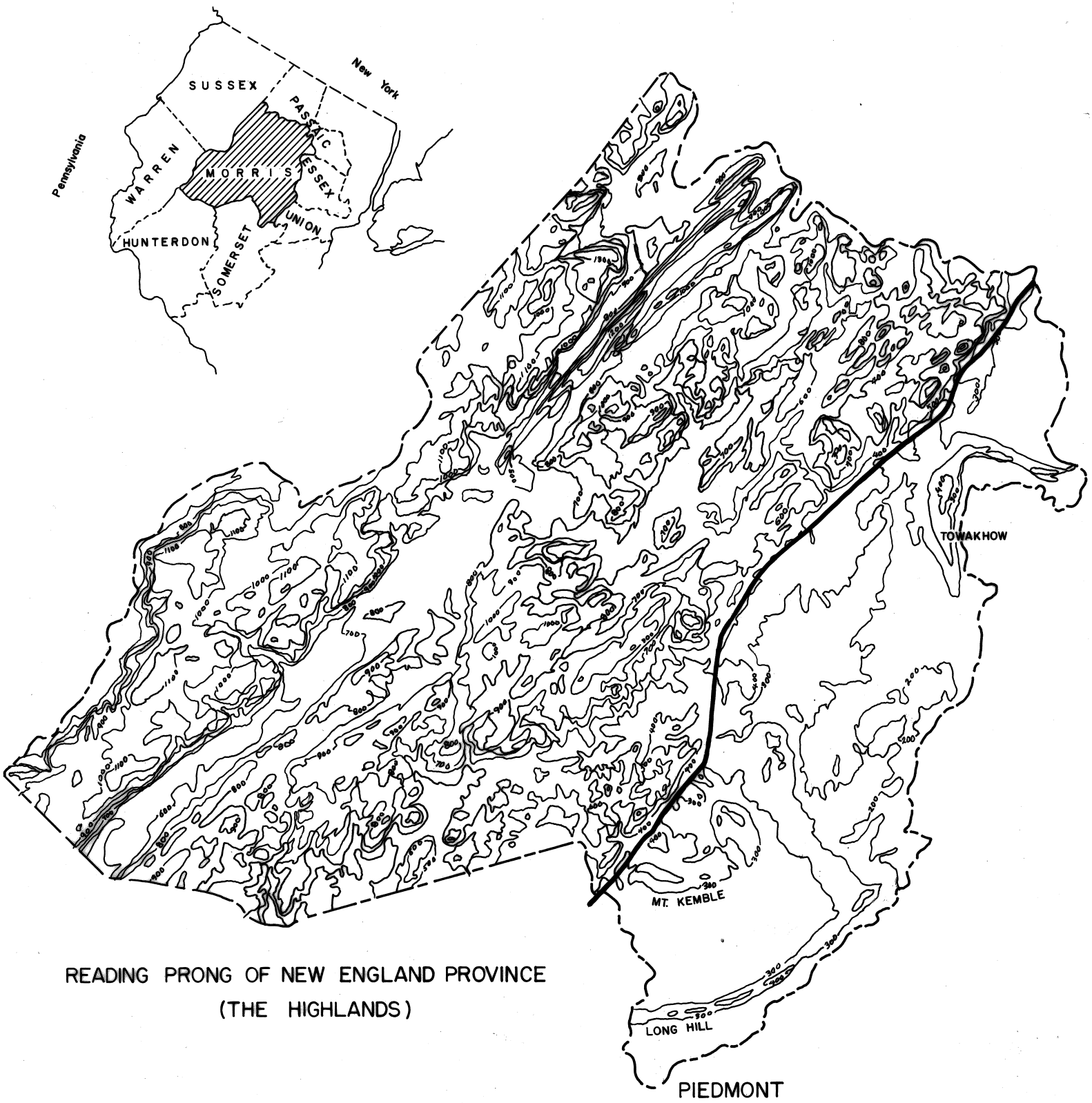
sedimentary rock, causing further alteration. These alterations formed metamorphic gneiss, a coarsely grained rock in which light and dark colored bands can be distinguished. Many varieties of gneiss were formed but they are not separated by name in this report. Besides forming the Highlands, the Precambrian rocks are the "basement" on which the Piedmont Plain sediments have been deposited.

Specks or small stringers of graphite found in some of the Precambrian rocks of the Highlands suggest that some form of life existed during Precambrian time. Most of the fossils found in younger rocks consist of hard parts such as shells or bones, but in Precambrian times most life forms were probably without these, and due to the metamorphism other types of fossils were destroyed. In general, the lack of fossils and slight evidence of life is characteristic of Precambrian rocks.

Paleozoic Era

Paleozoic time began with the slow depression of parts of the continents and the invasion of a shallow sea over the surface from a southwesterly direction. Sediments gradually began accumulating in the northeast-southwest trending basin which extended from Newfoundland, through northwestern New Jersey, and southward into Alabama. Sediments, derived from uplifted landmasses to the east and southeast, were continually being eroded, transported and deposited, changing the size and shape and gradually filling the trough. Near the end of the Paleozoic the seas retreated and non-marine conditions prevailed.

In New Jersey, sediments were deposited during the Cambrian, Ordovician, Silurian and Devonian Periods. Rocks from the last three periods of the era, the Mississippian, Pennsylvanian and Permian, are not present in New Jersey but are found in Pennsylvania to the northwest and west.



PHYSIOGRAPHIC PROVINCE MAP OF MORRIS COUNTY

CONTOURS IN 100FT. INTERVALS

Scale of Miles

0 5 10 MILES

Fig. 1 Diagram showing location and physiographic provinces of Morris County.

Cambrian Period - At the beginning of Cambrian time, the eroded Precambrian surface was covered with rock debris. As the sea slowly advanced, the debris was gradually washed, rounded and sorted. During sorting, the finer material settled in the calm deep water while the coarser material was deposited nearer shore where the currents were stronger. The sands and gravels which accumulated during this time constitute the Hardyston Quartzite. As the name implies, this formation is normally a quartzite, but some conglomerate appears near the base of the formation. The conglomerate contains pebbles of Precambrian material - quartz, feldspar, gneiss and shale.

Cambro-Ordovician Time - During the latter part of the Cambrian and the beginning of the Ordovician Periods, warm shallow seas prevailed throughout most of the basin. The abundant lime organisms and the conditions of the quiet seas resulted in the precipitation of calcium carbonate which formed the dolomitic limestones called the Kittatinny Formation.

Ordovician Period - Following uplift and a long period of erosion the sea again invaded Morris County. The streams which flowed into the sea carried large amounts of fine silt and sand, which were deposited, creating a series of sandstones, shales and slates called the Martinsburg Formation.

It is likely that life existed for 100 million years before the Paleozoic Era, but pre-Paleozoic rocks have preserved little or no evidence of life. In New Jersey, the first fossil evidence is found in the Hardyston quartzite in the form of worm tubes. Although the fossil record in New Jersey is scant, over 500 species of invertebrate fossils have been found in other North American rocks. The prevailing type of deposition in New Jersey explains the meager fossil record. Generally, the seas were shallow, very warm, and rather stagnant, producing an environment where animals could

not flourish. Only a few fossils are found in the Kittatinny Formation. Two of the more common types are primitive types of algae and the scaphopod, Hyolithellus micans.

The types of fossils found in the Martinsburg Formation, combined with their relatively rare occurrence, indicate that this deposition was not favorable for abundant life. Graptolites, jellyfish-like animals with individuals living along hanging branches, are found in the formation. These animals lived in an open sea and are best preserved in a muddy bottom.

At the conclusion of Ordovician time there was a period of mountain building known as the Taconic Disturbance. Evidence of this activity in Morris County can be seen by the folded and faulted rocks of the Cambrian and Ordovician times.

Silurian Period - By early Silurian time the changes that had been brought about by the Taconic Disturbance were greatly modified by erosion. Northern New Jersey was gradually covered by an encroaching sea whose shoreline was variable. Rivers and streams flowing from the crystalline highlands reduced the quartz to fine sand and well-rounded small pebbles, producing the Green Pond Conglomerate. This formation is a coarse, highly siliceous conglomerate interbedded with, and grading upward into, quartzite and sandstone. The pebbles of the conglomerate range in size from 1/2 to 3 inches in diameter and are almost all white quartz with lesser amounts of pink quartz; black, white, yellow and red chert; red and purple quartz; with a few red shale and pink jasper pebbles. The rock is cemented together by quartz sand, generally red, but can be white, gray or greenish.

After Green Pond deposition, there was a gradual emergence followed by a later submergence and invasion of a shallow marine sea. At this time the

Longwood shale was deposited. The Longwood is a soft red shale which breaks in many directions. Because of the erosive properties of the shale the formation is rarely seen.

There are isolated outcrops of impure limestone overlying the Longwood shale but not in contact with it. This formation is called the Decker and is a dark gray impurely siliceous and shaly limestone. The uppermost ten feet of the Decker beds contain fossils.

Life during Silurian time was still dominated by marine invertebrates such as brachiopods, ostracods and corals. During this time some of these animals began to decline in number of varieties and others became more important. Because of the prevailing conditions in Morris County at this time, no fossil evidence is found in the Green Pond Conglomerate or the Longwood shale. The marine formation, the Decker, contains corals, brachiopods, bryozoa and crinoids in one of its layers.

Devonian Period - The beginning of Devonian time saw a narrow sea extending itself across northwestern New Jersey. The Morris County area was higher in elevation than the Sussex County area; however, the sea invaded the region in middle Devonian time and sandy sediments were laid down, forming the Kanouse sandstone.

The Kanouse sandstone is a thickly bedded, fine-grained conglomerate below and thinner bedded greenish sandstone above. The pebbles of the conglomerate are composed of quartz ranging from 1/4 to 1/2 inch in diameter. The conglomerate is loosely cemented together in fine grained quartz, making it break apart easily. The sandstone, on the other hand, is resistant. The exposures of this rock form a narrow belt parallel to the Decker Formation.

Succeeding the Kanouse sandstone upward is the Pequanac shale, a black

and dark gray, thickly bedded, slaty shale. The rock breaks smoothly in different directions so that the way in which the rock was deposited cannot be clearly seen.

Without any interruption, the Bellvale sandstone was deposited. The main differences between the Bellvale and the Pequanac are that the beds are coarser and more sandy in the Bellvale, with a gray color predominating.

During Devonian time, the interior of the seas swarmed with animals of many kinds; brachiopods reached their greatest number, pelecypods (clams) became more common, and corals were abundant. The coral reefs were covered by bryozoa and crinoids. Gradually, trilobites declined in number.

There are few fossils in the Kanouse sandstone and those which are found are broken sufficiently to be unidentifiable. This occurred because the Morris area was near the shoreline where waves broke the animals into pieces. The area where material was being eroded was gradually uplifted and the mud and sand which compose the Pequanac shale and the Bellvale sandstone was deposited. This environment was favorable to the deposition of fossil brachiopod, trilobite, and coral.

Mesozoic Era

Following Devonian time, the next period from which there is evidence is the Triassic. Therefore, we are missing evidence of the Mississippian, Pennsylvanian, Permian, and the Jurassic Periods in the county, making it impossible to decipher the local geologic events. Evidence found beyond the borders of the county must be used in reconstructing the geologic history.

Triassic Period - In the latter part of the Triassic period a widespread earth movement affected Morris County. During this orogeny, the

Highlands as a whole were uplifted, while the areas to the east of the Highlands were relatively depressed. Following this uplift, a series of discontinuous intermontane basins were formed from Nova Scotia to North Carolina. The present Piedmont region of New Jersey formed the northern end of one of these basins and extended from southeastern New York to New Jersey, southwest across Pennsylvania and Maryland into Virginia. Because of the characteristic red color and general absence of organic matter of the sediments, the depositional environment is interpreted to have been an arid climate with seasonal torrential rains. Debris was carried from the higher areas and spread in broad alluvial fans over the adjacent plains. The sediments deposited during this time have been referred to as the Newark Group.

When the seasonal rains began, heavily laden streams flowed from the Highlands carrying sand, silt and clay. When the material flowed into the valley of which Morris County was a part, the material was gradually deposited, forming the Brunswick. This formation is a reddish brown shale and sandstone.

Adjacent to the Highlands, beds of Triassic border conglomerate and pebble-bearing sandstone are found replacing the Brunswick Formation and interfingering with the finer grained sandstone. Fan-like accumulations were formed by sediment laden streams flowing at high velocities where they debouched upon a low plain. Exposures of this material can be seen near Montville and New Vernon. There is an absence of gneissic material in the conglomerate which might be expected in an alluvial fan so close to the gneissic outcrops at the Highlands. This indicates that Paleozoic sediments covered the Highlands gneiss during the time of erosion and deposition of Newark sediments, but was all eroded off the Highlands, exposing the rocks we find today.

The latter portion of the Newark period of deposition was marked by volcanic activity in New Jersey. Three or more successive eruptions resulted in the flow of thick and extensive lava sheets across the sediments. Each eruption was followed by a quiet period during which sedimentation proceeded as before and the lava flow was buried. These flows resulted in three great sheets of igneous basalt, each of which is made up of two thinner sheets. Prolonged erosion, brought about by uplift accompanied by faulting and tilting toward the northwest, has removed enough of the overlying sediments so that basalt beds are now exposed. The basalt is harder than the shale and sandstone; therefore, the edges of the third sheet now form Long Hill and Mount Kemble in the southern portion of the county and Towakhow Mountain in the northeast portion.

Because of the arid climate prevailing during red bed deposition, plants are not plentiful but can be found in some of the darker gray beds formed under more favorable conditions during the wetter, but still semi-arid, cycles of the Triassic climate. Vertebrates were evolving rapidly and much evidence can be found for their existence. Fossils include dinosaur footprints, skeletons of crocodile-like reptiles, gliding reptiles, and fish.

At the close of the Triassic, movement along a series of northeast-southwest fractures brought the deposition to a close. The fractures divided the earth's crust into a succession of long and narrow blocks, which were tilted to the northwest.

During the Jurassic a peneplain was gradually formed. A peneplain is a nearly featureless plain developed by erosion of a more rugged terrain.

Cenozoic Era

Tertiary Period - A very prominent peneplain, called the Schooley,

was formed during Tertiary time. After gentle uplift, the increased velocity of the streams allowed them to erode, carving out valleys in the non-resistant shales. Remnants of the Schooley Peneplain in Morris County include the crests of the basalt mountains and the crests of the Highlands, including flat-topped Schooley Mountain in the west, from which the name of the peneplain was derived.

Quaternary Period

Pleistocene Epoch - During the Pleistocene Epoch four main glacial ages and three interglacial ages covered parts of the world. Three glacial advances reached New Jersey, the Kansan (oldest), Illinoian, and Wisconsin (youngest). Each stage was named after a state in which the deposits, called drift, are well represented. The evidence left from the Kansan stage is patchy. Scattered rocks and clayey till (tough, stony clay) are found in the uplands, usually the Highlands. The Illinoian stage has left more drift than the Kansan, but the evidence is still scattered. The material is composed of leached and oxidized pebbles and boulders. The appearance of the material is due to the long exposure to the elements of weathering and erosion. This drift is found on hilltops and in low terraces along streams.

The Wisconsin ice sheet is the most recent and, therefore, has left the most evidence. The southern extension of the ice during this stage is marked by a great terminal moraine which crosses Morris County at Madison, Morristown, Dover, and Netcong. A moraine is a heterogeneous mixture of clay, sand and stone dumped at the front of the glacier. An end or terminal moraine is a ridge-like accumulation of drift formed when the glacier stagnated. The ridge-like deposit is more or less discontinuous, broken by gaps, most of which mark the places where meltwater streams existed.

North and south of the moraine the rock surface is covered generally by drift deposits, stratified and unstratified. The unstratified drift or till is an unsorted mixture of boulders, pebbles, sand and clay. The stratified drift is composed of beds of clay sand and gravel which, in the process of deposition, were assorted and deposited by streams fed by water from the melting glaciers.

It is assumed that none of the drift material was derived from regions north of New Jersey and that erosion did not exceed 25 feet in most places. Comparison of the topography in areas to the north and south of the moraine leads to the conclusion that the ice sheet did not greatly erode the surface over which it passed. It is estimated that the ice stagnated in Morris County for over 200 years.

Temporary lakes were formed during glacial times in several valleys which drained northward and whose lower courses were blocked by ice. The largest glacial lake and the one whose history has been most carefully worked out is Lake Passaic, which occupied the upper Passaic Valley between the Highlands and the Second Watchung Mountain on the south and east.

The preglacial drainage of the Passaic Basin was different than it is today. (Compare Fig. 2 and 3.) This is known from the existence of the deep drift-filled gap discovered in the Second Watchung Mountain at Short Hills. If the material in this gap were to be removed, the level would be lower than the gap at Little Falls, where the river now flows. Therefore, it is concluded that all the drainage of that part of the Passaic Basin which is southwest of the moraine flowed to the sea through Short Hills until the drift filled in the gap.

Therefore, Lake Passaic did not come into existence until the ice ad-

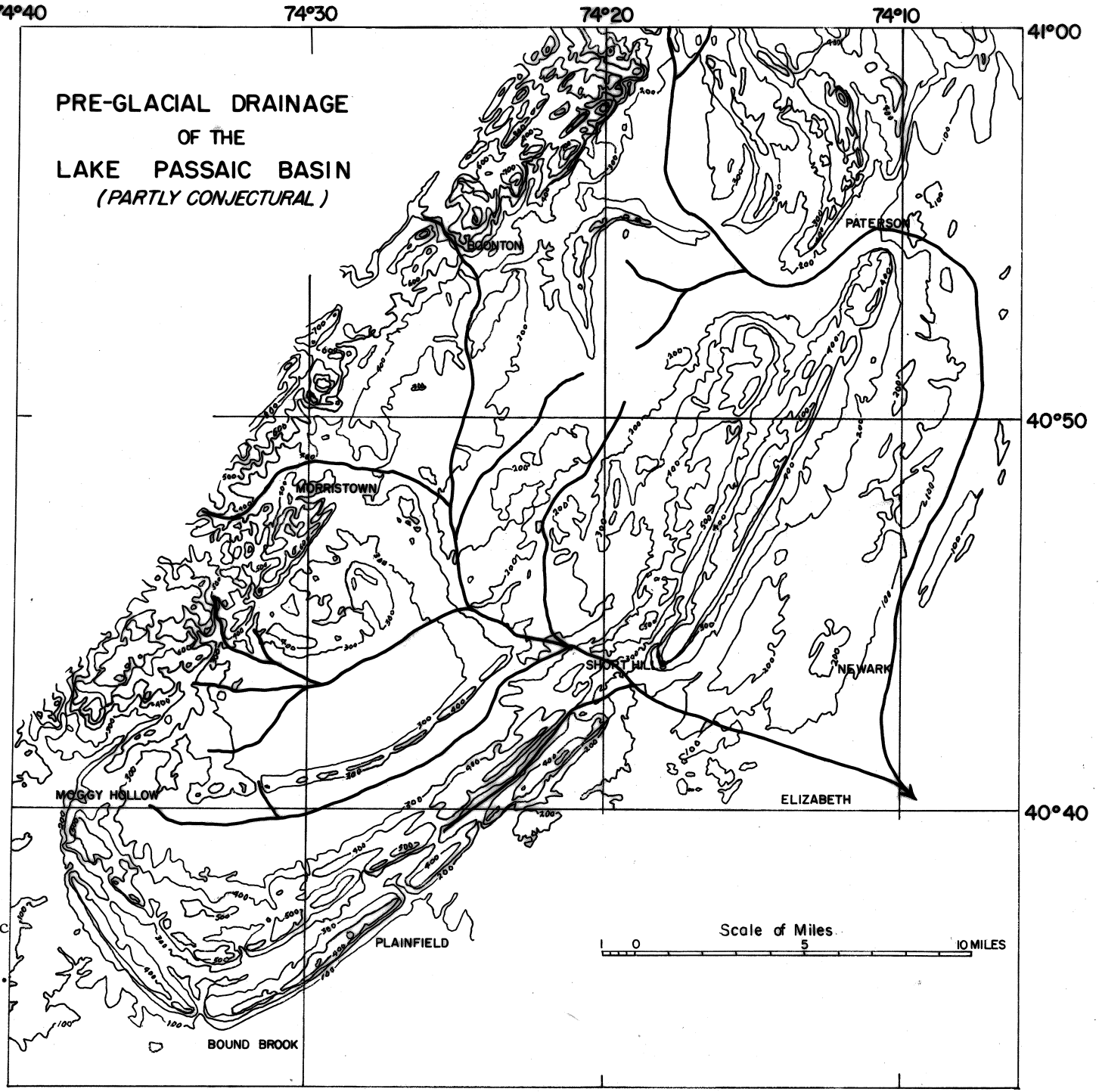


Fig. 2 Diagram showing the supposed course of the drainage in the Passaic Basin previous to the Wisconsin glacial invasion.

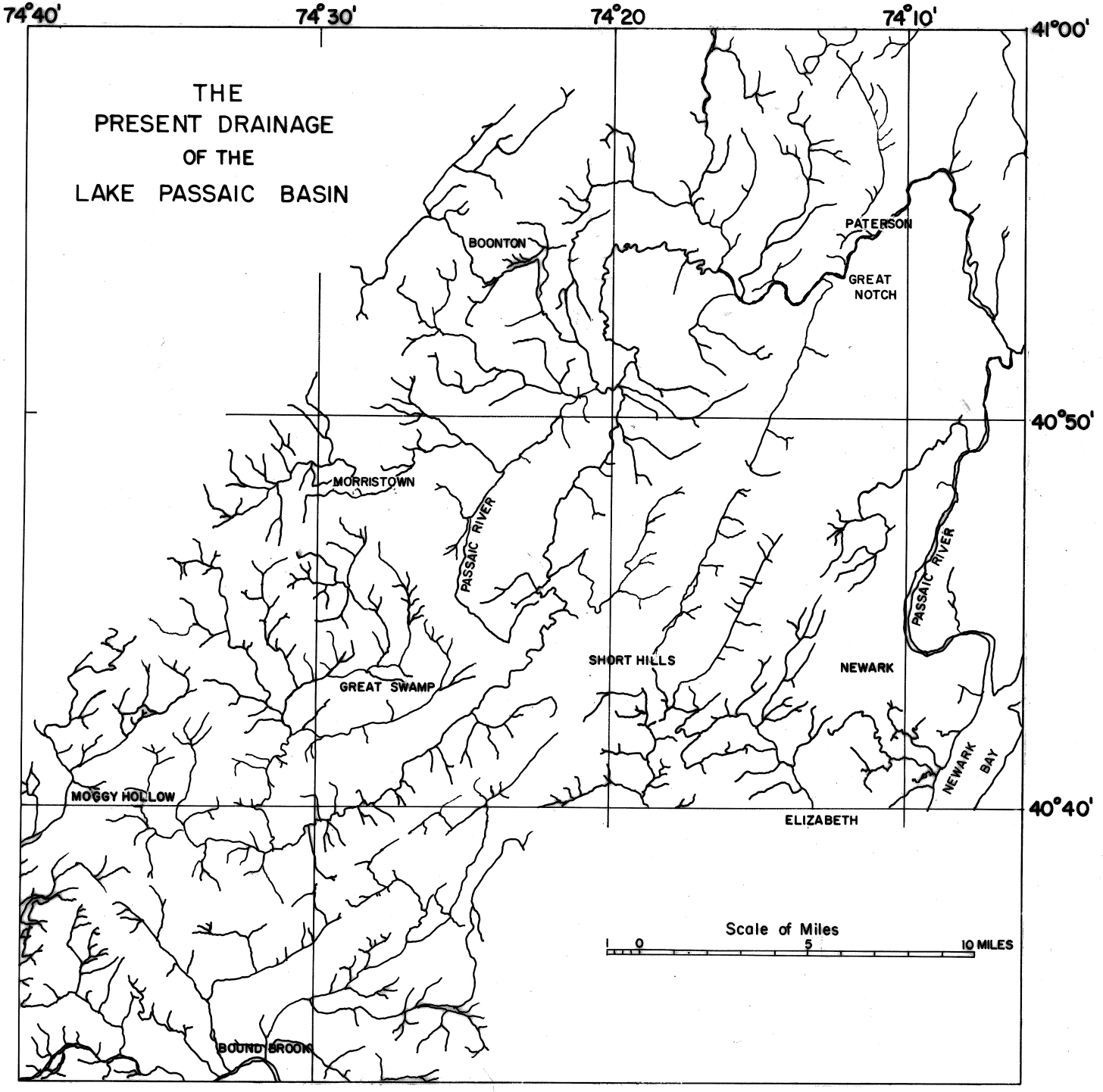


Fig. 3 Diagram showing the present drainage in the Passaic Basin after the Wisconsin glacial invasion.

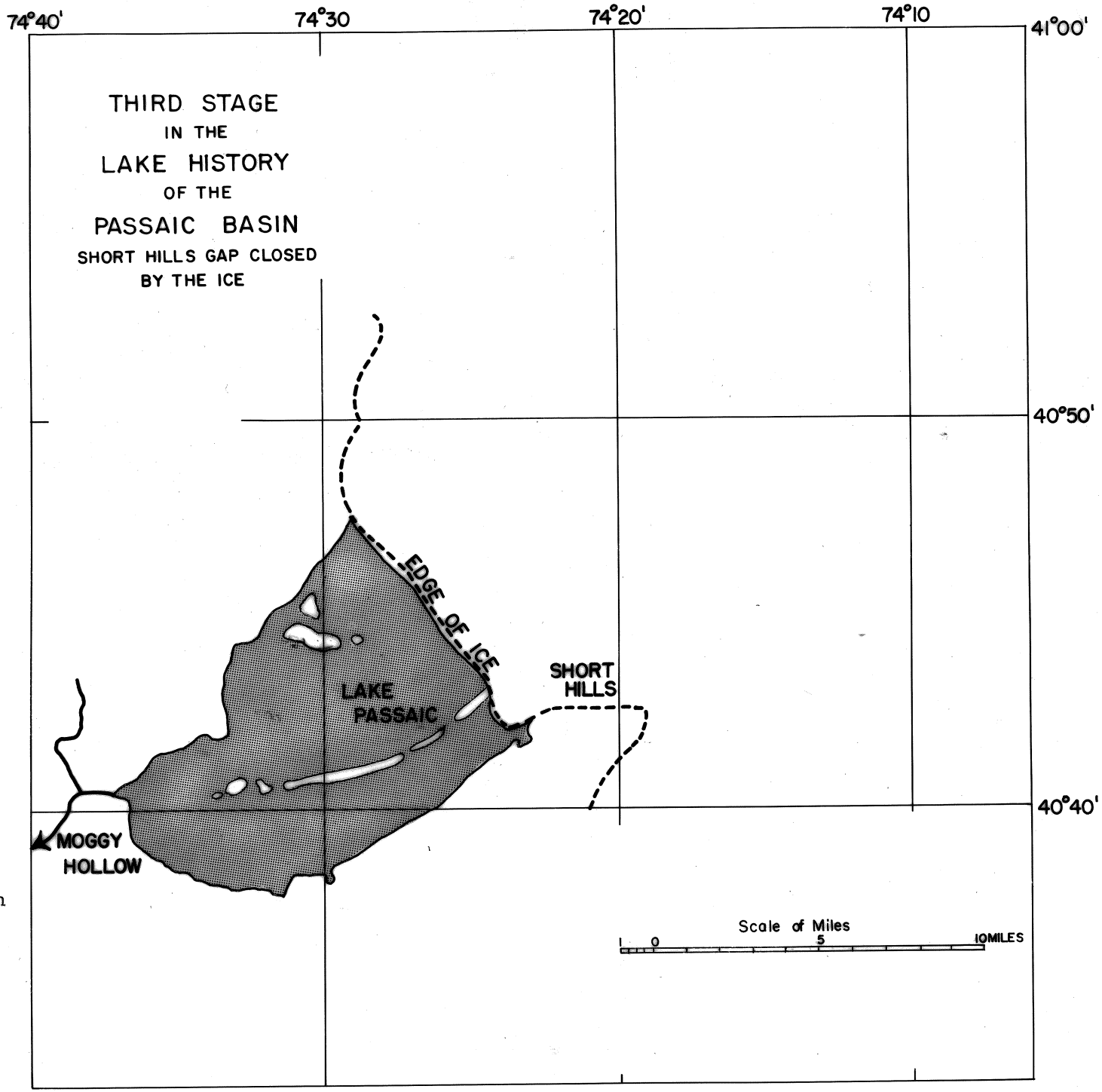


Fig. 4 Diagram showing size of Lake Passaic when Short Hills Gap was blocked by ice and Moggy Hollow was the outlet.

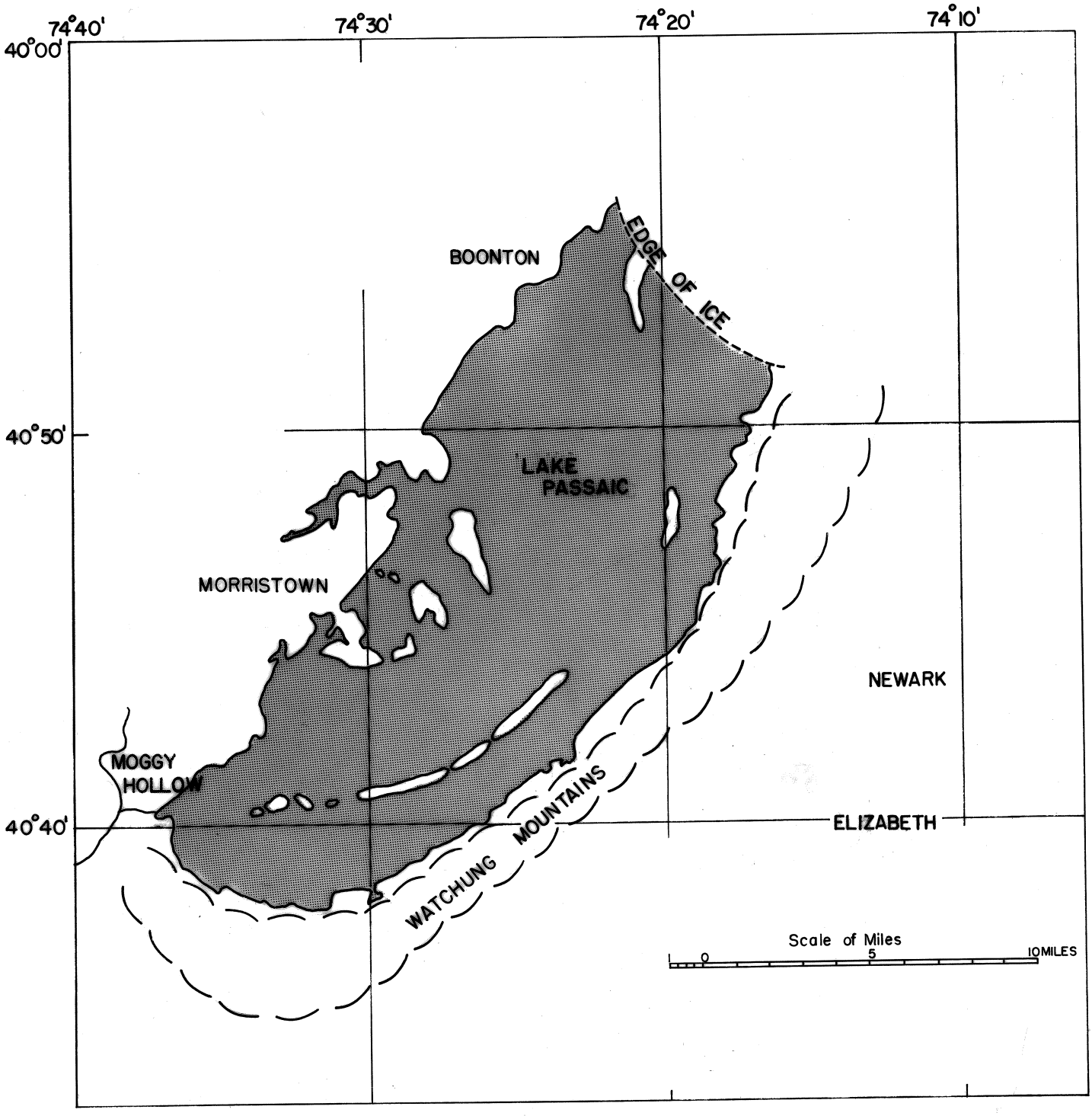


Fig. 5 Maximum Stage of Lake Passaic.
All outlets except at Moggy Hollow were either blocked by ice or filled with drift.

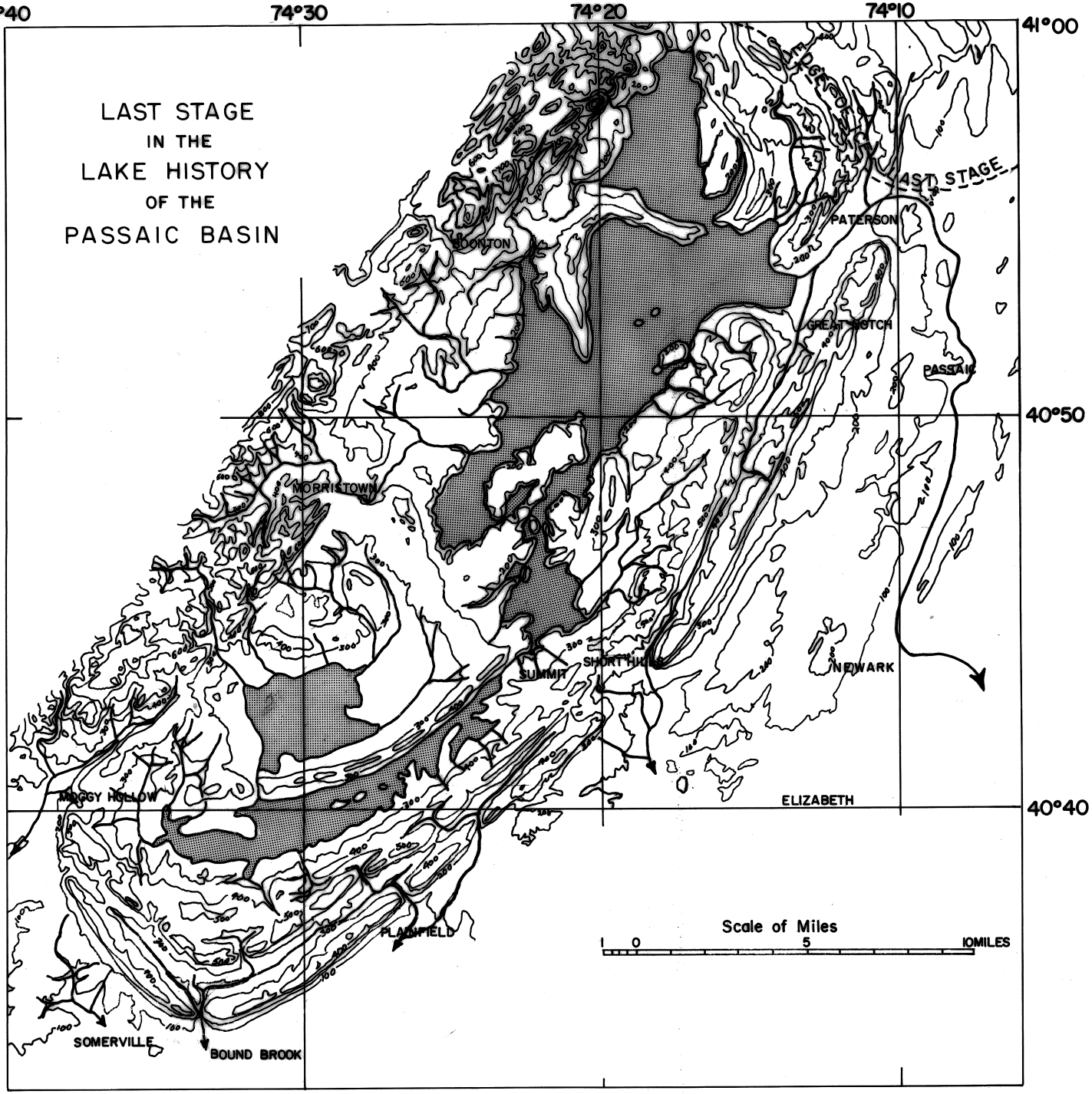


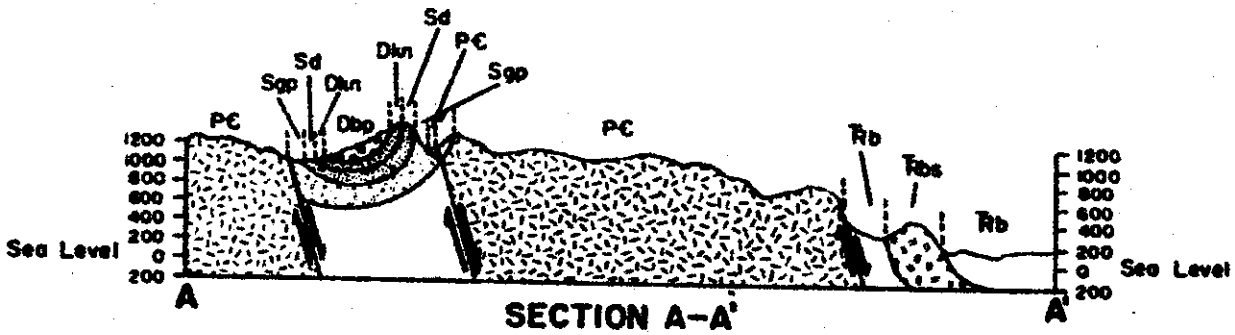
Fig. 6 Diagram showing lakes existing in the lower Passaic Basin when the ice melted far enough back for the outlet to be at Little Falls.

GEOLOGIC CROSS-SECTIONS MAP
OF
MORRIS COUNTY

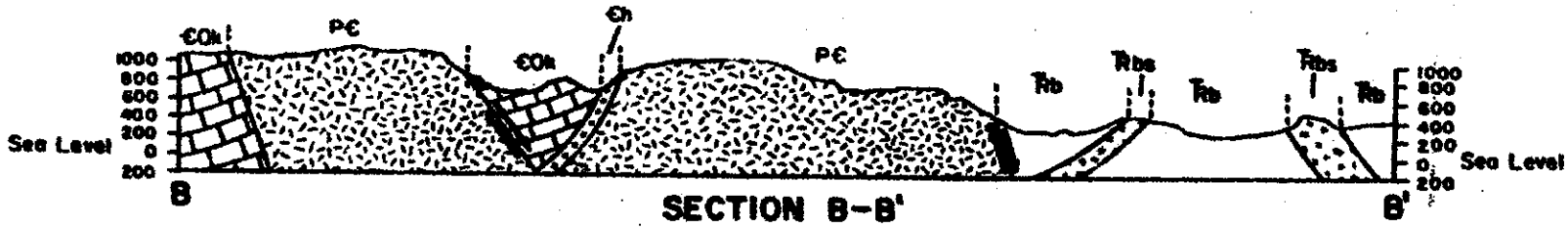
New Jersey Geological Survey 1970

Horizontal Scale: 1" = 4 Miles

Vertical $\frac{1}{10}$" = 200 Feet



SECTION A–A'



SECTION B–B'

LEGEND

Trb — Brunswick Formation

Trc — Conglomerate

Trbs — Basalt (Extrusives)

Dbp — Bellvale Sandstone & Paperville Shale

Dln — Kanouse Sandstone

Sd — Decker Limestone & Longwood Shale

Sgp — Green Pond Conglomerate

Oml — Martinsburg Formation

€Ok — Kittatinny Formation

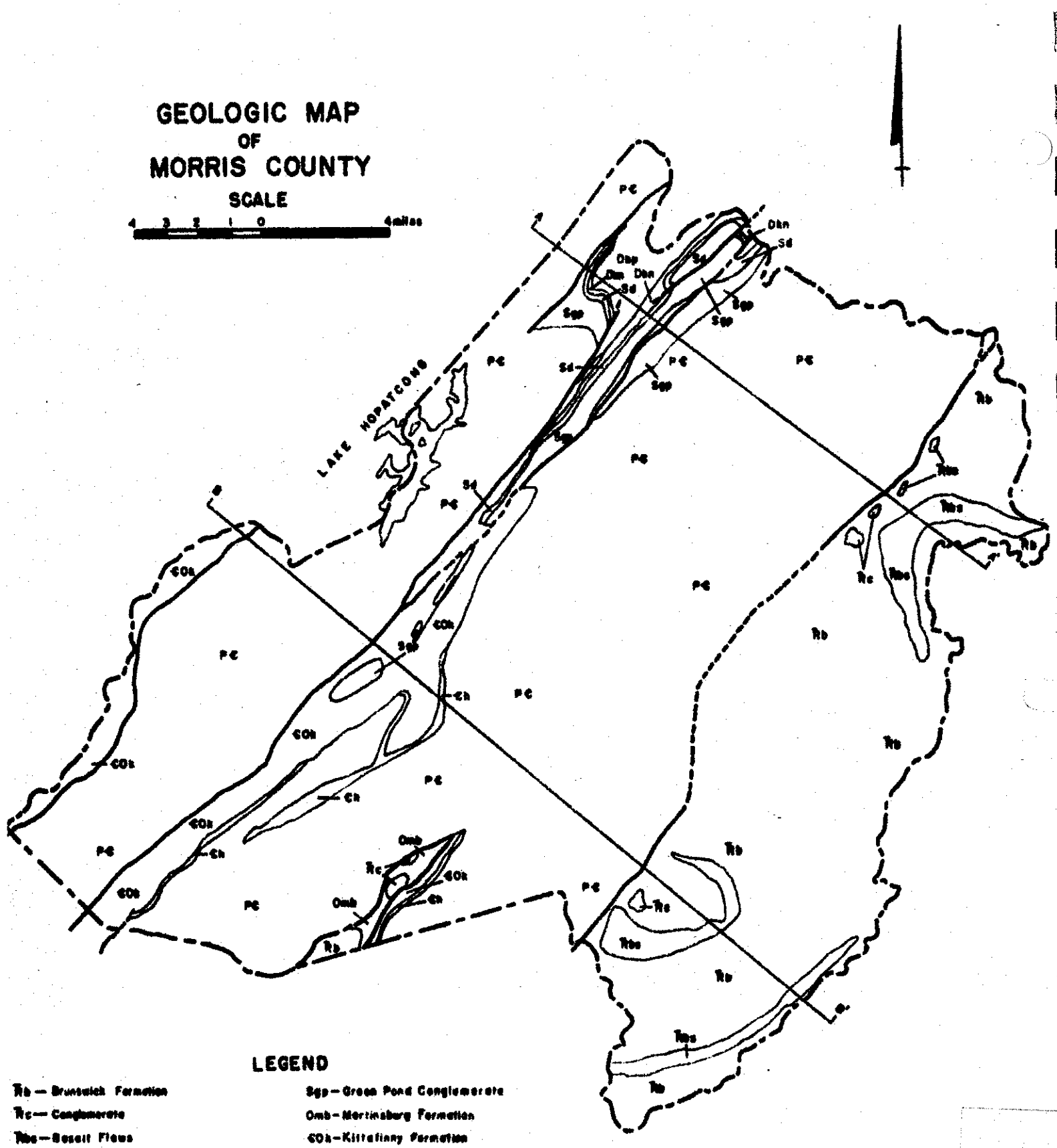
€h — Hardyston Quartzite

P€ — Precambrian (Undifferentiated)

GEOLOGIC MAP OF MORRIS COUNTY

SCALE

4 3 2 1 0 4 miles



LEGEND

Rb — Brunswick Formation

Rc — Conglomerate

Rbs — Basalt Flows

Dbp — Bellvale Sandstone & Peaquenoc Shale

Dkn — Kanouse Sandstone

Sd — Decker Limestone & Longwood Shale

Fault ——— Formation Contact ———

A ——— A' Cross Section

Sgp — Green Pond Conglomerate

Omb — Martinsburg Formation

COk — Kittatinny Formation

Ch — Hardyston Quartzite

PC — Precambrian (Undifferentiated)

NOTE:
Surficial Quaternary deposits not shown

Base Map Atlas Sheet No. 40

vanced to the line of the moraine between Short Hills and Morristown and the Short Hills gap was filled. Once the lake was formed in the southern portion of the basin the level of the lake rose until it overflowed at the lowest point of the rim, which is Moggy Hollow. At its maximum height, the lake level was not more than 25 feet above the bottom of the outlet. Water escaped through this channel to the north branch of the Raritan and then to the sea. As the ice gradually melted away from the moraine, the Moggy Hollow pass remained the outlet since the former gap at Short Hills was closed due to drift (Fig. 4). The lake then increased in area and remained at the same level as the ice melted. At the time of its greatest extent, Lake Passaic was about 30 miles long, 8 to 10 miles wide, and had a maximum depth of 240 feet. Over wide areas it was 160 to 200 feet deep (Fig. 5).

The former shoreline of this lake is shown by wave-cut terraces and cliffs, small wave-built spits, bars and terraces of water-worn gravel, and large glacial deltas.

When the ice front had gradually melted far enough north, Little Falls became the outlet because it is lower in elevation than Moggy Hollow. Shallow lakes still existed in the basin's lowest parts, but the lake never reached the level it had been before (Fig. 6). It is thought that north of Long Hill a lake existed for quite a long time but was gradually drained, leaving evidence for its existence in the Great Swamp.

MINERAL HISTORY IN BRIEF

Morris County began producing iron ore as long ago as 1710. Possibly, the area may have produced iron even earlier, for the first smelter for converting iron ore into bar iron was built at Tinton Falls, New Jersey, in 1682, and it seems certain that some iron ore was being mined in the Highlands at the same time.

The area has been the principal source of iron ore in New Jersey and has contributed over 70 percent of New Jersey's total iron production. Through 1950 it had yielded more than 26 million tons of iron ore.

The ore produced was magnetite, a magnetic oxide or iron which is hard, dense, black and opaque. In Morris County, magnetite occurs in the Precambrian gneiss of the Highlands. This gneiss includes the minerals hornblende, pyroxene, feldspar, quartz, apatite, sphene and pyrite.

The origin of the material is thought to be magmatic in origin, that is, the source of the ore is regarded to have been deep-seated molten magma. After intrusion of the magma into the overlying rocks, gneiss of the Highlands was formed. After the gneiss partially cooled it was again intruded by iron rich portions of the magma, and these were later enriched by more iron rich solutions and gases.

There were over 200 mines in Morris County. The oldest mine is thought to be the Mount Hope mine, which was located in Rockaway Township. Its history begins in 1710 or maybe earlier and ends in 1963. Connected originally to the Mount Hope mine property was another famous mine, the Richard. This mine was worked from 1749 to 1956.

The Scrub Oaks mine, located two miles west of Dover, on the west slope of the hill overlooking the valley in which Succasunna and Kenvil

are located, exceeded the production of any other mines in New Jersey. It was closed in 1966.

Another natural resource is granite, which is still quarried by two companies. This material is used for riprap, concrete aggregate, stone, sand, and fill.

Sand and gravel is another valuable economic commodity in Morris County. This material is worked at several pits and is washed and sorted for use in building and highway construction. The sand and gravel was deposited during glacial times.

GEOLOGIC TIME SCALE

Geologic time intervals are unequal subdivisions of the earth's history corresponding to earth's geologic events. Eras are the longest divisions of time and contain many periods which are further subdivided into epochs. Formations, which are mappable units of rock or sediments, usually have lithology or characteristic distinctions and are assigned to that period or epoch during which they are formed.

A formation's place within the stratigraphic column is determined by the predominant form of life preserved as fossils within the rocks or sediments. If fossils are lacking, a formation's location in the time scale may be determined by its relationship to previously dated units. Only recently have geologists been able to place an absolute date on these relative time units by radioactive methods.

The geologic column is used throughout the world, although some regional modifications may be used for greater clarity.

In the accompanying stratigraphic column, the rock type given after the name is the most common variety found in the county. There may be variation of lithology within the formation from place to place.

GEOLOGIC TIME SCALE OF MORRIS COUNTY

Era	Period	Formation or Rock (approx. thickness)	Approx. Number of Million Years
CENOZOIC	Quaternary		0-1
	Recent	Soil and Alluvium	
	Pleistocene	Glacial Drift (0-460 ft.)	
	Tertiary	Not present in county	1-60
MESOZOIC	Cretaceous	Not present in county	60-130
	Jurassic	Not present in state	130-155
		Brunswick Formation (6000-8000 ft.)	
	Triassic	Basalt (lava flows)	
PALEOZOIC	Permian	Not present in state	185-210
	Penn. Carboniferous Miss.	Not present in state	210-265
	Devonian		265-320
	Silurian	Green Pond Conglomerate (1200 ft.)	320-360
	Ordovician	Martinsburg Formation (3000 ft.)	360-440
	*Cambro-Ordovician	Kittatinny Formation (2500-3000 ft.)	
	Cambrian	Hardyston Quartzite	440-520
PRECAM-BRIAN		Assorted gneiss and schist	520-

*Dashed lines indicate formation was deposited in two time periods.

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