The Industrial Archaeology Study of Vermont: 1978-1993

By Victor R. Rolando

On May 29, 1974, the Vermont Division for Historic Sites prepared nomination forms to place the Forest Dale iron furnace property at Brandon on the National Register of Historic Places. It was the first industrial site to receive that recognition in the state, but it was only a harbinger of the flood of industrial archaeology (IA) sites that would follow it into the State Archeological Inventory (SAI). Four years later, when the author was preparing to present a paper at the 1978 fall meeting of the Vermont Archaeological Society, the scope of Vermont's IA resources slowly started to unfold. He was at the time studying ironworks in New York State for his MA thesis at The College of Saint Rose, and this initial field and archival work not only inspired him to change his research area of interest to Vermont, but eventually led to his continuing well beyond the original scope of that 1980 thesis to include sites pertaining to charcoal and lime burning.

This 15-year effort resulted in identifying 99 sites relating to ironworks, 71 sites relating to charcoal burning, and 118 sites relating to lime burning, all in 95 towns across 13 of the state's 14 counties. Although these 288 sites were active from 1666 to 1971, a majority only operated for the past 200 years, thus the title of *200 Years of Soot and Sweat: The History and Archeology of Vermont's Iron, Charcoal, and Lime Industries* from which this paper is drawn (Rolando 1992).

Introduction

For most people, the name "Vermont" is synonymous with a rolling landscape of cultivated fields and forests punctuated by small villages complete with town hall, church, general store, and white clapboard homes. Because of this popular image, we tend to overlook the fact that Vermont has been a national leader in the production of iron, copper, slate, marble, and granite, and the manufacture of farm machines and machine tools; and that in the 19th century, most towns had at least one mill or factory and often more.

Among the typical industries were mills engaged in manufacturing iron, either working ore into wrought iron at small bloomery forges, or smelting ore into cast iron in tall blast furnaces. These early forges dotted banks of swift-running streams and rivers, answering the needs of Vermont settlers. Associated with ironmaking was the need for charcoal to fuel the forges and furnaces. Initially made in mounds, charcoal kilns evolved into round stone structures and eventually into red-bricked kilns. By the 1880s, hundreds of these kilns were reducing Green Mountain forests into black charcoal for ironworks inside and outside Vermont. Less well-known than rural furnaces, lime kilns also dotted the early countryside, capitalizing on the agricultural and industrial need for burned lime and the availability of limestone. Hundreds of these ruins lie in varying degrees of abandon up and down the eastern and western slopes of the Green Mountains, mystifying those who happen upon them in obscure corners of the forest, sometimes prompting speculation of prehistoric or exotic origins. Some tower dozens of feet upward; others display mere foundation walls. They range in shape from square to rectangular to oval. They are near waterways in broad valleys or high up in the mountains. Some are single ruins; some are clusters of ruins. Most are made of native Vermont stone. Some are made partially or wholly of brick. They are seemingly unconnected with the traditional concept of Vermont history.

All ruins were found to be fragile. Walls of fully and partially standing furnaces and kilns can collapse without warning on anyone exploring them, crushing a person under tons of rock and brick. Stone ruins are especially precarious in springtime when the melting winter ice can cause the collapse of numbers of large, heavy stones and possibly whole sections of wall.

Finding IA sites in the field was not easy, even with good

Plate 1. *Circle of blackened brick identifies the site of one of the four brick-type charcoal kiln ruins in Winhall, adjacent to the Long Trail. The site is a walk of about five minutes north of Route 30. The trail here is very black with charcoal run-off from the ruins. Photo by the author, 1982.*

reference material. The best time of year for field work was before or after foliage season, although each was not without its hazards. In mid-spring there was still cold surface water and mud to be dealt with, and snow and ice at higher elevations. In the post-foliage season, shot and arrows were flying about, and some of the smaller ruins and features were obscured by fallen leaves.

Information regarding site location came mainly from maps, archival material, and informants. A few sites were found by chance. Three series of maps were used to determine site location and time period: the 1796 to 1838 James Whitelaw maps of Vermont, the 1854 to 1859 series county wall maps, and the 1869 to 1878 series Beers county atlases. The Whitelaw maps used the symbol o ("iron" in alchemy) to indicate ironmaking sites without differentiating between forges and blast furnaces. The county wall maps and Beers maps identify bloomeries and furnaces by owner or company name, and display foundries, machine shops, mines and ore beds, raceways, dams, a few charcoal kilns ("coal kilns") and lime kilns.

Inspection of aerial photos for charcoal kiln ruins was tried at the Vermont Mapping Program at Waterbury with no success. The photos were 1:1250- to 1:5000-scale orthophotos taken at about 30,000 feet (1 inch of orthophoto equals about 416 feet on the ground). After spending hours squinting through a magnifying glass at dozens of these 3-foot-square black-and-white photos and then days field-checking some possibilities, the only sites confirmed were those already known. Kiln ruins measure less than 1/16th inch in diameter in the orthophoto and look like tiny moon craters. It was one thing to know where they exist and find them in the orthophoto; it was another to determine whether that tiny round feature was a kiln ruin or an empty swimming pool (as in Stamford), circular depression (Tinmouth), frozen puddle (Winhall), silo foundation (Panton), or just a pile of manure (Shoreham). (See Plate 1.)

Lime kiln research also utilized geology maps and reports. Charles G. Doll's *Centennial Geologic Map of Vermont* (1961) shows various limestone outcrops, indicating areas of probability for finding limestone quarries, but was not detailed enough to provide specific surface information for finding lime kiln ruins. Of special help were the *Report on the Geology of Vermont* by Hitchcock et al. (1861), the 1899 through 1934 biennial geology reports by George H. Perkins, and the *U.S. Geological Survey Bulletin* on the geology of Vermont dolomite and marble by T. Nelson Dale (1915). The Perkins geology reports provided information on the locations of quality limestone, annual production capacities of lime works, and regional and national trends of the industry. The Dale Bulletin included small detailed maps of quarries discussed in the text, which greatly facilitated the search for lime kiln sites. Informants included friends, property owners, and those who gave directions or shared thoughts on the subject along the way. Some knew only where a suspicious mound of stones was to be found; others knew a furnace or kiln ruin when they saw one and were specific with directions and descriptions. Almost all property

Table 1. Summary of IA Study

County	Ironworks		Charcoal		Lime Kilns		Total	
	Sites	Remains	Sites	Remains	Sites	Remains	Sites	Remains
Addison	32	17	13	12	12	10	57	53
Bennington	13	7	38	83	15	4	66	94
Caledonia	2	-	1	-	1	-	4	-
Chittenden	07	2	1	2	5	5	13	9
Essex	-	-	-	-	-	-	-	-
Franklin	7	2	-	-	9	16	16	18
Grand Isle	1	-	-	-	1	-	2	-
Lamoille	1	-	2	-	5	-	8	-
Orange	1	-	-	-	1	-	2	-
Orleans	2	1	-	-	-	-	2	1
Rutland	2	14	13	69	19	19	59	102
Washington	2	-	1	-	-	-	3	-
Windham	1	1	1	1	16	12	18	14
Windsor	3	1	1	-	34	27	38	28
Total:	99	45	71	181	118	93	288	319

owners and residents were generous with their time and knowledge of where things were and what they knew of them. Many were surprised that anyone was interested at all in "that old pile of stones."

Overall Results of the IA Study

This study resulted in the identification of 288 blast furnace, bloomery forge, foundry, charcoal mound and kiln, and lime kiln sites. Of these, 162 sites yielded 319 ruins or remains, while 30 sites revealed no surface remains; all are now listed in the State Archeological Inventory. The remaining 96 sites have not yet been precisely located and are not yet in the SAI. Many sites are disturbed beyond surface recognition but after further study might be determined to have archaeological value. Sadly, there will remain a significant number of sites that probably will never be found in the field, either due to insufficient archival data or because the sites have been completely destroyed through land development or natural deterioration.

In terms of significant IA materials, the study found ruins or remains of 22 blast furnaces, 18 bloomery forges, 5 foundries, 130 charcoal kilns, 51 charcoal mounds, and 93 lime kilns (see Table 1). The majority of these were built in the 1790s-1860s, which is the generally accepted period of the Industrial Revolution in the United States. These valuable artifacts are, therefore, some of the last physical links between what followed the end of Vermont's pre- industrial era and that which preceded the modern industrial period.

The Ironworks Study

Significant Vermont ironworks commenced a few years after the end of the Revolutionary War and ended a century later. During that period, blast furnaces, bloomery forges, and foundries made or worked iron in all of the state's 14 counties. A majority of the blast furnaces and bloomery forges lay west of the Green Mountains, generally in the valley of the Otter Creek. Because few business records of these industries remain, it is not known for sure where all that iron went. Some iron found markets in local foundries and mills, but most probably ended up in works at Troy, New York, and Boston. Other iron made its way to markets in Quebec (Williamson 1949:142). The ironworks data is the result of archival and field work done mainly from 1978 to 1988. When this project began, the author knew of only two blast furnace sites in Vermont: one at East Bennington with the ruins of two collapsed stacks, and the other at East Dorset. The sites were visited, neighbors were queried, and libraries were visited where card files were inspected for anything relating to the Vermont iron industry.

Trade journals and reports that provided 19th-century operating and production figures and descriptions for forges and foundries throughout the United States were of immense value. Many of these were found only outside Vermont. Also used were 19th-century town and county histories, historical society publications, and U.S. Census reports. Much ambiguity in the historical descriptions of ironworks was encountered.

It would not appear to require a "technique" to locate a 19th-century stone blast furnace. In terms of its massive size, a blast furnace is about the height of a two- or three-story structure. It was usually made of large stone blocks, surrounded by other structures and waterpowered devices, and thus should be in the midst of an acre or so of stone foundations. Some standing blast furnaces were quickly located, but a collapsed furnace resembles no more than a low, brush-covered mound (see Plate 2). It can be as difficult to locate as a fully standing 30- to 40-foot-high stack in the heavily foliated Vermont countryside. The locations of the few obvious blast furnaces, such as Bennington and East Dorset, were verified from the highway. The more difficult ruins resulted in many hours, and sometimes many weekends, of hiking through brush and wading in streams.

Other than the standing blast furnace ruin, a less obvious ironworks artifact is slag, a waste by-product of the iron industry. Good blast furnace slag was usually multicolored with a glassy surface. It shatters easily if struck, and its slivers injure unprotected eyes, hands, and feet. Slag can be shades of blue, green, black and gray. Some glassy blast furnace slag contained pieces of stone, iron, or charcoal. Other slag betrayed its former molten state through ripple marks on the surface or holes left by gas bubbles. Blast furnace slag weighs less than bloomery forge slag. Because the process of making bloomery iron (wrought iron) did not involve the high temperatures of the blast furnace process, bloomery slag did not become glassy or multicolored. The lower bloomery forge temperature also resulted in an incomplete smelting process, resulting in a product that at one end of the bloom was more iron than slag, while at the other end was more slag than iron. Bloomery slag (the waste end of the bloom), therefore, contains much iron; the slag is much heavier and darker than blast furnace slag. Heavy, dark slag will usually indicate the site of a bloomery, and this slag is most often loaded with high levels of iron, unburned charcoal, and bits of stone.

Results of the Ironworks Study

Forty-three ironworks sites were reported during the 1978-1990 state-wide ironworks study period and are in the State Archeological Inventory. Five other sites, for which evidence was inconclusive, have been reported in the field site (FS) category. In-progress research continues at 51 more sites. The total number of ironworks

Table 2. Summary of Ironworks Sites and Remains

County	Sites	Blast Furnace Ruins/Remains	Bloomery Forge Ruins/Remains	Foundry Ruins/Remains
Addison	32	3	10	4
Bennington	13	6	-	1
Caledonia	2	-	-	-
Chittenden	7	-	2	-
Franklin	7	2	-	-
Grand Isle	1	-	-	-
Lamoille	1	-	-	-
Orange	1	-	-	-
Orleans	2	1	-	-
Rutland	27	9	5	-
Washington	2	-	-	-
Windham	1	-	1	-
Windsor	3	1	-	-
Total	99	22	18	5

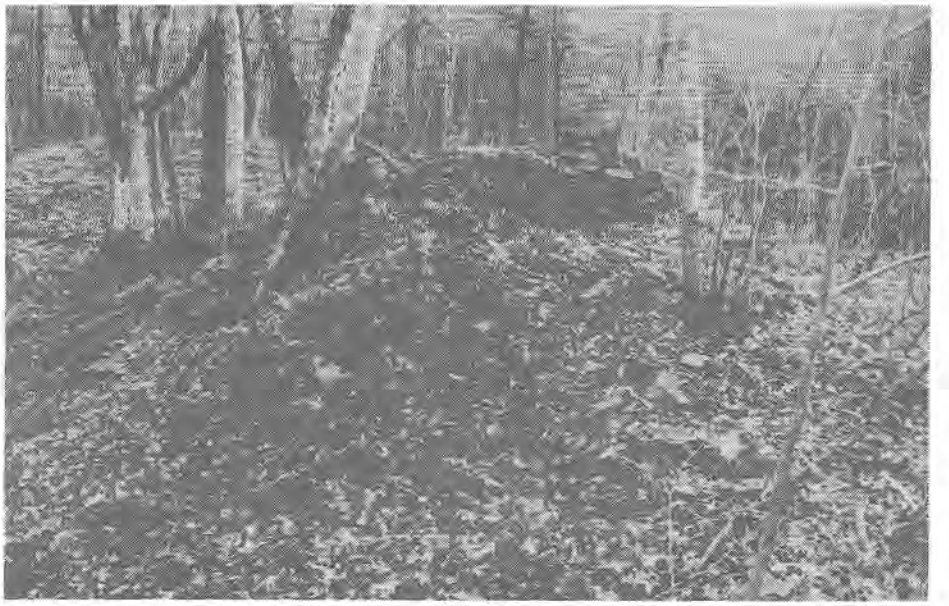

Plate 2. *Mound remains of the Curtis blast furnace at North Dorset, which operated from ca. 1825 to possibly the 1840s. The throat of the furnace is visible, sticking slightly upward through the surrounding mound of collapsed stone walls. Photo by the author, 1982.*

sites studied, which include blast furnaces, bloomery forges, and foundries, is therefore 99. While some sites contained a furnace and/or forge, other sites also contained foundries.

Breakdown of results and distribution of sites and remains by county is presented in Table 2. Ruins/remains include standing or partially collapsed ruins, mound remains, or any visible, identifiable surface evidence such as slag, bits of charcoal, or pieces of brick. A majority of the sites were found in Addison, Bennington, and Rutland counties. The study identified no ironworks in Essex County, although some most likely did operate there.

The sites of 36 blast furnaces and 66 bloomery forges were researched, with furnace ruins or remains found at 22 sites (61 percent) and forge remains found at 18 sites (27 percent). The apparent discrepancy is probably due to a forge's ruin being smaller and easier to raze than a furnace's imposing tower. Three blast furnace ruins were found to be wholly or substantially standing, 6 were partially standing, 3 were mound remains, and 10 were trace

Table 3. Distribution and Types of Blast Furnace Ruins or Remains

County	Fully Standing Ruins	Partially Standing Ruins	Mound Remains	Trace* Remains	No Field Evidence	Total
Addison	-	-	-	3	2	5
Bennington	1	2	1	2	5	11
Caldonia	-	-	-	-	1	1
Franklin	-	-	1	1	2	4
Orange	-	-	-	-	1	1
Orleans	-	1	-	-	-	1
Rutland	2	3	1	3	2	11
Washington	-	-	-	-	1	1
Windsor	-	-	-	1	-	1
Total	3	6	3	10	14	36

* Slag finds only

Table 4. Distribution of Bloomery Forge Ruins and Remains

County	Ruins/Remains	Trace* Remains	No Field Evidence	Unsure of Location	Total
Addison	3	7	15	2	27
Bennington	-	-	2	2	4
Caledonia	-	-	-	1	1
Chittenden	-	2	4	1	7
Franklin	-	-	2	1	3
Grand Isle	-	-	-	1	1
Lamoille	-	9	1	-	1
Orleans	-	-	1	-	1
Rutland	-	5	6	6	17
Washington	-	-	-	1	1
Windham	-	1	-	-	1
Windsor	-	-	1	1	2
Total	3	15	32	16	66

*Slag finds only

surface remains. Except for a partially standing furnace ruin at Troy, 12 furnace ruins and remains were found along the western slopes of the Green Mountains or in the Champlain Valley. Table 3 presents the distribution of blast furnace ruins and remains by county.

Only 18 bloomery forge sites yielded surface evidence. No field evidence was found at 32 sites, and 16 sites have eluded attempts at finding them. Almost all forge sites were along the western slopes of the Green Mountains or in the Champlain Valley. Many more operated at an early time east of the Green Mountains and in the Connecticut River Valley, of which only those at Calais, St. Johnsbury, Cady's Falls (Morristown), and Weathersfield are included in this study. Table 4 presents the distribution of bloomery forge ruins and remains by county.

Fifteen foundries were researched, although this category of ironworks was not a major thrust of the study. Thirteen foundries found to be components of blast furnace and bloomery forge sites plus two others not directly associated were included in the study. Additional foundries associated with 19th-century stove manufacture, a side interest of the author, were also noted, but since stove manufacture was not the mainstream of the ironworks study, these foundries are not included in the Table 2 foundry category.

Study of Charcoal Mounds and Kilns

Charcoal kilns were not always found near waterways, as were ironworks, because waterpower was not required for their operation; but they were sometimes built near sawmills, which did have a need for water. By the 1860-1900 period of major charcoal-making in Vermont, steam-powered sawmills had arrived, and although steam sawmills continued to operate near streams, water now was required only to replace that lost by the boiler in the form of steam. It was a small amount compared to the amount of water previously required to power a large waterwheel or turbine-powered sawmill.

Mounds and kilns were built as close as possible to the source of their wood supply. Rather than build kilns at the foot of the mountain, near flat roads and local transportation, it was determined early on that hauling heavy logs to the kilns should be minimized and effort concentrated on carting the lighter-weight charcoal. Thus, most charcoal mounds and kilns were found at high elevations. Hauling tons of iron reinforcement bands, doors, covers, and other hardware in addition to thousands of bricks up steep mountain roads to build charcoal kilns in the days of non-mechanized transportation must have been a sight.

Brick-type kilns in Vermont were each made from 33,000 to 40,000 bricks, depending on various design

features (Egleston 1879:393). Bricks, therefore, were obviously one of the things to watch for when searching for charcoal kilns. Most of the bricks tended to remain where they have been since collapse of the kiln structure, except for those moved through flood and ice action or bulldozing as part of nearby trail or road maintenance. A number of kilns were built of stone, and probably because stone is available everywhere in Vermont, stone- built kilns are less vandalized than brick ones. Not all charcoal kilns found in Vermont were round or conical. Four ruins found at two sites in Chittenden were rectangular.

In the process of discharging the kilns, and loading and driving the charcoal wagons, much spillage occurred. The closer to the kiln, therefore, the darker the soil. But black soil can also be caused by rotting vegetation. Charcoal does not significantly disintegrate over centuries, otherwise the process of carbon-dating today at prehistoric sites would be impossible. But charcoal can be made by other ways than a prehistoric cooking fire or a charcoal kiln. Finding a burned tree stump beneath some charcoal could indicate evidence of a forest fire. Domestic debris mixed with charcoal could mark the site of a house or barn fire. Camp fires usually leave charcoal. The presence of charcoal, therefore, does not always indicate a charcoal mound or kiln site. Bits of charcoal can be as small as grains of sand. Having accumulated through dozens of years of kiln operation and being light in weight, much charcoal washed downhill from the kiln sites in the past century over the ground, along hiking trails, and onto roads.

Kilns were usually built into 15- to 20-foot-high embankments. A single-kiln site may have a single concave depression cut into the adjacent low hill; an eight-kiln site may have eight such concave depressions. These concave features were sometimes reinforced with 3- to 5-foot-high stone walls. While the kiln was standing, the distance between the concave wall and the kiln wall was 3 to 4 feet, enough space to allow a kiln tender to walk behind the kiln to maintain vent hole operations or repair the kiln walls.

Charcoal remains were characterized either by 3- to 6-foot-high stone walls with vent holes; 1- to 2-foot-high, 28-foot-diameter, blackened brick walls (see Plate 2); circular mounds of blackened bricks or stones; or only a very black circle of ground. The closer the site to public view, a motorized access, or heavily used trails, usually the higher the incidence of trash in the ruin, potholing in the walls, and the fewer ruins to view. Over the years, many ruins have become the source of brick for chimneys and backyard fireplaces of nearby residents.

Searching for the earth-covered mounds (meilers) was more difficult because no bricks or iron hardware were used in their construction, and they were not usually built into embankments as were the structure-type charcoal kilns. Having predated the brick-type kiln, nature had much more time to hide the evidence with more trees to disguise the site, more leaves and soil to cover the burned pitch floor, and more rains and spring thaws to reconfigure the site and scatter charcoal more thinly over a wider area. One clue to a mound site was the presence of lush vegetation. An 1851 agricultural journal noted that the effect of charcoal dust resulted in the "quickening" of vegetation: "The spots where charcoal pits were burned 20, and some say even 30 years since, still produce better corn, wheat, oats, vegetables or grass, than the adjoining lands (Carey 1851:516). The preference of white birch and yellow birch for charcoal-making (and lime-burning) areas was noticed while doing field work. Ground preparation for mound construction in areas liberally covered with surface stones required clearing the area first, resulting in a more dense distribution of stones in the circular area immediately outside the perimeter of the mound site than the area farther out. A shallow, circular ditch, called the "gutter," was dug around the perimeter but outside the mound floor. The gutter and area of stones were good indications of a mound site. Charcoal was made inside the gutter area, and this floor was saturated a foot deep with charcoal and pitch. Charcoal spilled during unloading was also found outside the perimeter. The gutter was more obvious when dry leaves or light snow had blown into it and became trapped in the depression.

The lack of hardware and bricks made finding a charcoal mound site very difficult. Since charcoal mounds took longer to prepare, charge, burn, and discharge than the later brick-constructed kilns, the need for a sawmill to cut wood and keep up with the charring had not yet become a necessity. Wood was cut by axe, so the mounds could be remote from a waterpowered sawmill. During routine surveys of forest tracts for logging potential, mound sites were discovered by U.S. Forest Service personnel high up the slopes of Worth Mountain in Hancock and on Bloodroot Mountain in Chittenden, far from any obvious sawmill site. Sharp-eyed forest rangers first noticed cellar holes at both sites with scattered bits of charcoal nearby. The remains of six charcoal mounds were found in the immediate vicinity at Worth Mountain and 20 by the author at Bloodroot Mountain.

Table 5. Summary of Charcoal-Making Sites and Types of Remains

County	Sites	Brick	Stone	Brick/ Stone	Concrete	Mound
Addison	13	7	-	1	-	18
Bennington	38	53	8	11	-	11
Caledonia	1	-	-	-	-	-
Chittenden1	-	-	-	-	-	2
Orange	2	-	-	-	-	-
Rutland	13	48	1	-	-	20
Washington	1	-	-	-	-	-
Windham	1	-	-	-	1	-
Windsor	1	-	-	-	-	-
Total	71	108	9	12	1	51

Results of the Charcoal Study

Fifty-seven charcoal-making sites were reported during the 1983-1991 state-wide charcoal study and are in the State Archeological Inventory. Forty-two sites contained 130 kiln ruins: 108 were made of brick, 9 of stone, 12 of stone andbrick combined, and 1 of concrete block. Fourteen of the sites contained remains of 51 mounds (one site contained both a brick-type and a mound-type). The data show that 122 were round, 5 were rectangular, 1 was conical, and 2 are unidentified. All except two sites are within the new proclamation boundary of the Green Mountain National Forest; many are on federal property. Two other sites with inconclusive surface evidence were reported in the field site category. Subsurface material from four charcoal kilns and an undetermined number of mound remains might exist at these sites. Archival and field work continues at 12 more sites. A total of 71 charcoal-making sites was studied.

Brick-type ruins were generally laid up in a modified common bond with headers laid every third course. Walls were laid three bricks thick on the stretcher courses and 1 1/2 bricks thick for the header courses, generally measuring 17 1/2 inches thick. Walls and reinforcement hardware supported a vaulting brick roof, compensating for the kiln's heating and cooling cycles that caused the structure to expand and contract slightly with each burning cycle.

In addition to the heavy cast-iron bands that reinforced the brick walls, other hardware found included large front charging doors made of 1/2-inch-thick iron plate bolted together to form one unit measuring up to 6 feet high by 7 feet wide; iron wall binders with end plates; heavy iron lintels that provided a platform across which the iron doors slid; and cast-iron vent hole linings. One kiln site at Ripton contains massive, half-buried iron castings of unknown purpose. Inspection of the few pieces of hardware that survived scrap metal drives at various sites indicates little similarity between hardware designs and dimensions, suggesting that hardware for the kilns was made "on order" at a foundry. Some front charging doors had U-shaped iron handles bolted or welded to them; other handles were a U-shaped section of long iron bars that reinforced the entire height of the door.

Variations in design of round covers that were used for closing the round charging holes in the tops of the kilns were found. These 6- to 7-foot-diameter by 1/2-inch-thick iron covers displayed varieties of vent holes. Some covers had small rectangular holes cut into the cover so the holes could be closed simply by laying bricks on them. One cover found at Peru had four square holes with small, sliding iron doors that could be opened and closed to control the draft allowed to enter the kiln through these top vents. A few covers had no holes at all. Cover handles varied from pairs of U-shaped iron units bolted or welded to the covers to U-shaped sections of long iron bars that reinforced the entire diameters of the covers (similar to variations of handle designs on the large iron doors). Probably because of their round, flat shape, these doors and covers escaped detection by scavengers. Except for their uniquely shaped iron doors, no hardware was found associated with stone-type kiln ruins because their beehive design created a much more stable structure.

All kiln ruins, whether brick- or stone-type, contained vent holes that conveniently allowed the lengthwise insertion of an ordinary red brick to close the hole and control draft. Stone-type kiln ruins used a pair of bricks set lengthwise side by side with another lengthwise brick-size space between them. These were laid over and under with large flat stones. Variations in vent holes were found at two sites of brick-type kiln ruins that had cast-iron vent linings. At one stone-type kiln site, vent hole linings were found made of an unidentified tile material.

Kiln ruins and mound remains were found at elevations of 660 to 2,400 feet. Vermont's lowest elevation, 95 feet, is Lake Champlain; the highest point is Mount Mansfield at 4,393 feet. The average state elevation is approximately 1,000 feet. In the area of the most kiln and mound finds, 12 mountains reach 3,000 to 3,800 feet. Brick-type ruins averaged 1,815 feet with a range of 660 to 2,360 feet. The largest concentration of 59 brick-type ruins was found between 1,500 and 2,000 feet. Stone-type ruins averaged 2,057 feet with a range of 1,560 to 2,400 feet, somewhat higher in elevation than the brick types, but significantly compacted in a tighter range. The largest concentration of 10 stone-type ruins was found at the 2,000- to 2,500-foot level. Mound remains were found at the lower average of 1,336 feet, with a range of 700 to 2,360 feet; there was no significant concentration at any elevation.

The number of kiln ruins indicates that charcoal manufacture was a major 19th- century Vermont industry. The charcoal not only fueled local furnaces, bloomeries, and foundries, but after the demise of the Vermont iron industry in the mid-19th century it found markets throughout New England and New York State. Charcoal also found its way to copper-smelting operations at Strafford and Vershire, iron and brass foundries that dealt with metals requiring special qualities, and glass foundries. A summary of charcoal-making sites and types of remains found in Vermont is presented in Table 5.

Study of Lime Kilns

The study of lime kiln ruins and sites in Vermont started with the inspection of a ruin in Leicester Junction in 1984, where attention was directed by a friend who claimed that large blast furnace ruins were to be seen. Inspection confirmed suspicions that the ruin was that of a lime kiln, but the physical similarities between blast furnaces and some early commercial lime kilns encouraged further archival research and field inspection. The Vermont lime business received minimal recognition in many 19th-century history books, and incredibly little has been written about lime-burning. At best, a few books made a statement or two alluding to lime-burning at some obscure time in the past. Not until recognition of lime as an agricultural additive did lime-burning in Vermont become an industry. While using the T. Nelson Dale geology Bulletin (1915) to find the kiln ruins in the field, it was noticed that some of the descriptions referred specifically to a lime kiln in the vicinity of a quarry. Other references, however, were merely to lime having been burned in the vicinity at one time. Field work resulted in finding ruins at 13 of 14 sites at which lime kilns had been specifically mentioned, but at only 4 of 7 sites at which only vague references were made to lime-burning. It is not known whether Dale could not find some of the kilns or perhaps did not intend to accurately document kiln ruins; the reports were mainly about the geology of the state's marble industry and not about the manufacture of lime. This could mean that lime kilns might have also operated at some of the many marble quarries he discussed (and maybe at some quarries he did not discuss) but at which no mention of lime-burning or lime kilns was made. Information from Dale identified the vicinity of a potential kiln ruin, but it usually took local inquiry and hours of bushwhacking to find it.

Early 19th-century farm-type kilns were usually found near the base of a hill, sometimes just below a limestone outcrop. Attention was paid to ledges and quarries in suspected areas, alongside which these small kilns might have operated. Chance finds were also made, such as noticing Lime Kiln Road in Charlotte while driving up Route 7 one Sunday afternoon, or Arnold Kingsley's directions to a lime kiln in his Whitingham pasture instead of the one being sought (and still not found) farther down the road. Although not a common occurrence, a few kiln ruins were discovered while driving by or just by having glanced in that direction at the right moment. There were many unproductive hikes into pastures and fields to check out suspicious-looking mounds of stones or clumps of white birch.

The use of firebrick differentiated early from later commercial ruins. Large kiln ruins near extensive quarries were obviously not farm kilns but more of a commercial operation; and these ruins, in which the internal lining is made of stone, are in the early commercial (1850s-1900s) category. Those in which firebricks were found are in the later commercial (1870s-1920s) category. The presence of firebrick is taken to indicate a definite techno-

Plate 3. *An early commercial-type lime kiln just south of Cavendish Station, showing the front working arch. Although the entire rear section of the kiln has collapsed, the front section is securely tied together with a system of iron bindings. Photo by the author, 1991.*

logical step forward.

Bricks made great dating tools, and correlating firebrick markings and/or dimensions with firebrick manufacturing data provided valuable kiln-operating dates. Firebrick markings indicated that many came from Troy, New York. A common mark was McL&H CO TROY NY, which was McLeod & Henry Company, manufacturer of stove linings and firebrick, and founded February 1, 1887 (Anderson 1897:313). Other firebricks associated with 1880s to 1920s lime kiln ruins were: H. W. SPEC; BOSTON [FIRE?] BLOCK CO; U.S.A.; and BRANDON VT. On the floor of the razed lime works at Winooski Park are firebricks marked LEHIGH, BESSEMER, POWER, TYRONS, D-TYRONS, and ALUSITE 81. Some of these firebricks are quite large, on the order of a cubic foot. Some red bricks found at many sites were identified DRURY (of Essex Junction); most red brick, however, contained no markings at all.

Another indicator of technological progress at kiln sites was the use of binders to stabilize the stack and keep the stonework together. Common bindings were one-inch-diameter iron rods, threaded at ends that protruded out the walls. The rod ends had large nuts and washers that snugged the binding assembly against the kiln walls. At the Lyman-Martell ruin in New Haven, a double set of bindings across the outside wall of the kiln was reinforced by a flat iron plate bolted to the rods. Nowhere did the strength of the lime kiln binding approach that of binding used at blast furnaces, however, which were much more massive in size.

Kiln ruins ranged from a 20-foot-square stone base with 25-foot-high iron shells to a barely distinguishable grass-covered stone mound in a pasture. The general configuration and character of lime kiln ruins differentiated them from a charcoal kiln or blast furnace, as did the presence of burned lime in the form of a gray-white grainy powder or small, cracked, white stones in the direct vicinity of the kiln ruin. Because the bottom opening in the front wall of the kiln created a built-in weakness, the front walls of many early ruins had collapsed and their stonework slumped outward to the ground, hiding the burned lime in this area and giving the ruin a random stone mound appearance. At Scotch Hill in Fair Haven, moving a few stones from a collapsed front wall during a reinspection of this previously unidentified ruin exposed a hidden archway, confirming its past use as a lime kiln.

Results of the Lime Kiln Study

Seventy-one lime kiln sites were reported during the 1984-1992 overall state-wide lime kiln study period and are in the State Archeological Inventory. These sites contained 93 fully or partially standing ruins or mounds (something visible on the surface). Twenty-nine sites were found within the Green Mountain National Forest new proclamation boundary. Ruins include 71 made of stone, 13 of stone and concrete combination, and 9 of concrete.

Table 6. Distribution of Lime Kiln Sites and Ruins

County	Sites	Types of Ruins: Stone	Stone/ Concrete	Concrete	Total Ruins
Addison	12	3	1+6*	-	10
Bennington	15	4	-	-	4
Caledonia	1	-	-	-	-
Chittenden	5	1	-	4*	4
Franklin	9	8	3+3*	2	16
Grand Isle	1	-	-	-	-
Lamoile	5	-	-	-	-
Orange	1	-	-	-	-
Rutland	19	16	-	3	19
Windham	16	12	-	-	12
Windsor	34	27	-	-	27
Total	118	71	4+9*	5+4*	93

*Contained remains of iron shells

Thirteen stone and/or concrete types displayed remains of their tall iron shells in various stages of deterioration. Forty-three kilns probably operated at one time with iron shells.

An additional 14 sites at which inconclusive or no positive surface evidence was found but subsurface material might exist were also reported in the field site category. Archival and field work continue at 33 more sites. The total number of lime kiln sites studied is 118; over 160 lime kilns are estimated through archival and field work to have operated in Vermont.

Lime kiln ruins were generally found associated with limestone outcrops or quarries. Although the earlier primitive farm-type lime kilns were usually found well away from the nearest farmhouse, almost all commercial-type lime kiln ruins were found near roads, highways, and railroads. Farm-type ruins were the smallest type found; the commercial-type ranged from much larger round shapes to imposing square structures (see Plate 3), some with their rusting iron stacks rising wholly or in part above stone and/or concrete bases. One ruin was found associated with an early-20th-century calcium carbide plant.

Many lime kilns were built of stone from the same quarry where they obtained stone to burn. Concrete kilns and combination stone-and-concrete kilns were usually found associated with firebrick, although two stone-built kiln ruins were also found with firebrick. All combination stone-and-concrete kilns contained iron shells.

Ruins were generally round or square. Some were built into a hillside or slight rise with their front side (the opening side) faced with stone. This stone wall was as high as the kiln and extended to 20 feet on either side to act as a retaining wall, supporting the work area above and around the top of the kiln. Some sites contained up to seven ruins. Fifty sites contained one ruin, made of stone, and mostly of the early-19th-century "pot kiln" variety. The variability in design of lime kilns ranks just behind the variability in design of charcoal kilns. As is the case with charcoal kilns, ruins and remains of lime kilns reflect the various construction materials used, the configurations of the kilns, and the numbers of kilns at each site. Of the 118 lime kiln sites researched, 85 sites were found, and 64 of these yielded 93 ruins. Thirteen ruins still contained remains of their tall iron shells. Thirty-four ruins were found to be internally lined with firebrick. Table 6 presents the distribution of lime kiln sites and types of ruins by county.

The largest concentration of lime kiln ruins was found in Windsor County at Plymouth, where 17 ruins were found adjacent to outcrops of limestone that in the early 19th century were considered to be of exceptional quality.

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