UNEARTHING NEW JERSEY

NEW JERSEY GEOLOGICAL AND WATER SURVEY
Department of Environmental Protection

Vol. 7, No. 2 Summer 2011

MESSAGE FROM THE STATE GEOLOGIST

Since the mid-1800's, the New Jersey Geological Survey has experienced many changes. The mission of the Survey has recently been expanded to include water resource planning and regulatory functions. These responsibilities have been added to the geoscience mapping, research and interpretive roles traditionally overseen at the Survey. While the Water Allocation and Well Permitting programs have always been supported by the Survey, these NJ Department of Environmental Protection (NJDEP) regulatory programs are now its direct responsibility. With this expanded role, the Survey will continue to provide governmental agencies, the business community and the public with information necessary to address environmental concerns and make economic decisions.

The Survey's name has changed to reflect these added initiatives. Now known as the New Jersey Geological and Water Survey, it is organized into two Bureaus: the Bureau of Water Resources and Geoscience, led by Bureau Chief David Pasicznyk, will continue to meet the more traditional role of the Survey, and the Bureau of Water Allocation and Well Permitting, led by Bureau Chief Terry Pilawski, will manage the water regulatory program.

As the State Geologist, my direct functions have also expanded to include coordinating NJDEP input to the Delaware River Basin Commission, as well as providing information on issues associated with natural gas drilling processes such as hydraulic fracturing.

In this issue, among other articles, staff geologist Scott Stanford explores mapping clays and interbedded sands in the important Cohansey Formation. Indeed it is the Cohansey Formation that gives the nationally reknowned Pine Barrens, also known as the Pinelands, its sandy, acidic, nutrient-poor soil.

The Survey welcomes your feedback on the content or format of the newsletter. All Survey publications are available as free downloads from the web site. 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 Unpublished information is provided at cost by writing the State Geologist's Office, N.J. Geological and Water Survey, PO Box 420, Mail Code 29-01, Trenton, N.J. 08625-0420. Staff are available to answer your questions 8 a.m. - 5 p.m. Monday through Friday by calling (609) 292-1185 or by e-mail at njgsweb@dep.state.nj.us.

Karl W. Muessig
New Jersey State Geologist

Oyster Creek, Wells Mills Park, Ocean Township, Ocean County. *Photo by Z. Allen-Lafayette*.

MAPPING CLAYS AND INTERBEDDED SANDS IN THE COHANSEY FORMATION

By Scott D. Stanford

In the middle to late Miocene Epoch, 10 to 12 million years ago (Ma), sea level was about 200 feet higher than present in the New Jersey region. What is now the Pine Barrens was then a coastal area of beaches and bays. Sand was deposited on and adjacent to beaches, in tidal channels and deltas, and in offshore bars. Clays settled out in the calmer waters of bays and coastal marshes. These deposits today are known as the Cohansey Formation. As sea level rose and fell slightly during Cohansey time, beaches advanced inland and retreated seaward. With

Figure 1. Clay beds and interbedded sand in the Cohansey Formation, exposed in a cut near Forked River Mountain in the Brookville quadrangle. Clay beds are pink to white, sand beds are browbn to yellowish-brown.

each advance, layers of sand were laid down atop bay and marsh sediment. Sand was more abundant than clay in the shore area in the Miocene, as it is today, so sand beds are thicker and more widespread than clays.

After 10 Ma, sea level fell, exposing the Cohansey as a coastal plain. Over the past 10 million years, rivers and streams flowing on this plain have slowly eroded into the Cohansey, giving us the present-day landscape of broad, shallow valleys and low, flat uplands.

The thick, clean quartz sands of the Cohansey, combined with the broad valleys and uplands, give the Pine Barrens their distinctive hydrology and vegetation. The sands are highly permeable. Rain and snowmelt soak into and flow through the sand easily, producing dry uplands and valley-bottom wetlands where groundwater seeps to the surface. Drought-tolerant and fire-adapted pines and oaks grow on uplands; moisture-loving Atlantic White Cedars and Red Maples colonize the lowest-lying wetlands. Seasonally wet areas between the uplands and valley bottoms undergo regular fluctuations in the water table. In places, rare plant communities are adapted to these seasonal fluctuations.

Clays are much less permeable than sands. Even thin clay layers with interbedded sands like those of the Cohansey (fig. 1) impede and redirect the flow of groundwater. When groundwater draining down through sand encounters a clay bed, it pools atop the clay and flows laterally along the top of the clay layer until it emerges as seepage at the land surface, or comes to the edge of the clay, where it may continue to drain vertically. Where seepage emerges, outflowing water erodes material at and downhill from the point of emergence. Over time, this erosion forms scarps and hollows on the sides of valleys. The outflowing water joins with the valley-bottom seepage to feed stream flows. Continuous, extensive clays that underlie surface drainage divides may direct groundwater from one basin to another (fig. 2). Clay beds that lie at shallow depth on uplands may hold up perched groundwater in settings that would ordinarily be dry if underlain by sand. In either case, knowing the geometry of clay beds is essential to understanding groundwater and stream flow and the effects of well pumpage and surface-water diversions on the water table.

Recently published geologic maps of the Brookville (N. J. Geological Survey Open-File Map OFM 81) and Woodmansie (N. J. Geological Survey Geologic Map Series GMS 10-2) quadrangles, funded by the STATEMAP component of the National Cooperative Geologic Mapping Program, show clay beds in the Cohansey in part of the eastern Pine Barrens. These clay beds were mapped using hand-augering and study of exposures to trace their outcrop at the land surface, and by drilling power-auger holes and compiling water-well and test-boring records to identify their subsurface extent. The maps also show seepage-generated landforms and surficial deposits of sand and gravel that cover the Cohansey throughout most of the area.

The hydrologic effects of the clays is particularly evident in the Brookville quadrangle, which includes an upland area forming the headwaters of Oyster Creek (photo, p. 1), Forked River, Cedar Creek, Mill Creek, and the Oswego River (fig. 3). The Oswego River flows south on a long, gentle course to join the Mullica River which empties into Great Bay. Mill Creek, Oyster Creek, Forked River, and Cedar Creek all flow on a shorter, somewhat steeper route eastward to Barnegat Bay. An extensive clay bed beneath the divide between the Barnegat drainages and the Mullica drainage directs groundwater eastward from the Mullica basin into the Barnegat basins. This diversion is documented by stream baseflow measurements, collected continuously for periods of 20 to 60 years for these rivers by the U. S. Geological Survey. Baseflow volumes were calculated by dividing the long-term, low-flow stream discharge by the area of its corresponding drainage basin, and are expressed as inches of recharge for the basin, shown as the red numbers in figure 3 (Gordon, 2004). The higher numbers in the Barnegat basins reflect eastward flow of groundwater into those basins. The Oyster Creek and South Branch Forked River valleys have especially high recharge values because a second, lower clay bed that crops out in those basins intercepts groundwater from the neighboring Fourmile Branch and North Branch valleys.

The many active seepage scarps and amphitheater-shaped embayments in the headwater hillslopes of Oyster Creek, Forked River, and Cedar Creek, are the product of,

NJGWS
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Kim Guadagno, *Lieutenant Governor*
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Bob Martin, *Commissioner*
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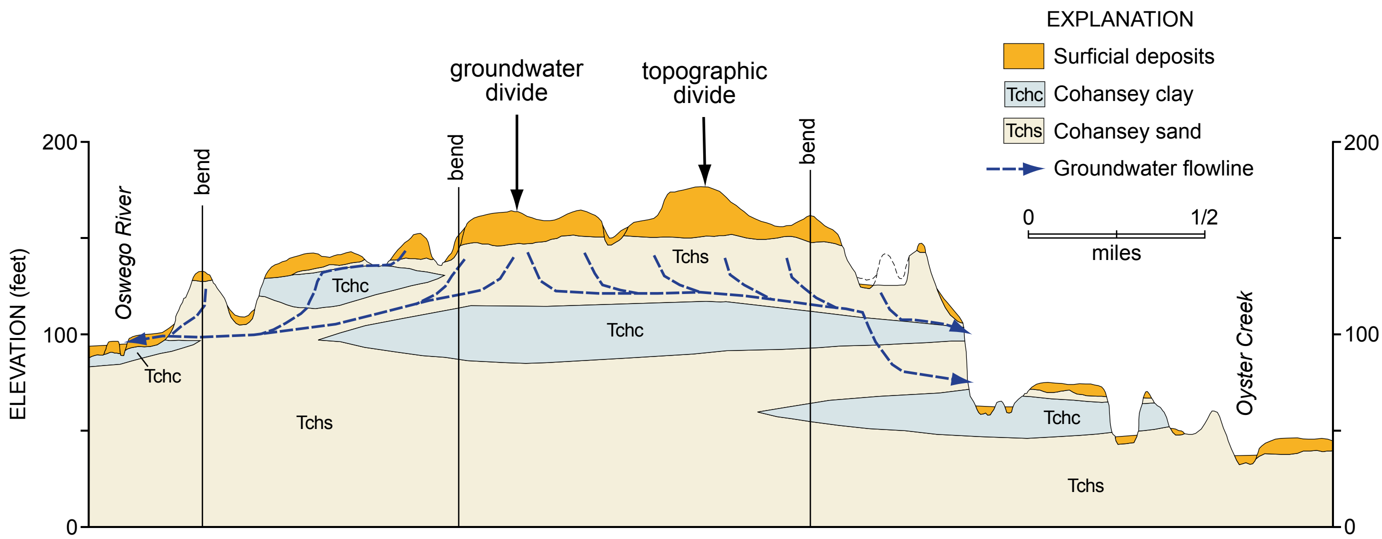

Figure 2. Cross section showing how lateral flow atop a clay bed diverts groundwater from the Oswego River basin into the Oyster Creek basin. Line of section shown in figure 3. Groundwater flow is shown schematically.

and evidence for, this groundwater diversion. These features may be observed in the Oyster Creek basin at Wells Mills County Park, an Ocean County property on Route 532 (Wells Mills Road) in Waretown, Ocean Township. Take the white-blazed trail leading west from the visitor center. This trail winds around the headwaters of Raccoon Branch, which is fed by groundwater flowing eastward along the top of the two clay beds shown in figure 2. Erosion by the emerging water cut the steep hillslopes and small gullies traversed by the trail, creating the embayed form of the valley. Penns Hill and Laurel Hill are two high points on the top of the seepage scarp along the trail. Penns Hill offers a good view of the amphitheater-like seepage valley.

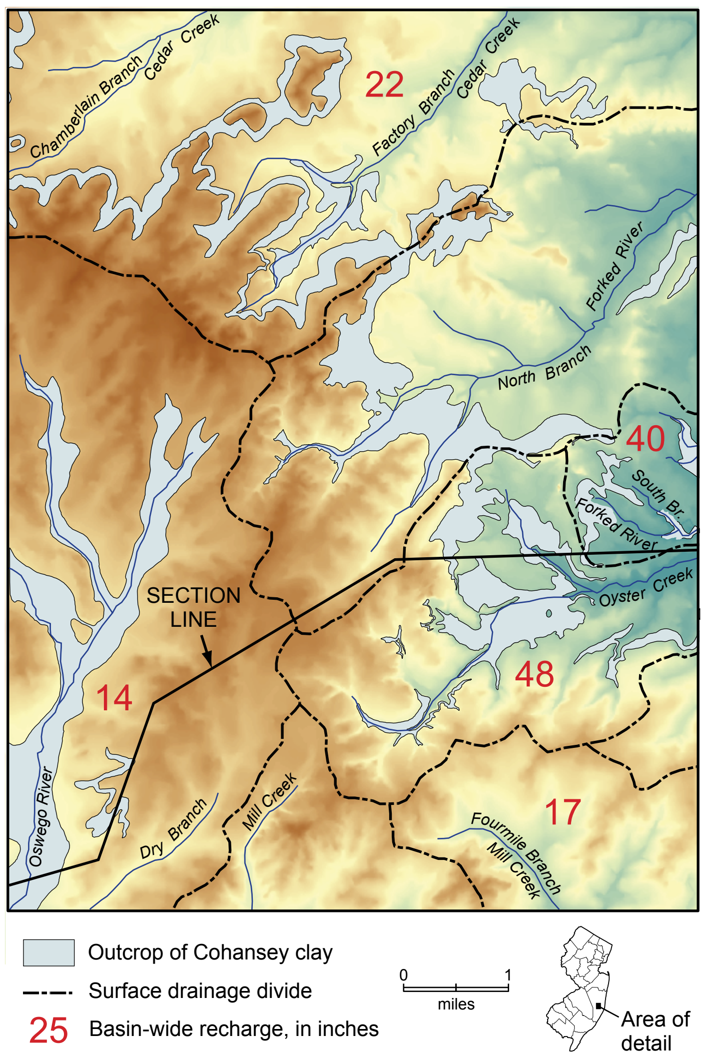

Figure 3. Outcrop of Cohansey clays in the Brookville quadrangle, and recharge rates for drainage basins showing eastward diversion of groundwater from the Oswego basin atop a clay bed. Elevation data from U.S. Geological Survey National Elevation Dataset, 10 meter resolution.

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$NaCa_2Al_5Si_{13}O_{36}14H_2O$

CARBON SEQUESTRATION INVESTIGATIONS BY THE NEW JERSEY GEOLOGICAL AND WATER SURVEY

By Peter J. Sugarman and Donald H. Monteverde

In 2010, the New Jersey Geological and Water Survey (NJGWS) joined the Midwest Regional Carbon Sequestration Partnership (MRCSP). The role of the MRCSP is to assess the technical potential, economic viability, and public acceptability of carbon sequestration within a nine-state region including New Jersey. The NJGWS, in conjunction with Rutgers University, recently completed a preliminary characterization of geological sequestration potential of carbon dioxide (CO_2) in New Jersey and adjacent offshore

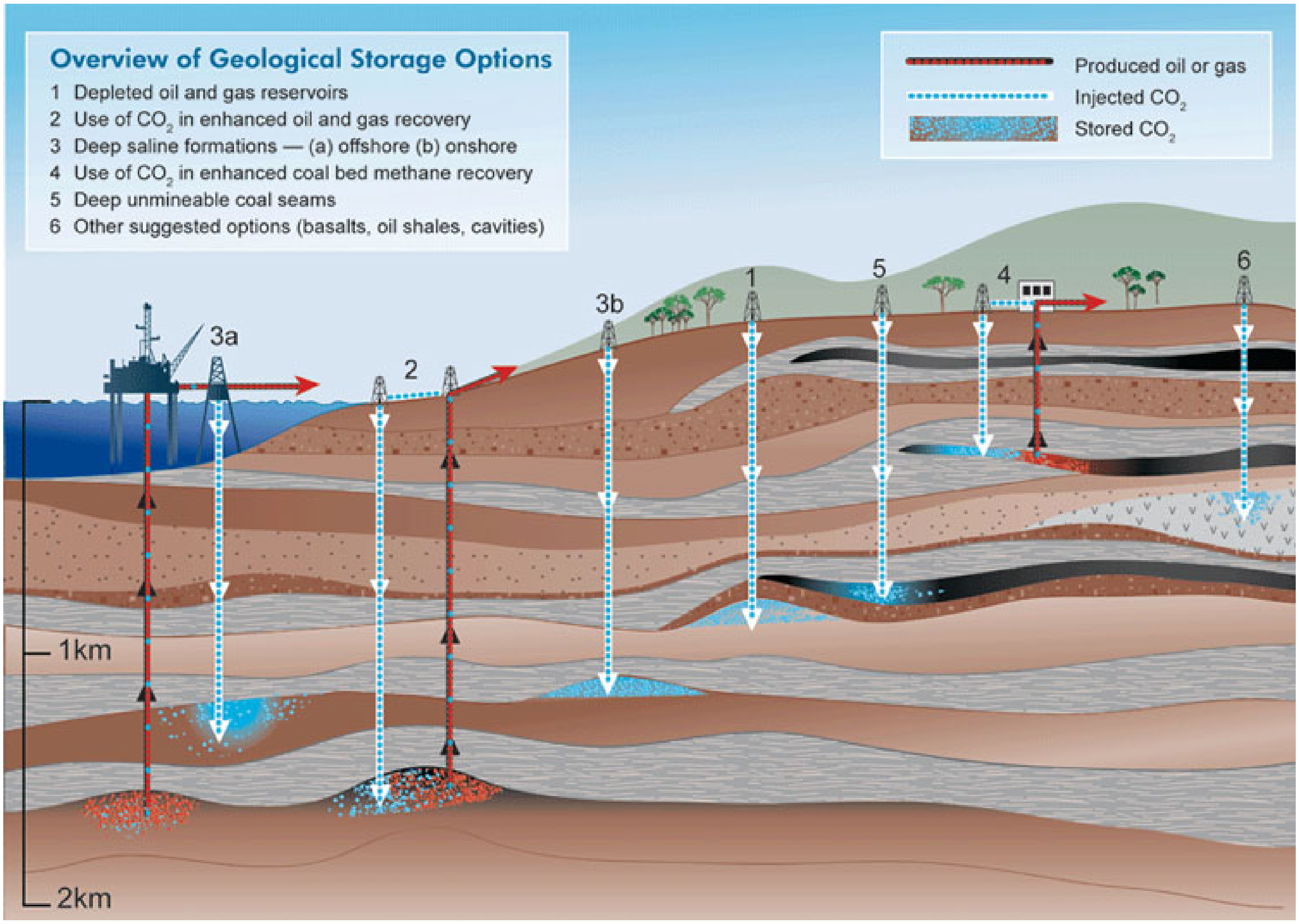

Figure 1. Types of CO_2 Geological Storage Options. In New Jersey, deep saline formations, both offshore (3a) and onshore (3b) offer the best potential for geological carbon sequestration. *Figure from* [Intergovernmental Panel on Climate Change]

region, including the continental shelf and slope.

Carbon sequestration involves the burial and storage of CO_2 in underground reservoirs. Carbon dioxide is an important greenhouse gas. The levels of CO_2 in the atmosphere have increased from roughly 315 ppm in 1958, when measurements began at Mauna Loa Observatory in Hawaii, to a current level of approximately 393 ppm. As atmospheric levels of CO_2 increase, global temperatures are also increasing. Doubling of CO_2, which will likely occur in this century, will raise global temperatures 2-5°C. Climate

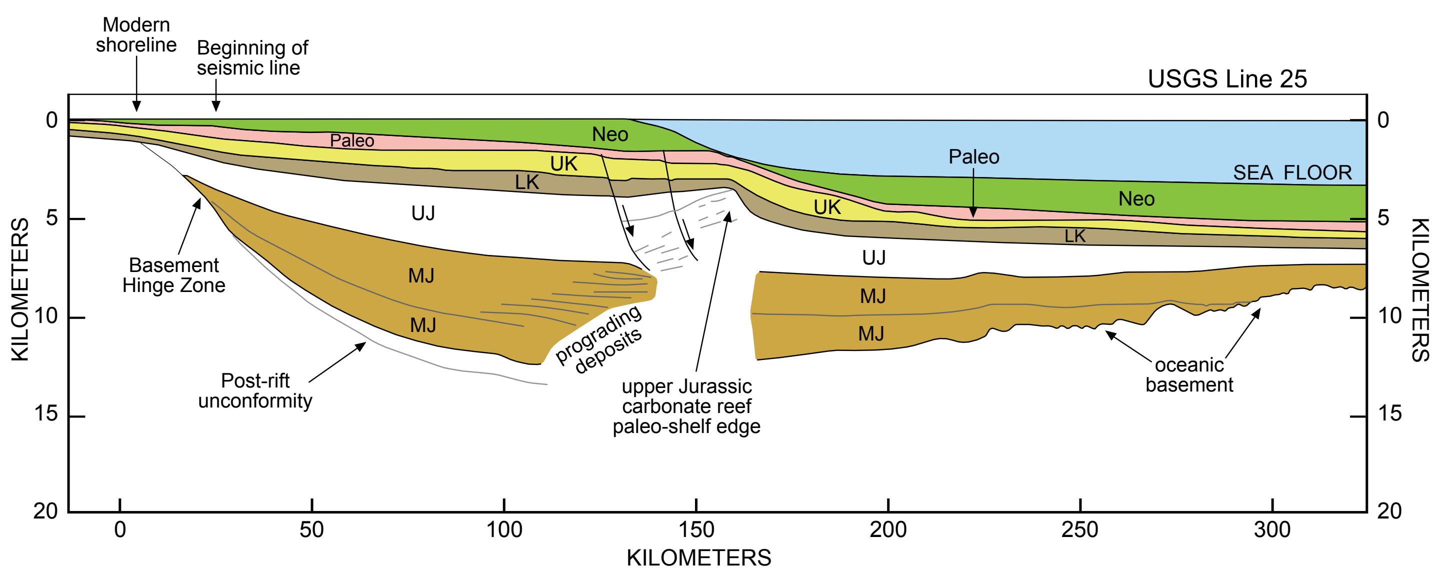

Figure 2. Schematic cross-sectional interpretation of USGS Line 25 based on Grow and others, (1988) and Poag (1985) across the New Jersey margin. LK (Lower Cretaceous) and UK (Upper Cretaceous) strata which are in part equivalent with the onshore Potomac Formation can be seen to thicken from onshore across the margin.

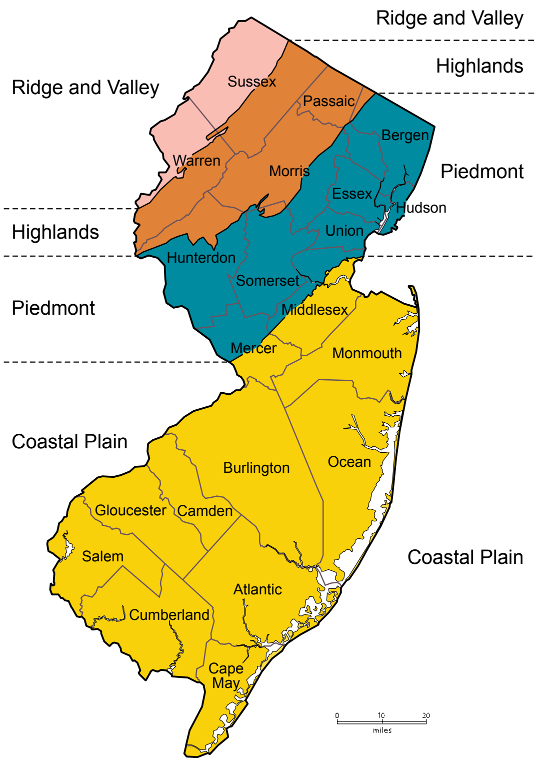

Figure 3. New Jersey physiographic provinces.

models point to higher CO_2 levels and higher temperatures in the future, so carbon sequestration is a possible option aimed at reducing the levels of CO_2 in the atmosphere.

Geologic options for the long-term storage of CO_2 include old, depleted oil, and gas reservoirs, coal seams, and deep saline horizons or sand bodies (fig. 1). For New Jersey, which lacks production of oil, gas, and coal, one possible option is injection of CO_2 into porous, deep saline formations that underlie the New Jersey Coastal Plain and adjacent continental shelf and slope. These formations are thick, and burial depths exceed 2500 feet, a necessary criterion for supercritical storage of CO_2. In the supercritical state, CO_2 has the density of a liquid, but flows like a gas, facilitating storage of large volumes of CO_2. Additionally, these formations are capped by thick, low-permeability confining beds required to isolate CO_2 in the sequestration target horizons.

Our preliminary studies indicate that the Potomac Formation, the deepest unit in the Coastal Plain (fig. 2), appears suitable for sequestration of supercritical CO_2. The formation lies at the required depth south of Island Beach, Ocean County, where it contains saline groundwater.

Initial studies of the offshore New Jersey continental shelf and slope suggest that several deep sand bodies provide potential targets for geological sequestration. These sands are likely equivalents to sand bodies in the onshore New Jersey Potomac Formation (fig. 2).

The Stockton Formation, within the Piedmont Province or the Newark basin (fig. 3), also has some potential, based on preliminary data that is far from conclusive. It exceeds 2500 feet in depth in about two-thirds of the Newark basin, and its thickness ranges from 500 to 4,600 ft. Owing to a lack of deep data, hydrologic parameters and lateral continuity of target lithologies, the Newark Basin as a sequestration target is speculative. However, the U.S. Department of Energy is supporting new coring and data collection in the New York part of the Newark Basin. Results of this work may offer new information on buried rocks in this region.

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Poag, C.W. "Depositional History and Stratigraphic Reference Section for Central Baltimore Canyon Trough." In *Geologic Evolution of the United States Atlantic Margin*, edited by C.W. Poag, 217-263. Chicago: University of Chicago Press, 2006.

$NaCa_2Al_5Si_{13}O_{36}14H_2O$

MODERATE EARTHQUAKE IN VIRGINIA FELT IN NEW JERSEY

by Richard Dalton

At 1:51:04 PM EDT on August 23, 2011, a moderate earthquake (magnitude M5.8) occurred in central Virginia and was felt throughout most of the East from Georgia to southern Canada and from Indiana to coastal Maine. This event was followed by four aftershocks. In New Jersey the intensity ranged from 1 to 4 (weak to light). Generally areas

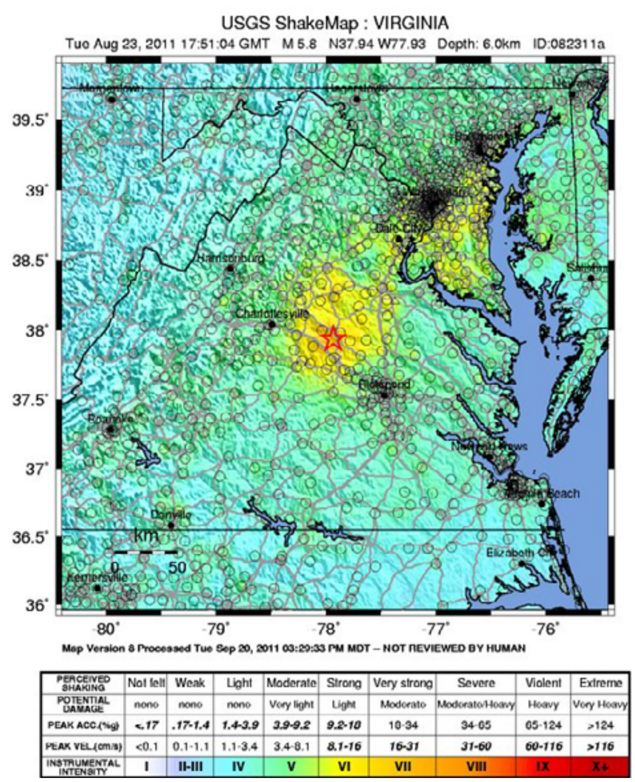

Figure 1. U. S. Geological Survey ShakeMap for Virginia. *Figure by USGS*

underlain by thick silt and clay felt a stronger ground motion than did those where rock was very close to the surface.

Earthquakes in the central and eastern U.S. typically are felt in a much larger area than are those in the western states. For instance, a similar earthquake (magnitude M5.3) on the Colorado-New Mexico border on August 22, 2011 at 11:46:19 EDT local time was felt mainly in eastern Colorado and eastern Kansas. According to the U.S. Geological Survey website “A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred (fig. 1), and sometimes causes damage as far away as 40 km (25 mi).” This is because the eastern U.S. is on the trailing edge of the North American Plate and most local faults are extremely old and healed. Many faults in the western U.S. are much younger, have had more recent movement and have not healed. Hence they absorb much of the energy of the earthquake before it can be transmitted long distances as it is in the east.

Most earthquakes in New Jersey are very small, generally a magnitude M3.0 or less, and are seldom felt very far from their epicenter. The most recent earthquake in the State was a magnitude M1.6 near South Plainfield, Middlesex County, on June 9, 2011. The largest recorded earthquake in the New Jersey/New York area was a magnitude M5.5 in 1884.

Two seismic networks cover parts of the state. The Lamont-Doherty Cooperative Seismic Network has some stations in the northern part of the state and the Delaware Seismic Network has some close to the southern border. They can detect moderate local earthquakes, but the low intensity ones may be obscured by background noise, especially if it is distant from the nearest station. The NJGWS monitors and responds to questions concerning possible earthquakes in New Jersey.

If an earthquake of larger magnitude (> M5) such as the 1884 earthquake were to occur today it would likely cause significant damage. The Survey currently is evaluating earthquake hazards on a county-wide basis using the HAZUS model developed by the Federal Emergency Management Agency.

Figure 1. Laumontite crystal on stilbite bowtie, approximately 7 mm in length. Specimen from Prospect Park Boro, Passaic County. *Photo by J.H. Dooley*

STILBITE AND LAUMONTITE

By F. Larry Müller

I was only about ten years old and when I visited the Summit Quarry, Springfield Township, Union County, with two of my neighbors. Looking at the surface of a gray rock I had collected, I was transfixed by tightly packed group of radiating crystals, forming a circle. They told me the mineral was stilbite. I was thrilled with my discovery, and thus my romance with geology began more than half a century ago. Summit Quarry was a classic location for stilbite. Later, when Route 78 was constructed through the quarry, a two-foot-thick vein of stilbite was uncovered. I still have a sample from that great vein in my collection.

Stilbite is a zeolite, and it forms many interesting aggregates of radiating crystals and sheaths. When railroad tunnels, quarries and roads were excavated many years ago, the New Jersey trap rocks became world famous for their zeolites. Zeolites are common to the basaltic rocks of eastern North America. The New Jersey quarries at Paterson, Great Notch, Snake Hill, Scotch Plains, Bound Brook, Stockton, Pennington, Rocky Hill, and Lambertville have zeolite suites of minerals. Those in areas of pillow basalts have more than others.

Stilbite is a silicate with the formula $NaCa_2Al_5Si_{13}O_{36}nH_2O$ and is in the monoclinic crystal system. The crystals are penetration twins and commonly form sheaths, which resemble bow ties. Other common forms the aggregates take are globular, bladed or radiating masses. Its hardness ranges from 3.5 to 4 on the Mohs Scale, and density ranges from 2.09 to 2.20. Stilbite has perfect cleavage in one direction and an uneven fracture. Its color varies from white to pink, reddish, or brown. Its streak is colorless. To test for stilbite, place a specimen in hydrochloric acid (HCl) and it will dissolve. Stilbite occurs with other zeolites like laumontite (forming crystals encrusting the bow tie shown in fig. 1) in igneous rocks and sites of hydrothermal activity where it fills voids such as amygdules, fissures and crevices. It also occurs in gneisses and schists, sedimentary tuffs, “hot spring deposition, and deep-sea deposits” (Dana and Dana, et al. 1997, 1675). The best examples of stilbite at mineral sales come from the Deccan Traps basalts from the Pune (Poona) and Nashik areas of India (Dana and Dana, et al. 1997, 1675).

Laumontite, pictured in figure 1 with the stilbite, is also a zeolite mineral and has the chemical formula $CaAl_2Si_4O_{12}{\cdot}4H_2O$. The specimen is from the famous zeolite locality at Prospect Park, New Jersey. Laumontite may be colorless, translucent, pink, or rose. It becomes chalky-white as it dehydrates. Like stilbite, it is in the monoclinic crystal system. Crystals that are elongated and twinned may form swallowtails at their c-axis ends. It may be stained by iron or manganese. The mineral has perfect cleavage in two directions, and imperfect cleavage in the third direction. Its hardness is 3 to 4 on the Mohs Scale and its specific gravity ranges from 2.20 to 2.41 (Dana and Dana, et al. 1997, 1651). Laumontite may fluoresce a white, cream, or yellow color in long and short wave ultraviolet light. The mineral occurs in a wide variety of geologic environments with other zeolites like stilbite, apophyllite, and chabazite (Hochleitner 1994, 170).

The quarries where I collected as a youngster are all on private land and to trespass is to risk arrest and prosecution. However, some quarry owners grant permission to clubs and organizations to visit and collect. So, if you are denied permission to collect as an individual, try going with a club or other organization.

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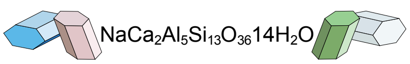


WATER TRANSFERS IN NEW JERSEY, 2007

by Jeffrey L. Hoffman

New Jersey uses over a trillion gallons of water a year. This graph (fig. 1) summarizes for 2007 the volumes of water from different sources, shows how much water moves from each source to the various water uses, and then how the water is disposed of (after appropriate treatment). The number in each box gives the volume, in billions of gallons, for that particular step. The connector lines summarize the transfer of water, from left to right on this graph. Line width is proportional to the volume of water that takes that path. For example, hydropower generation is the largest use of water - 569 billion gallons in 2007. Most of this water was withdrawn from surface water in the Delaware basins in northern New Jersey, with smaller volumes from the Passaic & Hudson basins, and the Raritan & Arthur Kill basins. This water is then returned to fresh water. This summary is based on data from reports by water purveyors and dischargers to the NJDEP. The data, and connections between source, use and destination, are stored in the New Jersey Water Transfer model (NJWaTr). Analysis of these data is an important part of New Jersey's water supply planning process.

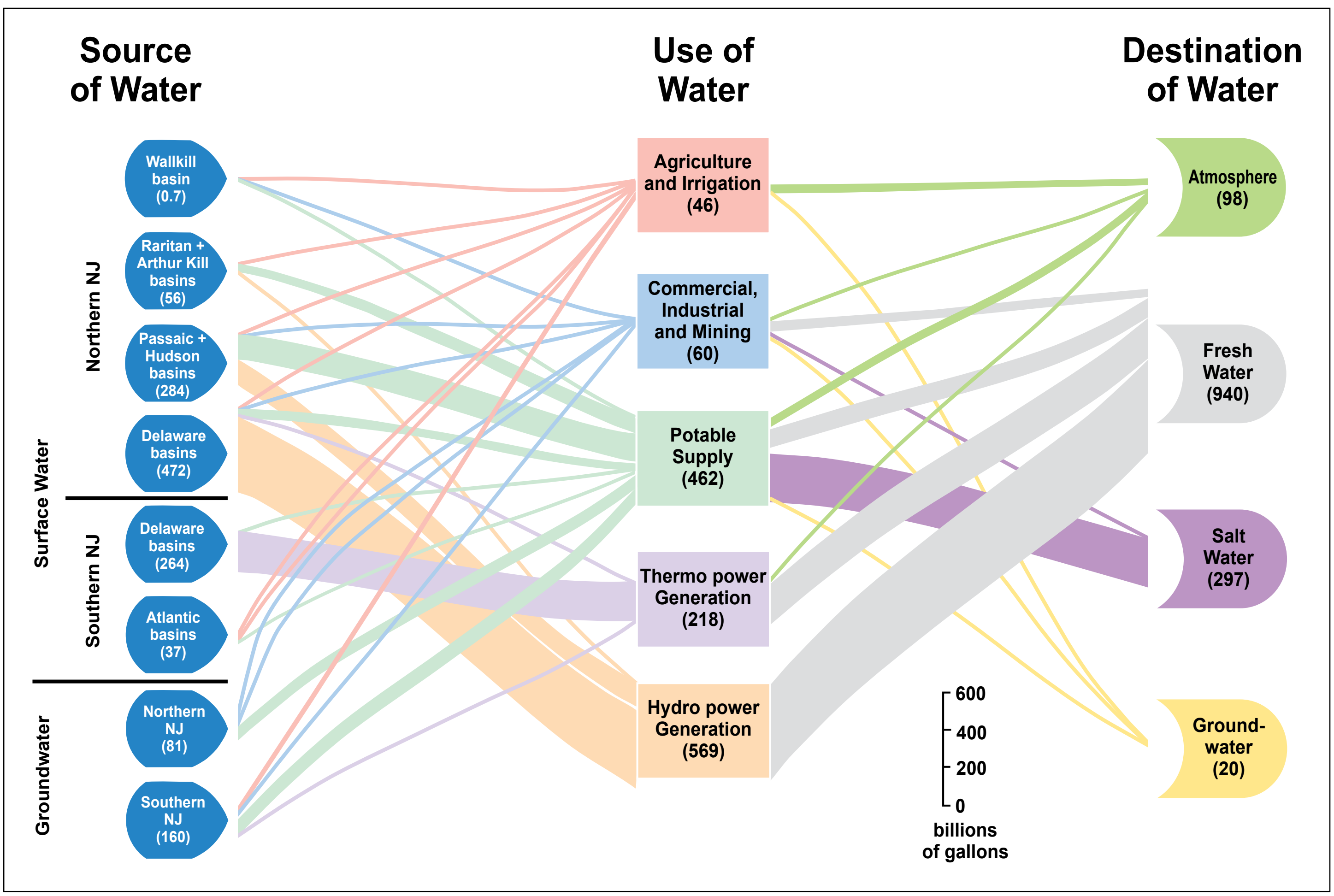
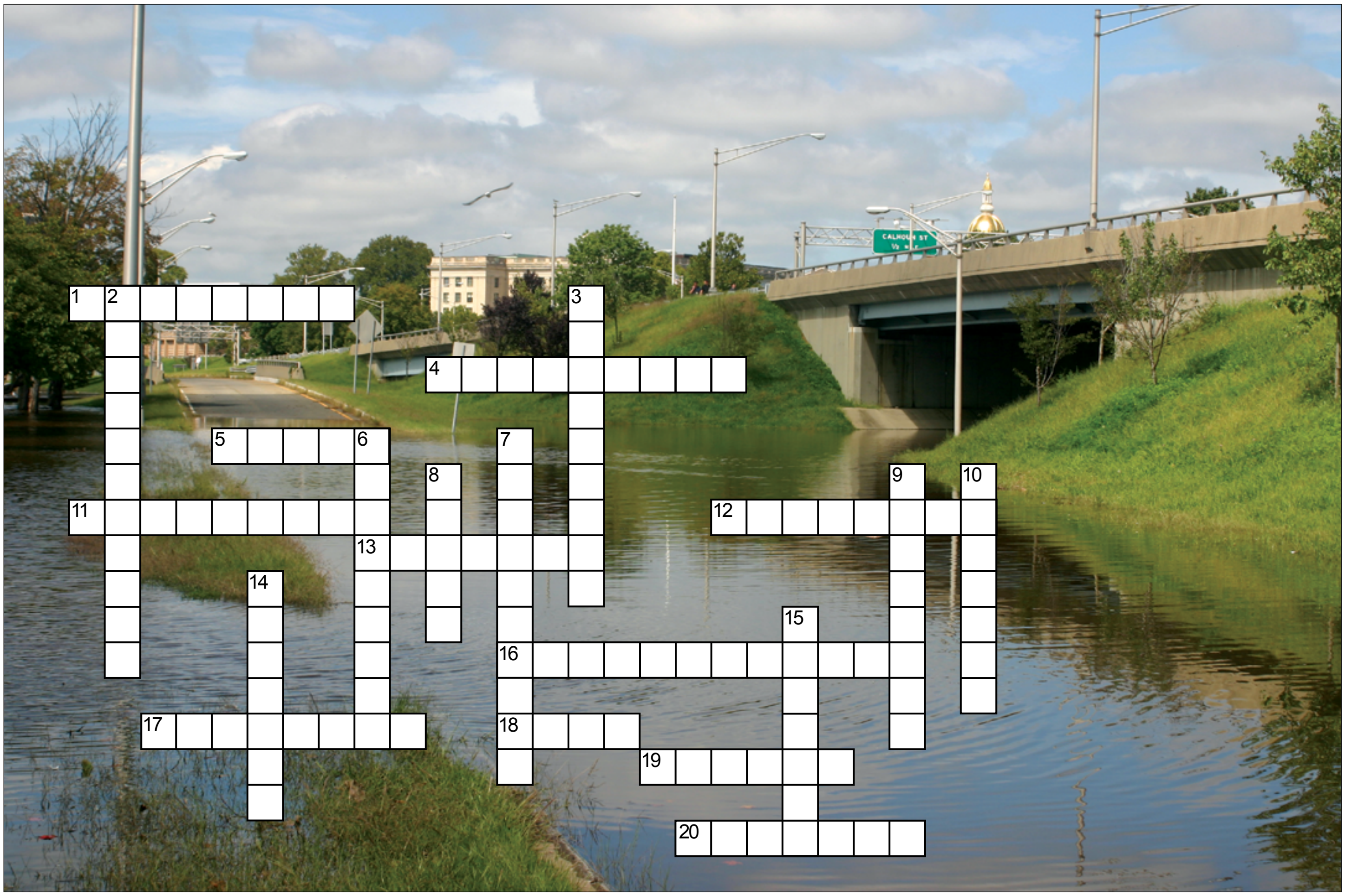


Figure 1. Water use graph, 2007. *Figure by B. Graff*

CROSSWORD DELUGE



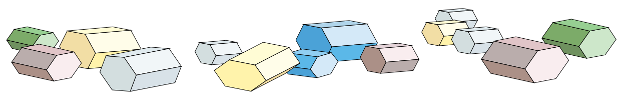
In September 2011, the Delaware River flooded Route 29 in Trenton for the third time in seven years. This important thoroughfare into the capital city was closed for several days. The gold dome of the capital building can be seen in the upper right of the photograph. *Photo by Z. Allen-Lafayette.*

ACROSS

1. Compound whose crystal structure contains SiO4
4. Measure of the strength of an earthquake
5. Line of cliffs formed by erosion
11. Source of a stream
12. Breaking of a mineral along crystallographic planes
13. Series of the Tertiary System
16. Hot water of magmatic origin
17. Formation made up of white to yellow, cross-bedded, medium to coarse sand, with gravel and clay occurring locally
18. Plastic material consisting mainly of particles having diameters less than 0.074 mm
19. Crystalline silica
20. Hydrous aluminosilicate

DOWN

2. Alternating beds of different character
3. Point on the Earth's surface that is directly above the focus of an earthquake
6. Permits liquids or gasses to seep through
7. Earthquake that follows a larger earthquake
8. Geochronologic unit
9. Part of stream discharge not attributable to runoff
10. Earth vibration
14. Slow movement of water through a porous material
15. Homogeneous, solid body of a chemical element having a regularly repeating atomic arrangement and that may be expressed by external plane facies



Perfect as the wing of a bird may be, it will never enable the bird to fly if unsupported by the air. Facts are the air of science. Without them a man of science can never rise.

--Ivan Pavlov (1849-1936), Russian physiologist--

CROSSWORD PUZZLE ANSWERS. ACROSS: (1) silicate, (4) magnitude, (5) scarp, (11) headwater, (12) cleavage, (13) miocene, (16) hydrothermal, (17) cohansey, (18) clay, (19) quartz, (20) zeolite. **DOWN**: (2) interbedded, (3) epicenter, (6) permeable, (7) aftershock, (8) epoch, (9) baseflow, (10) seismic, (14) seepage, (15) crystal.

NEW PUBLICATIONS

BULLETIN (B)
NEW REPORT. B 77, Contributions to the Geology and Hydrogeology of the Newark Basin, Herman, Gregory C. and Serfes, Michael E., eds., 2010, 550 p., 152 illus., 22 tables, 4 appendices. Available for download. $100.00

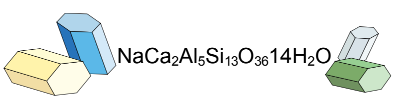
OPEN-FILE REPORT (OFR)
NEW REPORT. OFR 11-1, Expansion of Monitoring Well Network in Confined Aquifers of the NJ Coastal Plain, 1996-1997, Mullikin, Lloyd, 2011, 55 p., 21 illus, 3 tables. Available for download.

DIGITAL GEODATA SERIES (DGS)
NEW DATA. DGS 10-2, Surficial Geology of New Jersey (scale 1 to 24,000). GIS data sets available for download.

NEW DATA. DGS 10-3, New Jersey Water Transfer Model Withdrawal, Use, and Return Data Summaries. Microsoft Access data sets available for download.

OPEN-FILE MAPS (OFM)
NEW MAP. OFM 81, Geology of the Brookville Quadrangle, Ocean County, New Jersey, Stanford, Scott D., 2011, scale 1 to 24,000, size 36x49, 3 cross-sections. Available for download. $10.00.

NEW MAP. OFM 82, Surficial Geologic Map of the New Jersey Part of Unionville Quadrangle, Sussex County, New Jersey, Witte, Ron W., 2011, scale 1 to 24,000, size 34x35, 1 cross-section and a 13-page pamphlet. Available for download. $10.00



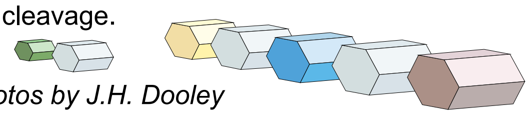
The Cohansey sands of southcentral New Jersey, an area known as the Pine Barrens, are the foundation for an extremely productive agricultural area. The lowlands create bogs perfect for cranberry growing (582,000 barrels per year) and the uplands with their excellent drainage are home to blueberry farms (50 million pounds of blueberries per year). This blueberry field in Washington Twp, Burlington County, displays the sandy soil typical for this region. *Photo by Z. Allen-Lafayette*

Joe Rich surveying Tri-States Monument, on the New Jersey/New York/Pennsylvania border, 2004. *Photo by W. Marzulli*

JOE RICH RETIRES

Joseph A. Rich retired on May 31, 2011 after 30 years of service to the State of New Jersey. Joe began his career as a surveyor with a brief stint at Department of Transportation and in the private sector before joining NJGWS as an Engineering Aide I in the Geodetic Control Survey. When the Geodetic Control Survey transferred out of NJGWS, Joe remained and supervised many important surveying projects for our ground water programs as a Principal Engineering Aide and Chief of Survey Party. When GPS came into the forefront, Joe shifted gears and GPS-located and inspected countless ground water wells and their associated systems in order to refine our hydrogeologic database as a Supervising Environmental Technician, Investigator II and Investigator I. Most importantly, Joe was responsible for inspecting boundary monuments on the New York and Delaware borders as required under state statute. Full inspections were completed in 1990 and 2001 along with many local inspections during his career. His dedication to his work and his professionalism will be missed.

The name "stilbite" is from the Greek "stilbein" meaning to shine, so named because of the pearly luster of the faces of this crystal. Stilbite is usually colorless or white, but can also be yellow, brown, pink, salmon, orange, red, green, blue or black. The luster is vitreous in nature and on the cleavage.



Banner photos by J.H. Dooley