UNEARTHING NEW JERSEY

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MESSAGE FROM THE STATE GEOLOGIST

New Jersey has a natural treasure along her eastern border with the Atlantic Ocean in the form of nearly 130 miles of sun-soaked beaches where domestic and international tourists gravitate as the weather turns warmer. Over the years, we have featured several articles in *Unearthing New Jersey* about our long-running offshore sand resource exploration and beach nourishment program. That NJGWS program is critical to ensure our beautiful sand beaches, fanned by cooling fresh ocean breezes, will continue to be enjoyed by many for years to come.

Among other topics covered in this edition, we dig below the sand at Sandy Hook, the northernmost point of the Jersey Shore, to investigate the sediments beneath. These sediments offer a unique record of sea-level rise and coastal environmental change since the last glaciation. The geologic history of Sandy Hook is also detailed.

Our recent exploration of Sandy Hook is not the first time we have explored this peninsula. State Geologist George H. Cook detailed, in his 1885 Annual Report, the outline of the "Hook" as it was that summer, drawn as curved contour lines of equal elevation for every five feet above the mean tide. What is interesting to view is the Map of Sandy Hook (page 2), which shows the progressive changes in the shore line over 200 years of natural history. The map displays surveyed contour lines from 1885, 1853, 1844, 1836, 1732, some time prior to 1764 and astonishingly from 1685, 330 years before to our recent glacial and postglacial study. George Keith, Surveyor General of East Jersey (at that time, New Jersey was divided along its provincial line between East Jersey and West Jersey) surveyed the "Hook" in 1685 using hummocks as markers and plotted only a single line. However, the 1685 shore line on the 1885 map was interpreted from the descriptions presented by George Keith on January 17, 1685.

Regardless of the accuracy of previous surveys, George Cook stated in 1885 that, "it will be perceived that the Hook has increased in length and in breadth so as to include more than four times the area it covered in 1685 (compared to 1885)", a process that continues today.

Karl Muessig
New Jersey State Geologist

$Ca_5\ [PO_4]_3\ (F, Cl, OH)$

View of Sandy Hook from Mount Mitchell Scenic Overlook, Atlantic Highlands Boro, Monmouth County. Bottom to top: Sandy Hook Bay, Sandy Hook, Raritan Bay, Brooklyn, (*right*), and Manhattan (*left*). On Sandy Hook, *center of photo*, white building is Sandy Hook Lighthouse; on Manhattan, *left of center*, tallest building is One World Trade Center. *Photo by Z. Allen-Lafayette*

COREHOLES REVEAL GLACIAL AND POSTGLACIAL HISTORY AT SANDY HOOK

By Scott Stanford, Ken Miller, and Jim Browning

Sandy Hook is a peninsula of beach sand that extends seven miles into Raritan Bay to form the northernmost point of the New Jersey shore (fig. 1). The Hook rests on a thick succession of estuarine and fluvial sediment deposited within the past 25,000 years, as ice sheets in North America, Europe, Asia, and Antarctica melted and ocean levels rose. This thick postglacial sediment was first recognized from fossils found during the drilling of deep water wells for Fort Hancock, a former military base on the Hook, from the 1890s through the 1940s (Meredith E. Johnson, NJGWS permanent notes). In the 1960s, James P. Minard of the U.S. Geological Survey drilled auger borings along the Hook that confirmed the presence of thick postglacial estuarine and beach sediments (Minard, 1969). Plant material in the estuarine sediment at a depth of 85 to 92 feet in one of the auger holes was dated using radiocarbon to 11,300 years (11.3 ka) (9.8 ka in radiocarbon years), indicating that the sediments were postglacial. These studies suggested that postglacial sediments beneath the Hook are more than 250 feet thick, which would make them among the thickest postglacial sections accessible from land in the mid-Atlantic region.

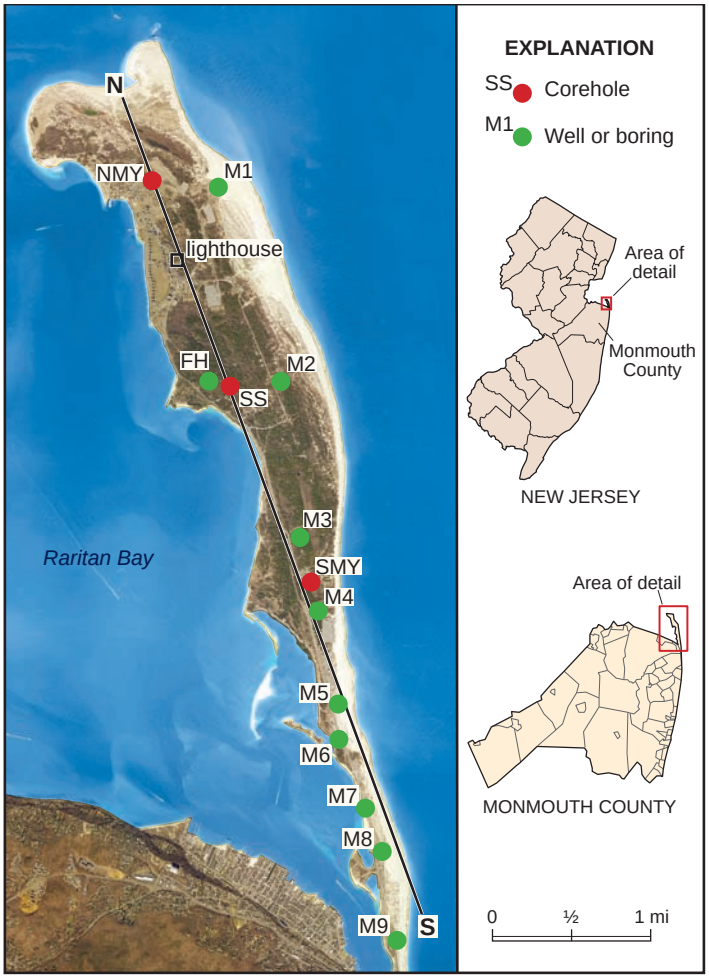

Figure 1. Sandy Hook, with locations of coreholes and earlier wells and borings. Line of section in figure 2 shown in black. NMY=North Maintenance Yard corehole, SS=Salt Shed corehole, SMY=South Maintenance Yard corehole, FH=Fort Hancock water well, M1-M9=auger borings from Minard (1969).

The sediments beneath Sandy Hook thus offer a unique record of sea-level rise and coastal environmental change since the last glaciation. The rise of sea level during the past century or so is recorded by tide gauges. In the New Jersey area, gauges with long records are situated at the Battery in lower Manhattan, at the Coast Guard station at the north end of Sandy Hook (just west of corehole NMY in fig. 1), in Atlantic City, Cape May, Lewes, Delaware (across Delaware Bay from Cape May), Reedy Point, Delaware (at the head of Delaware Bay), and at Philadelphia. These gauges record sea level rising 3 to 4 mm/yr through the 20th century (Miller and others, 2013). Sea level at earlier times is determined by coring and dating tidal-marsh deposits, which aggrade vertically as sea level rises. In the New Jersey area, these cores provide a record back to about 9 ka. The estuarine sediments beneath Sandy Hook could extend this record considerably, perhaps to before 14 ka.

In addition to their record of sea level, the sediments may also document hurricanes and other coastal storms. Large storms typically wash sand from barrier beaches into back bays and estuaries, leaving thin sand or gravel layers within muddy bay deposits. A geologic record of storms extending back thousands of years provides frequency and intensity data that is not otherwise available. Such data is important when planning for rare events like Hurricane Sandy.

To obtain sea-level and paleoenvironmental records, geologists at Rutgers University, in cooperation with the NJGWS, cored three test holes on Sandy Hook in May 2014. The holes were drilled by the U. S. Geological Survey under contract to Rutgers, with funding from the NJDEP. The holes were drilled to depths of 282 feet at the North Maintenance Yard (NMY in fig. 1), 254 feet at the Salt Shed site (SS) and 172 feet at the South Maintenance Yard (SMY). The Salt Shed and South Maintenance Yard holes penetrated Cretaceous Formations underlying the Quaternary section. The North Maintenance Yard hole bottomed in Quaternary fluvial gravel beneath estuarine sediments. Coring recovers 2.5-inch-diameter samples in five- to ten-foot lengths. Sands can be difficult to core as they have a tendency to flow out from, or jam inside, the core. For this reason, recovery was less than 50 percent in the upper 50 to 70 feet of each corehole, which is the depth of the beach and shoreface sand that makes up the Hook (Qbs in fig. 2). Silt, fine sand, and clay in the underlying estuarine deposits are more cohesive than sand, and recovery of these sediments was nearly complete. The cores were described on site, and then brought to the Rutgers core repository, where they are archived for future reference. Downhole gamma-ray geophysical logs of each corehole were recorded by the NJGWS when drilling was completed (red lines in fig. 2). Potassium and other elements in clay minerals produce more gamma radiation than sand-size minerals, which consist chiefly of quartz, so gamma logs are a good indicator of clay content of the sediment. At the repository, the cores were described in detail by Rutgers and NJGWS geologists and organic material was sampled for radiocarbon dating.

GEOLOGIC HISTORY OF SANDY HOOK

The great thickness of postglacial sediment beneath Sandy Hook is the result of the unusual glacial and postglacial history of the Raritan and Hudson Rivers (fig. 3). Before the last glaciation, the Hudson River flowed east of its current location (fig. 3a). Based on the location and depth of former valleys now filled with glacial deposits, the Hudson flowed down what is now the Harlem River, between Manhattan and the Bronx, and then southward across what is now

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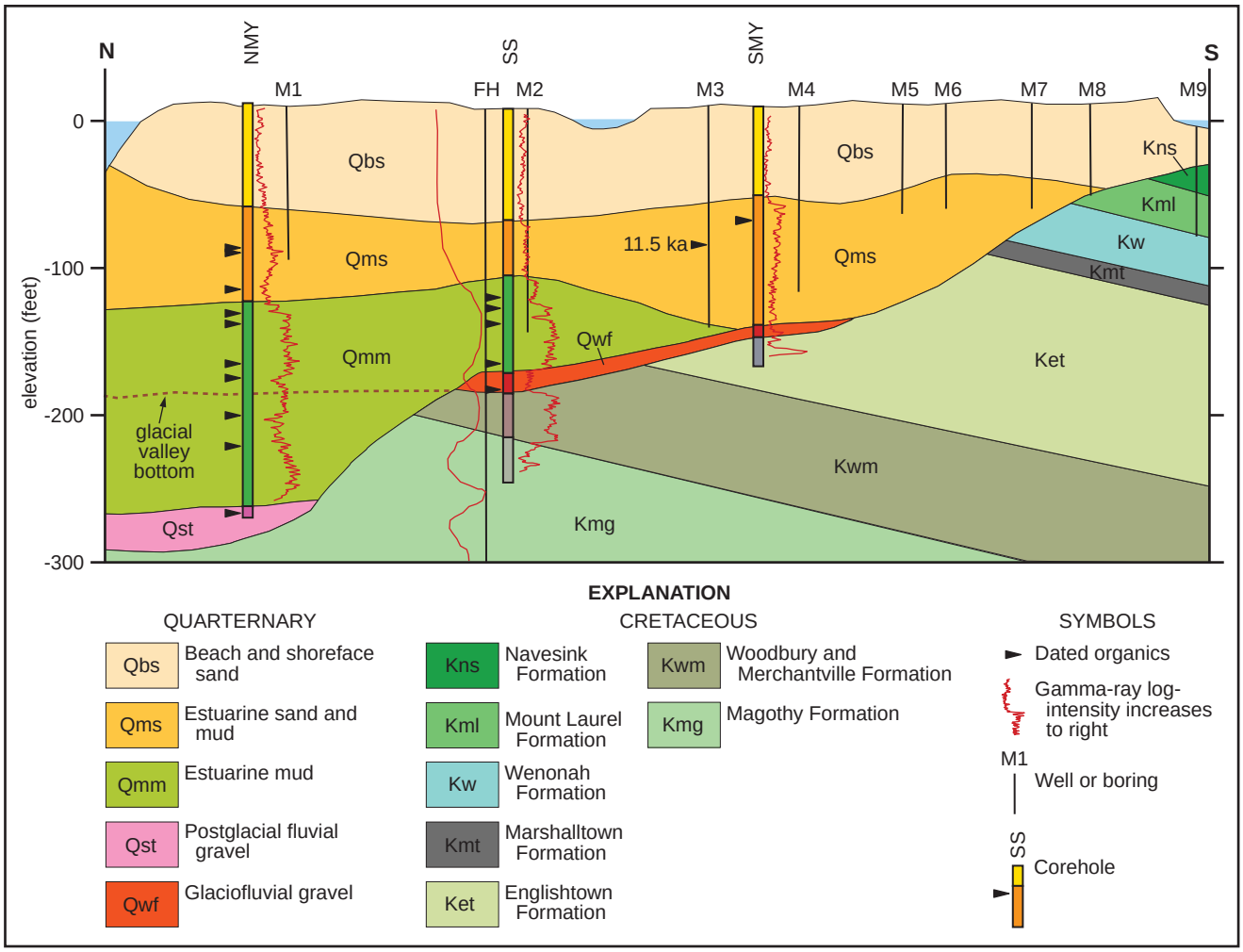

Figure 2. Cross section of Sandy Hook. Line of section shown on figure 1.

Queens and Jamaica Bay (Buxton and Shernoff, 1999). Geophysical surveys offshore between Long Island and New Jersey show that the preglacial Hudson turned eastward and flowed parallel to the south shore of Long Island, about 6 miles south of the present shoreline (Schwab and others, 2003). Buried valleys in New Jersey (Stanford, 1993) and Brooklyn (Buxton and Shernoff, 1999) show that the Raritan was a tributary to the Hudson. It flowed eastward from the Bound Brook, New Jersey, area, through what is now the Kill van Kull between Bayonne and Staten Island, and then eastward through Brooklyn to join the Hudson in Queens. The area now occupied by Raritan Bay was a wide, but shallow, valley of the South River. The South River, and with the Navesink to the south, were probably also Hudson tributaries, although their eastward links to the preglacial Hudson have not been clearly identified by geophysical surveys, in part because they were later deeply eroded.

At the peak of the late Wisconsinan glaciation, which was between 23 to 26 ka in New Jersey, the front of the Laurentide ice sheet advanced to, and stood at, the terminal moraine position (fig. 3b). As it built at the moraine, perhaps for 700 to 1000 years, meltwater draining from the glacier deposited a large outwash plain of sand and gravel in front of the moraine, in what is now Raritan Bay, the inner continental shelf east of Sandy Hook, and the south shore of Long Island. The SS and SMY coreholes penetrated the southern edge of this outwash at the base of the Quaternary section, at a depth of 150 to 190 feet (Qwf in fig. 2). The outwash gravel consists of gray and white quartzite, quartz, gray and red sandstone, siltstone, and a trace of diabase. It is similar to the outwash exposed on the south shore of Staten Island (Stanford, 2010a). Farther west, a smaller outwash plain was deposited in front of the moraine in the Raritan valley. The Raritan River, with its preglacial course now blocked by the outwash plain and the moraine, established a new course to the southeast across a low upland into the South River valley. Similarly, the preglacial Hudson valley in Queens was filled with outwash and moraine deposits. As the glacier retreated, the Hudson occupied a new valley that had been carved by glacial erosion between Manhattan and New Jersey.

As the glacier retreated from the terminal moraine, starting around 23 ka, a glacial lake formed in the Hudson valley north of the moraine. This lake was dammed by the moraine at the Narrows (fig. 3c) and was bordered by the retreating ice margin to the north. At about 18 ka, when the ice margin had retreated north of the Hudson Highlands near Newburgh, New York, 60 miles north of the Narrows, a large glacial lake in the Wallkill valley drained suddenly into the Hudson valley. This flood breached the moraine dam at the Narrows. Subsequent meltwater outflow and floods from the drainage of glacial lakes in the Hudson valley, and

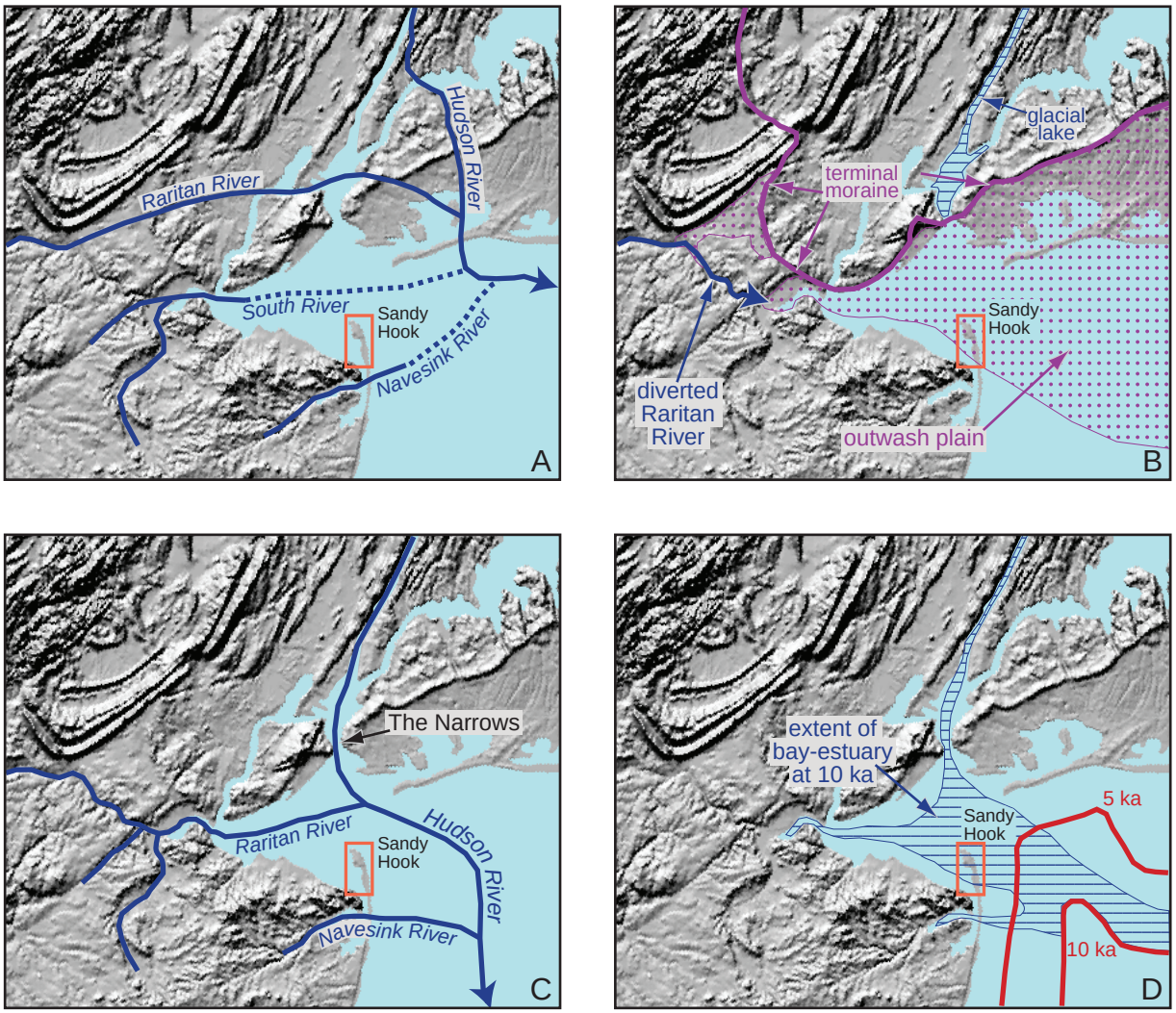

Figure 3. Geologic history of Sandy Hook. A. River drainage before the late Wisconsinan glaciation (>26 ka). B. Late Wisconsinan glacial limit, extent of outwash plains and glacial lake in Hudson valley, and location of glacially diverted Raritan River (23-26 ka). C. River drainage after breaching of the Narrows moraine dam at 18 ka. D. Approximate position of ocean beaches (red lines) at 5 and 10 ka, and extent of estuary (blue ruling) at 10 ka.

from lakes in the Champlain valley and Great Lakes basins that emptied into the Hudson valley, deepened the moraine breach and carved a valley into the outwash plain and underlying Coastal Plain sediments downstream from the Narrows. The bottom of this valley, known as the Hudson shelf valley, is more than 300 feet below sea level offshore of Sandy Hook (Thieler and others, 2007).

The Raritan River, now relocated into the South River valley, downcut into the outwash plain and underlying Cretaceous sediments in step with the deepening of the Hudson shelf valley at its mouth. Beneath the north end of Sandy Hook, the Raritan valley was deepened about 100 feet below the bottom of the outwash plain (dotted line in fig. 2). The incision of the Hudson and Raritan valleys was completed between 18 ka, when the Narrows was breached, and 14 ka, when estuarine conditions were first established in the Hudson valley. Postglacial fluvial gravel was deposited by the Raritan River in the floor of the deepened valley (Qst in fig. 2). The NMY corehole penetrated this gravel at a depth of between 276 and 282 feeth. The gravel consists of quartz pebbles with some red and gray siltstone and a trace of chert, a mix typical of gravels in the Raritan basin.

The deep incision of the Hudson and Raritan valleys enabled the rising ocean to enter the valleys earlier than elsewhere along the New Jersey shore (fig. 3d). Radiocarbon dates at the base of estuarine sediments in the Hudson valley near Bear Mountain and in the Raritan valley at Perth Amboy indicate marine incursion by about 14 ka (Newman and others, 1969; Stanford, 2010b). The 11.3-ka date at Sandy Hook indicates that submergence had created a sizable bay between New Jersey and Long Island by 10 ka (fig. 3d). By 6 ka submergence had enlarged the bay and fringing marshes to close to their present extent, although ocean beaches continued to erode landward (red lines in fig. 3d). Beach recession and northward longshore transport of sand along the New Jersey shore built Sandy Hook northward over the past several thousand years and the northward growth is ongoing. The Sandy Hook lighthouse was built 500 feet from the north end of the Hook in 1764; today it is 1.5 miles from the north end (fig. 1), and would probably be farther if a ship channel at the north end had not been kept clear by periodic dredging.

ESTUARINE AND BEACH SEDIMENT IN THE CORE-HOLES

Sediments in the coreholes record this submergence history. The lowermost estuarine deposits (Qmm in fig. 2), below a depth of about 120 feet in the NMY and SS coreholes, are predominantly gray clayey silt to silty clay, some interbeds of silty fine sand, and a few beds of medium-to-coarse sand. Clam, oyster, mussel, and scallop shells are common, and abundant in some beds. Fragments of peat, wood, and plant material are also common. In several beds the cores show thin inclined sand layers and lenses interbedded with clay. This type of bedding is common in sediments deposited by the regular ebb and flow of tidal currents. The muddy sediments of this lower unit are typical of inland parts of estuaries, away from the influence of open-ocean waves and currents.

The muddy estuarine deposits pass upward into fine-to-medium sand and silty sand, a few beds of clayey silt, and a few beds of gravelly sand (Qms in fig. 2). Shells are common as in the lower unit, also peat and wood fragments in places. The sands in this unit include fragments of red and gray siltstone, indicating that they were transported either by tidal flows eroding the glacial outwash on the inner shelf north and east of the Hook, or by fluvial transport from the Raritan basin. The sandy sediments of this unit are typical of the seaward or outer parts of estuaries, where tidal currents and storm flows transport sand from barrier beaches and the inner shelf into the bay or estuary behind the barrier.

Above a depth of 50 to 70 feet, the estuarine sand is overlain by clean medium-to-coarse sand, and fine-to-medium sand, with beds of quartz-pebble gravel (Qbs in fig. 2). These are beach, shoreface, and tidal-channel deposits laid down at the ocean front. They consist entirely of quartz, and a few opaque and heavy minerals, but no siltstone or other rock fragments. This indicates that the sand was derived from Coastal Plain sediments south of the Hook, which are rich in quartz but do not contain rock fragments, rather than from the shelf to the north and east, or from the Raritan valley. This upper sand thus records the growth of the Hook supplied by northward longshore transport of Coastal Plain sediments.

COREHOLE SEDIMENTS AND SEA-LEVEL RISE

Northward growth of the Hook is important to the interpretation of the Sandy Hook tide-gauge data. This gauge records sea level rising at a rate of 4 mm/yr since 1932. The Battery tide gauge, only 16 miles north of Sandy Hook, records a rise of 3 mm/yr since 1856. There is thus a significant 1 mm/yr difference in the rates. The Battery gauge is situated on about 30 feet of glacial-lake sand resting on bedrock. The Sandy Hook gauge, based on records of the NMY corehole, is situated on 70 feet of beach sand, much of which was deposited in the past 200 years as the Hook grew northward from the lighthouse, on top of 200 feet of postglacial estuarine sand and mud. The weight of the recently added beach sand has compressed the underlying sand and mud. The estuarine deposits have been continuously saturated since their deposition and, unlike the glacial sediment at the Battery, have never been dried or weathered. This compression causes the land surface at the Hook to subside more than it does at the Battery, producing the 1 mm/yr difference in apparent sea-level rise.

Similar, but smaller, differences have been measured among the tide gauges situated on coastal sediments at Atlantic City, Cape May, Lewes, Delaware, and elsewhere and also those on or close to bedrock at Philadelphia, Baltimore, and Washington, D.C. (Miller and others, 2013). The other coastal gauges in the New Jersey area do not rest on as thick a postglacial deposit as the Sandy Hook gauge. This suggests that compaction at those sites is not as great as at Sandy Hook, perhaps accounting for their slightly smaller rates. When organic material from the cores is dated, and measurements of the density and porosity of the sediments are completed, we will have a better understanding of these effects. This understanding will provide a more detailed picture of future sea-level rise in New Jersey and along the east coast.

ACKNOWLEDGEMENTS

Ken Miller and Jim Browning of Rutgers are the lead scientists for the project. Gene Cobbs III and Jeff Grey of the U. S. Geological Survey drilled the coreholes. NJGWS staff helping with the project include: Brian Buttari, John Curran, Rachel Filo, Mike Gagliano, Michelle Kuhn, Don Monteverde, Karl Muessig, Helen Rancan, Scott Stanford, Gregg Steidl, and Peter Sugarman. Several Rutgers students and faculty also helped with onsite core description and archiving. Pete McCarthy, Sandy Hook Site Manager for the National Park Service, facilitated site access and logistics.

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$Ca_5\ [PO_4]_3\ (F, Cl, OH)$

GRANITE IN NEW JERSEY

By Richard A. Volkert

INTRODUCTION

Probably no other rock type is as well known as granite. Almost everyone has heard of it and is likely to have seen it. Granite is a very common igneous rock formed from magma in the Earth's crust. It consists mainly of the minerals quartz, potassium feldspar and sodium feldspar. Most granite is massive and homogeneous, forming a dense, hard rock that is fairly tough and resistant to erosion. The grain size is typically uniform, but it may range from medium grained to very coarse grained, the latter commonly known as granite pegmatite. Granite may be of diverse colors (for example, white, gray, pink, or red) depending on the proportion of light and dark minerals that compose the rock, but most granite owes its characteristic pink color to an abundance of potassium feldspar that makes up much of the rock.

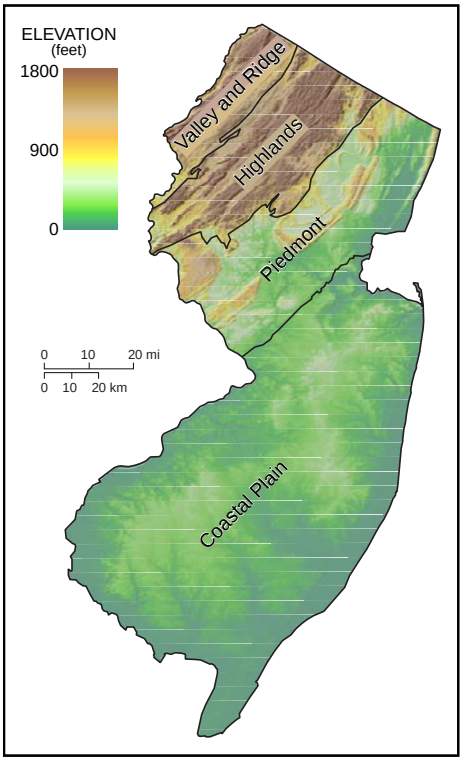

Figure 1. Physiographic province map of New Jersey showing the location of the Highlands.

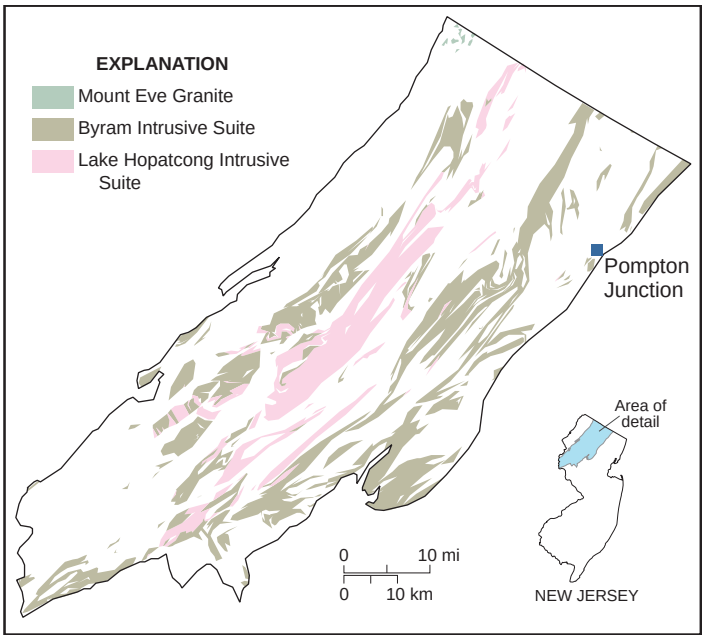

Figure 2. Map showing the distribution of the various granites in the New Jersey Highlands.

Geologists use several different classification methods to identify and name granites that may use either the mineralogy or the geochemical composition of the rock. Mineralogical classification relies on the proportion of quartz and feldspars, whereas geochemical classification uses the concentration or the ratio of major and trace elements in the rock. After granites are classified, those which are mineralogically and geochemically similar, and of the same age and origin, may be grouped together and referred to as a suite. Suites are typically named for their "type location"; that is, the geographic area where they are best exposed. Geologists are able to determine the age of granite by using radiogenic isotopes of uranium and lead to date minerals such as zircon that crystallize from the magma that produces the granite.

DISTRIBUTION OF GRANITE IN NEW JERSEY

In New Jersey, granite is found only in the Highlands Physiographic Province (fig. 1) where it underlies approximately 50 percent of the region (fig. 2). Most of the granites are Mesoproterozoic (Precambrian) in age, and at more than 1 billion-years-old, they are among the most ancient rocks in New Jersey.

The most abundant granites in New Jersey are part of the Byram Suite and the Lake Hopatcong Suite that form linear belts tens of miles long (fig. 2). Byram granite is characteristically pinkish-gray, medium-to-coarse-grained, and composed of quartz, potassium feldspar, sodium feldspar, and hornblende (fig. 3). Lake Hopatcong granite is greenish-gray, medium-to-coarse-grained, and composed of quartz, potassium feldspar, sodium feldspar, and pyroxene (fig. 3). Granites of the Byram and Lake Hopatcong Suites have been dated at 1.185 billion-years-old using isotopes of uranium and lead and are the oldest known granites in New Jersey.

The Mount Eve Granite is confined to the northwestern

Figure 3. The principal granites of the New Jersey Highlands include the Byram (*left*), Lake Hopatcong (*center*) and Mount Eve (*right*). *Photos by R.A. Volkert*

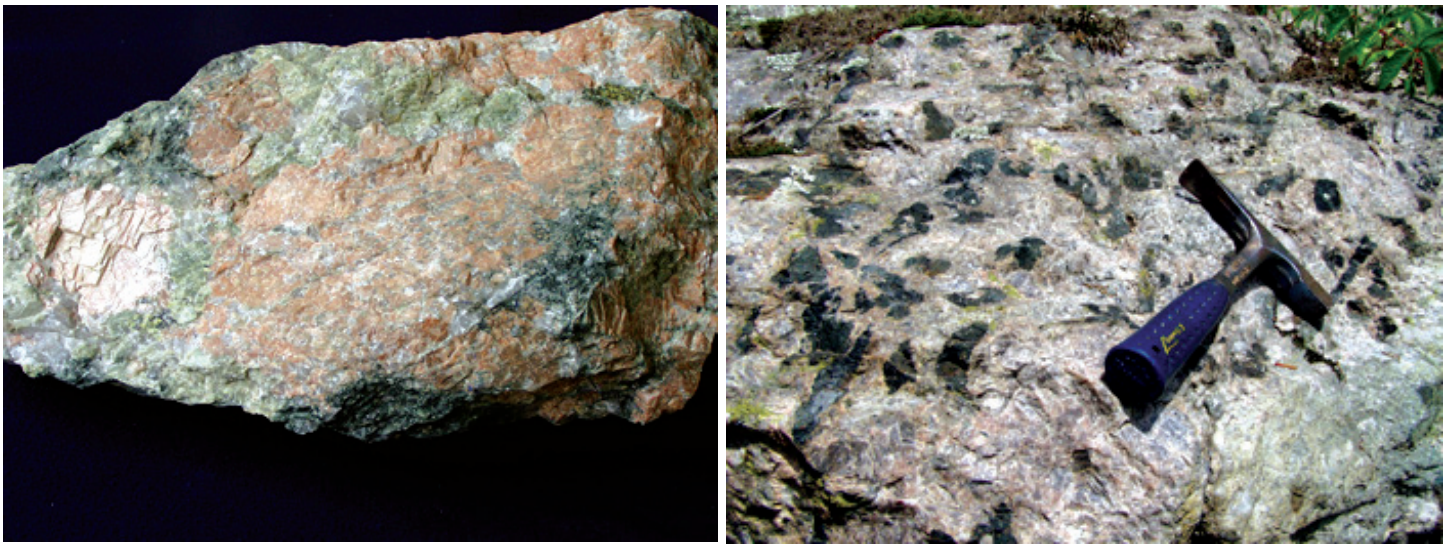

Figure 4. Pompton Pink Granite (*left*) and granite pegmatite (*right*). Note the very coarse grain size of both rocks that contain crystals as much as several inches long compared to the grain size in granites shown in figure 3. *Photos by R.A. Volkert*

Figure 5. A modern quarry (*left*) and an abandoned historic quarry (*right*) both developed in granite of the Highlands. Note the close-spaced holes in the detail photo (*top right*) which were drilled into the rock to facilitate splitting the blocks by hand. *Photos by R.A. Volkert*

Figure 6. Examples of the use of granite in New Jersey as a building stone include: (1) Coopers Mill in Chester Township, (2) Boonton Iron Works in Boonton Township, (3) Ford-Faesch House in Rockaway Township, (4) Wawayanda Furnace in Vernon Township, (5) St. Peters Church in Morristown and (6) St. Paul's Episcopal Church in Paterson. *Photos by R.A. Volkert*

Highlands (fig. 2) where it forms a series of bodies that continue to the north into New York State. Mount Eve Granite is pinkish-white, medium-to-coarse-grained, and composed of quartz, potassium feldspar, sodium feldspar, biotite, and hornblende (fig. 3). Mount Eve Granite has been dated at 1.02 billion-years-old using isotopes of uranium and lead, so it is 165 million years younger than granites of the Byram and Lake Hopatcong suites.

The Pompton Pink Granite is found only in the northeastern Highlands at Pompton Junction, in Passaic

County, and nearby at Riverdale, in Morrris County (fig. 2). Pompton Pink Granite is pink with light green mottling, coarse grained and is composed of quartz, potassium feldspar and sodium feldspar (fig. 4). The exact age of this granite is unknown, but based on its texture and discordant contacts with other Precambrian rocks it is probably about 1 billion to 965 million-years-old.

Granite pegmatite is widespread throughout the Highlands where it forms very small bodies that have intruded into, and cut across, other Precambrian rocks. Pegmatites are very coarse-grained and may be pinkish-white, gray, white, or greenish-gray, depending on the type of granite they are associated with, or the magma source they formed from. Pegmatites consist mainly of quartz, potassium feldspar and sodium feldspar. They may also contain varied amounts of hornblende, biotite, or pyroxene (fig. 4). Granite pegmatites in the Highlands have been dated at about 1 billion to 965 million-years-old using isotopes of uranium and lead.

ECONOMIC USES

Granites of the Byram and Lake Hopatcong suites, particularly the latter, are rich in iron and were mined during the 18th and 19th centuries for the iron ore (magnetite) deposits they hosted. During this same time, granite was quarried extensively throughout the Highlands (fig. 5) for use as building stone, mainly in Passaic, Morris and Sussex Counties. The Pompton Pink Granite is especially notable for its use in 1918 in the construction of the landing at the entrance to the Smithsonian National Museum of Natural History in Washington, D.C. It was also used in 1895 for construction of St. Paul's Episcopal Church in Paterson (fig. 6). Other granite quarried in the Highlands was used to construct structures, such as Coopers Mill in Chester, forges and furnaces for roasting iron ore, such as those at the Boonton Iron Works and at Wawayanda State Park, houses and churches (fig. 6), monuments, and fountains. New Jersey granite continues to be important in the construction industry for use as crushed stone in aggregate and ballast for railroad tracks, road metal, rip rap for drainage and slope stability, and for landscaping.

$Ca_5\ [PO_4]_3$ (F, Cl, OH)

APATITE: A COMMON MINERAL (BUT NOT USUALLY RECOGNIZED)

By F. L. Müller

One does not have to travel far to see the mineral apatite in operation. It supports the body of vertebrates--bones, and enables them to eat--teeth. Both are composed largely of calcium phosphate. The International Mineralogical Association Commission on New Minerals, Nomenclature and Classification names apatite a supergroup of minerals consisting of 43 mineral species in 5 groups. Apatite is the common name for the mineral group consisting of the pyromorphite series, the svabite series, and the apatite series. Only the apatite series of this group is discussed in this article.

Figure 1. Apatite crystals, from the Hamburg Quarry, Hamburg Boro, Sussex County, 7.5X magnification. *Photo by J.H. Dooley*

The apatite series consists of fluorapatite ($Ca_5[PO_4]_3F$), chlorapatite ($Ca_5[PO_4]_3Cl$, and hydroxylapatite ($Ca_5[PO_4]_3OH$) --the bone-and-tooth apatite, and two polymorphs, chlorapatite-M and hydroxylapatite-M. Another mineral of this series, although not as common and not recognized as a discrete species, is carbonate apatite (~ $Ca_{10}[PO_4]_6[CO_3]OH$), called francolite by some collectors. Apatite is a very common phosphate mineral and is the dominant source of phosphorus. Collectors in the main simply call their specimens apatite unless they have used sophisticated optical methods of identification or x-ray diffraction to discriminate between species.

Apatite can confuse collectors because it resembles so many other minerals. However, its physical properties may enable the collector or the geologist in the field to identify it. For example tourmaline in the field may look like apatite (both have a hexagonal crystalline structure except for the two polymorphs chlorapatite-M and hydroxylapatite-M which are monoclinic). But tourmaline is much harder, 7 on the Mohs hardness scale; whereas apatite is the type mineral for a hardness of 5). Because of its deceptive nature, early workers named it *"apate"* which is Greek for deceit. Its color can be highly variable--colorless, white like those apatites which are fluorescent in UV light in the magnetite of the iron mines in the Mount Hope area; brown to green apatites of the Hamburg Quarry (fig. 1); or the blues from the limestone of the Kittatinny Formation; and even some multicolored ones. Although colorful in hand specimens, most apatites tend to be colorless in thin section. Apatite's color varieties are caused by differing proportions of fluorine, chlorine, and/or hydroxyl ions (Marchefka and others, 2002). Also many other elements can substitute into the apatite crystal lattice and thus alter somewhat its appearance.

Apatite minerals crystalize in the hexagonal crystal system with the exception of hydroxylapatite-M and

chlorapatite-M which are monoclinic. Apatites' streak is white and its luster vitreous. Its cleavage is poor; some basal parting has been observed. Its fracture is uneven. The specific gravity of apatite is 3.1 - 3.2. It is a resistant mineral and is ranked stable by Pettijohn and others (1973). Its density and resistant qualities account for apatite being a component of heavy mineral sands. Many apatite specimens fluoresce in ultraviolet light, x-rays, and cathode rays; and some may be phosphorescent (Palache, Berman, and Frondel, 1966, p. 881).

Apatite was mined for phosphorus at two locations in New Jersey. The owners hoped to use the phosphorous in apatite for agricultural purposes. Opened in 1870, the Canfield Phosphate Mine in Mine Hill Township, two miles southwest of Dover Town, Morris County, had two prospect shafts that were each 40 feet deep. The phosphate was found in the abundant fluorapatite together with magnetite (fluorapatite locally as high as 35 percent [Bayley, 1910, p. 381]). The accessory minerals in the ore were quartz, orthoclase, and mica. The extraction of the phosphorous was too large a problem so the operation closed (Bayley, 1910). The other mine was at Hurdtown in Jefferson Township five miles north of Dover. The Hurdtown operation, which opened before 1855, sought the fluorapatite which was found with magnetite and pyrrhotite. The operation ceased shortly thereafter because once again, extraction of the phosphorous was deemed too great a problem.

Today apatite minerals can be found in all of the physiographic provinces of New Jersey. In Sussex County at the Hamburg Quarry, long, brown, and green crystals are found. The apatite here is largely fluorapatite in Precambrian gneiss and orange-pink calcite which make handsome cabinet specimens. (The quarry management used to entertain rock and mineral clubs and collectors once or twice a year on special collecting days. Clubs field trip chairman should make contact with the quarry management to see if this is still possible.) Quarries throughout Sussex County have produced fine specimens of fluorapatite. Sadly, many are now closed, and some filled with water when the pumps were shut off. The LimeCrest Quarry in Sparta Township was one such location. Two sites are now accessible to collectors and geologists seeking apatite minerals. For a small fee one may collect them at the Buckwheat Dump. The Franklin Mineral Museum oversees this venue. Fluorapatite from here is known to fluoresce a dark orange. And at Ogdensburg, in the Sterling Hill Mine tailings piles and at the Noble Mine pit and the Passaic Mine pit, apatite has been found. One crystal found in the calcite was 15 centimeters long. One can collect here on special days allotted to this; again a fee is required.

Fluorapatite is a common constituent of the rocks of the iron mines--both in the ore and the host rock. At the Edison Mines on Sparta Mountain in Sussex County a yellow fluorescing fluorapatite was found in masses; some were recorded as large as 18 centimeters. The iron mines of Morris County in the Mount Hope area (specifically the Weldon, the Byram, and the Richards mine tailings, where years ago I collected) produce fluorescent fluorapatite in the magnetite. This fluorapatite is actually a contaminant of the iron ore, and as such weakens its value

In the igneous rocks of the Piedmont Providence, fluorapatite is notable. In Fort Lee, near the George Washington Bridge, nice pale yellow crystals were found. Also at Bergen Hill in Bergen County in 1881 when the New York-West Shore Rail Road Tunnel was dug, fluorapatite was discovered along with 17 other certified species of minerals. In Mercer County, at the Trap Rock Industries Quarries, fluorapatite is found in the diabase, and it is likely found in other central New Jersey locations.

At the New Jersey Geological and Water Survey labs we have seen apatite in our study of Coastal Plain sediments. Apatite masses of pebble size and smaller have been x-rayed, as were nodules of likely biogenic origin. These were most prevalent in the sediments of the Navasink Formation. One needs a good hand lens or microscope in the search for these Coastal Plain apatites. Much larger apatite specimens can be found in the bones and teeth found in streams and outcrops of South Jersey. The student who wishes to collect and examine these apatites should consider that they can be found in the heavy mineral sands on the beaches and in outcrops of a variety of the geologic formations. McMaster (1954) in his study of the Coastal Plain sands shows that apatite in New Jersey heavy mineral sands ranges from a minimum of zero or trace up to a high of four percent. These heavy mineral sands tend to be very dark or black *in situ,* but on a slide under the microscope they sparkle with a rainbow of colors. A warning when collecting: Do not climb on the outcrops as one never knows when they may give way. Safe collecting can be done in the shallow stream beds like those of Big Brook or Poricy Creek in Monmouth County. These are now parks. Please obey the rules, and never trespass on private property.

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Ca_5 $[PO_4]_3$ (F, Cl, OH)

NEW PUBLICATIONS

BEDROCK GEOLOGIC MAP OF NEW JERSEY 2014

NEW MAP. Bedrock Geologic Map of New Jersey 2014, Dalton, Richard F., Monteverde, Donald H., Sugarman, Peter J., and Volkert, Richard A., compilers, 2014, scale 1 to 250,000, size 37x47, 5 cross-sections. $20.00. For additional information click here.

GEOLOGIC MAP SERIES (GMS)

NEW MAP. GMS 14-3, Bedrock Geologic Map of the Hamburg Quadrangle, Sussex County, New Jersey, Dalton, Richard F., Volkert, Richard A., Monteverde, Donald A., Herman, Gregory C., and Canace, Robert J., 2014, scale 1 to 24,000, size 36x54, 2 cross-sections, 14 figures, and a 6-page pamphlet. $10.00.

OPEN FILE MAP (OFM)

NEW MAP. OFM 101, Surficial Geologic Map of the Lake Maskenozha Quadrangle, Sussex County, New Jersey and Pike County, Pennsylvania, Witte, Ron W., 2014, scale 1 to 24,000, size 33x54, 2 cross-sections, 6 figures, and 1 table. $10.00.

NEW MAP. OFM 102, Surficial Geology of the Trenton East and Trenton West Quadrangles, Burlington and Mercer Counties, New Jersey, Stanford, Scott D., 2014, scale 1 to 24,000, size 36x50, 3 cross-sections, 4 figures, and a 9-page pamphlet. $10.00.

NEW MAP. OFM 103, Geology of the West Creek Quadrangle, Ocean County, New Jersey, Stanford, Scott D., 2014, scale 1 to 24,000, size 36x60, 3 cross-sections, 5 figures, and a 5-page pamphlet. $10.00.

NEW MAP. OFM 104, Bedrock Geologic Map of the Wawayanda Quadrangle and the New Jersey Part of the Pine Island Quadrangle, Sussex and Passaic Counties, New Jersey and Orange County, New York, Volkert, Richard A., 2014, scale 1 to 24,000, size 34x60, 2 cross-sections, and 6 figures. $10.00.

NEW MAP. OFM 105, Geology Map of the Millville Quadrangle, Cumberland and Salem Counties, New Jersey, Stanford, Scott D., 2015, scale 1 to 24,000, size 36x46, 2 cross-sections, 6 figures, and a 5-page pamphlet. $10.00.

Ca_5 $[PO_4]_3$ (F, Cl, OH)

AHOY, MIKE

NJGWS welcomes Michael Castelli to our ranks. Starting in 2012, Mike worked for several summers at NJGWS as a seasonal geologist. He inventoried and processed the NJGWS archive of marine seismic data into a common format, reclaiming that data for current analysis. Mike also assisted with well-drilling, GPR, EM, and borehole geophysics, and other methods supporting NJDEP's Ambient Groundwater Monitoring Program, and Green Acres Programs. He also joined our 2013 marine seismic survey.

In 2014, after graduating from Lafayette College, Mike returned to NJGWS. Since being hired into a full-time position in February 2015, Mike is training in geologic field mapping with Don Monteverde, Peter Sugarman, and Scott Stanford. He also finalized the Monmouth County offshore sand resources map for publication, a promised product in a NJGWS grant from Bureau of Ocean Energy Management, U.S. Department of Interior. In addition, Mike pitches in on a range of short-term geophysics and drilling jobs.

Mike Castelli on board ship during the NJGWS 2013 marine seismic survey. *Photo by J. Uptegrove*

Ca_5 $[PO_4]_3$ (F, Cl, OH)

The good thing about science is that it is true whether or not you believe in it.

-- Neil deGrasse Tyson , astrophysicist --
(b. 1958)

NJGWS LOCATES SHIPWRECK IN BRICK TOWNSHIP, OCEAN COUNTY

By Michael Gagliano, Michelle E. Kuhn, and Michael V. Castelli

In November 2014, the Army Corps of Engineers discovered a shipwreck on Normandy Beach in Brick Township, Ocean County. While driving 45-foot steel pilings into the sand to construct a seawall, workers hit an object that resulted in a broken piling. The object turned out to be a historic shipwreck, confirmed by wooden debris and a windlass found during excavation around the piling. By law, the remainder of the ship would be left undisturbed. This meant work could not continue on the seawall until the extent of the shipwreck was confirmed so that no further damage would occur. The New Jersey Geological and Water Survey (NJGWS) was asked to conduct an archaeo-geophysical survey, including a Geoprobe investigation, to locate the extent of the buried shipwreck.

Geologists Mike Gagliano, Michelle Kuhn and Mike Castelli used Electrical Resistivity Tomography (ERT) to map the approximate location of the ship (fig. 1). ERT is a non-invasive geophysical technique for imaging subsurface structures by measuring the resistivity distribution. In this case, the wooden ship should be more resistive than the surrounding sand. After an anomaly was found along the 267-foot ERT line (fig. 2), John Curran, Gregg Steidl, Brian Buttari and Mike Schumacher of NJGWS utilized a Geoprobe mounted on a skid-steer to ground truth the resistivity data. Close to the steel pilings where the shipwreck was suspected, they probed every five feet to a depth up to 45 feet. Locations of resistance were recorded to produce a more accurate location of the ship. Work on the seawall resumed after the ship's location was determined not to be in the path of the remainder of the seawall. Research is still being conducted to determine which ship ran aground, and so far archeologists have determined it may be one of approximately 90 shipwrecks.

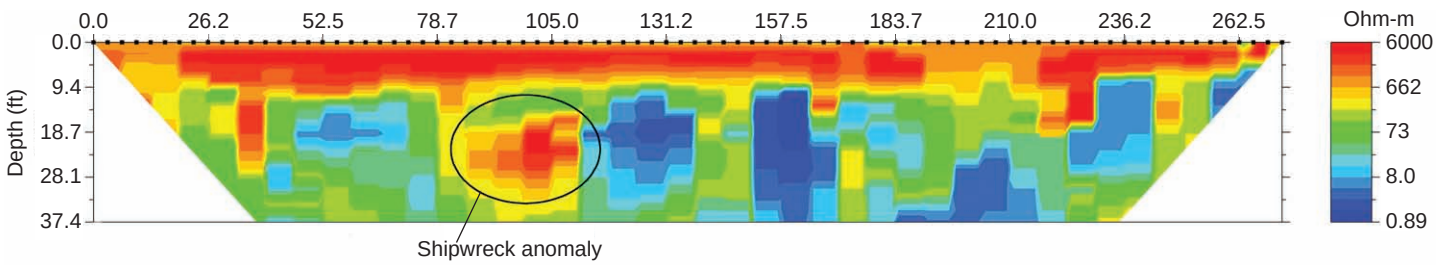
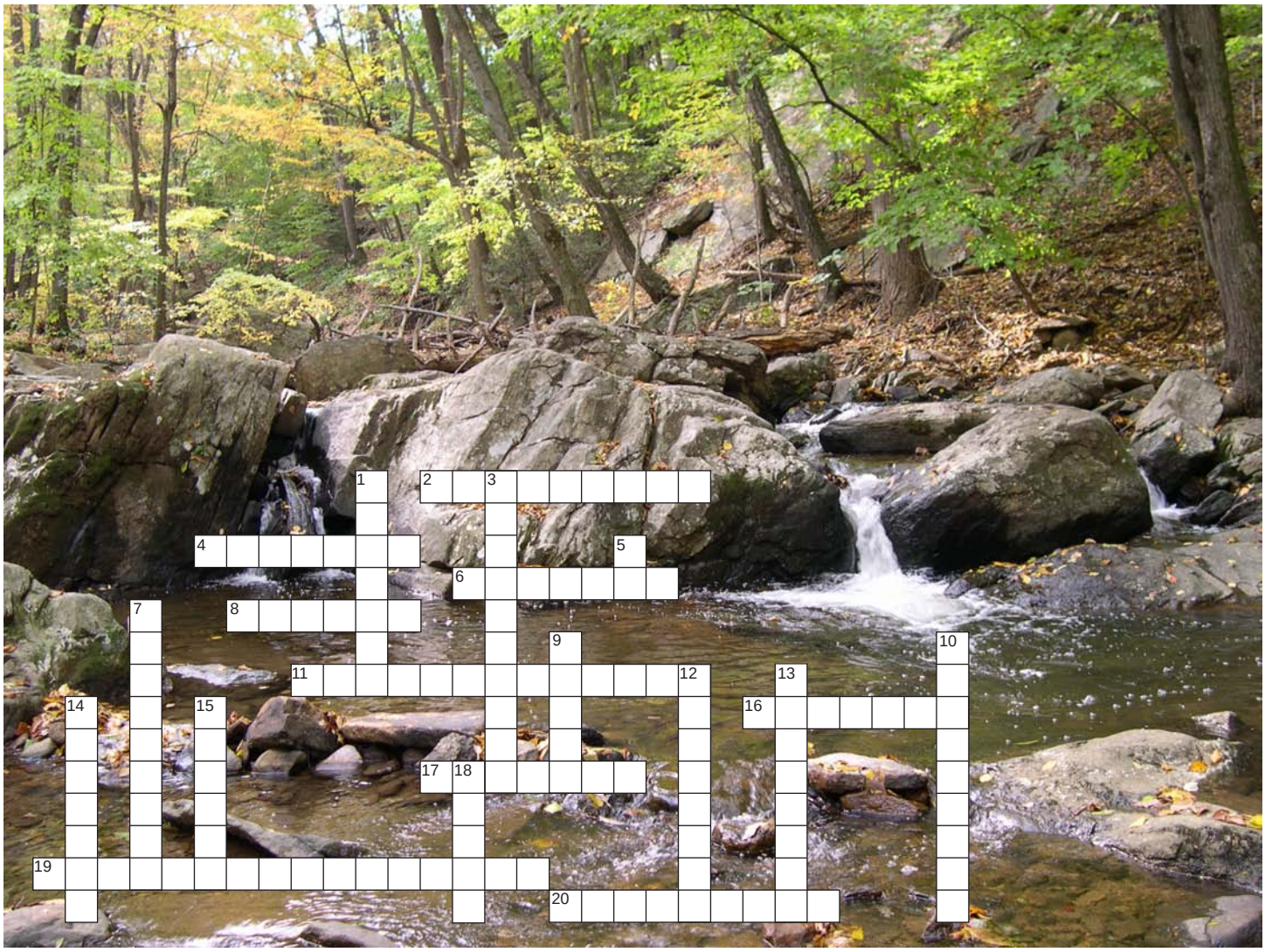


Figure 1. Electrical resistivity tomography scan of Normandy Beach, Brick Township, Ocean County. Resistive area is circled showing approximate location of ship.

Figure 2. Set-up of resistivity array along the beach. NJGWS staffers (*left to right*) are Mark Godfrey, Michelle Kuhn and Mike Castelli. The seawall is on the right, additional steel pilings are on the left. *Photo by M. Gagliano*

$Ca_5\ [PO_4]_3\ (F, Cl, OH)$

CROSSWORD FALLS



Jackson Brook, Hidden County Park, Dover Town, Morris County. *Photo by Z. Allen-Lafayette*

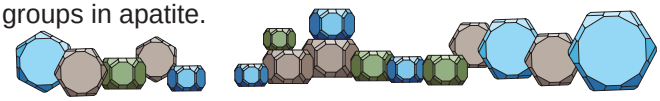
ACROSS

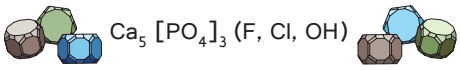
2. Emplacement of magma in pre-existing rock
4. Igneous rock consisting of quartz, potassium feldspar and sodium feldspar
6. Produced by the action of a river
8. A layer of broken rock used to prevent erosion by water currents
11. Geomorphic
16. Six sided
17. Heavy broken stone used to stabilize a ship
19. Environment in the geologic past
20. A mass of rock particles

DOWN

1. Tidal mouth of a river valley where fresh water meets seawater
3. Milled ore too poor to be treated further
5. Kilo-annum
7. Coarse-grained igneous rock
9. Molten rock
10. Tract of land jutting out into the water
12. Well drilled for geological information only
13. Unconsolidated material formed into layers on the Earth's surface
14. Relating to the activities of glaciers
15. Composed of large parts
18. Screw-like boring tool

Teeth are made of calcium. The calcium mineral in teeth is a crystalline form of calcium phosphate which is also known as hydroxyapatite. Acidic foods (such as citrus fruit) and drinks (carbonated sodas) can dissolve the mineral structure of the teeth. Fluoride, in the form of fluorapatite, is resistant to acid attack. Fluoridated water strengthens the mineral structure of the teeth by allowing the exchange of fluoride ions for hydroxyl groups in apatite.





$Ca_5\ [PO_4]_3\ (F, Cl, OH)$

CROSSWORD PUZZLE ANSWERS. Across: (2) Intrusion, (4) granite, (6) fluvial, (8) riprap, (11) physiographic, (16) hexagon, (17) ballast, (19) paleoenvironment, (20) aggregate. **Down:** (1) Estuary, (3) tailings, (5) Ka, (7) pegmatite, (9) magma, (10) peninsula, (12) corehole, (13) sediment, (14) glacial, (15) coarse, (18) auger.