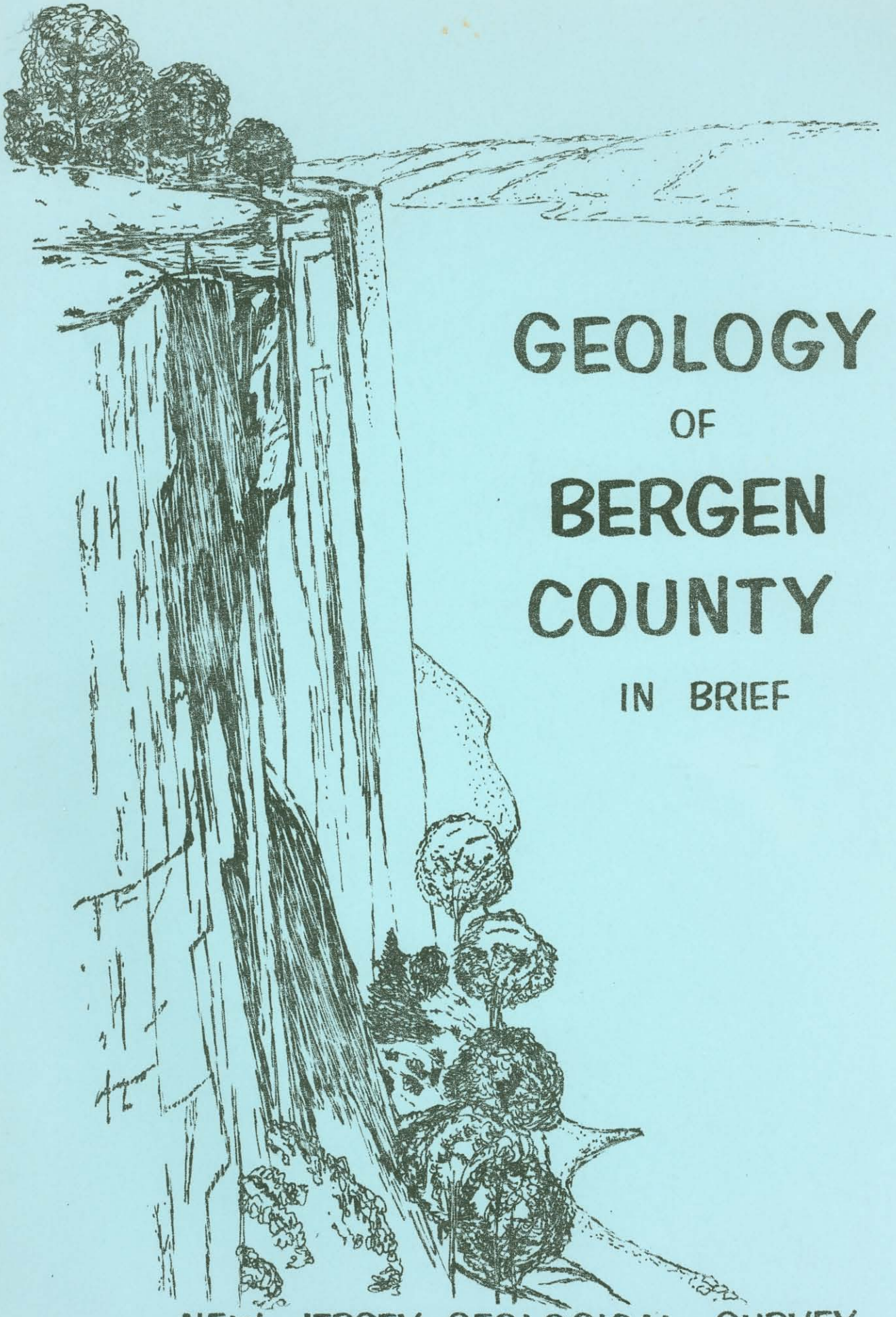

GEOLOGY OF BERGEN COUNTY

IN BRIEF

NEW JERSEY GEOLOGICAL SURVEY

STATE OF NEW JERSEY

Department of Environmental Protection
Richard J. Sullivan, Commissioner

Division of Water Resources
Charles M. Pike, Director

GEOLOGY OF BERGEN COUNTY IN BRIEF

by

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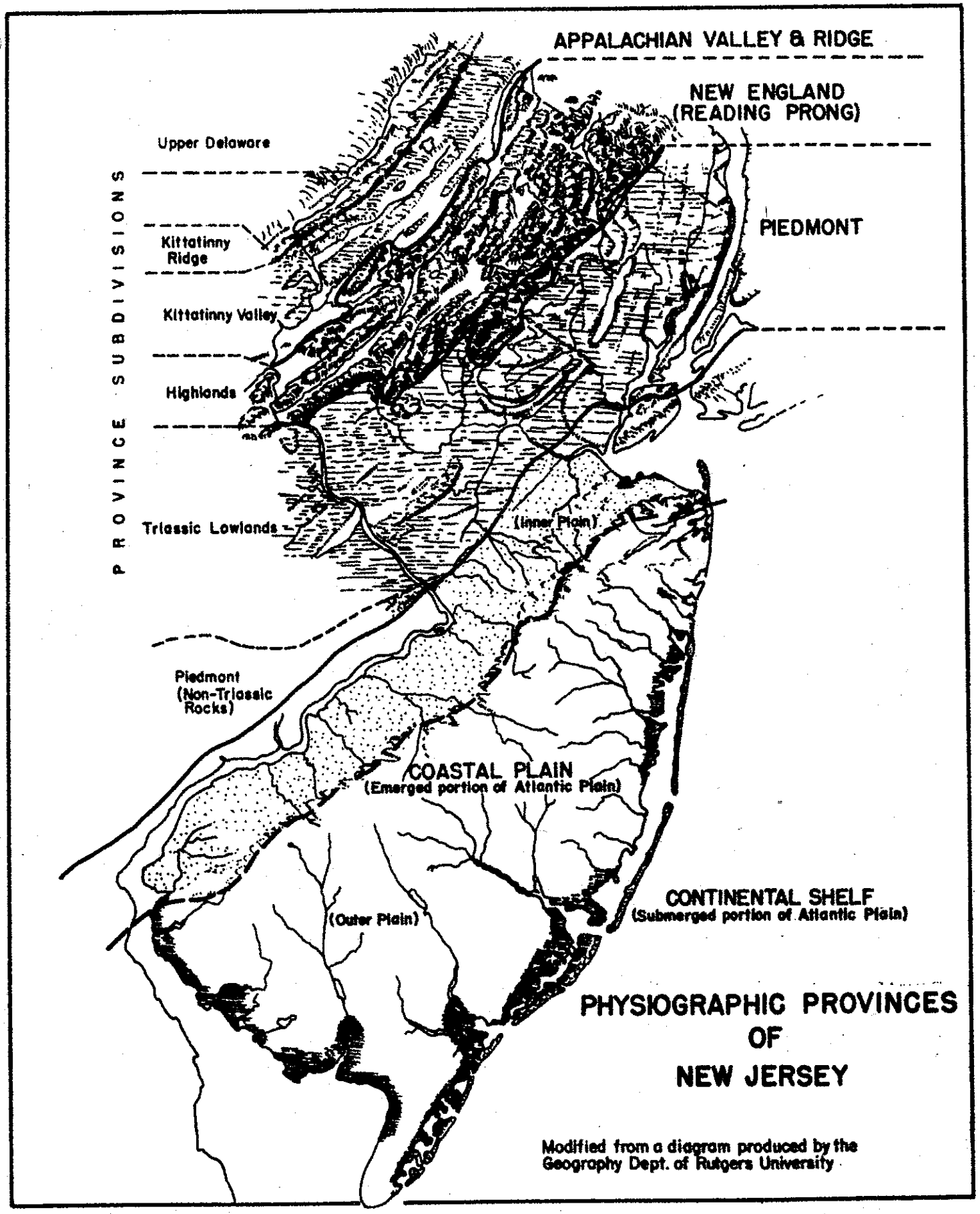

APPALACHIAN VALLEY & RIDGE
NEW ENGLAND
(READING PRONG)
PIEDMONT
PROVINCE SUBDIVISIONS
Upper Delaware
Kittatinny Ridge
Kittatinny Valley
Highlands
Triassic Lowlands
(Inner Plain)
Piedmont
(Non-Triassic Rocks)
COASTAL PLAIN
(Emerged portion of Atlantic Plain)
(Outer Plain)
CONTINENTAL SHELF
(Submerged portion of Atlantic Plain)
PHYSIOGRAPHIC PROVINCES
OF
NEW JERSEY
Modified from a diagram produced by the
Geography Dept. of Rutgers University

Geology of Bergen County in Brief

Topography

Bergen 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 the Palisades igneous sill, and to the west near Franklin Lakes by the basaltic First and Second Watchung Mountains. The Watchungs are approximately 750 feet above sea level near Franklin Lakes. In Bergen County, the Palisades range in height from 150 feet at Cliffside Park to a high of 550 feet above sea level at Closter.

The general level of the plain and crests of the ridges gently slopes toward the southeast. North of Paterson and Hackensack the plain is approximately 300 feet above sea level and along the lower course of the Hackensack River it dips below sea level. South of Englewood, extending into the southern portion of Bergen County, where the plain is below sea level, large areas are covered by tidal marshes which are a part of the Hackensack Meadows.

The New Jersey Highlands are a portion of the Reading Prong of the New England Physiographic Province. The Highlands consist of a series of ridges, one of which is located in the northwestern part of the county and is called Ramapo Mountain. The mountains are composed of hard, crystalline, resistant Precambrian igneous and metamorphic rocks. The highest elevation of the county is found in this region at Bald Mountain, 1164 feet above sea level.

Geologic History

Proterozoic Era

Precambrian Period - In Bergen 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, faulting, and compression coupled with increased heat and pressure metamorphosing the rocks. Molten igneous rock then intruded the 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.

Mesozoic Era

Following Precambrian time, the next period from which there is evidence is the Triassic. Therefore, we are missing evidence of the entire Paleozoic Era and the Jurassic Period in the county. During the Paleozoic there was deposition but only erosional fragments are found in Triassic sediments. Paleozoic rocks probably also make up a portion of the "basement" on which Triassic sediments were deposited.

Because no rocks from Paleozoic time are found in Bergen County, the specific events in the local geologic history cannot be deciphered completely. Evidence found beyond the borders of the county must be used in reconstructing the geologic history during Paleozoic times.

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

Triassic Period

In the latter part of Triassic Period a widespread earth movement affected Bergen County. During this orogeny, the Highlands as a whole were uplifted, while the areas to the east of the Highlands were relativey 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.

The first formation to be deposited was the Stockton Formation, a light colored arkosic sandstone and conglomerate with interbedded red sandstone and shale. The composition and size of the material indicate rapid stream erosion in the mountains, and rapid deposition as layers across the basin.

Deposition of the Brunswick Formation followed the Stockton Formation. The Brunswick Formation is usually a soft red shale with some interbedded sandstone, but in Bergen County it is mostly a coarse-grained sandstone with some conglomerate.

Adjacent to the Ramapos, 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 Oakland. There is an absence of gneissic material in the conglomerate which might be expected in an alluvial fan so close to the gneissic outcrops of the Highlands. This indicates that Paleozoic sediments covered the Highlands gneiss during the time of erosion and deposition of Newark sediments.

Associated with the Triassic sediments are two types of igneous rock, basalt and diabase, which are commonly known as traprock. Basalt is a hard, fine grained, dense textured, extrusive igneous rock which is formed by the solidification of lava flows. There is a record of three or more periods of volcanic activity when lava was spread widely over the area. The bottom of the lava flows cooled quickly and, as a result, the rock is fine grained and dense while at the top of the flow it is porous and spongy due to escaping bubbles of steam and other gases as the lava cooled and solidified. Since the rock is more resistant to erosion than the sandstone and shale, it was not worn down as fast as the surrounding rock. It therefore forms the higher ridges of the Watchung Mountains.

Diabase, the chemical and mineralogical equivalent of basalt, is coarser grained and, as a sill, has a salt and pepper look because the crystals are bigger, resulting from slower cooling deep beneath the land surface of Triassic times.

Because the Palisades diabase is intrusive rather than extrusive, there are features present which are not found in the Watchungs. The magma was injected parallel to the bedding of the Triassic sedimentary strata, forming an igneous body called a sill. The rock near the top and bottom contacts of the sill are of a glassy texture which formed when the hot magmatic material came in contact with the cooler sides; solidification took place so quickly that crystals could not develop.

The Palisades diabase sill is approximately 1000 feet thick and is well exposed near the George Washington Bridge in Bergen County. The intruding rock "baked" the sedimentary strata above and below producing a rock known as hornfels. The resemblance of the cliff to a defensive wall of logs called a palisade is a result of columnar jointing (vertical partings) formed by shrinkage of the rock during cooling.

Due to the slow cooling conditions within the main mass of the sill a process called gravitational settling was able to occur. As the magma cooled, crystallization began with heavy minerals of magnetite and chromite first sinking to the bottom, then followed by the mineral olivine. Gradually, there was an upward concentration of water and other volatiles as the liquid phase in the last stages of cooling of the magma was displaced to the top by the sinking crystals. Pegmatites crystallized from the liquid phase of the melt and are therefore found near the top of the sill. The main minerals found in the sill are olivine, plagioclase feldspar, and pyroxene with minor amounts of magnetite, chromite, biotite, hornblende and apatite. Some other results of the settling process are:

1) In the sill, olivine accumulated in sufficient quantity to form an olivine layer, 15 feet thick, 30 to 60 feet from the base of the sill.
2) The grain size of the rock coarsens from the bottom upward - reflecting the concentration of water and volatiles of the liquid phase of the magma as it was gradually displaced upward by sinking crystals.
3) The specific gravity of the whole rock increases downward because the heavier crystals settled out first.

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. Subsequent erosion has leveled the blocks and etched out the Palisades and the Watchungs.

Because of the arid climate prevailing during red bed deposition, plants are not plentiful but can be found in 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. In 1910, a fossil phytosaur, Rutiodon (a carnivorous armour covered reptile), was found at the bottom of the Palisades in the Stockton Formation at Fort Lee. Very few finds have been made in Bergen County, though dinosaur tracks probably are abundant but have not been discovered because rock surfaces are rarely exposed in an area which is so densely populated. Fish and small shells are found in the Triassic lake bed deposits but as yet none have been found in Bergen County.

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. In the last glacial stage, the Wisconsin, ice advancing from the north and northwesterly direction, covered all of Bergen County, depositing an unsorted mixture of boulders, pebbles, sand and clay, called till. Stratified drift, composed of layered and sorted sand, gravel, and silt, was deposited by streams fed by water from the melting glaciers.

Low steep sided hills of stratified drift called kames and eskers are

scattered throughout Bergen County. Kames are terraces or flat-topped hills formed when the glacier melts and leaves patches of sediment which fill former crevasses and holes in the ice or are laid down by streams flowing along the ice margin. Eskers are long winding ridges formed by streams that flowed in tunnels beneath the ice or along crevasses presumably after the ice became almost stagnant.

Prior to invasion of the ice the topography was not as even as it is today. Gradually, low areas were covered by glacial deposits as can be seen in the banks of the Hackensack and Passaic Rivers which are filled with glacial debris.

Other characteristic effects of glaciers are evident. Striations and grooves of various sizes are found on the top of the Palisades where the outcrops are flat. These marks were gouged into the bedrock by rock debris being carried in the ice on the bottom of the glacier.

One of the most visible remnants of the glacier, a large glacial erratic, is found in Glen Rock. An erratic is a boulder transported by ice and resting on bedrock of different composition than that of the erratic. The boulder at this location is composed of gneiss resting on the Brunswick Formation and was probably carried from the Highlands approximately ten to twenty miles to the north. The boulder in Glen Rock is the largest erratic found on the Triassic area and one of the largest in the State, measuring 42 x 22 x 11 feet.

The Hackensack Meadows are an interesting problem to geologists. In some places up to 250 feet of glacial debris are found above bedrock. Most of this material consists of varved clay, indicating a lake once existed in the meadow during glacial times. Ice blocked the outlets of the streams and rivers causing a dam to be formed. When the ice melted, the lake gradually emptied, leaving behind the glacial deposits.

Mineral Production and History

One of the earliest mines in North America, known as the Arlington or Schuyler Copper Mine, was discovered in 1712 or 1713 in Bergen County. The legendary story is that one of Schuyler's slaves uncovered a heavy green colored rock which he brought to his master. Schuyler sent it to England for analysis and it was found to contain 80% copper. The slave, according to the story, was granted his freedom and three wishes, which, after much deliberation were: 1) always to live with his master, 2) to get a dressing gown like his master's, and 3) to have all the tobacco he could use.

Early yield of the mine was approximately 100 tons of ore a year. The diggings were manned by Schuyler's slaves, who were poor and unwilling miners, and it was not until 1754 that skilled Welsh and Cornish miners were imported. Substantial profits were made during the eighteenth century and the Schuyler home became a social center of the middle colonies during the Revolution. The mine is also important for using the first steam engine in North America to pump out excess water. Schuyler ordered it in 1748 and it arrived secretly in 1754, for the British forbade exportation of material which could compete with the Mother Country.

The full extent of the underground passages is considerable. Approximately 75 acres of property are honeycombed by underground workings. It was reported in 1900 that "the dimensions of the mine chambers are indeed tremendous; one especially is 75 feet wide with a length of 300 feet and varies 12 to 30 feet in height."

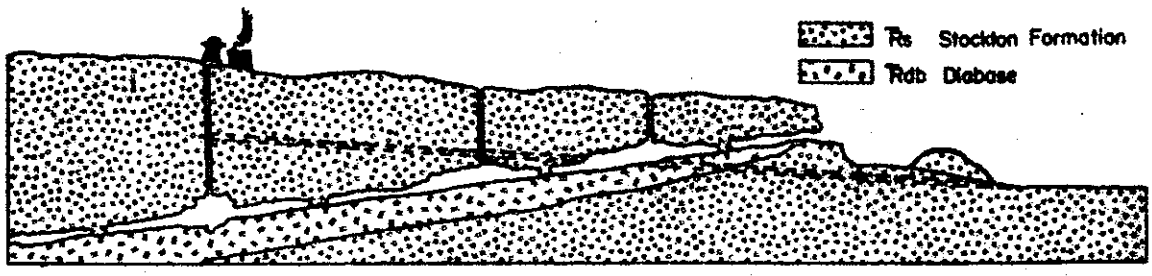
Except for some mushrooms which were raised in an old tunnel about 1940, the mine has produced nothing of value since the Civil War. All openings have been sealed for many years and today there is nothing to be seen of an important colonial mine.

The copper ore at the mine is found in two sandstone layers that overlie a diabase sill. At one time solutions containing copper percolated upward through the diabase into the sandstone, filling between the grains with copper minerals. The principal copper mineral found is chalocite, in small veins which do not run for more than a few feet. The useable pockets are too meager and widely dispersed to warrant the effort necessary to extract them.

Another natural resource is building stone, which was very important in the nineteenth century. At one time it was quarried in Bergen County at Alpine, Closter and Englewood from the Stockton sandstone formation. The stone is usually light colored, from white to buff to pink and occasionally deep red. Operations in some quarries continued into the 1940's but have since been dormant.

Clay is dug near Moonachie for making building brick. The clay is derived from glacial debris of sand and gravel, which has a considerable amount of rock flour. This material, which is used for brick, is extremely fine grained and was the last material to be deposited by the streams. Under favorable conditions it was deposited in lakes, near the edge of the ice or in estuaries.

The most valuable economic commodity in Bergen County today is sand and gravel. This material is worked near Wyckoff, Mahwah and Ramsey and is washed and sorted for use as construction sand and gravel. The sand and gravel deposits occur as stratified kames and kame terraces.



Abandoned Schuyler copper mine at Arlington, New Jersey.

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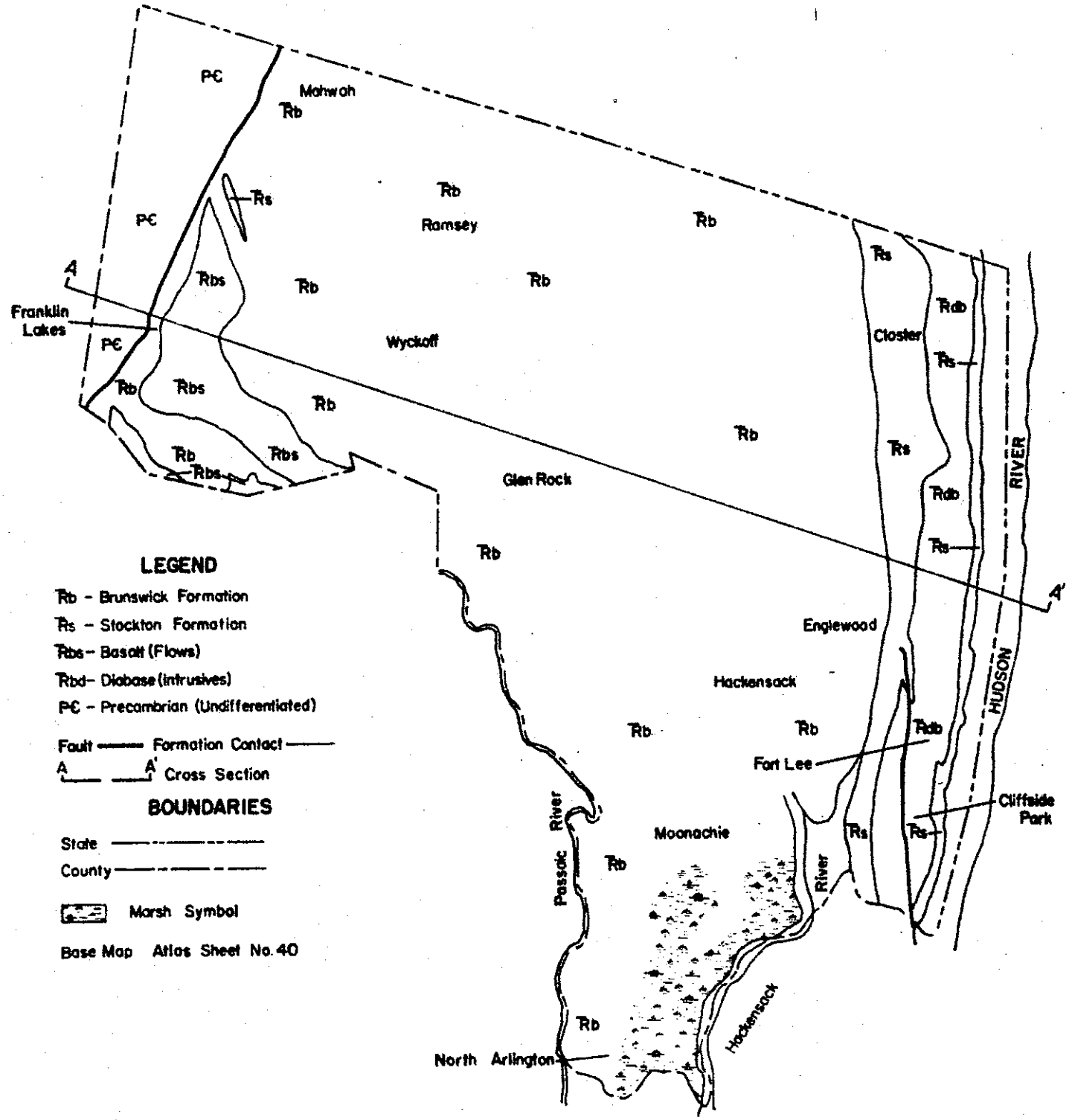
County Series:
Geology of Mercer County in Brief - Kemble Widmer, State Geologist
Geology of Sussex County in Brief
Geology of Hunterdon County in Brief → Carol S. Lucey, Senior Geologist
Geology of Warren County in Brief

GEOLOGIC MAP
OF
BERGEN COUNTY

SCALE

4 3 2 1 0 4 miles



LEGEND

Trb – Brunswick Formation

Trs – Stockton Formation

Trbs – Basalt (Flows)

Trbd – Diabase (intrusives)

PC – Precambrian (Undifferentiated)

Fault ——— Formation Contact ———

A ___ ___ A' Cross Section

BOUNDARIES

State ———·———·———

County ———·———·———

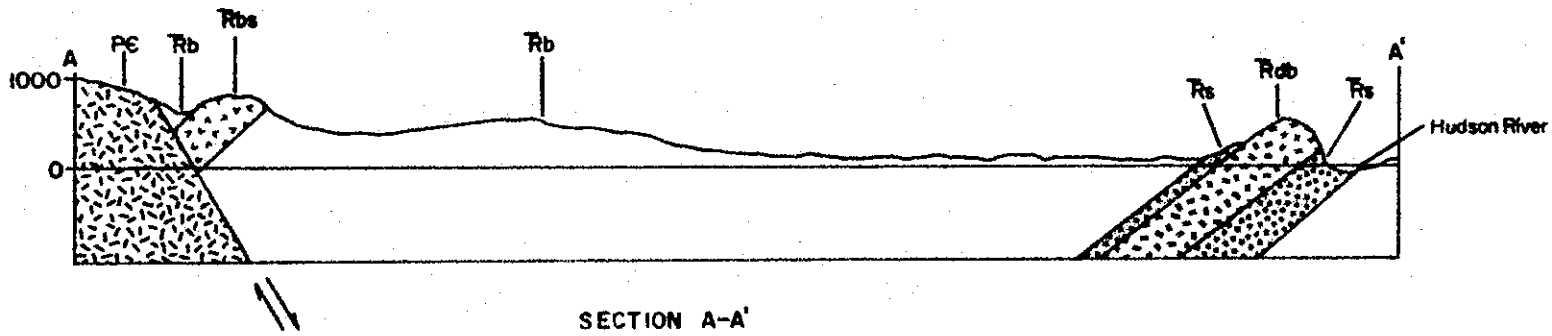
Marsh Symbol

Base Map Atlas Sheet No. 40

NOTE:
Surficial Quaternary Deposits not shown

GEOLOGIC CROSS-SECTIONS
OF
BERGEN COUNTY

New Jersey Geological Survey 1971



SECTION A-A'

LEGEND

Trdb	Diabase (Intrusives)
Trbs	Basalt Flow
Trb	Brunswick Formation
Trs	Stockton Formation
PC	Precambrian (Undifferentiated)

SCALE

4 3 2 1 0 4 miles

Horizontal Scale: 1.3" = 4 Miles

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

GEOLOGIC TIME SCALE

Era	Periods	Epochs	Formation or Rock Type (approx. thickness)	Approx. no. of million years ago
CENOZOIC (recent life)	Quaternary	Recent	Soil and Alluvium	0-1
		Pleistocene	Glacial Drift (0-460 ft.)	
	Tertiary	Pliocene	Not present in county	1-70
		Miocene		
		Oligocene		
		Eocene		
		Paleocene		
MESOZOIC (middle life)	Cretaceous		Not present in county	70-135
	Jurassic		Not present in state	135-180
			Diabase (intrusive)	
			Basalt (flows and dikes)	
	Triassic		Lockatong Formation (not present in county)	
			Brunswick Formation(6000-8000 ft.)	
			Stockton Formation (2300-3100 ft.)	
PALEOZOIC (ancient life)	Permian		Not present in state	225-270
	Pennsylvania		Not present in state	270-285
	Mississippian		Not present in state	" "
	Devonian		Not present in county	285-400
	Silurian		Not present in county	400-440
	Ordovician		Not present in county	440-500
	Cambrian		Not present in county	500-600
PROTEROZOIC	Precambrian		Assorted gneiss (? ft.)	600-2100+

Geologic time intervals are unequal subdivisions of the earth's history corresponding to definite geologic events. Eras are the largest divisions of time and contain many periods, which are further subdivided into epochs. Formations, mappable rock units, are placed within the period during which they were formed. A formations's place within the stratigraphic column is determined by the predominant forms of life preserved within the rocks, distinctive lithology, and 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 local or regional modifications are sometimes used for greater clarity.