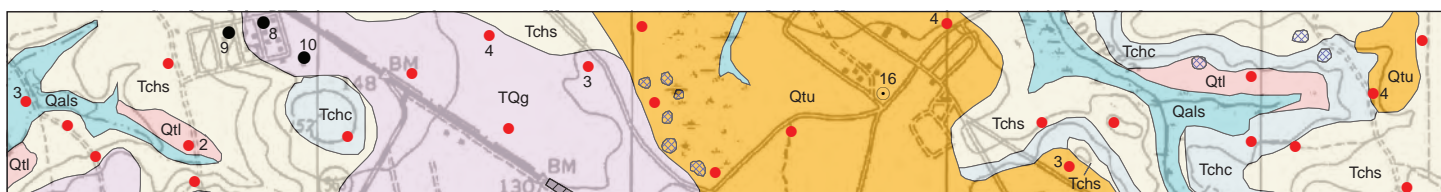


New Jersey Geological and Water Survey: *Information Circular*



Geologic Maps: Documenting New Jersey's Earth Resources

Our Geologic Heritage

Human society depends on water, minerals, and fuels provided by the earth. Our health and safety depend on our ability to understand and manage geologic hazards. Our food supply depends on soil fertility and our structures depend on stable foundations. The sediments and rocks of the top several thousand feet of the earth's crust provide these essential resources. These sediments and rocks form a complex three-dimensional puzzle that is the result of millions of years of changing tectonic, geographic, and climatic settings. Understanding and fitting together the pieces of this puzzle are the first steps in the wise stewardship of earth resources. Geologic maps enable us to gain this understanding by determining the history, structure, and properties of earth materials.

The sediments and rocks beneath New Jersey are the product of geologic events extending back more than a billion years. During this long history, what is now New Jersey has been in a variety of tectonic settings, producing rocks that record geographies varying from Himalayan-scale mountain ranges to shallow, quiet seas, to rift basins containing large lakes. More recently, as the North American continent and Atlantic Ocean formed during the past 100 million years, sediments overlying the rocks record the rises and falls of the Atlantic Ocean, the shifting courses of rivers, and the advance and retreat of glaciers.

Three layers of information are needed to fully characterize the uppermost crustal and surface materials that

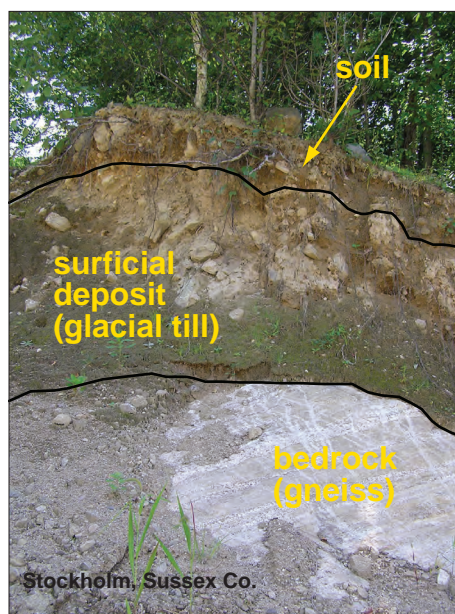


Figure 1. Examples of soil, surficial deposits, and bedrock in New Jersey. In northern New Jersey (left, photo by S. Stanford), bedrock is consolidated sedimentary, igneous, and metamorphic rock. In southern New Jersey (right, photo by J. P. Owens, USGS), bedrock includes unconsolidated marine deposits.

society depends on: 1) soil, 2) surficial deposits, and 3) bedrock (fig. 1). Soil forms in the upper several feet of the earth from weathering and biologic alteration of geologic material. Soil, because of its importance to plant growth, is a major interest of agronomy and, in the United States, it has been mapped on a county-by-county basis by the Natural Resources Conservation Service of the U. S. Department of Agriculture. Surficial deposits are unconsolidated sediments laid down by rivers, glaciers, wind, tides, and waves; by movement of soil and rock on hillslopes; by accumulation in lakes and wetlands; or by weathering of bedrock. In New Jersey, surficial deposits are generally less than 5 million years old and may be as much as 400 feet thick. Bedrock includes sedimentary rocks formed by compaction and cementation of sediments from ancient

river, lake, and marine deposits; igneous rocks that formed when magma cooled and hardened; and metamorphic rocks formed by intensely heating and compressing sedimentary and igneous rocks. Bedrock in northern New Jersey ranges from more than 1 billion to 200 million years old and has been folded and faulted by several periods of collision and rifting of tectonic plates. These rocks extend many miles below the surface. In New Jersey, by convention, bedrock also includes unconsolidated and semi-consolidated Coastal Plain formations consisting of sand, silt, and clay laid down in coastal and marine settings along the margin of the Atlantic Ocean between 100 and 5 million years ago. The Coastal Plain formations thicken seaward from a feather edge in central New Jersey to as much as 6,500 feet at Cape May.

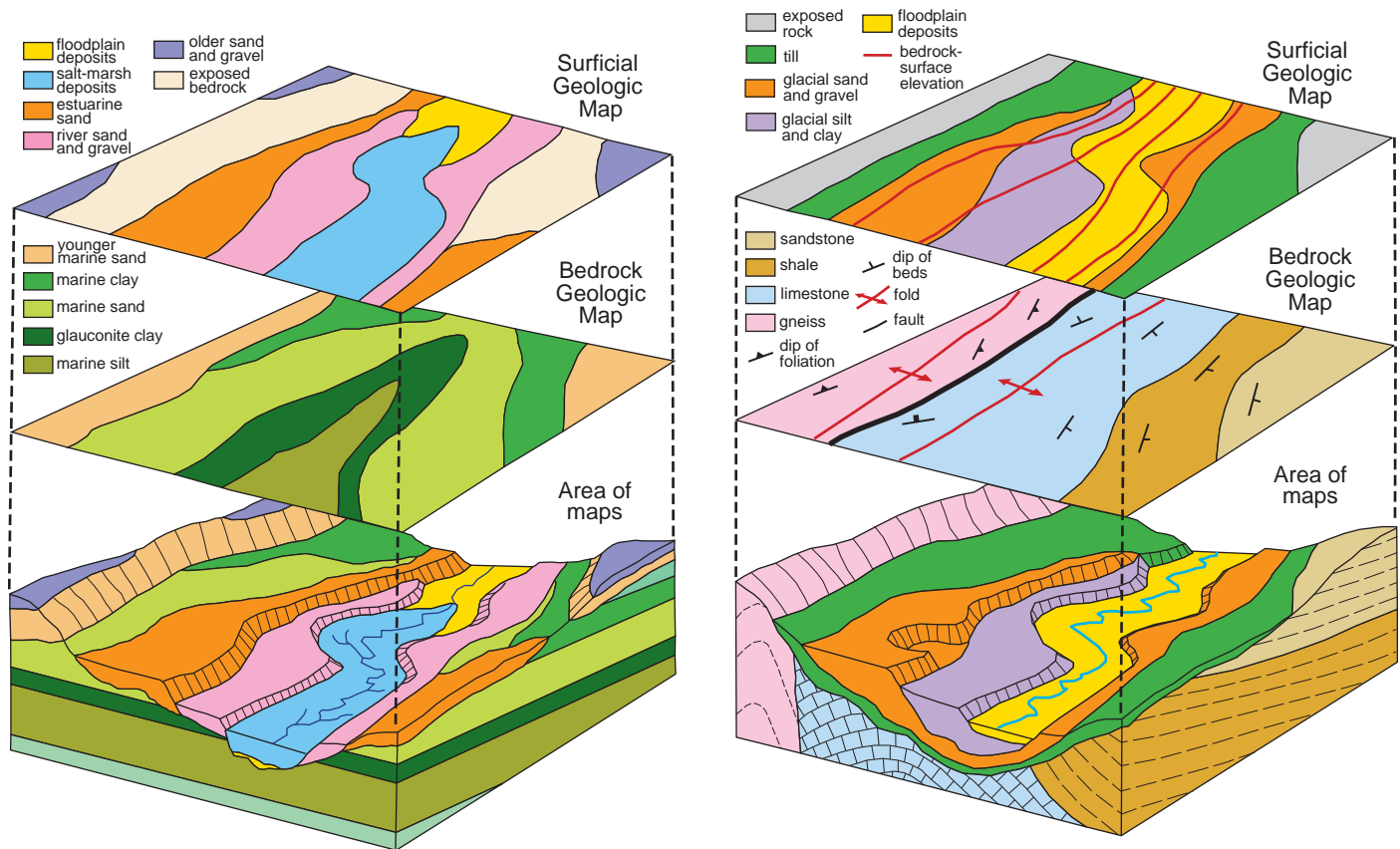


Figure 2. Block diagrams illustrating bedrock and surficial geologic maps in the Coastal Plain (*left*) and northern New Jersey (*right*).

What are Geologic Maps?

Formations are bodies of rock or sediment with distinctive properties that extend over areas large enough to be shown on a map. New Jersey's long and complex geologic history has produced about 200 different bedrock, Coastal Plain, and surficial formations. Geologic maps display the three-dimensional geometric relationships of these formations (fig. 2). Measurements and observations of outcrops and exposures are combined with data from wells, test borings, and geophysical surveys to produce the maps. Cross sections (fig. 3) show the subsurface arrangement of the formations. Geologic maps show several types of information essential to understanding the physical properties, composition, and geometry of rocks and sediments. The boundaries between formations are known as contacts. Contacts on geologic maps are shown as lines; different line styles show the type and location accuracy of the contacts. In sedimentary formations, the deposited layers, which are generally flat when

laid down, are known as beds. Tectonic deformation may tilt, fold, or break beds. Symbols on geologic maps show the direction and angle of tilt (known as dip) of deformed beds and the location of folds and faults. Layering also occurs in igneous and metamorphic rocks, formed by physical and chemical processes that act under high temperature and pressure. These layers, known as foliation, may also be folded and faulted. The direction and angle of dip of foliation, like that of bedding, is also shown by symbols on maps. Rocks also contain fractures that formed during the Earth's crustal movements when rocks were squeezed or pulled apart. Like bedding and foliation, the direction and dip of fractures is displayed on the maps. Where surficial deposits are thick and cover the rock, elevation contours may be used to show the top-of-rock surface, as determined from wells, test borings, and geophysical surveys. The mineral composition and physical properties of the formations are detailed in map-unit descriptions. The age of the formations, which is determined from the fossils they contain, or

from radioactive decay of the minerals or organic remains they contain, and the age of periods of erosion when no rocks or sediments were formed, are also shown on the maps through the use of stratigraphic columns and correlation charts.

The Uses of Geologic Maps

Each of the formations in New Jersey has distinctive physical properties and mineral composition. These properties define the extent and productivity of aquifers and the quality of the water they yield. They also control how groundwater enters and moves through aquifers, how contaminants seep into and move through soil and groundwater; where hazards like radon, sinkholes, landslides, and soil instability may occur, and where resources such as sand, gravel, peat, clay, quarry rock, and mineral ores are located. These properties also determine soil fertility, the suitability of an area for the use of septic systems, the management of stormwater and surface-water runoff, and the stability of foundations for

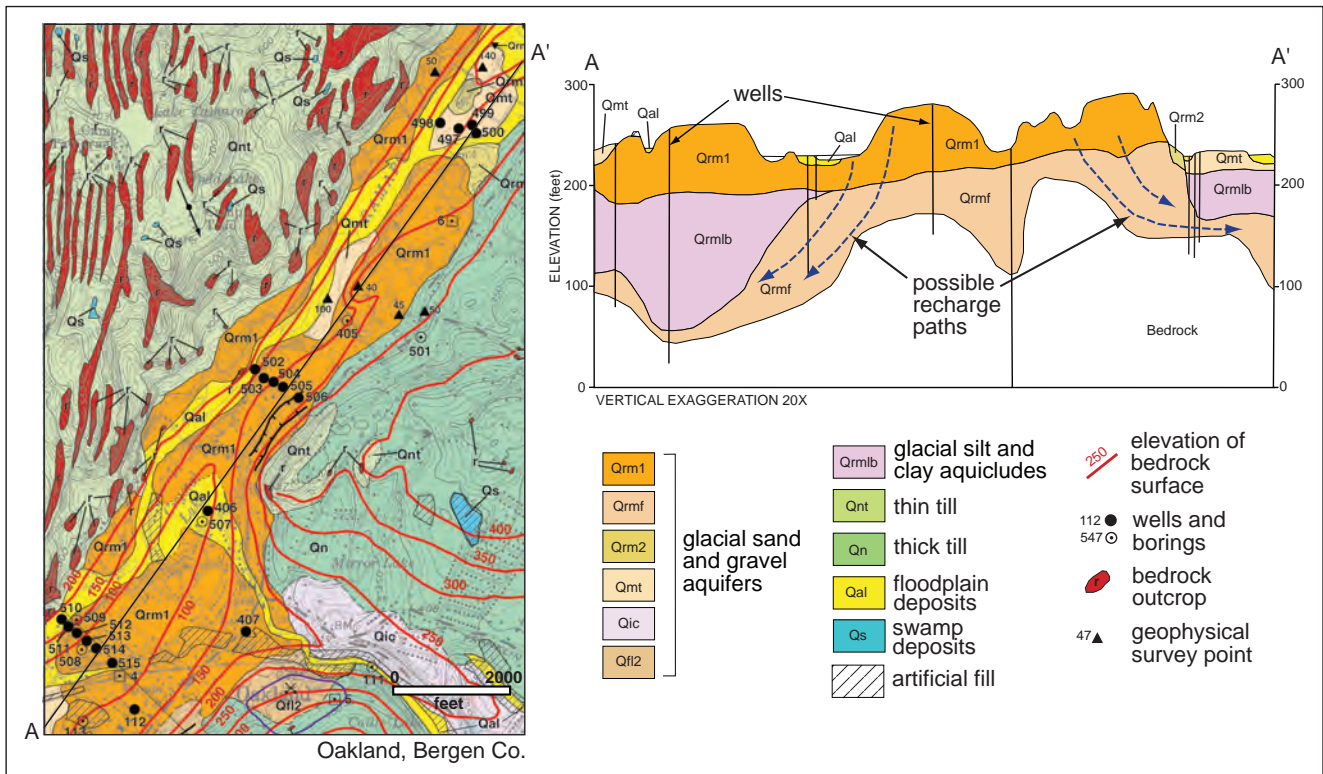


Figure 3. Map and cross section of a glacial valley-fill aquifer in the Ramapo River valley. From N. J. Geological Survey Open File Map OFM 62.

buildings, bridges, tunnels, and other structures. As archives of earth history, formations are valuable as indicators of past landscapes and environments, and so provide information for paleoecologists, paleontologists, archeologists, and others interested in their natural surroundings.

In New Jersey, geologic maps are used to manage water resources, identify and mitigate natural hazards, design structures and public-works projects, understand ecologic and archeologic sites, and locate mineral resources. Groundwater-resource management is particularly important in New Jersey. Groundwater supplies 40 percent of the drinking water in the state. The aquifers that supply this water are permeable formations that contain water in pore spaces in sand and gravel or in fractures and other voids in rock. They are replenished by water from the surface that enters the aquifers either directly where they crop out, or by flow through pore spaces and fractures in bordering formations. Pollutants that contaminate aquifers also follow these paths. Clay and dense, unfractured rock contain

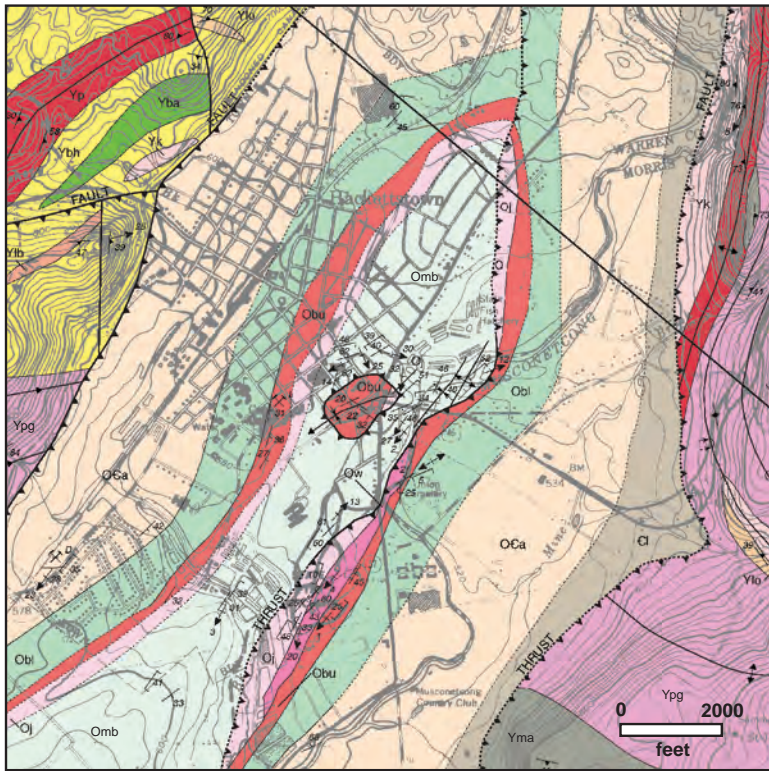
little water and impede groundwater flow. These formations are known as aquitards. The geometry and permeability of aquifers and aquitards (fig. 3) determine the rates and pathways of recharge and the vulnerability of an aquifer to contamination. Knowing the geologic framework through which groundwater moves is essential for aquifer protection.

Geologic hazards in New Jersey include sinkholes, radioactive radon gas generated from uranium-bearing minerals, arsenic and other toxic elements and minerals, landslides, and earthquakes. Sinkholes form when limestone, which crops out in belts in valleys in northwestern New Jersey, is dissolved by groundwater to form underground cavities that enlarge with time. When they reach the surface they may collapse to form sinkholes, which damage structures and roads (fig. 4). Limestone occurs in 19 formations that differ in solubility and sinkhole development. Geologic maps show the distribution of these formations. Several municipalities in the limestone belt have used the maps to draft building

ordinances.

Elevated concentrations of uranium-bearing minerals occur in some granites, limestones, and shales in northern New Jersey and in glauconite clays (particularly at certain contacts) in the Coastal Plain sediments of southern New Jersey. Geologic maps show these formations and contacts, providing a guide to potential radon hazards in residences. Arsenic and other toxic elements occur naturally in minerals in some formations in both northern and southern New Jersey, and they are also released from atmospheric deposition, industrial disposal, and pesticide application. Elevated concentrations of these elements in soil or groundwater may require remediation and identifying the pollutant's geologic source is essential for an effective remedy.

Damaging earthquakes, although rare in New Jersey, are a potential hazard. The damage resulting from an earthquake is caused by ground shaking, and the amount and type of shaking depends on the thickness, layering, compaction, and water content of



Hackettstown area, Warren and Morris Counties.



Phillipsburg, Warren County. Photo courtesy of Rick Rader.

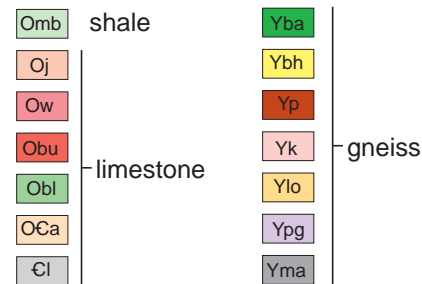


Figure 4. Map of limestone formations in the Musconetcong River valley, from N. J. Geological Survey Geologic Map Series GMS 94-1 (left) and sinkhole damage in Phillipsburg (right).

surficial deposits and bedrock. More shaking and damage occur on soft, thick, saturated sediments than on hard bedrock. Data from mapping are used to classify sediments and bedrock into seismic vulnerability categories. These categories are then entered into earthquake-simulation software to predict damage, plan emergency response, and identify areas where structures should be strengthened.

Although New Jersey is not thought of as mountainous, more than 200 landslides have been recorded in the state since colonial times. The susceptibility of a hillslope to landsliding, and the type of landslide that might occur, depend on the steepness of the slope and the surficial deposits, bedrock, and Coastal Plain formations beneath. Steep slopes in clay are more likely to slump and slide than steep slopes in hard stable rock like granite and quartzite. Vulnerable slopes can be identified using geologic maps in combination with topographic data.

Large engineering and public-works projects like bridges, tunnels,

dams, pipelines, ship-channel dredging, flood-control structures, and beach replenishment, require information on the strength, thickness, layering, and depth of surficial material and bedrock; and the location and quality of fill materials, in order to design foundations and select appropriate excavation and tunneling techniques. A public works project of particular importance in New Jersey is beach replenishment. Coastal tourism generates about \$16 billion annually in the state and it depends on attractive beaches. Narrow, eroding beaches must be artificially replenished using sand from offshore sources. Mapping by means of ship-borne geophysical surveying and core sampling identifies sand of the right grain size, depth, volume, and distance from shore, for replenishment.

Sediments and rocks are also integral parts of our natural world. By influencing soil properties, hydrologic conditions, and landforms, formations provide the foundation of ecosystems. For example, rare plant communities grow on certain types of bedrock contain-

ing minerals that weather to produce unusually acidic or alkaline soil conditions. Only specialized plants can tolerate such conditions. Small, ephemeral ponds in the Coastal Plain are another example. These ponds occupy shallow basins created when permafrost in stream-terrace deposits melted following periods of cold climate. Today these basins form seasonal ponds that, because they are not stream-fed and dry up in the summer, are habitats for rare plants and amphibians. Insuring that this hydrology is not disturbed by new groundwater withdrawals or surface-water diversion requires knowledge of the distribution of the river deposits and underlying clay and sand beds.

Mapping Needs and Goals

New Jersey, with nearly 1,200 people per square mile, is among the most densely populated places on earth. It has a long history of industry and waste disposal, with more than 14,000 known sites of soil or groundwater contamination. It depends on groundwater from more than 2,500 public-

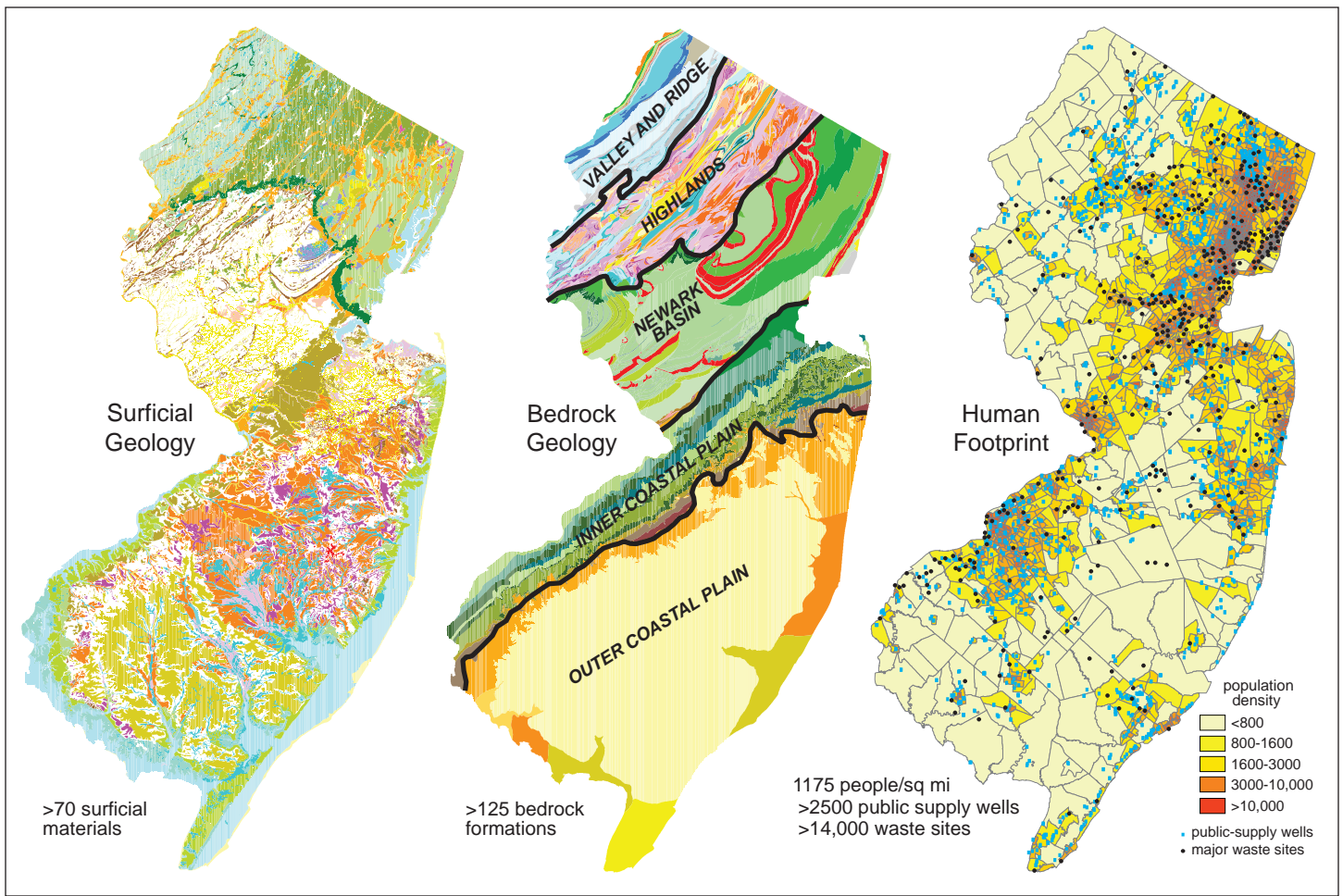




Figure 5. In New Jersey, a heavy human footprint (*right*) rests on a complex foundation of bedrock (*center*) and surficial (*left*) formations.

supply wells and tens of thousands of individual household wells. This heavy human footprint rests on a geologic foundation of more than 125 bedrock formations and more than 70 types of surficial material (fig. 5). For these reasons, New Jersey needs detailed bedrock and surficial geologic maps of the entire state if we are going to have the information we need to manage earth resources wisely.

The New Jersey Geological and Water Survey is filling this need by mapping geology on U.S. Geological Survey topographic base maps, known as 7.5 minute quadrangles, at a scale of 1:24,000, where 1 inch on the map represents 2,000 feet on the ground. This level of detail is sufficient to provide information usable at site or parcel scale. These maps cover rectangular areas about 8.6 miles in a north-south direction and 6.7 miles in an east-west direction. The entire state is covered by

a grid of 172 quadrangles. For a typical quadrangle, the geologist identifies and measures formations at 500 to 1,000 field stations, including natural outcrops, excavations, road and railroad cuts, pits, streambanks, and, in the case of surficial deposits and Coastal Plain formations, hand-augered holes. Sub-surface information is collected from records of several hundred wells and test borings. Stereo aerial photographs and digital topographic imagery are used to map landforms and vegetation patterns that aid in recognizing formations, contacts, and structures like folds and faults. The data are then compiled, converted to digital form, reviewed and edited, and published free of charge on the NJGWS website (<http://www.njgeology.org/pricelst/geolmapquad.htm>). The maps are available as viewable/printable graphics and as digital files for use with geographic software. Printed maps are also available for a small fee.

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2013

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