Graphite Deposits in the New Jersey Highlands

What is Graphite?

Graphite is a dark gray to black, soft mineral with a metallic luster that occurs most often as flakes due to the sheet-like arrangement of the atoms in its structure. Because graphite is composed almost entirely of crystalline carbon, it is also a native element. Graphite derives its name from the Greek word graphien which means to write. It is also referred to erroneously as plumbago, meaning leadlike, and black lead, both of which are misleading names because graphite is a nonmetal and does not contain lead.

The earliest known use of graphite was by primitive man to draw on cave walls. Later, Egyptians decorated pottery using it, and about 1400 AD in Bavaria, it was used to fashion crucibles. Because graphite is a good conductor of heat and electricity, today it is used as a source of carbon in steelmaking, for high-quality crucibles and refractory ware, carbon brushes in electric motors, and in foundary facings. It is also used in dry-cell batteries, as a lubricant, an additive in paint, and for pencils. More recently it has replaced asbestos in the manufacture of brake pads, and is used in the aerospace, nuclear power and sporting goods industries and as a component in military technology.

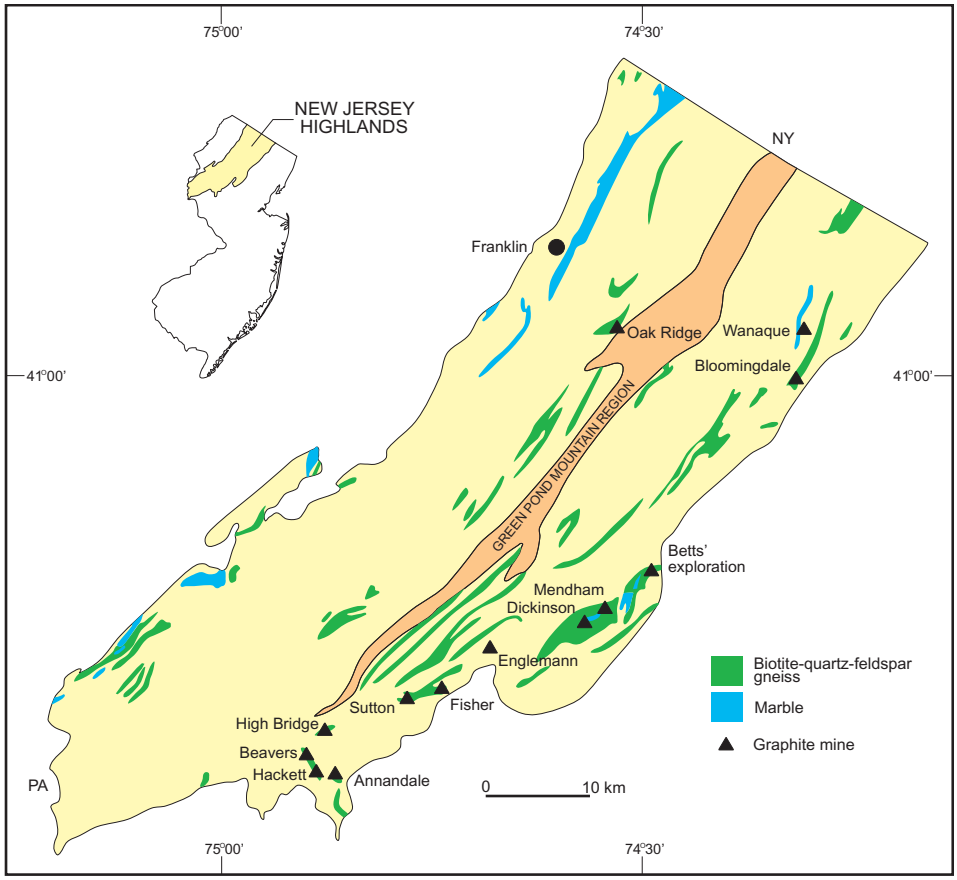

Figure 2. Simplified gelogic map of the Highlands showing the locations of graphite mines and the Precambrian rocks that host the graphite.

Graphite Mining in New Jersey

New Jersey has a long and interesting mining history that dates back to Colonial times when Dutch settlers first began mining iron and copper ore. The comparatively small and short-lived industry devoted to the exploration of graphite ore is often overlooked, or perhaps unknown to most except for a few surviving reminders (fig. 1). From about 1848 until 1931, various attempts were made to commercially mine graphite at 14 locations in the New Jersey Highlands (fig. 2). Most of the mines, especially the smaller ones, encountered financial problems soon after opening and either closed or changed ownership. Problems included an inefficient and uneconomical method of separating graphite ore from the host rock, as well as competition from much larger mines in Ceylon (now Sri Lanka) and locally the Adirondack Mountains in New York. The reliance of consumers on less costly imported graphite, and the development of synthetic graphite manufactured from coal in electric furnaces, or as a by-product of blast furnaces, marked the end of graphite exploration and mining in New Jersey.

Figure 1. Vestige of a bygone era, a street sign in Bloomingdale Township, Morris County, points the way to Lead Mine Hill and the Bloomingdale mine.

During the peak of mining activity, four separate mills were in operation to process the ore. These were located at the Bloomingdale Mine in Passaic County, Dickinson Mine in Morris County, and the Annandale and High Bridge Mines in Hunterdon County. At the time, most mills were separating the ore from its host rock by using a "dry" process in which the ore was crushed under stamps and washed through sieves. The graphite was then separated on five different dressing tables into various grades. This technique permitted only 34 percent of the ore to be separated after the first run, often requiring two or sometimes three additional runs. The mill at Annandale (fig. 3) was modified about 1928 to utilize a new, more efficient, "wet" process to separate the graphite that involved wet grinding of the ore followed by separation in flotation cells. This technique reportedly enabled 98 percent of the ore to be recovered on the first run. Unfortunately, it developed too late to revive the struggling graphite industry in New Jersey.

Figure 3. Mill of the Annandale Graphite Corporation in Clinton Township, Hunterdon County. Nothing remains of the original building. Photograph from New Jersey Geological Survey archives taken in 1928 by M.E. Johnson.

The Annandale Mine, the last operating graphite mine in the State, ceased operation about 1931.

Graphite in the Highlands

New Jersey graphite deposits and the rocks that host them in the Highlands are Precambrian in age. They are among the oldest rocks in the State and are about 1.2 billion years old. These rocks were metamorphosed deep within the Earth's crust about 1 billion years ago under conditions of high temperature (about 700° C, or 1300° F) and pressure (about 5 kilobars, or 73,500 pounds/square inch). The graphite deposits are exposed at the surface today because of geologic events over the past 1 billion years that included uplift and then erosion of the overlying rocks.

Graphite in New Jersey is neither widespread, nor random in its occurrence. It is found in the Highlands, primarily in the eastern part of the region (fig. 2). Most of the deposits occur along a similar trend that stretches north from High Bridge to Wanaque.

The Bloomingdale and Annandale Mines were unquestionably the two largest. Total production figures for these mines are unavailable, because mine operators were reluctant to report vital information that could be used by competitors. However, historic annual reports of the New Jersey Geological Survey indicate that between 1882 and 1883 the Bloomingdale Mine produced 300 tons of ore, and in 1928 the Annandale Mine produced 45 tons of ore.

The size of the graphite deposits varied from mine to mine. Widths of ore zones ranged from 4 feet to 50 feet and lengths ranged from a few hundred feet to as much as several miles. Graphite in the ore zones was concentrated in layers and occurs as flakes a few tenths of an inch, but occasionally as much as 1 inch in diameter (fig. 4). Graphite concentrations in the layers comprise anywhere from 6 percent to as much as 40 percent of the rock. The ore zone layers are parallel to the rock layers that host the deposits. Underground workings at all of the mines were relatively shallow and even the deepest shaft, that occurred at the Bloomingdale Mine, extended no further than 60 feet below the ground. Workings at some of the smaller mines consisted of prospect pits and trenches excavated at the surface.

Origin of the Graphite Deposits

Geologic investigations often resemble "detective" work because they involve the careful assembly and examination of information and the reconstruction of an event from the accumulated scientific data. To solve a complex problem such as interpreting the origin of New Jersey's graphite deposits, geologists rely on historical descriptions of the mines, detailed geologic mapping, and laboratory examination of the ore samples and host rocks using microscopic, geochemical, and isotopic analysis.

Rocks that host the graphite deposits reveal valuable information about the environment in which they originated. This information is especially significant if the graphite deposits and their host rocks were formed at roughly the same time. Prior to being metamorphosed into gneiss (pronounced "nice"), and quartzite, the host rocks were originally deposited as sand and mud along an ancient ocean margin adjacent to what would later become eastern North America. The carbon (now graphite) in these rocks could be biogenic, that is, it might derive from organic matter, the biologic remains of once-living organisms. Other possible origins of this carbon include magmatic fluids, volcanic gases, metamorphic fluids, or the breakdown of carbonate minerals in limestone.

Figure 4. Thin, graphite-rich layers (dark gray and black) enclosed within gneiss (tan) at the Bloomingdale graphite mine. Hammer for scale is eleven inches long.

Stable isotopes of carbon are particularly useful in identifying the carbon source because each preserves its own distinct isotopic signature from the time of formation, providing clues as to the origin of the carbon. Graphite from the New Jersey mines has carbon isotope ratios that are enriched in ^{12}C relative to ^{13}C. Since biologically-derived carbon preferentially concentrates the "lighter" isotope ^{12}C, the data provide compelling evidence that the graphite is what remains of ancient living organisms.

A billion years ago land plants had not yet developed. Thus the ocean would have been the source of this biogenic carbon. Given the depositional environment of the host rocks, the most likely source for this organic matter was algae. Geological evidence suggests the algae collected in some of the sediments in this ancient ocean environment and were then preserved through rapid burial of the sediments and (or) stagnation and fouling of the water due to the absence of oxygen. The algae was later converted into graphite upon being metamorphosed at high temperature along with the rocks that now host the deposits. Perhaps the essence of the New Jersey graphite deposits is best expressed in the words of the English poet Lord Byron: "The dust we tread upon was once alive."

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