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An Overview of the History and Economic Geology of the Natural Cement Industry at Rosendale, Ulster County, New York

ABSTRACT: The Rosendale region of southeastern New York State is widely recognized as the source of the highest quality natural cement in North America. The North American natural cement industry was founded in 1819 by Canvass White in central New York, but soon shifted to Rosendale where it flourished for over 150 years. By the end of the 19th century, the superior quality of Rosendale cement was known worldwide and was actively used in the construction of some of America's most enduring landmarks. Rosendale natural cement's reputation stems from the unique composition of the clay-rich layers of dolostone in the Upper Silurian Rondout Formation from which it is manufactured. Miners utilized room-and-pillar techniques to extract this dolostone from strongly deformed strata in the Rosendale region, creating unique bedrock exposures in mines that are something of an engineering marvel. The exposures resulting from these mining activities have long attracted the attention of geologists for research and education. Production of natural cement transformed extracted dolostone into barrels of cement through a labor-intensive process involving calcination in kilns, cracking, and grinding. Barrels of cement produced were quickly shipped at competitive prices via the Delaware and Hudson Canal, which directly connected the Rosendale natural cement region to major shipping avenues.

KEYWORDS: natural cement, Canvass White, Delaware and Hudson canal, cement production, geology, education, Rosendale, Ulster County, New York

Introduction

The momentum of the North American Industrial Revolution in the opening years of the 19th century sparked a number of large-scale building projects, including the construction of regional canal networks. These canal projects required quantities of high-quality mortars unavailable in North America prior to the introduction of natural cement. Natural cement forms a surprisingly tenacious mortar and is made from clay-rich dolostone or limestone that is capable of hardening while submerged. Thus, natural cement was well suited for many applications including canal construction and quickly gained popularity. Commercial production of natural cement in North America began in 1819 near Chittenango, central New York, and quickly expanded to include factories in several states. However, the region near the town of Rosendale in the central Hudson Valley of southeastern New York State is most commonly associated with the American natural cement industry (Fig. 1).

The highest-quality natural cement in North America originates from the mines in the low northeast-trending hills of the Rosendale region [1]. In addition to various North American canal projects, natural cement produced at Rosendale was used in the construction of some of America's most enduring landmarks. Thousands of public works projects, including portions of the U.S. Capitol building, the Brooklyn Bridge, the Starrucca Viaduct, Roebling's Delaware Aqueduct, the pedestal of the Statue of Liberty, and the Croton Aqueduct Dam and High Bridge began underground in cement mines near Rosendale. Use of Rosendale natural cement was so widespread that Uriah Cummings

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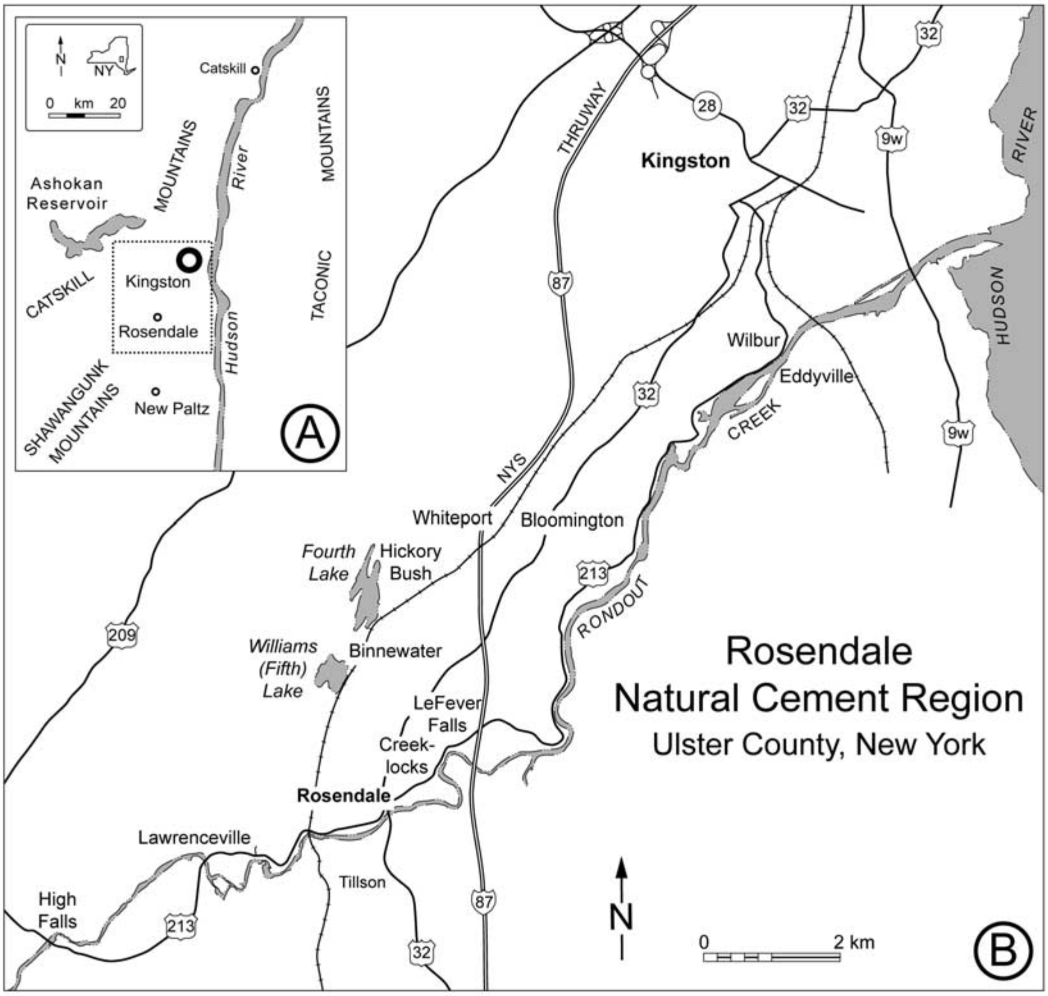

FIG. 1—*Map (A) showing the location of the Rosendale natural cement region in the central Hudson Valley of southeastern New York State. Dotted outline corresponds with area of larger map (B), which illustrates the relative locations of major natural cement producing locations within the Rosendale natural cement region. The trace of the Delaware and Hudson Canal in the Rosendale region follows State Route 213 and the Rondout Creek from High Falls to Eddyville.*

remarked that both New York and Boston were likely built entirely from mortars using this cement [2].

The excellent bedrock exposures within the mines of the Rosendale region also attracted the attention of numerous geologists. Some of North America's first professional geologists, including Mather [3] and Davis [4] examined the exposures created during the earliest days of the cement industry at Rosendale. Large-scale bedrock exposures in the mountains of eastern North America are uncommon, and the Rosendale region quickly developed a reputation as a unique geologic classroom as mining activities continued to uncover new areas. Princeton University students regularly used the Rosendale region for field studies during the early 1990's. Princeton students compiled a remarkably detailed series of theses and reports, containing photographic archives of quarry and mine exposures taken prior to reforestation of the Rosendale region. These important photographs record historical and geologic relationships that have since been covered or destroyed. These historical records add a valuable perspective to ongoing research projects in the Rosendale natural cement region and provide a foundation for the field-based education of geologic principles.

FIG. 2—*Canvass White (1790–1834) learned of natural cement while studying canal construction methods in England and later worked as an engineer on the Erie Canal project. White was the first individual to manufacture natural cement in North America (collections of the Century House Historical Society).*

Canvass White, Canals, and the Birth of the American Natural Cement Industry

Canal construction occurred at a frenzied pace during the first half of the 19th century. The rapidly growing network of canals integrated regions across the northeastern United States and provided a nexus for politics, trade, and technological advances. Engineers associated with these canal projects commonly sought local sources of building materials to minimize costs. Canvass White, an engineer on the Erie Canal project, discovered rocks suitable for manufacturing natural cement in 1818 in northcentral New York (Fig. 2). White learned of natural cement while studying canal construction methods in England and knew this material was ideally suited for the construction of North American canal systems. The explosion of the North American natural cement industry quickly followed White's discovery. In less than 25 years following White's discovery, natural cement works were established in Illinois, Kentucky/Indiana, Maryland, New York, Pennsylvania, and Virginia.

Canvass White began the first North American commercial production of natural cement at Chittenango, in central New York, in 1819 and received a patent for his product the following year. With this patent, White expected to be the sole supplier of cement to the State of New York for the construction of the Erie Canal. However, competition developed rapidly as others along the proposed canal course began manufacturing natural cement and selling it to the State of New York. White sued several of these manufacturers for patent infringement and royalties. White's attempts to protect his patent rights drew widespread attention and were supported by such luminaries as Benjamin Wright, De Witt Clinton, Secretary of State John Quincy Adams, and Senator Henry Clay. Ultimately, in a move to end litigation, in 1825 the State of New York purchased the patent rights for natural cement from White for $10 000.

Following the completion of the Erie Canal, Canvass White and his younger brother, Hugh White, continued to manufacture natural cement at Chittenango. Canvass White soon accepted a position as engineer for the Union Canal Company, leaving Hugh White to manage the Chittenango cement works. In a partnership that proved extremely profitable for several years, the elder White specified amounts of cement necessary for projects on the Union Canal, which were in turn provided by the younger White. However, in a letter written to the Chittenango cement works in the spring of 1825 from Reading, Pennsylvania (terminus of the Union Canal), Canvass White remarked that a local brand, Bald Mountain Cement, was entering the market due to the limited availability of White's cement. This event marked the beginning of a protracted period of increased competition with other successful natural cement producers that beleaguered Canvass White until his death in 1834.

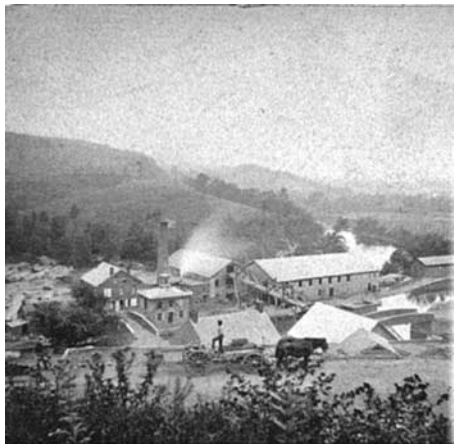

FIG. 3—*Cement works (ca. 1872) along the Rondout Creek at Lawrenceville (Fig. 1) in the Rosendale natural cement region. This location was the site of Lucas Elmendorf's cement works in 1828 (photograph by D. J. Auchmoody, collections of the Century House Historical Society).*

Natural Cement at Rosendale

Rocks suitable for the manufacture of natural cement were discovered in 1825 along the proposed course of the Delaware and Hudson Canal near Rosendale. Soon after the discovery of this resource, the first contract to supply natural cement to the Delaware and Hudson Canal Company was awarded to John Littlejohn. As with the Erie Canal project, fierce competition quickly developed as others joined Littlejohn in natural cement production. This competition sparked Rosendale's nascent natural cement industry, which was first mentioned in the Report of the Committee on Roads and Canals in 1828 [5]. Among the early competitors were Lucas Elmendorf and Watson E. Lawrence, who began manufacturing under the Rosendale Cement brand in the fall of 1827. Elmendorf obtained a charter to incorporate the Rosendale Manufacturing Company from the New York State Legislature in 1827, which was subsequently acquired by Lawrence in 1831 (Fig. 3).

Canvass White sought to transport his products to the Hudson Valley from Chittenango via Albany in response to the growing market for natural cement in southeastern New York and competition he faced from new producers near Rosendale. However, White conceded in a series of letters in late 1827 that the White brothers were in a poor position to compete for business with the producers near Rosendale. This realization proved correct as the demand for natural cement produced at Rosendale continued to grow and quickly expanded beyond the Delaware and Hudson Canal project. For example, Rosendale cement companies secured a contract in 1829 for the construction of Fortress Monroe in Hampton, Virginia, with an initial shipment of 500 barrels of natural cement. In a final attempt to spur business and expand the market for White's cement, Peter Remsen, Canvass White's agent in New York City, began placing advertisements for White's cement in several major newspapers during the summer of 1829.

The White brothers' cement business suffered another setback later the same year. Benjamin Wright, the chief engineer of the Chesapeake and Ohio Canal Company, and Robert Leckie identified rocks suitable for the manufacture of natural cement near Shepherdstown, Virginia, in the spring of 1829 [6]. Leckie began commercial production of natural cement production in August 1829 and subsequently provided most of the cement used in the construction of the Chesapeake and Ohio Canal from local sources. As a result, the Chesapeake and Ohio Canal Company used only 1204 barrels of White's hydraulic cement between 1829 and 1832 [6]. Finally, in an attempt to end nearly ten years of difficult competition with better located cement producers, Hugh White relocated his cement works in 1836 from Chittenango to Whiteport, near Rosendale (Figs. 1 and 4).

Hugh White's move to Rosendale coincides with a time of considerable growth in the natural cement industry. W. W. Mather, a geologist working for the State of New York, noted during his first visit to the Rosendale region during the late 1830s that the only active cement works were located in

FIG. 4—*Newark and Rosendale cement works at Whiteport (ca. 1880s). Located north of Rosendale and west of Bloomington (Fig. 1), this was the site of Hugh White's cement works between 1838 and 1848. White sold the property to the Newark and Rosendale Cement Company, who in turn sold the facilities to the Consolidated Rosendale Cement Company in 1902 (photograph courtesy of M. Pavlov, collections of the Century House Historical Society).*

Lawrenceville, approximately two kilometres west of the present village of Rosendale (Fig. 1) [3]. Mather returned to Rosendale in the early 1840s to find 13 companies operating 16 cement works collectively producing 600 000 barrels of cement annually [3]. Mather's description of the burgeoning Rosendale cement industry also notes a broad range of uses for cement produced in this region, including the construction of cisterns, wet cellars, the Croton Aqueduct system, and various other North American government projects [3].

The success of the Rosendale natural cement industry depended upon unobstructed access to the Delaware and Hudson Canal. The Delaware and Hudson Canal, the Rondout Creek, and the Hudson River connected Rosendale to markets and fuel, providing local companies with a significant cost advantage over cement factories in competing regions. Thus, Rosendale natural cement could generally be delivered at a significantly lower cost due to the proximity of water-borne conveyance systems. As a result, the market for the high quality and relatively inexpensive Rosendale cement continued to broaden and eventually included all of the major Atlantic ports and the West Indies [3].

American natural cement production reached its peak in 1899 with an estimated annual production of their 9 868 000 barrels of cement. The natural cement industry declined rapidly during the early 1900s, but lingered until 1970 when the Century Cement Manufacturing Company in Rosendale, the last natural cement works in North America, finally closed (Fig. 5). Annual reports of the United States Geological Survey suggest that the Rosendale cement region led the nation during most of the 151-year span of the natural cement industry, often accounting for nearly 50 % of all the natural cement manufactured in North America. Cummings [2] highlighted the quality of Rosendale natural cements in his comprehensive review of American cement, in which he ranked them among the foremost American cements in quality.

FIG. 5—*The Century Cement Plant in Rosendale (ca. 1955) was the last cement works to manufacture natural cement in North America. This plant was operational between 1928 and 1970 (collections of the Century House Historical Society).*

FIG. 6—*A newspaper advertisement for Knight's Patent Hydraulic Cement Pipe from the Salem (Massachusetts) Observer, February 1, 1873 (collections of the Century House Historical Society).*

Applications of Rosendale Natural Cement

Debates over the application of natural cement mortars over other types of mortars were frequently addressed in publications written for 19th century agriculturalists and engineers. Some authors suggest that metallic cements (a historical term referring to natural cements like Roman and Parker's/English natural cements) are inferior to lightly hydraulic lime mortars [7]. Indeed, Canvass White overcame contemporary reluctance to employ natural cement mortar on the Erie Canal project instead of the relatively popular lime mortars commonly used in canal construction during the early 19th century. However, many advocated the use of natural cements for various construction applications. For example, Henry Heath used Rosendale natural cement in 1858 to construct the Allen House (later renamed Hotel Allen), the first concrete hotel in Pennsylvania [8]. Newspaper advertisements provide evidence for other early applications of natural cement. For example, the *Observer* of Salem, Massachusetts, featured advertisements for Knight's Patent Hydraulic Cement drain pipes, sewer pipes, and culverts and Down's Patent Concrete walks in 1870 (Fig. 6) [9].

Rosendale natural cement quickly became popular enough to compete for business in regions with well established, local natural cement works. For example, an interesting advertisement published by John Drucker of Chicago, Illinois, in 1878 lists the prices and relative qualities of three brands of cement: Bangs & Gaynor's, Ramsey's Hydraulic, and Rosendale [10]. Bangs & Gaynor's cement is noted as being of equal quality to brands from Akron, Buffalo, and Milwaukee and is listed for $1.00 per barrel. Ramsey's cement is listed at $1.25 per barrel and suggested to be of comparable quality to brands from Louisville. Rosendale cement is listed at $1.30, the highest price. No comparison of relative quality is provided for Rosendale natural cement. This omission is likely because Rosendale natural cement had a widespread reputation of being of superior quality to the other brands listed. Newspapers in major cities commonly listed the current price of Rosendale cement along with imported European portland cements and eventually with American portland cement in the financial pages. An example from the General Market Report for Building Materials in the *New York Daily Tribune* of 9 October 1889, lists Rosendale cement as the cheapest cement for mortar relative to American, English, and German portland cements. Thus, the popularity of Rosendale natural cement persisted long after the introduction of portland cements in the 1870s because of its reputation for quality at competitive prices.

Geology of Rosendale Natural Cement

The rock mined for the production of natural cement at Rosendale occurs within a stratified sequence of sedimentary rocks including limestone, dolostone, sandstone, shale, and conglomerate deposited during the Ordovician, Silurian, and Devonian periods approximately 450 to 375 million years ago

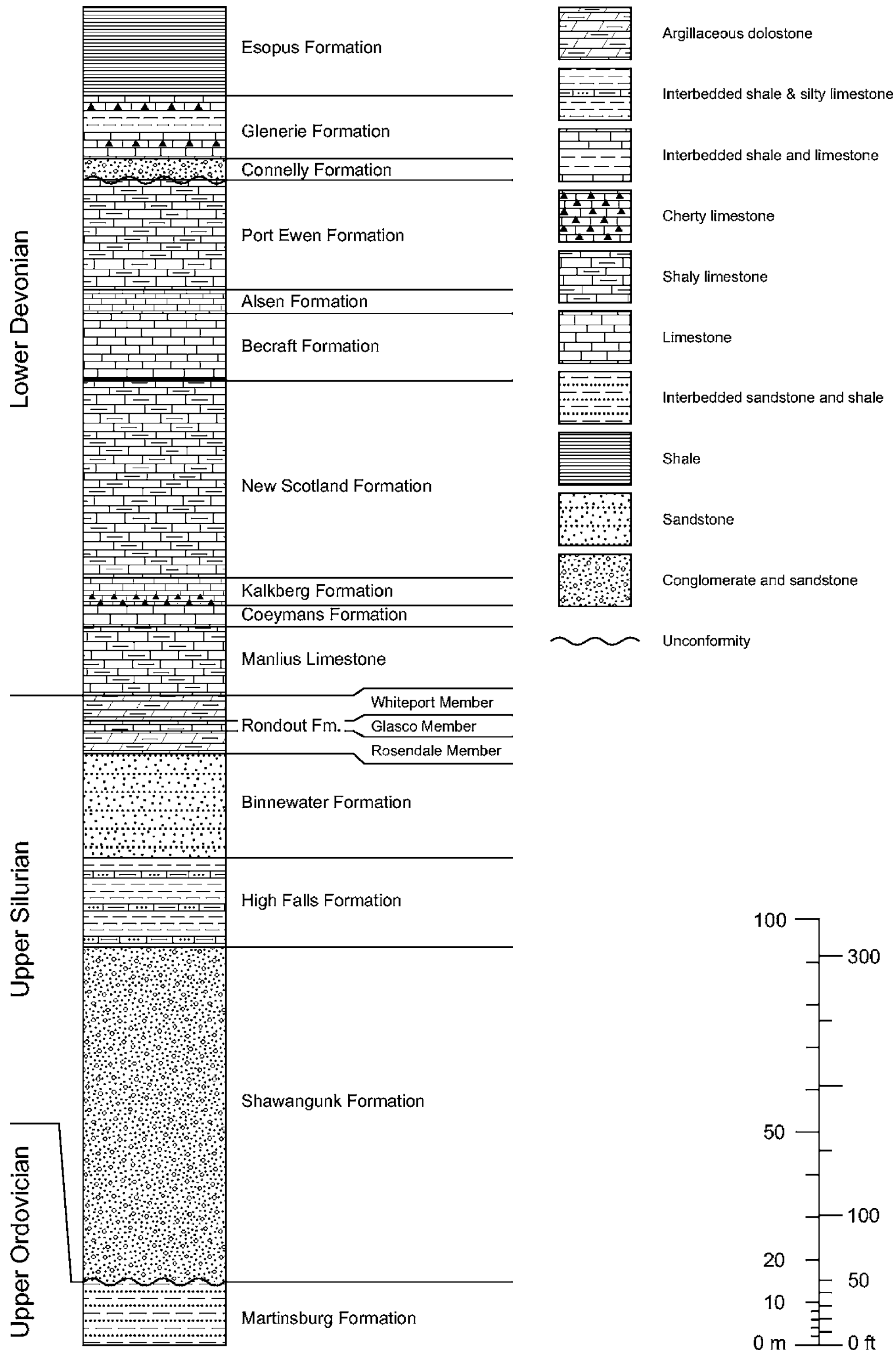

FIG. 7—*Simplified stratigraphic column of the Ordovician, Silurian, and Devonian rock units exposed in the Rosendale natural cement region. Dolostone from the Rosendale and Whiteport members of the Upper Silurian Rondout Formation was used in the production of natural cement. The Glasco Member of the Rondout Formation was not suitable for natural cement production. Stratigraphic thicknesses after Waines and Hoar [13] (please refer to discussion therein for information regarding geologic units not mentioned within this text).*

(Fig. 7) [11–15]. The oldest geologic unit exposed near Rosendale is the Middle Ordovician Martinsburg Formation, a thick sequence of dark gray shale and sandstone. The Upper Silurian Shawangunk Formation, a thick sequence of silica-cemented quartz pebble conglomerate and sandstone, unconformably overlies the Martinsburg Formation. The Shawangunk Formation likely comprises the deposits of gravel-choked, braided streams that once flowed out of the ancient Taconic Mountains of present day eastern New York and western Massachusetts [16]. The Shawangunk Formation is overlain by the Upper Silurian High Falls Formation and Binnewater Formation. These strata record a gradual transition from continental to nearshore environments associated with the eastward advance of a broad, shallow, inland sea that at times extended from present day New York to Iowa. The Upper Silurian Rondout Formation, a thickly bedded sequence of dolostone and moderately fossiliferous limestone, unconformably overlies the Binnewater Formation. The Rondout Formation records a shift from nearshore to marine depositional environments. These Silurian strata are overlain by limestone, shale, and sandstone of the Lower Devonian Helderberg and Tristates Groups [12,13,17,18].

A series of tectonic collisions between the eastern margin of North America and other land masses during the Devonian and Carboniferous to Permian periods (approximately 400 and 300 million years ago, respectively) deformed the sequence of Silurian and Devonian rocks in the Rosendale region and uplifted the ancient Appalachian Mountains. Today, the deeply eroded western flank of the ancient Appalachian Mountains is exposed in a narrow belt of deformed strata near Rosendale and elsewhere along the western margin of the Hudson River Valley [19]. These complexly folded and faulted rocks presented both challenges and benefits to miners working in the Rosendale natural cement region. Brittle fractures associated with folding and faulting weakened rock layers, compromising the stability walls, pillars, and ceilings in quarries and mines. However, folding and faulting often duplicated the stratified sequence of rocks in imbricate stacks, which facilitated the extraction of certain rocks for cement production.

Rondout Formation

Rosendale natural cement was produced from dolostone mined from the Upper Silurian Rondout Formation (Fig. 7). The Rondout Formation comprises a highly variable sequence of clay-rich dolostone, silty limestone, and calcareous sandstone exposed along much of the western margin of the Hudson Valley [12,13,20,21]. The thickness of the Rondout Formation is variable in the Rosendale area, ranging from more than 15-m thick southwest of Rosendale to less than 9-m thick near Kingston [13,21]. Near Rosendale, the Rondout Formation is divisible into three stratigraphic members: Rosendale, Glasco, and Whiteport [22]. The composition of the clay-rich dolostone in the Rosendale and Whiteport members of the Rondout Formation are ideally suited for natural cement production and were extensively mined in the Rosendale region. The Glasco Member contains limestone, dolostone, and shale that are not suitable for natural cement production and is generally left untouched in mines near Rosendale [13].

The lowest of the members in the Rondout Formation locally is the Rosendale Member, which is a fine-grained, blue-gray, clay-rich dolostone that weathers rusty, light orange-brown. The Rosendale Member is approximately 8-m thick south of High Falls, but thins to less than 2-m thick north of Kingston. Fossils within the Rosendale Member are rare, but include fragments of brachiopods and echinoderms. The Glasco Member, a moderately fossiliferous, fine- to medium-grained, gray, silty dolostone and limestone with local coral-rich facies, overlies the Rosendale Member [23,24]. Silicified fossils of the chain coral *Cystihalysites sp.*, favositids, and stromatoporoids are abundant in the lowermost Glasco Member. Thickness of the Glasco Member varies near Rosendale, ranging between 4 and 0.2-m thick [25]. The Whiteport Member overlies the Glasco Member and is a very fine-grained, thinly bedded, light blue-gray, clay-rich dolostone that weathers light gray-brown. The Whiteport Member contains disarticulated fossil fragments of the ostracod *Leperditia sp.* and cup (solitary rugose) corals [25]. The Whiteport Member thins northward from approximately 4.8-m thick near Rosendale to 3-m thick near Kingston [25].

Complex Nomenclature of the Rondout Formation

The varied nomenclature used to discuss the rocks within the Rondout Formation is the source of much confusion regarding the age, distribution, and stratigraphy of this unit [12,25]. Hall [26] first

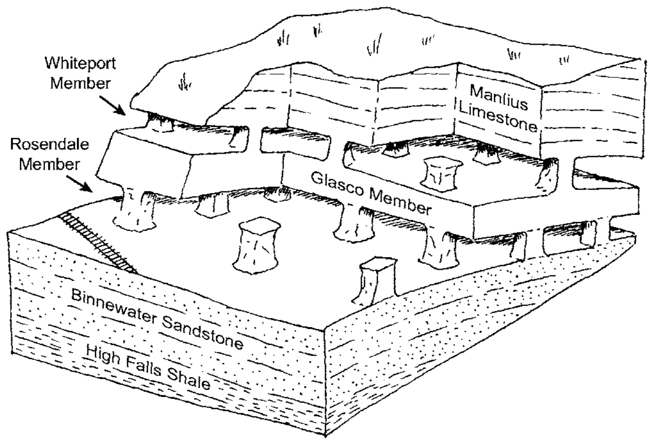

FIG. 8—*A three-dimensional sketch of the inner workings of a typical room-and-pillar mine in the Rosendale natural cement region. Cement rocks were extracted from the Rosendale and Whiteport members of the Rondout Formation (see also Fig. 7). Rocks in the Glasco Member of the Rondout Formation were unsuitable for cement production and were commonly not removed, resulting in a ledge that separated the two mined horizons. Mining of cement rocks began with the excavation of a series of rooms in the Rosendale or Whiteport members, or both along a surface exposure. Subsequent mining interconnected these rooms at depth, leaving pillars of cement rock to support the weight of overlying strata. The initial rooms were then extended with new shafts, which were later interconnected to form a new row of rooms and pillars.*

named the unit by proposing the terms Rosendale "upper cement" and "lower cement" for the series of units quarried for cement rock in Ulster and adjacent counties. Darton [27] subsequently referred to these strata as the Salina Waterlimes. In a slight variation, Clark and Schuchert [20] referred to the Rondout Formation as the Rondout Waterlime. Hartnagel [22,28] was the first to recognize a "middle ledge" (the Glasco Member) separating the natural cement bearing rocks that he referred to as the Cobleskill and Salina units. Van Ingen and Clark [29] referred to strata within the Rondout Formation near Kingston as the Vlightberg sequence. Logie [23] assigned the geographically based name LeFever Limestone. Chadwick [24] reintroduced the designation Rondout, which was later supported and refined by Rickard [12] and Hoar and Bowen [25] into the presently accepted convention discussed above.

Natural Cement Production

Room-and-Pillar Mining

During much of the 19th century, miners utilized sledge hammers, star drills, black powder, and room-and-pillar mining techniques to extract dolostone from the Whiteport and Rosendale members of the Rondout Formation. Despite the eventual incorporation of technological advances such as pneumatic drills, the use of basic room-and-pillar mining techniques persisted throughout the entire course of the cement industry near Rosendale. Room-and-pillar mining is an effective technique for removing cement rock from stratified deposits by leaving a carefully arranged array of pillars to support the ceilings of excavated spaces (Fig. 8). Mines in the vicinity of Rosendale generally began with the quarrying of a series of 4 by 9-m shafts spaced at roughly 4-m intervals along an outcrop exposure in one of the dolostone-bearing members of the Rondout Formation [30]. These shafts were then connected by 16 m^2 sized rooms, resulting in a honeycomb of main shafts separated by pillars of rock along the original surface. The mining process continued by extending the original main shafts deeper into the mine before connecting them with an additional row of rooms. Mining of dolostone generally continued in this fashion until the rock layers became friable, were truncated by

FIG. 9—*Photograph looking north into an abandoned cement mine in the Rosendale Member of the Rondout Formation (see also Fig. 7) in the west-dipping limb of the Hickory Bush anticline near the Fourth Binnewater Lake (Fig. 1). This mine was completed in strata that are dipping at roughly 80° from horizontal. Pillars are approximately 4-m (13-ft) tall.*

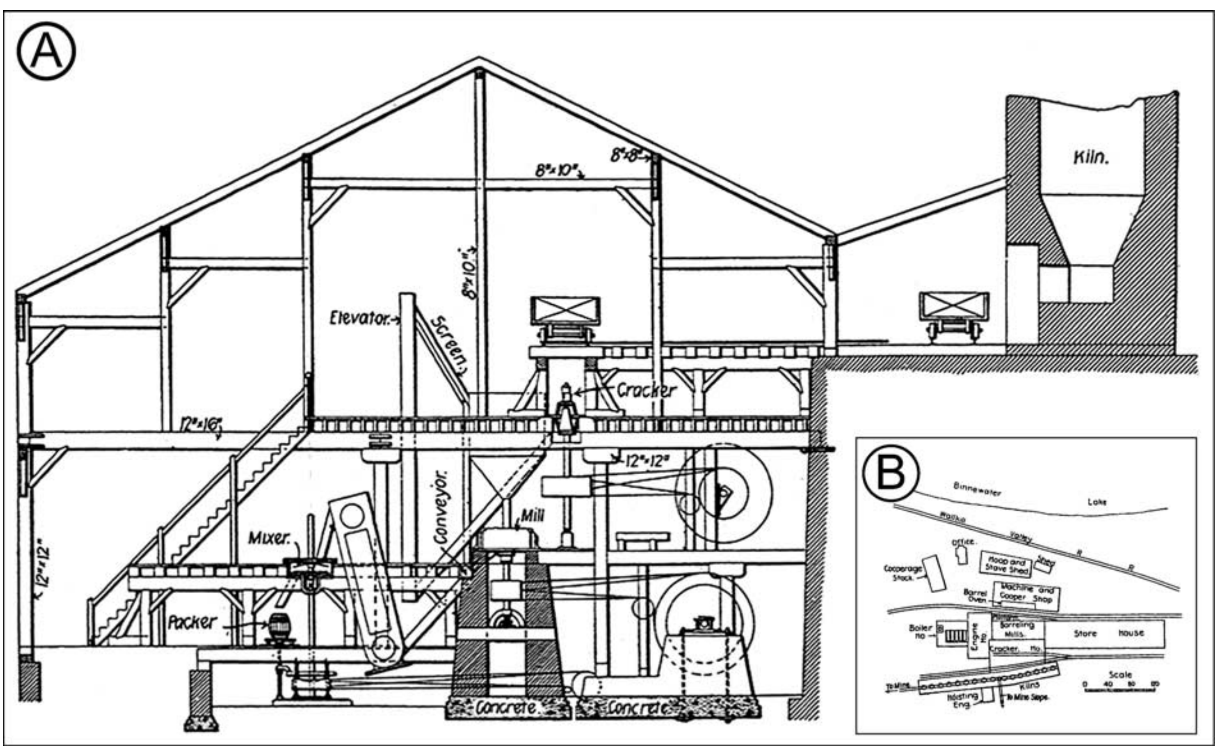

FIG. 10—*Cross-sectional elevation (A) of the kiln battery and mill structure of the Lawrence Cement Company at Binnewater (Fig. 1). Note the relative positions of the kiln battery, cracker, grinding mill, and packing areas. The tramways atop the kiln structure leading to the adjacent mines are not shown. The various buildings of the Lawrence Cement Company were located immediately east of Binnewater Lake (now known as Fifth or Williams Lake), along the Wallkill Valley Railroad (inset B). Figure after Lewis [30].*

faults, or until miners encountered property lines or claim boundaries. Extracted rock was collected laterally along rows of rooms using networks of narrow-gage rail cars before being hauled to the surface by steam-driven hoists along one of the main shafts [30].

In modern room-and-pillar mines, engineers carefully account for pillar height, overburden weight, rock creep, and structural defects in the rock when calculating room to pillar area ratios to maximize both safety and returns [31]. In general, only about 60 % of a rock layer can be safely extracted from a room-and-pillar mine, but it is possible to increase this percentage to upwards of 90 % if the pillars and roof rocks are competent enough support wide spans [31]. However, the load on pillars increases rapidly as the percent of extracted material increases. For example, pillars of rock in a mine with 40 % extraction experience 1.67 times the normal load, whereas pillars in a mine with 75 % extraction experience four times the normal load [31]. Pillars in strata that dip more than a few degrees from horizontal are subjected to additional hazards associated with shear stress. For this reason, engineers generally utilize room-and-pillar mining techniques only in horizontal or very shallowly dipping strata. Given these constraints to the application of room-and-pillar mining techniques, the mines of the Rosendale natural cement region are truly engineering wonders. These mines were successfully completed in highly fractured and faulted rocks, and the strata within many of these mines are steeply dipping. For example, strata in the mines near Hickory Bush dip upwards of 80 degrees from horizontal (Fig. 9).

Calcination, Cracking, Grinding, Packing, and Shipping

Elaborate tramways transferred cement rock extracted from mines in the Rosendale natural cement region to batteries of kilns to begin the refining process (Fig. 10). Round kilns constructed of brick and local rock fired the dolostone in a process called calcination, which uses heat to drive off carbonic acid and yields a soft yellow product [30]. Workers charged the kilns at their upper openings with alternating layers of fuel and dolostone. Initially, locally hewn wood was the preferred fuel. However, following deforestation of the region, pea coal shipped from Pennsylvania on the Delaware and Hudson Canal became the primary fuel. Workers carefully regulated the kilns, because if temperatures became too intense the dolostone recrystallized into a clinker that was unsuitable for the production of cement [32]. Workers drew the calcined materials from the base of the kilns and removed the clinker before feeding the properly burned rocks into crackers. The gravity-fed, coffee-mill type cast iron crackers crushed the relatively soft burned rocks into smaller fragments. (Fig. 10). Mills containing large grindstones quarried from local exposures of the Shawangunk Formation ground the crushed burned rock fragments into a fine-grained powder. Workers discharged the resulting powder directly into paper-lined, 20 lb (9.07 kg) wooden barrels commonly manufactured in on-site cooper shops. Each finished barrel contained approximately 300 lb (136.1 kg) of powdered natural cement product.

Shipping

As discussed earlier, manufacturers in the Rosendale natural cement region used the Delaware and Hudson Canal, the Rondout Creek, and the Hudson River to transport their products to market. Factories along the Delaware and Hudson Canal (now State Route 213 and Creek Locks Road) generally loaded barrels of cement directly onto barges from company-owned docks (Fig. 11). Cement works located inland near the Binnewater Lakes, Hickory Bush, and Whiteport, with no direct access to the canal, utilized either the Wallkill Valley Railroad or other creative methods for transporting their goods to nearby docks. One such innovative solution was a horse-drawn railroad that connected remote cement works near Hickory Bush with docks on the Rondout Creek at Eddyville (Fig. 12).

Summary

The success of the Rosendale natural cement industry stems from both the quality of the available raw materials and the proximity to shipping avenues. Rosendale natural cement's reputation for

FIG. 11—*Loading dock of the Consolidated Rosendale Cement Company along the Delaware and Hudson Canal at Binnewater Road in Rosendale. Notice the tramway directly above the canal barges. The cars on this tramway are loaded with barrels of natural cement produced from the Beech Mine along Binnewater Road. The structure built from dark iron girders at upper right is a footing for the Wallkill Valley Railroad Trestle over the Rondout Creek. This photograph was originally published by the Consolidated Rosendale Cement Company in a 57-page advertisement booklet in 1910 (collections of the Century House Historical Society).*

superior quality is related to the unique composition of the clay-rich layers of dolostone within the Rondout Formation. The Rosendale region was directly connected to a distribution network via the Delaware and Hudson Canal that ensured the rapid delivery of natural cement products to various markets at competitive prices. After nearly 150 years of production, the legacy of Rosendale natural cement is preserved in some of our nation's most recognizable landmarks. The abandoned mines in the Rosendale region, excavated using room-and-pillar mining techniques, contain unparalleled exposures of strongly folded and faulted rocks. These mines provide a window into the deeply eroded remnants of the Appalachian Mountains that continually attract geologists for purposes of research and education.

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FIG. 12—*Photograph of the horse-drawn railroad (ca. 1899?) that once transported natural cement manufactured at plants near Whiteport and Hickory Bush to docks at Eddyville along the Delaware and Hudson Canal (collections of the Century House Historical Society).*

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