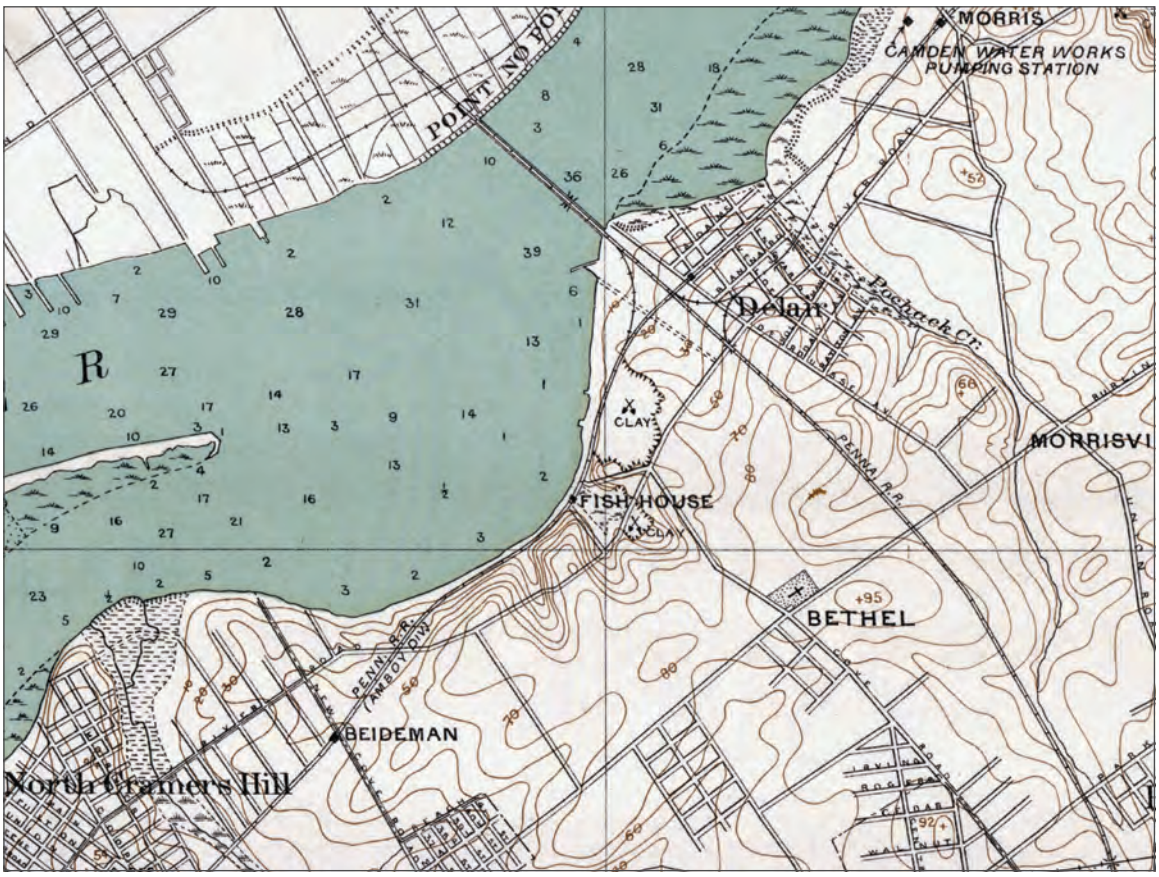
New Jersey Geological and Water Survey
Open-File Report 20-1

The Geology, History, and Industry of the Fish House Clay of Camden County



New Jersey Department of Environmental Protection

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

NJDEP's core mission is and will continue to be the protection of the air, waters, land and natural and historic resources of the State to ensure continued public benefit. The Department's mission is advanced through effective and balanced implementation and enforcement of environmental laws to protect these resources and the health and safety of our residents.

At the same time, it is crucial to understand how actions of this agency can impact the State's economic growth, to recognize the interconnection of the health of New Jersey's environment and its economy, and to appreciate that environmental stewardship and positive economic growth are not mutually exclusive goals: we will continue to protect the environment while playing a key role in positively impacting the economic growth of the state.

NEW JERSEY GEOLOGICAL AND WATER SURVEY

The mission of the New Jersey Geological and Water Survey is to map, research, interpret and provide scientific information regarding the state's geology and groundwater resources. This information supports the regulatory and planning functions of DEP and other governmental agencies and provides the business community and public with information necessary to address environmental concerns and make economic decisions.

For more information, contact:
New Jersey Department of Environmental Protection
New Jersey Geological and Water Survey
P.O. Box 420, Mail Code 29-01
Trenton, NJ 08625-0420
(609) 292-1185
www.njgeology.org

Cover photo: Detail from *Camden Sheet,* C.C. Vermeule, Geological Survey of New Jersey, 1899.

New Jersey Geological and Water Survey Reports (ISSN 0741-7357) are published by the New Jersey Geological and Water Survey, P.O. Box 420, Mail Code 29-01, Trenton, NJ 08625-0420.

More information on NJGWS reports is available on the Survey's website: www.njgeology.org

New Jersey Geological and Water Survey
Open-File Report 20-1

The Geology History, and Industry of the Fish House Clay of Camden County

by

Corinne Kosar

New Jersey Department of Environmental Protection
New Jersey Geological and Water Survey
P.O. Box 420, Mail Code 29-01
Trenton, NJ 08625

2020

CONTENTS

FIGURES

THE GEOLOGY, HISTORY, AND INDUSTRY OF THE FISH HOUSE CLAY OF CAMDEN COUNTY

Introduction

New Jersey has been the source of geologic materials valuable to humans for millennia. Examples of early human use of geology include rock shelters and caves for living and protection, lithics for tools and weapons, and clay for pottery. European explorers and settlers of the 17th and 18th centuries also used geologic resources. Clay, specifically, was used for building materials, bricks, earthen wares, and industrial and agricultural applications. Both indigenous and European peoples were limited to human or animal power to mine clay, but the Industrial Revolution of the 19th century changed their processes. More clay was extracted by industrial machinery than could ever be removed by hand. The speed of processing, availability of materials, creation of goods, and consumption of products increased. In turn, more clay needed to be located and mined to fill the increased demand.

A significant deposit along the Delaware River – the Fish House Clay – had been known to settlers since the 1700s. The clay was so heavily mined from the mid-1800s into the 20th century that mere traces of it remain. The deposit would have been almost lost to history if not for the attention it received in the late 1800s by the Geological Survey of New Jersey. Photographs, paleontological studies, clay and soil reports, and geological maps were produced at the time of the mining, spurred partly by the push to discover additional sources of materials for industrial use. The understanding of New Jersey geology also advanced greatly in this period because of the investigations of geologists and paleontologists.

The Fish House Clay was a 400,000-year-old geologic record that was discovered, exploited, and permanently altered. Its history illustrates how New Jersey geological research advanced, how industry flourished, and how voraciously humans consumed and sometimes obliterated natural resources. It also reveals how important interdisciplinary approaches were and still are to geology, and how vital it is to be mindful of the past.

Fish House History and the Brickmaking Industry

In the 18th and early 19th centuries, the region that is Camden County today was an agricultural center. Local settlements were reliant on Delaware River ports to bring in and send out goods, as was much of pre-industrial New Jersey (Hughes and Seneca, 2014). George Reeser Prowell (1886), a 19th century gentleman who was interested in local histories, wrote about the Camden area and a cove east of Petty's Island in the Delaware River that was known as the Pea Shore, wherefrom a large quantity of spring vegetables produced in the area were shipped. Either from the vegetable production or the pea gravel that is found on the banks of the Delaware River in the area came the early name "Pea Shore". Over time, fishing became the major industry in the area and the first formal fishing business

Figure 1. *Tamany Fish House, on the Pea Shore, River Delaware*, image modified by author, from Scott, circa 1852).

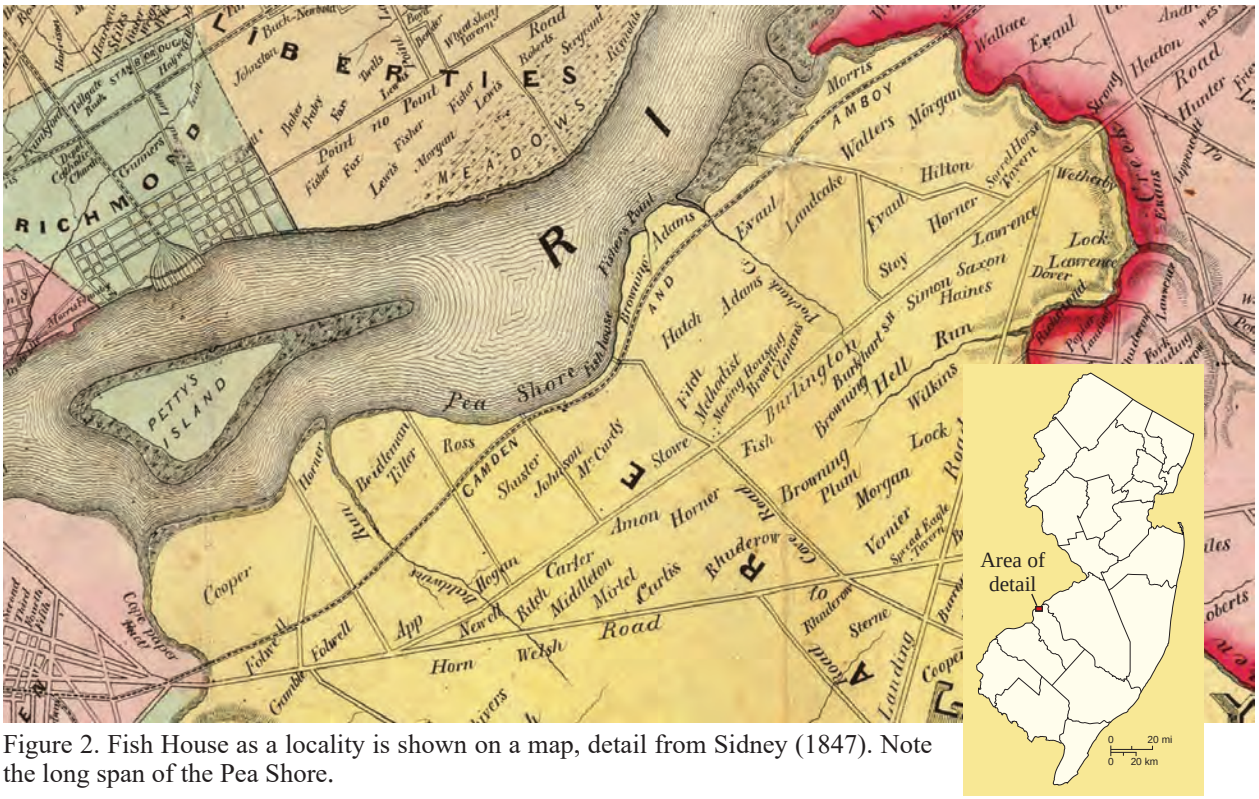


Figure 2. Fish House as a locality is shown on a map, detail from Sidney (1847). Note the long span of the Pea Shore.

was established in 1790 around Coopers Creek (now Cooper River). Even with the presence of fishing companies, the pastoral setting was desirable and recreational clubhouses (fig. 1) sprung up along the water. The clubs drew so many members and tourists from Philadelphia that it quickly became a destination but with no formal name. Early 19th century companies and clubs – such as Fish House Company and Tamany* Fish House – may have provided the generalized name for this popular area (Prowell, 1886). Fish House, as a locality, was on the map by 1843 (fig. 2).

Pockets and layers of desirable clay were known along the Delaware River from colonial times (Newell and others, 2000, p. 8), and the discovery of such pockets approximately four miles northeast of old Camden City slowly changed Fish House from an agrarian and fishing community to a brick and terra cotta manufacturing site. The Delaware River provided convenient and ample water and waterpower for clay processing and brickmaking. Prowell (1886) noted some of the clay products fabricated in the Camden region; red and salmon brick for building and paving and terra cotta for waste and drainage pipes, chimney components, and a wide variety of utilitarian earthenware items. George H. Cook (1878), State Geologist of New Jersey from 1863 to 1889, wrote that white clay was used for fire bricks and retort furnaces intended for gas and zinc industries; but a special, dark clay that occurred at Fish House (and was otherwise found only at Woodbridge, Middlesex County) had a high refractory quality suitable for high temperature pieces such as chimney flues, fire-place bricks (fire-brick), and other building materials (fig. 3) (Cook, 1878, 311-313, 314). Domestic dwellings still relied on fireplaces, stoves, and early furnaces to heat interior spaces; businesses and utilities using furnaces needed the heat-resistant bricks. The special clays found at Fish House had a steady and demanding market.

Fish House Clay, like other clays, was first obtained by probing with a simple hand auger to locate a pocket. Then it was "surface-

*Also spelled Tammany

Figure 3. An 1883-1884 Camden City Directory advertisement for products manufactured by the Pea Shore Brick and Terra-Cotta Works (Cohen, 2018).

worked" or dug from open pits or exposed cuts, a common and easy way to mine. Overlying layers of undesirable soils, known as stripping or bearing, were removed and placed aside until they were needed for backfilling pits that were exhausted of clay. A pick and shovel, manual labor, and literal horse power was all that was required in the early days of the clay industry (fig. 4) (Ries and Kümmel, 1904). While it was easy to remove soft clays exposed at the river bank, clay further into the bank would have been much more difficult and expensive to extract and process by hand. Some Fish House brick works owners, like Joseph Matlack[†] and his business partner, Joseph Wharton, ultimately closed their works down, partly because of the economics; Matlack left the industry completely for other trending industrial enterprises (Swarthmore College, 1971). Prowell (1886) wrote that the property was purchased by entrepreneur Augustus Reeve in 1866 and that his forty-five-acre brick and terra cotta business – the Pea Shore Brick and Terra Cotta Works – was producing tens of thousands of bricks per day. Such production lasted into the first years of the 20th century (Cohen, 2018).

Unfortunately, shortly after the start of the 20th century, the riverside clay beds of Augustus Reeve's Pea Shore Brick and Terra Cotta Works were exhausted and continuing to do business was not profitable. While the clay had been running out for Reeve, sediment in the Delaware River had been building up rapidly through the late 1800s. This made shipment by water difficult and expensive not just for Reeve but for many other local businesses; thus, the brickyard was closed, and the plant buildings gone by circa 1900 (U.S. House of Representatives, 1916). Luckily, Augustus Reeve had opened a second, smaller, inland brick works to the east at Maple Shade in 1890 (Weaver, 2018) where additional black clay like that at Fish House was located (Ries and Kümmel, 1904). This kept Reeve in the clay business for a few more years.

Fairview Brick Works was another Fish House clay producer that also experienced great success but also hard times. According to Prowell (1886), the Hatch family, had leased land containing clay to brickmakers for years. They entered the clay industry in 1869 as partners of Stone, Hatch & Co by purchasing an existing brick works on their property and establishing Fairview Brick Works. Two years later, brothers Hugh and Joseph Hatch bought out the works – which abutted Reeve's lot to the northeast -- and produced millions of bricks per year. The property suffered multiple devastating fires over the years but was rebuilt each time

Figure 4. General view of Hatch & Son's clay pit, at Fish House (Ries and Kümmel, 1904, Plate XLII).

[†] "Matlock" is an alternate historical spelling.

Figure 5. Topographical change in the Fish House area. The magenta line indicates an earlier extent of engineered land according to an 1895 map of the vicinity (overlay) (Woolman, 1897, Plate XI). The Reeve (orange) and Hatch (yellow) brickworks were waterside. The clay pits (green outline) were east of the rail lines. Additional areas with white clay (blue lines) were noted south of the works. The land mass left of the magenta line was not created until circa 1931. (2015 satellite imagery: NJDEP).

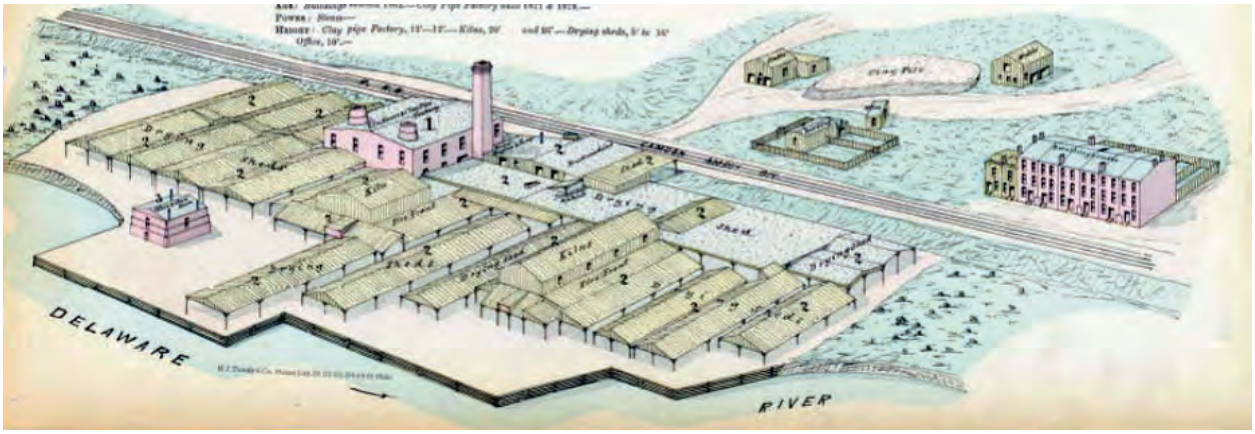


Figure 6. Drawing of the Pea Shore Brick & Terra Cotta Works. detail from Hexamer (1878).

(Prowell, 1886; Clay Record, 1907). Fairview thrived into the mid-1920s, producing around 5 million bricks annually, but was listed as "idle" in the 1930s and was finally out of business in 1940 (New Jersey Geological and Water Survey files).

The unique pocket of clay at Fish House had provided an essential resource for over half a century for two large clay producers, but it could not last indefinitely. Ironically, while the clay had been running out, sediment in the Delaware River had been building up through the late 1800s, which made shipment by water for Reeve, Hatch, and many other local businesses both difficult and expensive (U.S. House of Representatives, 1916). Reeve's buildings were long gone and the Hatch site was closed by 1931, when the shoreline was engineered into its present form with dredge spoils (fig. 5) (Historic Aerials, 2019).

Fish House was noted for its contribution to the overall prosperity of Camden City, which once competed with larger cities like Paterson and Trenton (1868). Camden once had its own slogan: "On Camden Supplies, the World Relies" (Hughes and Seneca, 2014). Prowell (1886) remarked how employment had been strengthened and how important the Camden & Amboy Railroad was to the brickmakers' success: Hatch and Reeve each needed at least a few score of men during times of high production; clay products were shipped from the works' own wharfs on the Delaware River, which gave the makers a strong presence in the local market. Also, railroads conveniently ran behind both brickyards, and the rail system – which was regularly improved and expanded – transported Fish House clay goods throughout

the region and afar (fig. 6).

Fish House slowly became extinct overall during the first half of the 20th century. In the 1950s, the petroleum industry began encroaching upon the old clay pit areas. The clay, clay works, fish houses, and clubhouses had disappeared, although Fish House as a locality remained on the map into the 1960s (Historic Aerials, 2019). Today, vacant lots and road construction material industries sit atop the land (Google Maps, 2018). "Fish House" is now a relatively obscure name, a relic of another time, place, and way of life.

Fish House Clay Fossils and Early Geology

The Fish House Clay is in the Coastal Plain physiographic province and is a remnant from a fluvial-estuarine environment much like that along the lower Delaware River today (Stanford, written commun., 2018). Owens and Minard (1979) and Bogan and others (1989) surmised that the paleoenvironment included oak-hickory upland forests and freshwater tidal meadows; a century before, Lewis Woolman (1897) found that the animal and plant life included vertebrates, mollusks, deciduous trees, and other plants. In the few million years before the Fish House sediments were deposited, New Jersey rivers experienced a major reorganization that reshaped the land and environment. About 10 million years ago, rivers that ran south-southeast through the northern part of New Jersey began shifting and, around 5 million years ago, became a southwesterly flowing river. These ancient rivers brought sediment from Pennsylvania and northwestern New Jersey, the Hudson River valley, southern New England, and northeastern New Jersey down to the Camden region and beyond to form the Pensauken± Plain (fig. 7) (Owens and Minard, 1997; Stanford, 2005). Downcutting of the river into older, preexisting marine sediments

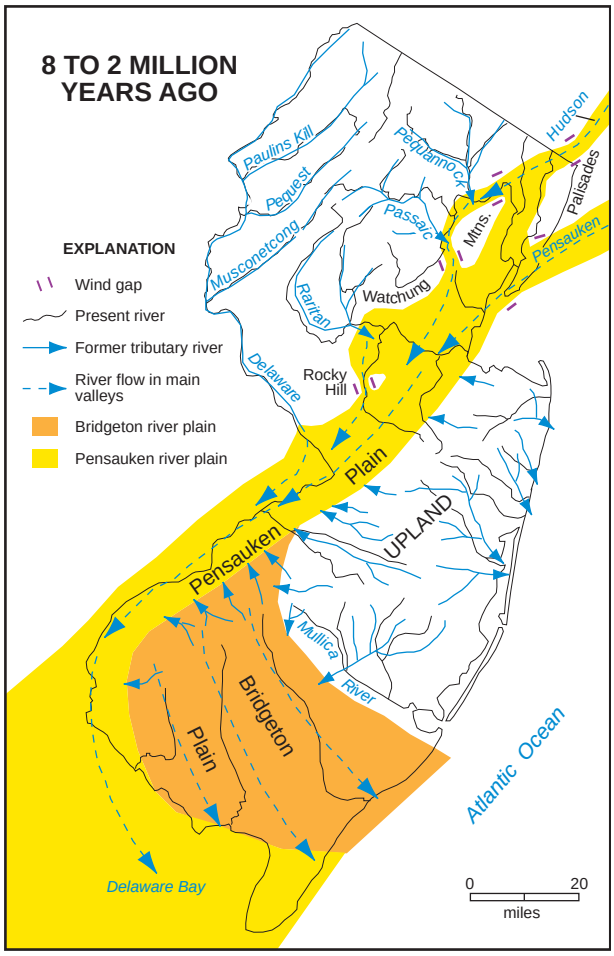


Figure 7. The path of the river system and sediments that created the Pensauken Plain and formed the Fish House geology (Stanford, 2005).

resulted in the deposition of new sediments against the old. Stanford (2005) suggests that, within the past 2 million years, the Delaware River – a smaller successor to the Pensauken River – deepened its valley by cutting into the Pensauken Plain. The downcutting and deposition events resulted in unconformities: old and new sediments resting adjacent to each other, a physical gap in the geologic record.

As sea level fluctuated with the growing and melting continental glaciers in the past two million years, more sediment was removed as well as laid down. Twice, sea level rose higher than at present, submerging the lower Delaware valley and forming an estuary. Lacovara (1997) showed that geomorphic features in shore sediments and infilled channels of the Delaware River reveal periods of sea level rise and high

± "Pensauken" has had various historical spellings including Pennsauken, Pensaukin, and Penshawken. "Pensauken" is used on area maps of the mid-to-late 19th century; the contemporary geologists retained the spelling.

stands. Current thought is that the Fish House Clay was deposited during the earlier high stand about 400,000 years ago. In the early 1800s, this information was unknown to scientists. Around mid-century, the New Jersey Geological Survey was tasked with subsurface investigation and surface mapping to provide information on resources for economic development (Cook, 1868, p. vii-xvi). The Fish House Clay proved to be an intriguing resource, but difficult to understand. Geologists and paleontologists – including Edward Drinker Cope, Isaac Lea, Robert P. Whitfield, Lewis Woolman, Henry A. Pilsbry, and Rollin D. Salisbury – worked in conjunction to explore, describe, classify, and explain the complicated history and placement of the clay. Geologists found that the economically viable clay was limited to localized pockets and varied from a few feet to a maximum of 17 feet in thickness (Jenkins, 1898). Dating of the clay remained problematic for over a century.

Much added attention was given to the clay because of vertebrate and invertebrate fossils near its base. The invertebrate fossils were found in somewhat poor condition (fig. 8). Those identified by Lea (1868) and later described by Whitfield (1886) were classified in the family *Unionidae* (river mussels) under genera *Unio* and *Anodonta* (Woolman, 1897). From those specimens plus others collected later by Cope, J. Carvill Lewis, and others, Lea (1868) described 10 new type species. By the 1880s, two more species had been identified by Whitfield (1886). Woolman (1897) noted that attempts were made to relate the fossils to modern mollusks and determine their paleoenvironment, but comparisons were limited to the physical characteristics of the shells and drew heavily upon species from modern rivers far to the north, west, and south of New Jersey. Both he and Pilsbry (1896), in subsequent agreement with Lea and Whitfield, believed that the mollusks had lived in a fluvial environment along an ancient Delaware River. However, some fossil mollusks were not represented at all among modern species (Woolman, 1897). This would

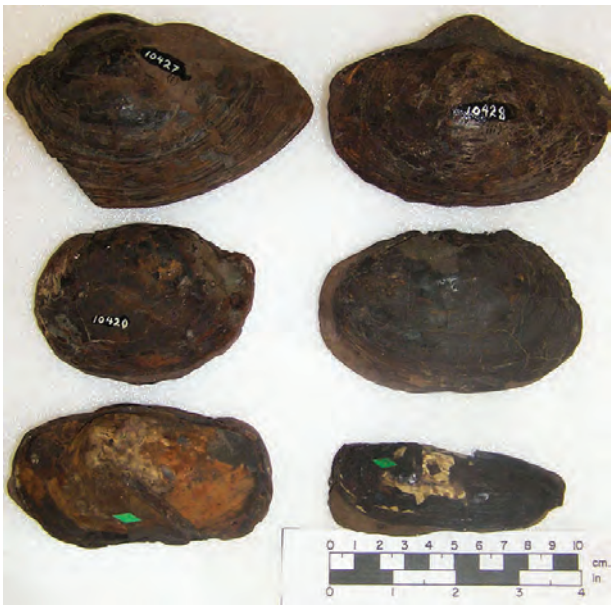


Figure 8. *Anodonta* and *Unio* bivalve fossils from the 1868 findings. New Jersey State Museum, Department of Natural History, Natural History Collection. *Photo by C. Kosar*.

be partly supported by 20th century research by Bogan and others (1989): when one modern species was found among the Fish House fossils, another that would be expected was not; and one of the *unionids* that was reexamined was deemed possibly a new extinct species, based on features that are distinct from the other observed specimens. All of this confusion, plus cataloguing errors and disagreements among scientists, would affect the study of the fossils for about a century.

Noting that there were no large differences between the fossils of the Fish House Clay and those of underlying and regional beds of late Cretaceous clays, scientists of the late 1860s and 1870s arrived at a Cretaceous age for the Fish House Clay. Pilsbry (1896) suggested the concept of a fluvial environment of shifting rivers alternately cutting channels and depositing sediment followed by abandonment of the environment by the rivers to explain the perplexing geology. Cope (1871) supported this information but changed his opinion in 1870 when, just east of Pea Shore, unconformities surrounding the Fish House Clay pockets showed that the Fish House material had been

deposited later than the Cretaceous material. A Pleistocene age for the clay was suggested when parts of an *Equus fraternus* skull and teeth from *Equus complicatus* (both species being early horses) were found just above the *Unio* fossils (Woolman, 1897).

The 1880s saw fervent geologic work across New Jersey and new understandings of the Fish House Clay. In an 1884 report, Cook (1884) stated that "no associated beds of clay or sand of known age have been found in contact" with the Fish House Clay; however, in the same year, white clay underlying the black Fish House Clay was reached by the clay miners. The white clay, also found at Woodbridge, was already known to be Cretaceous. This sparked more interest in the geology of the Fish House area.

Studies continued on the yellow gravel and sand in central and southern New Jersey. Salisbury (1894) named the gravel-sand layer the "Pensauken Formation" and recognized a fluvial origin and glacial era, but he still had difficulty explaining the various elevations at which it was found. Erosion, glacial events, land subsidence, and sea level changes were considered. Salisbury (1896) originally believed that uplift and subsequent erosion were responsible for the variation in elevation, but faulting was quickly rejected as an explanation as there was no evidence of fault offsets in the underlying Cretaceous beds. Erosion and deposition became favored as the cause for the formation, but the Pensauken still could not be determined as Pleistocene, Pliocene, or an in-between age (Salisbury, 1894). Where the Fish House Clay fit into geologic history was still unknown.

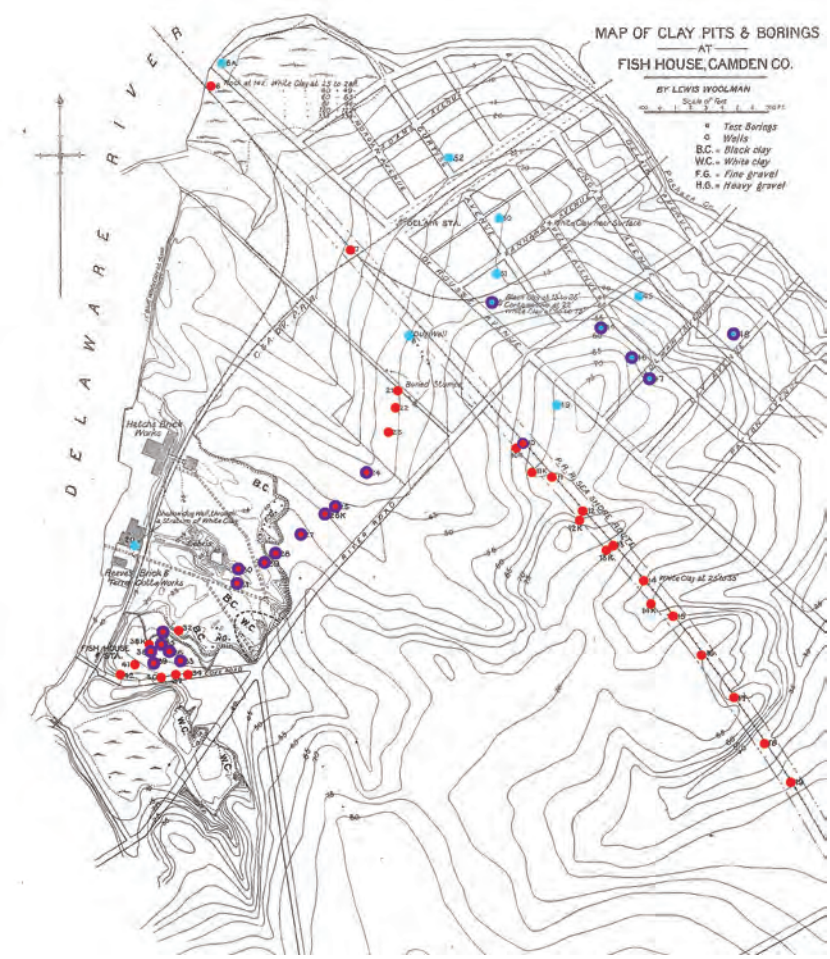


Figure 9. Borings and well locations at Fish House and vicinity. Colored symbols were added to the black and white image to indicate where borings (red dots) and wells (blue dots) were drilled. Locations where black clay was encountered are indicated by a purple ring around the red or blue dot (Woolman, 1897, Plate XI).

In 1896, Lewis Woolman (1897) of the New Jersey Geological Survey further investigated the Fish House Clay and made significant observations about the geology by using existing soil boring and well logs from the Fish House area including along the rail lines in the vicinity (fig. 9). Traces of the black clay were found in a patchy southwest-northeast trending line. The borings exemplified that very little black clay was found outside the pit areas and that the clay thinned out rapidly toward the limits of the pits. The clay was typically bounded by sands and gravels at the top and by an ironstone crust at its base that separated it from additional underlying

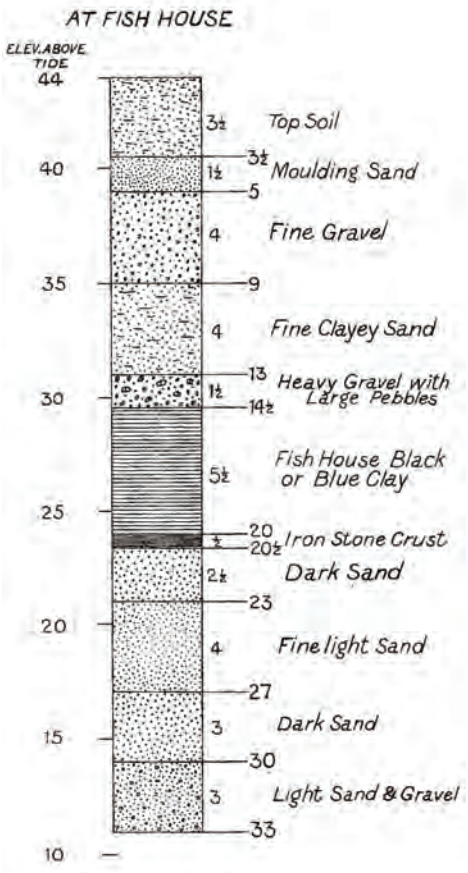


Figure 10. Soil profile at Fish House, showing the black clay bounded by the iron crust beneath it (Woolman, 1897, Plate 14).

sand and gravel (fig. 10); the crust also served as a reliable and convenient marker for the clay workers to cease digging. The borings also clearly showed that the Fish House Clay lays over and is younger than the white clay of Cretaceous age that were assigned at the time to the Raritan Formation (now considered to be part of the Potomac Formation). The soil boring study was the last significant early investigation of the Fish House Clay. By the end of the century, both the Fairview and Pea Shore works had mined away the thickest, most continuous, and most economically viable areas of the clay since the 1860s. The field studies at Fish House came to an end.

Investigation of the New Jersey Coastal Plain proceeded, however. Salisbury (1898, p.19-20) named the Cape May Formation, proposing that the primitive coastal area had subsided and become a marine or estuarine environment. The Fish House Clay was included in this territory, but with time the subsidence concept was disproven and the clay remained an uncertain age in geologic history.

Fish House Clay Studies in the 20th Century

In the early 1900s, Rollin Salisbury and George Knapp extensively investigated the Pensauken Formation. Their findings supported Salisbury's concept about erosion and deposition. Sediment had clearly infilled terrain of variable elevation, and erosion had juxtaposed nonsequential layers of sediments and mixed younger and older sediment. Salisbury and Knapp were certain that the Pensauken sands and gravels had come from the drainage of ancient waterways from Raritan Bay to the Delaware River basin, but they could not determine if the sediments came from a fluvial environment, a marine environment, or both. Additional research found that glacial sediments covered or were mixed with the Pensauken Formation in places, influencing a Pleistocene age for the Pensauken. Though these geologists could not provide a definitive explanation of the geology, they noticed a general composition of boulders, gravels, sands, and clays in changeable quantities, and a particularly exceptional clay bed at Fish House (Salisbury and Knapp, 1917). Additional research by McClintock and Richards (1936) on the Cape May Formation determined that it was an interglacial deposit laid down during periods of high sea level in a warmer climate. This seemed to match the historical environmental conditions of the Fish House Clay.

In the 20th century, Owens & Minard (1979) proposed that the Pensauken Formation was of late Miocene age, based on its assumed interfingering with Miocene marine sediments in the Delmarva Peninsula. Fossils that remain in museum collections helped scientists narrow down the environment of the clay. The 12 Fish House *unionid* species, most now believed to be extant, were brought to light again in the 1980s.

In the study by Bogan and others (1989), length and height measurements of undistorted fossil specimens were compared with measurements of modern mollusks of the Delaware River. The shapes of modern representatives were found to match those of the fossils, but the modern mollusks were much smaller, evidencing prehistoric environmental factors or possible 19th century sampling biases. Overall, the size and shape of the Fish House fossils resemble those of *unionids* presently found in the southeastern states, suggesting a warmer climate for the early Fish House fauna. In addition to size and shape, sediment remaining on the mollusk fossils was studied in greater detail with improved laboratory tools and sediment classification. The fossils retained slightly different sediments: clay, silty clay and sand, or silt only. This study proposed that Fish House had waterways and banks that underwent frequent small changes, with multiple depositions of slightly different sediments.

The vertebrate fossils – fish scales, bones of a wolf, and the skull and maxillary bone and teeth of a horse – were visually analyzed during the initial Fish House studies. Based on their stratigraphic proximity to the *Unionid* fossils, these vertebrate fossils were believed to be about the same age. Unfortunately, quite early on, the wolf specimen went missing, fish scales were either lost or not collected, and fish specimens were given away. However, Woolman (1897) noted in 1895 that the two fossils bones from *Equus complicatus* (a horse contemporaneous to *E. fraternus*) were a significant factor in determining a Pleistocene age for the Fish House Clay, as other *E. complicatus* fossils from the region were associated with known Pleistocene-age fossils such as those from mastodons and giant sloths. While these fossils have survived and were used in the 1989 study, no traces of sediment remain on them to assist in determining a depositional environment (Bogan and others, 1989).

Plant remains were also important finds at Fish House. Lignite (fossil wood) was identified in the 19th century but the species were indeterminate due to significant distortion (Woolman, 1897, p. 212). With advances in the 1970s in the study of fossil seeds, Owens and Minard (1979) demonstrated that the Fish House Clay was from a temperate interglacial period in the late Pleistocene epoch. The studies did not include absolute dating of materials (though suggested for future study) and so a narrowed date for the Fish House Clay remained undetermined. When a fossil leaf was found with a *unionid* shell in the 1989 study by Bogan and others, it showed that the two were "contemporaneous at a time of sediment deposition if not in life" and revealed that the Fish House Clay "was of limited geographic extent and probably of limited extent in time" (Bogan and others, 1989, p. 122-123). Altogether, the study concluded that the Fish House Clay was deposited in a changing channel environment with periods of deposition of different sediments. Through all of this research, the Fish House Clay was believed to be part of the Pensauken Formation.

While the Fish House Clay itself has not seen absolute dating, other studies have determined dates that better classify the sediments associated with the Clay and surrounding layers. In the 1990s, pollen from a clay bed in the Pensauken in Middlesex County was analyzed and found to include pre-Pleistocene taxa but not taxa commonly seen in Miocene deposits. This new finding indicated a Pliocene rather than a Miocene age for the Pensauken (Stanford and others, 2002). Then, geologic mapping by the New Jersey Geological and Water Survey in the early 2000s indicated that the Fish House Clay is part of the Cape May Formation, Unit 1, rather than the Pensauken Formation as previously believed (Stanford, 2004). O'Neal and others (2000) dated the Cape May, Unit 1, using amino acid racemization (AAR), a technique based on chemical changes in fossil organic matter. This was performed on fossil shells from Cumberland and Cape May counties. Based on the AAR results, the Cape May 1 is about

300,000 to 400,000 years old. The 400,000-year age corresponds to an interglacial period when sea level in eastern North America was 60 to 70 feet above present sea level, equivalent to the elevation of the top of the Cape May 1 deposit; this interglacial saw the highest global sea level in the past 1 million years (Sprat and Lisiecki, 2016). AAR has never been performed on Fish House Clay shell fossils but, based on the Cape May Formation studies, the Fish House Clay was reassigned to the Cape May Formation, Unit 1 (Stanford, 2004).

At Fish House, the Cape May 1 forms a wedge-shaped deposit that backs against and slightly overlies the Pensauken Formation and caps higher land to the south of Fish House (fig. 11). Further confusing matters, sand and gravel from the areas of the Pensauken at a higher elevation than the Cape May bench were eroded from the Pensauken and redeposited as part of the Cape May. This distribution of yellow sand and gravel below, beside, and above the Fish House Clay is the reason the clay was long thought to be within the Pensauken (Stanford, written commun., 2019).

The Pensauken is now known to be a pre-glacial Pliocene fluvial deposit. The Fish House Clay was a piece of a complex geological puzzle that remained unsolved for well over a century. Its age and depositional environment are now known, and little more research can be conducted at this time. However, as we see how past technological developments helped change geological understandings, we can only speculate on future developments and possibilities for reexamining even inaccessible or nonextant sites like Fish House.

A Geology/Industry/History Package

The Fish House Clay certainly made a positive mark on history, industry, and geology. This special resource provided material for the creation of useful and necessary products, helped

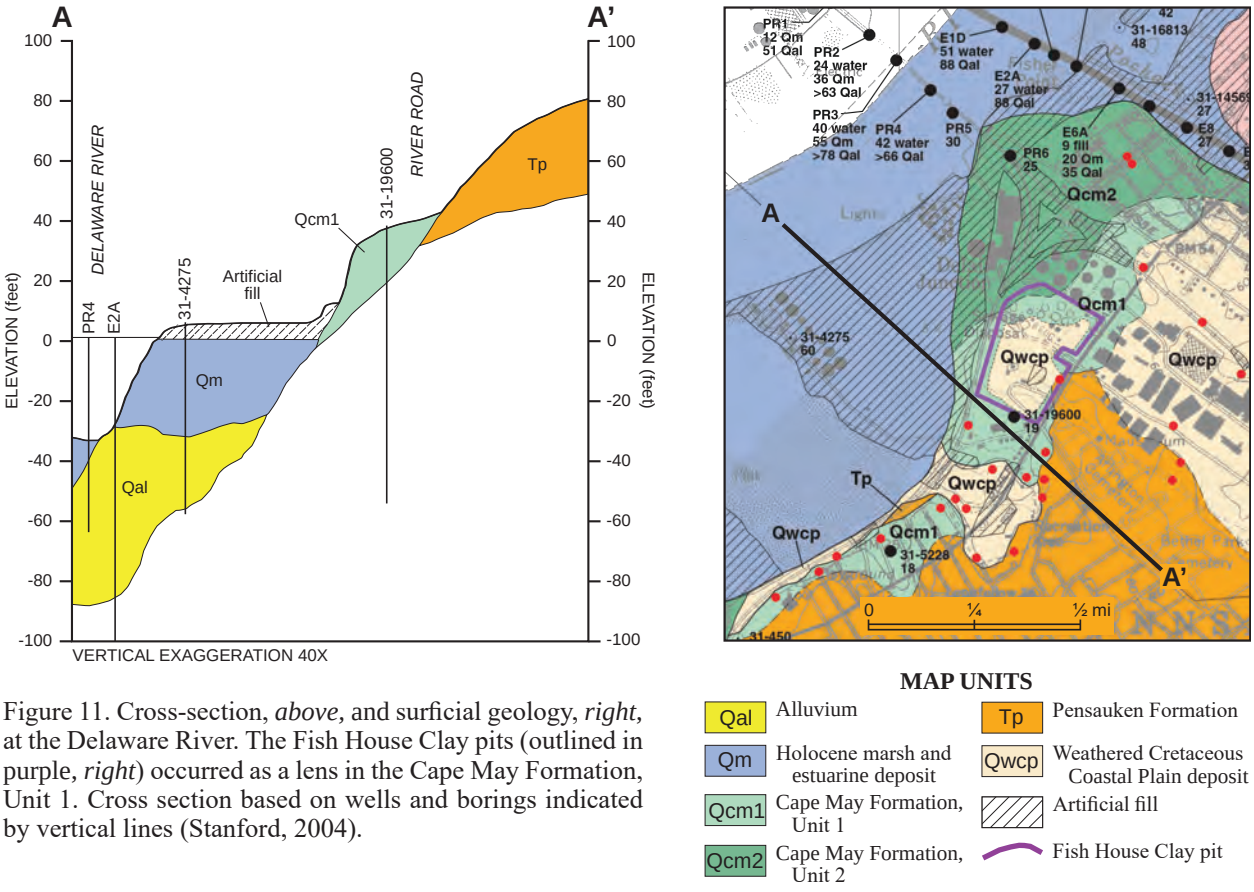


Figure 11. Cross-section, *above*, and surficial geology, *right*, at the Delaware River. The Fish House Clay pits (outlined in purple, *right*) occurred as a lens in the Cape May Formation, Unit 1. Cross section based on wells and borings indicated by vertical lines (Stanford, 2004).

to increase employment, bolstered Camden in becoming a powerful industrial center, and gave geologists important fossils and information to advance the understanding of New Jersey geology. However, in only a few decades, the hand of man – rather than the forces of nature over thousands to millions of years – transformed a bucolic recreational destination and productive fishing grounds into a stripped shoreline with an altered geology. New Jersey geology will continue to change due to natural and human influences, but modern geologists can move forward by necessarily looking backward – to historic books, maps, field notes, newspapers, industrial logs, and other enlightening records that explain what the geology was like before significant human alteration. The need is clear for quality documentation and historically sensitive studies today that will reveal vital information to geologists in the future. As the Fish House Clay demonstrates, there is always more to New Jersey Geology than meets the eye.

REFERENCES

Bogan, A.E., E.E. Spamer, G.C. Manville, W.B. Gallagher, and A.J. Cain, 1989, *Preliminary Reexamination of the Fish House Local Fauna and Flora (Pleistocene), Pennsauken, Camden County, New Jersey*, p. 111-126, *in* The Mosasaur, Delaware Valley Paleontological Society, Volume IV, October 1989, 178 p. Accessed July 16, 2018.

Clay Record, 1907, Chicago: Illinois Clayworkers' Association, v. 31, no. 5, September 14, 1907, p. 19-38. Accessed August 23, 2018.

Cohen, P., 2018, *Augustus Reeve*. DVRBS, digital image accessed August 21, 2018.

Cook, G.H., 1868, Preface p. vii-xvi *in* Geology of New Jersey: Newark: Daily Advertiser Office, 899 p. with illustrations and 8 folded maps.

Cook, G.H., 1878, Part IV – Economical Uses of Clays, &c., p. 307-318, *in* Report on the Clay Deposits of Woodbridge, South Amboy, and Other Places in New Jersey, Geological Survey of New Jersey: Trenton, Naar, Day & Naar, Printers, 381 p.

Cook, G.H., 1884, IV – Glacial Drift, and Yellow Sand, and Gravel, p. 17-20, *in* Annual Report of the State Geologist for the Year 1884, Geological Survey of New Jersey: Trenton, John L. Murphy, State Printer, 168 p.

Cope, E.D., 1871, *Synopsis of the Extinct Batrachia and Reptilia of North America*, p. 1-252, *in* Transactions of the American Philosophical Society, Vol. XI, December 1871, Philadelphia: M'Calla & Stavely, Printers, 483 p.

Google Maps, 2018, River Road and Cove Road, Pennsauken Township, NJ, accessed October 17, 2018.

Hexamer, Ernest, 1878, Plate 1230 [modified by author], *Drawing of the Pea Shore Brick & Terra Cotta Works, Augustus Reeve*, Hexamer General Surveys, Volume 13, Philadelphia. Found at Greater Philadelphia GeoHistory Network, accessed February 14, 2019. Source: Map Collection, Free Library of Philadelphia.

Historic Aerials by Nationwide Environmental Title Research, LLC., 1999-2019, Delair Junction, NJ (aerial and topographic maps), accessed July 15, 2019.

Hughes, J.W. and J.S. Seneca, 2014, The State's Many Economic Transformations, *in* New Jersey Business, March 6, 2014, accessed November 19, 2018.

Jenkins, G.E., 1898, Part VI -- Supplemental Notes on The Mining Industry of New Jersey -- Clay and Brick Industry, p. 324-350, *in* Smock, J.C., Annual Report of the State Geologist for the Year 1897, Geological Survey of New Jersey: Trenton, The John L. Murphy Publishing Co., Printers, 368 p.

Lacovara, K.J., 1997, Definition and Evolution of the Cape May and Fishing Creek Formations in the Middle Atlantic Coastal Plain of Southern New Jersey: Newark, University of Delaware, Ph.D. dissertation, 257 p. Figshare, posted August 29, 2014, accessed March 21, 2019.

Lea, I., 1868, *Descriptions of Unionidae from the Lower Cretaceous Formation of New Jersey*, p. 162-164, *in* Proceedings of the Academy of Natural Sciences of Philadelphia: Philadelphia, v. 20, 429 p.

MacClintock, P. and H.G. Richards, 1936, *Correlation of late Pleistocene marine and glacial deposits of New Jersey and New York, in* Bulletin of the Geological Society of America, v. 47, no. 3, p. 289-338. GeoScienceWorld, 2018. Accessed July 15, 2019.

Newell, W.L., D.S. Powars, J.P. Owens, S.D. Stanford, and B.D. Stone, 2000, Surficial Geologic Map of Central and Southern New Jersey: United States Geological Survey IMAP 2540-D, scale 1:100,000. Accessed October 16, 2018.

New Jersey Geological and Water Survey, permanent files: file 602: Clay/Pottery; Mineral Producers – Old Statistics (1908-1940) G-O, "Hatch".

O'Neal, M. L., J.F. Wehmiller, and W.L. Newell, 2000, *Amino acid geochronology of Quaternary coastal terraces on the northern margin of Delaware Bay, southern New Jersey, U.S.A*, p. 301-319, *in* Perspectives in Amino Acid and Protein Geochemistry, Glenn A. Goodfriend et al., editors: New York, Oxford University Press, 366 p.

Owens, J.P. and J.P. Minard, 1979, Upper Cenozoic Sediments of the Lower Delaware Valley and the Northern Delmarva Peninsula, New Jersey, Pennsylvania, Delaware, and Maryland: Washington, United States Geological Survey, United States Geological Survey Professional Paper 1067-D, 47 p., accessed July 17, 2018.

Pilsbry, H.A., 1897, 1896, *Geology of the Mussel-Bearing Clays of Fish-House*, New Jersey, p. 567-570, *in* Proceedings of the Academy of Natural Sciences of Philadelphia - 1896, v. 48, 614 p., 27 pls. Jstor, accessed July 25, 2018.

Prowell, G.R., 1886, The History of Camden County, New Jersey: Philadelphia, L.J. Richards & Co., HathiTrust Digital Library, accessed August 15, 2018, 767 p.

Ries, H. and H.B. Kümmel, 1904, Part 1, Chapter 11 -- Methods of Working Clay Deposits, p. 25-38 and Part IV, Chapter XIX -- Clays and Clay Industries by Counties, Burlington County, p. 376-391, *in* The Clays and Clay Industry of New Jersey, Volume VI of the Final Report of the State Geologist. Trenton: MacCrellish & Quigley, Book and Job Printers, 548 p.

Salisbury, R.D., 1894, Part I – Surface Geology, Section I – The Yellow Gravel, p. 39-72, *in* Smock, J.C., Annual Report of the State Geologist for the Year 1893, Geological Survey of New Jersey: Trenton, The John L. Murphy Publishing Co. Printers, 457 p.

Salisbury, R.D., 1896, Part I – Surface Geology – Report of Progress, p. 1-16, *in* Smock, J.C., Annual Report of the State Geologist for the Year 1895, Geological Survey of New Jersey: Trenton, The John L. Murphy Publishing Co. Printers, 198 p.

Salisbury, R.D., 1898, Part I – Surface Geology – The Pensauken Area, p. 15-17, and The Cape May Formation, p. 19-20, *in* Smock, J.C., Annual Report of the State Geologist for the Year 1897, Geological Survey of New Jersey: Trenton, The John L. Murphy Publishing Co., Printers, 368 p.

Salisbury, R.D. and G.N. Knapp, 1917, The Quaternary Formations of Southern New Jersey, Volume VIII of the Final Report Series of the State Geologist, Department of Conservation and Development, Division of Geology and Waters: Trenton, MacCrellish & Quigley Co., State Printers, 218 p.

Scott, T.M., circa 1852 [image modified by author], printer: Peter S. Duval Lithography, Philadelphia, accessed in World Digital Library. Accessed August 15, 2018

Sidney, J.C., 1847, *Map of the Circuit of Ten Miles Around the City of Philadelphia.* Philadelphia*:* Robert P. Smith, Publisher. David Rumsey Map Collection, Cartography Associates. Accessed May 28, 2020.

Sprat, R.M. and Lisiecki, L.E., 2016, *A Late Pleistocene sea level stack, in* Climate of the Past, Vol. 12, p. 1079-1092. ResearchGate, August 2015, accessed June 18, 2019.

Stanford, S.D., 2004*, Surficial Geology of the Camden and Philadelphia Quadrangles, Camden, Gloucester, and Burlington Counties, New Jersey*: New Jersey Geological Survey, Open-File Map OFM 60, accessed August 14, 2018.

Stanford, S.D., 2005, *The Geologic History of New Jersey's Landscape, in* Unearthing New Jersey, v. 1, no. 2, Summer 2005, p. 1-4, accessed November 19, 2018.

Stanford, S.D.; Ashley, G.M.; Russell, E.W.B.; and Brenner, G.J., 2002, *Rates and patterns of late Cenozoic denudation in the northernmost Atlantic Coastal Plain and Piedmont, in* Geological Society of America Bulletin, v. 114, no. 11, p. 1422-1437. ResearchGate, 2019, accessed February 4, 2019.

Stanford, S.D., August 2018-March 2019, personal communication.

Swarthmore College, 1971, Joseph Wharton Family Papers, 1691-1962: Swarthmore, Pennsylvania, Friends Historical Library of Swarthmore College, accessed August 7, 2018.

United States Congress, U.S. House of Representatives, 1916, *Delaware River from Mouth of Cooper River to Fishers Point Dike*: 64th Congress, 2d Session, House Documents, v. 21, Document No. 1734, United States Congressional serial set, no. 7147, December 4, 1916-March 4, 1917, 41 p. HathiTrust Digital Library. Accessed 30 October 2018.

Weaver, D., 2018, Maple Shade, N.J. Brickyards Deed Histories. Maple Shade, N.J. Brickyards Deed Histories, accessed August 29, 2018.

Whitfield, R.P., 1886, Paleontology of the Cretaceous and Tertiary, Volume I, *Brachiopoda* and *Lamellibranchiata* of the Raritan Clays and Greensand Marls of New Jersey: Trenton: John L. Murphy, State Gazette Printing Office. 269 p., 35 pls., folded map in back.

Woolman, L., 1897, Part IV – Report on Artesian Wells – Stratigraphy of the Fish House Black Clays, p. 95-254, *in* Smock, J.C., Annual Report of the State Geologist for the Year 1896, Geological Survey of New Jersey: Trenton, MacCrellish and Quigley, State Printers, 377 p.