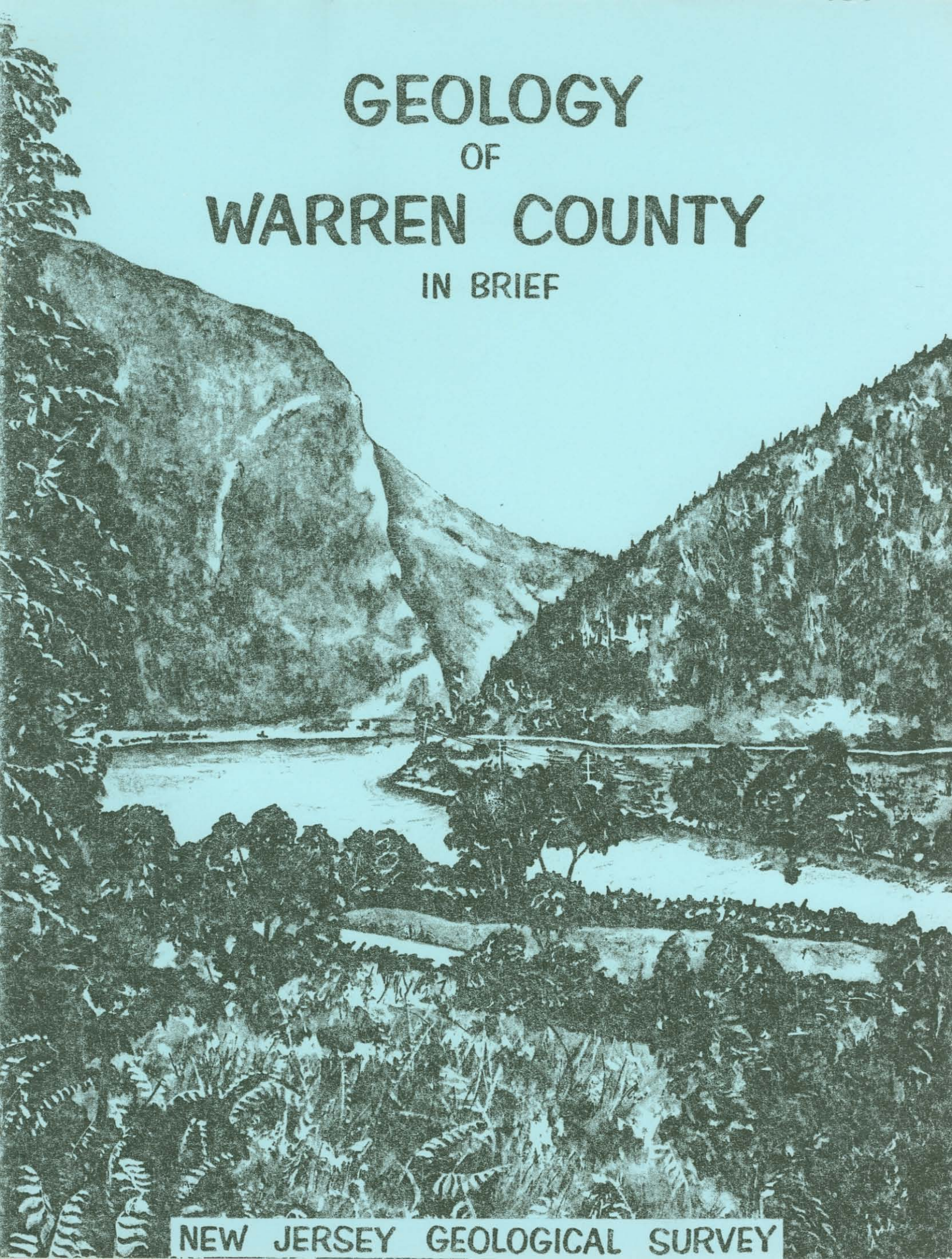
GEOLOGY
OF
WARREN COUNTY
IN BRIEF



NEW JERSEY GEOLOGICAL SURVEY

State of New Jersey

Department of Environmental Protection

Richard J. Sullivan, Commissioner

Division of Water Resources

THE GEOLOGY OF WARREN COUNTY IN BRIEF

by

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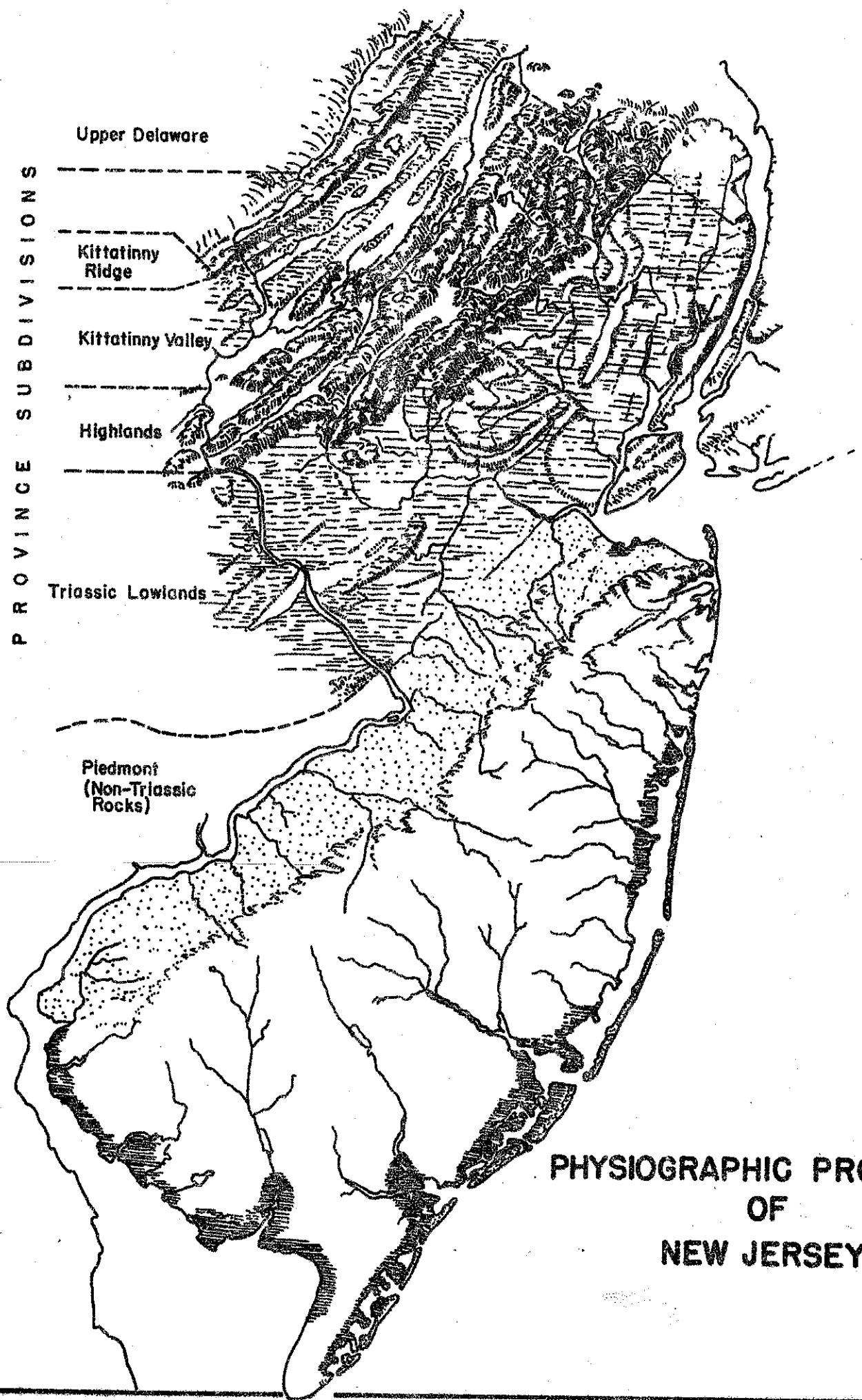


PHYSIOGRAPHIC PROVINCES OF NEW JERSEY

GEOLOGY OF WARREN COUNTY IN BRIEF

Topography

A physiographic province is a subdivision of the earth's surface based upon topographic similarity due to a unified climate, geologic history and structure. Warren county lies within parts of two such provinces; the Appalachian Valley and Ridge Province and the New Jersey Highlands.

The southern portion of Warren County from a line connecting Harmony and Allamuchy Townships southeastward, lies within the Highlands. The New Jersey Highlands are part of the Reading Prong of the New England Province. It is composed of a series of ridges formed when blocks of Precambrian gneiss were thrown upward. The erosional resistance of the gneiss causes them to form prominent ridges with great relief, in some areas exceeding 1,000 feet.

The Appalachian Valley and Ridge Province, underlain with Paleozoic sedimentary rock forms the Kittatinny Mountain and the associated valleys. The prominent ridge is composed of highly resistant Shawangunk quartzite and conglomerate and cuts across the county in a northwestern direction. The valleys on each side of the Kittatinny Mountain are composed of less resistant shales and limestones. The shales are usually fine-grained rocks which are susceptible to erosion and the limestones, being slightly soluble in water, are the least resistant rocks in the valleys.

Geologic History

Proterozoic Era

Precambrian Period - The oldest rocks in the county were originally marine sediments deposited over 600 million years ago. These rocks have

since been folded, faulted, and metamorphosed with the formation of gneiss and marble resulting. The metamorphism and igneous intrusion of the Precambrian rocks took place deep beneath the earth's surface where folding and compression provided the necessary heat and pressure to metamorphose or change the rocks. Present exposure of the rocks is due to removal of great thicknesses by erosion over millions of years.

The coarse-grained metamorphic gneiss possess distinguishable bands caused by the concentration of dark ferromagnesian minerals. Detailed work has been done to subdivide the gneisses, but that distinction need not be included. The Franklin Formation is also a remnant of sedimentary rocks and in the oldest carbonate rock in New Jersey. It is a white crystalline limestone and marble containing some graphite and sandy layers. At great depth, millions of years ago, the Franklin Formation was intruded and metamorphosed by molten igneous rock. The present extent of the gneiss and Franklin Formation is only a fraction of the original area covered by these rocks.

The only evidence of life in the the Precambrian can be interpreted by the graphite found in the Franklin Limestone. Graphite is composed entirely of carbon and is believed to be a remnant of the hydrocarbons of living organisms.

Paleozoic Era

Paleozoic time began with a slow depression of parts of the continent and the invasion of a shallow sea over the surface from southwesterly direction. Sediments gradually began to accumulate in an elongate depositional basin which extended from Newfoundland through New England, New York,

northwestern New Jersey, across eastern and central Pennsylvania, western Virginia and the central Carolinas into Alabama. Source areas for the sediments were land masses to the east and southeast. The Paleozoic Era lasted approximately 320 million years and the interior sea during this time varied greatly in size, shape and position.

In New Jersey, Paleozoic 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.

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 mechanically reduced by the tidal currents and wave action to uniform size and the non-resistant minerals were chemically altered. During sorting, the finer material was laid down in the calm deeper water while the coarser material was deposited nearer shore where the currents were stronger. The resulting formation consists of a well sorted rock composed almost entirely of quartz. Occasional conglomerates containing pebbles of gneiss, feldspar and quartz record areas where waves and currents were not strong enough to break down the Precambrian rock debris. The sands and gravels which accumulated during this time constitute the Hardyston Quartzite.

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 Appalachian Basin. The lack of an active influx of

sediment into the basin allowed calcareous organisms to flourish. The adundant lime organisms and the conditions of the quiet seas promoted the precipitation of calcium carbonate. These sediments are today recorded as a dolomitic limestone with occasional quartz layers and fossil remains called the Kittatinny Formation.

Ordovician Period - Following uplift and a long erosional interval, the Jacksonburg Limestone was deposited over Kittatinny sediments in a warm sea which once again invaded the area. Conditions were such that the sea contained abundant life and large quantities of organic remains were deposited. The resulting Jacksonburg Formation is dark colored and fossiliferous.

After the Jacksonburg was deposited, the region was gradually uplifted and the seas retreated from New Jersey and eastern Pennsylvania. During this period of uplift, the exposed land was slowly worn down by erosion.

Deepening of a basin caused fine muds to deposit. Occasionally, landslides or mudflows along the steep slopes of the basin produced thin sandy beds. These sediments are today recorded as a thick sequence of alternating sandstone, shale and slate beds called the Martinsburg Formation.

The end of Ordovician time was marked by an extensive period of folding faulting and uplift which is called the Taconic Orogeny, named after the Taconic Mountains of Vermont which were formed at this time.

It is likely that life existed for 100 million years before the Paleozoic Era, but earlier rocks have preserved little or no evidence of life. In New Jersey, fossil worm tubes from the Hardyston Quartzite are the first evidence. Although the New Jersey Cambrian fossil record is scant, over 500 species of invertebrate animals have been found in other

North American rocks. The meager New Jersey record was caused by the prevailing type of deposition. 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 are primitive types of algae and the scaphopoda, Hyolithellus micans. The Jacksonburg Formation environment was very favorable for abundant life so that brachiopods, crinoid stems, conodonts, and bryozoa are found.

The types of fossils found in the Martinsburg Formation, combined with their relatively rare occurence, 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.

Silurian Period - Following the disturbances of the Taconic Orogeny, the uplifted landmasses to the northeast, east and southwest provided a rich source of sediments which was carried into the Appalachian basin by high velocity streams. The poorly sorted conglomerate and quartzite deposited by these streams are preserved as the Shawangunk quartzite and conglomerate of which Kittatinny Mountain is composed.

As the source for these sediments was gradually reduced by erosion, the streams were unable to maintain their velocity and erode such coarse material. Finer-grained, iron-rich silt and clay was spread out at the foot of the source mountains in an alluvial plain environment. Upon the well aerated flood plains of the streams, oxidation of the iron present produced a red sediment, while the reducing environment of the stream channels resulted in olive green and gray beds. The resulting bands of grayish green

beds and red shale are called the High Falls Formation.

Even though marine invertebrates predominated during Silurian time the fossil record in New Jersey is scant. The Eurypterids, scorpion-like animals up to 16 feet in length, were the largest animals of the time. Their remains are found in the Shawangunk quartzite and conglomerate.

Recently, near Delaware Water Gap, fossils were found similar to jellyfish, in the Shawangunk. The soft bodied, jellyfish-like animal was first discovered in Southern Australia in rock over 560 million years old. This discovery, in the United States, extends the time range from Cambrian to the Silurian Period when this animal lived.

One of the most common fossils, the ostracod, is found in the High Falls Formation. The presence of these animals indicates that the depositional environment was a very muddy sea bottom.

From the end of the Silurian Period through the Devonian, Mississippian, Pennsylvanian, Permian, Triassic, Jurassic and Cretaceous Periods, there was a continuing period of erosion in Warren County. Therefore, it is impossible to decipher the specific events in the local geologic history.

Cenozoic Era

Tertiary Period

Erosion continued in the area during the Cenozoic Era (beginning 70 million years ago) reducing the relief even further. The theoretical end point in the cycle of stream erosion is called a peneplain, a gently sloping surface of little relief upon which streams meander toward the sea. During the Cenozoic Era, such surfaces of erosion were recorded.

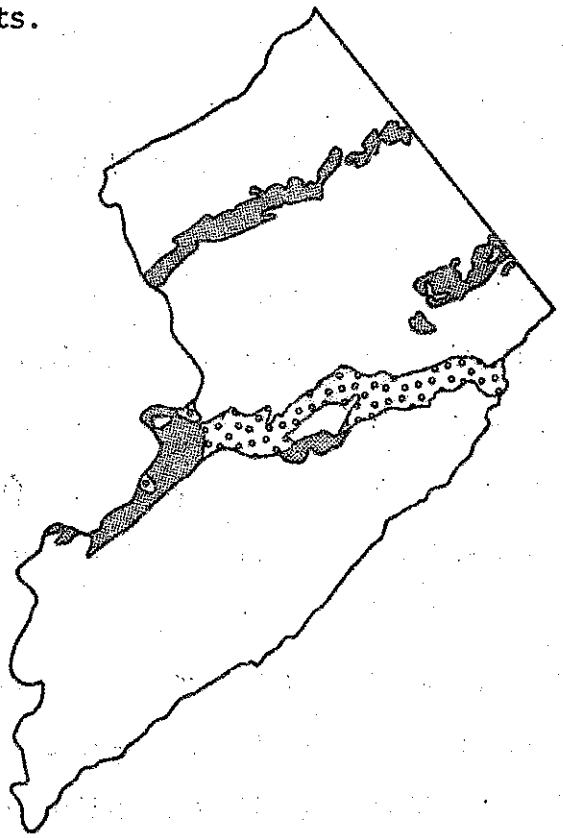
The erosion surface called the Schooley Peneplain, was formed during early Tertiary time. After gentle uplift, the increased velocity of the streams allowed them to erode, carving out valleys in the non-resistant shales, dolomites, and limestone. As the process of erosion continued, the surface of the land was again reduced to gentle relief. The Schooley surface was only recorded in the sandstone and gneissic ridges which resisted erosion. Subsequent uplift and erosion of intervening valleys has elevated this dissected Schooley surface to its present level at the crests of Kittatinny Mountain, and the gneissic ridges of the Highlands in Warren County. During this time the Delaware Water Gap was formed (see section on Water Gap, p. 9-10).

Quaternary Period

Pleistocene Epoch - The Pleistocene Epoch, known as the Ice Age, was a time when glaciers covered a much greater area than they do today. Ice ages or glacial stages alternated with warmer interglacial stages when the ice sheets receded temporarily.

In Warren County the glacial deposits are believed to belong to three glacial stages, Kansan (oldest), Illinoian, and Wisconsin (youngest). Each stage was named after a state in which the deposits, called drift, are well represented. In New Jersey, the evidence left from the Kansan stage is very patchy. Scattered rocks and clayey till (tough, stoney 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 appearance of the debris is a result of the long exposure to weathering and erosion. This drift is found on hilltops and in low terraces along streams.

The Wisconsin ice sheet was the most recent, and therefore has left the most evidence. The most distinctive glacial feature of the county is the sinous terminal moraine. This narrow ridge of coarse unstratified material extends across the middle of the county from Belvidere to Hackettstown. This moraine marks the terminal margin of the glacier where the material pushed by the advancing sheet remained after the ice melted. South of the terminal moraine the topography has been greatly modified by streams which deposited the large volume of sediment which the melting glacier had carried. North of the moraine, the ice has scoured, polished and striated rock surfaces and boulders. As drainage was blocked and disorganized by the ice sheets or as stream valley were gouged out and over-deepened, numerous lakes were formed, many of which still remain in Warren County as recreational resorts.



The Delaware Water Gap

A water gap is a pass in a ridge of resistant rock through which a stream has carved its course. Kittatinny Mountain, a continuous ridge from south central Pennsylvania where it is called Blue Mountain, through New Jersey to southeastern New York where it becomes Shawangunk Mountain, rises abruptly as an almost unbroken wall of the Silurian Shawangunk Conglomerate. Subsequent to the formation of the Schooley Peneplain in early Tertiary time, the land was gently uplifted, allowing the streams to once again sculpture the surface. In areas underlain by non-resistant shales, limestones and dolomites, the streams carved out deep valleys. The land underlain by resistant sandstones, quartzites and gneisses, however, stood out as ridges forming a barrier to the seaward drainage of Pennsylvania and northern New Jersey. In northwestern Warren County the Delaware River has successfully eroded its way through the Kittatinny Mountain to a present level of only 285 feet, where it forms the Delaware Water Gap. The remarkably level crest of Kittatinny Mountain rises to a height of 1,400 feet on either side, coinciding with the Schooley surface. The Gap, which is 300 yards wide at the river and 1,400 yards wide at the crest, forms an impressive notch in the horizon which is visible from the gentle hills of Kittatinny Valley to the southeast.

Many theories have been proposed concerning the mechanisms by which the Delaware River was able to erode its course from a once higher level to its present level through the Gap. In the light of most recent investigations, it seems highly probably that gentle folding and associated faulting and

jointing produced a weakness in the Shawangunk Formation at the Gap, making it more vulnerable to erosion. (Epstein, 1966).

Another theory is the erosion of peneplains. Peneplains are relatively flat surfaces formed by erosion over a wide area. In Warren County, the most obvious peneplain is the Schooley Peneplain, the remnants of which can be seen in the almost even crests of the Pocono Mountains in Pennsylvania, the Kittatinny Mountains and the Highlands. Gentle upwarp and subsequent sculpturing of the different rocks by stream erosion have formed the topography as it appears today. Over many thousands of years this wearing down process carved out the weaker rocks to form the valleys, and left the more resistant rocks as ridges.

During development of the peneplains, the streams were flowing at much higher levels than they are today. The Delaware River, flowing through what is now Delaware Water Gap, eroded the rocks forming a notch..

WARREN COUNTY'S MINERAL HISTORY IN BRIEF

Warren County has a variety of mineral deposits. The Pahaquarry Copper deposits, located near the Delaware River seven miles north of the Delaware Water Gap, were discovered by Dutch explorers in the 1650's. They came from Esopus (now Kingston) New York, down the Old Mine Road, through Minisink, to the Pahaquarry mine. Old Mine Road was originally constructed to haul ore, and for more than a century it was the longest stretch of good road in the colonies, with a length of 104 miles. Mining occurred on a limited scale at the Pahaquarry mine, the chief ore being chalcocite from the High Falls Formation. The mining ceased in 1664, when the English took over the Dutch colony of Manhattan. This is believed to have been the first mine worked by Europeans on this continent. Each mining attempt since then in the Pahaquarry deposits has ended in failure.

Today, in Warren County, sand and gravel, used chiefly as a building and paving material, is quarried near Carpenterville, Belevidere and Phillipsburg.

The Royal Green Marble Company of Phillipsburg produces marble for terrazzo. Near Oxford, limestone is crushed for cement and fertilizer.

Humus peat, recovered near the Great Meadows, is used primarily as a soil conditioner. Organic matter gradually accumulated on the Pleistocene Lake bottoms and underwent slow and partial decomposition under the water. This residual organic material formed peat.

GEOLOGIC TIME SCALE

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 formation'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.

Geologic Time Scale

Eras	Periods	Formation or Rock (approx. Thickness)	Approx. no. of million years ago
Cenozoic	Recent Quaternary Pleistocene	Soil and alluvium (0-30ft.) Glacial drift (0-460ft.)	0-1
Mesozoic	Tertiary	Not present in county	1-60
	Cretaceous Jurassic Triassic	Not present in county Not present in state Not present in county	60-130 130-155 155-185
Paleozoic	Permian	Not present in state	185-210
	Penn. Carboniferous Miss.	Not present in state Not present in state	210-265
	Devonian	Not present in county	265-320
	Silurian	High Falls Form.(2300 ft) Shawangunk Conglomerate(1500 ft)	320-360
	Ordovician	Martinsburg Fm.(3000 ft) Jacksonburg Fm.(125-300 ft)	360-440
	Cambro-Ordovician	Kittatinny Fm.(2500-3000 ft)	
	Cambrian	Hardyston Quartzite(5-200 ft)	440-520
Proterozoic	Precambrian	Franklin Formation and various gneisses and schists (? ft.)	520-2100+

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

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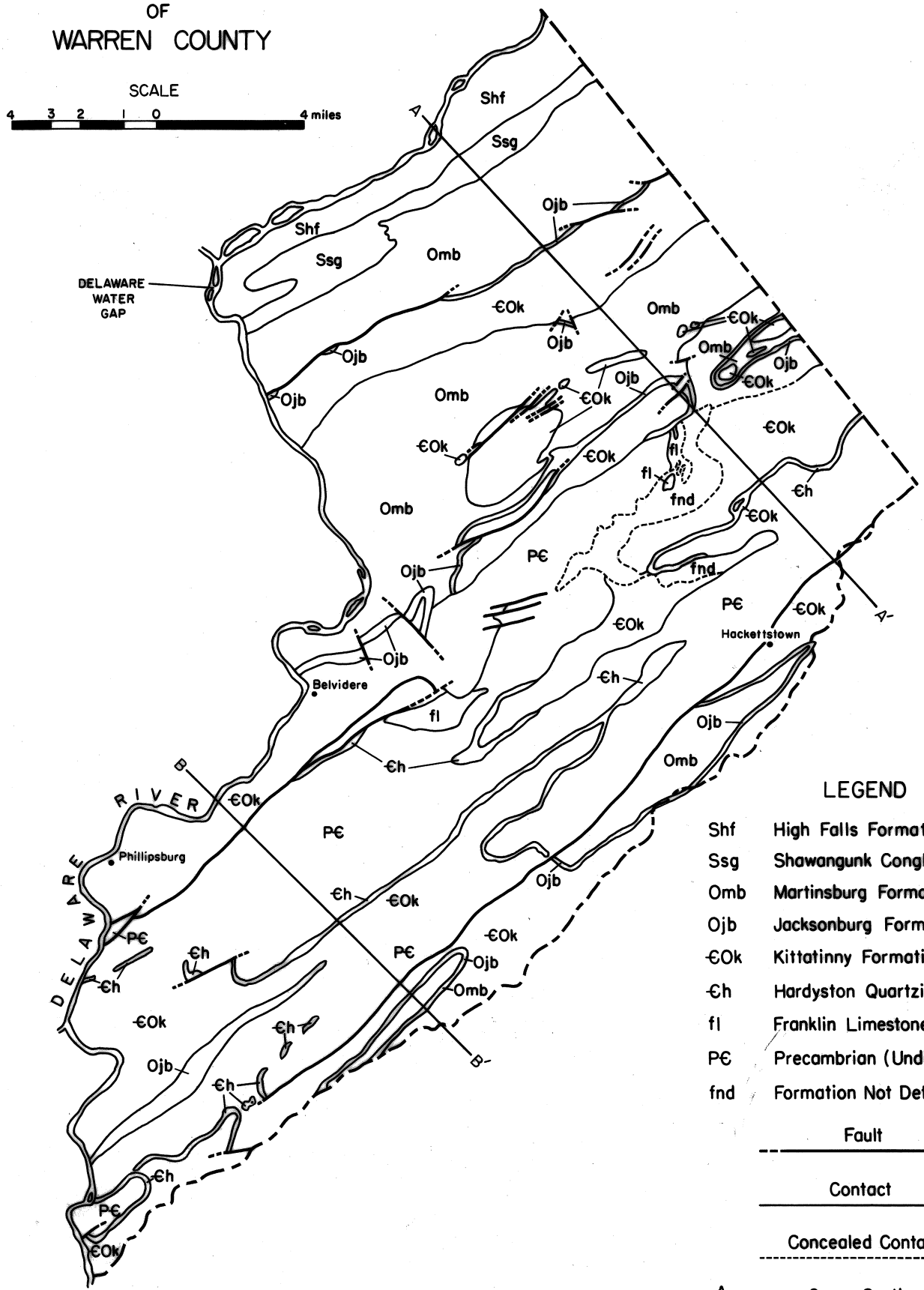
GEOLOGIC MAP OF WARREN COUNTY



LEGEND

Shf	High Falls Formation
Ssg	Shawangunk Conglomerate
Omb	Martinsburg Formation
Ojb	Jacksonburg Formation
€Ok	Kittatinny Formation
€h	Hardyston Quartzite
fl	Franklin Limestone
PC	Precambrian (Undifferentiated)
fnd	Formation Not Determined

Fault

Contact

Concealed Contact

A Cross Section A'

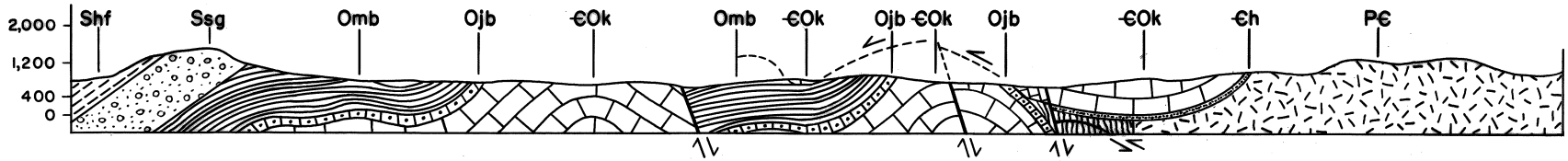
NOTE
Surficial Quaternary deposits not shown. Base Map, Atlas Sheet No. 40 – N.J.G.S. 1969.

GEOLOGIC CROSS SECTIONS
OF
WARREN COUNTY

New Jersey Geological Survey 1970

Horizontal Scale: 1" = 2 Miles

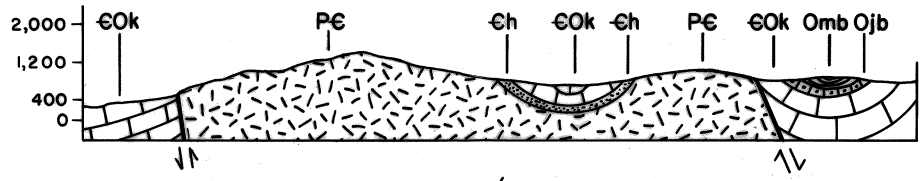
Vertical Scale: 1" = 400 Feet



SECTION A-A′

LEGEND

Shf	High Falls Formation
Ssg	Shawangunk Conglomerate
Omb	Martinsburg Formation
Ojb	Jacksonburg Formation
-€Ok	Kittatinny Formation
-€h	Hardyston Quartzite
P€	Precambrian (Undifferentiated)



SECTION B-B′