Archeological Perspectives on the Diffusion of Technology: An Example from the Ohio Trap Rock Mine Site

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The Ohio Trap Rock Site is a mid-19th century copper mine in Michigan's Upper Peninsula. Archaeological excavations at the company's stamp mill uncovered portions of the crushing and washing system where copper was concentrated. Residual copper in the stamp-sand sediments preserved buried wooden components of the mill to an exceptional degree, including the remains of two Cornish-style, circular, convex wooden buddles. Circular buddles were the leading edge of ore dressing technology in the 1850s. This technology was not well known in North America, and the Ohio Trap Rock mine provides insight into the diffusion of Cornish copper-processing technology.

Introduction

The Ohio Trap Rock mine operated atop the 410-foot Norwich bluff in Ontonagon County of western Upper Michigan. The Norwich bluff is part of a mineral-bearing range running through the center and south of Michigan's Keweenaw Peninsula (see figure 1). This is one of the few places in the world where large quantities of copper exist in a natural, metallic state, unalloyed with other elements. Prehistoric and historic copper miners worked veins that run parallel to the mineral range and angle down under Lake Superior. Prehistoric trade and use of the copper from this region has been intensively studied by archeologists.[1] This paper focuses on historic Euroamerican mining in the region, and the archeological study of a mid-19th century stamp mill at the Ohio Trap Rock mine site.[2]

Michigan's first geologist, Douglass Houghton, wrote a report on the Keweenaw copper deposits in 1841.[3] Houghton's report ignited North America's first great mining boom, and the 1840s witnessed large-scale Euroamerican exploration and mineral speculation in the region. The earliest Euroamerican copper ventures concentrated at the north and south ends of the Keweenaw Highland. Then slightly later, central mines tapped profitable amygdaloid and conglomerate lodes, and became large, successful operations. As the mines in the central part of the range rose to dominance, the earlier ventures at the north and south ends of the range declined and eventually closed.

The Ohio Trap Rock was one of the first full-scale Euroamerican mining operations in the Ontonagon River basin, beginning explorations at the site by 1846 and mining by 1848.[4] A major expansion of the company's operations began in 1851, with the hiring of Captain Joseph Buzzo, an experienced Cornish miner, to act as the company's on-site manager. Buzzo increased the workforce and supervised construction of new surface facilities. In a report to the company directors dated October 3, 1854, Buzzo described the workforce of 28 miners and 62 surface workers as having been "considerably reduced lately."[5] He also inventoried the surface buildings:

> 22 dwelling houses; 1 stamps, sawmill, and engine house, all in connection; 2 barns and stabling; 1 office; 2 smitheys; 1 warehouse; 1 water-wheel saw-mill; 1 pressure engine; 1 changing house; 1 cooper shop; 1 magazine; and one church—total, 35 buildings.

Although the Ohio Trap Rock showed great promise at the outset, it never achieved profitability, and "became one of the region's more notable failures."[6] The extreme isolation and harsh climactic conditions posed problems for the company. Transportation of supplies to the mine and copper to market was both problematic and expensive. In a Lake Superior gale in October 1851, the company lost a steam engine being shipped to the site, delaying the construction of the stamp mill by a year. Materials also had to travel overland approximately 10 miles from the port at Ontonagon by wagon or, during the winter, by sleigh. The heavy investment in surface works and the massive increase in the size of the workforce in the early 1850s apparently depleted the company's capital. When work was permanently suspended in 1857 or 1858, fully $150,000 of the company's money had been spent for very little return in copper.[7]

The general nature of the mining and ore dressing practices initially employed in the district is well documented.[8] Keweenaw copper miners distinguished three types of copper: large pieces of mass copper; barrel work, consisting of fist-sized pieces of mass copper shipped out in barrels; and copper-rich stamp rock. Stamp rock was roasted on a fire, hammered into fist-sized pieces, crushed in mechanical

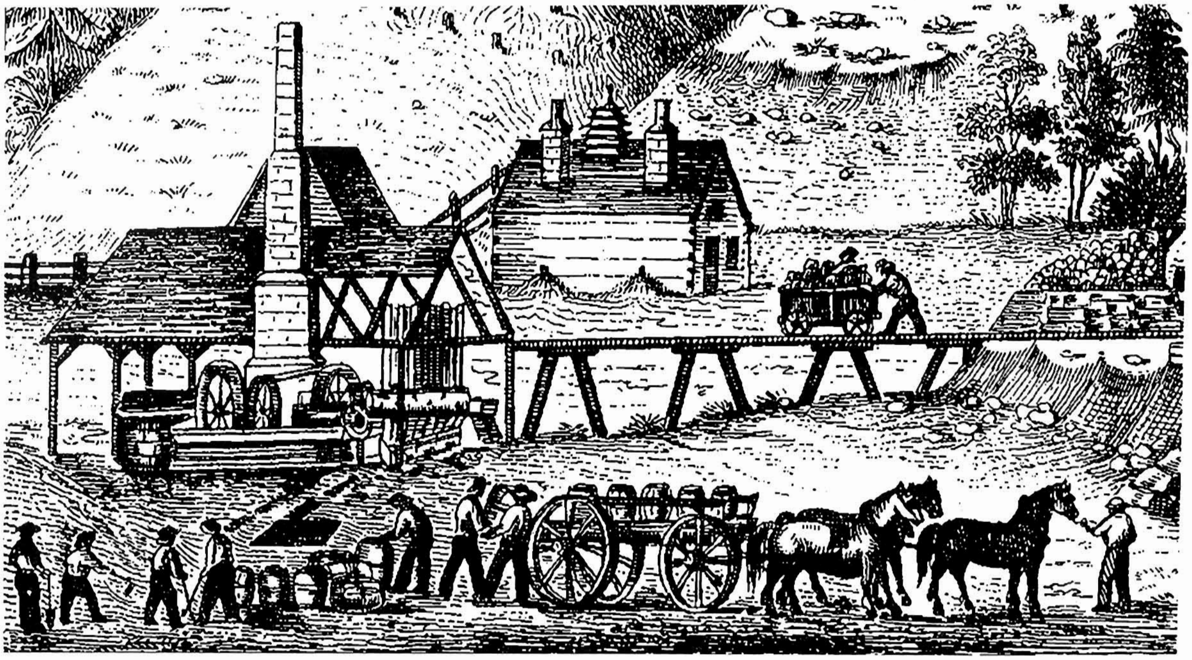

Figure 2. *The stamp mill and washing area of the Cliff Mine, c.1849. The tram car is bringing calcined stamp rock to the mill. The stamps are shown at the right side of the mill with their upright stems, horizontal cam, and battery casing. The large stack is for the engine boiler. The trenches and pits in front of the stamps are common buddles and settling pits. The method of feeding water and rock to the stamps is not illustrated.* From Foster and Whitney, *Report on the Geology and Topography of a Portion of the Lake Superior Land District in the State of Michigan* (Washington DC, House of Representatives, 1850).

stamps, and washed to collect the copper. The stamp mill was a key copper-processing facility at the early mines (see figure 2). Prepared stamp rock was brought by wagon or tram and loaded into a hopper that fed the stamps. The stamp batteries consisted of a series of wooden or iron pestles with iron stamp shoes attached. A cam driven by a steam engine raised and dropped the stamps onto copper-rich rock in an iron trough. Water flowed into the trough, which had perforated iron plates on its sides. Once the rock was stamped fine enough, it flowed through the holes or slots in the stamp trough plates and into the washing system.

Different patterns of washing were used in the early days of the district, but all were designed to allow the heavier copper to settle out while separating or washing away the waste rock. The simplest systems of this type were inclined rectangular wooden trenches built in the ground, known as common buddles. As the copper and water mixture, slime, ran through the trench, the heavy copper settled out first, and the waste sand was deposited further down the trench. The copper-rich headings were prepared for shipment, while the copper-poor tailings were shoveled or washed out of the trench.

The Ohio Trap Rock mine, as an early and short-lived venture, provides insight into the earliest surface processing technologies used in the region. Archeological evidence provides site-specific information about the physical organization of production and the remains left by specific technologies. The site also shows the importance of skilled surface captains and mechanics, and shows how ore dressing technologies that these immigrants brought with them were altered to fit the conditions in the Keweenaw copper district.

Archeological Research at the Ohio Trap Rock Stamp Mill

An archeological survey of the Norwich bluff took place in 1984, and annual field projects at the Ohio Trap Rock site ran from 1991–96.[9] The site has been mapped, three structures have been partially excavated, and approximately 10 acres have been systematically surface collected. The project has encompassed a variety of research and management goals, including public education, site preservation, and interpretation. Since 1993, archeological excavations have focused on the stamp mill and ore-processing area (see figure 3). This work was designed to recover information about the physical organization and characteristics of the earliest ore-dressing systems used in the Keweenaw district. During eight weeks of fieldwork, spread over four summers, a total area of 210 square feet (64 square meters) has been excavated (see figure 4). Excavation was crucial for interpreting this site, as the only remaining above-ground component of the stamp mill is a section of a stone foundation.

Archeological excavations at the stamp mill have been aided by unique preservation conditions. Charred wood in many of the excavation units suggest that part of the superstructure of the mill burned before it collapsed. The bottoms of the walls and other lower portions of the structure appear to have avoided the fire. Some partially processed copper rock and stamp sand, an olive-green coarse to very fine sand that is the waste product from the stamping process, was left in the mill when it was abandoned. After the mill collapsed, the eastern side of the mill was covered with additional stamp sand that washed or blew over the structure. The sills, most of the mill's washing system, and some portions that collapsed are buried under stamp sand. This sediment has a small amount of residual copper that escaped recovery.[10] The copper has acted as a biocide, inhibiting the action of bacteria and fungus that would normally attack buried organic materials, including leather, textiles, and wood. Organic preservation in the stamp sands is phenomenal. Buried wooden components of the structure that were covered with stamp sand are intact, while any part that was above ground is gone.

Interpretation of the preserved structural features is aided by excellent historical information. In an article published in the *Lake Superior Miner* on February 2, 1856, Captain Buzzo described part of the ore-processing system then in use:

> A steam engine has been erected on the concern of 40 horsepower, with 24 head of stamps . . . the stuff [finally crushed copper rock and water] as it passes from the stamps grate, is delivered into a sift, the rough taken from thence is cleaned by a jigging machine—and the fine which passes through the sift is conveyed into a circular buddle, where it is operated upon by brooms suspended to arms attached to a perpendicular shaft driven by the machine. When this buddle is full, the richest part of it is taken to a second sift of finer mease. The second last part of this buddle is again passed through the same operation, and the remainder being found worthless is thrown to the waste heap. But to return to the second sift where the head of the big buddle is sized over; the rough of this is passed to a second jigging machine where it is cleaned for the market. The fine stuff passing through this last sift, (which forms but a small proportion of the stuff stamped) is taken to the tossing tub and case, which complete the whole operation.

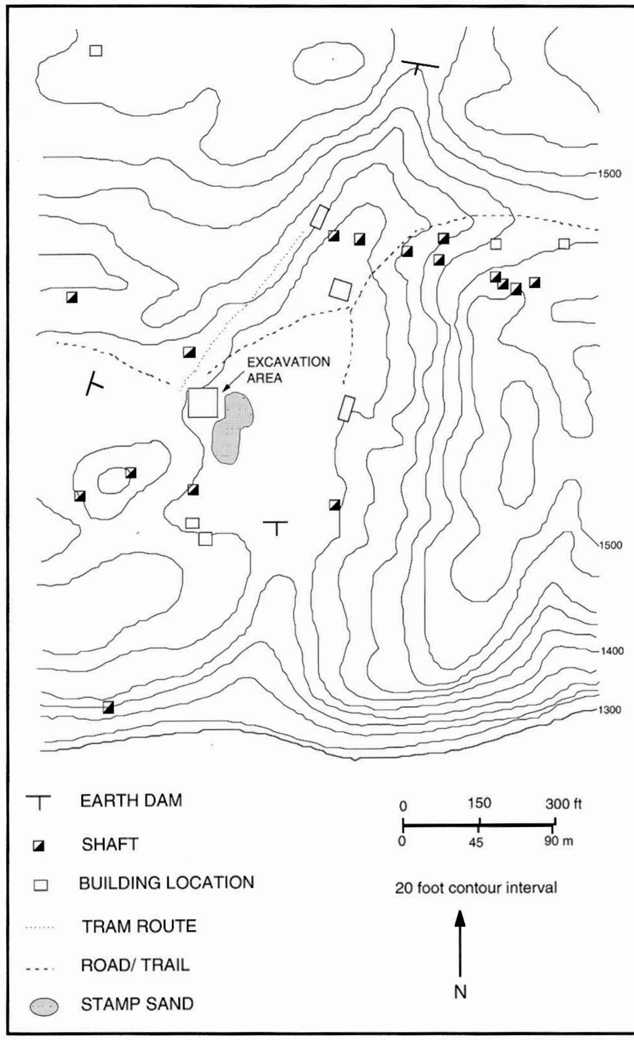

Figure 3. *Map of the primary industrial area of the Ohio Trap Rock Mine Site.* Drawing by D. Landon and P. Martin.

The excellent archeological and historical evidence, in combination, provide a sound basis for reconstructing the layout and organization of the stamping and washing process (see figure 5).

The stamp mill was probably first put into operation in 1852 after the arrival of the company's steam engine. A rubble-masonry platform and chimney for the boiler were constructed of poor rock (figures 4 and 5). Immediately adjacent to the boiler was the engine pit, where several upright iron bolts show the position of the flywheel. The builders anchored the bolts by putting them through an unfinished timber, keying a slot in the end of the bolt, and

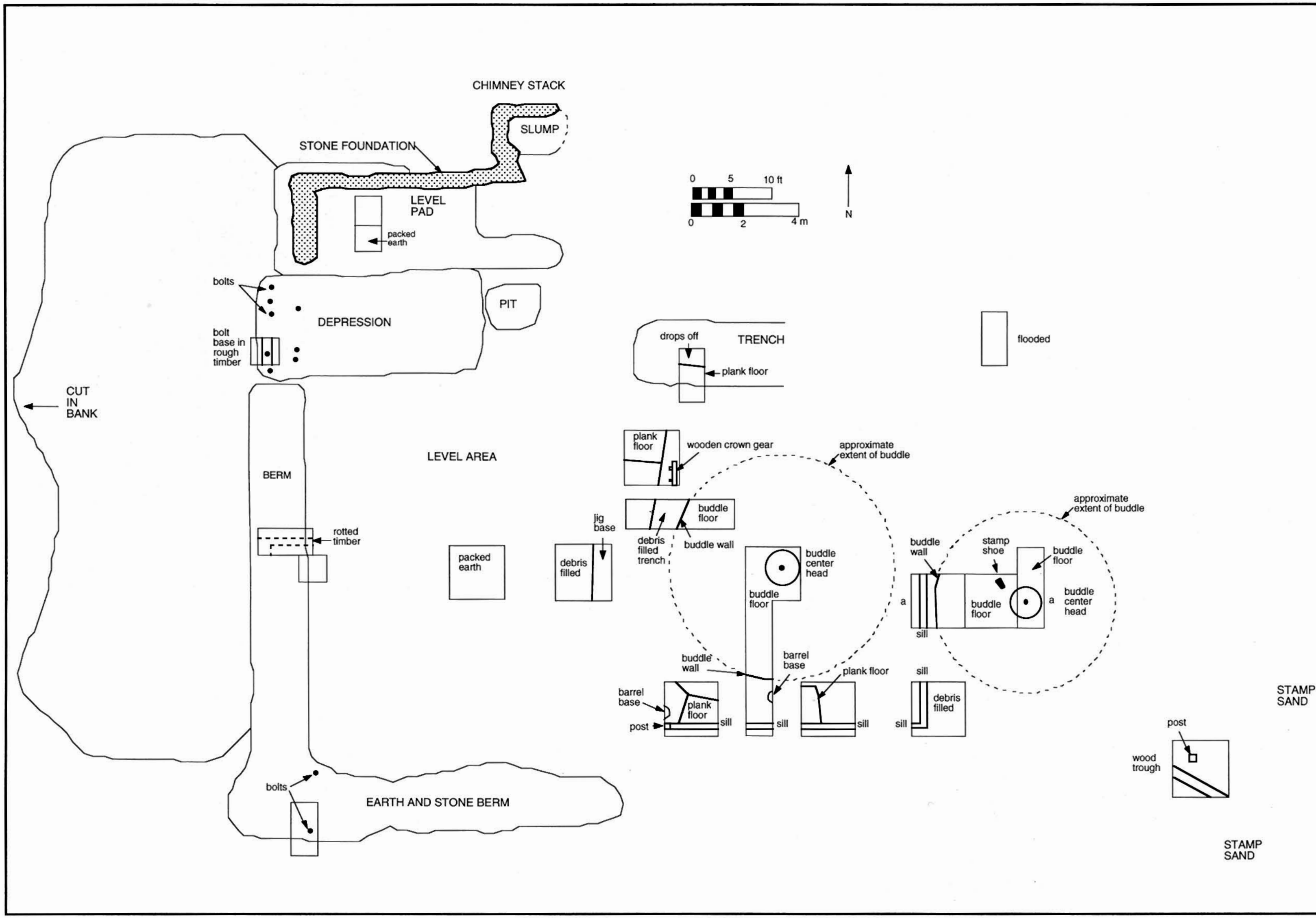

Figure 4. *Plan view of archeological excavations at the Ohio Trap Rock stamp mill.* Drawing by D. Landon and M. Hill.

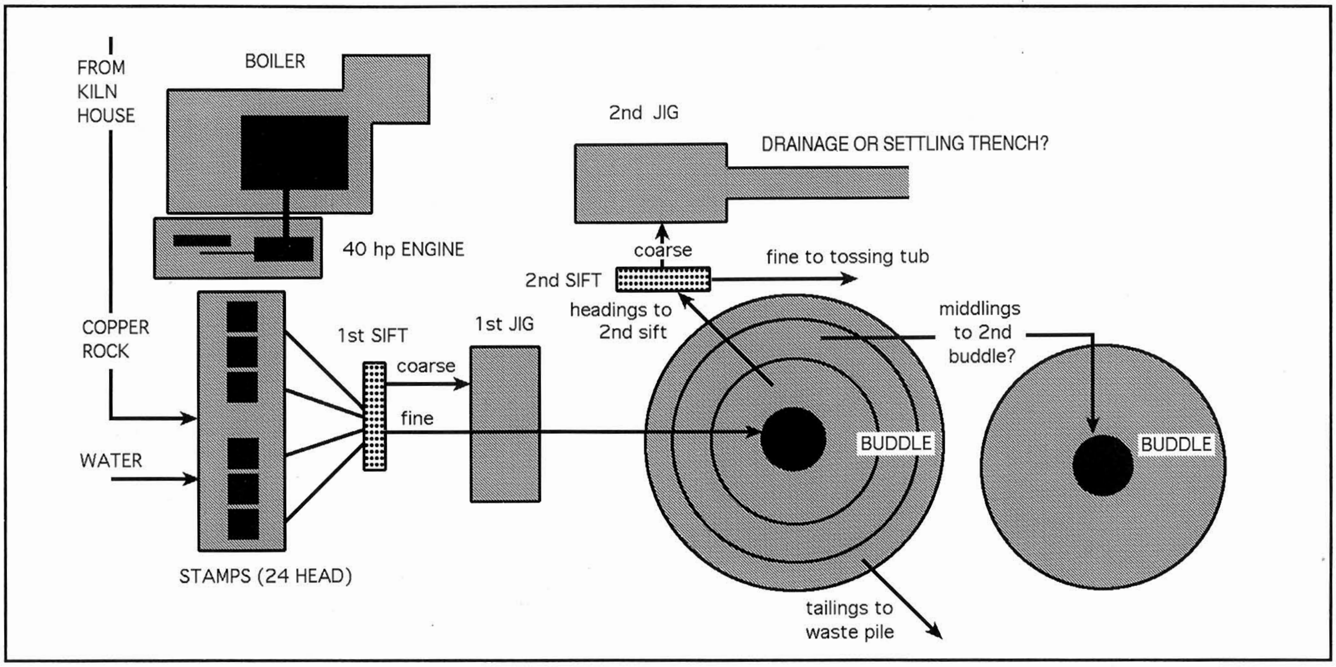

Figure 5. *Schematic process drawing of the Ohio Trap Rock stamp mill, c.1852–58, based on archeological and historical evidence (not to scale).* Drawing by author.

burying the timber. The upper ends of the bolts had nuts and hand-cut washers to hold the wheel in place. The horizontal, high-pressure engine, which had a 12-inch diameter bore and a 5-foot stroke, apparently produced about 40 horsepower, although one report describes a 26-horsepower engine at the mill.[11]

Running south, perpendicular to the engine pit, is a low berm, built as a timber crib packed with rock and earth. This was the foundation for the stamp machines (see figures 6 and 7). A level bed for a tramway cuts into the bank just north and west of this area, showing the route where the burned stamp rock entered the mill (figure 3). Water for the stamping and washing operations must have also entered the mill from this direction, though the specifics are unclear. Small dams to impound water exist to the west, north, and south of the mill (figure 3), and a small stream flows by the mill to the east. Water from the stream or dam to the north could flow in by gravity, but water from the other dams would necessitate pumping. The mill had no year-round water supply. Water availability, together with historical information on the mill's production (discussed below), make it likely that the stamping and washing operations were a seasonal operation, drawing on impounded water from the spring snow melt and early summer rains.

Most early mills in the district used 4-stamp batteries, so the 24-stamp mill at the Ohio Trap was likely organized in 6 batteries.[12] The only archeological evidence of stamping machines is several cast-iron stamp heads still present at the site. One of these was found in stamp-sand deposits above one of the buddle floors (figure 4). The others are on the surface northeast of the mill, clustered with a series of other iron artifacts that were gathered together at some time in the past. Originally, three stamp shoes existed in this location, but one was looted from the site. Though slightly irregular due to wear, the stamps shoes are about 19 inches long by 6¾ inches deep, tapering from 6¾ inches wide at the top to 9½ inches wide at the bottom. Gravity stamp heads of the period ranged from 100 to 500 pounds, and averaged around 300 pounds.[13] The stamp heads at the Ohio Trap must have been heavier than average when originally cast, as the worn examples are still more than 300 pounds. The excavated and the looted heads were both stamped "KNAP & WADE, PITTSBURGH." This company made steam engines and other products, but the extent of their mining machinery manufacturing is not known.

Given the difficulty of shipping in machinery, and the excellent evidence of wood construction at the stamp mill, it is possible that the cam shaft to lift the stamps and the stems attached to the heads were made of wood. The heads

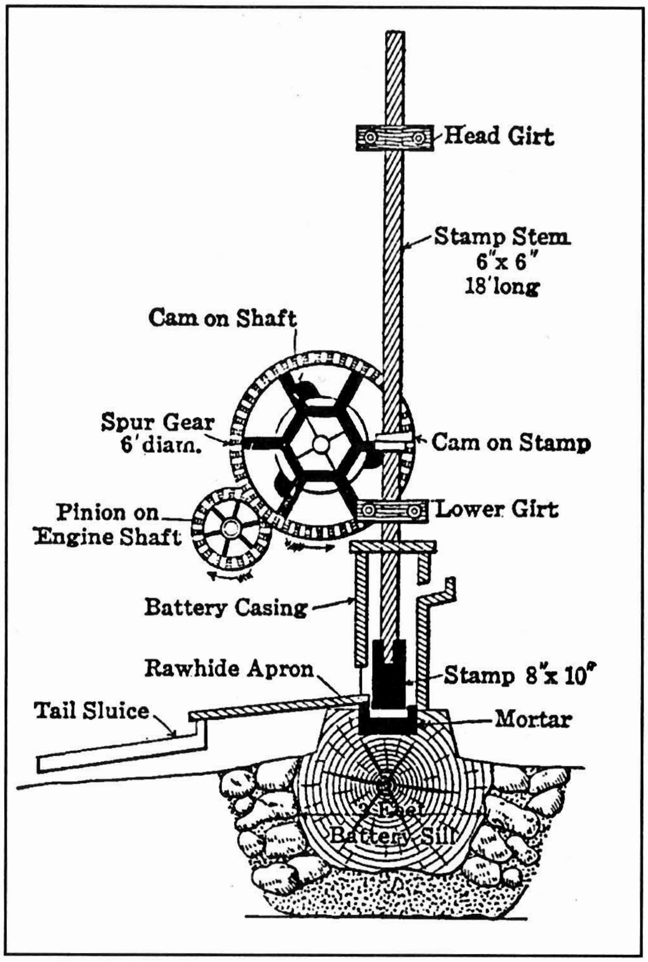

Figure 6. *A "California" stamp. Note the hewn timber used as the battery sill.* From Del Mar, *Stamp Milling: A Treatise on Practical Stamp Milling and Mill Construction,* 1912, 4.

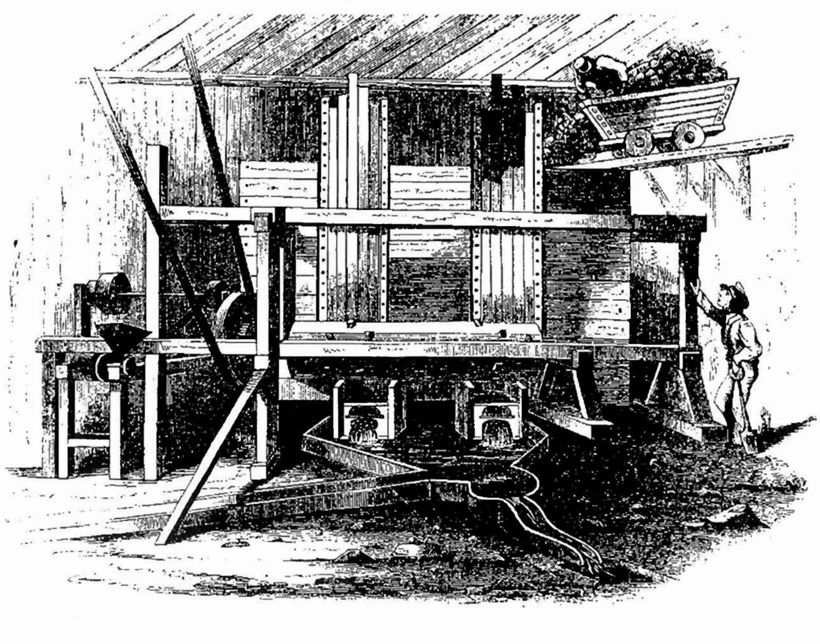

Figure 7. *Copper-stamping battery at the Cliff Mine, c.1852. Stamp rock is being fed into the stamps from the upper right. A belt-driven cam shaft is visible in the front, with cams to lift the vertical stems attached to the stamps. Crushed copper rock and water flow into the trenches below the cam. This illustration shows five stems (hence five heads) for each battery, but most historical accounts of the district suggest four-head batteries were more common.* From *Harper's New Monthly Magazine,* April 1853.

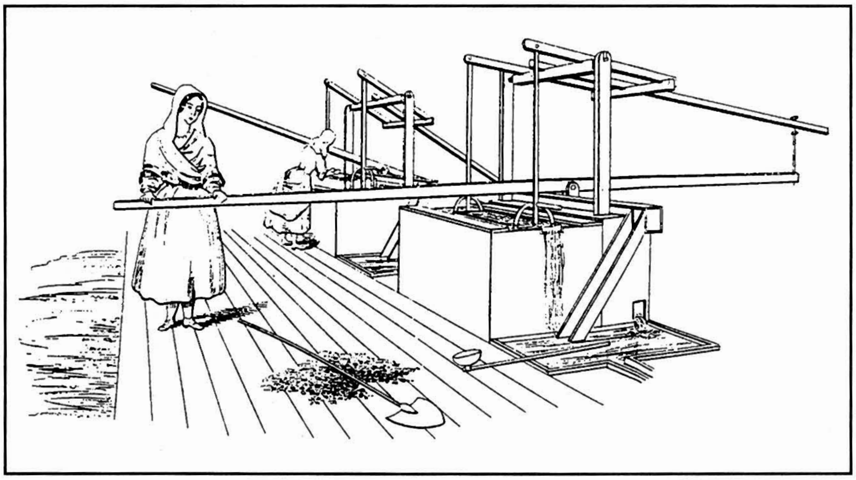

Figure 8. *Cornish women operating a jigging machine, c. 1857. Sharply depressing the long lever forced a screened tray full of copper-rich sand down into a tub of water, leaving the stamp sand momentarily suspended in the water. As the sand settled out, dense copper would fall faster, accumulating on the bottom of the screen, with poorer material on top. Once the jigging was complete, the shovels would be used to skim the waste sand from the top of the screen, so that the copper-rich sand could be collected from the bottom of the screen. There is currently no evidence that the Cornish practice of hiring female surface workers transferred to the Keweenaw copper district.* From *Proceedings of the Institution of Civil Engineers,* 2 February 1858.

Figure 9. *The base of a jigging machine excavated in 1995, looking north. The sign board is 16 inches wide.* Photo by author.

at this site have no shank at the top, and were probably fitted into sockets cut in the end of the stems. A cast-iron mortar was considered more effective, but there is no evidence for an iron mortar for the stamps. Stamps were sometimes built to drop on a packed rock surface, and it is possible that the Ohio Trap Rock stamps operated in this fashion.[14] However, there was relatively little stamp sand left on the top of the berm, suggesting that rock was not crushed directly on the surface. The iron stamping mortar might have been salvaged with other machinery when the mill was closed.

Rock was stamped until it could wash through a heavy iron screen on the battery casing into a wooden launder that flowed to a classifying area (figure 5). Neither the rate of flow nor angle of the mill's launders has been determined. At this first sift, the coarse particles were caught and taken to a jigging machine (see figure 8). We excavated the base of a jig used for the coarse material (see figure 9). All that remained was a wooden box built into the ground, filled with slightly under 3 feet of very homogeneous coarse stamp sand. As a result, the details of the jigging operation are unclear. In general, a jig had a finely perforated screen hanging in a water-filled container.[15] Stamp sand to be concentrated was piled on the screen. The screen was dropped quickly, forcing water through the screen and temporarily suspending the grains of stamp sand. As the sand dropped through the water back onto the screen, the denser copper-rich particles fell faster and accumulated on the bottom of the pile. When the screen became full, and the jigging was

Figure 10. *View of a 1994 excavation unit, looking west. A sill corner is visible in the foreground. Remnants of vertical siding are visible on the near side of the north-south sill. The wood pieces in the foreground include partially burned pieces of vertical siding and shingles.*
Photo by P. Martin.

complete, the person tending the jig removed the screen from the water. The jig tender scraped copper-poor sand off the top for discard, took the copper-rich sand from the bottom, and barreled it for the smelter or washed it in another fashion. Some jigs used plungers to force water up through the screens instead of dropping the screen. The screen size could be quite variable, but the general process was the same. Jigging could also be done by hand, using a hand-held screen and a barrel or trench filled with water.[16] Small pieces of iron screen were recovered in several excavation units, but none were directly associated with the jig base. The oxidation of the iron screen fragments makes it hard to estimate mesh size, and it remains difficult to conclusively relate any of the screen fragments to a particular step in the process.

The fine material that passed through the first sift went on to a circular buddle (figures 4 and 5), and the remains of two center-head circular buddles were found at the site. The first buddle, closer to the stamps, was enclosed in a large building. The building was made of wood, and buried portions are preserved in the stamp sand. The sill, parts of vertical siding, shingles, wooden flooring, and a door (complete with hinge attached) have all been partially excavated, giving a good picture of the building surrounding the buddle (see figures 10 and 11). Posts were fitted with mortise and tenon into the sill, with vertical planks enclosing the building. Wooden shingles survived in a deposit of building rubble, suggesting shingle siding or a wood shingle roof. In some areas, the edge of the buddle abutted the wall; while in other areas, a plank working floor was built between the wall of the buddle and the edge of the building.

The two circular convex wooden buddles are the most interesting find at the stamp mill. Circular buddles were one of the last steps in the washing process, used to concentrate copper

Figure 11. *Bottom of a wooden door to the washing area, looking north. The sill of the building is visible in the lower right, the base of a post in the lower left, and the base of a barrel north of the post. The door is partially burned, as are many wooden components in other excavation units, suggesting that part of the mill burned before it collapsed.* Photo by L. Buhr.

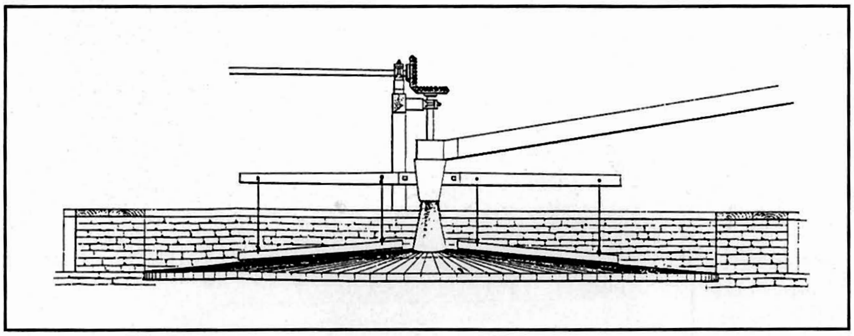

Figure 12. *Cross section of a Cornish buddle, c. 1857. The trough leading in from the right fed water and finely stamped copper and rock into the center of the buddle, where it washed down over the center cone and onto the sloping floor. The gears drove sweeps that helped agitate the slime on the buddle floor.*
From *Proceedings of the Institution of Civil Engineers*, 2 February 1858.

from finely crushed stamp rock (see figure 12). The two buddles at the Ohio Trap Rock were constructed in a similar manner (see figures 13–16). Each had a vertical cast-iron shaft in the center to support the sweeps that operated on the slime washing over the buddle floor. In both cases, the central bearing was anchored in a large tree stump. The center spindle was surrounded by vertical staves approximately 22 inches out from the bearing. Outside the vertical staves was a horizontal wooden floor that sloped down slightly away from the center. The floor was made of wood planks that radiated out from the center of the buddle. These tongue-and-grooved planks were cut with a taper so that they widened towards the edge of the buddle. The outside edge was not truly round, but polygonal. Vertical planking was attached to the exterior edge, about 9 inches high on the first buddle and 16 inches high on the second buddle. In one area, a wood-lined trench abutted the edge of the first buddle. Several holes piercing the buddle wall at this point were pegged (see figure 17), suggesting the trench was designed to help drain water and fine sand out of the buddle. The first buddle was about 28 feet in diameter with a 3-degree pitch to the floor; while the second buddle was about 22 feet 6 inches in diameter with a 4-degree pitch to the floor.

Several smaller wooden components suggest how the buddles operated. Sections of wooden launder troughs, part of the system for moving crushed copper, rock, and water through the washing operation, were found in the sand fill

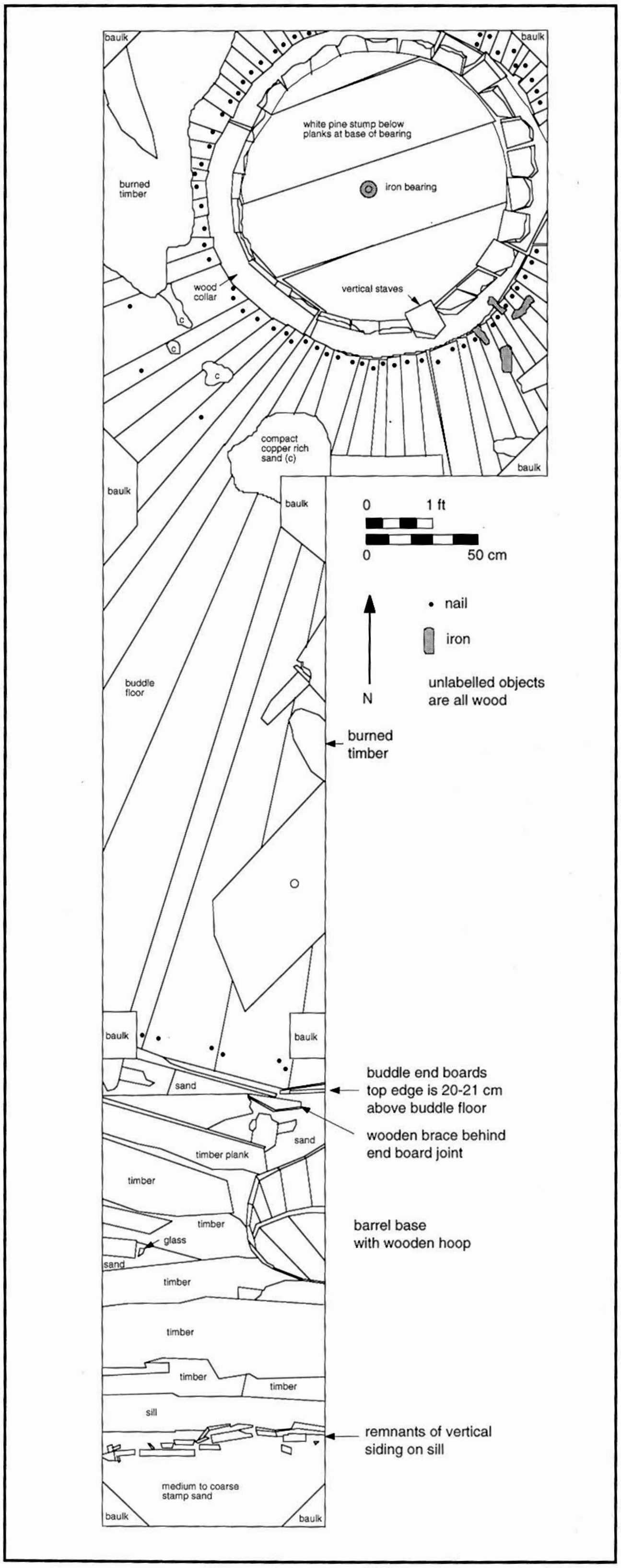

Figure 13. *Plan view of the section excavated across the first buddle. Many of the vertical staves surrounding the center head show evidence of burning.* Drawing by D. Landon, E. Doser, L. Buhr, and E. Feldhusen.

Figure 14. *View of the buddle floor, looking north. The vertical edge of the buddle is in the foreground; the center head and center bearing are in the rear.* Photo by G. Day.

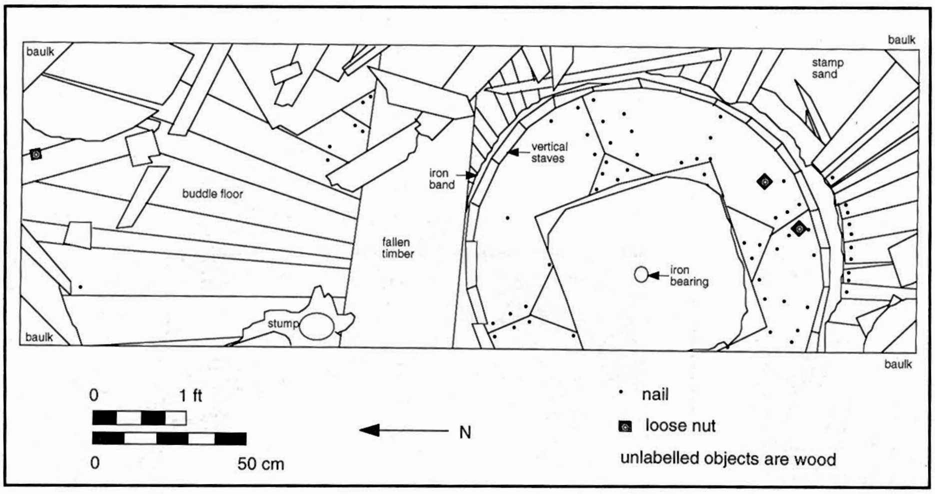

Figure 15. *Plan view of the center head and adjacent floor of the second buddle.* Drawing by D. Landon, E. Doser, and J. Ferone.

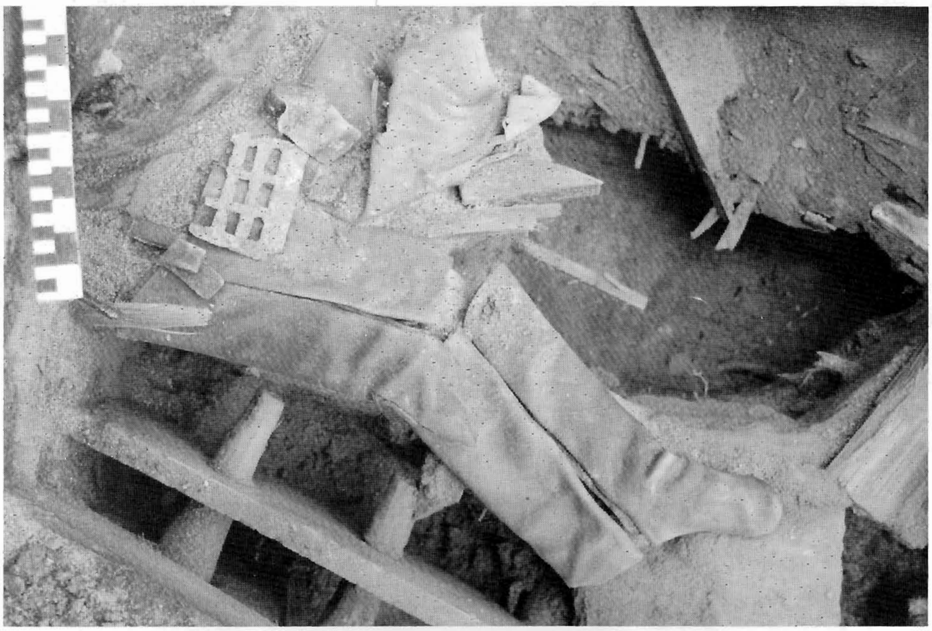

Figure 16. *Pegs through the buddle wall. North is to the right. This section of buddle wall is on the northwest side of the western buddle (figure 4). Note the preserved leather boot uppers and the section of slotted iron plate. Thick slotted screens like these were probably used on the stamp battery casing.* Photo by S. Cowie.

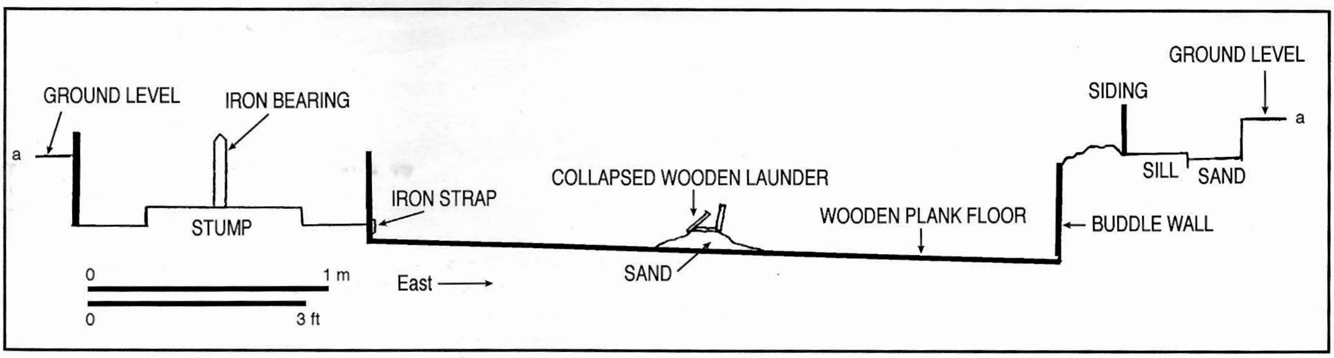

Figure 17. *Diagrammatic profile of the second buddle. Points labeled "a" match points on figure 4.* Drawing by author.

above each buddle (see figure 18). These might have been moved from their original position, but troughs of this type were used to feed slime onto the center of each buddle. A wooden crown gear, about 3 feet in diameter, was uncovered where it had fallen into the trench abutting the first buddle (see figures 19 and 20). No direct evidence exists that this gear was associated with the buddle, but some gearing was undoubtedly used to transmit power from the steam engine to the sweeps working the buddle floor.

The general operation of circular convex buddles is well understood.[17] The fine slime flowed down the launder onto the top of the center head, dropped down onto the convex floor of the buddle, and ran down towards the circumference. The surface of the slime on the buddle floor was constantly swept smooth by revolving brushes. As the slime spread, it became thinner and moved more quietly, so that the particles dropped out and built up into a layer of mineral: the heaviest near the center and the lightest out toward the periphery. The biggest impediment to efficient particle separation occurred when the slime was delivered onto the buddle too rapidly. If the mineral particles were caught by the current and held partly in suspension, they were quickly carried down the slope into the tailings. For the buddle to function properly, the slimes needed to flow over the floor at a very slow pace. The launders' gradient and flow rate were thus important to the successful operation of the buddle.

When full, the buddle contained three concentric portions: the head, the middle, and the tail, each occupying about a third of the whole breadth (figure 5). The brush arms were then unplugged, and the contents shoveled out according to grade.[18] If the head was rich enough, it could be barreled for shipment. At the Ohio Trap Rock mill, the head was sometimes sent through a second sift, with the coarse going on to a second jig. If not rich enough, the head could be rebuddled. The middlings were rebuddled, and the tailings were discarded as waste.[19]

Buzzo reported that the Ohio Trap Rock shipped 20 tons of copper in 1855, most of it from the stamp mill.[20] The Ohio Trap Rock was stamping copper rock that was returning 1–1½ percent copper.[21] Gravity stamps in good working order could stamp about 1½ ton per head in 24 hours.[22] Stamping 1,600 tons of rock, with the stamps averaging ⅔ ton per head in a 10-hour day, would thus only require about 100 days work at the stamp mill. The buddles could have easily handled this volume. An 18-foot-diameter buddle was able to handle about 20 tons of slime in a 10-hour shift.[23] The 28-foot-diameter buddle at the Ohio Trap Rock could handle proportionately more slime. With the coarse taken off at the first sift and the second buddle in use, the washing operation could have easily kept pace with the stamps.

Figure 18. *Wooden launder fallen in on the buddle floor. Troughs of this type were used to feed slime onto the center head of the buddle. No good evidence exists to estimate the angle or flow rate at which the launders fed slime onto the buddles. North is to the right; the trench section is 3.28 feet wide. This section of buddle floor is just inside where the pegs go through the buddle wall.* Photo by author.

Figure 19. *View into a debris-filled trench showing a remnant of a wooden crown gear in the lower left. The iron band encircled the gear, which has three wooden peg teeth still intact.* Photo by S. Cowie.

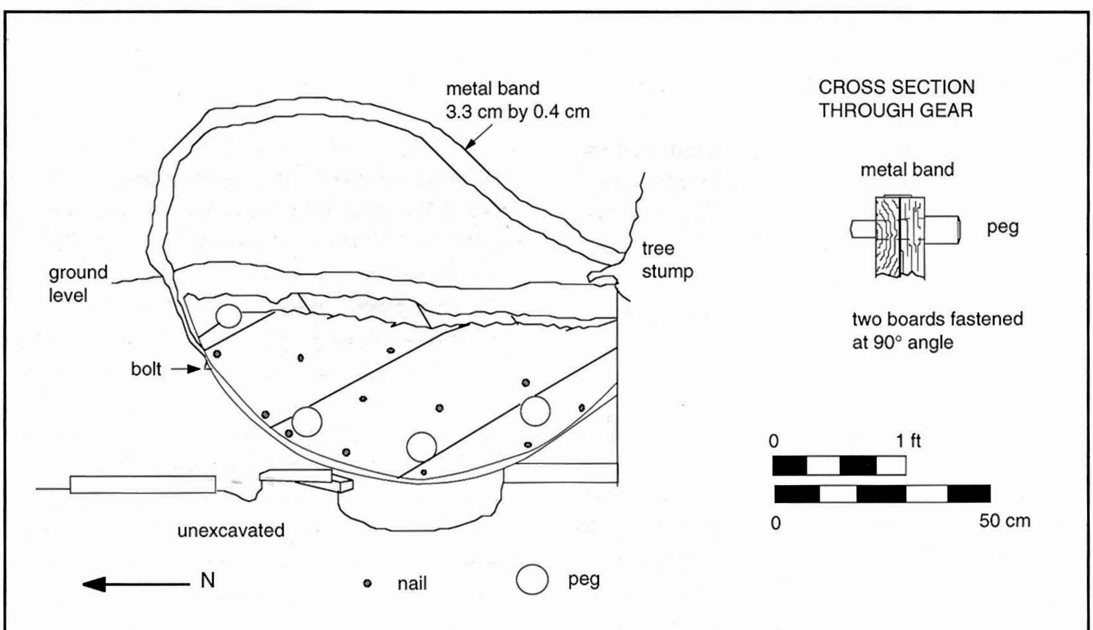

Figure 20. *Drawing of the gear face and peg cross section.* Drawing by M. Hill.

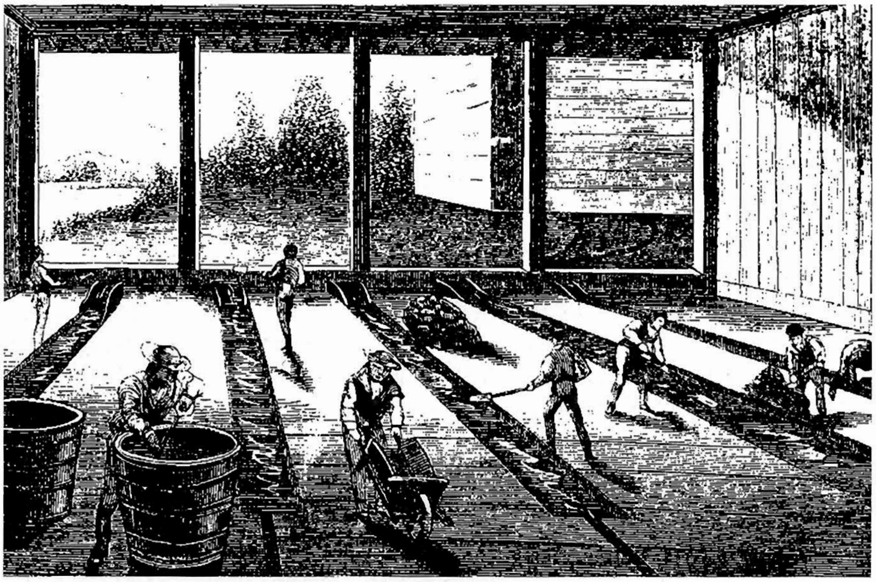

Figure 21. *Washing floor at the Cliff mine, c. 1852. The trenches in the floor are common buddles. Copper-rich sand settled out at the head of the trench, while copper-poor sand washed to the tail of the trench. The man at the front left is working at a tossing tub or keave. He mixes and agitates the sand in water. The heavier copper settles to the bottom of the barrel, with poorer material on top.* From *Harper's New Monthly Magazine,* April 1853.

Several aspects of the stamping and washing operation at the Ohio Trap Rock are noteworthy. The mill was built on an intermittent interior drainage, a feature shared with only the earliest sites. Later mills were located on larger water sources, especially in the central portion of the district. Here the mines focused on amygdaloid and conglomerate copper lodes, and stamping was the only method of obtaining the copper. Many aspects of the stamp mill reflect the frontier-style construction: the unfinished timber supports for the engine wheel, the use of undressed and dry-laid mine rock, the anchoring of the buddles' central bearings in tree stumps, and the emphasis on wood construction. The best constructed part of the washing system was the circular buddles, which represented a serious investment of time and money. Interestingly, this type of circular buddle is not common in the Keweenaw copper district or other areas of North America. Rather, this is an imported technology that must be interpreted in the context of Cornish ore-dressing technology.

The Development and Diffusion of Cornish Ore-Dressing Technology

Stamp mills were probably introduced into Cornwall before 1402, and the basic layout of a common buddle was established before the mid-1500s.[24] Common buddles were simply inclined or level trenches built into the ground. Finely stamped mine rock and water were run through the trenches, and the heavier metals tended to settle out at the head of the trench, while lighter metal-poor rock was washed to the tail of the trench. Common buddles continued to be used, virtually unchanged, well into the 19th century. The Cliff Mine used common buddles in the early 1850s (see figure 21), and some sites in the Keweenaw apparently continued to use common buddles into the 1860s.[25] Washing systems that relied only on common buddles and settling pits were sometimes criticized as wasteful of copper.[26] Later mills that processed vast quantities of lower-grade rock developed more-complex systems of mechanized jigging and washing, reserving common buddles for the tail-house, where they were used primarily as a check on the effectiveness of the mill.[27]

The exact origins of the round buddle are unclear. It is possible that round buddles were tried at the London Lead Company's North Pennines mines in the 1820s, but in general, the use of round buddles appears to have been limited until the 1860s.[28] Warington Smyth, who wrote one of the first articles about round buddles, states that they were first developed in Cornwall by John Taylor and sons.[29] Round buddles were probably used in conjunction with common buddles at first.[30] Once introduced more widely, round buddles evidently caught on very quickly, as at least one source claims that most large mines used such buddles after 1860.[31] Diameters of round buddles generally ranged from 14 to 24 feet. Buddles up to 50 feet in diameter were built in Cornwall, but examples this large were very rare.[32] The number of brushes used to smooth slime on the buddle surface varied from two to eight, and a variety of materials could be used to form the sweeps.[33] Details of the Ohio

Trap Rock buddle sweeps are not known, but in terms of size, the buddles were large for the period.

Round buddles were just starting to gain widespread recognition in Cornwall in the 1850s, and did not become common until after 1860. Yet workers built two at the Ohio Trap Rock mine in Upper Michigan between 1852 and 1855. This is a clear example of the transfer of a foreign technology into the U.S. and shows the importance of immigrant Cornish workers in establishing the site. It is interesting to note that the domestic artifact assemblage from the site includes nothing that provides such a clear ethnic marker as the Cornish-style buddles. Very few personal or domestic artifacts were recovered in the stamp mill excavation, and the small assemblage of pipe stems and other materials tells little about the workers who ran the mill. A greater range of domestic and personal artifacts was recovered in a systematic surface collection over the areas where the mine housing had existed. The collection included a variety of kitchenware and tableware, bottle and pipe fragments, stove parts, and other architectural and personal items, but this much larger assemblage still contained nothing that would clearly signify the presence of Cornish workers and their families. This has important implications for other archeological sites where immigrant workers comprised an important part of the labor force.

Immigrant Cornish workers played a key role in the opening of the Keweenaw copper district. Cornwall is located in one of the richest mining districts in the world. In the middle of the 19th century, over 340 mines employed more than 40,000 workers in Cornwall, and Cornishmen were considered some of the best hard-rock miners. Cornwall's copper production reached its peak in 1856, with 209,000 tons. Already then, however, its dominant position as a producer was receding. From 1800 to the 1830s, Cornwall produced two-thirds of the world's copper, but, by the 1850s, that figure was down to one quarter.[34] Cornwall faced severe competition from the large, cheaply worked deposits discovered in Chile and on Lake Superior. By 1860, the Cornish copper industry had essentially collapsed. A large number of skilled copper miners and surface workers chose to emigrate to overseas mining districts, and many parishes paid the ship fares that allowed Cornish families to relocate.[35]

Cornish mining and milling experience stood at a high premium in America. Skills and techniques that developed in one of the oldest mining regions in the world were maintained by a system that at one time permitted a son to work beneath the watchful eye of his father when he was only seven years old. A boy would literally grow up at the mines, and knowledge about mining and ore dressing passed from one generation to the next.[36] Immigrant miners and mechanics brought this knowledge with them to the Keweenaw, and often applied their traditional practices in this new setting.[37]

From the start, the early mines in Michigan depended on Cornishmen to be their mine captains and foremen.[38] Ore-dressing skills were also deemed important, and most stamping and washing mills were managed by Cornishmen.[39] The Ohio Trap Rock followed this pattern when, in 1851, the company recruited Cornish mining Captain Joseph Buzzo to expand its operations. One of the workers Buzzo hired was Elias Sweet, a machinist who had learned his trade in St. Austell, Cornwall, before emigrating in 1848.[40] Sweet worked erecting machinery at the Ohio Trap Rock from sometime in 1851 until February 1854, when he went on to the Ridge Mine to supervise construction of its stamp mill and adjoining plant. Rivot, a French engineer traveling through the district, described round buddles in use by the end of 1854 at the Ridge, presumably built under Sweet's direction.[41] Rivot goes on to say that the round buddles had advantageously replaced the cases ["caissons," common buddles?] and sleeping tables, and that this apparatus would soon be in use in a much larger number of stamp mills. Sweet went on to become the machinery foreman at the Minesota mine in 1859. It is unclear if he fulfilled Rivot's prophecy and built circular buddles for this company.

The reliance of the mining companies on skilled immigrant workers is the main reason convex buddles were installed at the Ohio Trap Rock. This technology was beginning to gain a foothold in Cornwall at the time Elias Sweet was finishing his training as a machinist. As large numbers of miners and skilled surface workers began to move from Cornwall to the Keweenaw copper district, they brought along techniques developed at Cornish mines. The hard-rock mines in Upper Michigan were similar in many ways to the Cornish mines, and the immigrants had every reason to believe that the latest, state-of-the-art technology from Cornwall would make the new mines successful.

This vernacular knowledge was altered to fit the local resources and conditions. The Ohio Trap Rock was extremely isolated with supplies difficult to acquire. The construction of the buddles emphasized local materials. The center bearings for the sweeps were anchored in the stumps of newly cut trees. The buddle was constructed of locally available pine, hemlock, fir, and other wood instead of masonry, and the gearing for the sweeps was apparently wood instead of iron. The harsh climate also influenced construction practices. At least some stamp mills had open washing areas in the late 1840s, yet by 1852, both the Ohio Trap Rock and the Cliff had built structures around their washing floors (compare figures 2 and 21).

Cornish convex buddles were never widely used in North America. There are suggestions that buddles were introduced onto the mining frontier of the American West, but it seems that newer and improved methods were already in place.[42] New technology developed rapidly in the Keweenaw copper district, and the circular buddles used at the Ohio Trap Rock were superseded. Stamping and washing became the mainstay for the mines in the central part of the Keweenaw copper district, where companies working disseminated copper lodes were forced to dress large volumes of ore. Innovations that became the district's standard technologies in the 1860s and 1870s were developed and put into practice here: the Ball steam stamp, the Collum jig, and the Evans slime buddle.[43] These changes all took place after initial experiments with washing technology at the mass mines of the north and south ends of the district.

The Ohio Trap Rock mine was one of the first copper mines in the southern end of the district to set up extensive surface works. Many of the early mines followed the same path as the Ohio Trap Rock: overbuilt their surface facilities relative to their copper deposits and depleted the investors' money. Sweet, Buzzo, and the other workers at the site envisioned a long-term operation, but the veins they mined did not return enough copper. Financially the mine was a failure and had little influence on the overall history of the region. Yet, for a short period, the mine had one of the most progressive mills in the district. Immigrant Cornish miners and mechanics brought their knowledge of ore-dressing techniques to the Keweenaw, adapted them to local resources, and established a stamping and washing operation that incorporated the newest technology.

Notes

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2. An earlier version of this paper was presented at the 1996 meeting of the Society for Industrial Archeology, Sacramento, Calif. The archaeological work at the Ohio Trap Rock Mine Site was supported by the Ottawa National Forest and Michigan Technological Univ. Special thanks to Mark Hill, Susan Martin, Kelly Dixon, and the many students and Passport in Time volunteers who participated in the project. For another view of historical archeology in the region, see Patrick Martin, "An Archaeological Perspective on 19th-Century Copper Mining Communities in Upper Michigan," in *Sozialgeschichte des Bergbaus im 19. und 20. Jahrundert*, ed. Klaus Tenfelde (Munchen: Verlag C. H. Beck, 1992), 197–212.
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7. Stevens, *Copper Handbook,* 215 (see n. 4); James K. Jamison, *The Mining Ventures of this Ontonagon County* (Ontonagon, Mich.: James K. Jamison, 1950), 3; "Mining Magazine," Transcribed Information on File at the Michigan Technological Univ. and Copper Country Archives, 1857, 390.
8. Lankton, *Cradle to Grave,* ch. 1 (see n. 3); Foster and Whitney, "Report on the Geology," (see n. 4); Robert E. Clarke, "Notes from the Copper Region," *Harper's New Monthly Magazine* VI, no. XXXV (1853): 573–88; Graham Pope, "Some Early Mining Days at Portage Lake," *Proceedings of the Lake Superior Mining Institute* VII (1901): 17–31.
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13. Robert Hunt, *Ure's Dictionary of Arts, Manufactures, and Mines,* vol. II (London: Longmans, Green and Co., 1878), 98.
14. Ibid., 99.
15. Ibid.; T. Egleston, "Copper Dressing in Lake Superior," *Metallurgical Review* 2 (May 1878): 227–36; (June 1878): 285–300; and (July 1878): 389–409.
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26. Foster and Whitney, *Report on the Geology,* (see n. 4).
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33. Earl, "Tin Preparation and Smelting," 51 (see n. 18); Louis, *Dressing of Minerals,* 297 (see n. 19); Richards, *Ore Dressing,* 369 (see n. 19); Robert Hunt, *British Mining* (London: Crosby Lockwood and Co., 1884), 766; E. Henry Davies, *Machinery for Metalliferous Mines* (London: Crosby Lockwood and Son, 1902), 303; Bryan Earl, *Cornish Mining* (Cornwall: D. Bradford Barton Ltd., 1968), 84; James Henderson, "On the Methods Generally Adopted in Cornwall in Dressing Tin and Copper Ores," *Proceedings of the Institution of Civil Engineers, London* XVII (1857–8): 201.
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42. Donald L. Hardesty, *The Archaeology of Mining and Miners: A View from the Silver State,* Special Publication No. 6, Society for Historical Archaeology, 1988, 43; Otis E. Young Jr., *Western Mining* (Norman: Univ. of Oklahoma Press, 1970), 137.
43. Egleston, "Copper Dressing," (see n. 15); Harry S. Benedict, *Lake Superior Milling Practice: A Technical History of a Century of Copper Milling* (Houghton, Mich.: Michigan College of Mining and Technology Press, 1955), 11. Not all of these technologies were based on skilled immigrants, for example, the Ball steam stamp was the product of a Massachusetts mechanic. The Evans patent slime buddle was a convex round buddle, but the working table was mounted on a frame above ground. The entire table rotated, separating and discharging copper-rich sand and waste. Slime processing on stationary convex buddles had to be stopped when the buddle got full for workers to shovel it out.