UNEARTHING NEW JERSEY

NEW JERSEY GEOLOGICAL AND WATER SURVEY Vol. 9, No. 2 Summer-Fall 2013
Department of Environmental Protection

MESSAGE FROM THE STATE GEOLOGIST

As residents of New Jersey prepared to mark the one year anniversary of Hurricane Sandy, NJGWS geologists were tasked with a unique project that focused on lesser publicized storm damage.

The hurricane's energy caused the redistribution and re-suspension of coastal sediments. Sand along the eastern shoreline was pulled into the back bays, while pre-storm sediments were re-suspended into the water column. When the storm passed and the waters settled, the resulting homogenized sediments in the navigation channels caused these vital thoroughfares to become insufficient for the needs of the locally-storm-impacted economies.

Together with a variety of more obvious reconstruction projects, it became a priority to improve state-owned navigation channels to a design depth of at least six feet. Post-storm, many of the Department of Transportation's (NJDOT) navigation channels are filled in to one-third of the design depth. FEMA funds were available to support the state's future dredging activities only for storm caused sedimentation, however there was a federally imposed deadline of October 31st to capture, calculate and submit to FEMA total sediment volumetrics for the purposes of financial reimbursement. In real numbers, approximately 4,000 vibracores needed to be sampled and the resulting sediment column analyzed in nearly 90 channels, from Sandy Hook to Cape May. On October 1st, NJGWS was asked to supply geological oversight and expertise.

On October 4th, sixteen NJGWS geologists and four technical support staff were presented the project and received training at the Stockton Coastal Research Center, whose staff members developed the protocol for collecting and assessing sediments. After two in-field training days, the geologists were assigned to one of eight boat teams and given locations of the channels to be visited.

Work began on October 9th. Cores were collected by a consulting company, and turned over to the geologist on-duty who determined the contact depth between pre- and post-storm sediments, described the core and photographed the top, bottom and contact depth for each core. Because the sediment was homogenized, contact locations were not usually based upon a specific change in sediment or color along the core, but determined based upon water content, the comparative change in sediment consolidation between the bottom and top, the odor of the sediment in that the October, 2012 sediment had more of an oily aroma, as well as a visual inspection on a granular scale.

The NJGWS geologists worked on the boats and from

continued on page 8

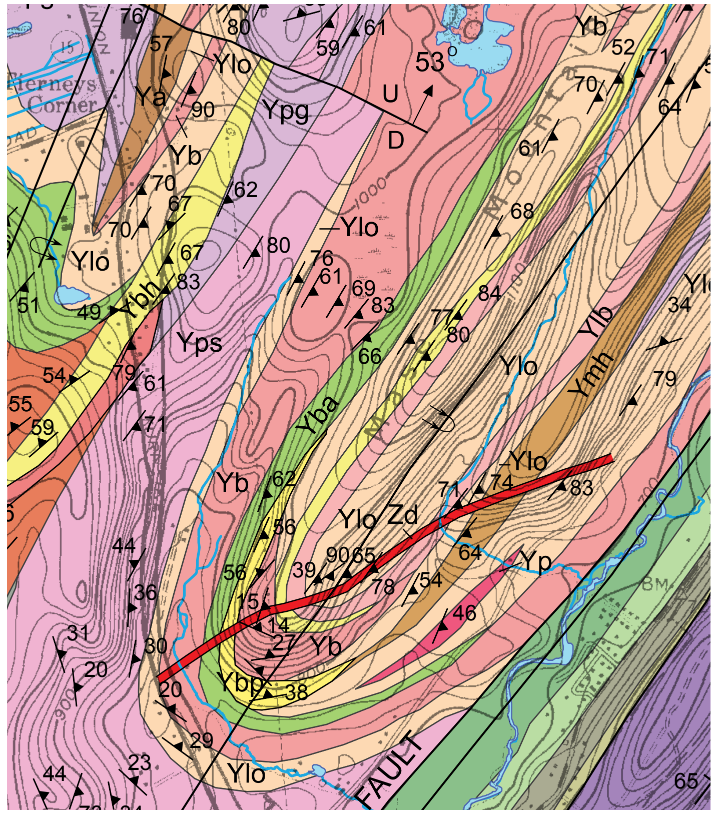


Figure 1. Detail from STATEMAP grant deliverable, *Bedrock Geologic Map of the Dover Quadrangle, Morris and Sussex Counties, New Jersey by R.A. Volkert.*

GEOLOGIC MAPS FOR NEW JERSEY: 20 YEARS OF STATEMAP

By Scott D. Stanford

The year 2013 marks the 20th anniversary of STATEMAP, a nationwide program that provides federal matching funds to state geological surveys for geologic mapping projects (fig. 1). This program, authorized by the National Geologic Mapping Act of 1992 and reauthorized three times since then (most recently in 2009), is an annual competitive grant administered by the U.S. Geological Survey. It is focused on the completion of detailed bedrock and surficial geologic maps at a scale of 1:24,000, at which 1 inch on the map represents 2000 feet on the ground. This is the scale of the familiar USGS topographic quadrangles, which serve as the base for geologic mapping. New Jersey is covered by a grid of 172 quadrangles, and each quadrangle covers an area of about 7 miles east-west by 9 miles north-south. Some STATEMAP funding is also available for digitizing geologic maps. (For an explanation of geologic maps, refer to the New

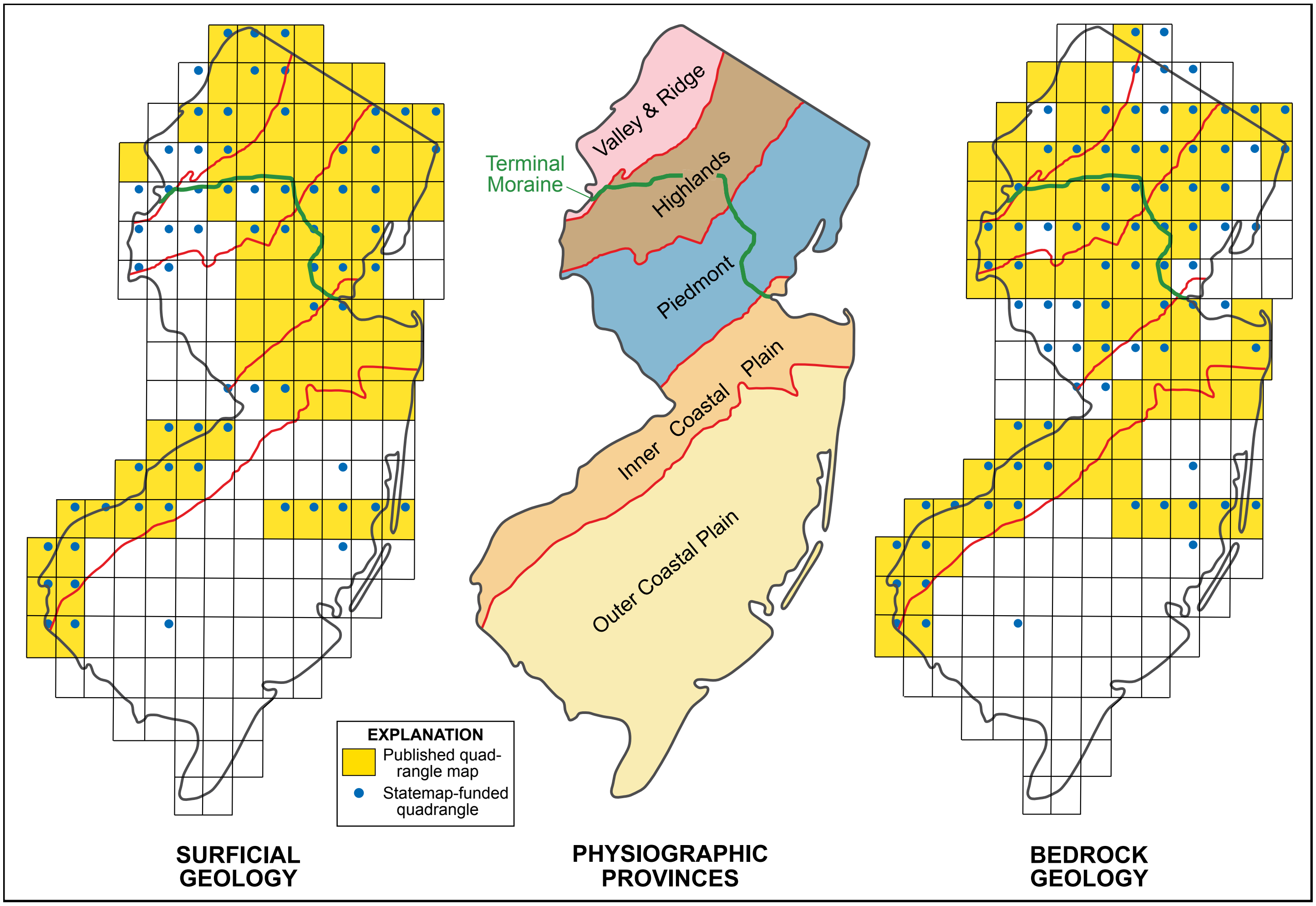


Figure 2. Published quadrangle maps (yellow) and STATEMAP-funded quadrangles (blue dots) of surficial geology (*left*) and bedrock geology (*right*) as of October 2013. New Jersey physiographic provinces map in center. Quadrangle grid in black outline.

Jersey Geological and Water Survey (NJGWS) Information Circular.

This program has had a very productive 20 years in New Jersey. Since 1993, NJGWS has completed maps of 75 bedrock geologic quadrangles and 67 surficial geologic quadrangles (fig. 2; see factsheet). We have also completed two digital geologic datasets at 1:100,000, 32 datasets at 1:24,000 scale, three offshore geologic maps at 1:80,000 scale, and an aquifer framework study. We have received more than $2.4 million in federal matching funds for this work. We are currently working to complete an additional six bedrock quadrangles, four surficial quadrangles, and one county geologic map, under the 2013 STATEMAP grant. Our STATEMAP products are available to the public at no charge on the NJGWS website (see listing by quadrangle).

A committee of seven geologists who work in New Jersey in the private sector, academia, and government meets annually to advise us on our geologic mapping activities. Our long-term goal, developed in consultation with the advisory committee, is to complete surficial and bedrock geologic map coverage at 1:24,000 scale for the entire state. This goal is appropriate for New Jersey because 1) we are among the most densely populated places on Earth, with 1195 people per square mile in 2010; 2) we are dependent on local groundwater, which provides 40 percent of our potable water, pumped from more than 2500 public supply wells; 3) we have a long history of industrial waste-disposal, involving more than 14,000 sites of confirmed soil and groundwater contamination, including 227 Superfund sites; and 4) this heavy human footprint rests on a complex geologic foundation, including more than 70 types of surficial material and more than 125 bedrock formations. The complex issues of water-resource and land management that arise in our state require detailed geologic data.

NJGWS
1835

STATE OF NEW JERSEY
Chris Christie, *Governor*
Kim Guadagno, *Lieutenant Governor*

Department of Environmental Protection
Bob Martin, *Commissioner*

Water Resources Management
New Jersey Geological and Water Survey
Karl Muessig, *State Geologist*

NJGWS
29 Arctic Parkway
P.O. Box 420, 29-01
Trenton, NJ 08625-0420
Telephone: (609) 292-1185
FAX: (609) 633-1004
www.njgeology.org

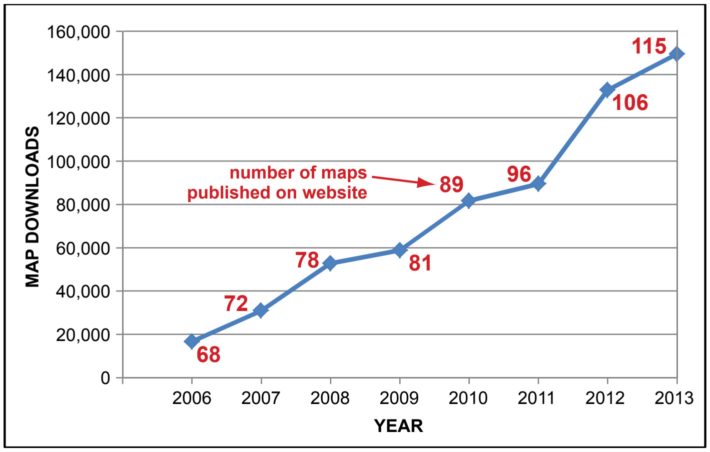


Figure 3. Geologic map downloads recorded at the NJGWS website from 2006 to 2013.

Of the 172 quadrangles covering New Jersey, 105 surficial quadrangles and 118 bedrock quadrangles have been completed, including both STATEMAP work and non-STATEMAP work by the NJGWS, as well as earlier mapping by the USGS in the 1960s and 1970s (fig. 2). Our STATEMAP work focused initially on northern New Jersey and the Inner Coastal Plain, where the geology is most complex and where most people live. Coverage for these areas is now nearly complete, and since 2007 we have extended our mapping effort into the Outer Coastal Plain and offshore areas. Here, the mapping depends to a greater degree on subsurface data from test borings, coreholes, and, in offshore areas, ship-borne seismic surveys. Fortunately, a series of 15 scientific coreholes drilled in the Outer Coastal Plain from 1993 to 2008 by a cooperative program of the NJGWS, USGS, and Rutgers University Department of Earth and Planetary Science, and more than 2000 line-miles of seismic data, and 200 vibracores collected in offshore areas by NJGWS in cooperation with the U. S. Army Corps of Engineers since 1994, provides this subsurface data.

Mapping is mostly field work. Geologic materials are examined at several hundred to as many as 1000 points per quadrangle, in natural outcrops, pits, quarries, excavations, and hand-auger holes. We also compile and interpret records of wells, test borings, and geophysical surveys of the subsurface, especially in areas lacking surface exposures. Typically, records of several hundred wells and borings per quadrangle provide useful information. We use aerial photography and LiDAR imagery to identify landforms, vegetation patterns, and drainage features that are indicative of specific rocks, sediments, or geologic structures like folds and faults. Typically, six to eight months are required to complete field work in a quadrangle; and additional time is required to compile the data, draw the map and cross sections, and complete the explanatory text and illustrations. STATEMAP grants are funded on an annual cycle, and a draft geologic map, ready for the publication process, is submitted as the grant deliverable at the end of the project year. The publication process, which includes digitizing, cartography, scientific review, and editing, starts after submission of the grant deliverable.

Geologic maps are used by engineering and environmental firms, government agencies, nonprofit organizations, academic researchers, educators, and interested citizens for a variety of purposes, including geologic-hazard assessment, water-resource and land-use management, pollution remediation, foundation design, scientific research, and environmental education. There has been steady growth in the number of downloads of geologic maps recorded at the NJGWS website, and in the number of published maps on the website (fig. 3). In 2006 there were 16,695 downloads of 68 maps; by 2013 there were 149,508 downloads of 115 maps.

$Ca_2(Fe^{3+},Al)_3(SiO_4)(Si_2O_7)(O,OH)_2$

FROM THE ARCHIVES: HISTORIC PHOTOS FROM THE NJGWS PHOTO LIBRARY

By Ted Pallis & Laura Brachfeld

The New Jersey Geological and Water Survey (NJGWS) is in the process of digitizing and cataloging more than 4,000 images from its photo library. Many of these photos document the middle years (1898-1937) of NJGWS' 178-year history as well as the history of photography. Henry B. Kummel (fig.1), the fifth State Geologist (1901-1937), took most of the photos in this oldest part of the collection. More than 400 of his glass plate negatives survive.

Ever the tech-nerd, as photography changed, so did Kummel. He moved from glass plate negatives to film, a much easier, less cumbersome process to use in the field. Later geologists documented their work using color film, lantern slides, color slides, and digitial images.

The images shown (figs. 2-7) are part of our collection. They document the building of Round Valley Reservoir (1962-1965) in Clinton Township, Hunterdon County. The Round Valley Reservoir was a project of the New Jersey

Figure 1. Henry B. Kummel heading out on his state-issued vehicle to do field work. Kummel left NJGWS an irreplaceable legacy in photographs which visually document the geologic wonders of New Jersey. *Circa 1898, photographer unknown.*

From the Archives: Round Valley Reservoir, Clinton Township, Hunterdon County, was constructed by the New Jersey Water Supply Authority in the early 1960's. Building of the reservoir required the construction of two large dams and the flooding of a valley. The reservoir became operational in 1965. *Unless otherwise noted photos were taken 1962 - 1965 by former Acting State Geologist Frank Markewicz.*

Figure 2. Dam construction, 1962.

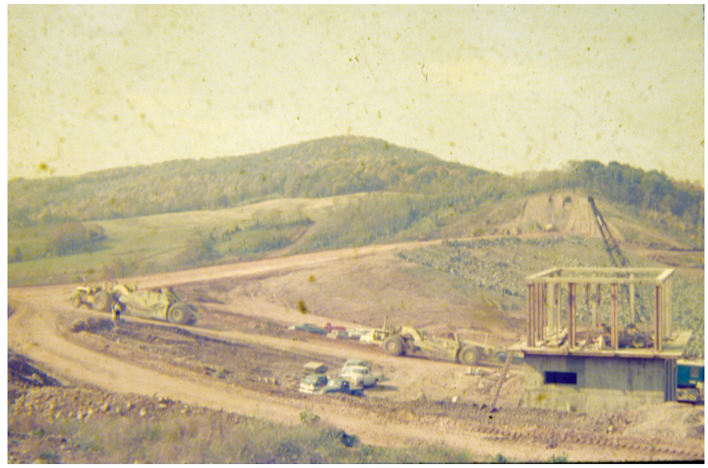


Figure 3. Reservoir construction, 1963.

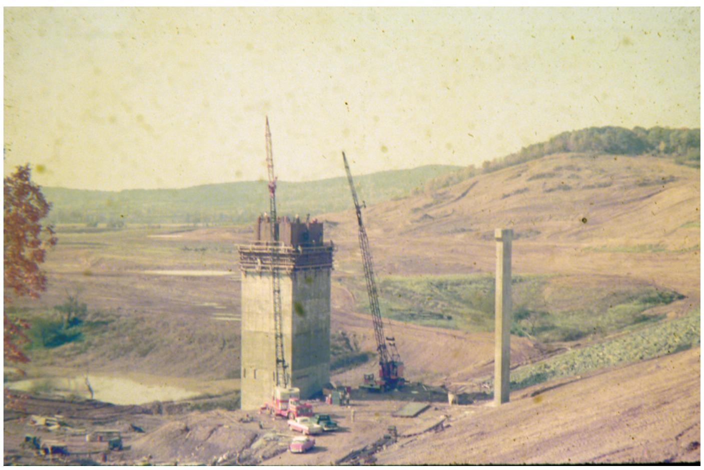


Figure 4. Reservoir construction, 1963.

Figure 5. Pipeline excavation tunnel in ridge of gneiss, date unknown, *photographer unknown*.

Figure 6. Pipeline construction, 1964.

Figure 7. Round Valley Reservoir filling up, 1965.

Water Supply Authority, designed to assist municipal water supply during prolonged droughts. Round Valley is also used for recreational purposes, including fishing, boating and swimming.

Reaching depths of 180 feet, this 2,350 acre reservoir contains 55 billion gallons of water, making it the largest reservoir in the state. At the south end of the reservoir, the Cushetunk Mountains lie on a bed of igneous rock that rises nearly 500 feet above the shoreline and 834 feet above sea level. At times of drought, Round Valley supplies water to the nearby South Branch of the Raritan River which provides populated areas of the state downstream with potable water.

In future issues of **Unearthing New Jersey** our "In the Archives" column will share with you photographs documenting geologic features, fossils, quarrying, mining and more.

$Ca_2(Fe^{3+},Al)_3(SiO_4)(Si_2O_7)(O,OH)_2$

EPIDOTE IN NEW JERSEY

By F. L. Müller

Found throughout New Jersey from the Highlands of Sussex County to the heavy mineral sands of the Coastal Plain and the beaches of Cape May, epidote is a common but distinctive mineral. It is used by geologists to determine the metamorphic history of rocks, and by lapidaries to cut fine cabochons and, more rarely, faceted semiprecious gemstones. Most of the local epidote lacks plane faces and occurs in pegmatites, vugs, fissures, amygdules and other cavities. Some, however, are found in brilliant euhedral microcrystals as is shown in fig. 1.

Epidote is a member of a group of 12 minerals showing similar chemical structure. It has the chemical formula $Ca_2(Fe^{3+},Al)_3(SiO_4)(Si_2O_7)(O,OH)_2$. Its color ranges from green to black. The most easily recognized specimens are bright pistachio-nut green. The green is caused by the presence of iron. Epidote's streak is gray-white. Its luster is vitreous or pearly, and it is translucent. Its hardness is 6.5 to 7 on the Moh hardness scale *(it will scratch common window glass)*. Although it is soluble in hydrofluoric acid it is only partially soluble in hydrochloric acid. It is a heavy mineral (density greater than quartz) with a specific gravity of 3.38 to 3.49. Epidote is also brittle. It has perfect cleavage in one direction [001]and good cleavage on another [100]. "Epidote crystals are monoclinic, and the base of the rhomboidal prism has one side longer than the other" (Deer, Howie, and Zussman 1967, p. 194). Its fracture is uneven, conchoidal or splintery (Gaines and others 1997, p. 1200). Its hardness and its low solubility make it a very stable, resistant mineral. Its resistance and density explain why epidote is a common constituent of heavy mineral sands.

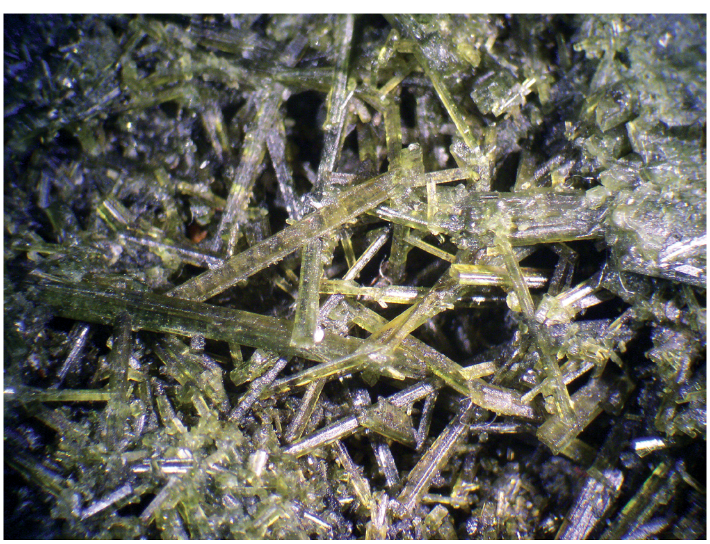


Figure 1. Epidote crystals collected by Warren Cummings in Oxford Quarry, Oxford Township, Warren County, magnification 7.5x . *Photo by J. Dooley*

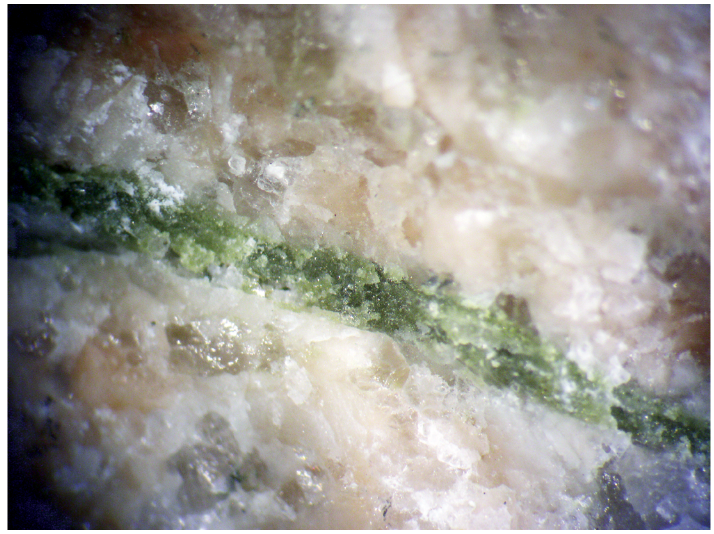


Figure 2. Epidote vein in a leucocratic host rock from Hamburg Quarry, Hamburg Boro, Sussex County, magnification 22x. *Photo by J. Dooley*

Epidote is common in both regionally metamorphic and contact metamorphic rocks. It is a very important constituent of greenschist and epidote-blue-schist-facies rocks. Although called by some a stress mineral and having much in common with others so called, "Its formation appears to be favored by shearing stress and low temperatures, it is also a characteristic mineral of metasomatic rocks. Moreover epidote crystallizes from late hydrothermal liquids and in such other unstressed environments as amygdales, vugs and fissures" (Deer, Howie and Zussman 1967, p. 208).

Epidote is common in the fractures of the granites and gneisses of the Highlands Physiographic Province. At the Oxford Quarry in Warren County, beautiful euhedral epidote crystals occur in fissures with ferroaxinite crystals. The bright green of the epidote crystals contrasts with the pale lavender of the ferroaxinite to make a very showy mineral specimen. Specimens of epidote like the one in figure 1 turn up in mineral shows in this area on rare occasions. It was collected by Warren Cummings of the New Jersey Department of Transportation about fifteen years ago. This quarry is not open to the public; do not trespass! Epidote in its massive form is well known as a constituent of the metamorphic mineral suites of the Hamburg Quarry in Sussex County. The epidote veinlet in the light-colored gneiss of figure 2 is a microscopic specimen; many of the veins and masses in this quarry are considerably larger. In the past, the quarry has permitted mineral clubs access on special days to collect under its supervision. If you are interested have your club secretary or field-trip coordinator contact the quarry to find out if and when it is having a special day. A little south of this location at the Tar Hill Mine in Andover, pistachio-nut green epidote occurs with pink-rose orthoclase feldspar in a pegmatite. Lapidaries call this attractive rock “unakite” and cut cabochons with it or tumble the material for jewelry. Epidote is a common pegmatite mineral throughout the state.

In the Piedmont Province epidote occurs in the contact zones between the basalt and diabase and the Triassic/Jurassic sedimentary beds. It occurs in the shear planes of the small faults and in slickensides. It also occurs in vugs and fissures. It is prominent in the Pennington Quarry, Mercer County where it is present with jasper, opal, hematite and chloritic material in the fissures, and with the hematite and iron oxides and oxyhydroxides (limonite) on the rock surfaces. It also forms euhedral microcrystals in veinlets.

As rock weathers, epidote washes down to the beaches and heavy-mineral deposits of the Coastal Plain. The sand-size grains create a vivid color splash on a slide of these heavies under the microscope. The serious hiker or geologist will also find epidote in glacial outwash deposits where this material has been scraped from the bedrock and deposited in moraines and ancient river beds. This material is commonly washed, and the rounded rocks are sold as decorative bedding to landscapers and gardeners. I have a rounded, smooth piece of epidote on my desk which I picked up in a local parking lot because it is so colorful and makes a fine paperweight.

Keep your eyes open at mineral shows and as you hike around the state; you don’t have to be Irish to appreciate green. As I close this column I remind the reader, most land in New Jersey is privately owned. You should have permission to gain access; do not trespass!

REFERENCES

Bonewitz, R. L. *Rock and Gem: Smithsonian Project.* Edited by J. Laing. New York: D. K. Publishing Inc., 2008.

Deer, W.A., R.A. Howie, and J. Zussman. *Rock Forming Minerals, volume 1.* London and Beccles: William Clowes and Sons Ltd., 1967.

Gaines, R.V., H.C.W. Skinner, E.E. Foord, B. Mason, A. Rosenzweig and V.T. King. *Dana’s New Mineralogy, Eighth Edition.* New York: John Wiley and Sons, 1997.

Hotchleitner, R. *Minerals: Identifying, Classifying and Collecting Them.* Hong Kong: Barons Educational Series, Inc., 1994.

NEW PUBLICATIONS

GEOLOGIC MAP SERIES (GMS)

GMS 13-2, Geology of the Forked River and Barnegat Light Quadrangles, Ocean County, New Jersey, Stanford, Scott D., 2013, scale 1 to 24,000, size 36x60, 3 cross-sections, 4 figures and a 7-page pamphlet. $10.00. Download PDF

OPEN-FILE MAPS (OFM)

OFM 99, Surficial Geologic Map of the Port Jervis South Quadrangle, Sussex County, New Jersey and Pike County, Pennsylvania, Witte, Ron W., 2013, scale 1 to 24,000, size 35x42, 1 cross-section, 1 table, and 4 figures. $10.00. Download PDF

OFM 100, Geology of the Keswick Grove Quadrangle, Ocean County, New Jersey, Stanford, Scott D., 2013, scale 1 to 24,000, size 36x52, 4 cross-sections, 4 figures, and a 4-page pamphlet. $10.00. Download PDF

$Ca_2(Fe^{3+},Al)_3(SiO_4)(Si_2O_7)(O,OH)_2$

NJGWS PUBLISHES OFFSHORE GEOLOGIC MAP

By Jane Uptegrove

This past year, NJGWS published GMS 12-3, *Geology of the New Jersey Offshore in the Vicinity of Barnegat Inlet and Long Beach Island*, the first in a planned series of maps which correlate onshore surficial geology to the offshore (0-7 miles). With increasing stress on New Jersey’s coastal region due to sea-level rise and population increase, this map is targeted at resource managers, coastal planners, coastal geologists, and the public at large. The map is based on seismic stratigraphic analysis of NJGWS-acquired high-resolution (100 millisecond) marine seismic data and 20-ft vibracores. Originally acquired in support of sand resource exploration for New Jersey’s beaches, the seismic profiles, vibracore ground-truthing, and “value-added” Carbon-14 dating of core sediments reveal laterally continuous reflectors bracketing sediment packages with

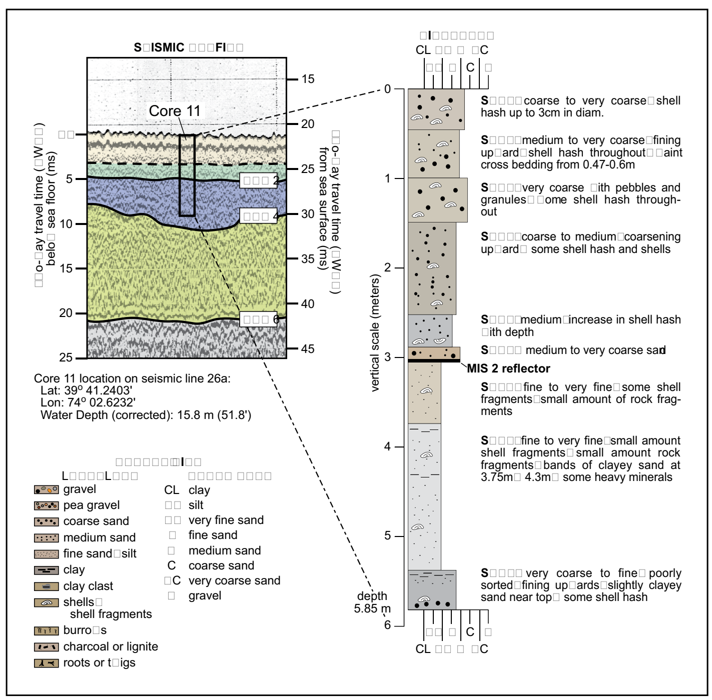


Figure 1. Detail of Figure 14, *Geology of the New Jersey Offshore in the Vicinity of Barnegat Inlet and Long Beach Island.*

distinctly different seismic stratigraphy, interpreted with both radiocarbon and amino-acid racemization dating to be Marine Isotope Stages 5 (Sangamonian), 3 (Wisconsinan), and 1(Holocene). These units are correlated to gamma and lithologic logs (fig. 1) from known onshore units, onshore scientific borehole data, and previous studies and seismic data. The onshore-offshore correlation is demonstrated via two onshore-offshore cross-sections which intersect a third onshore cross-section. Analysis of age-controlled sediment packages and cores reveals 1) a broad southward-oriented Sangamonian paleo-channel; 2) a Wisconsinan-age inlet and associated paleo-shoreline near present-day Harvey Cedars; and 3) a sand resource shoal southeast of Barnegat Inlet containing an estimated 64 milliion cubic yards of sand. This known sand resource is now part of New Jersey's inventory of sand sources for long-term beach-replenishment planning.

$Ca_2(Fe^{3+},Al)_3(SiO_4)(Si_2O_7)(O,OH)_2$

NJGWS WELCOMES NEW TALENT

MIKE GAGLIANO

Mike Gagliano joined the Survey as an hourly assistant almost one year ago and basically hit the ground running. He stepped in to help fill the void in the Offshore Resources and Exploration Program left by recently retired Jeff Waldner. He became part of the team that successfully completed a marine seismic survey in June 2013. In September we were able to hire him as an Assistant Geologist. Mike earned his BA in mathematics at Temple University and received his MS` in Geophysics there also. He did research for his thesis at Mirror Lake, New Hampshire, and presented *Assessment of Electrical Resistivity Method to Map Groundwater Seepage Zones in Heterogeneous Sediments* at the 2009 Symposium for the Application of Geophysics to Environmental and Engineering Problems in Fort Worth, Texas. Mike is also an Instructor at Temple, teaching Geology. He enjoys the outdoors, has a broad knowledge of outdoor equipment (from working at retailer REI), and is an avid biker. Mike is assigned to the Geoscience Research and Support section.

Mike Gagliano (*left*) and hourly assistant Michael Castelli (*right*) perform an onshore tank test prior to offshore deployment in June, 2013. *Photo by J. Curran*

ALEXANDRA PETRIMAN

The newest employee at NJGWS is Alexandra (Ally) Petriman. Ally has been working with us since May 2011 as an hourly assistant doing hydrologic data analysis and GIS assistance. She was also very involved in the Survey's abandoned mines database, maintaining field data. Ally began work as a Environmental Services Trainee in November 2013. Her duties will include watershed boundary mapping, analysis of LiDAR elevation data, and Highlands groundwater quality. Ally received her BS from The College of New Jersey in 2011 and MS in Environmental Science from the New Jersey Institute of Technology in 2013. Ally is assigned to the Water Supply Modeling and Planning section.

Ally Petriman preparing for field inspection of arsenic contaminated wells in Hunterdon County. *Photo by Y. Stroiteleva*

YELENA STROITELEVA

The New Jersey Geological and Water Survey welcomed Yelena Stroiteleva (photo on p. 8) as an Assistant Geologist starting September 2013. Yelena has a combined BS/MS in Mining Engineering and Geology from Kazakh National University in Almaty, Kazakhstan. She is married with two sons.

Previously, Yelena worked with us as an hourly assistant since May 2012. During her hourly time with us, she worked and contributed greatly on studies of arsenic and natural radiation in ground water and private wells. During that year she also oversaw and supported drilling of sentinel observation wells in Cape May County in support of the

Investigator 2 Walt Marzulli and Yelena Stroiteleva take a GPS reading at an observation well along the Cape May Canal, Cape May County. *Photo by S. Johnson*

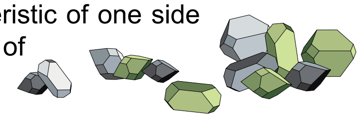
Water Allocation Program, and aquifer test analysis for an upcoming Information Circular on the Englishtown Aquifer.

Yelena will work in the Hydrogeologic Analysis section and will largely work on support to ground water allocations, aquifer test analysis, and aquifer delineation and mapping.

2013 SEISMIC SURVEY TEAM

Pictured above are members of the NJGWS 2013 Seismic Survey Team, which collected over 300 miles of seismic profiles in the New Jersey near-shore between Barnegat and Manasquan Inlets. The purpose of the survey is to acquire, analyze, and interpret seismic data to find offshore sources of beach replenishment sand. Team members are NJGWS staff unless otherwise noted, *standing* (*left to right*) Michael Castelli, Don Monteverde, Bill Fehn (vessel captain, Northstar Marine, Inc.), Mike Gagliano, Greg Mountain (Rutgers University). Kneeling (*left to right*) Lindsey Lugrin (Rutgers University), Jane Uptegrove. Cape May Canal, Cape May County. *Photo by D. Burton, Northstar Marine, Inc.*

Epidote is an abundant rock-forming mineral of secondary origin. It occurs in marble and schistose (metamorphic rocks) and feldspar, mica, pyroxene, amphibole and garnet (igneous rocks). It is typically pistachio-nut green in color but can also be gray, black or brown. Named in 1801 by Rene Just Haüy, from the Greek "Epidosis" alluding to the crystal characteristic of one side being longer at the base of the prism.



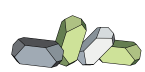
continued from page 1

shore, from sunrise to sunset. After a long day in the field, they were tasked each night with uploading all data they processed, as well as data collected by the consulting company. This project's protocol caused many geologists to work 14, 16, even 18 hours per day, seven days a week.

High and medium priority channels were completed ahead of schedule. By October 29th, NJGWS geologists processed over 3,300 cores along the entire New Jersey coast line. Since then, NJDOT has supplied FEMA with the Hurricane Sandy-caused sediment volumetrics. Because of the tremendous skills and dedication of its geologists and technical support staff, NJGWS provided the state with information which could equate to millions of federal dollars to improve the navigation channels in New Jersey.

The Survey welcomes your feedback on the content or format of the newsletter. All Survey publications are available as free downloads from the website. Hard copies of some maps and reports are also available for purchase by check. Our order form has more information. Unpublished information is provided at cost by writing the State Geologist's Office, N.J. Geological Survey, P.O. Box 420, Mail Code 29-01, Trenton, NJ 08625-0420. Staff are available to answer your questions 8 a.m. - 5 p.m. Monday through Friday (609-292-1185) or by e-mail at njgsweb@dep.state.nj.us.

Karl W. Muessig
New Jersey State Geologist

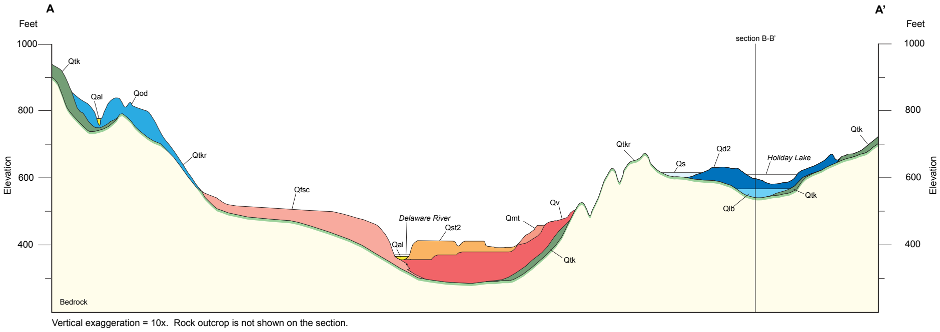


Rocks are records of events
that took place at the time they formed.
They are books.
They have a different vocabulary,
a different alphabet,
but you learn how to read them.

--John McPhee, non-fiction writer--

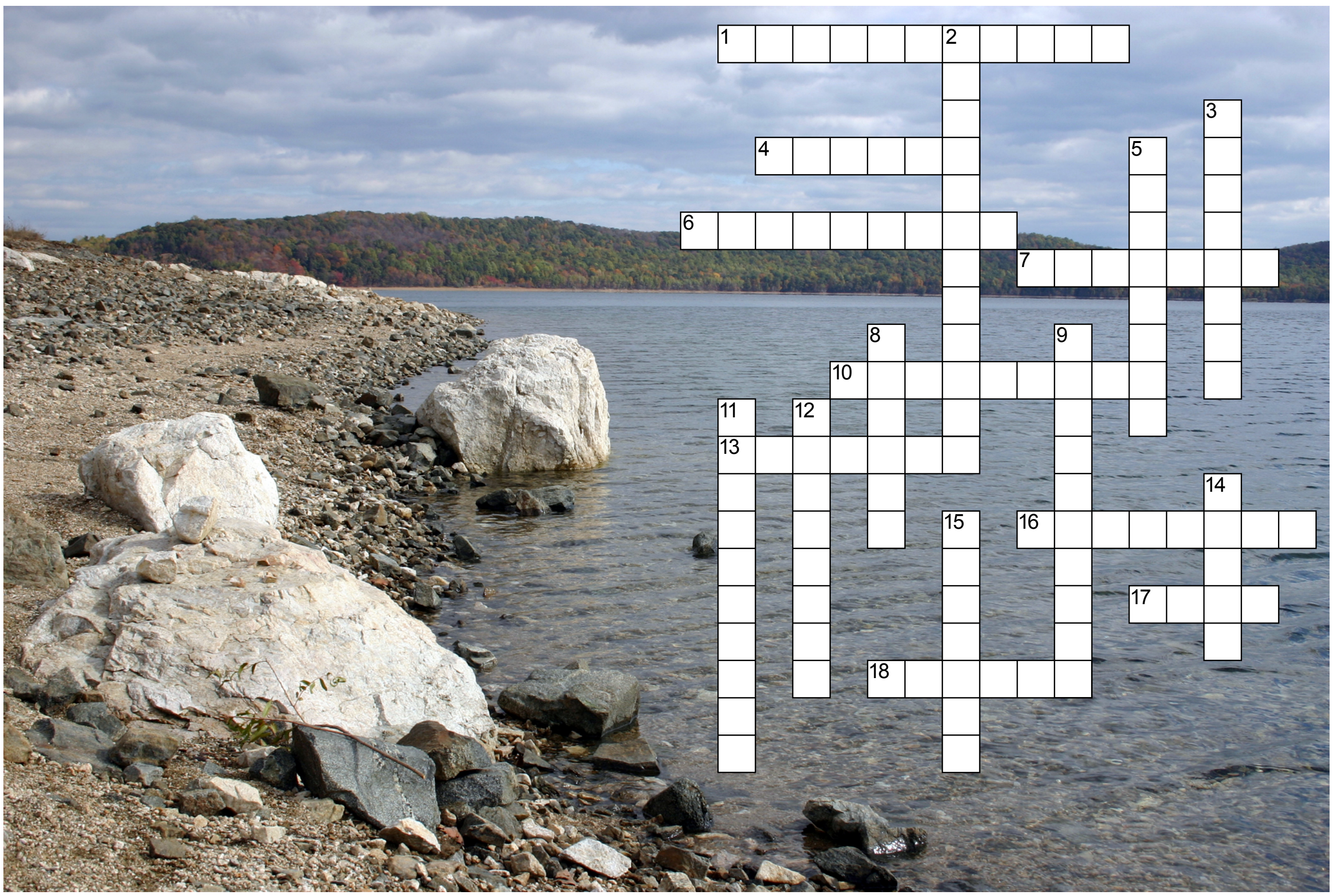
CROSSWORD PUZZLE ANSWERS. Across: (1) Geophysical, (4) facies, (6) vibracore, (7) epidote, (10) reservoir, (13) unakite, (16) drainage, (17) fold, (18) quarry. **Down:** (2) subsurface, (3) fracture, (5) landform, (8) aerial, (9) topography, (11) quadrangle, (12) lapadary, (14) fault, (15) outwash.

STATEMAP AND YOU, PERFECT TOGETHER



Cross Section A-A', *left*, at 35 percent scale, from *Surficial Geologic Map of the Milford Quadrangle, Sussex County, New Jersey and Part of Pike County, Pennsylvania* (OFM 96), 2012. *Right*, Stony till exposed in a foundation cut-face dug in the Montague moraine. Recessional moraines in the Milford quadrangle, like the Montague, consist largely of till with minor pockets and lenses of statified sediment. Visit our website to see all of our STATEMAP products.

CROSSWORD SHORES



Round Valley Reservoir, Clinton Township, Hunterdon County, 2005. *Photo by Z. Allen-Lafayette*

ACROSS

1. Physics of the earth
4. Aspect of a rock unit reflecting conditions of its origin
6. Continuous sample from coarse-grained sediments
7. $Ca_2(Fe^{3+}, Al)_3(SiO_4)(Si_2O_7)(O,OH)_2$
10. Artificial storage area for water
13. Epidote-rich granite
16. The processes of surface discharge of water from an area
17. Curve or bend of a planar structure
18. Excavation

DOWN

2. Geologic features interpreted on the basis of drill records
3. Crack
5. Earth's surface
8. From the air
9. Land surface configuration
11. Rectangular area bounded by parallels of latitude and meridians of longitude
12. Cutter of precious stones
14. Planar rock fractures which show evidence of relative movement
15. Stratified detritus removed from a glacier by meltwater