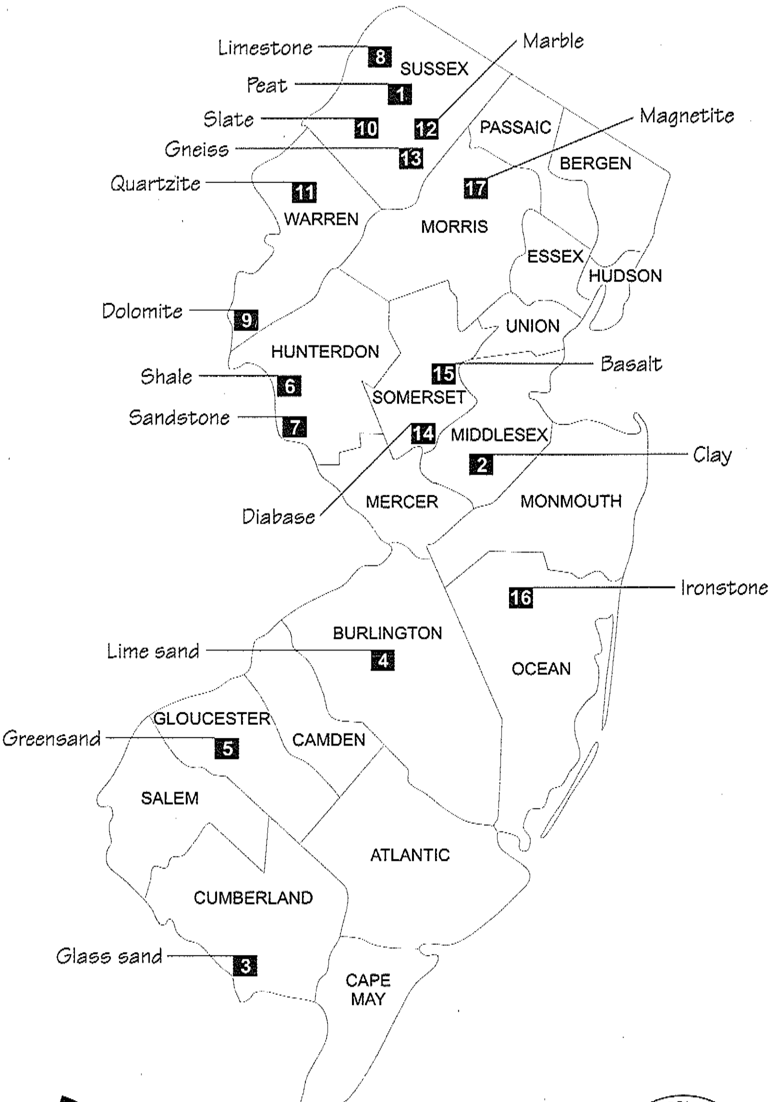
New Jersey Rocks and Sediments



Department of Environmental Protection
Land Use Management
New Jersey Geological Survey

STATE OF NEW JERSEY
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Department of Environmental Protection
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Land Use Management
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New Jersey Geological Survey
Karl Muessig, *State Geologist*

Geologic source and geographic location where each specimen was collected.

Specimen	Geologic Source	Township	County
1 Peat	Peat bog	Lafayette	Sussex
2 Clay	Woodbury Clay	Monroe	Middlesex
3 Glass sand	Cohansey Sand	Downe	Cumberland
4 Lime sand	Vincentown Formation	Southampton	Burlington
5 Greensand	Hornerstown Formation	Mantua	Gloucester
6 Shale	Stockton Formation	Kingwood	Hunterdon
7 Sandstone	Stockton Formation	Delaware	Hunterdon
8 Limestone	Glenerie Formation	Sandyston	Sussex
9 Dolomite	Allentown Dolomite	Pohatcong	Warren
10 Slate	Martinburg Formation	Newton[1]	Sussex
11 Quartzite	Shawangunk Formation	Blairstown	Warren
12 Marble	Franklin Marble	Sparta	Sussex
13 Gneiss	Microcline gneiss	Sparta	Sussex
14 Diabase	Rocky Hill diabase	Franklin	Somerset
15 Basalt	Orange Mountain basalt	Bound Brook[1]	Somerset
16 Ironstone	Cohansey Sand	Jackson	Ocean
17 Magnetite	Biotite-quartz-oligoclase gneiss	Rockaway	Morris

[1]Borough

New Jersey Geological Survey

New Jersey Rocks and Sediments

A booklet to accompany a set of 12 rocks and 5 sediments collected in New Jersey

by
John H. Dooley
and
David P. Harper

1996
(Revised 1998, 2005)
Printed on recycled paper

Conversion Factors

For readers who wish to convert to metric units, conversion factors for terms used in this booklet are listed below:

Multiply	by	to obtain
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
degrees Fahrenheit (°F)	(°F-32) x 0.5555	degrees Celsius (°C)
pound (lb)	0.4536	kilogram (kg)
ton, short (2000 lb)	0.9072	metric ton (t)
pounds per square inch (lb/in^2)	0.0703	kilograms per square centimeter (kg/cm^2)

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Additional copies of this booklet, the rocks and sediments set, and other reports, maps and products may be obtained from:

DEP Maps and Publications Sales Office
P.O. Box 438
Trenton, NJ 08625-0438

A price list is available on request.

Contents

INTRODUCTION

Most geologists working for the New Jersey Geological Survey from its founding in 1835 to the beginning of the 20th century mapped the state's geology or undertook other investigations related to Earth Science. They looked for useful materials like clay, building stone, minerals and gravel. In time, new responsibilities were added; today, environmental education ranks as an important Survey commitment.

The New Jersey Geological Survey prepared this set of 17 rocks and sediments to promote awareness and knowledge of the state's geology. The set is intended to provide elementary and secondary school students with earth science materials that are specific to New Jersey, but it can be enjoyed by anyone. This collection contains a wide sampling of rock types from the four geologic regions of the state. A one page color geologic map of New Jersey is also provided. The text on the back of the map expands on some of the information provided in this booklet.

Much of this booklet was adapted from a 1963 set of rocks and sediments prepared by James Yolton, Upsala College, and Kemble Widmer, New Jersey State Geologist.

Caution: some samples may have sharp edges. Please be careful.

ACKNOWLEDGMENTS

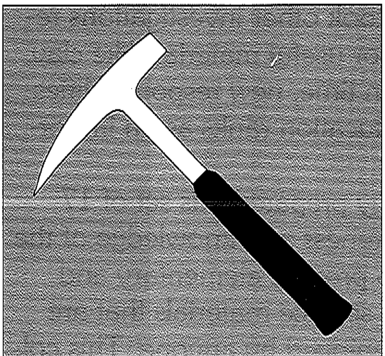
The New Jersey Geological Survey wishes to thank the following mineral producers for contributing samples to this set:

B. and J. Warren Company
Baer Aggregates Company
Inversand Company
Southdown
Millington Quarry Company
Mt. Hope Hydro, Inc.
Scott Company
Trap Rock Industries
Unimin Company

The authors are also indebted to Warren Cummings of the New Jersey Department of Transportation for recommending collecting sites and assisting in gaining access to active quarries, and William Graff, Thomas Seckler and Irving (Butch) Grossman of the New Jersey Geological Survey for help in manuscript preparation. Finally, a special thanks to Matthew Bonner for preparing and boxing the samples.

What is a mineral?

A mineral is a substance formed by natural and generally inorganic (nonliving) processes. It has a definite crystal structure, a fixed chemical composition or limited range of compositions, and definite physical properties. The atoms of a mineral are arranged in a regular and repeating three–dimensional network that is the same in all parts of the crystal and in all crystals and specimens of the same mineral



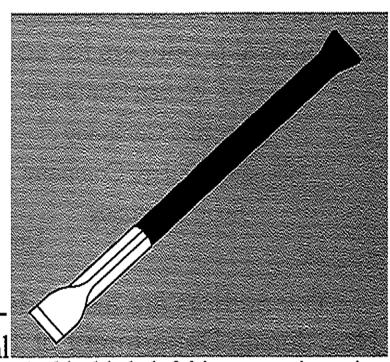
A rock hammer will be needed to collect samples of "hard rock."

Natural substances which do not fit the criteria for minerals are called mineraloids. Coal, petroleum, and amber (a solid resin from pine and other coniferous trees) are examples of mineraloids.

More than 3,000 minerals occur worldwide. Of these, 12 groups form 98 percent of the Earth's rocks, and about 200 minerals serve important human needs.

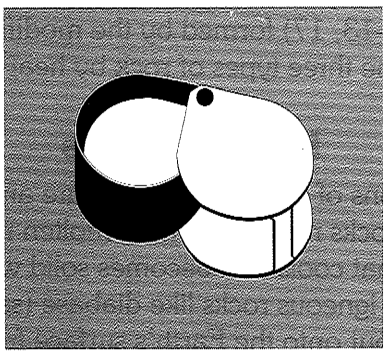
What is a rock?

A rock is a solid aggregate of one or more minerals. For example, limestone (sample 8) may consist entirely of calcite, whereas gneiss (sample 13) consists of several minerals – quartz, feldspar, and mica. Two rocks with identical mineral (and chemical) composition may have different names because of the form or arrangement of the minerals that make them up. For example, quartz is the principal mineral constituent of most sands (sample 3), but if the grains are cemented together, the resulting rock is called sandstone (sample 7). Sandstone may be tightly bound by crystalline quartz (silica) after exposure to intense heat and/or pressure,



A chisel is helpful in recovering minerals, fossils, or special pieces of the "hard rock" of northern New Jersey.

producing an extremely hard rock known as quartzite (sample 11). Another example of two rocks with similar chemical compositions but different appearance and names is diabase (sample 14) and basalt (sample 15). Both rocks formed by the cooling of a liquid melt, both have the same gross chemical composition, and both contain the same minerals. The diabase cooled slowly, allowing mineral crystals to grow to visible size. The basalt, on the other hand, cooled quickly, and is made up of microscopic crystals.



A magnifying lens of seven to ten power is essential for identifying mineral grains that compose a rock.

What are ores and gems?

Ores are rocks from which one or more metals can be extracted at a profit. Magnetite (sample 17) is an example of iron ore. An ore deposit may be worthless today, but become valuable tomorrow if the need for its constituents increases enough.

A gem is a precious or semiprecious solid which may be cut or polished for ornamental purposes. A potential gem possesses two or more of the following qualities: great hardness, pleasing color, brilliance, durability, rarity and attractiveness.

What are the main rock types?

Rocks are the building blocks of planets like Earth, and of many moons throughout the solar system. The scenic beauty of many landscapes is the result of geologic formations that make up mountains and valleys. Based on the way they formed, all rocks are classified into three major groups, (1) igneous, (2) sedimentary and (3) metamorphic. The igneous rocks in this set (samples 14 and 15) crystallized or solidified from molten (melted) material. The sedimentary rocks (samples 6–9, 16) formed by either the cementing together of bits of rock weathered away from older rock, or from minerals precipitated from solution. The metamorphic rocks (samples 10–13, 17) formed by the modification (metamorphism) of any of the three types of rock by heat and pressure.

Igneous Rocks

Under conditions of extreme temperature and pressure deep within the Earth, rocks may melt into a molten material called magma. Magma that cools and becomes solid within the Earth produces intrusive igneous rocks like diabase (sample 14) and granite. If it flows out onto the Earth's surface from volcanoes, it is called lava. When it cools and hardens, lava becomes an extrusive igneous rock, like basalt (sample 15). Most of the Earth's crust consists of igneous rocks.

Sedimentary Rocks

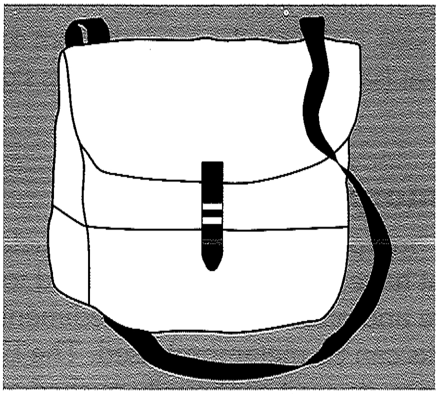
Rocks at the Earth's surface are slowly broken into smaller particles or grains by physical and chemical weathering. Weathered material may be transported, sorted, and deposited as sediment. Some of the New Jersey sediments in this collection, like sand (sample 3) and clay (sample 2), are familiar. Others, such as lime sand (sample 4), are made up of small fossil pieces, whereas peat (sample 1), made up of partially decomposed plants, may be new to you. As sediment accumulates, layer upon layer, its increasing weight squeezes particles together. Chemicals dissolved in the water between sediment grains may cement the particles together and form sedimentary rock. Examples of such rocks are shale (sample 6) and sandstone (sample 7). These formed from clay (sample 2) and sand (sample 3). Limestone and dolomite (samples 8 and 9) are sedimentary rocks that form by the cementing together of shells or the precipitation of minerals from seawater. Also classified as sedimentary rocks are halite (commonly known as table salt and rock salt), a chemical precipitate from seawater, and coal, formed from peat (sample 1). New Jersey lacks significant salt or coal deposits.

Metamorphic Rocks

"Meta" means change; "morph" means form. Thus, metamorphic rocks are rocks that have changed form. Exposed to sufficiently high temperature and pressure, igneous, sedimentary, and even metamorphic rocks can be metamorphosed. The Earth is a dynamic and active planet, its crust continually pushed and pulled by geologic forces. Some rock layers buckle downward in deep troughs and trenches, in places miles deep, whereas others are pushed upward as great mountain chains miles high. They are buried, heated and compressed for millions of years, and eventually reappear on the Earth's surface dramatically changed. Some of New Jersey's metamorphic rocks look much like the kind of rock they started out as. For example, quartzite (sample 11) somewhat resembles sandstone, and slate (sample 10) looks similar to shale. Others, like gneiss (sample 13), are so thoroughly changed that it is almost impossible to tell what kind of rock they were formerly.

Where did New Jersey's rocks come from?

Some rocks originated at the roots of ancient mountains and were later uplifted during continental collisions. Some formed from lake and river sediments deposited in long, narrow rift valleys that opened when continents were torn apart. Others started as sand and mud along ocean beaches and ancient shorelines. And finally, some formed by precipitation of calcium and magnesium dissolved in warm, shallow seawater. New Jersey's rocks and sediments preserve an almost complete history of the natural forces that shaped eastern North America throughout geologic time. This history includes reefs formed in tropical seas near the equator, deserts far inland on a continent larger than any now on Earth, giant lava flows, and glaciers more than 2,000 feet thick.



A rock and mineral collector needs a sturdy bag in which to bring home samples.

Sediments

1) **PEAT** is made of partially decomposed plants. It is found in swamps and bogs because the organisms that normally recycle roots, leaves, and branches back into minerals, air, and water cannot survive in the oxygen-poor, acidic water of these environments. Most of New Jersey's peat accumulated in low-lying, undrained areas during the 17,000 years following the end of the last ice age. If deeply buried, these peat deposits might eventually be changed into coal. The process would require time and burial deep in the Earth. The sequence of change from peat to the highest grade of coal is: peat, lignite, bituminous coal, and anthracite. During each step of these changes, water and some gasses are lost and the plant debris becomes darker, denser, and harder.

In addition to plant remains, animal fossils may also be preserved in peat bogs. Parts of at least 40 mastodons (an extinct kind of elephant from the end of the last ice age) have been found in New Jersey peat deposits. Teeth and a few bones are all that is left of most of them, but at least seven nearly complete mastodon skeletons have been discovered and are on display in museums.

The peat in this rock set is from Lafayette Meadows, a bog in Sussex County. Peat has been mined here since before 1900. At one time New Jersey was one of the largest producers of peat in the United States, and continues to mine it from sites in Warren and Sussex Counties. Most of it is mixed with soils to improve and condition them. Because of its spongy nature, peat has a significant water-holding capacity that makes it useful for shipping live plants, and for retaining moisture in lawn and garden soils.

Most of New Jersey's bogs are not used for peat production. Some, like Great Meadows in Warren County, are rich farmlands which produce several vegetable crops each year. Others are protected for their valuable wetland habitat. The best known of New Jersey's protected bogs are the Cedar Swamps of the Pine Barrens and parts of the Great Swamp in Morris County.

2) **CLAY** minerals form by chemical weathering and decay of the common mineral feldspar and similar silicate minerals. They are so small they cannot be seen with the naked eye. Their identification requires special tests and equipment, such as X-ray analyses and high-powered microscopes.

At the turn of the century, hundreds of thousands of tons of clay were dug each year in central New Jersey. A pit in Middlesex County supplied the Sayre and Fisher brickyard in Sayreville, one of the largest brickyards in the northeastern United States. Millions of bricks in factories and apartment buildings throughout northern New Jersey, New York, and Connecticut came from the Sayre and Fisher brickyard.

New Jersey clay was also used for pottery, roofing tile, and ceramic pipe. In the past, more pottery was made in Trenton, Mercer County, than in the rest of the Atlantic States combined. Woodbridge and The Amboys in Middlesex County supplied clay for much of the roofing tile and ceramic pipe produced in the United States. Because some of the clay from Woodbridge contained almost no sand, it was used for filler in linoleum, plastic, and paper, and to make fire brick for lining blast furnaces.

Billions of tons of clay remain in New Jersey, and a few pits continue to supply some for brick and foundry work. Production, however, declined to a small fraction of its former volume when the use of brick and tile for building construction declined, and metal, glass, and plastic replaced pottery for cooking and storage containers. Most of the clay now mined in New Jersey is used for sealing the tops of landfills. This is known as "capping" a landfill. Sample 2 in this rock set was dug to be used for this purpose.

Capping is necessary because rain falling on an unsealed landfill soaks in and mixes with polluted material. The pollutants may then seep into the ground water, eventually making their way into streams and water supplies. But if several feet of clay, which is essentially watertight, is placed over a landfill, rainwater runs off the top and remains unpolluted.

3) **GLASS SAND**, used for making glass, consists almost entirely of quartz. New Jersey's best glass sand is more than 99 percent pure quartz and comes from Cumberland and Salem Counties. It developed from common beach sand which formerly included softer minerals like feldspar and mica. These minerals subsequently decayed (weathered), broke down, and were washed away by waves or currents, or blown away by wind. Heavy minerals like ilmenite were also sorted out by water or wind into concentrated deposits, further purifying the residual quartz.

The first successful glass factory in England's American colonies opened in Alloway, Salem County, in 1739. Glass making has continued in New Jersey ever since.

In addition to supplying the raw material for glass, the pure quartz sands of the state are used for making molds into which molten iron is poured to produce cast iron. They also supply abrasives for sandblasting buildings, and for making silica gel, a drying agent, and silica flour, used in cosmetics. More than 1,500,000 tons of glass sand and other pure silica sand, worth more than $33,800,000, was produced in New Jersey in 2003.

4) **LIME SAND** is made of the mineral calcite which, unlike quartz and most other minerals, will fizz in a weak acid such as vinegar. The gas that fizzes off is carbon dioxide.

The lime sand in this set is from Vincentown, Burlington County. It consists almost entirely of fossil fragments. See if you can find a piece covered with small holes. This was part of a bryozoan colony. A bryozoan reproduces until a single animal has grown to a colony of thousands. You may also find worm tubes (most of which are coiled) and fragments of clams, snails, and sea urchins. Some of the small grains are not ground-up pieces of larger fossils, but complete fossils of single-celled animals known as foraminifera ("forams" for short). Many of these tiny fossils can easily be seen with a magnifying glass, hand lens, or low magnification microscope. Burial, compaction, and the addition of calcite cement would convert this lime sand into limestone.

5) **GREENSAND** is a green, sandy mixture of glauconite, clay, and quartz sand. It was called "marl" by early miners, although it does not fit today's scientific definition of a marl. Glauconite, the mineral that gives greensand its color, is made of potassium, iron, silica, and water. It forms on the ocean floor and often contains fossil clams, oysters, snails, shark teeth, and fish and reptile bones.

Greensand contains several chemicals necessary for plant growth, including potassium and phosphorus, essential plant nutrients, as well as lime. It was mined and used as fertilizer in New Jersey as early as the 1700's. In the peak year of greensand mining, 1868, nearly a million tons was extracted. Although some greensand is still used for soil improvement, artificial fertilizers had put most greensand producers out of business by 1900.

Greensand is also used for softening water. Hard water generally has high levels of dissolved calcium or magnesium carbonate (mineral names: calcite and magnesite). This prevents soap from lathering, forms white crusts on pots and pans, and builds up deposits that clog pipes. Glauconite has a sieve-like molecular structure that traps calcium and magnesium. When calcium and magnesium are trapped, an equivalent amount of sodium is released into the water. Sodium does not form crusts, clog pipes, or keep soap from lathering. The result is a softened water. As with fertilizers, artificial compounds have replaced greensand in most water softeners.

The greensand in this rock set is from the Inversand Pit in Sewell, Gloucester County. For many years, this pit has been the only place in North America where greensand is produced. Most of its greensand is used in water softeners, but some serves as a natural soil conditioner (fertilizer).

Sedimentary Rocks

6) **SHALE** forms from the compaction of mud or clay. Because most sediment produced from the weathering of rock is

mud, shale is the most common sedimentary rock.

The black or gray staining of sample 6 comes from iron minerals and organic debris showing that it formed on the bottom of a shallow lake with little or no oxygen. Oxygen combines with iron to form red, yellow, and brown minerals similar to rust. Most Triassic and Jurassic rock in New Jersey is shale, colored bright red by such oxygen-rich iron minerals. The red soil seen throughout much of central and northeastern New Jersey formed by the weathering of this shale. Some of the shale is soft enough to be ground into a clay-like material used to make bricks and terra cotta. Flowerpots, tiles and ceramic pipes are all made from terra cotta.

7) **SANDSTONE** forms from the cementing together of sand grains. The example in this rock set dates back approximately 210 million years to the Late Triassic Period, the early days of dinosaurs. It formed from sand deposited by rivers in a desert environment.

The sample is called brownstone, and is a kind of building stone used in thousands of houses, apartments, churches, libraries, bridges, and train stations built in the northeastern United States between the early 1700's and about 1900. New Jersey was the nation's most important producer of brownstone and supplied most of the material used in New Jersey, New York, and Philadelphia.

The ironstone in the rock set (sample 16) is another type of sandstone that formed in an oxygen-rich environment much like that of today's Pine Barrens. It formed when iron dissolved in water precipitated in sand, cementing the grains together. Whereas most of New Jersey's sandstone formed under elevated heat and pressure several thousand feet underground, the ironstone formed at, or close to, the surface.

8) **LIMESTONE** and (9) **DOLOMITE** are chemically similar rocks formed from minerals dissolved in water. Limestone, like lime sand, is made of the mineral calcite; the rock dolomite, or dolostone, consists of the mineral dolomite. Limestone fizzes energetically in a weak acid like warm vinegar because calcite dissolves easily. Dolomite does not dissolve as easily, and fizzing is less readily seen unless the rock is first reduced to a powder to speed up

the chemical reaction.

Limestone and dolomite form mostly in warm climates. The dolomite in this rock set comes from a belt of formations that stretches from eastern Canada to Georgia; in New Jersey these formations are almost a mile thick. The minerals that make up these rocks were precipitated from sea water, primarily by one-celled plants called algae. Cabbage-like "stromatolite" fossils formed by these algae are sometimes found in the beds from which the rock samples were taken. A few limestone samples in these sets have also yielded parts of trilobites and brachiopods. Pieces of other fossils, including crinoid stems, may also be found.

Nearly all of New Jersey's caves and rock shelters are located in the limestones of Sussex and Warren Counties. Some of these were once occupied by Native Americans. In colonial times, limestone was used to construct farmhouses, many of which still stand. Limestone and dolomite have also been widely quarried for cement and agricultural lime in the northwestern part of the state. Agricultural lime is used to reduce the acidity of soils and to provide calcium for plant growth. It is produced by roasting limestone or dolomite in a sandstone-lined oven, called a limekiln, until the mineral breaks down into a powder. The ruins of hundreds of limekilns, unused since the 1800's, remain in northwestern New Jersey, a mute reminder of the state's past. Most limestone quarried now is crushed for road building material and other construction work.

Metamorphic Rocks

10) **SLATE** is formed from shale buried deep underground and subjected to temperatures of 1,000 to 3,000°F, and pressures of 2,000 to 4,000 pounds per square inch. The slate in this set was first deposited as clay and mud in a marine environment about 450 million years ago. These fine-grained sediments were buried and slowly converted to shale. With increasing heat and pressure, the shale was eventually changed (metamorphosed) to slate. If the process had continued, and temperature and pressure intensified, the rock would have changed to schist, and finally to gneiss. Schist consists mostly of mica and is not common in New Jersey. Gneiss, on the other hand, is common throughout the New Jersey High-

lands (see geologic map for the location of the Highlands).

Most of the slate in New Jersey is exposed along the base of Kittatinny Mountain in Sussex and Warren Counties. It forms a belt 30 miles long and 2 to 4 miles wide. New Jersey's slate contains sand layers, and for this reason does not break into the large, flat pieces once used to make blackboards. Some of it is good enough for roofing material, and a few quarries operated in the 1800's for this purpose. They could not compete, however, with much larger quarries in Pennsylvania that had higher quality slate. Small amounts of New Jersey slate continue to be quarried for construction needs.

11) **QUARTZITE** is a sandstone in which quartz grains have become tightly bound together by silica precipitated out of solution, or recrystallized under intense heat and pressure. The sand grains are so strongly united that the rock breaks through the grains instead of around them, as it does in brownstone and ironstone. Quartzite is tough, and more resistant to erosion than any other common rock. High Point (the highest spot in New Jersey) and Mount Tammany near the Delaware Water Gap, lie at the two ends of Kittatinny Mountain, a 35-mile-long, 1,000-foot-high mountain of quartzite.

An unusually attractive quartzite in New Jersey is the Green Pond Conglomerate. It is distinctly red and contains white quartz pebbles. Millions of boulders of this conglomerate were carried south and east from Green Pond Mountain by glaciers during the ice age, and are distributed as far away as Perth Amboy. The boulders are so common eight miles east of Green Pond Mountain near Montville, Boonton, and Morristown in Morris County, that they are used to build walls and houses.

12) **MARBLE** is a massive metamorphic rock formed from the recrystallization of limestone or dolomite. It is exposed in several belts in the New Jersey Highlands. Some consists of the mineral calcite, and some of dolomite. How can you tell which mineral the marble in this rock set is made of? (See the write-ups for samples 4, 8, and 9.)

Marble quarried in New Jersey is generally too coarse-grained to be carved or used in architecture, but it is mined for construction. Most of it is crushed and used for landscaping. Pieces like the one in the rock set can be found along walks and around bushes and trees throughout the northeastern United States. It is also used as grit in chicken feed (chickens don't have teeth, and need grit in their crop to grind their food) and for agricultural lime. Some samples contain a shiny, steel gray to black mineral called graphite. Graphite is essentially pure carbon and is used in lead pencils, paints, as a lubricant, and in cooling rods for nuclear reactors. Check the sample for graphite!

13) **GNEISS** (pronounced "nice") is a metamorphic rock made mostly of quartz and feldspar. These are the light-colored crystals in this sample. The darker crystals are amphibole (hornblende) or biotite mica, and owe their color to iron and magnesium. Characteristic of gneiss is an irregular layered appearance caused by light and dark mineral bands. Wetting the rock with water may bring out this banding, but the samples are too small for it to be seen on some of them. Gneiss is common in the New Jersey Highlands where it forms hills 500 to 1,000 feet high. Softer or more soluble rocks would long since have worn away.

Unlike slate, quartzite, or marble, gneiss is so completely metamorphosed that it doesn't look like the rock or sediment it formed from. Gneiss can originate from slate, sandstone, igneous rocks, and even other metamorphic rocks.

New Jersey gneiss is almost as hard as diabase and basalt. Like them, it is quarried mostly for road metal, to be mixed as aggregate with concrete, and for other construction uses. But there is less quarrying of gneiss than of diabase and basalt because it is farther from New Jersey's cities than the igneous rocks are. It is expensive to transport stone more than a few miles.

Igneous Rocks

14) **DIABASE** and (15) **BASALT** are igneous rocks formed from magma (molten rock) which rose in fractures that opened when the North American and African continental plates split apart. The basalt erupted from volcanoes or fissures, and the lava hardened within a few weeks. Because it cooled quickly, there was no time for visible crystals to form.

Unlike the basalt, the diabase did not reach the Earth's surface.

It squeezed between sandstone layers about two miles beneath the land surface, and spread out as a flat sheet. Insulated by the sandstone, the magma took thousands of years to cool and harden. This slow cooling gave crystals plenty of time to grow, resulting in the light and dark crystals you see in sample 14. The dark specks are a mineral called pyroxene; the white ones are feldspar or plagioclase. Basalt is made of the same kinds of light and dark crystals, but they are so tiny you need a microscope to see them. Wetting the diabase with water will bring out the salt-and-pepper texture. Try wetting the basalt also, and note the difference.

Diabase and basalt, like quartzite and gneiss, are harder than most other rocks and remain as mountains after the softer or more soluble rocks have eroded away. The magma that squeezed between sandstone layers and cooled to form diabase forms the cliffs of the Palisades along the Hudson River. In the millions of years since the diabase cooled, erosion has removed two miles of other rock above it, exposing the Palisades at the surface. The Watchung Mountains are underlain by basalt that formed from lava flows. Magma repeatedly rose up through the Earth's crust while the North American and African continental plates were pulled apart (rifted). Volcanic activity lasting more than a few thousand years during each event spread lava across an area that measured at least 10 by 30 miles. The lava beds from these eruptions are shown in red on the geologic map. They now form the Watchung Mountains.

New Jersey Ores and Economic Minerals

A rock set with all the economic minerals ever mined in New Jersey would include zinc ore from Franklin and Ogdensburg (Sussex County), titanium and zirconium minerals from sand near Lakewood (Ocean County), copper ore from central and northwestern New Jersey, serpentine from the Phillipsburg area (Warren County), mica and graphite from the the Highlands, uranium from Stanhope (Sussex County), barite (a barium ore) from Hopewell Township (Mercer County), and iron ores from around the state.

16) **IRONSTONE** is quartz sand cemented together by iron minerals resembling rust. These minerals form when iron dissolved in acidic water is deposited (precipitated) by chemical changes

and bacterial action. Ironstone contains far too much sand and far too little iron to be an ore. But the same iron minerals free of sand form bog iron along many of the rivers of the Pine Barrens of southern New Jersey. Ironstone is included in this set because it is common, easily found throughout many parts of the Coastal Plain, and had the iron concentration been high enough, could have been mined as an ore.

To extract the bog iron, ore is heated along with coal and calcium carbonate in a furnace. The water in the ore is driven off as steam, calcium carbonate combines with oxygen in the ore to form slag, and liquid (molten) iron sinks to an outlet at the bottom of the furnace.

New Jersey bog iron was first worked in 1674 using charcoal from the Pine Barrens' forests and calcium carbonate from shells bought from clam and oyster houses along the seashore. This source of iron was critical during the Revolutionary War when America's supply of imported iron was cut off by a British blockade. After the war, New Jersey's bog iron industry continued operating successfully until about 1790. Then, because the deposits are small and far from coal needed for fuel and limestone needed for calcium carbonate, the industry began to decline. Rich magnetite deposits closer to coal and limestone deposits were developed that put New Jersey's bog iron producers out of business by about 1868.

17) **MAGNETITE**, an ore with enough iron to be picked up with a magnet, is found within the gneisses of northern New Jersey. Magnetite mining was first attempted in New Jersey in 1685, but was not successful until about 1710. By the time of the Revolutionary War, magnetite mining was well established. Iron from the Ringwood Mines of Passaic County was used to forge a great chain that was stretched across the Hudson River to prevent British warships from advancing to West Point. A hundred years later, New Jersey was the leading iron producer in the United States, reaching maximum output in the 1890's. But then newly-discovered and easily mined ore deposits in the Upper Midwest put Michigan first among U.S. iron producers. Within a few years, only the largest and most efficient of New Jersey's mines could compete with those of Michigan, Minnesota, and Wisconsin. The magnetite in this rock set is from the Mt. Hope Mine in Morris County, the last New Jersey iron mine in operation. It remained open until 1978.

INFORMATION SOURCES

New Jersey Museums with Earth Science Exhibits

Bergen Museum of Arts and Science
Ridgewood Avenue
Paramus, NJ 07652
(201) 291-8848
www. thebergenmuseum.com

Franklin Mineral Museum
Evans Street
PO Box 54
Franklin, NJ 07416-0054
(973) 827-3481
www.franklinmineralmuseum.com

Liberty Science Center
251 Phillips Street
Jersey City, NJ 07305
(201) 200-1000
www.lsc.org

Meadowlands Museum
91 Crane Avenue
Rutherford, NJ 07070
(201) 935-1175
www.meadowlandsmuseum.org

The Morris Museum
6 Normandy Heights Road
Morristown, NJ 07960
(973) 971-3700
www.morrismuseum.org

New Jersey State Museum
205 West State Street
Trenton, NJ 08625
(609) 292-6464
www.state.nj.us/state/museum

Newark Museum
49 Washington Street
PO Box 540
Newark, NJ 07101
(973) 596-6550
www.newarkmuseum.org

Paterson Museum
Thomas Rogers Building
2 Market Street
Paterson, NJ 07501
(973) 321-1260
www.passaiccountynj.org/ParksHistorical/Historical_Attractions/patersonmuseum.htm

Poricy Park Nature Center
Oak Hill Road
PO Box 36
Middletown, NJ 07748
(732) 842-5966
www.monmouth.com/~poricypark/center.html

Rutgers University Geology Museum
George and Somerset Streets
New Brunswick, NJ 08903
(732) 932-7243
www.geology.rutgers.edu/museum.html

Sterling Hill Mine and Museum
30 Plant Street
Ogdensburg, NJ 07439
(973) 209-7212
www.sterlinghill.org

Trailside Nature and Science Center
452 New Providence Road
Mountainside, NJ 07092-1409
(908) 789-3670
http://unioncountynj.org/svcsgov/parksrec/trailsde.htm

Books on New Jersey Geology

Although much has been learned since it was first published, a good overview of the state's geology can be found in *The Geology of New Jersey* by Henry B. Kummel, 1940, New Jersey Geological Survey Bulletin 50, 230 p. It is available from the Department of Environmental Protection Maps and Publications Sales Office in photocopy (see p.19).

The books listed below are out-of-print. If they are not in your local library, they can be borrowed using interlibrary loan.

The Geology and Landscapes of New Jersey by Peter E. Wolfe, 1977, Crane Russak, New York, 341 p.

The Geology of Geography of New Jersey by Kemble Widmer, 1964, Van Nostrand, New York, 193 p.

Lectures, Open Houses, Geologic Trips

Geologic Association of New Jersey
PO Box 5145
Trenton, NJ 08638-0145
An annual meeting and field trip focus on a particular aspect of New Jersey geology. Trips are oriented toward geologic understanding rather than collecting. Guidebooks for past years can be ordered from:
Dr. Richard L. Kroll
Department of Geology and Meterology
Kean University
Union, NJ 07083
(908) 737-3698
www.ganj.org

Center for Earth System Education
Kean Universiy
Union, NJ 07083
(908) 737-5967
Maintains a reference resource of educational material.
http://hurri.kean.edu/cese/

New Jersey Earth Science Teachers Association
Kean University
Union, NJ 07083
www.njesta.org
An annual meeting and several workshops are held each year. These focus on a particular aspect of earth science, meterology, or astronomy.

Rutgers University
Department of Geological Sciences and Geology Museum
New Brunswick, NJ 08903
(732) 932-7243
http://geology.rutgers.edu/museum.html

An open house usually the last weekend in January.

Friends of the Rutgers Geology Museum
Lectures on geology and palentology given at irregular intervals. Can be contacted through the Rutgers University Geology Museum. (732) 932-7243

Collecting Trips

In 2004, three New Jersey sites were regularly open to collectors:

- Franklin Mineral Museum, Buckwheat Dump, Franklin Borough, Sussex County, (973) 827-3481, www.franklinmineralmuseum.com

- Poricy Park Nature Preserve, Middletown Township, Monmouth County, (732) 842-5966, www.monmouth.com/~poricypark/center.html

- Sterling Hill Mine and Museum, Ogdensburg Borough, Sussex County, (973) 209-7212, www.sterlinghill.org

New Jersey Outdoors Articles

New Jersey Outdoors is a magazine no longer published by the New Jersey Department of Environmental Protection that focused on the state's environment. If your library does not keep back issues, articles can be requested through interlibrary loan. Articles with information on geology and mineral use include:

- *Prospecting for Prehistoric Shark Teeth* by Don Kamienski, Summer 1994, v.21, no. 3, p. 10-11.

- *New Jersey's Haddonfield Dinosaur*, by Gene Montgomery, January-February 1984, v.11, no. 1, p. 8-9, 30-31.

- *Ghosts of Iron Past* by John T. Cunningham, May 1984, v.11, no. 3, p. 20-33

- *Mineral Collecting in New Jersey* by Helen Collins, January 1985, v.12, no. 1, p. 28-29.

  A Time of Glaciers and Mastodons by David Harper, Winter 1993, v.20, no. 1, p. 24-28

- *Maximus: New Jersey's Prehistoric Sea Monter* by Richard Fulton, Winter 1992, v.18, no. 4, p. 18-22.

- *Franklin Marble* by Richard Fulton, 1989, v.16, no. 2, p. 10-13.

- *Radon—Naturally Occurring in New Jersey* by Rachelle DePalma Garbarine, March-April 1987, v.14, no. 2, p. 9-11.

- *Cast in Iron* by Allen G. Eastby, January-February 1987, v.14, no. 1, p. 22-26.

- *Glorious Glass Collection* by Susanne Banta Harper and Sally Dudley, November 1985, v.12, no. 6, p. 26-27.

U.S. Geological Survey

U.S. Geological Survey, Water Resource Division, 810 Bear Tavern Road, West Trenton, NJ 08628, (609) 771-3900, nj.usgs.gov, will send free singles copies of the following leaflets on request:

- *Ground Water Issues in New Jersey*
- *Surface Water Issues in New Jersey*
- *Floods and Droughts [in New Jersey]*

"General Interest Publications of the U.S. Geological Survey" is available on-line at: pubs.usgs.gov/products/books/gip.html.

A price list of other U.S. Geological Survey materials is available on request from: U.S. Geological Survey, Earth Science Information Center, 507 National Center, Reston, VA 20192, 1-888-ASK-USGS, ask.usgs.gov.

New Jersey Geological Survey

Questions about New Jersey geology may be addressed to: Karl W. Muessig, State Geologist, New Jersey Geological Survey, PO Box 427, Trenton, NJ 08625-0427, (609) 292-1185; www.njgeology.org.

A price list of environmental and earth science materials, including topographic maps, geologic maps, and reports on water and mineral resources, is available from the DEP Maps and Publications Sales Office, (609) 777-1038, and at: www.njgeology.org.

Over-the-counter purchases:

DEP Maps and Publications Sales Office
Carroll Building
428 East State Street
Trenton, NJ 08608
8:30am-noon; 1pm-4pm (Mon-Fri)
Phone: (609) 777-1038

Mail-order purchases:

DEP Maps and Publications
Sales Office
PO Box 438
Trenton, NJ 08625-0438

New Jersey Department of Environmental Protection

Environmental education materials are available from:

Environmental Education Unit
PO Box 402
Trenton, NJ 08625-0402
(609) 777-3373; www.state.nj.us/dep/seeds

Organizations

Eastern Federation of Mineralogical and Lapidary Societies
PO Box 10119
Alexandria, VA 22310-0119
www.amfed.org/efmls

Geological Society of America
3300 Penrose Place
Boulder, CO 80301
www.geosociety.org

SME[1] Government, Education and Mining (GEM) Program
8307 Shaffer Parkway
Littleton, CO 80127
(303) 973-9550
www.smenet.org/education/GEM/index.cfm

[1] SME-Society of Mining, Metallurgy and Exploration

New Jersey Mineral and Fossil Collecting Clubs

Bergen County Mineralogy & Paleontology Society
15 Fahrner Street
Bergenfield, NJ 07621

Cape Atlantic Rockhounds
933 West White Horse Pike
Egg Harbor, NJ 08215
email: rockhounds@hotmail.com

Clifton Mineral and Lapidary Society
35 Lewis Place
Totowa, NJ 07512-2647

Delaware Valley Earth Science Society
P.O. Box 372
Maple Shade, NJ 08502
www.dvess.org

Franklin Mineral Museum
PO Box 54
Franklin, NJ 07416-0054
www.franklinmineralmuseum.com

Franklin-Ogdensburg Mineralogical Society
PO Box 146
Franklin, NJ 07416-0416

Mineralogical and Lapidary Society of the Raritan Valley
55 Balsam Court
Belle Mead, NJ 08502

Monmouth Mineral and Gem Club
PO Drawer J
Manasquan, NJ 08736-0640

Morris Museum Mineralogical Society
6 Normandy Heights Road
Morristown, NJ 07960
email: r.greipel@worldnet.att.net

Newark Mineralogical Society
54 Newman Avenue
Verona, NJ 07044

New Jersey Lapidary Society
177 Broadway
Clark, NJ 07066

New Jersey Mineralogical Society
1210 S. 10th Street
N. Plainfield, NJ. 07080

New Jersey Paleontological Society
776 Asbury Street
New Milford, NJ 07646
www.njpaleo.com
email: arlenecrocks@aol.com

North Jersey Mineralogical Society
18-04 Hillery Street
Fair Lawn, NJ 07410

Trailside Mineral Club
160 Mountain Avenue
Warren, NJ 07059-5136

Tri-County Mineral and Lapidary Society
P.O. Box 6892
Freehold, NJ 07728
(609) 426-1382
email: fluorite1@aol.com

GLOSSARY

Bog – Wet, spongy ground, consisting mostly of mosses, and containing acidic, decaying vegetation that may develop into peat.

Heavy mineral – Mineral material worn off of rock by mechanical means, having a specific gravity higher than a standard (usually 2.85).

Massive metamorphic rock – A metamorphic rock whose fundamental parts are not oriented in any way or arranged in layers; it does not have recognizable structure.

Precipitate – a substance separated from a solution by chemical or physical charge, usually as an insoluble amorphous (formless) or crystalline structure.

Recrystallization – The formation, essentially in the solid state, of new crystalline mineral grains in a rock. The new grains are generally larger than the original grains and may have the same or a different mineralogical composition.

Rift valley – A valley that has developed by extensional forces as a long, narrow trough, and is bounded by faults.

Silica – A chemically resistant dioxide of silicon (SiO_2). It occurs in crystalline (quartz), cryptocrystalline (chalcedony), hydrated (opal), and less pure forms (chert). When combined in silicates, it is an essential part of many minerals.

Slag – Impurities that remain after iron has been separated from ore in a blast furnace.

Terra cotta – A fired clay of a distinctive brownish-red color.

Chemical Formulas of Minerals Mentioned in Text

Barite – $BaSO_4$

Biotite – $K(Mg,Fe)_3(Al,Fe)Si_3O_{10}(OH,F)_2$

Calcite – $CaCO_3$

Dolomite – $CaMg(CO_3)_2$

Feldspar – $(K,Na)AlSi_3O_8$

Glauconite – $(K,Na)(Fe, Al,Mg)_2(Si,Al)_4O_{10}(OH)_2$

Halite – $NaCl$

Hornblende – $(Ca,Na)_{2\text{-}3}(Mg,Fe,Al)_5Si_6(Si,Al)_2\text{-}O_{22}(OH)_2$

Ilmenite – $FeTiO_3$

Lime – CaO

Magnesite – $MgCO_3$

Magnetite – Fe_3O_4

Mica – $(K,Na,Ca)(Mg,Fe,Li,Al)_{2\text{-}3}(Al,Si)_4O_{10}\text{-}(OH,F)_2$

Plagioclase – $(Na,Ca)Al(Al,Si)Si_2O_8$

Pyroxene – $(Ca,Na)(Mg,Fe,Ti,Cr,Mn)(Al,Si)_2O_6$

Quartz – SiO_2

Serpentine – $(Mg,Fe,Ni)Si_2O_5(OH)_4$

Geologic Time Scale

Years Ago[1]	Eon	Era	Period	Epoch	Geology, Life, Environment	Specimen Number[2]
0 to 10,000	PHANEROZOIC	CENOZOIC	QUATERNARY	Holocene	Modern humans evolve.	1
10,000 to 1.8 million				Pleistocene	Northern New Jersey glaciated at least 3 times.	
1.8 to 66 million			TERTIARY	Pliocene Miocene Oligocene Eocene Paleocene	Onset of Arctic glaciation. First large mammals appear. First bi-pedal ancestors of humans. Grasses and modern birds appear. Explosion of mammalian life.	3, 4, 5, 16
66 to 146 million		MESOZOIC	CRETACEOUS	Late Early	Heyday of dinosaurs, pterosaurs and marine reptiles until their extinction at end of period. First flowering plants.	2
146 to 200 million			JURASSIC	Late Middle Early	Earliest birds appear. Giant dinosaurs (sauropods) flourish. Plants: ferns, cycads and ginkos.	14, 15
200 to 251 million			TRIASSIC	Late Middle Early	Age of dinosaurs begins. First mammals. Mollusks are dominant invertebrate.	6, 7
251 to 299 million		PALEOZOIC	PERMIAN	Late Early	Age of Amphibians. Pangea forms. Greatest mass extinction ever. Trilobites go extinct.	Rocks from these periods not found in New Jersey
299 to 359 million			PENNSYLVANIAN[3]	Late Middle Early	Widespread coal swamps. First winged insects and reptiles.	
			MISSISSIPPIAN[3]	Late Early	Many ferns and amphibians.	
359 to 416 million			DEVONIAN	Late Middle Early	Age of Fishes. First shark. Many diverse land plants. Earliest amphibians, ferns and mosses.	8
416 to 444 million			SILURIAN	Late Middle Early	First insects, jawed fish, vascular land plants (with water conducting tissue).	11
444 to 488 million			ORDOVICIAN	Late Middle Early	First corals. Primative fish, fungi and seaweed. Non-vascular land plants (mosses) first appear.	10
488 to 542 million			CAMBRIAN	Late Middle Early	Age of Trilobites. Cambrian explosion of life occurs. First vertebrates. Earliest fish. First shells appear.	9
542 to 2500 million	PROTEROZOIC[4]	Neoproterozoic Mesoproterozoic Paleoproterozoic			Cold climate with three episodes of glaciation in late Proterozoic. First soft-bodied invertebrates and colonial algae. Oxygen build-up in atmosphere during Mesoproterozoic.	12, 13, 17
2500 to 3800 million	ARCHEAN[4]	Neoarchean Mesoarchean Paleoarchean Eoarchean		Lower limit of Eoarchean is not currently defined. Estimated to be 3800 million years.	Life appears. First bacteria and blue-green algae begin freeing oxygen to Earth's atmosphere.	Rocks from this time not found in New Jersey
3800 to 4600 million	HADEAN[4]				Earth molten. Sun and planets form.	

[1] Gradstein, F.M. and others, 2004, A Geologic Time Scale: Cambridge University Press, 589 p.

[2] From *New Jersey Rocks and Sediments* collection.

[3] Pennsylvanian and Mississippian comprise the Carboniferous System.

[4] Also called Precambian, a non-specific time term.