University of Nevada, Reno

The Historical Archaeology of Ore Milling:
Ideas, Environment, and Technology

A Thesis Submitted in Partial Fulfillment of the Requirements for the degree of Master of Arts in Anthropology

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Abstract

Changes in milling technology at the Cortez Mining District, a gold and silver mine located in a remote area of central Nevada, are examined through the study of five mills that were active between 1864 and 1944. Each mill is analyzed through documentary and archaeological sources in order to understand how different forms of technology were implemented and modified to most effectively treat ores over time. Locally, this process of technological adaptation was influenced by changing environmental knowledge. On a larger scale, the milling technology is contrasted against global trends relating to a second wave of industrialization, such as the use of engineering and scientific knowledge in industrial pursuits, and the increasingly systematic deployment of capital.
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Abbreviations

CCSMC = Consolidated Cortez Silver Mines Company
CGSMC = Cortez Gold and Silver Mining Company
CMC = Cortez Metals Company
CMRC = Cortez Metals Recovery Company
CM&RC = Cortez Mining and Reduction Company
CRM = Cultural Resource Management
CCGSMC = Consolidated Cortez Gold and Silver Mining Company
GLO = General Land Office
RMMC = Roberts Mining and Milling company
TM&MC = Tenabo Mill and Mining Company

Newspapers and Journals

DAC = Daily Alta California (San Francisco, California 1850 – 1891)
DNSJ = Daily Nevada State Journal (Reno, Nevada 1874 – 1907)
DRU = Daily Record-Union (Sacramento, California 1875 – 1891)
REG = Reno Evening Gazette (1876 – 1983)
RRR = Reese River Reveille (Austin, Nevada 1863 – 1993)
1. Introduction

Industrial mining is an important part of Nevada history. The mines of Nevada were often a proving ground for technological innovation. At the Cortez Mining District of central Nevada, mining persisted through many turbulent economic times, and the struggle to exploit resources took a variety of forms. This thesis is a survey of the archaeological remnants of five ore reduction mills at Cortez that operated over the eighty year span of 1864 to 1944, beginning with the construction of the first historical mill and ending when the last mill closed down. What changes occurred in the mills during this time and why? What were the factors driving technological change at Cortez? Did this technological adaptation enable Cortez to remain in production despite economic difficulties? A simple explanation is that the exploitation of increasingly scarce mineral resources led to changes in the mills as older technology was replaced when more efficient forms became available. This explanation implies that more efficient technologies were used over time and as a result the mines became better able to profit from ore.

The collected data examined below will show that the trajectory of the adoption of milling technology at Cortez was not an inevitable progression from less efficient and simple to more efficient and sophisticated. Instead, the decisions behind the construction and modification of the mills at Cortez were a response to multi-scalar stressors at both local and global levels. This also involved tension between what miners expected, and what the environmental and technological reality was, or “the ideal and the real” (White 2015:16). There are two linked aspects of historical mining that particularly influenced
the configuration of the mills and include a specialized knowledge of the environment and the adaptation of technology according to this knowledge. These features of the mining system will be laid out in greater detail in the following chapter.

**Ore Reduction Mills**

Mills are an important part of the mineral exploitation system and exhibit a variety of forms across time. As a result, they are extremely useful to guide a detailed study of patterns of technological change in the archaeological record. Ore reduction mills mechanically and chemically reduce the extracted ore to smaller component materials for the purpose of isolating those minerals that have economic value. Information for mills is often more abundant and of a higher quality than other mining related features. Mills are generally well documented and often demonstrate the productivity of a mining company. They also represent a physically prominent archaeological component as they are generally large, centrally placed structures. The mill structure includes a collection of machinery dedicated to the milling process, housed in a superstructure connected to but separate from other parts of the mining system. The mill includes a variety of activities that range from crushing and grinding, elaborate sorting and classifying, chemical and thermal treatments, and smelting furnaces, among many others. However, not all mines will have well developed milling components, and not all mills will include the entire suite of appropriate technologies. Each mill can be placed on a spectrum of size and complexity, and feature a mix of machinery. Mills represent but a single component of a system of extraction, reduction, and support components. They can be viewed archaeologically as part of a larger feature system. The mills may include a substantial array of subsidiary industries that support the milling
process, e.g. areas where charcoal was produced as fuel for the engine boilers and furnaces, or lime kilns where lime was produced for the leaching process (Hardesty 1988). As the complexity of studying an entire mining system is beyond the scope of this thesis, the current study is limited to the discrete unit of the mill where the ore reduction process was carried out.

Narrowing the focus of this study is not without inherent difficulties. There are issues with separating out the mills for singular study. As a component of the mining system, mills occupied a specific place within the mineral extraction system. Considering mills as discrete technological units ignores systemic factors that led to certain milling configurations being used in place of others. As an example, at Cortez, the placement of three of the mills also resulted in the development of adjacent residential areas, yet a thorough study of residential areas is beyond the scope of this thesis. Also, certain mills were constructed to treat ores from a variety of mines in the region, while others were built for a specific group of mines; these might exhibit differing elements of location and configuration, or include a more general process for different types of ore. Only considering the mills and their technology to the exclusion of the larger mining landscape introduces a limited view of change in the mining district. When appropriate, some of the factors that have influenced mill development, outside of the core necessity of milling a certain range of ore types, will be mentioned.

Shortcomings of the data available for the mills will be discussed in greater detail in Chapter 3 and Chapter 4. These include issues relating to documentary and archaeological data. Documents regarding the milling operations at a mine may be sparse,
vague, or misleading. Similarly, archaeological milling sites often exist in a poor state of preservation as milling equipment, particularly equipment that is portable and transferable to other areas, is frequently salvaged. Prior to the widespread use of Portland concrete, mills were built using dressed stone blocks that might be repurposed. With regard to fieldwork at mill sites, toxic chemicals used in the milling process create safety concerns surrounding archaeological excavation. These are only a few issues that need consideration when investigating mill sites.

**Thesis Outline**

This thesis is divided into five chapters. The current chapter introduces the project and overviews the methodology employed in this thesis, and provides a brief historical context of Cortez. Chapter 2 is a survey of the theoretical foundations for this study, and will include approaches to the archaeology of mining used by previous researchers. Chapter 3 is a synthesis of the various documentary sources regarding the mills that will provide insight into milling processes that were adopted over time. Chapter 4 includes a survey of the archaeological remnants of the mills and describes what data is available regarding mill construction, operation of the mill, and post abandonment impacts to the mill site. Chapter 5 compares documentary and archaeological data to identify trends in the changing mill technology and possible factors that influenced these changes. Areas for future research are identified, including areas where additional data might be useful.

**Methodology**

This thesis includes a compilation of fieldwork and archival research performed by the author while employed at Summit Envirosolutions, Inc. between 2008 and 2014.
Summit’s ongoing work at Cortez has been an important source of information about the district. It was during the course of working for Summit that I conceived of a thesis based on Cortez mining technology.

Archival sources are drawn from archaeological work conducted by myself and many others, including the first work done in the district by Dr. Donald Hardesty at the University of Nevada, Reno (UNR) and Dr. Eugene Hattori of the Desert Research Institute (DRI), and later work by Charles Zeier and Dr. Michael Brodhead to create a historical context for the area in the 1990’s as part of Section 106 Cultural Resource Management (CRM) work. Between 2011 and 2016, I consulted archival materials housed at UNR Special Collections and the Nevada Bureau of Mines and Geology archives. These included documents relating to various corporations that existed in the district that are housed at UNR. Additionally Google Books has been an important source for archival materials, including contemporaneous trade journals and mining related documents. Newspaper articles were collected from Summit’s archival library, newspaperarchive.com, and the Cooperative Libraries Automated Network.

Fieldwork was conducted sporadically between 2008 and 2016 as I was able to explore the district and become acquainted with the mills. This included visiting each mill site, photographing the mill remnants, recording the location of the mills using geographical information systems (GIS) data, and documenting the general features of the mill sites. I also drew on work conducted by Summit Envirosolutions, Inc., particularly for the three mills in Mill Canyon, to fill gaps in the data, including the presence of materials that have only very recently been removed.
What was not part of my methodology, but will need to be completed, is an exhaustive inventory of each mill. My goals for fieldwork visits were to record general features of each mill. This included examining the location and setting of each mill, what identifiable equipment and features remain, what materials were used in mill construction, and general observations regarding each mill. This did not include a mapping out of each area of the mills, the measuring of each machine footing, details such as a listing of dimensions for lumber or sizes of pipe used in the mills, a complete inventory of associated artifacts, or other descriptive information that was outside of the scope of my research. This work is necessary to create a more nuanced archaeological description of each mill that, once completed, will contribute greatly to studying technological change in the district.

**Historical Background**

In order to familiarize the reader with the Cortez Mining District, a framework for studying the history at Cortez relative to concurrent events in Nevada is outlined in Table 1-1. What is shown in the table and the subsequent Cortez historical narrative is that the events at Cortez occur slightly out of sync with events in the larger state boundary. For instance during periods of economic depression, Cortez was in full production. The chronological divisions for Cortez are adapted from work done by Hardesty and Hattori (1983) and Brodhead (1993) and are categories based on shifts in the balance between corporate power structures and small scale activity at Cortez. These periods of formal corporate production and informal lessee production, come about as result of complex factors inside and outside of the district.
Table 1-1. State and Local Historical Periods and Cortez Mills  
(Adapted from Brodhead 1993; Delacorte et al. 1992; Hardesty and Hattori 1983; Tingley et al. 1993)

<table>
<thead>
<tr>
<th>DECADE</th>
<th>GENERAL NEVADA HISTORICAL PERIODS</th>
<th>NEVADA HISTORICAL MINING PERIODS</th>
<th>CORTEZ HISTORICAL PERIODS</th>
<th>CORTEZ MILLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1870'S</td>
<td>Early Prosperity (1869 – 1880)</td>
<td>Consolidation (1871 – 1880)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1880'S</td>
<td>Depression (1881 – 1900)</td>
<td>Early Decline (1881 – 1891)</td>
<td>Early Production (1881 – 1900)</td>
<td>Tenabo Mill (1886 – 1915)</td>
</tr>
<tr>
<td>1890'S</td>
<td></td>
<td>Depression (1892 – 1899)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1900'S</td>
<td>Late Bonanza (1900 – 1915)</td>
<td>Late Discovery (1900 – 1907)</td>
<td>Early Lessee (1901 – 1915)</td>
<td></td>
</tr>
<tr>
<td>1920'S</td>
<td>Late Production (1916 – 1929)</td>
<td>Consolidated Cortez Mill (1923 – 1937)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1940'S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Global trends developed between 1870 and 1914 that dramatically changed how people lived and worked. This period of rapid change has been termed by some as a second industrial revolution, building on the urbanization and industrialization of the previous period. This trend includes a shift from informal industrial development based on personal experiences toward the use of applied science and university educated professionals and the development of formalized industries (Hudson 1983; Wolfe 2015).
In Nevada this trend is seen in the increasingly formal organization of the mining industry. This entailed a move away from the dominance of the self-made miner and an increasing reliance on engineers and scientists to develop industrial processes. This period also included the increasing ability to transmit power over larger areas through sophisticated steam engines and later combustion engines and electricity. This second process of industrialization has been explained through four trends: the division of production into specialized tasks, the standardization of parts, the development of specialized machinery, and the detailed planning and engineering of production (Twitty 2002; White 2016; Wolfe 2015:86–87, 98). Developments in transportation and communication also changed how industry was deployed across Nevada, and increased the speed of settlement of remote areas. With the development of the Comstock ore deposit, the western Great Basin was integrated into the global economy as infrastructure quickly developed (Hardesty 1998:81). This development included improvements to the Overland Stage Road in the 1860’s, establishment of the transcontinental telegraph in 1861, and completion of the transcontinental railroad in 1869 (Elliot 1987).
The discovery of the Comstock Lode in 1859 and establishment of Virginia City created an opening act for Nevada mining history that miners sought to emulate in other parts of the state. The Comstock, an unprecedented deposit of silver and gold bearing ore, convinced the public that there was likely additional mineral wealth waiting to be discovered throughout the mountains of the territory east of the Sierra Nevada. The discovery of silver ore in Pony Canyon, the future site of Austin, in the summer of 1862 confirmed the existence of mineral wealth in the hills east of Virginia City. The “Rush to Reese River” was the result of this discovery and prospectors scoured the Great Basin in search of other valuable mineral deposits (Abbe 1985; Elliott 1987).
**The Cortez District**

The Cortez Mining District was organized in 1863 around gold and silver deposits in a remote portion of the Nevada Territory. Although currently near the geographical center of the state, at the time of its founding Cortez was closer to the border with Utah Territory (Bowers 1996:24; RRR 27 June 1863). The district was founded at the west end of the Cortez Mountains. District bylaws state that the boundary was ten miles square around the primary mining area of Bullion Hill and the discovery of the Veatch Ledge (Cassel 1863). Production in the district would generally continue from 1863 up to the present, despite economic depressions and changes in legislation that created fluctuations in the price of silver and gold (Elliott 1987; Bowers 1996; Hardesty 1988). Cortez began as a silver mine, although it is currently one of the world’s largest gold producers. The primary target metals of all of the historical mines at Cortez have been silver and gold. Profitable amounts of lead, zinc, copper, and turquoise have also contributed to production in the district. Estimates of the production of Cortez during the period in this study range from between 10 to 15 million dollars (Lincoln 1923:85-86).

The map below (Figure 1-2) shows the boundary of the district with labelled populated areas, including the first settlements at Shoshone Wells and Cortez Camp, and the later Cortez Town site and worker’s camp at the Garrison Mine.
Discovery and Settlement (1863 – 1870)

Cortez was and still is a very remote mining area. The district was located in May 1863 by a prospecting party of eight individuals departing from Virginia City and prospecting across central Nevada via Austin, Nevada. This party, led by Andrew Veatch, was part of a larger movement of prospectors into the eastern part of the territory. The party was financed by wealthy Comstock miners, including George Hearst. This is likely the first mining activity that occurred in the area, although according to some later sources, Cortez was discovered by Mexican miners who brought a shipment of silver ore to the mills at Austin in 1862 (Paher 1984:165). Earlier work in the area is possibility. However, this account of prior mining in the district is problematic as there is no evidence for earlier workings. In addition, shipping ore to Austin mills was not possible.
in 1862 as there was no sizeable population at Austin, or indeed an Austin at all until early 1863. Although there were likely assayers in the area, the first mill wasn’t built at Austin until August 1863, after the founding of the Cortez District (Abbe 1985:17). Finally, there does not appear to be any primary source data to support any substantial mining prior to the organization of the district in 1863. First-hand accounts published in Austin’s newspaper, the Reese River Reveille, describe in great detail the discovery and subsequent organization of the district (RRR 8 July 1863).

At the time of the arrival of the prospecting party, local Western Shoshone people had improved a nearby spring by excavating to a depth of six or seven feet. This area was aptly named Shoshone Wells, and included an early residential area for the district. To the east of Shoshone Wells and across Grass Valley, Mount Tenabo rises as the imposing west edge of the Cortez Mountains. Tenabo exhibits the prominent dolomite ledge known historically as the “Nevada Giant,” the geological feature that purportedly drew prospectors to Tenabo. Although prospectors explored the west slopes of the mountain, their focus was on the easily reached outcroppings in Mill Canyon to the east, on the opposite side of the mountain, as these claims were believed to include the richest ore deposits (Bancroft 1889)(Figure 1-3).
By June of 1863 the Cortez Camp in Mill Canyon was established near perennial stream, Mill Creek, on the east slopes of Tenabo. The naming of Mill Canyon is a clue to the intentions of the miners. The remoteness of the camp likely made the construction of a local mill an appealing option, and locating a water source suitable for the operation of a mill appears to have been one of the objectives of the prospecting party, aside from locating the silver itself (RRR 7 June 1863; RRR 8 July 1863). Cortez Camp was the center for administration of the district. This area included the Cortez Company mining offices and a graded area where the first mill would be installed (RRR 7 April 1864:11-12). Detailed directions were printed in the Austin newspaper and included a description of Grass Valley ranches friendly to travelers and the character of the ore and type of claims that might be located. The district had a loosely corporate structure from the
beginning with the immediate establishment of bylaws, and the appointment of a district recorder (Cassel 1863).

The first transportation routes to the district were the wagon roads leading north from Austin to Cortez, a distance of 73 miles over rough and often boggy terrain. Today the drive along the length of Grass Valley from Cortez to Highway 50 takes two hours. In 1863 the trip took two days. The position of Cortez in relation to the outside world and access to materials, people, and information changed over time, having an impact on the formation, composition, and adaptive strategies of the district (Hardesty 2010:176).

When the district was founded, the early mining hub of Austin, located on the Overland Stage Route and the Transcontinental Telegraph corridor, was the regional supply center for the mines. That changed in 1869 with the completion of the Central Pacific Railroad and associated telegraph lines, established along the Humboldt River. Cortez experienced increased access to transportation and communication networks via the railroad station and town of Beowawe, 27 miles to the north across Crescent Valley. (Brodhead 1993:8; Hafen 2004:325–326).

Prospecting continued throughout 1863. Claims were staked that centered on both the eastern and western slopes of Mount Tenabo, although the focus of the Cortez Company was on the eastern slopes as this is where the most prominent geological activity was visible (Johnson and McQueen 2015). Work slowed over the winter as miners left their claims to resupply, report their findings, or simply give up on the district. By 1864, miners returned in full force and the Cortez Company Mill was constructed. The eight stamp pan amalgamation mill was constructed over the summer of 1864, and
was running by September. The construction of the mill was likely an important symbolic gesture; a mining district with a mill hinted at permanency and a large anticipated mineral reserve, and this might have influenced the character of the camp as miners would have anticipated a long term stay in the district (Hardesty 1998:84). There is evidence that the Cortez Company anticipated the need for local resources and allocated and fenced off timber reserves for use in the mill (Hattori and Thompson 1987:68).

Mining continued at Cortez on the many claims found across Mount Tenabo. However miners quickly grew disillusioned by the quality of the ore, the difficulty milling the ore, and the distance from supply centers and the more effective custom mills at Austin. Work dwindled in the district throughout the 1860’s, picking up once again by 1868 (Brodhead 1993:6-8). Although there was no fortune made by the Cortez Company, or likely by any of the early miners working in the district, Simeon Wenban, one of the initial prospectors and former Cortez Company employee, was able to amass enough capital from his mining claims and likely from additional investment, that he broke away from the company and developed his profitable St. Louis Mine. Wenban’s mine was the richest in the district, and he was able to purchase the Cortez Company Mill in 1869, hauling the low grade ore from the St. Louis, over the mountain by mule trail, and down into Mill Canyon. The high grade ore was shipped at a cost of $90 per ton south to the Austin mills (Brodhead 1993:7-8).

This initial period resulted in the discovery of the district, the decline of the initial company, and the emergence of Simeon Wenban as a prominent figure in the district. This period also saw a shift in where mining activity and capital were focused, as activity
moved from the chemically complex ores in Mill Canyon to the more consistent and easily milled ores on the west slopes.

**Consolidation (1871 – 1880)**

The last quarter of the 1800’s saw a tumultuous political landscape for precious metals, as nations around the world began to adopt a gold standard in response to a series of panics that had swept global markets. Bimetallism, or the purchasing and minting of both gold and silver to back bank notes and paper currency was seen as antiquated and a source of instability in the markets. In 1873 a gold standard was quietly established in the United States with the Mint Act of 1873, or the “Crime of ‘73” as it was known in Nevada. This legislation eliminated an important source of income for miners from federal purchasing of silver and resulted in a lowering of silver prices over subsequent years (Bowers 1996:110; Elliott 1987). This was a sharp blow to the Nevada economy, as silver had become the state’s dominant product (Bowers 1996:110). Despite the grim prospects for silver mining, the state continued to see profitable mining through the 1870’s. This included the mines at Cortez, as Wenban developed new workings, including the extensive Garrison Mine that became his primary source of ore. By 1870 Wenban had incorporated his Tenabo Mill and Mining Company and had commenced purchasing the major mines that had been part of the Cortez Company. The Wenban Group grew to include 26 mines, as competition in the district dwindled. The focus of mining by the 1880’s had shifted from the east slopes where the original Cortez Company offices and mill had been located. This focus of Wenban’s activities was fixed on the west slopes and the area around the new town site of Cortez (Brodhead 1993:8-9). The population of the district shifted from a demographic of Americans, Europeans, and
Mexicans respectively, to include a growing population of Chinese miners brought in by Wenban (Bancroft 1889; Johnson and McQueen 2016).

At the end of the Consolidation period, Wenban had effectively assumed a role as the dominant figure and the district, and controlled all of the major mines (Brodhead 1993:9-10). Wenban likely made much of his initial fortune during this period, possibly facilitated by the sudden introduction of the pneumatic drill and the ability to dig up to four times faster in underground workings than was previously possible (White 2016:157)
Early Production (1881 – 1890)

In early 1880, and despite a continued drop in silver prices, Wenban began to improve areas of the adjacent Grass Valley in anticipation of expanded operations on the west side of Tenabo. The Cortez Mill was at least 7 miles distant from Wenban’s mines, and haulage costs were considerable. Wenban began a long planning process for a mill early in the 1880’s. Wenban patented two springs in Grass Valley, sunk artesian wells, and pumped water seven miles north to a new mill and town site. The mill was constructed three quarters of a mile below the now dominant Garrison Mine tunnel that connected the major workings. The Cortez town site developed immediately below the mill, and included a company store and housing. Residential areas at Shoshone Wells also expanded. The new Tenabo Mill was completed and operating in 1886 using a newly developed Russell Lixiviacion Process (Hardesty 1983, 1988; Brodhead 1993:10-12). The construction of the mill initiated the most productive period at the mines, beginning in 1887 and lasting until 1891 (Hattori and Thompson 1987:64).

In 1888 the Bewick and Moering Firm based out of London expressed interest in the Cortez Mines, partnered with Wenban and incorporated Cortez Mines Ltd. Wenban retained controlling interest and acted as mine superintendent. This infused the area with new capital and allowed for the purchase of additional assets, including a light gauge rail that ran from the mine tunnels down to the mill, a new ore furnace, and new brick improvements to the mill structure (Brodhead 1993:9-10; DAC 22 October 1888; Johnson and McQueen 2015; NSJ 15 July 1891).
Between 1890 and 1893 the Sherman Silver Purchase Act was passed, subsidizing silver mining by requiring the purchase of 4 ½ million ounces of silver each month by the mint (Bowers 1996:110). Despite these efforts, the price of silver continued to fall and mining at Cortez began to shut down sporadically through the 1890’s (NSJ 7 May 1892). The English investors pulled out of Cortez and ownership reverted to Wenban in 1892 (Brodhead 1993:10).

*Early Lessee (1901 – 1915)*

The first quarter of the 1900’s saw a series of new discoveries in Nevada, and the retreat of the dominance of silver mining. Gold deposits were becoming an important resource as technological developments allowed for efficient gold recovery. In addition the dramatic rise of electricity as a power source and the sudden need for copper wire saw copper become Nevada’s primary export. As a result, silver as a political hot topic in Nevada was not as significant as it had been in the 1880’s and 1890’s (Bowers 1996:110).

Wenban died in San Francisco in 1901, and his estate controlled the mines and continued to operate the mill at Cortez while leasing the estate’s 42 claims and 15 miles of mine workings to various operations, including small scale miners. In 1908 the mill was modified to process tailings via the cyanide process (Brodhead 1993:11; Hardesty 1988:11, 18). Renewed interest in Mill Canyon at this time introduced a resurgence of work as small scale miners began developing mines in this area and large scale capitalists inspected the area with interest. This period ended with the burning of the Tenabo Mill in
1915 and a brief hiatus on the west slopes (Brodhead 1993:11-12; Hardesty 2010:11; NSJ 17 August 1908).

*Late Production (1916 – 1929)*

A new period of production and milling arrived at Cortez in the early 1900’s with the working of the Majestic Claims. These included a portion of the original Mill Canyon workings that were developed by John B. Menardi in 1911. Menardi constructed a concentration and possible cyanide mill in Mill Canyon in 1913. Although Menardi’s operation was not successful, and the company was bankrupt by 1916 (REG 27 December 1913; REG 6 April 1916).

Another group, the Consolidated Cortez Gold and Silver Mining Company (Consolidated Cortez Company), purchased the old Wenban Group on the west slopes of Mount Tenabo and constructed a large cyanide mill in 1923 (Brodhead 1993:12-13). CCGSMC worked the Arctic Tunnel, a mine started by Wenban’s earlier Tenabo Mill and Mining Company. The Arctic was the major mine of the Consolidated Cortez Company. The company operated into the Depression Era, closing in 1933 (REG 7 October 1933).

*Late Lessee (1930 – 1940)*

This period marks a departure from the large company workings. Depression era Cortez involved struggles on both sides of the mountain. On the west slopes, the Consolidated Cortez Company attempted to keep the mines producing. In Mill Canyon the Roberts Mining Company was leasing the old Menardi properties and had constructed a mill. Lessees likely continued to work on both sides. This may have been the result of
an economic climate that discouraged large capitalization, as small scale, cash poor subsistence miners are less effected by economic conditions (Hardesty 1998:83). The start of WWII and the moratorium on non-war related mining effectively ended the streak of mining at Cortez that had started in 1864. Production at Cortez between 1902 and 1936 is estimated at $171,786 in gold and $2,564,972 in silver, demonstrating that at Cortez silver was still the most important resource (Brodhead 1993:13-14). The 1950s was a quiet time for the district, as Lloyd High became the last resident of Cortez. Little activity occurred in the district, except for some lessee mining (Murbarger 1959). The 1950’s saw the sale and demolition of assets at both the town of Cortez and the Consolidated Cortez Mill, and the trucking out of Consolidated Cortez Mill tailings. In Mill Canyon, WWII scrap metal drives likely emptied the canyon of much of the remaining mine equipment, and it is likely that little mining was done (NSJ 5 March 1954; REG 28 February 1955; REG 13 February 1958). In the late 1960’s the district saw renewed activity, as pilot heap leaching activity was begun. Today Cortez is one of Barrick Gold Corporations most valuable assets.

The following chapter will outline some of the theoretical approaches to explaining differences in the mills at Cortez, how they were constructed, and what equipment was used. A framework for studying environmental learning, networks of exchange, and technology will be introduced, followed by a discussion of how they fit in to the archaeology of mining.
2. The Archaeology of Mining

The discussion in this chapter begins with an examination of the factors that create the mining landscape. This is followed by a discussion of two linked concepts: environment and technology. The physical environment exists outside of cultural systems until humans begin to visit, develop ideas about, and exploit resources within a specific area. This study focuses on the relationship between people, technology, and the environment via the archaeological remains of ore reduction mills. The archaeology of mining environments can be regarded as the “material expressions of the history of human-environmental interactions” (Hardesty 2010:8). During the activity of mining, humans target a resource and then develop exploitive strategies that inform subsequent behavior. Because of the difference between a specific physical environment and human perceptions of that environment, human exploitive strategies exist within a range of potential behaviors that change over time as a result of the acquisition of knowledge. These behaviors are not optimized and exist in relation to the imperfect knowledge that the individual and group possesses about the environment, not the actual environment itself. This knowledge should then be observable in technological trends.

The goal of this thesis is to understand trends in historical milling technology in a single mining district over an 80 year period and across five milling sites. What were prominent factors that affected the choice of milling technology used at Cortez over time? The primary argument proposed here is that Cortez milling technology changed based on how the miners understood the environment, and that this environmental knowledge underwent continuous change. This knowledge included ore location and
composition, distribution of resources including water and timber among others, and modifications to local environmental knowledge based on shared information with people in other environments. People modified and adapted technology to suit their understanding. A useful approach to specific environmental adaptation is the concept of landscape learning developed by Marcy Rockman (2003, 2009). Landscape Learning Models visualize how people form ideas about an unfamiliar environment, including details of resource patches, cyclical characteristics, and other information that makes exploitation possible.

Technology is used by people to interact the environment, and makes successful exploitation possible. A set of tools for studying technology in the archaeological record is provided by Behavioral Archaeology. These conceptual tools will assist in a study of how milling was implemented as part of the mining system, including what technology was chosen, how it was operated, and how it was modified. Technological invention, adoption, and adaptation has been studied in many contexts by Michael Brian Schiffer et al (Schiffer et al. 2010) and has resulted in multiple theoretical models and matrices for examining patterns in technological adaptation. These approaches will form the core of the theory used in this thesis and are discussed further below, along with their implications for the archaeology of mining.

The Mining Landscape

Mining is an activity that alters the environment and creates observable patterns. These patterns, specific to mining, may be very large and distributed over a wide area, depending on the scale of mining. The mining landscape will include underground and
above ground components. Features of the mining landscape include excavated prospects to sample ore; mine adits, shafts, and other manifestations of extraction; machinery and infrastructure to support underground workings, milling machinery, evidence for subsidiary industries, residential areas, and transportation and communication networks. Part of the reason for delineating a mining landscape from other types of landscapes is to single out behavior specific to mining that create these types of patterns, and to chart changes in the underlying behavior that produces them. Mining landscapes have a legal definition in the United States as a defined historical landscape that is then evaluated in relation to its compositional properties (Noble and Spude 1997:13-14). For the purposes of this thesis, the mining landscape is defined by the grouping of sites that result from the behavior of exploitation in a geographical area. This includes not only the primary resource areas but subsidiary industries and resources and residential areas and associated supporting sites. The process of mineral extraction has an enormous impact on the landscape that is impossible to repair. Mining scars can only be masked by infilling and revegetation. Historical mining from the last two centuries has created areas where the features of mining are highly visible to the casual observer. Despite this visibility, mining was not an important theme in archaeological research until relatively recently. Historical archaeologist Donald Hardesty describes the 1980’s as the decade that archaeologists discovered mining. Renewed mining activity and new environmental regulations in many historic mining districts created the need for archaeological research to be carried out, and this necessitated a critical look out how this was to be done (Hardesty 1988). Hardesty (1990:47-49) developed a significance matrix for evaluating data potential at mining sites. This matrix, adapted to specific locations, is divided into
research domains that include: demography, technology, economics, social organization, and ideology. As can be seen, some of these would fall under the purview of cultural studies and some under ecological studies. To fit within the scope of this thesis and focus on technological change, we will restrict our research to the changes in mining related mill sites based on environmental knowledge.

**Corporations**

From an organizational standpoint, the type of corporate organization had a direct impact on the deployment of milling technology. Milling often represents the apex of development at a mine, as mills are expensive and require extensive capital to construct. If miners believed that there are adequate reserves to develop over time, they will likely succeed at acquiring additional investment. A well-capitalized mine would likely have a corporate structure, at times quite rigid. How corporate structure was organized would determine how decisions were made about what technology to use. From a research perspective, this also influences the availability of archival sources, including the type and quantity of sources that are available.

Because of the control that corporate interests displayed within mining areas once they had gained control over a body of claims, industrial sites with a corporate structure will be characteristically different than smaller scale operations. (Twitty 2002). Corporate control of mineral resources played an important role in the organizational configuration of the mining district. This power was comprised of interlaced networks expressed as ideological, economic, military, and political. These networks had variable importance in the mining district, and tended to be permeable (Hardesty 1998:82). With regard to the
mill, not only would corporate structure influence available capital, but the size and composition of the corporate structure might influence innovation. Research seems to indicate that mid-sized companies employed innovative technology more often than small and large companies because small scale miners lack the resources to innovate and large scale operations were reticent to try untested technologies. Variability in the type of ore at a mine might also force larger companies to innovate in ways that they would not have done with more consistent resources (Hardesty and Little 2009:125).

Power structures may also include formal and informal hierarchies. This is expressed in a formal corporate structure versus an informal lessee or subsistence mining structure (Hardesty 1998:82). At Cortez this formal and informal organization coexisted to varying degrees. Although many of the choicest claims were controlled by capitalized interests, small scale miners existed at Cortez from the beginning and continued to mine at Cortez throughout the history of the area. Although lacking the power to affect large change in the district, small scale miners were often in a position to weather economic downturns, as the market for precious metals is itself counter-cyclical and a hardship globally might be an economic windfall for seasonal or small-scale miners (Hardesty 1998:83).

Environment and Technology

To understand changes in human behavior with regard to technology and the environment, two theoretical approaches are used to conceptualize the factors that might affect this change. These are the Landscape Learning Model and the organizational approach of Behavioral Archaeology. Both of these approaches seek to create an
approachable framework for the research of the complex subject matter of human behavior. Landscape learning is a broadly applicable model to study changes in human knowledge of details of an unfamiliar environment (Rockman 2003). Behavioral Archaeology, developed by Michael Brian Schiffer, Jefferson Reid, William Rathje and others, is not so much a model itself as a toolkit that seeks to understand human interaction with material culture so that inferences might be made with regard to the available data from artifacts and archaeological sites. This toolkit, explicitly materialistic, makes clear the position of archaeology in relation to the study of humans and their artifacts. Once the ground rules are set, and the tools are laid out, models can then be made to explain technological change in a restricted and contingent way (Schiffer 2010).

*Landscape Learning*

In historical archaeology, the relationship between the environment and human behavior has often been downplayed with the implicit assumption that humans in historical contexts had mastered their environments and had moved beyond being fundamentally affected by environmental considerations. This has led to a focus on social relationships, ethnicity, economics, and ideology, and often excluded environmental considerations (Hardesty 2009:67). This situation is rapidly changing and the environment has assumed an increasingly prominent role in historical archaeological research.

In order to exploit mineral resources, miners had to acquire knowledge about the mining landscape, specifically the quality and location of the ore that they would be mining. In historical mining periods, this activity was performed by the first prospectors
that arrived in an area and explored the terrain. These first arrivals sought out of promising claims by searching for faults and fissures, and exposing bedrock to collect samples for assaying. This also extended beyond the ore to other features of the environment, and was a continuous process as new exploitable resources were required. The need for a thorough knowledge of the environment is stressed in contemporary field manuals. Mining engineer John Murphy acknowledged this fact in his 1890 manual for miners: “Many people think that when an engineer has examined a mine, sampled the ore and had it assayed, and reported upon its quality, his work is completed. But is his work really completed? I think not…” (Murphy 1890:5–6). Murphy goes on to discuss the various resources that must be considered in location to the mine with special attention to water and timber. These considerations factor heavily in how mills were situated as part of continuing exploitation of the mining landscape. According to Rockman’s (2003, 2009, 2010) Landscape Learning Model, environmental knowledge is divided into two forms: prior and gained. Prior knowledge is carried with the new arrivals from a previous environment, and gained knowledge is acquired through the process of living in and interacting with the environment (Rockman 2009:51-52). The use of these concepts in the archaeology of mining, as adapted by Hardesty (2003) becomes clear, as the categories are based in degrees of changeability, and may be analogous to the forms of knowledge that are used as the mining landscape is occupied and constructed. Miners in this model can be regarded as “industrial foragers” that seek out patches of mineral resources (Hardesty 2003:93). The miners that organized districts in remote areas around the world were bringing with them environmental knowledge acquired through work in prior areas. For example miners that worked the Comstock Using this prior knowledge, early period
miners began to adapt what they knew about the oxidized, free milling ores at the
Comstock to other places in Nevada. As will be seen, this transplanting of knowledge
can be problematic when assumptions are made about a new environment. (2003, 2009,
and 2010) describes landscape learning as occurring in three knowledge categories:
locational, limitational, and social. These are sequential steps in the learning process that
begin with the arrival of people into an area (the location of the landscape), the length of
time acquiring knowledge about resource availability, climate, and other factors (the
limitations of the environment), and the eventual codification of environmental
knowledge into a transmittable form through spoken word, maps, newspapers, or other
forms of information transmission (the social knowledge of an environment) (Rockman
2010). A model for environmental exploitation adapted for mining is show in Figure 2-1
below. This flowchart shows the arrival of the miners into a new environment; the
accumulation of environmental, social, and technological information that will assist in
adaptation; and the synthesis of new understanding of the environment until either the
process is repeated or the resource is exhausted. In this case new resources are needed to
continue the process and allow for human exploitation.
Figure 2-1. Flowchart based on the Landscape Learning Model. Adapated from Rockman (2003) and Hardesty (2003).

Criticisms of this model include the omitting of cultural influences on environmental perceptions; this might include attributing human characteristics such as agency to non-human environmental features (Fontein 2007), or people purposefully providing false information, or other forms of cultural bias. Certainly all human behavior includes an imperfect translation of what appears in the environment into a form that can be used by themselves and by other people. The information that is generated is not a 1:1 representation of the environment. This misrepresentation might be an intentional if an exploitive strategy comes into play that includes spreading disinformation, such as has occurred at times in historical mining areas. In addition, the emphasis on the environment and constructed landscape is at odds with trends in social theory and anthropology that have moved away from what is perceived as environmental determinism that obscures human agency. Rockman (2009:52-54) acknowledges this, but ascribes misgivings to the misuse of evolutionary theory in early models, and asserts that macroevolutionary theory
is a powerful tool for understanding how culture both modifies and is modified by the natural landscape.

Finally, the acquisition and expression of environmental knowledge is itself a form of corporate power. As Orser (2009:264) observed, although Europeans in the new world possessed the technology capable of increasing the exploitation of resources and enforcing political power, they lacked the environmental knowledge that native people possessed, and until they acquired that knowledge themselves, were unsuccessful in their colonial endeavors. Similarly, mining corporations might benefit by including individuals with environmental knowledge specific to an area, limiting how effective outsiders might be in an unfamiliar area.

Changing Technology

The study of historical mineral extraction suggests a unique set of research questions and related issues that includes the study of technological change (Hardesty 1990:48). Trends in the technology that is seen in the archaeological record are an important part of mining related sites (Hardesty and Little 2000:35). The approaches to technological change included here are the adoption, operation, and adaptation of technology, relative to how the Cortez environment is situated in the understanding of miners

Michael Brian Schiffer, et al. (2010), working within the toolkit of Behavioral Archaeology, explains technology in terms of the transmission of certain types of knowledge that include: recipes, teaching frameworks, and techno-science. These three knowledge concepts, similar in their intention to Rockman’s landscape learning
knowledge concepts described above, involve the transmission of methods to reproduce a technology. The assumptions that are tackled by Schiffer involve what are understood to be improvements to the techno-science of the technology, and what is assumed but not made explicit by the learned technological recipe/teaching framework. These might include material features or properties of technology that have not been formally tested by the miner but are instead part of the ideology of what is assumed to be the most efficient process (Schiffer 2010:96-97). This creates a fascinating intersection of learned behavior that incorporates ideology and what has been observed by the miner to work, as was the case when the stamp mill at Cortez employed the Washoe Process developed at Comstock Mills (see Chapter 3).

Once a technology is reproduced in the environment, for instance a stamp mill, it resides within what Schiffer has described as the functional field, or “the set of techno-, socio-, and ideo- functions that the entirety of a society’s artifacts have to perform” (Schiffer 2010:95). In this space the mills might change based the needs of the miners, for instance to exploit a different type of ore, or to adopt an innovation that is perceived to increase the yield of the mill. Technical choices are the decisions that miners make in the initial selection for the mill, and later modifications, and determine the ultimate form that the milling archaeological site will take. By examining mill remnants, these choices can be examined in the context of the learned environment, as described previously.

An additional consideration is the insertion of social processes into the technical field. Sociotechnical theory developed out of studies at MIT that focus on the intersection of social and technical concepts, and seeks to explain the interaction of human groups
with technology in a variety of ways. Sociotechnical systems might describe how an office workspace affects the ability of a human agent to perform certain tasks, or why large technological systems fail as a result of social processes, or how vulnerabilities in the sociotechnical systems create more resilient technological manifestations (Hommels, Mesman, and Bijker 2014).

Part of the complications regarding interpreting mining districts is that technology does not appear to have spread evenly across the mining district, and although there might be national trends in one aspect of mining, districts also tend to follow unique historical trajectories in technological development. This has been described as differential adoption by Schiffer (2010:128-134). Even into the 1970’s it was observed that underground miners, rather than adopt more modern techniques, were implementing square set timbering that had developed a century earlier on the Comstock and with the same techniques manually wedging each timber (White 2016:159). This introduces an ideological and cultural dimension to the adoption of technology that does not simply involve calculated rationale.

Another important conceptual framework for examining the operation of the mills is the chaîne opératoire, or the behavioral steps that individuals take when interaction with a technology. A close examination of behavioral processes proposed by French archaeologist Claude Leroi-Gourhan that involves identifying steps in the process and isolating cultural aspects of each individual steps (Stollner 2014:134-135). Although applied to ancient mining sites, this is applicable to more recent mining landscapes as well. The activities that take place at the mill include overlapping layers of meaning and
understanding, so that the mining landscape (surface croppings, old workings, mining camps, tailing piles, etc.) include meaning as part of the way mining is conducted, but also as an accumulation of meaning as the mining district is developed through time (Evans 2004:35-36). This is apparent in the documentary sources, as renewed activity at an abandoned mining camp elicits interest in the history of the area and newspaper articles often include descriptions of the prior workings. Technology in this regard can be seen as a participant in social networks of the mining districts. The mills themselves are important demonstrates of the success of a mining venture, and may influence the decisions of miners and non-miners alike in a mining area by their presence alone. In this way, according to Actor-Network Theory technology can be a participant in social networks, as interactions with the mill and the ore in turn are related to subsequent behavior; technology is regarded as a participant in a network (Cowie 2015:53).

An approach that is explicitly grounded in the artifacts, or in the case of the mills, in the remnants of the mill and machinery, is the “life history” of the artifacts. Described by Schiffer (2010:21) as the most important tool used in Behavioral Archaeology, life history is the description of how an artifact is made, used, and discarded. This describes the minutiae of human behavior toward material culture in a systemic way, and is often described visually as a flow chart. In this way the life history of the mills might be described to include their construction, use, and abandonment. Indeed flow charts are already abundant within the mining industry to describe the milling process.

The above theoretical concepts are an attempt to isolate steps in the deployment of technology in the mining district, and explain types of behavior that might be the
culmination of accumulated experiences and learning. What is common in all of the above approaches is that behavioral change in the modern global paradigm requires the teasing apart of very interwoven and complex systems of relationships between people and the environment. These approaches, used in a more systematic way, will be revisited in Chapters 3 and 4 as the documentary and archaeological data of Cortez is described, and finally in Chapter 5 when the implications of the combined data and theory is discussed.
3. Cortez Documentary Sources

This chapter examines the nature of primary source material available for western milling operations, and then addresses data specific to the Cortez District to construct a detailed description of each of the five Cortez ore reduction mills. Considered alongside the archaeological record, primary sources help to identify patterns in how the mills were adapted, successfully or not, to their respective environments. These ore reduction mills span the years 1864 through 1944.

As discussed in Chapter 2, milling technology can be meaningfully divided into two categories of reduction: mechanical reduction of the ore to render it into smaller particles, and extraction technology that initiates chemical reactions to isolate metals from the gangue or valueless rock. Whatever material remains after processing is discarded as tailings. Reduction technology generally involves first mechanically crushing the raw ore into a size that is manageable for further sorting and milling. This is followed by classifying or additional sorting of the ore, often in a repetitious circuit, as the particles are reduced into a sand or powder. The type of beneficiation process will influence how and to what size the ore is crushed, and may involve roasting the ores prior to or after crushing. Beneficiation technology can be based on a physical or chemical process, or a combination of the two. On a side note, although it is useful to divide milling equipment into crushing and beneficiation, these technologies follow one another and cannot be completely decoupled. Milling processes become complex when necessary: stamp mills suffice when the ore is high grade; cyanide technology is developed when the ore is low grade; in turn cyanide leaching requires more efficient
crushing technology and initiates a shift from stamps to ball, tube, or roller mills (White 2010:69–70). This also brings up a point discussed in Chapter 2. The mills in any mining landscape are nodes in a resource exploitation network, albeit nodes with a particularly heavy archaeological and archival footprint (Kelly and Kelly 1983:92). Mills are also part of the feature system of the mining landscape and may both create subsidiary feature systems and influence transportation, communication, and resource networks in their vicinity and beyond (Hardesty 1988, 2010).

The milling technology at Cortez can be described in terms of five overlapping shifts. These include: mercury based pan amalgamation, thiosulphate leaching (lixiviacion), concentration, cyanide leaching, and oil flotation. On a national and global scale, these technologies do not replace one another. Components of each technology often occur simultaneously, and although cyanide heap leaching is the prevailing form of industrial gold processing in the world today, forms of all of the beneficiation technologies that were used at Cortez are still in use (Lynch and Rowland 2005). For instance, modern subsistence miners, or miners who practice small scale, informal, and non-capitalized mining on a seasonal basis, use a mercury amalgamation pan process that was similar to that practiced in the American West. A form of thiosulate leaching (the historical term is hyposulphate lixiviation), regarded as overly complex by many Victorian era miners, was recently implemented by Barrick Gold Corporation at the Goldstrike Mine in Eureka County, Nevada because it was regarded as far less toxic than cyanide leaching (McKown 2015).
**Introduction to Documentary Sources**

Primary sources provide an important insight into social and technical aspects of the construction, operation, and eventual shutdown of each mill that cannot be gathered directly from the archaeological record. Documentary sources, alongside the archaeology, create a richer context for the mills than is available from a single source. As Lu Ann De Cunzo (2013:266) has noted: “…increasing understanding of adaptation to industrialization and urbanization shall come only from understanding the complex pattern of relationships among documented and archaeologically analyzed aspects of adaptation.” To understand the relationship between the Cortez mills and documentary sources, we will further examine each type of document.

The mills that were constructed at Cortez include an array of accompanying historical documentation. The bulk of this documentation is housed at the University of Nevada, Reno both in the Mathewson-IGT Knowledge Center Special Collections and the Nevada Bureau of Mines and Geology archives. Other important sources are Nevada and California newspapers. The *Reese River Reveille* of Austin, Nevada is an important source for accounts of the earliest milling in the district. At this time California newspapers also provide information, including the *Daily Alta California* of San Francisco and the *Daily Record-Union* of Sacramento. From the 1880’s through the 1940’s trade journals become increasingly important sources of information. These include *The Engineering and Mining Journal* and *The Mining and Scientific Press*. Other important sources are government surveys and reports, and various milling manuals that describe the configuration of the mills in great detail. These will be described in greater
detail in the next section. The location and dates for the mills are shown on the map below (Figure 3-2).

The documentation that is available might be comprehensive or at times sparse, depending on the time period, preservation, and corporate structure present at Cortez. The documents also vary in their purpose, accuracy of information, and inherent bias, resulting in variation in the quality of the data available for each mill. For example the Tenabo Mill includes a variety of document types, from ledger books to newspaper and personal accounts, while the primary documentation associated with the Menardi Mill is restricted to a few newspaper articles and government documents. This is due largely to the small size and the relatively short time that the Menardi Mill operated.

Within the archaeology of mining, the importance of considering historical documents in conjunction with the archaeological record is to create a comprehensive overview of the hard rock mining feature system. As Hardesty (1988.ix) notes, “The most accurate image…comes from overlapping documentary sources and archaeological accounts.” This is because the archaeological data available at mines and mining camps will be a palimpsest of overlapping features. One major reason for this blending of features is due to the tendency of miners to mine in the same areas with different technologies, reuse equipment, and remove features as part of scrap metal drives, such as the massive effort to collect scrap metal during WWII. This has created a situation where the archaeology may not be easily interpreted or may be absent altogether (Hardesty 1988:13).
Types of Documents

For the purposes of the current study, the term documentary sources is used as a catchall for primary source material, and includes historical photographs and written oral histories. This written and visual record includes a variety of types of data. Each source conveys information in a different format and with different intentions. The United States Federal Census is aimed at collecting aggregate data for use in assisting the Federal Government devise policy, while company records might be used by investors or mine owners and management to assess the condition and performance of a mine, or to explain performance deficiencies. All documents include some form of bias. Even an objectively motivated census record is biased in the questions that it asks or the categories that are included. This feature of the documentary record requires an understanding of the provenience of the document and the motivations of the author, just as an archaeological artifact must be understood in the context of its location and association. Although the archaeology receives separate treatment in this study, Orser (2013), citing C. P. Russell, noted that the archaeological record might be regarded as another “three-dimensional” primary document. However, a consideration of the archaeological remnants of the mills themselves occur in the next chapter.

The primary sources discussed in this chapter tend to fall into six categories: newspapers, company records, government records, technical journals, cartographic sources, images, and first-hand accounts (Table 3-1). There are additional sources of information that are available to other mining areas, including recordings. However, the
primary sources briefly considered here are the sources that were consulted as part of this study.

Table 3-1. Document Types Relating to Cortez Mills
(Adapted from Hardesty 1988:6-9)

<table>
<thead>
<tr>
<th>Document Type</th>
<th>Data Potential</th>
<th>Possible Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newspapers</td>
<td>Cover a variety of events, particularly useful for the dates of operations.</td>
<td>Often sensationalized or promotional.</td>
</tr>
<tr>
<td>Company Records</td>
<td>Technical details of costs and processes.</td>
<td>Generally available for large companies and not small operations.</td>
</tr>
<tr>
<td>Government Records</td>
<td>Aggregate details of local and regional operations.</td>
<td>Poor reporting practices and incomplete data. Overly broad.</td>
</tr>
<tr>
<td>Technical Journals</td>
<td>Useful for tracking changes in technical processes.</td>
<td>Depict very specific technical processes to the exclusion of other details.</td>
</tr>
<tr>
<td>Cartographic Sources</td>
<td>Depicts spatial data and additional features that may be absent from written records.</td>
<td>Limited in scope and depicting specific features.</td>
</tr>
<tr>
<td>Images</td>
<td>Captures details of the mills that are absent from written records.</td>
<td>Biased toward the position of the photographer and can be difficult to interpret.</td>
</tr>
<tr>
<td>First-hand Accounts</td>
<td>Provide rich, anecdotal details and information absent in other sources.</td>
<td>Heavily biased and may be incorrect.</td>
</tr>
</tbody>
</table>

The following is a brief description of each type of document, adapted from Hardesty’s (1988:6-9) inventory of primary sources. Perhaps the most readily available source of information on the mills comes from newspapers articles. Austin’s Reese River Reveille offers detailed, if often exaggerated, descriptions of the construction and operation of the Cortez Company Mill. For some mills, including the Menardi Mill, newspapers are one of the few primary sources. The Depression era Roberts Mill and Consolidated Cortez Mill were closely followed in the Reno Evening Gazette as they operated into the Great Depression. Newspapers might feature itemized lists of equipment as part of auction listings, such as with the Roberts Mill.
Company records, when available, are invaluable to understanding the inner workings of the corporate structure. As mining archivist Richard Davis has noted, the classical method for appraising an archive of company documents is to divide the records into documents that deal with the organization of the mine and the use of capital and labor, and documents that detail the “persons, places, and things with which that enterprise did business” (Davis 1994:21).

Government records are very specific in their scope, and might include demographic data, company names and financials, production figures, and other technical data. Similarly, technical journals provide important specific information regarding what processes were in use at a mine. These journals, such as the *Engineering and Mining Journal*, were important for the exchange of ideas between mine engineers and mining regions.

Cartographic sources include plat and claim maps that depict patented lots or the location of mill sites and subsidiary resources. At Cortez, resources that are omitted from other primary sources are depicted, such as the Mill Canyon Schoolhouse (1938 USGS 15 Min. Quad Map “Cortez NV”). Images are particularly useful for depicting the environment that the mills are located in, but seldom show the interior of the mills. At Cortez, to the author’s knowledge only the Consolidated Cortez Mill has photographs of the interior.

Finally, oral histories are important for providing more anecdotal information. Personal accounts of the mills, although sparse, describe details and aspects of social relations that might be otherwise invisible in the documentary and archaeological records.
Using documentary sources, the configuration of the Cortez mills will be reconstructed below, with a brief context, descriptions of construction, equipment, personnel, and mill operation, including any known modifications that might have been made to the technology. This is done with the goal of identifying patterns in the deployment of milling technology that might answer questions about how people use technology to exploit their environment. Although the exploitation of previously unavailable resources is important to the development of the mill technology, it is important to keep in mind that with the passage of time, high grade ore in the district is depleted; each mill succeeding the prior one is operating in a diminished environment and is expected to profit from increasingly impoverished ore bodies (White 2010:69). The mills were located on either side of Mount Tenabo, and are shown in Figure 3-1.
The average lifespan for a mill at Cortez was 16 years, although the two earliest mills operated for considerably longer. There are reasons for the variation in operating time that will be discussed in Chapter 5. In brief, they include increasing technological adaptation in the form of new replacement technologies, changes in the composition of
the ore that make a milling technology obsolete, and both micro and macroeconomic forces. The mills are summarized in Table 3-2. The name of the mill, along with the company that operated, years of operation, and general technological configuration are outlined in this table.

Table 3-2. Cortez Mills (Zeier 1993; Johnson and McQueen 2016)

<table>
<thead>
<tr>
<th>Name of Mill and Company</th>
<th>Years Operated*</th>
<th>Crushing Technology</th>
<th>Extraction Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortez Company Mill/CGSMC</td>
<td>1864 – 1886</td>
<td>Stamp Battery</td>
<td>Washoe Pan Amalgamation converted to Reese River Pan Amalgamation</td>
</tr>
<tr>
<td>Tenabo Mill/TM&amp;MC, CMRC</td>
<td>1886 – 1915</td>
<td>Krom Rolls</td>
<td>Thiosulphate Leaching; converted to Cyanide Leaching</td>
</tr>
<tr>
<td>Menardi Mill/CM&amp;RC</td>
<td>1913 – 1915</td>
<td>Rolls and Tube Mills</td>
<td>Concentration converted to Cyanide Leaching?</td>
</tr>
<tr>
<td>Consolidated Cortez Mill/CCSMC</td>
<td>1923 – 1937</td>
<td>Gyratory Crusher; Sorting Screen; Drag Classifier</td>
<td>Cyanide Leaching converted to Oil Flotation</td>
</tr>
<tr>
<td>Roberts Mill/RMMC</td>
<td>1930 – 1944</td>
<td>Blake Crusher, Ball and Tube Mills</td>
<td>Mercuric Cyanide Leaching converted to Oil Flotation</td>
</tr>
</tbody>
</table>

*Note: Years operated includes periods of inactivity.

Cortez Company Mill (1864 – 1886)

The Cortez Company Mill was constructed by the Cortez Gold and Silver Mining Company in 1864. The mill was a stamp and amalgamation mill typical of the time period (Angel 1864). Although essentially a medieval technology and remarkably similar to the stamp batteries described by Agricola (1950 [1556]), the stamp mill represented the most effective means for processing ore that had been developed up to that point (Oberbillig 1967).
The Cortez Company Mill was built as a result of a larger movement of miners migrating east, outward from Virginia City and into central Nevada in 1863. A boom had developed in the Reese River District with the discovery of silver ore in 1862 that initiated a “Rush to Reese River” that resulted in the founding of Austin, Nevada and the creation of a regional supply and staging hub for prospecting, mining, ranching, and other subsidiary industries. This included the colonization of the surrounding, formerly unpopulated areas of central Nevada by a tremendous influx of miners and ranchers (Abbe 1985:2-8). As discrete areas were settled across the state, pockets of isolated Euro-American populations were established in remote areas, some far removed from supply centers. This situation was described by Hardesty as similar to a system of islands surrounded by an ocean of undeveloped hinterland (Hardesty 1988:1).

According to the *Reese River Reveille* (9 June 1863), the Cortez Mining District was organized as a result of this exploration. A group of six prospectors, led by Andrew Veatch, son of noted geologist John Veatch, surveyed the hills east of Austin. Veatch’s efforts were backed by capital provided by San Francisco, Sacramento, and Virginia City investors in an effort to rapidly establish claims over the perceived mineral wealth that was assumed to lie in the largely unknown interior of Nevada. The group worked their way north from the Overland Stage Road into Grass Valley and in March of 1863, located mineral claims in the Cortez Mountains approximately 70 miles northeast of Austin. The first claims were located on the northeastern slopes of Mount Tenabo, the highest peak in the Cortez Range. The original Cortez Camp and company workings are located in the deeply incised Mill Canyon that meanders along the eastern base of Mount
Tenabo as shown in the 1869 GLO plat map for T. 27N R. 48E (Figure 3-2). The Cortez Gold and Silver Mining Company was immediately incorporated and space for a town site that included company offices and an area for a mill were surveyed (Cassell 1863, RRR 27 June 1863).

There are indications that a mill was planned for Cortez from the beginning. At the time, the only access to the district was a stretch of dirt road that passed to the south and traversed Grass Valley, dipping into sometimes marshy lowlands that complicated wagon traffic. This made shipping ore south to Austin an arduous and expensive
proposition. This difficulty coupled with the ready capital provided by investors flush with cash from the Comstock made construction of a mill at Cortez, despite the remoteness of the location, a calculated investment. An additional clue to the intentions of Veatch and his backing investors comes from the naming of Mill Canyon and associated perennial water source Mill Creek, more than a year before the Cortez Mill arrived in the canyon (RRR 27 June 1863:4-5 and 8 July 1863).

In the year leading up the construction of the Cortez Company Mill the company started shipping high grade ore to the custom mills at Austin, where a milling industry was growing in response to the establishment of new mines in the region. In Austin’s newspaper, the *Reese River Reveille*, the Cortez District was celebrated with the exaggerated hype typical of the era: “People are arriving daily and it is very evident that from this time forward Cortez will be a most busy district, and soon be known as second to none in the Territory” (Abbe 1985; RRR 3 May 1864).

By the summer of 1864 it was reported that the Cortez Company had surveyed two sites for mills, one in Mill Canyon in the vicinity of Cortez Camp and another at the mouth of the canyon. June stream-flow at Mill Creek runs approximately 2.2 cubic feet per second (Zones 1961:37). This indicates that Mill Creek is a significant perennial water source for the area of the Cortez Mountains and also within the arid Great Basin. Prior to the construction of the first mill, the creek was advertised with extreme optimism as being able to power “several quartz mills” or “one hundred stamps” (RRR 15 July 1863 and 7 May 1864; Zones 1961:37). Water was an important resource for the working
of the mill as it was necessary for the steam engines and for wet crushing, a process used initially at the mill.

The 1869 GLO plat map (Figure 3-2) places the mill about one mile up Mill Canyon near the Tenabo Mine. Construction of the mill was supervised by mine superintendent Simeon Wenban, one of the original prospectors that had accompanied Veatch. Wenban was likely placed in charge of the new mill due to his experience with operating a quartz mill at Virginia City. Wenban had previously arrived in California from Ohio in the 1850’s and had worked at placer mining in California and later as a mill operator on the Comstock (Bancroft 1888). Wenban would have been familiar with the latest milling technology. The equipment for the new mill was shipped in late 1863 and newspaper accounts simultaneously marveled at both the shipping costs for the heavy machinery and the remoteness of the equipment destination (RRR 24 February 1864, RRR 7 May 1864).

The mill machinery arrived at Cortez in April of 1864; and the Reveille described the local Western Shoshone as “staring in… wonderment at the material and the work” (RRR 7 May 1864). This detail included in the mill write-up suggests that the construction of the mill carried with it ideological meaning as this technology, representative of American industry, was deployed into remote areas of the Great Basin. The final cost of the mill was described as approximately $100,000 (Bancroft 1888).

Leading up to the completion of the mill were frequent and expectant reports from the Reese River Reveille on the progress of construction, culminating in a detailed description of the mill equipment by Reveille editor Myron Angel (5 May and 7 May
The housing for the mill was constructed of locally masoned stone and both local and imported California pine timbers. The stamp mill superstructure included board and batten siding. Later mills would use double siding, or corrugated metal siding after 1900. Mills were often painted red with mineral paint to preserve wood, and this was likely the case for the Cortez Mill (Francaviglia 1997:53). According to Angel, the main mill structure was 95 feet long by 50 feet wide and was built of stone. The mill was constructed on a slope to employ gravity to drive the slurry through the milling process. Accounts do not discuss initial crushing machinery to reduce large chunks of ore into a size suitable for the stamp mill. After 1864, Blake’s Crusher was the dominant boulder crushing technology throughout American mining. Developed by the nephew of cotton gin inventor, Eli Whitney, Eli Whitney Blake’s crusher design is the basis for modern crushing equipment (Egleston 1887:179; Lynch and Rowland 2005:22). Because a crusher is not discussed in any primary source relating to the Cortez Company Mill, it is likely that run-of-mine ore would be manually sorted and simply pummeled with sledge hammers until the rock was reduced to a suitable size. The ore was then fed into the stamp mill intake where it would be crushed into a powder in the mortar box below the stamps. There were initially eight stamps installed at Cortez. The stamps for the mill weighed five hundred pounds each and were grouped into sets of four stamps per battery in two batteries. As the standard stamp battery was five stamps, the smaller size might have been an effort to reduce the weight of the mill for freighting. Slightly larger than the Cortez stamps, a 10-stamp battery is pictured below (Figure 3-3).
Although stamps had been around for centuries, the stamp mills of the 1800’s were complex pieces of early mechanized machinery. The stamps required constant cleaning and maintenance, and included many moving parts that were subject to wear. The shoe and die (where the pestle action occurred) experienced extreme wear and had to be replaced every few months, while the screens that were attached to the mortar box and sorted the ore had to be replaced every few weeks. Aspects of the operation of the stamps could be changed to influence crushing output: the battery box screens could be changed to sort to different sizes; the speed of the stamps could be adjusted from anywhere between 60 to 110 drops per minute; like the timing of the pistons of a combustion
engine, the striking order of the stamps could be adjusted to prevent the ore from piling up in corners of the battery box, and the number of stamps in each battery required that a different sequence be configured via the cam shaft. Despite their apparent “crudeness,” stamps required sophisticated planning to properly deploy (White 2010:67-68).

The action of the stamps resulted in a sandy powder that was transported by cart to the amalgamation pans (RRR 5 May 1864 and 7 May 1864). The mill was designed to treat Cortez ore with the Washoe Process, a pan process developed and successfully used on Comstock ore. This process supplanted the old Spanish Patio Process that had been in use for centuries and had been the first process in use on the Comstock (Figure 3–4). By 1860, the newly developed Washoe Process had allowed for a much faster processing time as it combined several steps of the Patio Process into a compact piece of milling equipment called the Knox Pan, essentially an iron tub that mixed the powdered ore, salt, water, mercury, and oxygen with a mechanical mulling arm. In this way the pans acted as a compact and quick Spanish arrastra and patio, and represented a miniaturization and consolidation of the old patio process (Oberbillig 1967:1-4). Compared to the patio process, which required a treatment time of 30 days, the Knox Pans had an operating time of six hours (Oberbillig 1967:1-20).
A modified form of the Knox Pans were used at Cortez. These were called Wheeler Pans (Figure 3-5) and represented an important innovation on the Knox design. Wheeler Pans mixed the ore and chemicals while providing grinding activity; simultaneously steam was piped into compartments below the slurry, providing heat to facilitate a more complete and quicker amalgamation (Eissler 1888:64-66). In his write-up, Myron Angel (RRR 7 May 1864), although mistakenly referring to the pans as the earlier Knox Pans, offers a useful description of the process as the ore passes from the stamp batteries to the amalgamation pans:
“The pulp will run from the batteries to settling tanks, from which it is carried on cars... There are twelve amalgamating pans of the Knox patent, each with its mullers, yokes, etc., weighing about three thousand pounds; they are five feet four inches in breadth eleven inches in inside depth, and fourteen and three quarter inches outside. A chamber of about two inches in depth is formed by a false bottom, and is for the admission of steam to heat the pulp in the pans. A charge for one of these will be from twelve to eighteen hundred pounds. They will be supplied with water and steam by iron pipes running beneath them and furnished with valves and stop cocks. Two large wooden tubs, about twelve feet in diameter, will be used as settlers, in a manner similar to the pans, and following them. From these, the pulverized mass is supposed to run away as valueless....”

Figure 3-5. Wheeler Amalgamation Pan.  
(Eissler 1889:65)
One pan could accommodate in the upward range of 1,200 to 1,800 pounds of ore, and required around three horsepower. Generally, the interior of Wheeler Pans measured four feet in diameter and were two feet deep, not including the false bottom for the introduction of steam. The ore was allowed to soak in the pan with a solution of salt and copper sulfate for an hour while the sulfides and chlorides “decompose” after which 60 pounds of quicksilver mercury is poured into the pan. Two more hours of amalgamation occur as the pan is heated with steam. The pan is then emptied of amalgam (Eissler 1889:52-54, 66; Kustel 1863:127; RRR 7 May 1864:18).

Once the silver formed an amalgam with the mercury and this was removed, the remaining solution was transferred to two approximately twelve feet diameter wooden settling tanks. Any remaining particles were settled to the bottom of the tanks and the amalgam was scraped out of the tanks. The resulting mass, amalgam and particles were then sent to a cast iron retort furnace where the mercury was burned off with heat and trapped in a curved iron retort. Figure 3-6 shows an example of the configuration of pans and settling tanks at the California Pan Mill in Virginia City, a much larger mill than that at Cortez. Once the mercury was retorted and conserved, the mass of silver, gold and other metals that remained could be shipped off for smelting into bullion (Blake 1867:245; RRR 7 May 1864).
The Cortez Company Mill failed to perform as expected. The ore at Cortez was not “free milling”; it had not been oxidized and therefore could not be easily amalgamated like ores at the Comstock. The terms for ores that are not easily reduced are refractory or rebellious and occur either as sulfides (with arsenic or antimony) or with a high lead content, or both. Cortez ore had all of these qualities (Lincoln 1923:87). This meant that a different beneficiation process was required at Cortez than at the Comstock. The Cortez Company began to look for alternatives (Egleston 1887:39; Oberbillig 1967:28; Raymond 1869:81).
Miners in the neighboring Reese River District were experiencing the same difficulties, and although a multitude of mills had been constructed in the district in 1863, by the end of the year milling at Austin had ceased as mill operators attempted to understand why the mills were failing to recover an acceptable amount of silver and determine what could be done. A cohort of Austin miners and investors, including assayers J. Q. C. Vanderbosch and John Veatch, initiated experimentation on the refractory ore at a mill owned by the Oregon Company and discovered that ore could be roasted with salt to “chloridize” it, replacing the troublesome sulfides with silver chloride and allowing the ore to be properly amalgamated. This roasting of the ore before amalgamation was called the Reese River Process (Abbe 1985:18-19).

In 1865 four reverberatory furnaces were built at Cortez to implement the Reese River Process. The labor required at the mill likely spiked as a result; the roasting process was labor intensive. At the Mettacom Mill in Austin, an additional 11 laborers and one foreman were needed just to roast the ores, as the roasters required large amounts of fuel and the roasted ore needed to be continually “rabbled” or mixed; this process required around seven hours of roasting (Oberbellig 1967:30-31). The situation was likely similar at Cortez. Roasting also meant that the ore had to be dry crushed. Initially wet crushing was used as it was easier on machinery and kept precious metals from floating away as dust. It was also much safer for the mill workers as it helped to prevent the formation of clouds of deadly quartz dust. Unfortunately for workers, dry crushing was necessary if roasting was to be used, as wet ore took longer to roast and required more fuel.
The modifications to the Cortez Mill necessitated by the Reese River Process were apparently not effective enough to make the mill profitable, or perhaps they were just profitable enough to warrant further enhancements. In 1867 an additional five stamp battery was added, expanding the mill to 13 stamps, while a type of pan that was believed to be more efficient, the Varney Pan, replaced the old Wheeler Pans (Bancroft 1889:16; Emmons 1910; RRR 16 August 1865; RRR 3 January 1867).

Overall, what effect these improvements had on the Cortez Company operations is unclear. What is clear is that Cortez was typical for the time period: mining regions were experiencing an enormous surge in available capital with little returns to satisfy investors. As described in a USGS report, “mills were furnished with expensive machinery which failed upon trial to reduce ore cheaply or effectively and was of necessity discarded and money was lavishly expended also in the construction and equipment of mills belonging to wealthy mining corporations, as if drawn from an inexhaustible treasury” (USGS 1883:122). The 1860’s were also a time of experimentation with different chemical processes that at times were comparable to alchemy in their arbitrariness. Journalist Dan DeQuille (1892) noted “Miners who were wholly ignorant of metallurgy and the nature and action of chemicals became smitten with the prevailing mania.” Mining engineer Thomas Egleston suggested that the failure of some mills with reverberatory roasters was due to the lack of experienced operators, as the ore required careful monitoring and constant rabbling to properly roast (Egleston 1887:227). Another factor at Cortez may have been the high lead content of the ore, preventing the silver from being amalgamated with mercury and requiring the silver-lead
ore to be smelted in blast furnaces to separate the silver from the lead (RRR 3 January 1867).

The troubles that plagued the mill were likely a combination of the above, with the added setback that each new mining region required a rethinking of the entire milling process, and incomplete knowledge of the local ore could spell disaster for mining operations. For instance at Cortez, the mill was ordered, shipped out to the district at an incredible shipping cost, and installed before the rebellious nature of the ore had been fully discovered. By the close of the 1860’s, many of the original miners had left Cortez. The mill ran sporadically if at all. High grade ore and ore mined in the winter months were shipped south to Austin. With shipping and custom milling costs running as high as $40 per ton, only the richest mines at Cortez could turn a profit (RRR 21 August 1868, 14 October 1867). By December of 1867 Cortez Company directors based out of San Francisco issued orders for the mill to be shut down, angering many of the local investors (Anglo-American Times 21 December 1867:14).

One successful miner at Cortez was Simeon Wenban. Wenban had quit the Cortez Company sometime in the mid 1860’s and had acquired many of the most promising claims in the district, buying out the original owners, including famed mine capitalist George Hearst, and consolidating the Wenban Group of mines that would eventually include 25 locations across the mountain. This left Wenban in a position in 1869 to purchase the mill from the Cortez Company for $10,000, around one-tenth the original construction cost. Wenban’s two primary mines, the St. Louis and the Garrison, were located seven miles along haulage roads to the west of the mill across Mount Tenabo.
Wenban began packing ore over the mountains with mule teams, reserving the richest ore for shipping to smelters via the newly built Central Pacific Railroad station located at Beowawe, 37 miles to the north (Bancroft 1889; Sacramento Daily Union [SDU] 25 December 1875; Zeier 1993).

By the 1870s Wenban had made some modifications to the mill, including a new Bruckner roasting furnace that was described as a success by the newspapers, a new boiler, and additional furnace equipment, likely to enhance the roasting process (Bancroft 1889:18; Daily Record-Union 28 March 1878:2; SDU 4 August 1876:3).

At some point in the 1870’s Wenban’s Cornish employees went on strike demanding back pay at a time when the mines were doing poorly. Chinese laborers were brought in from San Francisco to work Wenban’s mines. This included the use of a Chinese work company and an influx in the Chinese population at Cortez (Bancroft 1889; Johnson and McQueen 2016). By 1881 tensions stirred among non-Chinese and an article in the newspaper demands that Wenban release his Chinese workers “or steps will be taken to compel them to go” (Reno Evening Gazette [REG] 10 June 1881). Despite these threats, Chinese would continue to work many of the mines and the mills at Cortez throughout the 20th century.

**Tenabo Mill (1886 – 1915)**

As related in his biography by early Western historian H. H. Bancroft, the Tenabo Mill was constructed by Simeon Wenban and the Tenabo Mill and Mining Company in 1886. The mill incorporated a host of new technologies, including a new type of mechanical rolling technology, Krom rollers, and a new leaching technology called
hyposulfite lixiviation. This process involved roasting the ores and precipitating the gold and silver out of ore with a chemical solution. The variation of this process used at Cortez was the Russell Process of lixiviation (Bancroft 1889; Hardesty 1988:49-50).

As early as 1881 Wenban likely planned for a new mill on the same side of Mount Tenabo as his major mines. As discussed Wenban had been shipping his ore away from the mines, either to the Cortez Company Mill or to the smelters. As a cost saving measure, Wenban began to implement plans for a new mill, hiring Chinese laborers and also improving infrastructure around the site of his major workings and the site of the new mill, including acquiring land patents for the mill site. Wenban also patented a water source, Wenban Spring (Bancroft 1889; Salt Lake Daily Tribune 24 February 1881), sank an artesian well, and built a seven mile long pipeline to bring water to the new town and mill site (Nevada State Journal [NSJ] 23 September 1883; NSJ 14 June 1884).
During the 1870’s, silver was effectively demonetized in the United States in 1873 legislation dubbed the “Crime of ’73” by Nevada miners (Bowers 1996:110). The intent was to stabilize the national economy after a series of panics and depressions; perceived as less volatile because of its scarcity, gold was left as the primary coinage metal to back paper currency. This was a global trend that created a de facto gold standard and a crisis for Nevada’s silver mines (Elliot 1973). Lacking the cyanide technology that would allow for the successful exploitation of gold, Nevada mill operators began to adopt a new leaching technology called hyposulfite lixiviation that recovered higher rates of silver than amalgamation and additionally a larger amount of gold than amalgamation (Hardesty 2010:80-83; Marsden and House 2006:279).

Discovered in 1858 by chemist Adolf von Patera, lixiviation is based around the premise that with proper roasting and treatment with a hyposulfite solution (today called thiosulfate), silver and gold can be precipitated out of ore more efficiently and with less cost than amalgamation. A hyposulfite solution is relatively non-toxic and reusable, although it still requires a chloridizing furnace to roast the ore if the ore has not been oxidized and is refractory. Although both sodium hyposulfite and calcium hyposulfite were used in the process, calcium hyposulfite was found to recover a greater amount of gold (International Textbook Company 1902:9).

The caveat is that the Von Patera method of lixiviation is ineffective on lead bearing ore such as that found at Cortez. Standard lixiviation causes the silver and lead to bind, preventing the silver from being precipitated separately. An innovation on the Von Patera method that appears to solve this problem is the Russell Process. This process
involves adding sodium carbonate (soda ash) which binds to the lead and creates a lead carbonate that is removed from the solution. The difficulty with the Russell Process is that the leaching solution is limited to sodium hyposulfite only, restricting how much gold can be recovered. Significantly, an “extra solution” of copper hyposulfite was also added as it appeared to recover additional silver and allow for greater reuse of the solution. Recently, chemists experimenting with this process have reaffirmed that the addition of a copper hyposulfite, as described in the historical process, is not optional but is actually vital to the success of thiosulfate leaching (Aylmore and Muir 2001; Egleston 1887:45; Hardesty 2010:831; International Textbook Company 1902:17-18; Mardsen and House 2006:279). Hyposulfite leaching has experienced renewed interest as it is viewed as a much safer and environmentally friendly alternative to the use of cyanide in gold extraction (Barrick Gold Corp. 2016). Wenban likely learned of both the Russell Process and Krom’s innovations after visiting the nearby Bertrand Mill southeast of Cortez and viewing the process first hand. Wenban chose to adopt both innovations for the new mill at Cortez (Johnson and McQueen 2016; Krom 1885; Hardesty 1988:51).

Wenban also hired Bertrand Mill engineer Roswell Clark to run the new mill. Several years later Clark would attempt to implement the same technology at the Deadwood Reduction Works under Harris Franklin and famed Deadwood sheriff Seth Bullock. The mill burned down before producing any silver or gold (giving rise to speculation of arson) and Clark ended up back at Cortez (Wolff 2009). Clark would make his own contributions to the Russell Process used at Cortez with the addition of sodium bicarbonate (baking soda) to the hyposulfite solution to remove a buildup of lime that
prevents leaching and allows the solution to be “recharged.” Clark admitted in his patent that he did not understand how this process worked. His description of using calcium hyposulfite at Cortez hints at a misapplication of the Russell Process, for reasons described above, as this may have limited silver recovery (Clark 1888; Stetefeldt 1895:4-5).

The new leaching process is more complex than amalgamation, and mill operators were required to possess a detailed knowledge of the chemical processes involved to successfully implement this leaching technology. Mining engineer Carl Stetefeldt noted that although lixiviation was cheaper and more effective than amalgamation, the technical knowledge required and the specificity of the type of ore the process might be used on likely limited the spread of this technology (Stetefeldt 1895:2).

By 1885 Wenban had engaged engineer Stephen Krom to design a mill using lixiviation technology and incorporating equipment developed by Krom himself at various mills in Nevada, including the Bertrand and Mount Cory Mills (Figure 3-8 and Figure 3-9). This mill design included the use of Krom Rollers instead of stamps and various other innovations on existing technologies, including ore crushers and sorting equipment (Figure 3-10 and Figure 3-11). Krom Rollers used a durable phosphor bronze (copper alloy) cladding to protect against wear. Rollers were touted as including fewer moving parts and requiring less maintenance and replacement than stamps (Krom 1885:18). The drive wheels are on either side, and the ore falls into the center crushing apparatus and is driven by gravity until crushed (Figure 3-11).
Additional technology included Krom’s pneumatic jigs to separate the lead from the pulp for leaching and Bruckner Cylinder’s for roasting the ore. The rollers and other Krom patented equipment may have been built in London under exclusive license by manufacturers Bowes, Scott, and Read and shipped to Cortez (Eissler 1889:iv). The roasters were built by the Lane and Bodely Company and shipped from Cincinnati (EMJ 31 January 1885:76). The mill was completed in 1886 and was frequently discussed in mining journals, as Krom, Stetefeldt, and other mining engineers of the time lauded this technology.

Figure 3-8. Tenabo Mill circa 1888. (Nevada Historical Society)
Figure 3-9. Tenabo Mill circa 1900.
(Nevada Historical Society)

Figure 3-10. Krom’s Improved Rock-Breaker.
(Eissler 1889:45)
A detailed description of the milling process is described in H. H. Bancroft’s (1889) biography of Wenban. The milling costs totaled $375,000 annually. The ore was first transported to the mill via tram and subjected to initial crushing. The resulting smaller particles were then chloridized in the Bruckner Furnaces and further crushed by Krom’s Rollers into a fine sand of consistent size; the ore could not be crushed too fine or it would not lixiviate properly. These rollers were regarded as a novel and innovative crushing technology, as they were more effective than stamps. They were also designed specifically for dry crushing as part of the new leaching methods; Krom Rolls were enclosed in a housing that trapped the fine dust produced by dry crushing in addition to crushing the ore to a uniform size that was best suited to lixiviation. Two sets of rolls
could purportedly crush as much as a 50 stamp mill in the same span of time (Eissler 1889:213-216). The rollers were described as so efficient that the mill would only be run during the day (Engineering and Mining Journal [EMJ] 11 July 1885:27).

Then sand that resulted from the crushing process was sent to revolving screens to be sorted and classified before being roasted in the rotating Bruckner Cylinders with sodium chloride creating a silver chloride. The ore was then sent to vats for leaching with water that dissolved the salts. A solution of calcium hyposulphate was introduced with bicarbonate and this dissolved the silver chloride, which passed from the leaching vats to the precipitating tanks. This hyposulphate solution would be saved in vats for later use. Lime and possibly sulfur were introduced into the precipitating tanks. These converted the silver solution into silver sulfide. The silver sulfide was removed and filtered in a press, forming it into cakes. These were treated in a furnace that removed the sulfur as a vapor, leaving the silver and a smaller amount of gold. The resulting bullion was shipped to a refinery to separate and purify the metals (Bancroft 1889:255-256).

In addition to planning his new mill with the latest technology, Wenban sought to acquire local resources to use as reagents in the milling process as a cost saving adaptation. This included the creation of lime in locally constructed lime kilns using quarried limestone, salt from local salt flats, and sulfur from nearby Hot Springs Point in Crescent Valley. Bricks for the new mill were made with local clay in brick kilns on the valley floor (Johnson and McQueen 2016). The Tenabo Mill required water for its operation, but instead of constructing the mill adjacent to a water source, the water was brought via pipeline from Wenban Springs located seven miles to the south. The location
of the mill, between 0.6 to 1 mile from the entrances to two major mines and 850 ft. lower in elevation, may have been a tradeoff in order to pump the water from the artesian wells across the valley upwards 417 ft. in elevation using a Worthington Pump. Other materials required for the operation of the mill, including lime, charcoal, salt, and sulfur, were created and mined in Grass Valley and nearby Crescent Valley; in the case of charcoal, it was produced on charcoal platforms located throughout the Cortez Mountains and in the surrounding ranges, indicating that producers ventured into the surrounding landscape in search of appropriately wooded areas (Hardesty 1988; Johnson and McQueen 2016).

The elaborate methods and equipment in place at the Tenabo Mill attracted the attention of London investors and in 1888, the assets of the Tenabo Mill and Mining Company were purchased by the London mining firm Bewick and Moering and Co. and became Cortez Mines Limited, with Wenban still retaining management and a large portion of the company’s stock. Bewick and Moering apparently brought new capital to the mines, as a narrow gauge railroad was installed in the summer of 1890 to connect the main Garrison Mine to the mill less than one mile away (Myrick 1991:337, 888). The next year a $50,000 O’Hara furnace was installed but was found to be ineffective (NSJ 15 July 1891; Mining and Scientific Press 1920:803-804; Hardesty 2010a:111). These improvements came at a time when the Nevada State Journal (22 May 1891) reported that the Cortez Mines Ltd. had a monthly profit of $20,000 and an operating cost of $15,000 a month at a time when silver prices began falling sharply. By 1892 it was reported that Cortez had completely shut down (NSJ 7 May 1892).
The economic situation of the 1890’s was likely fueled by silver subsidies that were meant to bolster silver producers and those interested in the free coinage of silver, dubbed “silverites,” who opposed the gold standard for various reasons. In 1890 the Sherman Silver Purchase Act required the United States government to purchase silver with paper currency. The currency could then be redeemed for both silver and gold. This caused a run on gold as investors bought up the paper notes and exchanged them; gold reserves became depleted and silver lost value. The act was repealed several years later but not before contributing to a global depression in 1893, and setting the stage for a battle over the future vehicle of global capitalism (Elliot 1973; Franklin 2016).

Meanwhile at Cortez, Wenban bought back the British firm’s interest and the Tenabo Mill and Mining Company was reincorporated in 1896 (Daily Record Union 5 March 1896). Wenban rebuilt a portion of the mill foundation with brick, and additional buildings were constructed surrounding the mill. Wenban died in 1901 and for a short time operations continued. When exactly the leaching process was discontinued is unclear. By 1905 work was suspended indefinitely (NSJ 21 April 1901:4; 20 September 1927:7). The Wenban Estate controlled the company after his death, and likely leased company claims to miners who shipped ore by rail to smelters (NSJ 15 February 1906).

The early 1900s were a time when the potential for the new cyanide technology was being realized in North America. Prior to this, many misconceptions about the use of cyanide on ores held back the development of this technology for use in mining (Hardesty 1988:51). The cyanide process will be described in greater detail below. In the early 1900’s, mining booms at Goldfield and other districts in North America using this
technology took center stage, while the tailings at earlier mines were being reprocessed so that the gold and silver left from earlier processes could be profitably leached out (Johnson and McQueen 2016; Elliot 1974). This occurred at Cortez with the arrival of mining engineer A. W. Geiger in 1908. Geiger worked for the Cortez Metal Recovery Company, and refurbished the Tenabo Mill with cyanide tanks to retreat the impressive tailings flow left over from the lixiviation process (Mining and Scientific Press 1908:75).

For several years the tailings were processed in cyanide tanks. Writing in 1910, Geiger notes that “The ore had previously been roasted and treated by thiosulphate. Owing to faulty lixiviation washing methods, about half the metal content of the tailing was readily soluble in weak cyanide solution, enough more to make up an 80% recovery…” (Geiger 1910:130). The treatment of tailings appears to have ceased by
1912. At this time the mill may have been leased as part of the Cortez group of claims. However milling ceased permanently when the mill burned in 1915 (Hardesty 1982:7).

**Menard Mill (1913 – 1915)**

The Menardi Mill was a small concentration and cyanide mill constructed by John Blair Menardi in 1913 after five years of mine development in Mill Canyon (REG 12 March 1913). The mill was approximately one-half mile down the canyon to the north of the original Cortez Company stamp mill. The mill was situated near Menardi’s mines on a relatively level area in the narrow canyon. By the early 1900s Nevada’s mining was experiencing a new boom that had developed around cyanide technology. John Blair Menardi, Reno resident and retired U.S. Cavalry Captain owned an interest in the successful Red Top Mine at Goldfield, and expanded into the Cortez District in 1908, forming the Cortez Mining and Reduction Co. to bring the new cyanide technology to Cortez (Douglas 1909:70). Menardi’s experiences at Goldfield had likely exposed him to the workings of a cyanide mill, and upon leaving Goldfield Menardi bought out the Falconer and Erwin mines in Mill Canyon. From 1910 through 1913 reports in the *Reno Evening Gazette* published hints that Menardi, with his son and mining engineer Harold Menardi, planned on building a mill in the district, but it wasn’t until the end of 1913 that the 50-ton capacity per day cyanide mill was completed and cyanide concentrates began to be hauled by new auto-trucks to the train station at Beowawe, from there bound for the smelter (NSJ 17 October 1913:8; REG 27 December 1913:2).

Cyanide technology had initially arrived in the United States after development by Scottish engineers and successful use in New Zealand in 1891 (Hardesty 1988:53). At
the core of the cyanide process is a simple chemical formula developed in 1846 known as Elsner’s Equation:

$$4Au + 8NaCN + O_2 + 2H_2O \rightarrow 4NaAu(CN)_2 + 4NaOH$$

As can be seen, the gold (Au) and in this case sodium cyanide (NaCN) interacts with water and oxygen to create a gold-cyanide solution. Calcium cyanide is also used in some instances. Although the above formula is specific to gold, cyanide also dissolves silver and copper in a similar manner. Modern cyanide leaching uses more complex variations of this formula, but Elsner’s Equation is still at the core of the process (Marsden and House 2006:8).

Early cyanide technology depended on a systematic classifying scheme or flowsheet for sorting both the sand (coarse grained slurry) and slime (fine grained slurry) that were created by successive forms of crushing. There were two types of cyanide leaching processes in use: agitation for use on slimes to keep the particles suspended long enough for exposure to the cyanide solution, and percolation for use on larger grained sand in order to coat the grains with enough cyanide to promote precipitation. Beginning in 1904 Dorr began to develop technology specific to cyanide milling that included continuous classifying, filtering, and concentrating equipment. These innovations enabled a cyanide mining industry to become quickly established in the United States (Hardesty 1988:52-53; Marsden and House 2006:8-9).

Aside from very basic descriptions, there is little primary source documentation on the operation of the Menardi Mill. The mill was first run using a gasoline engine, but a later report noted that it used water power (REG 20 August 1914:8). The mill was also
described as a “gravity concentration mill built for the purpose of separating the lead-silver minerals from zinc minerals,” and says the mill was only “partially successful,” or somewhat of a failure, depending of the mood of the investors (Hanselman 1935:3).

The mill burned down after running for two years and was not rebuilt (REG 29 June 1926:7). By 1916 the Cortez Mining and Reduction Company was bankrupt and the Menardi family had left the district (Hanselman 1935; REG 6 April 1916:7). Because documentary evidence for the Menardi Mill is sparse, archaeological evidence is an important source of missing data, as shall be seen in Chapter 4.

**Consolidated Cortez Mill (1923 – 1937)**

In 1918, a large portion of the Wenban mines and claims were acquired by the Consolidated Cortez Company. After assessment of the ore reserves, a 150-ton daily capacity cyanide mill was completed in 1923. The mill was constructed in time to exploit high silver prices that had arisen from the subsidization of silver after passage of the Pittman Act (1918). The mill was to process ore from a new and extensive underground operation and remnant mill tailings not processed previously by A.W. Geiger (Pacific Mining News 1923:186; Hardesty 1984:53). The mill was located above the town site and the old Tenabo Mill, closer to the workings at the base of Mount Tenabo (REG 11 October 1922:10). The Consolidated Cortez Mill was constructed partially out of scavenged lumber from the Tenabo Mill and the Cortez town site. A tramway was constructed that led directly from the main mine tunnel, the Arctic Tunnel, to the mill.

The equipment installed at the mill was based around two mining supply companies that had come to prominence around the new cyanide technology: Allis-
Chalmers and Dorr. As larger mechanical excavation equipment and open pit mining techniques developed in the early 1900’s, so too did crushing and grinding equipment capable of handling larger sized pieces of ore (Lynch and Rowland 2005). The Consolidated Cortez Mill incorporated much of this new technology. Further innovations included a much more systematic crushing and classifying scheme than at any prior mill to create a powder suitable for cyanide treatment.

Hardesty (1988:58-59) provides an in depth step-by-step of the process used at the Consolidated Cortez: Ore was fed via the tramway into the Allis-Chalmers gyratory crusher, an improvement on the previously described Blake’s Crusher; the ore went through Bunker Hill screens; further classifying was done by a Dorr duplex drag classifier which created a flowsheet loop that ensured proper sizing for the ball and tube mills. As the Consolidated Cortez Mill used the slime method of cyanidation, the ore was ground into a slime by Allis-Chalmers ball mills to 40 per inch mesh and then by Allis-Chalmers tube mills to 100 per inch mesh. The ball and tube mills at this time had largely replaced stamps (White 2010:69-70). The ore passed over eight Deister concentration tables before entering the five Dorr thickening tanks. The sludge was then sent to three Dorr agitation tanks. Two Merrill clarifying presses removed suspended particles. Importantly, zinc is required to bond with the precipitated gold and silver, and this occurs by passing the solution through zinc boxes. Two Oliver Filters recover the zinc-silver-gold precipitate (Hardesty 1988:58-59).

Some of the equipment described above, including the Oliver Filter, is still in use in the mining industry, albeit in a slightly modified form. Post-processing, the cyanide
precipitate cakes was taken to a furnace in the bullion building to be melted down and shipped out (Hardesty 1988:59). The mill was powered by two 200-horsepower, semi-diesel Fairbanks Morse turbine engines that were housed in a powerhouse a short distance away; the engines also provided electricity to the Cortez town site (Johnson and McQueen 2016).

The cyanide process used by the Consolidated Cortez Mill was not particularly effective on the ores of the Cortez District. Part of the problem with the use of cyanide at Cortez was likely that the amount of sulfides in the ore. Sulfides made it difficult, but not impossible, for silver to be precipitated by cyanide. Sulfides also require a substantial increase in the amount of cyanide per ton to achieve proper leaching. In an attempt to increase productivity by producing concentrates, the mill was converted to use oil flotation in 1927 (Vanderburg 1938). Oil flotation was being used as an initial step to separate out the unwanted gangue and secure a silver and gold concentrate that would be better affected by cyanide. (Rickard 1916:91-92). As was recommended in manuals on flotation, the ore was likely still subjected to cyanide treatment after flotation.

Oil flotation technology was developed 50 years earlier in Germany in 1877 to separate graphite from ore. The process was lost for a time, before reappearing in Wales in 1899 where it successfully recovered gold, silver, and copper from ore via an oily residue that was “levitated” by creating an unequal air pressure and allowing air to escape the vacuum of the tank while simultaneously raising the temperature of the solution, creating a frothy, oily surface (Rickard 1916:25). The process was then applied with greater success in Australia and patented in 1906 by a group of London chemists. The
process appeared in the United States at Basin, Montana in 1911 (Fuerstenau 2009:4). However patent infringement and litigation restricted the use of oil flotation until 1923, when it began to gain widespread use, particularly in copper mining (Fuerstenau 2009:4). The process was designed to isolate minerals from gangue in a powdered form by applying various “reagents” including copper and various oils. The oily mineral solution was frothed under pressure until the desired mineral froth allowed to overflow out of the top of the flotation tank and the heavier gangue was left to sink to the bottom. The adoption of oil flotation greatly bolstered the ore reserves of many mines around the country by making lower grade ore profitable (Fuerstenau 2009:3-4; Sulman, Kirkpatrick-Picard, and Ballot 1906). Although copper mining was and still is the dominant industry that oil flotation is used in, the technique is also applied to lead-zinc and silver-gold ores. By 1960 this technology was seldom used on gold and silver ore (Fuerstenau 2009:5). Notably, this technique was ineffective on mine tailings, as there were too many chemicals that interfered with the process (Rickard 1916:95).

At Cortez, the equipment was described as Fagergren flotation cells (Figure 3-13), a type of cell designed by William Fagergren that started to be manufactured in 1927 as a standardized flotation component, available in various sizes throughout the 20th century (Fuerstenau 2007:652; Hardesty 1988). The reagents likely included pine oil used in conjunction with various acids, as this form of oil could be effective and relatively cheap, and was popular with flotation mill operators (Rickard 1916:94). Although advertised as a 150-ton a day mill, at peak capacity the Consolidate Cortez Mill likely only processed
125 tons. The silver and gold concentrate was shipped by rail to a smelter at Salt Lake City.

Figure 3-13. Fagergren Flotation Cell. United States Patent No. 1361342 (Margetts and Fagergren 1920)

By 1930 the mill had ceased to be profitable and several years followed of sporadic operation in an attempt to keep the miners working through the depression (REG 7 October 1933:7; Hardesty 2010). In 1936, the Agricultural Adjustment Act, which had been enacted in 1933 and contained a provision for the purchasing of silver, was ruled unconstitutional, effectively ending a period of artificially high silver prices. The Consolidated Cortez Silver Mining Company went bankrupt shortly afterward, in 1937, and the property and assets of the company were acquired by the Cortez Metals Company of New York. Additional improvements on the oil flotation equipment were
added (EMJ Vol 140 1939:68), and shipments to a smelter at Salt Lake continued (NSJ 8 August 1938:5; Vanderburg 1938:22).

Whether the mill ran between 1937 and the 1940’s is unclear, although it is evident that all operations in the district had ceased by the time of the entry of the United States into WWII in 1941. By 1954 the mill had been dismantled and largely scavenged for materials (NSJ 5 March 1954:16).

**Roberts Mill (1930 – 1944)**

The Roberts Mill was a 50-ton per day mill constructed in Mill Canyon in 1930, immediately adjacent and to the north of the ruins of the Menardi Mill. The process used at the Roberts Mill was either mercuric-cyanide, flotation, or cyanide-flotation, depending on the source and time period. The Roberts Mill includes a complex sequence of milling equipment and years in operation as a result of continuous litigation and changing management throughout the 1930’s. The mill was initially constructed as a result of increasing activity in Mill Canyon as silver prices began to rise during the 1920’s. In 1929 Los Angeles venture capitalist and newspaper owner Belle McCord Roberts purchased a large group of old Mill Canyon claims and properties and the Roberts Mining and Milling Company was incorporated with Belle Roberts as president. Plans were made for a 50-ton daily capacity mill. While the Roberts Company had begun construction of the mill at Cortez as early as 1930 (REG 27 May 1930:10) litigation kept the mill idle while the Roberts Company resolved lawsuits that involved their construction of an ore bin on a competing claim. The mill was running by 1932 and ran until litigation again shut down operations in 1935 (Hanselman 1935).
The mill initially used the Vandercook Process of mercuric cyanide leaching. This included exclusive, patented Vandercook equipment: two Vandercook mercuric generators, and three Vandercook thickeners that concentrated the heavy particles at the bottom of a tank that had a patented spiral design (Young 1922:124; Vanderburg 1938:99).

The Vandercook Process was developed by California mining engineer Albert Vandercook in 1915. The process was described as “amalgamating in cyanide solution” and was essentially an attempt to combine the technologies of mercury amalgamation and cyanide leaching into a single process and in a single tank (Figure 3-14) (Vandercook 1916).

![Figure 3-14. Profile and Plan View of Vandercook Mercuric Cyanide Tanks. (Vandercook 1916)](image)

At issue was that heavy particles do not leach very well in an enclosed cyanide solution. Vandercook’s mercuric cyanide process amalgamates the heavy particles of the ore with mercury, and leaches out the fine particles of ore with cyanide, both at the same time and within the same medium. Agitation is also required as the particles need a
supply of oxygen to precipitate and amalgamate (Vandercook 1916). This process forgoes the cyanide percolation treatment used on sand as described above by substituting mercury for cyanide. Vandercook (1916:2) asserted that although this process had been attempted prior to his invention, electrical contact between the tank’s agitator and the mercuric cyanide solution had created an electrical current that had interfered with the amalgamation. The process was refined over twenty years to include an elaborate classifying system to increase the exposure of heavy particles to mercury, and to eliminate a greater amount of base metals by further separating the metals from the gangue (Vandercook 1935) (Figure 3-15).

Figure 3-15. Flowsheet of the Vandercook Mercuric Cyanide Process (Vandercook 1916)

Unfortunately mercuric cyanide is extremely toxic and as it breaks down creates a poisonous, explosive gas. Poisoning with this substance, which can occur through the
ingestion of dust, elicits symptoms of both mercury and cyanide poisoning (Cheremisinoff 2010:245). Although experimented with in the early 1900’s, and used by Vandercook to precipitate gold, mercuric cyanide was also known as “…one of the suddenest poisons in chemistry’s toxic repertoire; in sufficient doses it will precipitate a funeral in less than 30 seconds” (Perry 1902:151). This seems to indicate that the costs associated with the use of mercuric cyanide might have been in safety to equipment and personnel. Additionally, there is no indication that the Vandercook process was used with any great success at the mills that it was deployed in, although attempts were made throughout the 1930’s.

A comparative sized 50-ton mercuric cyanide mill was constructed by mining engineer Cecil Hanselman and the Nevada United Gold Mining Company a year later in the McCoy District, 30 miles south of Battle Mountain and only around 35 miles west of the Roberts Mill. A co-owner and vice president of the company was H. D. Brown Jr., another Los Angeles investor, suggesting that Vandercook’s process was being advertised to Los Angeles capitalists (NSJ 7 August 1939:4; 13 November 1939:4). The assay office at McCoy would burn down the following year under mysterious circumstances, and the company shut down operations shortly afterward (REG 10 April 1940:12). Interestingly Cecil Hanselman, the mill’s designer, had conducted an inspection of the Roberts Mining and Milling property in 1935.

An inventory done at Mill Canyon by Hansleman (1935) indicates that the mill contained a Fairbanks-Morse stationary upright two-cycle diesel engine; one 40-ton capacity Rib-Cone Straub ball mill; one 40-ton capacity Marcy ball mill; 100-ton
capacity jaw crusher; classifier; and a battery of Ventura flotation cells. The crushing equipment and flotation equipment seem to indicate that the mill was producing concentrate at this time, and although the mill is listed as “modern in every respect.” no mention of Vandercook equipment is given. The mill was not operating at this time due to renewed litigation (Hanselman 1935:2). By late 1935, Belle McCord Roberts notes in a company memo that a $3,500 cyanide unit will soon be installed at the plant, implying that the company is modifying the Vandercook Process, or has replaced it altogether (Roberts 1935). To further confuse matters, a report produced in 1938 by Nevada Bureau of Mines geologist W. O. Vanderburg (1938) and clearly describes the Vandercook equipment and mercuric generators being in use at the mill, and his flowsheet closely resembles Vandercook’s 1935 flowsheet. However as Vanderburg did a reconnaissance of many mining districts during the 1930’s and compiled data from many sources, the flowsheet shown in his report might be from an earlier document, prior to the addition of new equipment.

By September 1937 the company was back in operation and the mill had begun crushing ore from Mill Canyon claims (REG 12 August 1937:16; NSJ 27 September 1937). Unfortunately for the Roberts Company, the subsidization of silver that had occurred via legislation had just been repealed and the country was deep in the Great Depression. In addition, despite the mill being in operation, the mines continued to be pursued by litigation. James O. Greenan, former mill superintendent at the Consolidated Cortez Mill across the mountain and a prominent lessee in Mill Canyon began leasing the property from the Roberts Company and running the operation (NSJ 8 April 1938:Sec.2,
By the end of 1938, less than a year after Greenan leased the property, the mill was processing 35-tons a day. Litigation ensued once again as Greenan filed suit that December to get lease payments reduced (REG 2 May 1939:16). The following year experienced metallurgist and mill operator James Moore was brought in by Greenan to consult on the process at the Roberts Mill (REG 4 February 1939:7).

By April 1940 the mill was closed due to a lack of run-of-mine ore to process (NSJ 29 August 1938; 22 July 1940:3; REG 20 July 1940:7). The mill might have been refurbished as a flotation mill in 1944. Joseph McCarthy optioned the Roberts Mill Canyon property and operated the mill using an oil flotation process that produced shipping concentrate. However all operations had ceased by the time of the WWII mining moratorium, suspending all mining not related to the war effort and ceasing production in the Cortez District between 1942 and 1945. There was discussion of restarting the mill in

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Figure 3-16. The Roberts Mill circa 1930’s. (Estelle Shanks Collection).
1945, but no activity has been documented and no new mineral resources were identified. The Roberts Mining and Milling Company declared bankruptcy in 1945 (REG 5 June 1945:7). (REG 7 March 1945:3). After the war, the Roberts Company property entered receivership and was up for sale in 1954. The listing includes some of the mill equipment: one 500 horsepower Fairbanks-Morse diesel motor; two ball mills; one crusher; two classifiers; and three cyanide tanks (NSJ 31 January 1954:21).

Small scale lessee mining would continue at Cortez, but it would be until the 1969 until large scale operations returned to Cortez, with the testing of a new form of cyanide leaching called heap leaching. This technology would eventually become the dominant form of gold processing in the world and mining would continue from the 1960’s until the present (Kappes 2002:1606).
4. Cortez Archaeological Data

This chapter will examine the archaeological data available for five mills located in the Cortez Mining District. This is intended as a preliminary study to identify theoretical directions and areas for further research. Due to these limitations in scope, descriptions of the mill sites have been generalized. Aspects of the archaeology, including detailed measurements for all milling components, lumber remnants, associated artifact counts, and other additional data have been omitted for brevity. These areas for future research will be identified in Chapter 5. In the current chapter, each mill description focuses on three phases of the lifecycle of the milling site: construction, operation and abandonment. This is to consider activities that have created the palimpsest of components of the mill sites as they exist today.

The five mill sites, spanning the years 1864 to 1944, exist in varying states of preservation (Figure 4-1). The Cortez Company Mill and the Menardi Mill exist primarily as foundations. In contrast, the Roberts Mill still retains the framing for the superstructure, while the Tenabo Mill and Consolidated Cortez Mill fall somewhere in between. This variability in the material remnants of the mills articulates the need to supplement investigations with documentary sources. For instance the scant archaeological data available for the Cortez Company Mill (1864-1886) is counterbalanced by detailed historical descriptions. However, bias in the primary sources for this particular mill might affect an analysis of the operation and modifications to the mill. A synthesis of the contributions of the archaeological and documentary sources will follow in Chapter 5.
The archaeological sites found across a mining landscape may or may not be connected in a spatially obvious way, but are still included as part of the same mining landscape. The technical site types relate to mineral extraction, beneficiation, and refinement, although not all of these types might be present (Noble and Spude 1997:10-14; Hardesty 2010). A useful way to group collections of features based on their purpose is the concept of the feature-system as an analytical unit (Hardesty 1988:9-11, 2010:17-19). Feature-systems are those components whose purpose relates to a specific industry, who interact to fulfill a specific role in the landscape, or serve the same function. An example of a feature system would be limestone quarries and lime kilns associated with the production of calcium carbonate (Johnson and McQueen 2015; Zeier 1993:26).
Mining feature-systems may be geographically distant from the extraction areas, yet are still included in the mining landscape. The question is, then, when are sites that enable mining to take place no longer included in the mining landscape? Milling equipment used at hardrock mines was manufactured elsewhere, as were other artifacts associated with the mining system. These areas are included in the global networks that create the mining landscape, and are categorized by Hardesty (1988:1-5; 2010:170-177) as materials, population, and information networks. On the local scale this translates into the creation of the mining landscape, as colonizers use these global networks as they adapt to a natural landscape. Previous archaeologists at Cortez have included outlying sites and feature-systems related to aspects of mining. This work is outlined below.

**Previous Work**

Previous archaeological investigation within the Cortez District boundaries is extensive as a result of modern mining development and subsequent work required for Section 106 compliance with the National Historic Preservation Act (NHPA). Although numerous archaeological projects have been conducted within the district boundary and the surrounding area for the mill site, only the sparse remnants of the Cortez Company Mill, the foundation for the Menardi Mill, and the extensive Roberts Mill feature system have been described archaeologically to any great extent. Subsidiary industries associated with the mills have been investigated, and sites relating to the Tenabo Mill and the Consolidated Cortez Mill have been excavated. To date, none of the mill sites themselves have been excavated. Two periods of archaeological fieldwork that are particularly important to the current study are the field schools conducted by the University of Nevada, Reno at Cortez in the early 1980’s, and more recent investigations by
ARS/Summit Envirosolutions Inc. beginning in the 1990’s. The latter has resulted in numerous small-scale archaeological inventories and the large-scale Cortez Hills Expansion Project, including further work by Summit Envirosolutions Inc. on behalf of Barrick Gold Corp. in the 2000’s. Decades of fieldwork at Cortez have laid the foundation for new ways to record and interpret mining related sites.

A significant obstacle to overcome is the difficulty in recording complex mining related sites. Hardesty (1988:48) describes the formation of mining sites as a horizontal stratigraphy that creates overlapping palimpsest of features. For this reason, remnant sequences of occupation must be looked for at the edges of subsequent features. In the case of milling technology, materials from previous mills have been incorporated into later mills, as was described in Chapter 3 with the construction of the Consolidated Cortez Mill from materials taken from the ruins of the Tenabo Mill a short distance downslope. A possible second example of the repurposing of materials might be seen in the archaeological remains of the Menardi Mill that will be described in further detail below. This evidence for reuse is not described in documentary sources; this is another important point in the use of both documents and archeological data. Francaviglia (1997:48-49) notes that industrial buildings are likely to be the most prominent architectural structures found across the mining landscape. At Cortez, the extant mills are no exception as they are easily visible and are striking features.

Although the mills are generally considered as discrete units, both in the documentary sources and archaeologically, the mills are an important part of the regional and even global sociotechnical networks that are in turn part of the extractive process.
These networks can vary depending on the type of industrial mining that is occurring, but when the mining landscape has been developed to the extent that a reduction mill is erected, generally requiring a more formal corporate structure, the landscape will be what Hardesty describes as an “engineer designed mine complex” that integrates mines, processing plants, settlements, and transportation networks.” (Hardesty 2010:8). This means that focusing on the mill as a discrete unit is to separate out a component of the complex mining network. This is done in order to ask questions regarding the development of specific technology, but also introduces problems of interpretation that will be discussed in Chapter 5.

The factors that resulted in the current form of the mill sites are divided into three categories: construction, operation, and abandonment.

**Construction, Operation, and Abandonment**

Construction of the mills relates to the situating and configuration of each mill. These include features that are not easily subject to modification, but are a part of the foundational structure or are fundamental components. Details of construction can indicate the extent to which a formal corporate structure is present, and indicate the amount of capital available to the mine as well as ideas about the amount of mineral reserves. A more permanent and carefully constructed mill might indicate that miners view the mine as a long term operation, while a more expedient foundation might indicate that the mill is meant to operate on a smaller timeline.

As the mill operated, the process used on the ore was adjusted to account for deficiencies and to improve recovery. Deviations from how archival sources describe the mill will likely appear in the phase of the mills operation. Modifications might be minor,
or involve the installation of additional equipment, or they might be much more substantial, such as when the Consolidated Cortez mill was refurbished from cyanide to oil flotation. This process reflects the changing ideas that miners have with regard to the ore, and also will reflect the availability of emerging technology. Modifications that are informal or vernacular in nature might also indicate that economic circumstances are pressuring miners to reuse broken equipment or to repurpose equipment for use in tasks that they were not designed for.

Abandonment occurs when the mill ceases to be used and is subject to post-abandonment processes. There were various expectations regarding the abandonment of the mills at Cortez. These include post abandonment modifications, although a consideration due to the impact that they may have on interpreting the archaeological data included with each mill, are not considered as a factor in the construction and operation of the mills. However, they may confound interpretation and introduce bias. As discussed in Chapter 3, a feature of mills that may be altered post abandonment are the mill tailings. Tailings represent the waste product that results from milling, and can serve as an archaeological indication of the quantity of ore that was processed through the mill. Tailings are often impacted by later activity; in addition to possibly having been hauled away and deposited elsewhere during operation, tailings might also have been reprocessed with the development of cyanide technology in the early 1900’s and would have been reworked with more efficient processing plants (Francaviglia 1997:130). These post-depositional modifications might impact other sources of data that are not considered here, but are a useful addition to archaeological research into milling sites,
such as horizontal and vertical analysis of the chemical constitution of tailings, as they might contribute data to the operation and effectiveness of the mills across time (White 2003:48-49).

The mill machinery and infrastructure were also subject to post-abandonment modifications, as historical accounts have indicate that WWII metal drives and the salvaging of elements of the mill equipment and superstructure often leave little behind. At Cortez, archaeological investigation has shown that some of the mill equipment has survived various salvage and scrap drive efforts. For instance the Bruckner furnaces installed at the Tenabo Mill are still largely intact (Figure 4-2), and large amount of components of the Roberts Mill remain in the canyon.

Figure 4-2. Tenabo Mill with Bruckner Furnaces at Top. Photographed in 1981 by Don Hardesty. (Courtesy of UNR Department of Anthropology)
Cortez Company Mill (1864 - 1886)

The Cortez Company Mill was an eight stamp pan amalgamation mill constructed in Mill Canyon between May and August of 1864 by the Cortez Gold and Silver Mining Company (Johnson and McQueen 2015). The mill was located one mile up the canyon, adjacent to Mill Creek, and immediately north of the Cortez Company’s offices and camp. The likely site of the mill has been located based on corroboration with primary source documents and sparse structural remnants and artifacts. The photo below is taken from the south edge of the milling site, looking northwest down Mill Canyon. Discarded milling machinery is visible to the right of the prominent road (Figure 4-3. This road is the modern alignment, and cuts through the middle of the site.

Figure 4-3. Image facing northwest from the Cortez Company Mill site. Note the milling equipment to the right of the road. (Photographed by Author, June 2016)
Very little remains of the Cortez Company Mill. What is believed to be the mill remnants were first located as part of a survey conducted by Summit Envirosolutions Inc. in 2014. This area was revisited by the author in June 2016 and the area was relocated. Although the data is sparse, there is both documentary and archaeological evidence that this is indeed the location of the mill. The stamp mill, according to the 1869 GLO map shown in Figure 4-4, was likely constructed along the northern bank of Mill Creek. Stamp mills are generally constructed on slopes to utilize gravity as part of the flowsheet of the mill and conserving energy (Francaviglia 1991:51). The construction of the mill near the water source of Mill Creek was likely to locate the process as near as possible to the water needed for the mill, both for the steam boilers and for the wet process of stamp crushing.

Contemporary accounts and the 1869 GLO map describe the Cortez Company Mill as being located one mile up from the mouth of Mill Canyon (Figure 4-4). Note that the GLO map references the Cortez Company Mill as the Tenabo Mill, likely because of the proximity to the Tenabo Tunnel on the east slopes of Mount Tenabo. This should not be confused with the 1886 Tenabo Mill that will be discussed later. The map also references the mines that were being worked in 1869, including the Tenabo and Independence Tunnels and the Berlin Ledge. The Berlin Mine was likely an important source of ore for the Menardi Mill and Roberts Mill, as was located directly behind both mills.
Figure 4-4. Cropped 1869 GLO Plat Map. Arrow shows the location of the Cortez Mill.

The likely location of the mill is based on structural elements observed on the ground. Mining periods subsequent to the period between 1864 and 1886 during which the mill operated have substantially altered the landscape. A new road has been graded and the old alignment is visible as a linear, incised depression running through the mill site. The landscape has likely been altered since the mill was dismantled at some point in the 1880s. Equipment from the crushing and stamping machinery, including at least three broken, cast iron drive wheels, have been piled to the east of the modern road. These wheels were turned via rubber or canvas belts, and would have transferred energy from the steam engine to various machinery found throughout the mill building.

Details of the construction and operation of the mill gathered from the archaeological data are sparse and occur in an area to the west of the modern road alignment. They include remnants of three 2-foot wide square timbers set vertically into
the ground; machine footings with vertically placed and threaded bolts; and piles of handmade brick near the timbers. The sparse remains of the mill echo accounts from the Reveille in that large, non-local timbers are used for the stamp battery and the mill is situated adjacent to the creek. There are puzzling features of the distribution of the mill, such as why was it apparently situated in the middle of the canyon, when most gravity driven mills of the 1860’s were utilizing slopes, and accounts describe the Cortez Mill as doing the same. In addition, if the drive machinery that was located on the east side of the modern and historic road alignments is in a correct place then it indicates that the road passed through the mill. This seems to suggest that the machinery for the mill is displaced and that the mill was likely on the west side of the historic road alignment (Figure 4-5). There is also a second historic road alignment closer to Mill Creek that may have been associated with the mill.

![Site overview facing southwest, with artifact, features and historic road alignment labelled.](Photograph by the Author, June 2016)
The heavy California timbers described as used for the stamp battery framing are likely the timber remnants observable near the creek (RRR 7 May 1864) (Figure 4-6). These timbers exhibit evidence of being burned and are highly desiccated; they generally measure two feet by two feet in diameter and are truncated approximately one to two feet above the ground surface.

![Figure 4-6. Remnant of heavy timbers set into the ground and fastened with an iron rod. (Photograph by the Author, June 2016)](image)

These timbers hint at the substantial construction of the mill. The work that went into constructing the foundation of the mill may have also have facilitated reuse of materials, as the mill remnants would have offered a ready source of timber and stone for subsequent works in the district. As will be seen below, the Menardi Mill likely repurposed stone from another source in the vicinity, possibly the Cortez Company Mill.
Near the timbers are six machine anchor bolts with threaded ends. These are set into the ground approximately two feet apart (Figure 4-7). Presumably these bolts are set into footings, although the size and nature of the footings is unclear without excavation. There may be more machine footings and additional intact evidence of the mill configuration under the extensive overburden at the site. The area has experienced periodic shifts in the creek, and the path of Mill Creek has likely been artificially modified. As a result, alluvial deposits likely cover portions of the mill foundation.

![Figure 4-7. Machine anchor bolts facing northeast. (Photograph by the Author, June 2016)](image)

On the east side of the canyon, and east of both the historic and modern road, are the remnants of a stone structure and assorted cast iron equipment, some visibly broken. The equipment is heavily overgrown, and further archaeological reconnaissance as part of a formal inventory might identify more equipment (Figure 4-8 through Figure 4-10). The
equipment appears to have been piled together in this area. This may have occurred either when the machinery was dismantled during abandonment, or when the current road alignment was graded. The stone structure includes two wall segments of dry stacked stone that appear similar in construction to other stone structures in the canyon. The age and purpose of the stone structure is uncertain.

![Image of the stone structure](image)

Figure 4-8. Overview facing east showing the displaced machinery and stone structure. (Photograph by the Author, June 2016)

The mill was apparently abandoned after the construction of Wenban’s Tenabo Mill in 1886. Because a portion of the cast iron machine parts that remain appear to be broken, they may have been discarded in favor of machinery that could be reused at other mines. Stamp milling parts were in demand throughout the 19th and into the 20th centuries (White 2010). There is the possibility that a Bruckner Furnace used at the Cortez Company Mill was salvaged and transplanted to the later Tenabo Mill, indicating that at
least a portion of the Cortez Company Mill machinery was reused at Cortez. This is indicated by the presence of two different Bruckner Furnace styles at the Tenabo Mill site. As Bruckner Furnaces were used at both mills, it is likely that the later Tenabo Mill borrowed a furnace from the Cortez Company Mill.

The displaced drive wheel shown below, and associated equipment (Figure 4-9 and Figure 4-10) were likely discarded when the stamps were removed. Some of the iron equipment appears broken. Work needs to be done at a time when vegetation allows for greater visibility to properly inventory the equipment.

Figure 4-9. Displaced drive wheel used to transfer energy from the steam engine to machinery. (Photograph by the Author, June 2016)
To infer what the mill may have looked like, a contemporary mill from the Comstock serves as an example of a simple stamp and pan mill, showing a configuration that might have been similar to the Cortez Company Mill (Figure 4-11). This also shows the size and placement of milling equipment, similar to the displaced machinery. None of the terracing that would have gone into a 13 stamp mill is easily visible. There is a slope down to Mill Creek, but nothing that appears to be a formal terrace. This is a testament to how dramatically the landscape has changed since the 19th century. Further indications of later modification is seen in a riveted pipe encased in concrete that proceeds to Mill Creek (Figure 4-12) and is located near the large timbers and on top of a brick pile.
A debris field was observed across the mill site, and includes square bolts and large steel spikes. Bottle glass and ceramic fragments were also observed across the site.
and appear to span the 19\textsuperscript{th} and 20\textsuperscript{th} centuries. Tailing remnants were observed downstream of the Mill Creek and are heavily eroded. The features described above are the only available information visible from the surface. Additional data is needed to describe the location and orientation of the mill terraces, and to provide evidence of changes in the process used and modifications made. This could be accomplished by subsurface exploration of the area. Machine trenching and hand excavation might expose features of the mill that have been buried beneath alluvial deposits. However, safety concerns may limit how much excavation may be done, as there is likely high levels of mercury in portions of the surrounding sediment.

**Tenabo Mill (1886 – 1915)**

Archaeological data for the Tenabo mill includes a better representation of the mill foundation and machinery than its predecessor, although in this case historical reports indicate that materials from the Tenabo Mill were salvaged for the construction of the later Consolidated Cortez Mill. This likely included lumber from the superstructure that survived the 1915 fire and possibly brick from the episodes of mill development. Figure 4-13 shows the mill shortly after it was constructed. The Tenabo Mill created the largest footprint of any of the Cortez mills. There are several smokestacks visible in the image that are puzzling, as there is little remaining equipment to demonstrate what machinery was employed at various stages, and the description of the operation of the mill, as described in Chapter 3, is vague regarding the drying and roasting that occurred at various points along the flowsheet for the lixiviation process (Bancroft 1889).
Figure 4-13. Tenabo Mill ca. 1888
(Nevada Historical Society)

Figure 4-14 and Figure 4-15 show the Tenabo Mill with Mount Tenabo and the Nevada Giant in the background. An abandoned automobile body is visible in the foreground in the first image. In contrast to the historical image, the mill remnants include the foundation and only a small portion of heavy machinery. The two Bruckner furnaces are visible atop one of the terraces. Visible in Figure 4-15 is the extensive vegetation that covered the site. Of note is that there were areas of particularly dense, green vegetation that seemed to indicate patterns of sediment or deposition that might represent activity areas or spots where charcoal or burned materials were placed after the mill burned down, creating a richer environment for plant growth. This highlights the need to survey archaeological areas at different times of year to make observations based on seasonal changes in vegetation.
Figure 4-14. Overview of the Tenabo Mill from the ground level facing east.
(Photograph by the Author, June 2016)

Figure 4-15. Tenabo Mill overview facing north.
(Photograph by the Author, June 2016)
The Tenabo Mill was constructed on a southwest facing slope and includes four large terraces and many smaller graded and constructed areas. Each main terrace is constructed of substantial, masoned stone blocks, carefully fitted and mortared to provide a solid foundation for the mill. The mill was built across the mountain from the prior Cortez Company Mill and closer to the prosperous mines on the west slopes. The location of the mine is 1.18 miles to the Garrison Mine and only 0.65 miles from the Arctic Mine, the two most productive mines in the district. This is a much shorter distance than the seven miles of mule trails were used to haul ore from these mines and over the mountains to the Cortez Company Mill. The mill is situated above the dry creek bed that issues from Arctic Canyon that forms the south edge of Mount Tenabo. This creek bed trends east to west along the base of the lowest terrace of the mill. There is no evidence that this creek was a significant source of water historically, and historical photographs suggest it was a dry bed. Two historic roads still exist that likely provided access to the various terraces of the mill. The Lander and Eureka county line passes through the mill; historically this created a problem for tax assessment. The mill is generally located above and to the northeast of the townsite of Cortez, although how much of the current Cortez townsite existed during the early operation of the mill is unclear, as settlement related to the later Consolidated Cortez Mill (1923-1937) likely impacted much of the earlier settlement. Figure 4-16 below is a satellite image that depicts the visible terraces and the large, eroded tailings pile.
Figure 4-17 shows the extent of the mill from above the top most terrace, facing west toward the modern open pit operation at the Cortez Mine. The distribution of vegetation coincides with disturbed areas across the site, and may coincide with subsurface features or burned remnants of the mill. The foundations of the mill appear to retain some integrity, and there is still some sparse machinery and metal debris across the site. The mill remnants have a total elevation drop of approximately 76 ft. from the floor of the top terrace to the ground floor at the base. The four relatively level terraces are constructed from locally quarried limestone that is dressed, fitted, and mortared.
The topmost terrace of the Tenabo Mill included the sorting and crushing departments, although no machine bolts or other indications of machinery are present. This terrace is very solidly built and the mortared and fitted stone blocks are further stabilized by packed cobble and boulder fill (Figure 4-18). Features of this stone terrace, and other terraces of the mill indicate that the foundations were created for specific activities. (Figure 4-19) shows how the topmost terrace exhibits a constructed pattern of stone similar to the crenellations of a castle and may represent some sort of chutes that are part of the sorting process of the mill. Figure 4-20, taken from the base of the topmost terrace shows that not all of the terraces were substantial stone foundations, as there are abundant brick features on leveled, cut-and-fill platforms. Further defining of this terraces is needed. It is possible that more refined dating of the individual terraces might provide information regarding various modifications to the mill over time.
Figure 4-18. Tenabo Mill top terrace.
Facing southeast.
(Photograph by the Author, June 2016)

Figure 4-19. Tenabo Mill overview.
From the topmost terrace facing west.
(Photograph by the Author, June 2016)
Figure 4-20. Tenabo Mill overview showing middle and lower terraces. Facing east. (Photograph by the Author, June 2016)

Figure 4-21 through Figure 4-23 show the Bruckner Cylinders that were used to turn and roast the finely crushed ore prior to leaching. Also visible is a small, subterranean room with a wooden staircase set into the terrace (Figure 21 and Figure 22). This area might have served as access to machinery, likely a flywheel to power machinery. Brick lined chutes were constructed into the terrace, and extend from the area where the Bruckner furnaces are located, down into the top of the lowermost terrace. Once again, further research is needed to identify what portion of the process this mill terrace was associated with. Noteworthy is that although the furnaces exhibit the cylindrical hallmark form for rotating while heating, they are of different designs. This might indicate that one of the furnaces was repurposed from the older Cortez Company Mill, where a Bruckner furnace was also in use.
Figure 4-21. Tenabo Mill with Bruckner Cylinders. Facing west showing a portion of the discharge portal. (Photograph by the Author, June 2016)

Figure 4-22. Tenabo Mill subterranean room set in the lower terrace. (Photograph by the Author, June 2016)
Other than wire nails, there is little to indicate the 1906 modifications to the mill to retreat the tailings via cyanide. However there are several concrete machine footings located on the lowest terrace of the Tenabo Mill that may be later additions. This area seems to be the focus of the machinery for the mill, and it is likely the engine and flywheel that drove the machinery was located here (Figure 4-24). In addition there is a concrete machine footing approximately 30 meters downslope from the mill that also may be associated with these modifications (Figure 4-25).
Figure 4-24. Tenabo Mill showing concrete machine pad with anchor bolts. (Photograph by the Author, June 2016)

Figure 4-25. Concrete footing near the Tenabo Mill. (Photograph by the Author, June 2016)
A post-abandonment image shows discarded cyanide equipment in the vicinity of the concrete footing (Figure 4-26). This indicates that the cyanide additions were positioned below the original mill, near the top of the tailings and within the vicinity of where the earlier leaching vats would have been located, according to archival accounts (Bancroft 1889).

Figure 4-26. Tenabo Mill date unknown, with portions of abandoned cyanide tank in foreground. (Gus Bundy Collection, UNR Special Collections)

Over the course of the approximately one hundred years since the mill burned in 1915, materials and equipment have been appropriated and sold off. Because of the state of the mill, comparisons to information provided from documentary sources is limited to details of structural construction. Figure 4-27 shows the mill shortly after the fire that destroyed it in 1915. There are abundant materials still present, including lumber and stone, that appear unburned and were likely repurposed. Figure 4-28 show portions of the
mill that have been removed from the feature, including a brick wall that was originally built on top of the stone foundation, and a brick smoke stack that was likely part of final steps of drying and smelting of the silver in the lixiviation process. Nothing remains of the lixiviation tanks, or any other traces of machinery aside from the two Bruckner furnaces.

Figure 4-27. Tenabo Mill after destruction by fire, after 1915.
(Estelle Shanks Collection)

Figure 4-28. Tenabo Mill date unknown showing that material has since been removed.
(Gus Bundy Collection, UNR Special Collections)
The Tenabo Mill tailings were reprocessed historically via the cyanide process through the refurbished Tenabo Mill, and possibly a second time in 1954 when the town site was purchased. What remained of value of the Tenabo and Consolidated Cortez mills were dismantled, and tailings were shipped off to Salt Lake City; this event likely involved tailings primarily from the later Consolidated Cortez Mill (Nevada State Journal [NSJ] 5 March 1954).

**Menardi Mill (1913 – 1915)**

The Menardi Mill exists as a stone foundation of likely locally quarried with partially dressed and mortared stone blocks. The mill is located 0.71 miles up the canyon and faces north, with the Berlin Mine on the slope above it and the Falconer and Erwin Mines, part of the Majestic Group, located in nearby canyons. The mill is built into the base of a northeast facing slope above Mill Creek and the Mill Canyon road. In front of the lowest terrace is a pound-in-place concrete floor. Two terraces measure 40 ft. wide by 6 ft. deep into the slope. The later Roberts Mill is built immediately adjacent to the Menardi Mill, and likely has impacted the mill remnants. A third terrace is buried under waste rock from the Roberts Mill. There is little evidence of the equipment of the Menardi Mill other than small machine footings. The only remnants are the foundation, with some assorted lumber that served as a platform for the lower terrace equipment. There is also steel pipe protruding from and laying across the mill remnants, and a portion of a steel flue constructed using rivets. Some of the later debris may be associated with the Roberts Mill, including a steel drum and various lumber fragments and galvanized, corrugated metal sheeting that is piled along the west edge of the foundation. Because of the incomplete archival information regarding the Menardi Mill equipment
and operation, additional fieldwork may identify archaeological features that relate to this “concentration” mill that possibly also utilized the cyanide process. Figure 4-29 below shows the location of the mill with the later Roberts Mill to the west.

![Figure 4-29. Satellite image showing the Menardi Mill, indicated with arrow. (Aerial from Google Earth 2016)](image)

Figure 4-29 is an overview of the mill terraces looking south. A machine footing is visible in the foreground, though association is difficult to indicate. Figure 4-31 is an opposing image from the top terrace. The footprint for the Menardi Mill is generally small, indicating a much less ambitious mill than others in the district. The mill has been stripped of all remaining machinery, and post abandonment impacts leave doubt as to what was originally a part of the Menardi Mill.
Figure 4-30. Menardi Mill overview facing southeast. Arrow indicates east corner of top terrace buried in rubble. (Photograph by the Author, June 2016)

Figure 4-31. Overview of Menardi Mill from top terrace facing northwest. Roberts Mill is visible in the background. (Photograph by the Author, June 2016)
A corner of the top terrace is visible beneath a pile of waste rock from the Roberts Mill. This indicates that the Menardi Mill was larger than just the two visible terraces indicate. Removal of the overburden might provide further information about what type of mill was used here, as the buried footprints of machinery may be exposed. There is a water diversion feature associated with the Menardi Mill that includes a diversion dam and pipeline used to appropriate water from Mill Creek.

Figure 4-32 shows the corner of the uppermost terrace of the Menardi Mill that is covered with waste rock from the adjacent Roberts Mill. The corner is constructed similar to the other terraces, with mortared stone. Little else can be learned without uncovering the terrace.

Figure 4-32. The eastern corner of the Menardi Mill, buried in waste rock. (Photograph by the Author, June 2016)
The ground surface and lowest terrace of the mill appears from historical images to have been used as storage for the Roberts Mill, and this has likely impacted the mill remnants. A concrete floor can be seen in Figure 4-31 that may be associated with the Roberts Mill, although it may be aligned with the Menardi Mill. Further brush clearing and investigation could determine what mill is associated with what ground surface components. Figure 4-33 and Figure 4-34 show evidence of the burning of the mill, with blackened lumber and staining. Rust colored staining on the front of the stone foundation may be from chemicals associated with the Roberts Mill that were stored on this terrace.

Figure 4-33. Menardi Mill overview from the concrete floor. (Photograph by the Author, June 2016)
The Menardi Mill site would benefit from additional archival and archaeological work to better infer the technology of the mill and how the mill operated. This site represents a mill that has been heavily impacted by its connecting neighbor, the Roberts Mill. Because of this proximal relationship, the Roberts Mill will be discussed next.

Roberts Mill (1930 – 1944)

The Roberts Mill (Figure 4-36) is the best preserved Cortez mill and the most recent. Much of the infrastructure still remains, and until recently the mill was relatively intact and included aerial tram cables leading to the loading platform and intake at the top of the mill. The mill superstructure has collapsed within the last 10 years, obscuring some of the interior machinery of the mill. Much of the Vandercook Process tanks and machinery remain behind, and offer insight into how the Vandercook Process was
executed. The mill is built into the northwest facing canyon wall of Mill Canyon, immediately to the west of the Menardi Mill foundation. The mill is approximately 57 feet tall from the mill intake to the ground level and includes three or four terraces. The maximum width of the mill is 102 ft. and it is set up to 70 ft. back into the slope. The platforms of the mill are constructed of planks of lumber set off of the ground, and the machinery and tanks of the mill are situated on these wooden platforms, some raised off of the ground surface and some set into the ground (Figure 4-35, Figure 4-36, and Figure 4-37). The foundation is pound-in-place reinforced concrete.

Figure 4-35. Roberts Mill ca. 1940’s.
Note that the Menardi Mill foundation is being used by the Roberts Mill.
(Estelle Shanks Collection)
Figure 4-36. Roberts Mill overview facing west. (Summit Envirosolutions, Inc.)

Figure 4-37. Profile of Roberts Mill facing northwest. (Photograph by Author, June 2016)
Figure 4-38 shows the top loading dock of the mill. There is archaeological evidence that ore was delivered directly to the mill via aerial tramway, ore carts, and haul trucks. The Berlin Mine is located directly behind and above the mill loading dock, and the Majestic Group of mines, including the Falconer and Erwin Mines, were located nearby and were associated with an aerial tram system. Ore was also stockpiled in a nearby ore bin. This indicates that a collection of mines contributed additional ore for the mill. Below this area is an ore bin that empties into the crushing department and at least two ball mills, associated with the overhead belt-drive system that powered the equipment. These are pictured in Figure 4-39 and Figure 4-40.

Figure 4-38. Top loading platform for the Roberts Mill. (Photograph by the Author, June 2016)
Figure 4-39. Roberts Mill middle terrace facing northwest. (Photograph by the Author, June 2016)

Figure 4-40. Roberts Mill. Grinding terrace. Facing northwest. (Photograph by the Author, June 2016)
The crushing machinery at the mill represents the portion of the Vandercook flowsheet that corresponds to the crushing of ore from sand to slime. The loop in the flowsheet involves a 4 foot by 4 foot Marcy ball mill discharging into a 4 foot by 4 foot Straub ball mill (Vanderburg 1938:9).

Figure 4-41 shows the amount of timber and corrugated, galvanized sheet metal that remains from the mill superstructure. The amount of material that remains from the mill might be an indicator that activity and population in the canyon had declined by 1944 when the mill permanently ceased operation. Subsequent mining would likely have led to the salvaging of a greater amount of material in the mill. Well preserved components of the mill are visible in Figure 4-41 through Figure 4-43. Abundant materials remain, including the cyanide tanks in the mill structure.

Figure 4-41. Roberts Mill overview facing northwest.  
(Photograph by the Author, June 2016)
Figure 4-42. Roberts Mill overview facing west.  
(Photograph by the Author, June 2016)

Figure 4-43. Roberts Mill view facing west with cyanide tanks.  
(Photograph by the Author, June 2016)
Figure 4-44 shows the difference in size and preservation between the Roberts Mill and the smaller Menardi Mill, with the footprint of the larger Roberts Mill impacting the Menardi Mill foundation.

The cyanide tanks are intact and at least one of the tanks contains a muddy sludge (Figure 4-45). The cyanide agitator is still visible descending from the drive wheel down into the tank. A second dislocated agitator is visible in Figure 4-46, and may indicate the patented Vandercook spiral design. Wooden tanks were likely in use for all of the historical mills at Cortez, and seem to indicate a stable design feature in the milling process.
Figure 4-45. Roberts Mill interior of cyanide tank facing south.
(Photograph by the Author, June 2016)

Figure 4-46. Roberts Mill displaced cyanide tank component
This may be a component of the patented Vandercook cyanide tank.
(Photograph by the Author, June 2016)
Remnants from the mill process are visible within the mill superstructure. The zinc bucket pictured in Figure 4-47 was used in the cyanide process. Zinc was added to the gold recovery box where it bonded with the precipitated gold and silver before being collected. Remnants of cyanide storage are also present, including this cyanide barrel with stenciled print still visible (Figure 4-48). These artifacts are easily dateable, and provide additional information regarding the operation of the mill.
Figure 4-49 and Figure 4-50 show the sizeable amount of timber that was used for this mill, and provides a glimpse of how the other mills might have been constructed. The mill was situated below the company workings that are in the canyon above the mill, and all of the materials for the working of the mill was likely shipped in along the graded Mill Canyon road, making this mill, like the Consolidated Cortez, increasingly reliant on outside sources for materials to operate the mill.
Figure 4-49. Roberts Mill Overview facing south.
(Photograph by the Author, June 2016)

Figure 4-50. Roberts Mill overview facing southwest.
(Photograph by Summit Envirosolutions Inc., 2014)
The Roberts Mill site provides the best example of a largely extant mill that allows for the full range of study. Further identification of machinery present at the mill and comparisons to what is known from company documents might provide a more complete picture of how the mill operated. Portions of the mill appear to have been modified post abandonment. There is a plastic pipe that currently runs along the side of the mill remnants that indicates modern activity.

**Consolidated Cortez Mill (1923 – 1937)**

The Consolidated Cortez Mill remnants are located at the base of the west facing slope of Mount Tenabo, facing west and located 0.5 miles to the east and above the Tenabo Mill. Similar to the other mills, the Consolidated Cortez Mill exists largely as foundational remnants, with some equipment and infrastructure still remaining, including the one Oliver Filter used to filter out cyanide particles. The Consolidated Cortez remnants also include a massive tailings flow that is eroding 2.25 miles southwest down the slopes of Tenabo Figure 4-51.
The mill includes three large concrete foundations, with various smaller concrete footings for the machinery. Some platform and superstructure timber are present, in addition to steel piping and remnants of machinery that are scattered across the site. Little that can be reconstructed directly from machinery is available, although the concrete footings might allow a comparison to machinery described in the primary sources. Terraces include the top, 35 ft. by 20 ft. terrace, followed by a second 90 ft. by 45 ft. terrace that includes the remaining Oliver Filter, followed by a much larger 150 ft. by 60 ft. terrace where the cyanide or oil flotation tanks were located. A rounded pile of tailings indicates one of the now missing tanks. Figure 4-52 shows the sizeable waste rock piled behind the mill and the extant truck shop to the north.
As can be seen in Figure 4-53, the Consolidated Cortez Mill is built on the steepest slope of any of the mills, and is also the largest concrete structure. This concrete includes a very heavy aggregate with a sealing finish that has deteriorated to expose the concrete beneath. Wire nails and an assortment of timbers are present across the site, as well as window glass and assorted piping and other remnants of machinery. Expansive tailings can be seen flowing downslope in Figure 4-54.
Figure 4-53. Consolidated Cortez Mill facing southeast.
(Photograph by the Author, June 2016)

Figure 4-54. Overview of the Consolidated Cortez Mill from top terrace facing west.
(Photograph by the Author, June 2016)
Machine footings are visible across all of the terraces of the mill, as seen in Figure 4-55 and Figure 4-56. Further investigation of these footings might indicate the extent of adaptation, as the ways that the Consolidated Cortez Mill was adapted over time are poorly understood. The footings could be matched to missing machinery, which may in turn reconstruct the chronology of adaptation.
There are several unexplained features that are not accounted for in the documentary sources, including a collapsed tank remnant at the top of the mill. This tank may be a part of a pre-treatment process or reflective of a later modification to the cyanide-flotation system (Figure 4-57). There are also areas where vegetation at the Consolidated Cortez Mill seems to be discretely growing which might indicate significant areas of disturbance (Figure 4-58).
Figure 4-57. Consolidated Cortez Mill showing tank on upper level. View facing east. (Photograph by the Author, June 2016)

Figure 4-58. Consolidated Cortez Mill overview. Note discrete vegetation growth. View facing north. (Photograph by the Author, June 2016)
Figure 4-59 shows the view downslope and the steep angle of the mill. The Oliver Filter is visible, as well as the tailings pile shaped by the cyanide tank at the center of the image. The Oliver Filter is the only machine remnant still present on the site, and is shown in detail in Figure 4-60. This filter is a first of its kind rotary vacuum drum that is suspended in the precipitated solution and sucks up the suspended particles as it turns. The filter at the Consolidated Cortez Mill is an early form of this technology. A discharge cake from this filter was smelted into bullion. The Oliver Filter is still in use today.

Figure 4-59. Consolidated Cortez Mill.
View Facing West.
(Photograph by the Author, June 2016)
In addition to lumber, the mill terraces also include various piping and metal debris, as shown in Figure 4-61. In this image Mount Tenabo and the “Nevada Giant” are seen in the background. There is also pipe constructed into the concrete terrace wall.
Waste rock might also be either an expedient construction material or an observable indicator for mine productivity. If there is sorting of ore at the mill, low grade or may be stockpiled nearby or discarded as waste rock. Figure 4-62 shows the waste rock at the top of the mill and the tailings below.
Figure 4-62. Consolidated Cortez Mill waste rock and tailings. View facing west. (Photograph by the Author, June 2016)

Figure 4-63. Satellite Image Showing Extent of Tailings flow from the Consolidated Cortez Mill. (Google Earth, 2016)
There is abundant information available from archaeological sources that is absent from the documentary record. Although the mill sites were not exhaustively recorded, even a general survey reveals details that, taken with documentary evidence, create a fuller picture of how each mill was constructed and functioned. The following chapter will look at the trends that emerge from the various documentary and archaeological descriptions of the mills, and will attempt to describe possible avenues for additional research that can assist in describing the changing mill technology at Cortez.
5. Discussion

The purpose of this thesis has been to identify trends in milling technology within a single mining area over time. There are enormous complexities that must be considered in describing these aggregate technological components of the mining system. Changes in the milling technology and mill placement at Cortez can be described as a movement from the limited technologies available as a result of the Comstock, including stamp mills and wheeler pans, to a wider menu of possible technological configuration, from crushing equipment to specialized agitators. Mill managers chose equipment for perceived effectiveness on local ore, or to expand reserves by increasing the exploitable ore. Guiding these choices were experiences and knowledge acquired via direct observation of the environment or secondhand through the exchange of information developed in other environments about what technology to adopt and how to adopt it. By examining documents generated by the mills, and the archaeology of the mill sites, it is possible to infer portions of the processes that were used. Based on this information, continuous and divergent trends can be identified and the implications for these trends explored. In addition, the larger question might be approached: how did the fundamental changes to human behavior that occurred on a global scale during the second industrial revolution manifest in a remote Nevada mining district? As described in Chapter 3 and Chapter 4, the mills exhibit characteristics that might help answer questions about changing technologies. Posing questions to historical mills requires a nuanced and contextualized description of the mills. The following observations were made to each mill.
The Cortez Company Mill (1864 – 1886) was constructed at apparent great expense, but was unsuccessful in being profitable for the Cortez Company who constructed it. Although the miners that planned the mill were reconstructing the recipe of the stamp mill learned at the Comstock, and similar to Schiffer’s (2010) description of how technology is transmitted, this technology was based on prior knowledge and not suited to the new Cortez environment. However, mine owner Simeon Wenban was likely able to put the mill to some use, as the mill was modified over the course of the fifteen years before the construction the Tenabo Mill. It is possible that using acquired knowledge gathered from personal experience, Wenban and the Tenabo Mill and Mining Company were able to create efficient transportation routes to ship ore over the mountain to the mill. Acquired knowledge also led to the abandonment of Mill Canyon to a few smaller scale miners, as the larger and more consistent ore was located on the west slopes of Mount Tenabo. Time spent in the district appears to have been the catalyst for this shift in focus. Archaeologically the mill barely exists, and only a vague footprint might be inferred. More work is needed to delineate the mill boundary, and to determine if modifications are visible in the mill remnants.

The Tenabo Mill (1886 – 1915) was planned to be appropriate to the environment that it was constructed in, and was tailored to the local ore that was mined from the main Garrison mine. This is an example of miners acquiring knowledge about the environment and applying it to the deployment of technology. In this case, based on what was known of the ore distribution, the Tenabo Mill and Mining Company refocused activity exclusively on the west slopes, abandoning Mill Canyon. Wenban minimized costs by
using local resources and adopting what was perceived as a more cost effective milling process, the Russell Process of ore leaching (Hardesty 1988:113). This process was important in that it was developed to process lead-heavy ores and additionally modified to recapture more of the hyposulphite solution. This strategy fits in with landscape learning if miners are using technology specifically oriented toward exploiting an ore that in this case includes abundant lead, as miners learned that the ore at Cortez had this quality. Once new technology was available, the mill was adapted for the cyanide treatment of tailings. This could have included adapting the original leaching tanks for cyanide. There is no written or archaeological evidence that this later salvaging of the tailings included participation in mining any claims.

The Menardi Mill (1913 – 1915) is the least understood mill in the district, as little archival or archaeological data remains. The mill foundation include stone construction similar to the Tenabo Mill, but with less care taken in the construction. Dressed stone blocks are interspersed with unmodified cobbles. Some of these blocks appear similar to the stone structures found further up the canyon that are a part of the earliest workings. The footprint of the mill is small in comparison to the adjacent and later Roberts Mill. The Menardi Mill has been partially buried by the waste rock from this later operation, and the extent of top terrace that is buried is unknown. The positioning of the mill closer to the entrance and a specific mine seems to indicate that the mill was intended for only a short duration. This is also the only mill that is not oriented along the contour of the slope, but is instead oriented to cardinal directions.

Described as both a concentration and cyanide mill, more information is required to
determine what process was used in this mill, how the process was arranged, and what machinery was used.

The Consolidated Cortez Mill (1923 – 1937) represents the first concrete mill foundation, and a generally steep, gravity fed, cyanide based milling process with abundant machine footings. Visible in the documentary and archaeological record is an elaborate milling process that was modified to use an innovative oil flotation process. This seems to represent a shift in the functional field of the mill, as the mill was likely modified to produce a dual cyanide/oil flotation concentrate. This represents a technical choice as a result of likely diminished ore reserves, and an attempt to keep the mine running during the difficult economic times of the Great Depression.

Finally, the Roberts Mill (1930 – 1944) represents the most comprehensive archaeological and archival site. This mill represents technology that exists at the intersection of mercury and cyanide processing. In this way differing technical recipes, as described by Schiffer (2010), have been merged in an attempt to benefit from differing technologies. How effective this approach was is uncertain, as production figures and additional archaeological investigation are needed to further describe the effectiveness of the mill.

**Continuous Trends**

At a basic level, the Cortez Mills exhibit similarities in their design linked to their function as ore reduction mills. The mills share general components of crushing, grinding, and some sort of chemical based component to extract the target minerals. The specifics of the technology might change, but these general characteristics persist. In a
similar vein, and characteristics of the sequence of milling equipment are relatively stable across time. The mills are logically arranged to place the crushing equipment at the top, followed by increasingly refined crushing and sorting technology, followed by the chemical treatment terrace below. Heat treatments might be located at the beginning, or end, or anywhere during the treatment process, as various drying, roasting, and heated leaching techniques were used. Other characteristics that are shared by the mills include the use of gravity to facilitate transport of material, and some form of corporate structure. One final characteristic that is shared by the mills is that each mill experienced some modification after construction. Despite careful planning, the mills did not work as efficiently as anticipated in any of the instances. The strategies that the modifications take are discussed in the next section. This brings up the point that during each period when a mill operated at Cortez, there was also frequent shipping of ore south to the Austin mills or north to Beowawe and the railroad, bound for smelters in Utah.

Trends that occur at Cortez also occur in other mining districts, and this represents an important area for future study. By tracking changes across time, but also across other mining areas, we can arrive at some more specific explanations for how knowledge and experience in an environment inform behavior and technology.

**Changing Trends**

General features of the mills at Cortez tend to be stable, but the specific equipment or process used in the mills changes over time. For instance crushing and grinding technology might provide the same function, but the stamp mills are replaced by the rollers, which are were turn replaced by the ball mills. Each of these changes in
reduction technology reflects the perceived needs of the chemical treatment used at the mills. These are based on broader ideas that were developed over years of experimentation, and represent the accumulation of learning over the decades after the Comstock, and the development of the recipes for the deployment of technology, to use the concept described by Schiffer (2010). Similarly, leaching technology functions to render the metals into a form that can be removed from the waste rock. Hyposulphate leaching and cyanide leaching are two forms of leaching technology that have different requirements for crushing and pretreatment.

One of the more intriguing trends visible in the archaeology of the mills at Cortez is the way that the milling foundations and structures were built. The Cortez Company Mill, Tenabo Mill, and Menardi Mill are more substantially built than the depression era Consolidated Cortez Mill and Roberts Mill. Although the Cortez Company Mill is very sparse in the archaeological record, the surviving timbers and fitted stone structures hint, as well as contemporary sources that describe, an impressive effort in construction, and that great effort was put into erecting a mill that would provide custom work for a long duration. Similarly the Tenabo Mill includes carefully fitted stone that appears to represents a long stay in the district. Conversely, the Consolidated Cortez Mill includes poorly aggregated concrete, and repurposed materials from the much older Tenabo Mill. Likewise the Roberts Mill includes portions that appear to be rigged to serve a temporary function, including repurposed drums, lumber that is an assorted jumble of measurements, and less substantial and expedient foundational elements.
Providing the reason for changes in milling technology is the elusive quality of the ore itself. Lacking a formalized way of exploiting ore such as modern drilling techniques and geologic profile building, historic era miners at best made do with expensive cross cuts to determine the size and shape of subsurface ore deposits, and at least at Cortez these were limited to exploring the most promising ore deposits. In the earliest stages of mining, locating substantial deposits might be little more than guesswork based on surface geology. Prospects are visible across all aspects of the slopes of Mount Tenabo, yet even when rich ore bodies were located, they often proved too shallow to encourage the development of large operations. Transportation costs might have prohibited small scale lessee miners from profiting from these deposits until trucking ore became common in the early 20th century. This situation necessitated the use of mills in some instances. Lower grade ore bodies, once encountered, could be processed on site, provided that the technology was capable of doing so and was deployed appropriately. In this way, mills could expand the reserves of the mine.

Between the discovery and closure of the mine, choices must be made. The longer that ore bodies are mined, the more difficult it becomes to sustain work, not only because of the logistics of extracting ore from an increasingly deep or remote ore body, but because the further the ore is from the surface, the more difficult it becomes to extract gold or silver due to chemical complexity (White 2016:159). This creates a situation of diminished returns and creates room for changing technology to exploit areas where previous technology has failed. This might occur until the mine is finally and irrevocably exhausted, as eventually occurs at all mines.
Hardesty (1988) has suggested that strategies employed by Simeon Wenban to adapt to adverse conditions in the economic times of the late 19th century allowed the mine to remain viable over a long period. The archaeological evidence seems to support this idea. Wenban had accumulated over twenty years of experience in the district prior to the construction of the Tenabo Mill, the longest running mill in the district, if this is a criterion for success. Wenban’s strategy included using environmental knowledge to refocus efforts out of Mill Canyon and onto the west slopes to exploit the larger and more consistent ore bodies. Wenban and company also adapted technology to better process the ore and utilize local resources. By contrast, later mills lasted in some cases only a few years, producing far less than earlier mills. This seems to indicate either that either the mills became more expedient, environmental knowledge was lacking, or that the resources were exhausted. Perhaps all three were factors. Later miners may have attempted to exploit Mill Canyon, as early period miners had done, and failed to use prior knowledge or acquire enough to successfully exploit the ore. Technology may have not been deployed correctly in Mill Canyon, as modifications and innovations, from the Cortez Company Mill to the Roberts Mill, appear to have been less successful than their counterparts on the west slopes.

**Future Work**

Although a general examination of the historical archaeology of the Cortez mills has revealed that there is much to be gained from looking at both the material remains of the mills on the ground, and the displaced artifacts that are primary source documents, additional work is needed to fill in gaps of the mill sites. Formal examination of each mill site is needed. Safety issues might be addressed to determine what portions of the mills
might be excavated, followed by subsurface examination of mills whose foundations are not well defined due to overburden, as well as careful measurement and recordation of machine footings and other features of the structure of the mill that might help to identify the exact configuration of the milling process employed over time. Although there will be a point where little additional information can contribute to a fuller description of each mill, there remains much more work to be done. The purpose of this research is to chart the changes that occurred in this important period of historical technological development, a period that we are likely still in, as our ideas about our environment and change, in turn influencing the material expression of our culture and our behavior through technology. Additional archaeological research on milling technology, and other aspects of historical mining, promise to contribute to our understanding of how we perceive and adapt to our environment in the past and in the future.
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