PHOENIX BRIDGE
(Bridge No. 6386)
Spanning Craig Creek at Virginia Route 685
Eagle Rock Vicinity
Botetourt County
Virginia

HAER No. VA-105

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Northeast Region
U.S. Custom House
200 Chestnut Street
Philadelphia, PA 19106

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HISTORIC AMERICAN ENGINEERING RECORD
PHOENIX BRIDGE
(BRIDGE NO. 6386)

HAER No. VA-105

LOCATION: Virginia State Route 685 over the Middle River, Eagle Rock vicinity, Botetourt County, Virginia
USGS Grottoes, VA Quadrangle, Universal Transverse Mercator Coordinates: 17.602360.4167920

DATE OF CONSTRUCTION: 1887

BUILDER: Phoenix Bridge Company, Phoenixville, Pennsylvania. Aldophus Bonzano, Chief Engineer, Phoenix Bridge Company.

PRESENT OWNER: Virginia Department of Transportation

SIGNIFICANCE: The Phoenix Bridge represents two types of technology typical of late nineteenth century factory-manufactured railroad bridges. The main span is an example of a pin-connected iron and steel Pratt through truss railroad bridge of a proprietary design developed and manufactured by the Phoenix Bridge Company. The secondary span is a representative example of a steel Warren deck truss. The Phoenix Bridge Company and Aldophus Bonzano made important contributions to bridge design and construction in the late nineteenth century.

PROJECT INFORMATION: The Phoenix Bridge was recorded in 1993-1994 by the Cultural Resource Group of Louis Berger & Associates, Inc., Richmond, Virginia, for the Virginia Department of Transportation (VDOT). The recordation was undertaken pursuant to provisions of a Programmatic Memorandum of Agreement (Draft) among the Federal Highway Administration, VDOT, the Virginia SHPO, and the Advisory Council on Historic Preservation concerning management of historic metal truss bridges in Virginia. Project personnel included Richard M. Casella, Architectural Historian; Alison Helms, Historian; and Bruce Harms, Photographer.

DESCRIPTION

Phoenix Bridge (VDOT Bridge No. 6386) is a two-span bridge consisting of a pin-connected iron and steel Pratt through truss and a steel Warren deck truss. The bridge carries Virginia State Route 685 in an east-west direction over Craig Creek. Phoenix Bridge was formerly a railroad bridge known as Bridge No. 13 on the Craig Valley Line of the Chesapeake and Ohio (C&O) Railroad. The bridge is located 0.8 miles northwest of the confluence of Patterson Creek and Craig Creek, in Botetourt County, Virginia (Figure 1). The east span is the Pratt through truss, 152' long, and the west span is the Warren truss, 75' long. Concrete deck slab approaches, 26' 5" and 13' 3" long, resting on the U-type abutments increase the overall bridge length to 266' 8" (Figure 2).

The river is approximately 60' wide at the bridge and is spanned by the Pratt truss at a height of approximately 28' above the water. The deck Warren truss spans the floodplain at an average height of about 22'. The immediate area around the bridge is open rolling farmland and pasture with widely spaced farm complexes and residences.

The Pratt truss has parallel chords, posts in compression and diagonals in tension. The Warren truss is characterized by parallel chords and diagonal members which function in both tension and compression. All members of the bridge are of cast iron, wrought iron, or steel, and are joined with pinned, riveted, or threaded connections.

The Pratt truss measures 24' high, 17' wide, and 152' long overall. The truss consists of seven panels, each 21' 5" long (Figure 3). Inclined end posts, top chords, and intermediate posts are riveted steel tubular members of a patented design known as a "Phoenix column." The Phoenix column is circular in section, typically consisting of between four and twelve rolled channels with radially deformed webs, joined with rivets every 6" along the out-turned flanges. The end posts and top chords consist of six channels joined to form a column 12-5/16" in outside diameter with a 5/8" wall thickness (Kidder 1908:485). The intermediate posts consist of four channels joined to form a column 6-13/16" in outside diameter with a 3/8" wall thickness (Kidder 1908:484). The ends of the columns are equipped with cast iron "joint-blocks" which accept pins to interconnect the other structural members of the bridge. The truss is carried by cast iron pedestals into which the end posts are socketed, which in turn rest on plate-and-roller and fixed-plate bearings.

Bottom chords are die-forged eyebars varying in size and number. Panels one and two have paired eyebars measuring 1-3/8" x 5". Panel three has a total of four eyebars, a pair measuring 1-3/8" x 5" and a pair measuring 1" x 4". The center panel has four eyebars, all measuring 1-3/8" x 5". Diagonal panel braces are of several types and sizes. The second panel diagonals consist of paired die-forged eyebars, 5" x 1-7/16". The third panel diagonals consist of paired die-forged eyebars, 4" x 1", and paired counters, 1-1/8" in diameter with upset threaded ends

and 7/8" square loop-nuts. The center panel diagonals consist of opposing paired counters, 1-3/4" in diameter, with upset threaded ends and 7/8" square loop-nuts. Hip-verticals consist of two die-forged bars measuring 3-1/2" x 7/8". Bottom chord pins and top and bottom end post pins are 4-5/16" in diameter. Intermediate top chord pins are 3-5/16" in diameter.

Upper and lower portal struts, and upper lateral struts are four-section Phoenix columns, 4" in diameter. Portal sway braces connecting the upper and lower portal struts consist of opposing paired rods, 1" in diameter with upset threaded ends and 7/8" square loop-nuts. The lower strut is further braced with a curved cast iron corner bracket decorated with pierced work consisting of a central quatrefoil flanked by two trefoils. Upper lateral bracing rods are 1" in diameter with threaded ends which pass through the cast iron post cap and are secured with nuts. Intermediate sway braces are 3" angles.

The floor beams are riveted I-beams, 36" x 12-3/8", suspended from the bottom chord pins by two 1-1/2" beam hangers. Two riveted I-beam floor stringers measuring 24-1/4" x 12-5/8" are riveted to the webs of the floor beams with angles. The stringers are spaced 4' to either side of the center of the beam. Rolled I-beam floor joists are carried by the stringers, perpendicular to the axis of the bridge. The joists measure 10" x 5-3/4" and are spaced approximately 18" on center. Bottom lateral braces are 1-3/8" diameter rods with upset threaded ends which pass through the ends of the floor beams and attach with hex-nuts. At the end posts, the bottom laterals pass through the cast iron pedestal and attach with hex-nuts.

The Warren truss deck span measures 6' high, 10' wide, and 75' long overall with eleven panels, each 6' 9" wide. The top and bottom chords are riveted T-sections, 12" x 12-3/4", constructed with 12" x 13/16" plate and two 6" x 4-3/8" angles. The diagonals are of three types: riveted T-sections built with two 3" angles measuring 3" x 6" overall; riveted T-sections built with two 3" x 5" angles measuring 5" x 6" overall; and starred angle sections built with four 3" x 5" angles measuring 6" x 10" overall. Sway bracing consists of 4" x 3" angles. Floor joists rest directly on the top chord and consist of rolled I-beams measuring 10" x 5-3/4" and 8" x 5-1/4".

The bridge decking runs lengthwise and consists of 4" x 10" pressure-treated wood planks, coated with asphalt and attached to the stringers with carriage bolts and deck clips. The roadway is 11' 5" wide and edged with 4" x 6" wood curbing raised 4" off the decking with wood blocks spaced approximately 4' on center. The bridge railings consist of a single horizonal angle, 6" x 3-1/2", supported by angle posts spaced 6' apart.

Two stone piers approximately 30' high support the Pratt truss and the east end of the Warren truss. The piers are constructed of coursed ashlar masonry with protruding rock-faced quoins on alternate courses. The piers are battered and capped with a rock-faced coping. An additional concrete cap approximately 2' high has been cast on top of the piers. The west side of the west

pier has a notched bridge seat, 12' wide, 4' high, and 2' deep, which accepts the Warren truss so that its top deck sits flush with the floor of the Pratt truss. The west end of the Warren truss rests on a straight concrete abutment and meets the breast wall of a second U-type concrete abutment which carries the concrete slab approach. Beveled wing walls constructed of random rubble masonry extend out approximately 20' to each side of the west approach abutment. The east abutment is a concrete U-type abutment cast against the east pier and carries the east concrete slab approach.

A cast iron bridge company name plaque, approximately 12' wide and 14" high, is bolted to the top center of the upper portal strut and reads:

BUILT BY
THE PHOENIX BRIDGE CO. PHOENIXVILLE, PA.

The plaque is richly decorated with classical motifs including a scrolled center pediment, embossed with entwining acanthus leaves and blossoms and capped with an anthemion. Roman poppy rosettes are spaced across the top of the plaque to the corners and support a square bar. The ends of the plaque feature acroteria mounted on a pair of scrolled consoles, set perpendicular to each other to form a corner. A cast iron date-of-construction plate, approximately 3' wide and 10" high, is bolted to the upper strut and hangs directly below the name plaque. The plate reads "1887" and features ogee curves and scrollwork. Palladian finials of the urn, candlestick, and ball type surmount the end posts of the bridge, and decorative cast iron braces, previously described, enframe the portal.

HISTORICAL INFORMATION

Background

Settlers established plantations in the James River and lower Craig Creek valleys of Botetourt County beginning in the middle of the eighteenth century, exploiting the flat bottomland of the valleys for agricultural purposes and the woodland of the adjacent mountains for building materials, fuel, and game. Valley products, including pig iron, forged iron, lumber, and farm produce, were shipped down the James River on flatboats. During the late eighteenth and early nineteenth centuries, turnpikes began to link the area with new markets, and in the 1840s and 1850s, the James River and Kanawha Canal emerged as part of a broad plan to improve transportation in the area. Projected to extend between Richmond and Covington, the canal was completed as far as Buchanan in 1851 (Corron 1971:1; Dixon 1991:3; Historical Marker-Buchanan; Morton 1923:58-60).

The Anderson and Beale families were among the first to settle in the valley at the junction of the James River and Craig Creek (Hensley 1979:15; Wood 1821). After the canal was opened to Buchanan, planters in the area gained access to a larger market and needed only to transport their produce 24 miles down the James River to reach the canal basin. By 1864, the number of farms in the area increased, and new families, including the Pettigrews, Wilsons, and Eagles, had moved to the area to join the Andersons (Confederate Engineer Bureau 1864).

After the Civil War, the James River and Kanawha Canal could not generate the financial backing needed to complete the project from Buchanan to Covington as originally planned. Railroads developed rapidly during this period, and quickly eclipsed canals as the primary means of public transportation. The Chesapeake and Ohio Railroad, formerly the Virginia Central, was extended to Covington, about 14 miles northwest of the junction of the James River and Craig Creek, in 1867 (Dixon 1991:3; Morton 1923:61). Railroad expansion took another leap in 1881 when the Richmond and Alleghany (R&A) Company acquired the James River and Kanawha Canal and, utilizing the towpath for a roadbed for much of the line, built a railway along the east bank of the James River from Richmond to Clifton Forge. This route, with its steady downward grade of less than 5' per mile toward Richmond, rapidly became an important freight-carrying line (Morton 1923:62).

Planning for westward expansion, the Richmond and Alleghany contracted with the Ohio Central Railroad and the Atlantic and Northwestern Railway of West Virginia for a route passing through Charleston, West Virginia, and crossing the Ohio River. The projected route was to connect with the R&A main line at the junction of the James River and Craig Creek, travel up Craig Creek valley, cross to the New River, and follow that river valley to Charleston. The plans, which would have made the Richmond & Alleghany a major competitor to the Chesapeake and Ohio, faltered during the depression of 1883. They were instead partially acted upon by the Craig Company, a corporation which formed in 1884, with the intent to build a line up Craig Creek to New Castle in order to access the iron deposits of the valley (Botetourt County Deed Book 46:445; Dixon 1991:3).

The Craig Company was made up of a collection of entrepreneurs experienced in the promotion of mining, iron production, and railroading. Some of the members included Edward Dillon, a Botetourt resident active in county development; W.A. Glascow, promoter of the town of Glascow; Samuel Coit of Hartford, Connecticut, a promoter of mining lands and member of the C&O Railway Company; H.C. Parsons, another member of the C&O; and Joseph R. Anderson, president of the Tredegar Iron Works in Richmond, which owned and operated the furnaces in Buena Vista and Clifton Forge. Several members of the Craig Company were from Ohio and West Virginia and probably also had C&O connections (Hensley 1979:14-15). The Craig Company contracted with the C&O to build a railroad up the Craig Valley and began construction on the roadbed during the fall of 1889 (Botetourt County Deed Book 46:445-449).

Between 1889 and 1890, the main line of the Richmond & Alleghany Railroad was sold and reorganized as the James River Division of the C&O (Morton 1923:62). In June 1890, the Craig Company, C.W. Howard, and W.Y. Sears agreed to convey all of their rights-of-way for the railroad up the Craig Valley to the Chesapeake and Ohio Railway Company. The C&O in return provided the funding needed to finish constructing the railroad to a point within three quarters of a mile of the courthouse in New Castle, Craig County. The Craig Company, C.W. Howard, and W.Y. Sears agreed to perform the grading, masonry, and timber work; furnish ties; and lay and surface the track. Howard and Sears were responsible for building an iron furnace with a minimum capacity of 75 tons per day on the line, and the C&O agreed to select locations and build depots. The entire project, called the Craig Valley Branch of the C&O Railroad, was projected to be completed by March 1, 1891 (Botetourt County Deed Book 46:445-449).

The railroads brought agricultural prosperity and an industrial-based boom to the entire Shenandoah Valley in the 1880s and 1890s, and prompted a wave of speculation that resulted in the establishment of new towns and industries (Hensley 1979:14). The village of Eagle Rock, located on the main line of the James River Division of the C&O at the base of Rathole Mountain, was one manifestation of this boom. In 1891, the Moore Lime Company, which quarried and sold high-quality limestone to local iron furnaces for flux, expanded its production capacity, and built a large storehouse at Eagle Rock. These improvements were followed by the construction of a millinery store by the Messrs. Meyers (*Fincastle Herald* 1891). By 1895, several stores and other businesses, three churches, and numerous dwellings had been built at Eagle Rock. This expansion was largely due to the success of the Moore Lime Company works (*Fincastle Herald* 1895).

The Craig Valley Company, a land development group incorporated on September 23, 1890, laid out the town of Bessemer in November 1890 (Botetourt County Charter Book 1:67; Botetourt County Deed Book 47:363). L.B. Jackson of Cincinnati, president of the Craig Valley Company, purchased five farms near Eagle Rock and at the junction of the James River and Craig Creek during the week before the company was incorporated. Located on the west side of the James River and the north side of Craig Creek opposite Eagle Rock, Bessemer was optimally sited to take advantage of the new railroad and the iron deposits of the valley. The town plan was laid out over part of a 200-acre farm which had been operated by James G. Whitten since 1876. In agreements with L.B. Jackson, Whitten reserved a 4-acre lot containing his dwelling house, located on the north side of the Craig Valley Line between Main Street, Twelfth, and Thirteenth streets in the town (Botetourt County Deed Book 47:47, 144, 363). The C&O station at Bessemer was later named Whitten (Botetourt County Deed Book 51:180; USGS 1913).

The C&O Railway Company originally planned to run the Craig Valley Branch along the south side of Craig Creek, but in November 1890 the company agreed to change the location of the

right-of-way so that it would cross the James River at a point north of the confluence with Craig Creek. From the James River bridge, the railroad ran straight through the planned town of Bessemer, crossed Craig Creek at the western end of town, and continued 26-1/2 miles up the valley to New Castle. As part of the agreement to relocate the branch line, the C&O built a trimodal truss bridge over the James River, which carried C&O mining trains through the middle; carriages, wagons, and later automobiles over one cantilever; and pedestrians over another cantilever on the opposite side (Botetourt County Deed Book 51:180; Hensley 1979:16). It was hoped that this bridge would promote exchange between Eagle Rock and Bessemer and that the two towns would one day unite (*Fincastle Herald* 1891).

The Craig Valley Branch of the C&O, which extended 26-1/2 miles from Eagle Rock on the James River Division to New Castle in Craig County, opened for service on August 24, 1891. The line was built by convict labor, and when the work was completed, the C&O held a banquet for the laborers and the local people. By September 1891, the town of Bessemer was actively growing. John Pettigrew, a former farmer in the area, had opened a store; William Pettigrew was managing a brick and tile company; a seat and body factory was preparing to begin production; a large saw and planing mill was under construction; and the depot was nearing completion (Dixon 1991:2; *Fincastle Herald* 1891; Hughes n.d.). By the end of October, 147 town lots had been sold. The high rate of lot sales in Bessemer dropped during the panic of 1893, and the town never reached the population hoped for by the founders. The depot at Bessemer was closed in 1899, and attention focused on the station at Eagle Rock, less than one mile away. In 1906, the peak year of the Craig Valley Branch, Bessemer supported 26 inhabitants (Dixon 1991:4; Hensley 1979:16, 26).

The Craig Valley Branch, also known as the Craig Mineral Railroad, was laid with light rail, light bridges, and supported light power. Two trains initially operated on the line: a passenger train from Craig City to Bessemer in the morning, returning in the evening, and a mixed freight and passenger train from Bessemer in the mid-morning, returning from Craig City in the mid-afternoon. In 1905, three trains covered the line, including two passenger and one freight daily. At this time, the maximum speed established for passenger trains was 25 miles per hour, and the maximum speed for mixed and freight trains was 20 miles per hour (Dixon 1991:3-5).

The iron mines at Oriskany, 15 miles up the Craig Valley Branch from Bessemer, became the most highly productive in the state, producing 1,000,000 tons of ore at a rate of 400 tons per day. The mines at Barbour's Creek, 21 miles up the branch, also became tremendously productive and by 1923 had produced a total of 938,560 tons of ore. In 1923, service on the Craig Valley Branch was increased to six trains daily, but this service was cut back to two sets of trains per day in 1927 (Dixon 1991:3; Hensley 1979:26).

Business on the Craig Valley Branch was directly linked to the success of the iron operations along its route, and when the iron mines began to close in 1926, the line began to experience

serious financial trouble. In October 1933, the C&O sought permission to abandon the line completely, but the application was denied due to strenuous local opposition. In April 1947 and December 1951, the railway was granted permission to discontinue the stations at Oriskany and Barbour's Creek. Between 1954 and 1958, a freight-only train operated twice a week, primarily carrying timber products, and after 1958, only once a week. The C&O applied to the state and federal governments for permission to abandon the line on December 15, 1958, after the company had figured a loss of $53,474.97 on the year. This request was granted, and the rails were taken up in 1961 (Beasley & Beasley 1961:14; Dixon 1991:4-5).

A plat of the town of Bessemer, filed at the Botetourt County Courthouse on November 19, 1890, records the original right-of-way of the Craig Valley Branch through Bessemer. The railroad used this route continuously from its opening day, August 24, 1891, until it closed operations in August 1961 (Botetourt County Deed Book 47:363; Botetourt County Tax Maps 1993; Dixon 1991:2).

History of Phoenix Bridge

Phoenix Bridge was formerly a railroad bridge known as Bridge No. 13 on the Craig Valley Line of the Chesapeake and Ohio Railroad. The bridge, located at the west end of the town of Bessemer, was the second railroad bridge built across Craig Creek at this site. The precursor to this bridge, probably a light iron structure, was built between November 1890 and August 24, 1891, the day the line was completed and opened for traffic (Botetourt County Deed Book 47:363; C&O Railway Company 1902:20; Dixon 1991:2). The existing bridge was moved to the site in 1903 by the C&O as part of a large-scale program to replace the light iron bridges and wooden trestles with heavy steel bridges (Beasley & Beasley 1961:44; C&O Railway Company 1902:20; Dixon 1991:6).

The bridge is composed of two distinctive spans, a 150' through pin truss fabricated in 1886-1887 by the Phoenix Bridge Company of Phoenixville, Pennsylvania, and a 70' 4" Warren deck truss built in 1888 (bridge plate; C&O Railway Company, Office of Bridge Engineer 1960).

Bridge No. 13 (Phoenix Bridge) over Craig Creek was one of many 150' through truss bridges fabricated by the Phoenix Bridge Company for the C&O Railway Company. Two trusses identical to the one over Craig Creek were built across the Little Sandy River on the Maysville & Big Sandy Railroad in Kentucky in 1886, and another identical truss was ereeted on the same line over Tygart Creek in 1886 (*General Plan for 2 150'-0" S. Tr. Thro' Spans — Little Sandy* 1886; Thomas Dixon, personal communication 1994). The existence of identieal bridges at other places on the C&O system makes it difficult to determine where Bridge No. 13 (Phoenix Bridge) originally stood before it was moved to the present location in 1903. It may have been

relocated to the Craig Valley Branch from the Maysville & Big Sandy line in Kentucky, but it could just as likely have been moved from somewhere else on the C&O system.

During the early and mid-twentieth century, the C&O Railway Company numbered the bridges on its lines using a system described in the Office of Bridge Engineer's Bridge Book (C&O Railway Company, Office of Bridge Engineer 1960; USGS 1913). According to this system, the number assigned to a bridge was derived from the position of the structure in relation to its mile post. Mile posts on the Craig Valley Branch were calculated beginning at the junction of the branch with the main line at Eagle Rock. Bridge No. 13, the third bridge on the line, was located at Mile Post (M.P.) 1.3.

Bridge No. 3, the first bridge on the Craig Valley Branch, passed over the James River, and Bridge No. 06, the second bridge, crossed Eleventh Street in the town of Bessemer. Bridge No. 13, the third on the line, crossed Craig Creek at Whitten. Moving west from No. 13, the bridges on the line included No. 66, the second over Craig Creek; No. 71, over a public road; No. 92, at Hipes (the third over Craig Creek); No. 135, at Ruble (the fourth over Craig Creek); No. 208, across Mill Creek; and No. 221, over Barbours Creek (C&O Railway Company, Chief Engineer's Office 1950; C&O Railway Company, Office of Bridge Engineer 1960).

Light steam engines operated on the Craig Valley Branch until January 1951, when the C&O authorized the expenditure of $18,700 for the strengthening of five bridges on the Craig Valley Subdivision, including Bridge No. 13, to permit the operation of heavier diesel locomotives. It was estimated that switching from steam to diesel power would reduce the annual cost of operation and maintenance by $37,225, and allow the company to save an additional $5,000 by retiring the water tank at New Castle. The annual cost of operating a diesel locomotive came to approximately one third of the cost of operating a steam locomotive. Converting to diesel also eliminated the need to implement costly fire prevention measures such as cutting and burning brush on the right-of-way and scheduling section forces to follow steam locomotives for the purpose of extinguishing fires. The strengthening of Bridge No. 13 to support diesel locomotives required adding 4,100 pounds of structural steel, cutting out and re-driving rivets, drilling holes to drive rivets, and removing and replacing ties. The total cost of the work was estimated at $3,600 (Nuckols 1951).

After the railway was abandoned in the late 1950s, the Virginia State Highway Department expressed interest in acquiring the right-of-way and structures for the branch. In 1961, the C&O Railway Company hired Beasley & Beasley, a firm of consulting engineers based in Washington, D.C., to estimate the value of the railroad property, including the right-of-way and the structures, for the purposes of sale (Dixon 1991:6). In the resulting valuation report, the total value of Bridge No. 13 (Phoenix Bridge), including superstructure and substructure, was estimated at $32,895 (Beasley & Beasley 1961:44-45). After the Craig Valley Branch right-of-way was sold to the Virginia State Highway Department in 1961, the railroad tracks were taken

up. Bridge No. 13 was subsequently converted to a highway bridge in August 1963 by "state forces" (VDOT 1970).

A bridge inspection conducted by the Salem District Bridge Engineer of the Virginia Department of Transportation in 1970 found the bridge nearly devoid of all paint, as it is today. The inspection report states that "although practically all metal is bare there is very little rust scale indicating the metal is a rust resistant type (wrought iron)" (VDOT 1970).

On February 18, 1975, the "Phoenix Bridge" was entered into the Virginia Landmarks Register, and on April 15, 1978, into the National Register of Historic Places.

Thomas Pratt and the Pratt Truss

Thomas Pratt was born in Boston in 1812, entered Rensselaer Polytechnic Institute at age 14, became an engineer with the United States Army Engineers at 18, and began a professional engineering career with Boston & Maine Railroad at age 21. Pratt worked his entire life in the employ of various New England railroad companies (American Society of Civil Engineers [ASCE] 1876:332-333; Condit 1960:108).

Pratt is famous for a bridge truss he designed in 1842 that consisted of two parallel chords connected by vertical wood posts in compression and double wrought iron diagonals in tension. Pratt's design was similar in appearance to an earlier truss patented by William Howe, but functioned structurally opposite. The Howe design put the verticals in tension and the diagonals in compression. The Pratt truss is considered to be the first scientifically designed truss, incorporating what are now considered basic structural engineering principles (Condit 1960: 109). Pratt used shorter compression members, allowing members of smaller cross section to be used without sacrificing overall strength. This innovation provided a lighter truss requiring less materials, yet offered greater span and load-bearing capability than the other truss designs of the time.

In 1844, Pratt was granted a patent for two truss designs, one with parallel chords and one with a polygonal top chord. The polygonal version reflected Pratt's understanding of the application of mathematical principles in calculating the forces involved and the precise strength of material required to counter those forces. Pratt's patent was renewed in 1858. The use of the Pratt truss for the deck of John Roebling's Niagara River Suspension Bridge in 1855 drew worldwide attention to the design and undoubtedly contributed to its increased use. By 1889, the truss in its iron form ranked first in usage for railroad bridges. Thousands of bridges, both highway and railroad have been built following the Pratt design or some variation (ASCE 1876:334-335; Condit 1960:111, 112, 302; Cooper 1889:11; Johnson 1929:179).

The Warren Truss

The Warren truss was designed in England by James Warren and Theobald Monzani in 1848. Their intention was to create the simplest possible truss, composed of members of equal length and dimension, allowing economy in its manufacture and assembly. In its original form, the Warren truss is composed of a series of connected equilateral triangles, with the diagonals functioning alternately in compression or tension. All loads on the truss produce a compressive stress in the top chord, a tensile stress in the bottom chord, and stresses equal in magnitude but opposite in sign in adjoining web members (diagonals). Although not a specific claim of the inventors, the design permitted easy calculation of the stresses involved and would become the standard textbook example on the subject (Condit 1960:117, 118; DuBois 1900:54; Ketchum 1905:65, 66).

The greatest contribution of Warren and Monzani, however, was their introduction of a concept that fifty years later would become the universally accepted "first principle" of structural engineering: simplicity is the highest attribute of good design. According to J.A.L. Waddell, a noted bridge authority at the turn of the century, "other things being equal, that design which is the most simple, or contains the fewest parts, or involves the easiest connections, is the one which will be preferred by competent judges" (Waddell 1900:13). The utility of the practical characteristics of the truss and its attractive simplicity have made it the most widely used and modified truss form.

Phoenix Bridge Company, Phoenixville, Pennsylvania

The Phoenix Bridge Company was one of the most important bridge companies in the United States in the late nineteenth and early twentieth centuries. The firm made significant contributions to the art and engineering of bridges including a compression member of rolled wrought iron patented as the "Phoenix Column," 1862; hydraulically upset forged eyebars, 1866; and the first published bridge specifications, 1871. These specifications served as a model for a multitude of other specifications that followed (American Railway Engineering and Maintenance of Way Association 1905:202; Clarke, Reeves and Company 1871:n.p.; Phoenix Bridge Company 1888:21).

The firm was distinguished as one of the first to build and use a hydraulic testing machine capable of stressing full-size bridge members to failure. This machine had a capacity of 1,080 tons and was capable of crushing large cast iron columns and pulling apart eyebars measuring 12" x 3" in section (*Engineering News* 1898:214). Phoenix's lead in materials testing led other companies to follow suit, resulting in the rapid acceptance of steel over wrought iron as a superior material for bridge building.

The firm began in 1790 as a rolling mill and nail factory, located on both sides of French Creek near its mouth at the Schuylkill River. The firm was known as the French-Creek Works, and later as the Phoenix Works (*Engineering News* 1898:214). The works went through several enlargements including the addition of a large rolling mill in 1846 for the production of "railway iron." Phoenix Works claimed to have produced "much of the railway iron that was used in the construction of the pioneer railroads of this country" (Phoenix Bridge Company 1888:21). The "Works" was incorporated in 1855 as the Phoenix Iron Company and by 1860 was one of, if not the, largest iron manufacturer in America. During the Civil War, Phoenix manufactured hundreds of wrought iron field artillery pieces. Another major expansion of the 30-acre plant was undertaken in 1870 when a new milling building covering 6.5 acres was erected, as well as numerous smaller buildings (Phoenix Bridge Company 1888:22).

Aldophus Bonzano (1830-1913) was Chief Engineer of the Phoenix Bridge Company from 1868 to 1892. Prior to joining Phoenix, he was Superintendent of Bridge Construction with Detroit Bridge and Iron Works. In 1868, he joined in a partnership with Thomas C. Clarke and David Reeves of Clarke, Reeves and Company, Philadelphia, as Vice President and Chief Engineer and formed Phoenix Bridge Works to work in conjunction with the Phoenix Iron Company. He remained with Phoenix Bridge Works until 1892 when he left to join Thomas C. Clarke as a partner in his New York City engineering consulting firm. Bonzano continually pushed the limits of bridge design and deserves a large share of the credit for the growth and success of the company during his tenure. Among the many important bridges he is noted for are the Girard Avenue Bridge, Philadelphia, 1874; the Chesapeake and Ohio Railroad bridge at Cincinnati, 1888, the longest truss span at the time; and the Atlantic and Pacific Railway's Red Rock Cantilever Bridge over the Colorado River, 1889 (ASCE 1972:14; Waddell 1916:598).

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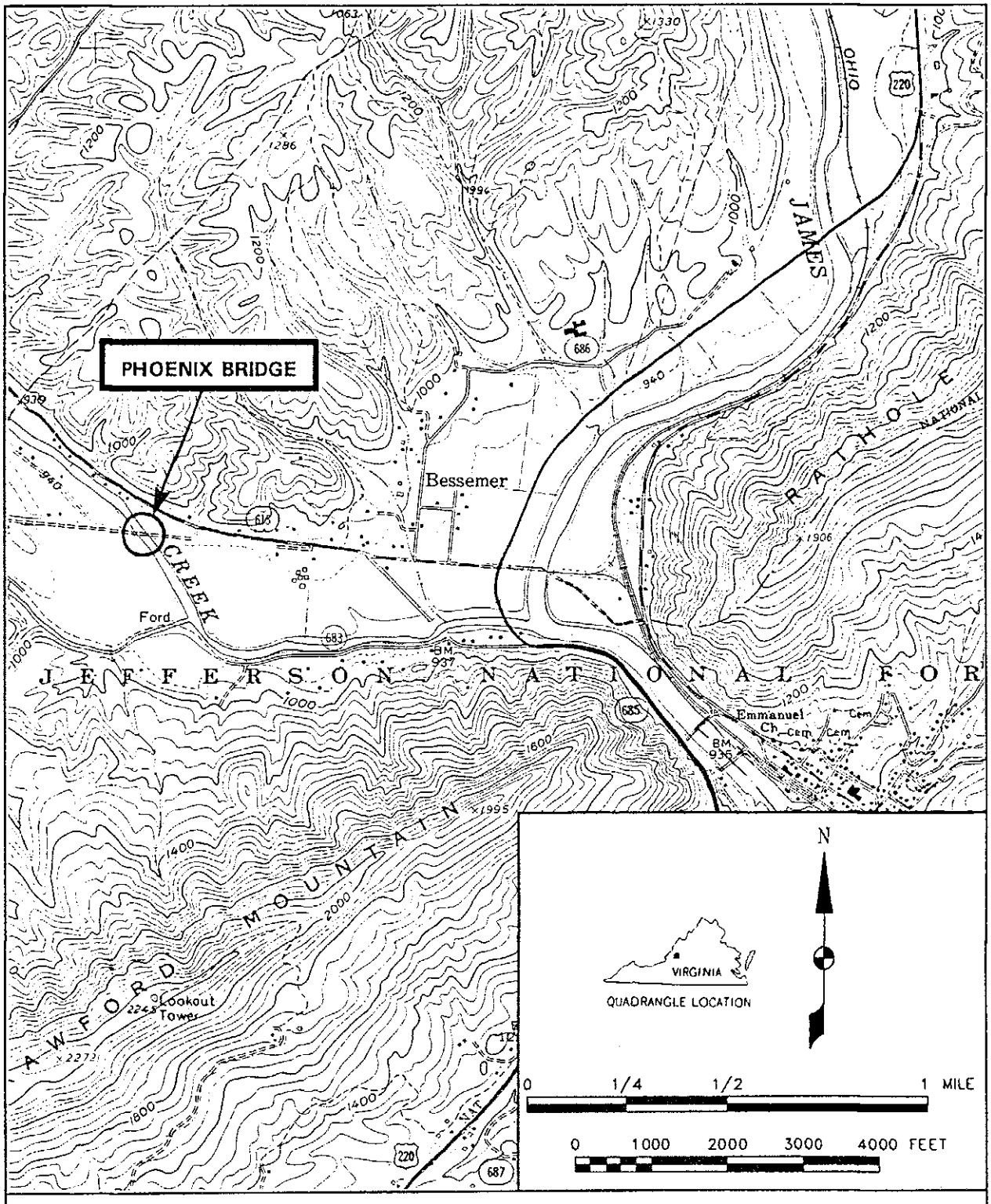

FIGURE 1: Location Map

SOURCE: USGS 7.5 Minute Quadrangle, Eagle Rock, VA, 1962 (Photorevised 1985)

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SOURCE: Virginia Department of Transportation 1970

FIGURE 2: Original Bridge Report, Bridge No. 6386, November 13, 1970

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FIGURE 3: Original Bridge Report, Bridge No. 6386, November 13, 1970 *SOURCE: Virginia Department of Transportation 1970*