2019

Fortune and Failure - Gold and Silver Smelting in the Colorado Rockies 1861 to 1900

Andrew Mueller

FORTUNE AND FAILURE – GOLD AND SILVER SMELTING IN THE COLORADO ROCKIES 1861 TO 1900

By

Andrew C. Mueller

A DISSERTATION

Submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

In Industrial Heritage and Archaeology

MICHIGAN TECHNOLOGICAL UNIVERSITY

2019

This dissertation has been approved in partial fulfillment of the requirements for the Degree of DOCTOR OF PHILOSOPHY in Industrial Heritage and Archaeology.

Department of Social Sciences

Dissertation Advisor: *Timothy Scarlett*
Committee Member: *Fredric Quivik*
Committee Member: *Steven Walton*
Committee Member: *Paul White*
Department Chair: *Hugh S. Gorman*

Table of Contents

Appendices

List of Figures

List of tables

Acknowledgements

I want to acknowledge the help of my committee on helping me complete this dissertation. Your comments and direction made the process possible. I would like to especially thank my advisor, Dr. Timothy Scarlett who stuck with me through two dissertation topics and nearly a decade of long-distance effort. I would not have been able to complete this without your support. Finally, I would like to thank my wife Megan who supported me throughout the process, sacrificing an immense amount of time and emotional energy in helping push me through this process. I would not have completed this project without your constant encouragement.

Abstract

This dissertation is a study of small-scale smelting in Colorado during the nineteenth century. Many small smelting enterprises were established throughout the mountains of the state from the mid-1860s to the mid-1880s. The smelters helped to revitalize a flagging mining industry by fostering its growth and, consequently, the development of the state before being outcompeted by larger smelting establishments developing in the growing cities on the Front Range. However, the life of these smelters was brief, and the majority failed within a few years. The role of these smelters in Colorado's history has been largely overlooked but provide a rich potential to contribute to our knowledge of Colorado history, and scientific studies relevant to contemporary society including rural economic development, technology transfer, sustainability, and the ecological impacts of industrial enterprises.

The primary pattern within the small-scale smelting industry of Colorado was one of failure. The study of the reasons for the failure of the small smelting businesses forms the main topic of this dissertation. These smelters required a specific set of conditions to survive, grew in isolated areas with difficult access, and failed when their isolation was ended by improved transportation, which opened their region to outside competition. Although there were many facets contributing to the failure of these smelters, competition from larger businesses is the main culprit as the small smelters could not compete with better capitalized

and more efficient large smelters once their niche market was incorporated into the larger economic sphere of the state.

1 Introduction

The gold and silver smelting industry was a vital component of Colorado's development. The Colorado smelting industry experienced almost continual growth from the construction of its first smelter in 1861 until the 1890s when economic and political forces on the national and international stage led to its decline. During the first 20 years of the industry small smelting establishments in the mountains dominated the industry. These small smelters rapidly failed in the mid-1880s due to competition from larger smelting operations on the Front Range.

The main focus of this study is the small mountain smelters which, despite their significance and rich potential for archaeological study, have been neglected by scholars and are underappreciated in Colorado's heritage infrastructure. In this dissertation, I examine the pivotal role of these establishments in Colorado's history through discussions of the technological, historical, and transportation issues that made small-scale smelting both a necessity in the state, and ultimately led to their demise. In many ways, these smelters were typical small businesses of their day and like today, most small start-ups fail within a few years of opening. The stories of these smelters are therefore rich illustrations of important topics in contemporary society: technology transfer, adaptation, entrepreneurship, rural economic development, sustainability, and the ecological consequences of industrial production.

The history of Colorado has been shaped by the mining industry. From the earliest rush to gather placer gold along its mountain streams and rivers in 1858 to the early twenty-first century, mining has been an important part of Colorado's economy. Gold and silver were the primary drivers of Euro-American settlement in the state and most of the major towns and cities owe their foundation and early development to mining. Mountain cities like Leadville, Georgetown and Aspen were created to support the mines in the surrounding area. Other communities like Denver, Pueblo, Durango, and Gunnison developed as supply centers to provide materials to the surrounding mining regions (Stone 1918; Ubbelohde et al 2006). Even agricultural communities on the plains developed to provide food to support the region's miners.

In the early years Colorado's isolated location made it difficult to profitably exploit its mineral wealth. The earliest gold deposits were placer and free-milling deposits. Placer deposits are located within active or ancient streambeds. The gold found in these sands and gravels were derived from the natural erosion of gold-bearing rocks in the adjacent mountains. The liberated gold was deposited in a water course where the metal grains settled to the bottom of the stream at locations where stream velocity dropped, forming deposits (often called bars) where economically exploitable quantities of gold gathered. In many places, placer gold is found in abandoned river channels, hundreds of feet higher than the current water courses where the gold was deposited thousands of years previously (Lakes 1906:106-108). Free milling gold was generally found in shallow deposits where particles of native gold were contained in quartz. The name free milling came from the fact that the gold in the ore could be easily sorted through crushing and collecting it through the use of a simple amalgamation process (the tendency of gold to adhere to mercury). Once these easily processed placer and free milling gold deposits were exhausted (usually within the first few years of work in a district), only the richest and most valuable ores could be profitably transported to processing facilities outside the territory's boundaries due to the high transportation costs of the early years. Colorado's economy became dependent on the development of a local smelting industry to allow the profitable expansion of mining to increasingly remote and marginal mining regions. The history of mining in Colorado is widely recognized and the importance of mining sites is well recognized. By contrast, the important role of smelting in stimulating the development of Colorado is not as well known.

Smelters were established throughout Colorado's mining regions. The presence of large smelters in Pueblo, Denver and Leadville during the nineteenth and early twentieth centuries is commonly known, but the smaller smelting establishments in the towns and isolated mining districts in the mountains receive much less attention. Public and professional interest in the industrial infrastructure of mining districts has tended to focus on the highly visible mines themselves or the remains of large concentration mills that have left larger and more dramatic ruins than the small area smelters. These mills and mines were often in production much later and present more dramatic ruins that capture the imagination better than the simpler foundations and slag piles left by the earlier smelters.

Researchers that have studied Colorado smelting have tended to focus on the larger smelting centers due to their economic and political importance, and because more documentation survived whereby people can study their operations. This study examines the large number of small establishments that existed in the mountains, largely forgotten due to their marginal existence and transient nature. Unlike the larger plants that operated for decades, many of these smaller smelters operated for a few years, or in many instances only a few months. Even with these short lifespans the small smelters enabled the development of new mining districts in remote or rugged areas.

Information Sources

I set out to build an inventory of the smelters and gather contextual information about them. Unfortunately, Colorado's small mountain smelters left scant primary documentary evidence of their operations. Correspondence with archives and local libraries throughout Colorado identified little surviving material. The archival records of the smaller smelters seem to have been largely discarded or destroyed. Smelter-related data in local collections is limited to returns in the records of mining companies that list the contents and values of ore shipments, most dating to the early twentieth century. Local histories often contained information based on the accounts of period witnesses, family stories, documents and local lore. Unfortunately, these types of documents are often sparsely referenced and determining their reliability is difficult.

Much of the information on historical smelters included in this dissertation was therefore collected through a review of historical Colorado newspapers, ranging in date from the 1860 to the 1920s. These reports were cross-referenced and supplemented with details from local histories, General Land Office (GLO) maps and records, United States Geological Survey (USGS) reports, historical engineering journals (primarily the *Mining and Engineering Journal*), and historical archives. Finally, a sample survey of the *Mining and Engineering Journal* for the years 1875 to 1885 was conducted, covering the main period of small smelter construction and operation in Colorado.

Only two archives in the state hold significant smelter-related material: History Colorado (the Colorado Historical Society) and the Western History section of the Denver Public Library (DPL). The DPL collection includes a cash book from James E. Lyon (an early smelter owner at Black Hawk) listing expenses for Lyon’s enterprises during 1865 including mines, the smelter, logging operations and other expenses. The entries are limited to brief descriptions and costs, however, making it difficult to assign expenses to specific industrial enterprises. This limits its value to in studying his smelter. DPL also contains period publications on smelting in Leadville, a monograph on the Boston and Colorado Smelting Works at Black Hawk, several prospectuses from mining and smelting companies, equipment catalogs from historic mining equipment manufacturers, and period publications on smelting technology. The History Colorado collection contains a cash book for the Malta Smelting Company at Leadville for 1880. The book details costs and quantities for fuel, fluxes and ores, but the entries are brief and often difficult to follow. The archive also has the Crawford & Louis Sneed-Hill collection containing records of the Argo (Boston and Colorado) Smelter from the period of its closure covering the liquidation of its assets. Finally, the archive has an excellent photograph album with pictures of the Argo Smelter taken from 1903 to 1907.

Academic context

While historical studies of western mining were already being produced before the end of the nineteenth century, the archaeology of mining began much later, only becoming common in the 1980s. General studies of the mining industry have focused largely on the actual mining and milling side of the metallurgical process. Less attention has been paid to the local smelting industry. Although relatively little archaeological research has been conducted on smelting in the western United States, a large body of literature has been developed discussing the region's mining and milling. These studies are referenced throughout, particularly in chapters 5 and 6. Archaeological studies of historical mining have been centered in three regions within the United States. Donald Hardesty and his students at the University of Nevada, Reno, have conducted long-term research in Nevada, with a strong concentration at the Cortez Mining District (Hardesty and Hattori 1982). Michigan Technological University has conducted research on the historic copper and iron industrial sites of the Upper Peninsula of Michigan and at Kennecott in Alaska (Martin 1990; Landon et al 2001). Finally, Paul White formerly of the University of Alaska Anchorage has been investigating mining sites within that state (White 2017).

In contrast, archaeological investigations into mining and industry in Colorado have been limited to a relatively small number of recordings conducted by cultural resource management firms in response to the requirements of Section 106 of the National Historic Preservation Act (NRHP). Other than a few contextual studies produced by History Colorado and the Office of Archaeology and Historic Preservation (King 1984; Fell and Twitty 2008), synthetic studies of Colorado industrial development and technology are rare.

Early scholarly work on the metal production industry tended to focus on individual components of the industry such as the mines or mills. During the 1990s, scholars' attention began to shift to the study of mining landscapes that placed the mines and ancillary industries in context with settlements and transportation networks including smelting (Francaviglia 1991; Hardesty 1999).

The mine ore requires processing to be rendered into an economically useable form. Archaeologists have examined how the ability and the expense to transport goods into and out of a mining district was a primary factor in the profitability of an area (Hardesty 1999:215). In these isolated industrial communities, almost all materials needed to be imported. The short-lived nature of many mining regions and the transient nature of the workforce created little incentive to develop non-metallurgical infrastructure. Although prices were high due to transportation costs, manufacturing had reached a stage where other necessities could be made readily available for purchase, allowing communities to focus on metal extraction and processing. The dependence on mass produced goods did limit the ability of local industries to adapt easily to changing conditions, leading to the periodic abandonment and resettlement of districts as new technologies would periodically revitalize mining in a region (Hardesty 1985). Other supporting components of the metals industry could not be easily imported and ancillary industries and facilities including charcoal kilns; quarries; and water-collection, transportation, and management ditches were developed in most districts (Francaviglia 1997; Lawrence et al 2016).

Industrial-scale mining and smelting also have significant impacts on the environment. Mine and smelter sites have been examined to provide information about industrial pollution or deforestation that can be applied to larger scale environmental studies, supplementing more traditional ecological data sets (Hardesty 2006, 2007:2; Mrozowski 2006:33). Archaeologists have studied the waste products produced by metallurgical industries. All stages of metal production produce large quantities of waste material. During mining, immense quantities of waste rock are generated and deposited onsite in large dumps.

Concentration and processing mills produced large amounts of tailings deposited along streams and watercourses. During smelting the valuable metals comprised only a small percentage of the ore processed and the discarded slag was disposed of in the most economically efficient method possible filling ravines and valleys, and creating large piles of slag. In some areas, like Leadville, these mounds of waste materials have become dominant features on the landscape that are not only impossible to miss but have become part of the identity of the community (Francaviglia 1991; Morin 2009, 2013).

In addition to impacting the visual aesthetics of an area, these waste deposits often contain toxic materials that pose a health risk to humans and wildlife in the area as they interact with surface or ground water or become wind-blown dust. The waste generated by all stages the industrial operation had to be disposed of in some manner, which usually meant downwind, downslope, or downstream. Lack of concern for the impact of waste materials on other inhabitants in the region led to some of the earliest environmental lawsuits in California, Colorado, and Montana (Knight 1898; Kelley 1954:356; Kelley 1956; EMJ 1911:656; Quivik 2000). During the operation of the Boston and Colorado Smelter in Blackhawk in the 1870s travelers on the Colorado Central Railroad that passed near the works reported noxious smells, burning eyes, and difficulty breathing due to the fumes emanating from the smelter’s roasting yard (Smith 2009:91-92).

Reuse of smelter slag became an important concern for large works, if only to dispose of excess waste material. Slag was commonly used for railroads and road construction work (HCD 1940; White 2003). The remaining deposits of waste now create strong reactions in most viewers, whether it is seen as an important part of the local historical heritage, or a contaminated ecological hazard best removed (Hardesty 2001; Quivik 2007:1).

Failure

The main focus of this dissertation is the pattern of, and the reason for, the failure of the small-scale smelting industry in Colorado. Failure can be the result of technological problems or lack of technical knowledge on the part of the user (i.e. “a hardware” failure, like not getting a furnace to work correctly), a lack of economic success, but more importantly can also arise from the complex interplay of social, technological, economic, infrastructural, and other systems. (Gooday 1998:268-269). While preservationists focus their energy on major successful businesses that had broad and long-term impacts on an area, failure is the most common pattern in the precious metals industry of the American West. Research into frontier industry reveals that many types of failure It is best recognized through the boom-bust cycle seen in mining districts where an initial rush to a district led to the rapid growth of an area, followed by an equally dramatic decline when the district became unprofitable. The collapse could be due to a number of issues. The most common was the exhaustion of ores that could be profitably processed, or deposits that proved promising on the surface sometimes lacked significant depth. In other instances changing national or world economic conditions devalued the mined product. Failure of mines, mills and smelters were common in all areas. Research on industrial operations have tended to concentrate on highly successful firms, largely due to the survival of a larger body of records either through sheer volume, or from the perceived value of the collection leading to its preservation in archival collections. Successful companies also built larger facilities more likely to survive or to attract public and government interest in examination and preservation (Heberling 2015:26). Records from small firms that failed rapidly or abruptly are also far less likely to have been preserved.

Although the Colorado smelting industry produced large quantities of metals, including ores shipped from throughout the Rocky Mountain region, the output was dominated by a small number of large smelting companies based at Leadville, Denver, and Pueblo. When looking at the small-scale smelters of the Colorado mountains it is clear that most failed within a few years of opening, usually without significant production. For the small players in the industry failure was ubiquitous. The firms had short lifespans and only a few evolved into larger, more stable companies. As with modern start-up companies, a few small firms can come to dominate a business sector, these are exceptional examples and most companies operated with the constant threat of bankruptcy.

Archaeological examinations of failure have been rare, although the phenomenon has been a subject of study in the fields of economics (Knott and Posen 2005; Nightingale and Coad 2013; Dannreuther and Perren 2013), history of technology (Basalla 1988; Blockley and Henderson 1980; Burt 2000; Gooday 1990; Petroski 1992a, 1992b, 1994), and anthropology (Pfaffenberger 1990, 1992, 1998). The causes of failure for small Colorado smelters occurred for a number of reasons that varied depending on the individual conditions experienced by a smelter. Factors that could contribute to the failure of these smelters included poor management, poor design, failures to adequately consider local conditions (mainly a failure to consider the quantity and quality of local ore deposits), poor choices of technology, over-optimism of local mining potential, inadequate capital reserves, fuel and material limitations, and the failure or inability to innovate when needed. The most common reason for failure, however, was competition with larger, more efficient smelters outside their district.

Small mountain smelters developed to fill a need experienced by most new mining districts to profitably export their ores. High transportation costs due to the poor transportation infrastructure of new districts made it practical to export only the richest ores, and the transportation costs would often consume most of the profit from those ores. Local smelters developed to fill this need by creating an intermediate product with a high value to weight ratio that could be profitably exported to exterior markets.

The small smelters supported the expansion of mining in their district, making it more attractive to railroad companies due to the potential for increased traffic. The arrival of a railroad at the district drastically reduced shipping costs, eliminating the need to process the ores locally and putting the small smelter in direct competition with cheaper and more efficient smelters outside the district. Business for the local smelter would dry-up leading to its rapid failure. This process occurred rapidly in most regions, and most failed within a few years of opening, a victim of their own success. Although ultimately failures for their owners and investors, they were often successful in allowing for the development and prosperity of their respective towns or districts.

Format

To place the failure of the small smelters of Colorado the dissertation is divided into six chapters. Chapter 2, Smelting Technology, described the types of ores common to Colorado and the major types of smelting used in the state. The chapter serves to provide the reader with a technical background to better understand the technical choices made by smelting establishments in the state. Chapter 3, Early Smelting in Colorado, is divided into two main sections. The first provides a summary of the mining and smelting history of Colorado from 1858 to 1900, including a review of the development of Colorado’s railroad network that greatly influenced developments in the smelting industry. The second portion of the chapter is a county by county discussion of the distribution of smelters in

Colorado’s high country with a summary of the available information for each. This section is the first description of these smelters contained within a single volume and provides a starting place for researchers to identify potential smelters in their region of research. Chapter 4, Later Smelting in Colorado, discusses the large smelters that developed at Denver, Leadville, and Pueblo. These smelters came to dominate the Colorado smelting industry from the early 1880s on and is included to provide the reader with information on the competition that led to the failing of the smaller smelters. Chapter 5, Success and Failure, discusses patterns of failure in select western industries before focusing on patterns of failure in the small-scale smelting industry of Colorado. The dissertation concludes with Chapter 6, which discusses heritage issues that includes determining the significance of individual smelting sites under the NRHP criteria, and issues pertaining to the importance of, and challenges to, preserving small smelter sites. Determining site eligibility to the NRHP is the basis of identifying sites with important heritage or research values. Using the example of the Hall Valley Smelter in Park County I examine the potential research values of small smelter sites and the needs for their protection and preservation.

2 Smelting Technology

This chapter describes in detail the smelting methods used in Colorado during the nineteenth century to process ores containing gold and silver. Understanding the types of smelting furnaces available to the metallurgists of the period provides the context for interpreting historical smelting sites. The section goes into detail on construction, operation, and products of these furnaces. This provides future researchers the ability to assess the smelting method used at sites with little or no surviving historical information. The section begins by defining common smelting terms and summarizes the processes used during the preliminary processing of ore for smelting. Following sections discuss the construction, use, and products of the different types of smelting furnaces. The smelting of lead-silver and copper-gold ores required different approaches. The smelting section is broken down by the methods used in the processing of lead-silver ores, which consists of hearth furnaces, reverberatory furnaces, and blast furnaces; and copper-gold ores, which consists of reverberatory furnaces and blast furnaces. The chapter concludes with a brief discussion of chemical (non-smelting) methods of processing ores.

Once Colorado mining moved beyond simple placer mining it became necessary to adopt methods of separating the precious metals from the host rock. An existing body of technology had developed in Europe since the Middle Ages provided a starting point to the development of reduction technologies adapted to the local conditions of Colorado. Some gold ores were contained in a simple matrix of quartz from which the gold could be liberated through a simple process of crushing and amalgamation with mercury. More sophisticated chemical techniques were developed later. Until the introduction of the cyanide process in the 1890s, however, most could not successfully compete with smelting for the efficient liberation of precious metals from the complex refractory ores common in the state.

Although the most obvious phase of metal extraction was the removal of ores from mines a variety of processes were then required to wrest the target metals from the non-metallic constituents of the rock. Depending on the characteristics of the ore the methods could be relatively simple or highly complex. *Ore* is:

> a natural mineral compound of the elements of which one at least is a metal. Applied more loosely to all metalliferous rock, though it contains the metal in a free state, and occasionally to the compounds of nonmetallic substances, such as sulfur ore. (Thrush 1968:477)

Or from the perspective of mining engineers:

> A metalliferous mineral, or an aggregate of metalliferous minerals, more or less mixed with gangue, which, from the standpoint of the miner, can be won at a profit or, from the standpoint of a metallurgist, can be treated at a profit (Thrush 1968:477).

Gangue is “the nonmetalliferous or nonvaluable metalliferous minerals in the ore” (Thrush 1968:773) that is discarded or removed during the mining and treatment process. In Colorado ores vary from simple mixes of native gold in a gangue of quartz to highly complex mixtures of sulfide minerals containing various elemental metals. Geologic conditions in the Colorado Rocky Mountains are highly variable and the conditions under which the various ores were deposited vary a great deal. Some generalizations however can be made. Most ore deposits formed along the contacts, faulting, and fracturing associated with intrusive bodies within Precambrian basement rocks of the state. Gold is usually found in a free form mixed with various gangue minerals such as quartz, or in a closely mixed form with pyrite (FeS_2) or chalcopyrite ($CuFeS_2$). Gold tellurides are less common but occur in many districts. These include minerals like sylvanite ($(Au,Ag)Te_2$), hessite (Ag_2Te), altaite (PbTe), calaverite ($AuTe_2$), and coloradoite (HgTe). In contrast silver is generally found chemically combined with other elements in complex forms that require significant treatment to be removed. Common minerals that sometimes contain silver that are found in Colorado include sphalerite (ZnS), galena (PbS), chalcopyrite ($CuFeS_2$), argentite (Ag_2S), pyrargyrite (Ag_3SbS_2), and pyrrhotite ($Fe_{1-x}S$) (Lovering and Goddard 1950).

One accepted definition used around the turn of the century described *smelting* as the means used:

> To reduce metals from their ores by a process that includes fusion. In its restricted sense *smelting* is confined to a single operation, as the fusion of an iron ore in a shaft furnace, the reduction of a copper matte in a reverberatory furnace, and the extraction of a metal from sweepings in a crucible; but in its general sense it includes the entire treatment of the material from the crude ore to the finished metal, and embraces: (a) the *calcination* or roasting, by means of which the sulfur and other volatile constituents are expelled; (b) The *reduction* of the resulting furnace products, or the smelting proper, and (c) the *refining* of the product from the second operation. (Hay 1920:627).

In this document I will be examining steps a and b as described in the definition. Precious metal smelting produced two main desired products, *base bullion* and *matte*, that were complex mixtures of metals that required further refining to remove the pure gold and silver. According to Rossiter Raymond (1881) base bullion is “pig lead containing silver and some gold, which are separated by refining” whereas matte is “a mass consisting chiefly of metallic sulfides got in the fusion of ores.” The refining of the bullion and matte from the smelting furnaces in Colorado during the nineteenth century was generally left to facilities outside the state. In addition to these targeted materials the smelters produced vast quantities of waste; smoke, dust and slag far exceeded the volume of metals produced in a works. The amount of impurities contained within the bullion and matte varied depending on the components of the ores, the arrangement of the smelter and the skills of the smelter men but smelter products were generally preferred by refiners as they usually contained less contaminants than products produced from other reduction methods.

The Denver Mint was a major purchaser of gold and silver from Colorado mines from its founding in 1863 and conducted studies on the constituents of bullions and mattes derived from various sources. The purest material purchased by the mint was gold derived from placer operations. In most cases these materials were free from significant impurities except sand that could be easily removed during the refining process. In later years some placer mining was conducted on sands deposited into water courses by defunct concentration mills that sometimes-contained lead and fragments of raw sulfide minerals as contaminants. Gold produced by amalgamation works (see Table 1 for definitions of amalgamation, chlorination, and cyanide processing) was usually less pure. The amalgamation process involved finely grinding ore and exposing it by various means to mercury. The resulting amalgam was then heated in a *retort* (still) to drive off the mercury leaving the gold. The process generally yielded a pure gold if the source ores were free milling, but incomplete retorting resulted in bullion that was contaminated by mercury residue. Bullion derived from mills processing sulfide minerals often contained small amounts of arsenic, copper, lead and small fragments of raw sulfide minerals. Retorts of either type, if badly prepared, also had the potential to contain large amounts of mercury and/or water. Other types of reduction generally cast their product as gold bars. Bars from chlorination works generally contained contaminates of arsenic, copper, lead and sulfide minerals. Those from cyanide works had the same contaminates as those seen in chlorination works but sometimes also contained zinc derived from the precipitation batteries. The products from the chlorination and cyanide works were generally of poor quality and were difficult for the mint to refine. Only the bars produced from the products of smelting works were generally free of significant amounts of contaminants (Furman 1895:25-31).

Table 1. Types of chemical reduction processes mentioned in text. Definitions of amalgamation and chlorination from Raymond 1881:4, 20. Definition of cyanidation from Meyerriecks 2003:156.

Process	**Definition**
Amalgamation	The process in which gold and silver are extracted from pulverized ores by producing an amalgam (an alloy of gold/silver and mercury), from which the mercury is afterwards expelled.
Chlorination	The process… in which auriferous ores are first roasted to oxidize the base metals, then saturated with chlorine gas, and finally treated with water which removes the soluble terchloride of gold, to be subsequently precipitated and melted into bars.
Cyanidation	A process in which ores in solutions containing either sodium or potassium cyanide, then run through filter boxes filled with zinc which precipitates the gold, cleaned with dilute sulfuric acid to remove remaining zinc.

Due to the ability of well-run smelting works to regulate the constituent metals in their bullion and matte output they dominated the reduction industry of Colorado until the development of *cyanide reduction* in the 1890s. The cyanide process allowed for a more economical recovery of gold and silver contents on ores than smelting and for many ores could be conducted at a fraction of the cost of conventional smelting. Direct comparison of the costs of operations is often difficult as there is little information in the literature directly addressing the problem. Malvern Iles (1906) provided one of the few lists of costs to make the process more transparent. Iles provided figures from the Globe Smelter at Denver for the period of the 1880s to 1890s. Roasting prices had cost $3.98 per ton in 1887 when hand-rabbled reverberatory roasting furnaces were introduced. The price was reduced to $2.62 per ton when a mechanical Brown-O’Hara roaster was installed, but the cost did not include the excessively high maintenance costs on the furnace which Iles considered to eliminate much of the reduced roasting coast. He attributed most of the price to the decrease in labor costs after the depression of 1893 combined with the replacement of lump coal for fuel with cheaper slack coal. The actual smelting costs were based on the prices of transportation of ores, fuel costs, fluxes, and labor. The price per ton of ore smelting dropped from $4.64 in 1887 to $2.26 in 1898, largely due to the same reduction in labor and fuel costs noted under the roasting program (Iles 1906:96-98).

The Colorado smelting industry declined after this period, with surviving works turning to the processing of base metals that are generally not suited to processing with cyanide (although gold and silver were still a valuable byproduct of the processing of many base metal ores). The following sections describe the smelting process starting with the initial steps required to prepare the ore for smelting. Later sections will discuss the individual furnace types.

2.1 Initial Ore Processing

Prior to smelting, some initial steps were necessary to prepare the raw ores. The ores produced by mines were generally broken into two classes. The richest ores that contained significant amounts of gold and/or silver were termed *first-class*, or smelting, ores. These ores were valuable enough to be sold to a smelter with little prior processing (Thrush 1968). *Second-class* ores contained lesser quantities of the desired metals and required further processing before a marketable product was produced. Processing second-class ores was accomplished by sorting or processing the ore either during mining or in concentration works located at or near the mines. To the extent possible, rocks with little or no metal content were removed to increase the content of gold or silver per ton. This reduced the burden on the smelter and decreased transportation costs allowing for the processing of lower grade ores.

Smelting plants received ore either directly from the mines, or through purchase from independent sampling works who purchased ores from many sources. Many small smelters were built by mining companies as dedicated plants to process the ores produced by their own mines which limited their ability to create efficient smelting charges. Larger plants acquired their materials from numerous sources allowing the mixing of ores with different constituent components for more efficient development of furnace charges. This was especially the case in the large plants of the Front Range that were able to cheaply acquire ores from districts throughout the state and beyond due to their good railroad connections. After purchase, the ores were delivered to the plants by wagon or rail and loaded into ore bins that were usually built at the highest point of the works. Only rarely were ores suitable for immediate smelting (the carbonate ores of Leadville being a notable example). Most ores required some form of preliminary processing prior to use.

The form of processing used depended on the method of smelting that would be used and the machinery available to the smelter. First, the raw ore needed to be broken into manageable pieces, the size depending on the characteristics of the ore and the requirement of the furnace type. Breaking generally employed mechanical equipment but breaking by hand was used under special conditions. After breaking most ores required roasting prior to use to drive off as much sulfur and other undesirable elements as possible to make the ore as amenable to the smelting process. Detailed information on both breaking and roasting is included in Appendix B for those interested in the details of the process.

The breaking and roasting process for preparing ores required a large investment of time and money prior to starting the actual smelting process. These steps were required by all smelting operations and should be visible at all smelting sites. The actual smelting processes are discussed in the following two sections and are further broken into discussions on lead-silver and copper-gold smelting furnace types.

2.2 Smelting Methods

The small smelting companies in the Colorado mountains used several different forms of smelting technology depending on their technological knowledge, capital, and the types of ores they intended to process. Although gold originally attracted miners to the state, Colorado was mainly a silver producing region. In

Colorado silver is most commonly associated with lead ores and the development and adaptation of lead smelting technologies became the state's predominant focus of smelting development. Colorado's gold deposits are generally associated with copper minerals that required different smelting techniques. The following section on lead-silver smelting techniques starts with the early hearth furnaces used in the mid-1860s, reverberatory furnaces used in lead-silver smelting in the late 1860s and ends by examining blast furnaces which came to dominate the smelting industry by the early 1870s. Later sections detail the methods used to process copper rich ores.

2.2.1 Lead Smelting

Prior to discussing the furnaces used in the Colorado lead-silver smelting industry it is necessary to briefly discuss the main types of silver deposits found in Colorado. Colorado lead ores always contain silver to some extent, but often in quantities too low allow for processing for silver content alone. The silver produced from such ores was usually a byproduct of base metal production although they were highly sought after as smelting was simpler if the furnace charges contained large amounts of lead. Depending on the type of minerals containing the silver the ores were classified as either carbonates or sulfides. Sulfide ores included galena (PbS), polybasite [$(Ag,Cu)_6(Sb,As)_2S_7$][Ag_9CuS_4], stephanite (Ag_5SbS_4), freibergite ($(Ag,Cu,Fe)_{12}(Sb,As)_4S_{13}$), tetrahydrite ($((Cu, Fe)_{12}Sb_4S_{13}$), and proustite ($Ag_3AsS_3$), although most silver values were contained in the galena. As many of the non-*argentiferous* (silver containing) sulfide minerals were removed as possible along with the sterile gangue material. Other sulfide minerals caused additional difficulty in the smelting process.

Carbonate ores were the most desirable ores as they were the easiest to smelt. The most common carbonate silver ores found in Colorado are anglesite ($PbSO_4$) and cerussite ($PbCO_3$). These minerals are usually found as sand sized or finer particles that are often cemented together by other minerals. Both are the result of the natural decomposition of galena and are found in secondary deposits (Hofman 1894:25-29). The most famous carbonate ore deposits in Colorado were those at Leadville.

Except for the experimental pyritic furnaces just coming into use in the last years of the nineteenth century, all smelting furnaces had difficulty processing sulfide ores. Only blast furnaces could effectively process ores with high sulfur contents. Hearth and reverberatory furnaces required thorough (and expensive) roasting of high-sulfur ores to efficiently reduce the ores, adding significantly to overall smelting costs. The hearth furnaces described in the following section were particularly sensitive to sulfur and other impurities in ores.

Lead Hearth Furnace

The earliest furnaces used to process lead-silver ores in Colorado were lead hearth furnaces. These furnaces were most commonly associated with the pioneer smelters in Clear Creek and Summit counties. The hearth furnaces had the advantage of being more fuel efficient than reverberatory furnaces and were better adapted to the small quantities of ore that were produced at irregular intervals that were available in early districts. The intermittent ore supply required frequent stoppages of work and hearths required less time and fuel to reach smelting temperature. The main disadvantage of the ore hearths compared to reverberatory furnaces was that they had lower production capacities and the use of air blast caused a greater volatilization of lead and silver, leading to lower recovery rates (Hixon 1906:67; Hofman 1893:110-111). By the late 1860s ore hearths were only rarely used outside the United States, with a few plants in northern England and Scotland still retaining the type in use (Percy 1870:278).

In the hearth the ore charge mixed with charcoal fuel floated on a pool of molten lead in the hearth base. Proper ore sizes to operate a hearth were the size of a pea or peanut. Coarser ores took longer to smelt properly while finer ores required some form of caking to prevent unacceptable losses to volatilization. The nature of the hearth furnace had the added advantage of essentially roasting the ore during the smelting process, allowing the elimination of the ore roasting process as a separate step and thus its equipment and fuel as well. The resulting lead oxide and lead sulfide reacted with the unoxidized sulfides in the ore to create metallic lead. The lead trickled through the liquid charge to collect in the hearth bottom. As the lead exceeded the capacity of the hearth it escaped as a continuous stream that was collected in a container outside the hearth (Eissler 1891:30-32).

Five separate products were produced by ore hearths during the smelting process. Lead was the main product of the hearth and was always contaminated by particles of unreduced ore that were removed by poling. If the ores contained undesirable elements such as antimony, arsenic, and/or copper these alloyed with the lead and could only be removed by refining. *Gray Slag* was a type of matte consisting of a mixture of lead, lead sulfide, lead sulphate, lead oxide, silica, gangue minerals, cinders and lime. If the works had a blast furnace available this material was crushed and run through for additional smelting. *Flue dust* was a mixture of fine ore particles, lead oxide, lead carbonates, lead sulphate, and small fragments of the fuel. The quantity of dust produced depended on the heat of the hearth (higher temperatures tended to create more fine materials) and the skill of the furnaceman. If the flue dust was recovered it was returned to the furnace with later charges. *Heath bottom* was hearth material that had absorbed part of the lead. If the works had a blast furnace available this could be smelted to recover more of the lead and silver. Finally, *browse* was a mixture of fuel, ore and slag left over at a smelting run that was cycled back through the furnace for further smelting.

A hearth furnace was highly sensitive to contaminates in the ore, and required that ores be low in antimony, sulfur and other similar minerals. This made the furnace less adapted to most Colorado ores than either reverberatory or blast furnaces and is largely the reason they rapidly dropped out of use. Although there were three different types of hearth furnaces, only the Scotch and American water-backed hearths appear to have been used in Colorado (Hofman 1894:80-81, 111-112). Although the two types of hearth furnaces are similar but have enough differences in design that they are discussed separately below.

The Scotch Hearth

A typical Scotch hearth consisted of cast iron box 2 feet long, 2.5 feet wide, and 1 foot deep which held about two tons of liquid lead. The well had an integral cast iron working plate at the front with a notch that channeled excess lead into an external collection kettle. The hearth box rested on a large cast iron block, while a second cast iron block containing a single tuyere was placed at the rear of the furnace. The tuyere was placed approximately 2 inches above the top of the lead well. A brick chimney was located behind the hearth. Fuel was fed into the furnace directly in front of the tuyere, and the ore charges were fed in at the front of the hearth. Work in a Scotch Hearth was by nature discontinuous as the furnace overheated after 12 to 15 hours of work and required about five hours to cool down before the process could be restarted (Hofman 1894:112-113; Middleton 1870:35).

The American Water-Backed Hearth

The American Water-Backed Ore Hearth (Figure 2-1) was functionally identical to the Scotch Hearth but were usually larger with a larger lead well capacity. The increased size of the hearth required the use of three tuyeres instead of one to provide sufficient blast. The main improvement of this furnace over the Scotch hearth was that the cast iron block walls were water cooled allowing the furnace to operate continuously if sufficient ores were available (Hofman 1894:113-114). Generally, these hearths had a production capacity of 7,500 pounds of lead per day employing a work force of four men. The cost of smelting was around $1.75 per ton (Percy 1870:289-291).

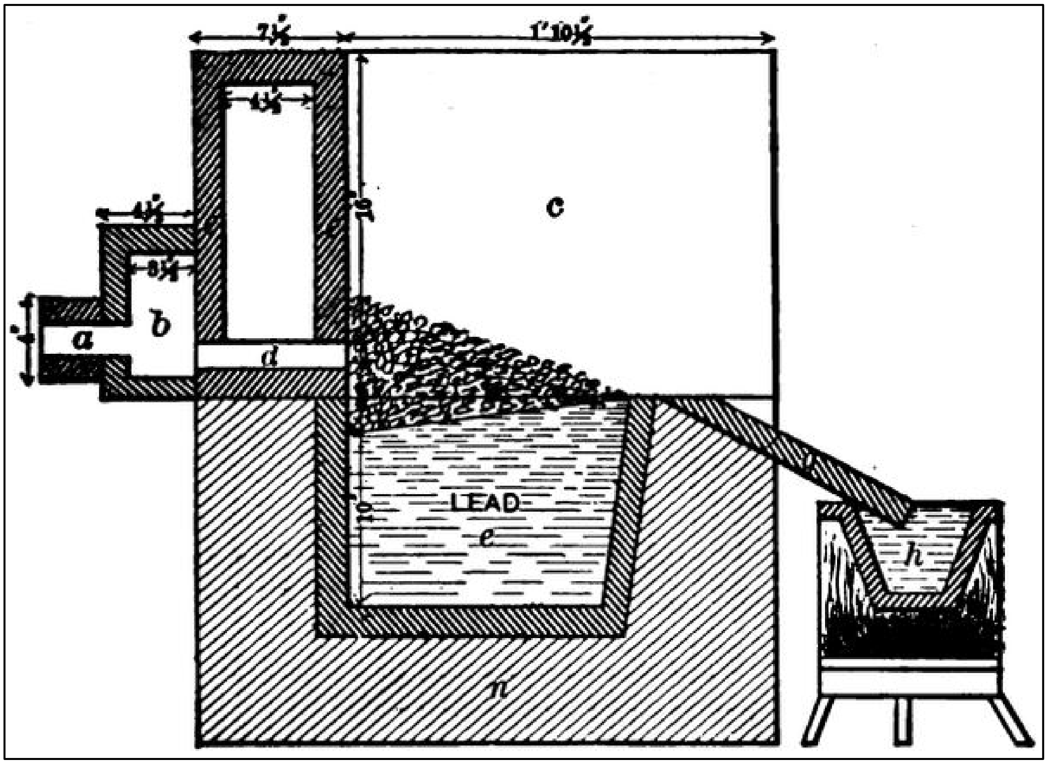


Figure 2-1. American Water Backed Hearth Furnace. a. blast nozzle, b. wind-box, d. tuyeres, e. lead well, g. work stone, h. kettle hearth box, n. brickwork. Illustration from Hofman 1893:113.

Ore Hearth Operations

The method of operating ore hearths was fundamentally the same for all types. To begin the smelting process a fire was started in the furnace and fuel added until the hearth was filled with ignited fuel. If available, residue from a previous firing was spread over the back of the furnace and an initial charge of 10 to 20 pounds of ore was added. When lead began to collect in the well additional ore was added and the contents lifted with a bar to ensure that sufficient openings in the charge were available to allow oxygen and lead to work through. Any portions of the charge that clumped or become molten were scraped onto the cast iron work stone at the front of the furnace and the slag separated from the working residue which was then returned to the furnace. The process continued until the well was full of lead. Once the lead well was full the furnace was at normal operating conditions and the fuel and partly reduced ore floated on the surface of the molten lead. At this stage typical charges consisted of 12 to 30 pounds of lead mixed with 1.5 to 2 percent lime. A small amount of additional fuel was spread on top of the charge as required. This was then allowed to sit for five minutes before a furnaceman loosened and stirred the charge with an iron rod. A second furnaceman drew the semi-molten mass beneath the charge onto the work stone to separate out the slag. As the process continued lead overflowing the hearth box ran through a groove in the work stone to collect in the kettle where it was occasionally poled and removed by ladle or siphon into molds. Lead and silver losses were mainly in the flue dust, which was not collected in the

1860s and early 1870s. Some of the silver and lead was also lost in the slag. In the early furnaces the gray slag could not be reprocessed, and any silver in the slag was lost. Later plants contained small blast furnaces for reprocessing the material (Hofman 1894:114-118).

Due to the inability of hearth furnaces to efficiently process ores containing significant amounts of sulfur and other contaminates they were quickly abandoned, and other types were adopted. Some smelters turned to reverberatory furnaces in an attempt to find a solution to their smelting problems.

The Lead-Silver Reverberatory Furnace

The reverberatory furnace, although most commonly associated with copper-gold smelting in Colorado, was used on a small scale in the late 1860s and early 1870s to process lead-silver ores. These furnaces had a number of advantages over hearth furnaces. Reverberatories were inexpensive to construct, required few fluxes, could use raw coal or wood rather than more expensive coke or charcoal, and did not require the use of air blast which saved costs in both machinery and minimized lead and silver losses through volatilization (Eissler 1891:15-16; Hofman 1894:80). As reverberatory furnaces were most commonly used for copper-gold smelting in Colorado, a description of their construction is included in that section as there were few differences in their construction (see page 75).

However, reverberatory furnaces also had significant disadvantages that led to their rapid replacement by blast furnaces in lead-silver smelting. Reverberatory furnaces were highly dependent on the proper composition of the ores. Ores needed to be galena rich, containing no less than 58 percent lead, to be usable in furnaces of this type. The ore also could not contain more than five percent silica and non-siliceous minerals such as barite, blende, chalcopyrite, or pyrite could only be present in very small quantities. And although the furnaces could use raw fuel rather than coke or charcoal, they did require large amounts of fuel to operate which rapidly became more expensive as their local areas were deforested. Finally, the furnaces required large amounts of skilled labor which was limited, and therefore highly expensive in frontier Colorado (Hofman 1894:80).

The process of operating a reverberatory furnace for lead-silver smelting involved two steps. The first step was to oxidize the ore. Ore was crushed to approximately ¼-inch size and laid in a thin layer on the hearth and heated to a low red heat until part of the lead sulfide in the ore was reduced. Furnace temperatures were kept low during this step as galena ores tended to cake at high temperatures. The ore was raked frequently during this process to encourage uniform oxidation of the ore and to prevent caking. The second part of the process was to reduce the sulfides in the ore. Lead began to be produced during this stage and flowed down the inclined surface of the hearth to collect in a basin. The sulfurous acid produced in the reaction passed off with the flue gasses and the residual non-molten materials were retained in the hearth. Temperatures were carefully manipulated during the process to prevent the entire charge from melting as the desired chemical reactions were only possible if the charge remained in a solid state.

The first smelting would not extract all the lead from the charge and the residue in the hearth remained rich in lead sulfide. This required several additional smeltings to extract most of the lead. The tendency of the ore to melt as the lead was removed required the addition of slacked lime which served to make the charge less fusible and also served as a flux contributed to the chemical process. Near the end of the process there was insufficient remaining lead sulfide to react with the lead sulphate and lead oxide of the charge, and charcoal or coal was added to the mixture to complete the reactions. (Hofman 1894:79-80). The reverberatory produced the same products as a hearth furnace (lead, gray slag (a form of matte), flue dust and hearth bottom) with the exception of browse as the fuel did not mix with the ore in a reverberatory furnace.

Reverberatory furnaces were highly sensitive to ore composition. Silica had a major effect due to its propensity to combine with lead oxide. More than 5 percent silica in an ore prevented it from being reduced in a reverberatory furnace, but a content as low as 0.5 percent could retard the process. Limestone was sometimes added to the charge as it helped prevent clumping. The largest acceptable concentration of limestone flux in a charge was around 12 percent.

Pyrite was helpful in the initial roasting stage by encouraging the formation of lead sulphate, and small amounts were helpful in the second stage of the process by making the charge less fusible. However, over 10 to 12 percent retarded the smelting process and 35 to 40 percent halted the process entirely. Chalcopyrite operated in the same way as pyrite, but with the additional problem of copper entering the lead reducing its purity. Blende (zinc sulfide, ZnS) in the charge could help the roasting process if the concentration was 4 to 5 percent, but at 10 to 12 percent it greatly increased the time needed for roasting, at 20 to 24 percent very little lead was produced from the ore, and 35 to 40 percent halted the process entirely. Even small (2 to 3 percent) quantities of antimony were harmful to the process as it greatly increased the tendency of the charge to cake, and antimony sulfide and oxides are volatile which led to high losses in lead and silver. Antimony which didn't volatilize combined with the lead as a hardening agent, making antimony one of the worst elements for the reverberatory process. Arsenic was also extremely harmful as it volatilizes like antimony and it enters the lead, lowering its quality. (Hofman 1894:81-83).

The general design of the reverberatory furnaces used in Colorado had an inclined hearth with one charging door and one discharging door, underneath which was a kettle to catch the flowing lead (see Figure 2-13). The bottom of the furnace consisted of a cast iron plate upon which a 6-inch layer of gray slag was melted as a covering. A charge of 1,400-1,600 lb. of galena was spread over the base of the hearth and roasted from 60–90 minutes at a low temperature during which it was constantly raked and moved from the hottest to coolest parts of the furnace to ensure even roasting. When the roast was finished the heat was increased and the lead collected. When the lead stopped flowing the residue was removed and discarded without attempting to recover any residual lead. One furnaceman with a helper worked a charge in 12 hours. Fuel consumption during the process was 1.5 cords of wood. (Hofman 1894:89-90).

Reverberatory furnaces had significant disadvantages that led to their abandonment by most lead-silver smelting operations at an early date. They had difficulty processing ores with high sulfur contents, and they required large amounts of skilled labor that was highly expensive on the frontier. As these limitations became obvious most smelting operations switched to the use of blast furnaces for smelting.

The Lead-Silver Blast Furnace

The blast furnace became the dominate type of furnace used in Colorado for the working of lead-silver ores in the early 1870s and dominated the Colorado smelting industry as a whole into the twentieth century. Blast furnaces required less maintenance than hearth and reverberatory furnaces, required less expensive labor, and had lower fuel consumption leading to its adoption in most mining districts in the western United States (Eissler 1891:34). Out of 19 major active smelters in Colorado in 1886, all but one (the Argo Smelter in Denver which was a reverberatory smelter) were water jacketed blast furnaces (Anon

1886:9053). Due to their ubiquitous nature local foundries and mining equipment manufacturers produced parts of blast furnaces for Colorado smelters. The Denver Engineering Works Company, established in 1876, produced smelting furnaces for the Globe Smelting Company's Denver plant and the Arkansas Valley Smelter in Leadville. The Stearns-Roger Manufacturing Company based in Pueblo built furnaces for the Holden Smelter (Globe Smelter) in Denver, and plants in Pueblo, Durango and Leadville (Mitick 1947:14, 61). Many of the smaller smelters were able to purchase complete smelting plant outfits from the Allis-Chalmers Company of Milwaukee. Blast furnaces could work all types of silver ores and were the only type capable of working ores containing over 4 percent silica. Carbonate ores could be fed directly into a blast furnace, but sulfide ores required preliminary roasting. Colorado companies that used blast furnaces often roasted their ores in reverberatory or mechanical furnaces to avoid the lead and silver losses that occurred due to leaching in heap-and-stall roasting (Eissler 1891:60; Iles 1902:141-145).

Blast Furnace Construction

Several different designs of blast furnaces were used for the treatment of lead-silver ores in Colorado during the nineteenth century. These varied in cross section and design, and all types were subject to a continual evolution in morphology as metallurgical knowledge advanced. Interior cross sections of the furnaces varied from circular to square, with circular and oblong becoming the most common patterns later in the period. The vertical cross-section of the furnaces was often prismatic, but some designs tapered toward the bases, and boshes above the tuyeres could be present but were often omitted. Early furnaces were largely brick, but furnaces using cast and wrought iron water jackets were soon developed. The lead produced in the furnace was removed from the crucible by tapping, but variations of the Arent's automatic tap became increasingly common. A large amount of material went into the construction of a blast furnace. Typical furnaces seen in the Rocky Mountains varied from 42 inches by 120 inches, to 48 inches by 160 inches at the tuyeres. The distance from the tuyeres to the top of the charge was 15 to 21 feet with a total daily capacity of 80 to 200 tons (Dwight 1906a:73). As an example, a large furnace built for the Globe Smelting Works at Denver (Figure 2-2) required 17,000 common bricks for the exterior portions of the furnace, 9,500 fire bricks for the hearth and lining, 27,300 pounds of cast iron castings, 3,200 pounds of wrought iron and 4,250 pounds of steel I-beams for use as reinforcement. The design included a separate, telescoping stack that required an additional 1,700 pounds of wrought iron. The total cost of the furnace as constructed at Denver was $1,200. This total did not include the price of additional equipment to provide the air blast for the furnace, or to supply the water required by the water jackets (EMJ 1893:344).

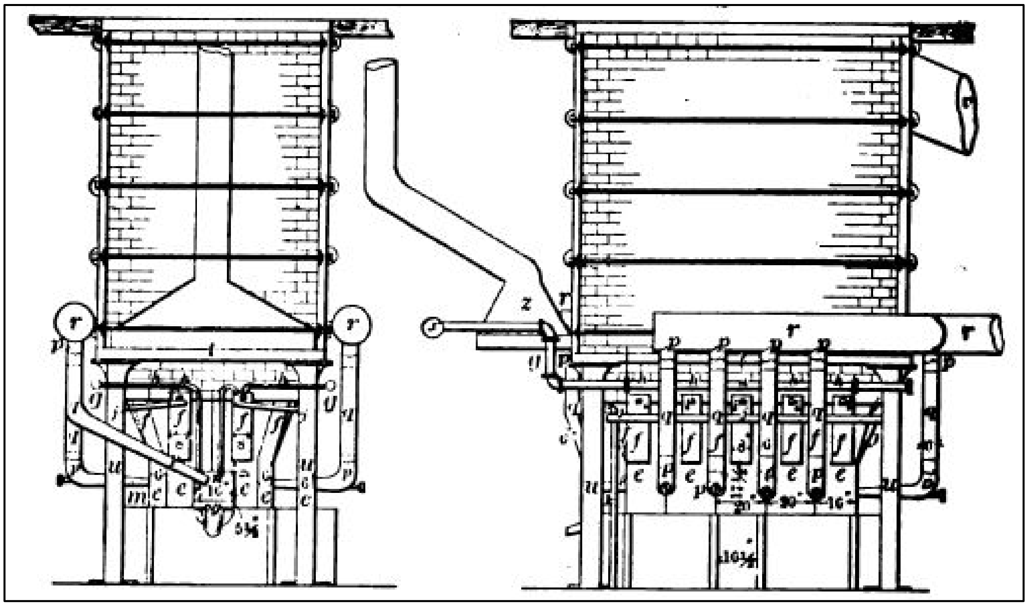


Figure 2-2. Blast furnace at Globe Smelter. Illustration from EMJ 1893:344.

The Foundation

Due to the weight of a blast furnace a strong foundation was a necessity. In mountain areas some plants were fortunate and able to dig to bedrock that provided the best foundation possible. If there was 10 feet or less sediment above the bedrock, it was common to dig down to the bedrock contact. In cases where this was not possible it was necessary to dig the foundation at least five feet deep to get below the frost line. In loose soil it was common to build a platform of 3 to 4-inch-thick planks as a base for the masonry foundation. The most common type of foundation was built of undressed rock compacted as tightly as possible into the foundation trench. The largest pieces formed the exterior and small spalls of rock were fitted as tightly as possible around the larger rocks in the interior. The entire foundation was then be covered with a grout consisting of one-part cement to four parts of lime. To ensure the top of the foundation was level, it was common to place a final layer of brickwork on the top (Eissler 1890:69-72; Hofman 1893:180).

If at least one furnace at the plant was already in operation the foundation was often be made by tapping liquid slag straight into the foundation pit, or where this wasn’t possible to use broken pieces of slag in place of rock, which was then cemented with liquid slag. In these cases, the top was be leveled by creating a sand or iron rail framing which was filled with liquid slag to level. If further leveling was required, this could be completed by shaping the top with a hammer and chisel. Once either type of foundation was completed, a thin layer of mortar was spread on the top and a wrought iron bed plate installed (Hofman 1893:180).

The Furnace Shaft

The shaft of the furnace was generally built on four hollow cast iron pillars set on the iron bed plate. The distance between the floor and the tuyeres varied but increased through time from 10 to 12 feet in the 1870s to 14 to 18 feet by the 1890s. This increase in the height of the shaft was necessary to compensate for the higher blast pressure required to smelt the increasingly refractory ores mined in the later part of the century (Hofman 1893:180).

Early blast furnaces often had square or polygonal cross sections, but these were abandoned and replaced by circular and oval patterns by the late 1880s (Figure 2-3; Figure 2-4; Figure 2-6). Experience had shown that the interior of square and polygonal furnaces naturally became roughly circular as partially smelted materials collected at any sharp angle (Hofman 1893:180). It was found that circular furnaces ran better than other types as the heat and blast were evenly distributed through the ore column. However, the circular type enforced a limit on the diameter of a furnace to approximately 42 inches as the blast could not penetrate deeper into an ore charge than this; 36 inches was the usual maximum size adopted. Efforts to increase the capacity of furnaces led to a gradual shift to oval designs as this allowed the length along the major axis of the oval of the furnaces to be increased greatly while ensuring that the air blast could still efficiently penetrate the charge. From 1880 to 1890 the diameter of oblong furnaces increased from a maximum of 60 inches to 120 inches. However, the shift in size was not without its drawbacks. The increased blast resulting from the greater number of tuyeres along the furnace periphery could cause the smelting zone to expand beyond the top of the water jacket causing erosion of the fire brick lining. The brick fragments then became incorporated into the charge creating unexpectedly silica-rich slags and mattes, injuring their quality. The oblong shape also tended to reduce the effect of the bosh (an area above the hearth where the furnace reaches its widest extent), decreasing the effective working height of the furnace (Hofman 1893:181).

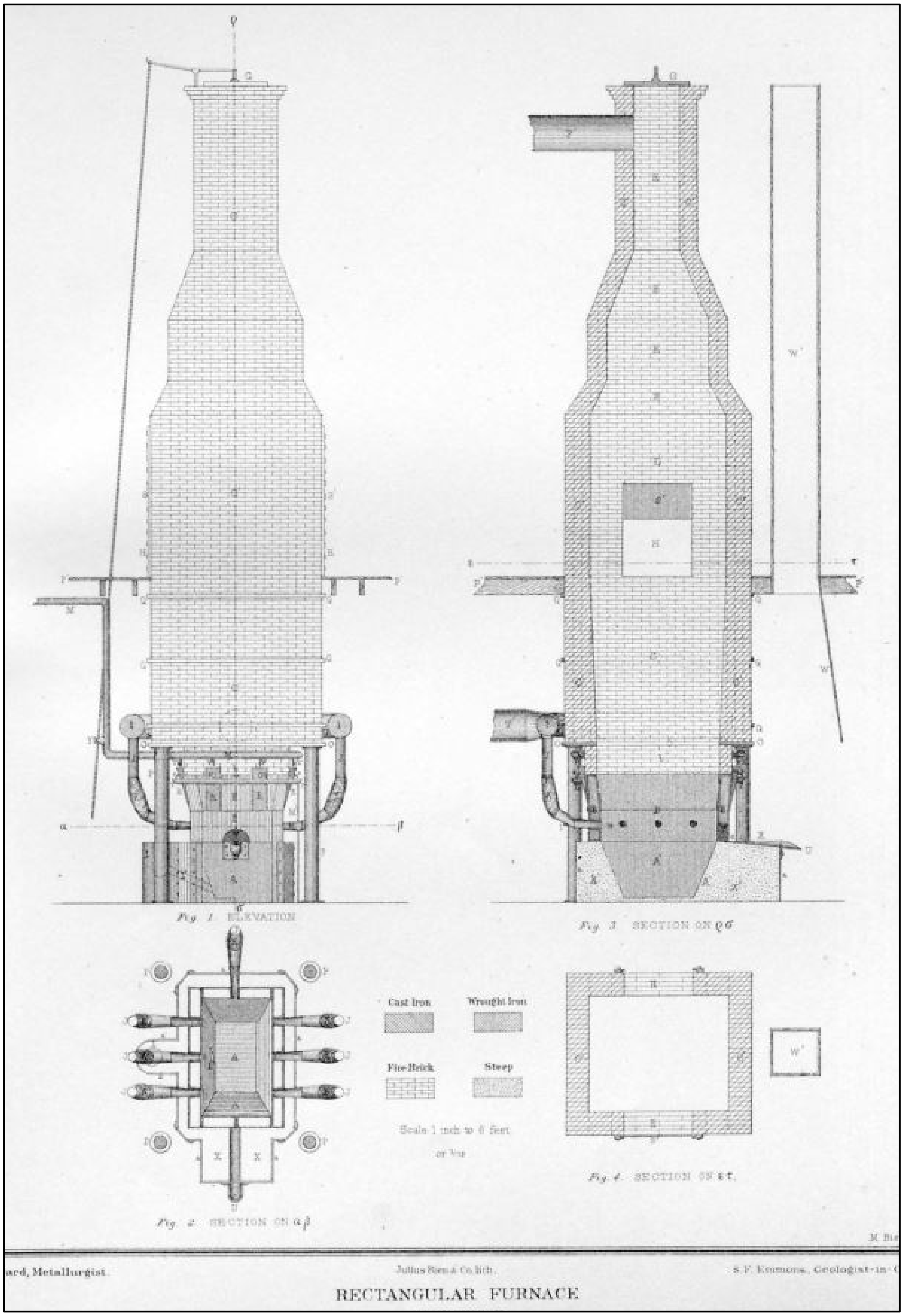


Figure 2-3. Rectangular blast furnace used at Leadville in 1879. Illustration from Emmons 1886 Plate XXIII

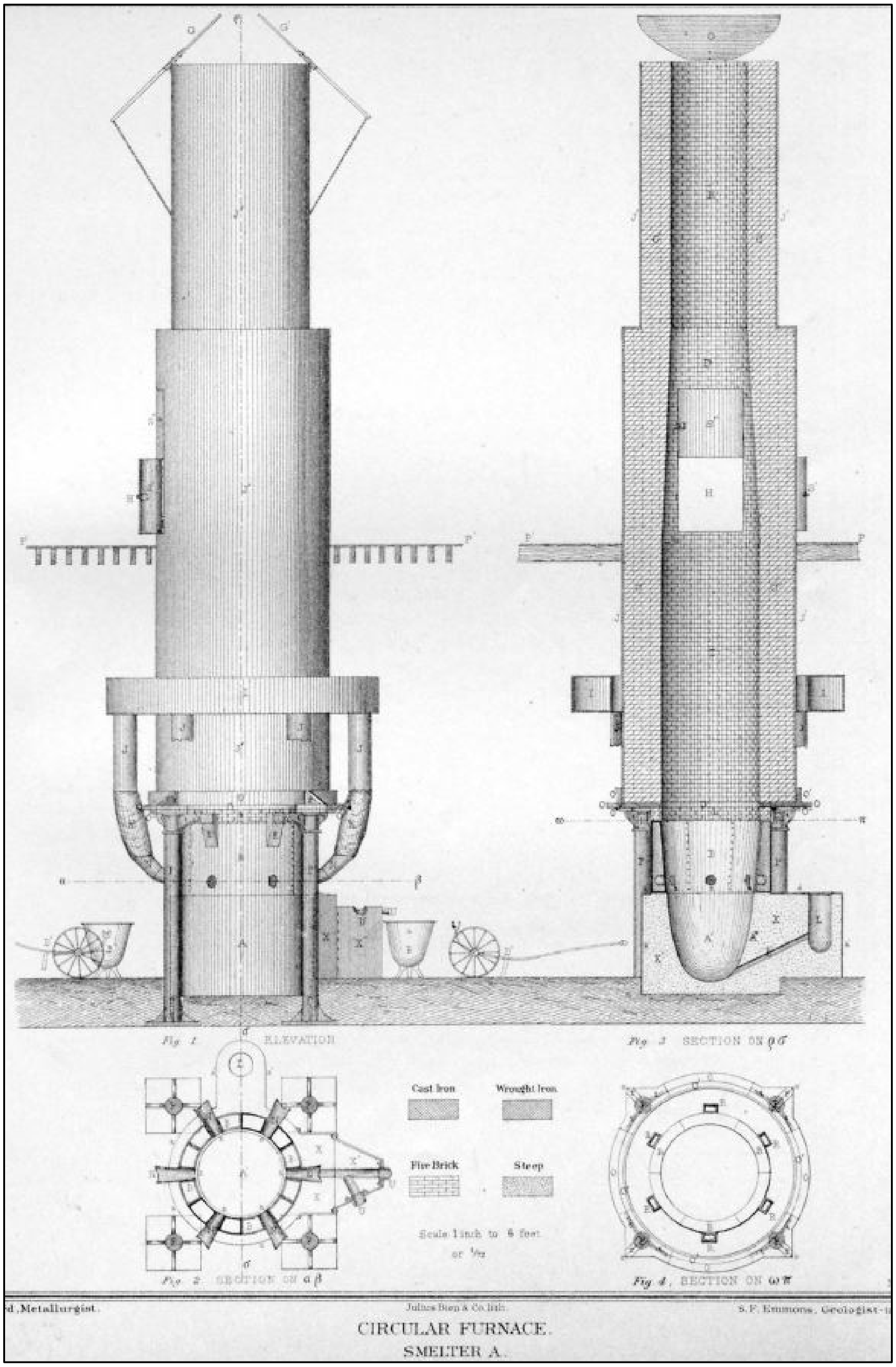


Figure 2-4. Circular blast furnaces at Leadville in 1879. Illustration from Emmons 1886 Plate XXIII.

The shaft of the furnace was built of common brick with a lining of fire brick up to the feed floor. The shaft rested on iron plates fastened to the pillars. In early furnaces the differential heating of the brick and cast iron had the tendency to stress the shafts leading to potential failure. This was avoided in later designs by building brick arches to support the shaft with the weight transferred directly to the columns. The lower portion of the brick shaft was often enclosed with cast iron plates bolted together and then screwed to the cast iron pillars to counteract any lateral stresses acting on the furnace. These cast iron supporting plates were not directly attached to the pillars to allow for expansion and contraction during the smelting process. The entire height of the shaft was braced with iron tie rods that connected to iron corner reinforcement. The brick walls of furnaces in the 1870s were around 17 to 18 inches thick. This increased to 32 to 39 inches thick by the later 1880s as the insulating effects of the thicker walls gave a substantial savings in fuel costs (Hofman 1893:182-184).

Furnace Feeding Considerations

Feeding ore charges into a furnace was a major consideration that drove furnace design. Charges needed to be evenly distributed across the area of the furnace to allow for efficient smelting. This requirement led to two main designs for the top of blast furnaces where charges were loaded. The first was a continuous brick chimney extending from the top of the furnace shaft with the charging doors located in the side walls. The second type had a sealed top with feeding doors in the roof of the furnace. The fumes from smelting were drawn through flues in the sides of the furnace shaft rather than passing directly through a chimney at the top of the furnace.

The first type had the advantage of allowing the charge to be more evenly spread over the width of the furnace and allowed for easier access to *bar* down (use a long-pointed iron bar to chisel off) any accretions that formed on the furnace walls. The feed doors in this arrangement were usually five to six feet tall allowing a worker to stand in them while baring accretions off the furnace walls). The fumes from the furnace were drawn off by a sheet-iron flue passing into the smelters dust chambers. In the top feed arrangement fuel was fed into the furnace through a cast iron top plate with feed openings small enough to discourage furnace gasses from passing through. The openings were still large enough to allow the charger to spread the charge across the furnace and give sufficient space to bar accretions off the walls. In these furnaces the flues to the dust chamber were originally constructed of sheet iron, but by the late 1880s and early 1890s it was becoming increasingly common for the flues to be built of brick resting on heavy iron rails (Hofman 1893:184-185). Toward the end of the century larger plants began to adopt mechanical forms of feeding. One of the earliest was installed at the Pueblo Smelter where counter-weighted doors were manually opened to allow automatically transported cars to empty into the furnace (Dwight 1906b:84).

In the early furnaces all furnaces had a suspended telescopic stack as the stack was a direct connection from the atmosphere was not generally desirable. Furnaces gasses were instead directed through the dust fume system to collect flue dust and the stack was only used during the blowing in and blowing out processes to draw off any smoke or fumes that were too great for the dust flume system to handle. They were also needed for the larger quantity of fumes and smoke that were produced during the blowing in or out process. By the early 1890s this method had been largely abandoned, although large plants retained one or two moveable stacks for use in special situations. Instead furnaces were equipped with a ¾-inch thick suspended iron plate that could be lowered to seal the furnace stack if necessary (Hofman 1893:185).

The Furnace Hearth

By the late 1880s most blast furnaces used variants of the Arent's Automatic Tap. The Arent's Automatic Tap formed part of the wall of the hearth and consisted of an inclined channel 3 to 4 inches square descending from the lowest part of the crucible to a dish-shaped lead well outside the furnace. During smelting the crucible inside the hearth remained mostly full of lead with the excess draining through the tap. The resulting lead was then ladled into molds or allowed to flow into a separate cooling pot (Eissler 1891:95-96; Hixon 1908:673). The Arent's tap allowed for the continual running of the furnace which was a substantial improvement over the older method where the lead and matte had to be periodically tapped.

The tapping method required the furnace blast to be halted and the combined lead and matte drained until the overlying slag appeared and then the tap hole was quickly sealed with a stopper of clay. The mixed slag, matte and speise were tapped into a slag pot where they settled into layers based upon their specific gravities. The interior crucible then had to be cleared, the tuyeres cleaned and the blast pipes reconnected to the furnace and blast slowly increased until smelting resumed. The use of the Arent’s tap avoided the labor and cooling associated with the earlier process.

The only situation where the Arent’s tap was inferior to the older tapping method was when working with ores with a high copper content could be processed in a blast furnace by adding sulfur to the charge to form a copper matte. When the copper content of the matte reached 12 percent, it became viscous and the Arent’s tap had difficulty operating. Blast furnaces processing copper rich ores required design changes which are discussed in a following section on copper blast furnaces (Hofman 1893:188-189). The description of the hearth given below assumes that the Arent’s tap is used.

The base of the blast furnace is the hearth. This consisted of a plate of boiler iron that was placed on the furnace foundation to prevent lead from seeping from the furnace into the foundation in early furnaces the hearth often consisted of just masonry and firebrick it was common for matte and bullion to collect within the stone work. The edges of the plate were sometimes extended beyond the brickwork of the furnace or included a small sharp-angled iron rim to enclose the lowest course of brickwork. Castings were placed on top of the base plate forming the walls of the hearth. Cracking of the castings was a common problem due to the stress of continual cycles of heating and cooling. To address the problem the plates were continually thickened and strengthened throughout the period. The front of the hearth contained a cast iron slag spout and a separate cast iron lead spout if the lead well was within the furnace proper. The base and walls of the hearth were lined with fire brick resting directly on the bed plate. Generally, a gap of 2.5 inches was left between the wall castings and the fire brick which was filled with a brusque consisting of equal parts of clay and crushed coke. This allowed for the expansion and contraction of the fire brick without putting undue stress on the cast iron components (Hofman 1893:186-187).

Air Blast

Another important consideration in the construction of blast furnaces was the air supply needed to encourage the chemical reactions occurring within the furnace column. Blast furnaces required more air than could be provided by natural draught to properly smelt ore. In lead-silver smelting blast was usually supplied by rotary positive pressure blowers of either the Baker or Root model (Eissler

1891:84). The most common and earliest of the designs was the Baker. The newer Root model had the advantage of more easily varying the blast pressure allowing the fan to more quickly come back to speed after blast had been reduced or stopped. The amount of air required by furnaces varied based on the size of the furnace and the types of charge being processed (Hofman 1893:194-195).

If a smelting plant had multiple blast furnaces the normal design was to have multiple blowing engines serving all the furnaces through a common blast main (Figure 2-5). The use of a main was common as it was cheaper than having dedicated blowers for each furnace and required less maintenance time and costs. The blast pipes serving the system were constructed of galvanized iron and ran along the back of the furnaces suspended at least 8 feet above the furnace room floor. The blast pipes were equipped with safety valves in case of a stoppage, and blast gates were mounted at both the blower engine and the furnace. Each of the branch pipes coming out of the shared main was equipped with its own blast gate allowing blast to be shut off to individual furnaces, and most had their own pressure gauge. The connection between the branch pipe and the furnace tuyeres were made with canvas wind bags soaked in alum or water glass (sodium silicate) making them more fire resistant (Eissler 1891:86-89; Hofman 1894:194-195).

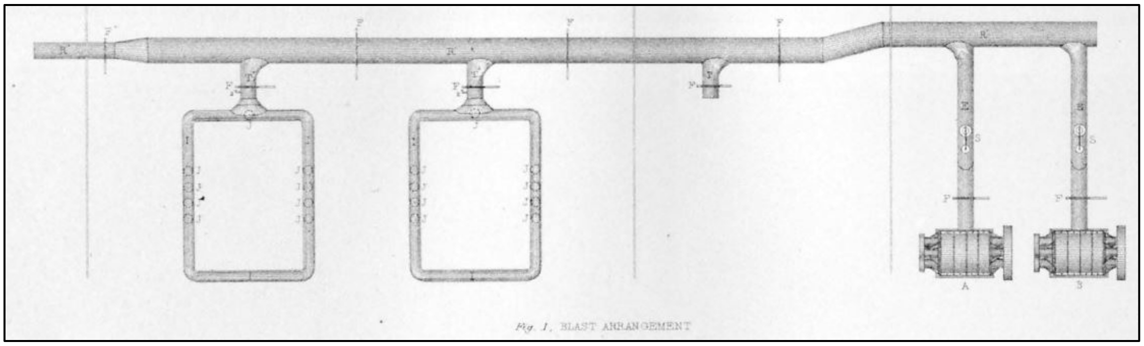
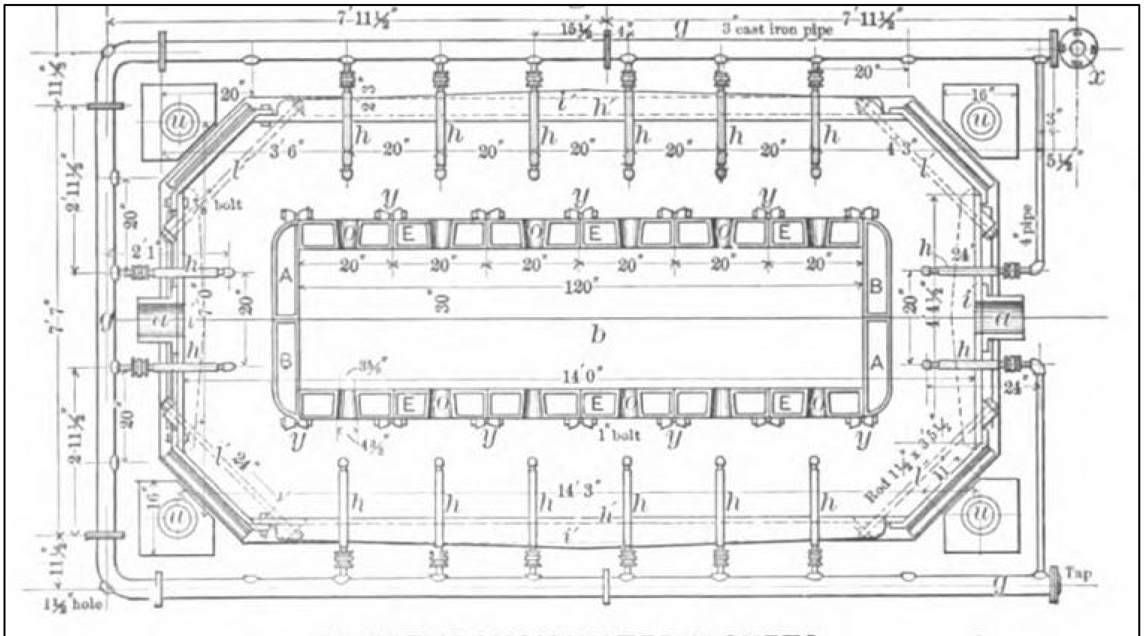


Figure 2-5. Blast arrangements for multiple furnaces in Leadville 1879. Illustration from Emmons 1886 Plate XXXI.

The number of tuyeres in a furnace was variable, with a 3-inch tuyere considered to supply sufficient air for two square feet of hearth area. In the early furnaces the tuyeres were distributed on all sides of the hearth, but it was later discovered that the tuyeres in the front and back plates of the furnace did not contribute greatly to the blast and were often in the way when plates needed to be removed, or other furnace cleaning and maintenance operations were conducted (Hofman 1894:196). The earliest tuyeres were simple metal pipes or castings but tuyeres with water jackets proved easier to maintain and less likely to burn through (Eissler 1891:88-91). Minor variations in the design of blast furnaces could be made to account for the characteristics of the ores. As previously mentioned, the method of tapping the furnace could be altered depending on the constituents of the ores. In some cases, as at Dudley sometimes even the type of furnace was be changed to better process ores (Peters 1874). Most small smelters lacked the capital or technical expertise to make significant modifications to their furnaces and relied instead on attempting to modify their charges by importing additional ores or materials.

Water Jackets

The earliest blast furnaces constructed in Colorado were solid brick-walled furnaces. These types required frequent repairs as the lining of refractory fire bricks was broken-down by the heat and chemical reactions occurring within the furnace. An improvement was introduced to the lead-silver smelting industry by 1873 consisting of cast or sheet iron water jackets (Figure 2-6) that rapidly replaced traditional brick-walled furnaces wherever local water supplies permitted their use. The use of water jackets greatly improved the ability of furnaces to work continuously, reduced the need for repairs, and generally allowed for cheaper operation than the older brick-walled types (Eissler 1891:100). The water jacket was placed at the tuyere zone of the furnace and extended above the hearth, forming an extension of the furnace on the interior of the brick furnace shaft. The height of the water jacket varied from 2 to 4 feet and covered the hearth walls to within a foot of the base plate supporting the furnace shaft. The tuyeres were generally 10 inches above the bottom edge of the jacket and the boshes of the furnace 8 to 10 inches above the tuyeres (Hofman 1893:189-191).



PLAN THROUGH WATER JACKETS.

Figure 2-6. Water jacket cross-section. Illustration from Hofman 1893:181.

Water jackets could be built of either cast iron or wrought iron, each of which had advantages and disadvantages. Cast iron jackets were around 6 inches thick with walls varying from 3/8 to 5/8 of an inch. The jackets were fed by a specially designed water feeder that entered the jacket 8 to 10 inches above the tuyeres and extended approximately 4 inches above the top of the jacket to ensure that the jacket was filled with water. The top of the water feeder was covered by a lid instead of a solid casting to allow the system to be opened and cleaned of accumulated scale (Hofman 1893:191). In early furnace models the water feed was cast as an integral part of the jacket, but maintenance problems led to the development of a separate model bolted onto the jacket to allow easy replacement. Later models added access ports at the bottoms of the jackets to allow for easier cleaning. Over time the buildup of scale and mud settling in the interior of the water jacket reducing the water capacity of the jacket and lead to a burn through of the furnace (Croll 1898:639).

In large furnaces where ore supplies were relatively constant it was considered acceptable to have only a small opening in the front jacket allowing access to the interior. However, in smaller furnaces that had frequent changes in the size and composition of charges, it was considered good practice to make the front jacket of the furnace about 10 inches smaller than the side jackets to allow for easier removal and access to the hearth as more frequent repairs were needed under these conditions. Early models of the water jacket were joined by screws or bands, but it was soon determined the easiest and most reliable method was to bolt the segments together via lugs cast into the jackets and the whole made water-tight through the use of a gasket (Eissler 1891:100-101; Hofman 1893:191-192; Hofman 1918:237).

Cast iron water jackets were gradually replaced with the development of wrought iron jackets, and only the wrought iron versions were generally used in the later large circular and oval furnaces. Wrought iron jackets had several advantages overcast iron versions. Wrought iron jackets did not required the specialized water feed devices used in cast iron models and were equipped with only water inlet and outlet pipes. The exterior of wrought iron jackets flared out near the top to increase the water space available at the outlet pipe. In most conditions wrought iron jackets were more durable than cast iron models, were less prone to cracking due to thermal and mechanical stress and, therefore, required less frequent replacement. Cast steel water jackets were just coming into use in the early 1890s but did not replace wrought iron models by the end of the century (Hofman 1893:192-193).

Water for the jackets was usually supplied by a raised wooden tank to limit expenditures on pumping machinery. In most furnaces the feed water entered the jacket at the top, the descent of the cold water causing the warm water in the jacket to rise where it was drained off either through a galvanized iron trough, or to a standpipe. The quantity of water needed to cool a furnace depended on its size, and the type of ores it was processing. For example, a blast furnace measuring 32 inches x 92 inches at the tuyeres creating a siliceous slag required approximately 11 gallons of water per minute, a good average consumption for a furnace working these types of ores. The amount of water required for cooling doubled during blowing the furnace in or out due to the higher temperatures generated during these periods and a sufficient reserve quantity of water had to be available to cover these actions (Eissler 1891:101-102; Hofman 1893:193-194; Iles 1902:61-63).

Slag Pots

The smelting process produced large amounts of waste material that needed to be disposed of throughout the smelting process. The slag was the largest product of the furnace and needed constant removal. This was accomplished through the use of slag pots to collect slag from the furnace tap and wheel it to its disposal site. Many designs of slag pots were developed and with highly variable capacities. There was some local innovation in the design of slag pots with two designs developed by Walter Devereux who managed a smelter in Aspen in the 1880s (patent numbers 312,439 [Feb 17, 1885] and 335,114 [February 2, 1886]).

For a blast furnace 33 inches by 100 inches, a total of 12 slag pots, 24 inches in diameter and 15 inches deep were needed (Figure 2-7). When slag was drawn both the slag and the matte flowed into the pot and separated based on their specific gravities. A number of modifications to the basic slag pot design were attempted, with one of the most successful being the Iles-Keiper pot. This was a large overflow pot with a spout on the side. It was designed so that the heavier matte settled in the bottom of the pot while the slag flowed through the spout into a separate, standard slag pot. The design included a removable cast iron lid that was intended to slow the cooling of the pot contents to encourage the clean flow of the slag. A different type of slag pot included a tap hole 3.5 inches from the bottom. This allowed the matte in the pot to separate and solidify while the slag could then be easily tapped to run off. The remaining solidified slag in the pot often contained sufficient metal values to justify breaking up to be returned to the blast furnace as part of a later charge. In large smelters the slag was removed using a device like the Nesmith Dumping Car (Figure 2-8). This consisted of a car body with two large tilting pots that were used to capture the slag from multiple furnaces and had a capacity of 5,000 pounds of slag (Nesmith Patent No. 388,708 [Aug 28, 1888]).

The movement of slag at small smelters was usually done by hand, but at the larger smelters more advanced methods were usually needed. At the Arkansas Valley Smelter in Leadville, and the Philadelphia Smelter in Pueblo slag was moved around the plant using locomotives, while the Omaha and Grant Smelter, the Globe Smelter, and the Pueblo Smelter used horses and mules to move slag carts (CIW 1896:51).

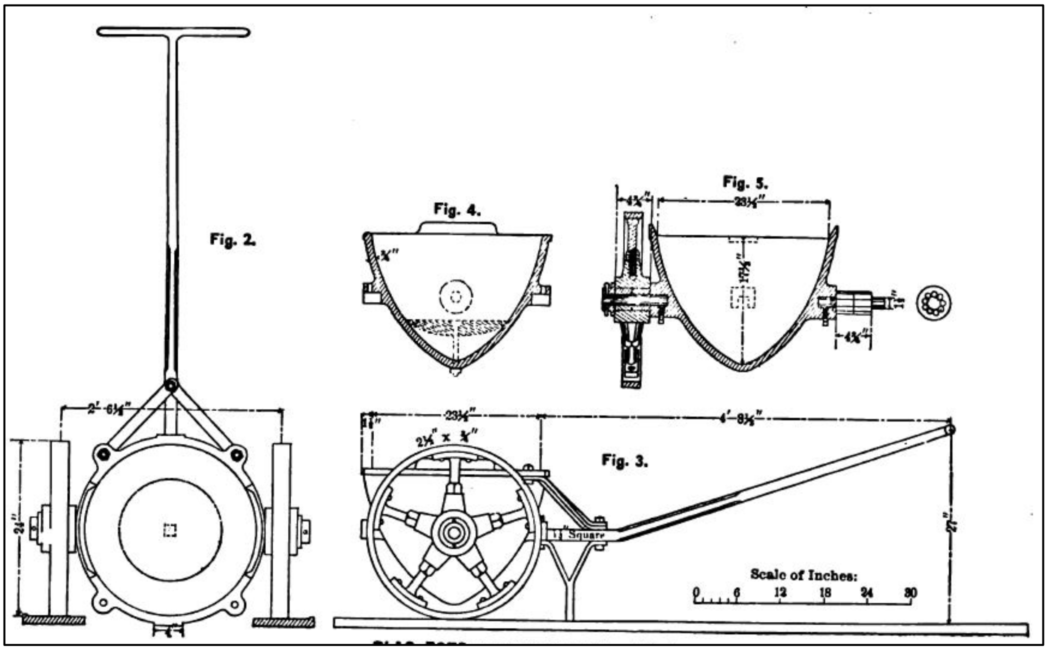


Figure 2-7. Slag pot. Illustration from Peters 1895:312.

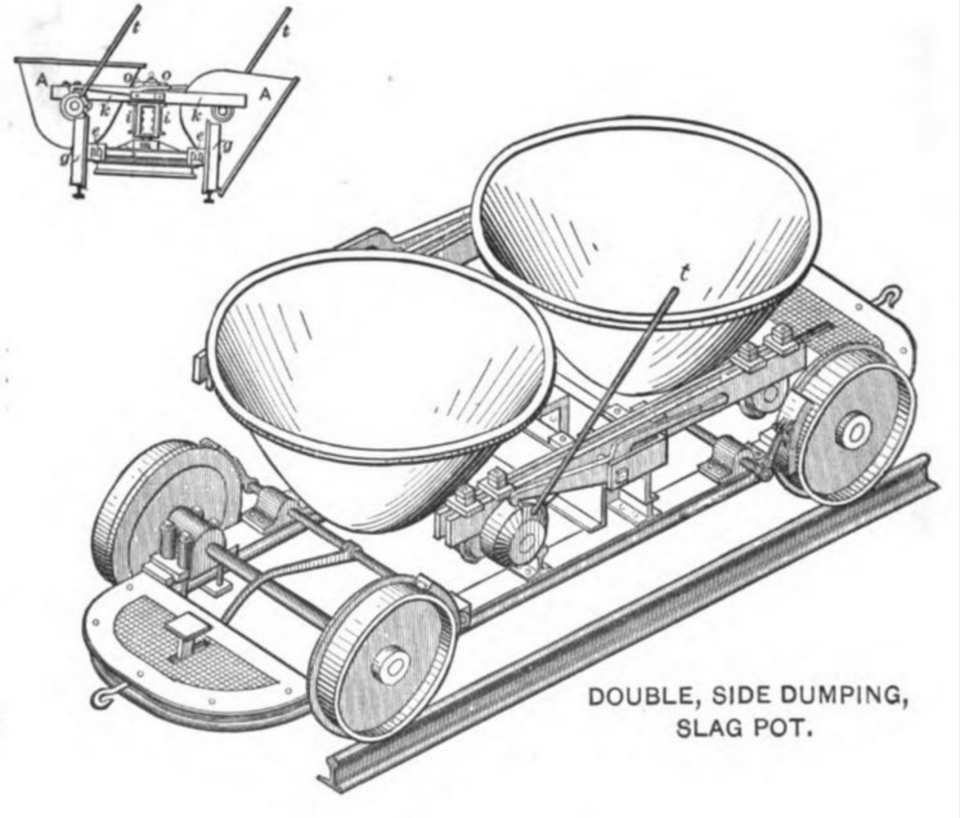


Figure 2-8. Dumping slag pots. Illustration from Hofman 1893:204.

Dust Chambers

Blast furnaces produced large amounts of flue dust during their operation. The earliest smelters made no provision to collect the dust leading to substantial losses in lead and silver values. Later smelters, however, included dust chambers and flues in their design to settle out the dust for later collection and recycling through the furnace. Flue dust consists of the small fragments of ore, partially reduced metals, fuel, and volatilized metals created during handling, crushing of the charge during settling, and materials partially vaporized during heating. The materials were carried by a combination of heat and the blast from the furnace. In furnaces without a method to capture these materials a significant amount of the metal content of the ores could be lost. Increasingly sophisticated methods to capture the dust were developed through the late nineteenth century. The earliest were simply long flues connecting the furnaces to a chimney. The idea was to give the dust particles in the furnace gasses more time to settle out of the air stream. The experimental stage at Leadville in 1879 shows a number of the designs that were being used in an attempt to capture as much of the flue dust as possible (Eissler 1891: 195-196). A relatively simple design is show in Figure 2-9. Flue dust entered from pipes in the chambers of the unit. The gases were then forced to pass through holes between the chambers set at opposite ends of the walls through openings that alternated between floor and roof level reducing air velocity to maximize the tendency of the dust to drop. The spent gas then passed through a brick flue along the back of the unit and exited the works through a chimney. A more sophisticated example is shown in Figure 2-10. Gases from multiple furnaces passed into a suspended pipe within a housing with a diamond-shaped cross-section. As the dust settled out of the pipe it passed through valves into the larger dust chamber housing. The dust was then periodically collected through valves along the low point of the chamber. An advancement on the typical dust flue method of collecting dust was observed by Guyard in his visit to the Grant Works and soon become a common method of collecting flue dust in blast furnaces was the new Bartlett Smoke Filter (Iles 1902:186-211), . One furnace was connected to the filter assembly by a cast iron pipe 150-feet long with the help of a blowing engine. This acted as a typical flue catching much of the dust during its progress to the filters. The air passed vertically through the filter bags exiting entirely clear, the filters capturing all visible dust and materials. The constant air blast through the system caused the bags to continuously shake allowing accumulating clumps of dust to fall back into the main dust chamber below. When enough dust collected in the chamber a small fire was lit within which ignited the soot in the dust creating a white material that was easier to handle. During the five-day run, 3,030 lb. of calcined dust was collected from the furnace, although due to imperfections in the experiment Guyard believed up to 7,000 pounds could have been collected. The dust assayed at 70 percent lead and 6 ounces of silver per ton indicating that a typical 35 to 40-ton furnace lost 1,000 lb. of lead and 4.5 ounces of silver to the open air per day (Emmons 1886:674). Both these elaborate flue chambers and the smoke filter were found only at larger well financed plants. Most smaller smelters made do with simple linear dust chambers or pipes connected to a tall chimney at some distance from the works. In these systems the dust accumulated in the pipes until cleaned out into barrows by workers. No previous mention of the use of this system was located and it is likely one of the earliest, if not the earliest use of the method.

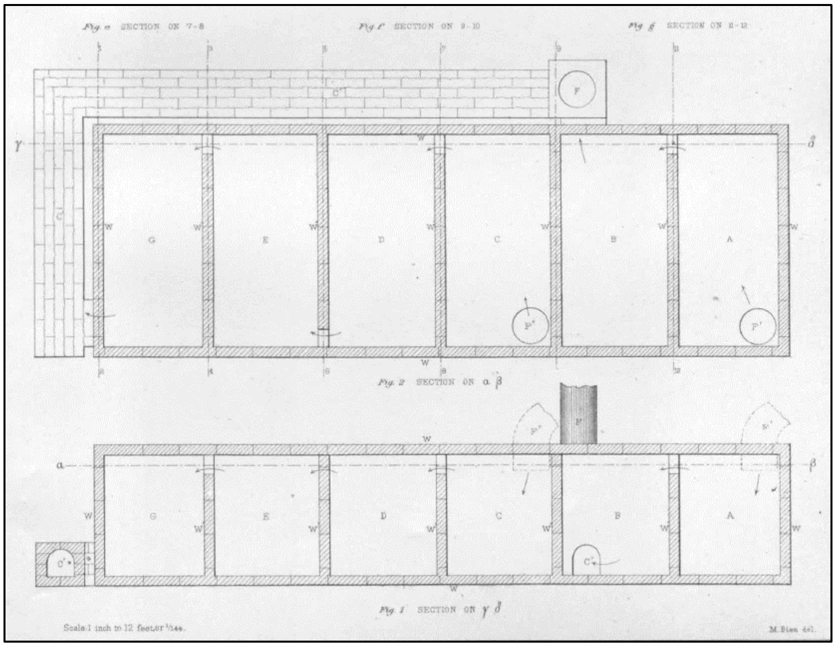


Figure 2-9. Dust Chamber design from "Smelter C" at Leadville in 1879. Illustration from Emmons, Plate XXX, 1886.

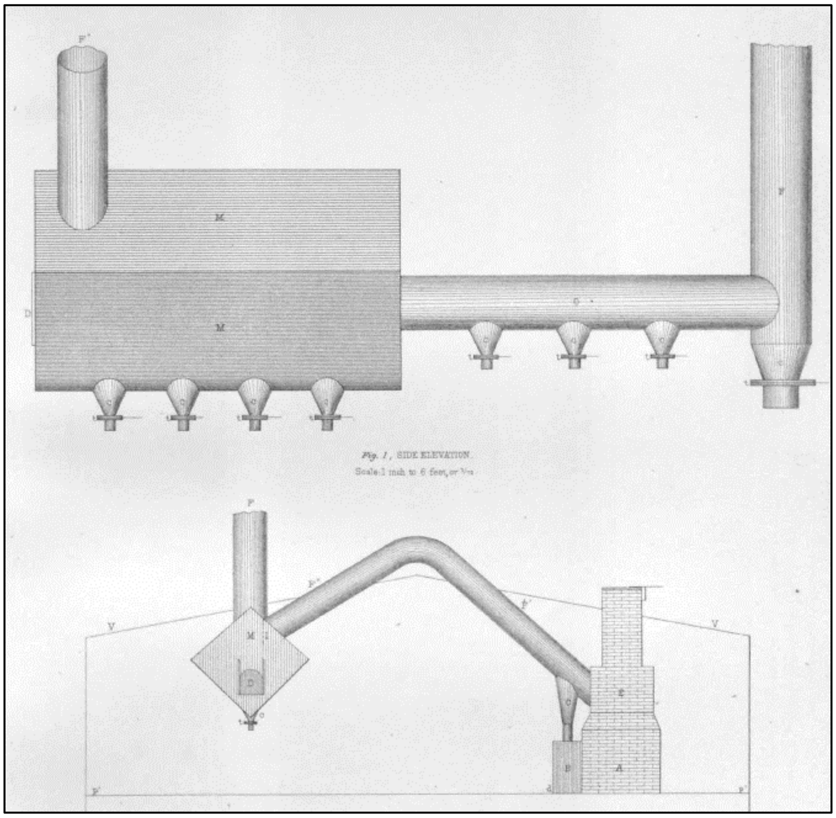


Figure 2-10. Dust Chamber design from "Smelter F" at Leadville in 1879. Illustration from Emmons, Plate XXXIV, 1886.

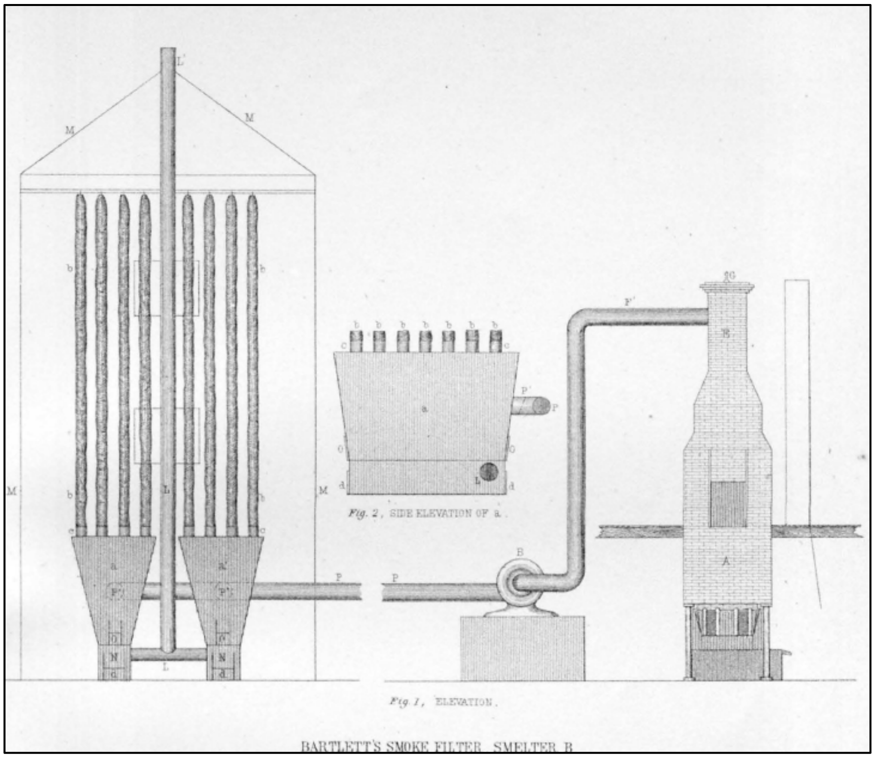


Figure 2-11. Bartlett's Smoke Filter at Leadville Smelter B (Grant Smelter) in 1879. Illustration from Emmons Plate XVIII 1886.

Blast Furnace Operation

The previous sections discussed the physical design of the smelting plants. The information in this section will be of use to archaeologists recording smelter sites. Many of the components described above will be evident at many smelting sites. Various components of the furnace will have left physical remains on the ground including the hearth and dust chambers that should be easily identifiable. Artifacts or features associated with the water jacket, air blast systems, and construction materials from the furnace shaft are likely to remain onsite providing information about the types of furnace used and potentially provide information on the period of use for the smelter. The current section discusses the methods of operating the smelter. An understanding of the operational methods used at smelters provides a background that can be used by archaeologists to reconstruct the flow of materials through the site and the work patterns onsite.

The Blowing-In Process

The first stage of the smelting process at a blast furnace was termed *Blowing-in*. This was the process of preparing the empty furnace for starting normal operation. The process began with the warming of the crucible, continued to fill the furnace with its initial charge, and ended with the furnace at full temperature to begin the smelting process. The furnace required careful warming, especially if it was newly constructed, as it was necessary to drive off excess moisture within the brick and masonry of the furnace to prevent damage due to uneven heating or the creation of steam from water in the masonry. The initial warming fire was usually fueled by wood until the exterior of the crucible was warm to the touch. The wood was then replaced with charcoal and the whole heated until the crucible was red hot and then a load of hot lead was placed in the hearth. The initial charge fed into the furnace consisted mostly of slag from a previous firing, combined with the necessary fluxes and an excess of fuel. As the slag charge worked down, ore was added in increasing amounts in subsequent charges until the furnace reached proper operating conditions, a process that normally took about six to seven hours (Eissler 1891:141-142; Hofman 1893:331-335; Iles 1902:86-87).

Normal Operation

Once the furnace was blown-in it was ready for normal operation. After the furnace was brought up to temperature and slag was being generated normal charging of the furnace commenced. From the charging floor at the top of the furnace charges were created either by weighing, or by the shovelful. The weighing method was superior, as it allowed for more accurate modification of the charge if problems were encountered during smelting. Fuel and ore were fed into the furnace in alternating layers to minimize the exposure of the fuel to the open air. Fuel was usually fed toward the center of the furnace, as it tended (especially charcoal) to work towards the side of the furnace as the charge descended (Hofman 1893:227).

A blast furnace was operating efficiently if it was cool at the top, the charge was sinking evenly, and if the production of fumes was uniform across the furnace indicating an even reaction in the charge (Eissler 1891:147). The size of the material in the charge was also an important consideration. Too fine a mix resulted in the creation of blow holes preventing the blast from passing evenly through the charge. Too large a size had a similar effect with the blast passing through the column too retarding the reduction (Dwight 1906a:75-78). A typical blast furnace 32 to 42 inches wide and 84 to 120 inches long at the tuyeres required a crew of three (one feeder and two wheelers). If multiple furnaces were fed by the same crew the number of wheelers could be reduced slightly. (Hofman 1893:230-231).

Workers on the furnace floor were required to monitor and regulate the water supply feeding the water jackets, monitor the air blast, tap the matte, slag and speiss into slag pots, tap lead into molds, and collect and store the resulting bars of bullion. The water temperature in the jackets was maintained at around 60° to 70°C and was checked periodically by passing a hand quickly through the water outflow from the jacket. If the worker's hand was scalded the jacket was not operating efficiently and adjustments had to be made. If water flow had stopped in the furnace it was necessary to carefully monitor the temperature of water added to bring the water level up, as the introduction of cold water into a hot jacket could cause the jacket to explode or rupture. Blast pressure was monitored by observing the color of the tuyeres (Eissler 1891:147-148; Hofman 1893:231).

Each furnace required one furnace-keeper, one tapper, and 2 or 3 pot pullers. The tools of the furnace keeper and tapper consisted of an assortment of iron or steel bars, skimmers, shovels, picks, a ladle, and a set of dies (for marking bars of bullion). The pot pullers only required a steel bar and a sledgehammer to loosen solidified slag or matte on the pots and molds. If normal slag pots were used at the furnace, they were wheeled out on the dump and allowed to cool. The resulting cone of cooled slag was then tipped out onto the dump and broken with a sledgehammer to separate out the matte and speise. If the furnace used overflow pots, the slag was emptied onto the dump while still liquid. If catch pots were used the tap hole was opened to either discard the liquid slag on the dump or drain it into a large side-dumping pot. Any slag remaining in an overflow or catch pot was broken up and returned to the furnace for resmelting as the hardened residue was generally richer in metals than the remainder of the slag. A single furnace required a dump crew of two men working a 10-hour shift. The crew required a round pointed shovel, a pick, a sledgehammer, a steel bar, and an iron wheelbarrow (Hofman 1893:234-235).

The Blowing-Out Process

When it was necessary to halt the operation of a furnace for some reason the process was termed *Blowing-out.* As the processing of stopping and restarting the smelting process was expensive and time-consuming this was only done if repairs were required, problems with the charge were encountered that could not be easily rectified, or if there was an interruption in the fuel or ore supply for the furnace. To properly close the furnace the normal charges was replaced with charges consisting of slag until the remaining ore in the furnace column melted down. The charge was then allowed to sink, and the blast was slowly reduced. When black smoke appeared at the top of the charge the flues to the dust chamber was sealed and the resulting fumes and smoke allowed to pass directly into the chimney. When the descending charge reached the top of the water jackets the blast was stopped and the tuyeres removed. Any remaining slag in the furnace was tapped out, the front section of water jacket removed, and the fire brick face of the furnace was dismantled. Any residual slag in the hearth was removed with a hoe and carried off in wheelbarrows to the dump. The lead in the hearth was then ladled into molds (Eissler 1891:140; Hofman 1893:241-242).

Products of the Lead Blast Furnace

The smelting process in a blast furnace produced its own class of materials that differ from those produced in hearth and reverberatory furnaces. An analysis of materials remaining from the smelting process at a smelting site could help identify the type of furnace used if no historical or other archaeological evidence can be identified. The main products of the blast furnace were base bullion, matte, speise, slag and flue dust (Hofman 1893:244). Base bullion was the commercial name for argentiferous lead which contained a mix of lead, silver, gold, and a variety of metallic impurities based upon the ores worked. The impurities within the bullion tended to collect near the top of the bar during the cooling process, while the bottom part of the bar will be higher in silver. The bullion was usually sold or shipped to outside refining works to recover the precious metals (Hofman 1893:246-249). Speise is an iron rich compound, although the iron can be partially replaced by copper or nickel. Speise almost always contained some lead and tended to retain gold. In lead smelting, speise was generally produced in small quantities and was difficult to process to remove the precious metals. The speise was roasted in open heaps of 50 tons for a period of two to four weeks. This was then sorted and crushed before further roasting in a calcining furnace. The calcined speise was then smelted in the blast furnace with either matte or pyrites to produce base bullion and a subsequent matte that was rich in gold and copper. Unlike speise, mattes generally did not retain much gold, but could be rich in silver. Matte could be roasted in heaps as the process was cheap and tended to produce fragments of the proper size for easy smelting, but care had to be taken as exposure to precipitation leached lead and silver out of the ore. The process was also inefficient and usually required multiple roasting events, leading to additional losses from handling (Hofman 1893:250-255).

Stall roasting limited leaching, used less fuel, and was completed more rapidly. Matte was also roasted in reverberatory furnaces and there were some experiments with roasting in Brückner cylinders and Stetefeldt furnaces. When roasted in reverberatories these were built to the same general design as ore calciners holding charges of 5,400 pounds of crushed matte. Three charges could be processed daily in a 60 foot by 14-foot furnace using two tons of coal. The roasted matte was then added to blast furnace charges where it served as an iron flux. Flue dust consisted of the fine particles of the charge that were carried out of the furnace by the blast, in combination with metals (mainly lead and silver) that had volatilized during smelting. The amount of flue dust produced was determined by a number of factors. The use of charcoal or soft coke created many small particles, while the crushing of ore during its descent through the furnace also contributing to the dust. As an average, approximately 5 percent of a charge turned into flue dust, but in adverse conditions this could go to as high as 15 percent. Early on flue dust was allowed to escape, which led to substantial losses in assayed silver values. By the 1880s methods were developed to capture the dust. In Colorado the most common method was to allow the dust to settle out in long flue systems. However, filter methods were also introduced to filer the dust out of the air stream. Due to the fine size of the dust the recovery and treatment of the dust was problematic as it tended to blow off again if put directly back into a furnace. This led to the development of methods of compressing the dust into bricks or briquettes using pressure or other binding agents (Hofman 1893:261-264, 281-290).

Slag

The main product of a blast furnace was slag. This was an unwanted, but unavoidable, waste product of the furnace consisting of the molten remains of the non-metallic components of the furnace charge. The characteristics of the slag produced by a furnace were one of the main methods used historically to determine the effectiveness of the smelter and it was the topic of much discussion in period mining journals. Slag analysis has the potential to provide archaeologists with an estimate of the effectiveness and types of smelting techniques used at a site and may help identify problems that contributed to the smelter's failure.

Slags are combinations of iron, lime, and silica combined with small amounts of other ore constituents. Anton Eilers defined a good slag as one that contains at maximum 0.75 percent lead, 0.5 ounces of silver per ton, a specific gravity of less than 3.6, does not cause accretions to develop in the hearth, and that keeps the lead red hot. (Eilers 1881:247) Much attention was spent on determining the proper composition of slags, with a typical good slag consisting of 28 to 36 percent silica, 24 to 52 percent iron oxide, and 6 to 30 percent calcium oxide (CaO). The fusibility of slag depended on the silica content and the various bases in the charge. The more fusible the slag, the greater amount of charge that could be processed for a given amount of fuel. The slag had to be sufficiently liquid to create a clean separation between the molten lead and slag. A slag with a good composition tended to crystalize, rather than show an amorphous or glassy appearance. Lead slags are generally black due to their high iron content (Hofman 1894:137-138).

The creation of the desired slag properties generally required the addition of either acid or basic fluxes to generate the proper chemical reactions. The most common fluxes were lime, iron ore, manganese ores (rare), and slag from previous smeltings of the furnace.

Lime was commonly used as flux in blast furnaces, usually as raw limestone. The lime assisted the efficient separation of the matte and slag and was often used instead of iron ore due to its lower cost. The main problem with lime rich slags is they required a greater smelting temperature than iron. When limestone wasn’t available dolomite was often used, but the magnesia in dolomite tended to create a thick slag that was more difficult to work (Hofman 1894: 141-142).

Iron ore used as flux had three effects. It provided a base to counteract silica in the ore, it released lead oxide from its combination with silica, and it improved the liquidity of the slag (the higher the iron content, the thinner the slag). However, the amount of iron slags used in the furnace had to carefully monitored as it contributed to the formation of accretions on the furnace interior. High iron contents were necessary if the ore contained large amounts of zinc as it encouraged the passage of the zinc into the slag. Manganese ore has similar properties to iron and was sometimes used in its place (Hofman 1894:139-140).

Slag was reused in blast furnace charges for four main reasons. Slag tended to reduce the density of the charge, as a furnace product it re-melted easily and helped the charge to smelt, and served as a flux when the base charge was more acid or basic than the slag, and sometimes the slag was too high in lead or silver content to be thrown away without significant loss of metal values. Although not necessary for the proper smelting of a charge, slag was generally added to at a rate of 150 to 200 pounds per 1,000 pounds of ore. The quantity was increased with fine ores as the slag helped to prevent blow holes in the charge which reduced the ability of the furnace to oxidize the charge, and in these cases sometimes reached 25 percent of the charge (Hofman 1894:142-143).

Impacts of Ore Impurities

Blast furnaces were more efficient than hearth and reverberatory furnaces for working ores with high amounts of undesirable elements like sulfur and arsenic but were still negatively affected by these impurities in the ore. These impurities would be identifiable during a chemical analysis of historical slags giving some information on potential problems experienced by the smelter. Copper in the charge could be helpful as it had a greater affinity for sulfur than other elements, but if there was insufficient sulfur in the charge to combine with the copper some of the copper would be reduced to a metallic form and enter the bullion reducing its value and had a tendency to plug the lead well. This was only a problem if the resulting matte contained at least 12 percent copper but became increasingly serious as the copper concentration rose (Hofman 1894:145-146).

The worst metal for a blast furnace was zinc. Zinc ores required roasting to convert the zinc to zinc oxide or the resultant matte was less fusible and other metal sulfides ran into the slag and were lost. Fully removing zinc from ores was a major problem was not successfully addressed during the nineteenth century (Hofman 1894:146-147). Antimony was also difficult to process as it caused high losses due to volatilization and tended to enter the lead rather than slag requiring the more extensive refining of the bullion. Arsenic, which was common in rich silver ores, also caused loss through volatilization and combined with the lead. However, it has a greater affinity for iron than antimony and could be removed as a speise if sufficient iron is included in the charge (Hofman 1894:149-150).

Blast Furnace Fuels

One of the primary considerations for a smelting plant was its source of fuel. Although blast furnaces were more fuel efficient than a hearth or reverberatory furnace with a similar capacity, blast furnaces still used large quantities of fuel. The primary fuels used by blast furnaces were either charcoal or coke. At times smelters included raw wood or bituminous coal in charges, but generally only when coke or charcoal were unavailable, of poor quality, or too expensive. Remnants of the fuels used at a smelter should remain onsite. Charcoal was the most commonly used fuel in Colorado smelters due to its availability, but most operators considered charcoal produced from Colorado’s pine and aspen trees poorly suited for smelting and many preferred to use coke when it was available. The type of fuel used at a site can hint at the relative prosperity of the smelter. The main fuel types, coke and charcoal, are discussed in the following sections.

Coke

The preferred fuel for most blast furnaces was coke. The coke had to be sufficiently hard to support the weight of the charge, have a low ash content and be slightly porous. The best available, and the standard to which other cokes were compared, was Connellsville coke from Pennsylvania. The worst coke for smelting was produced as a byproduct of gas production and was of such poor quality it was generally considered worthless for smelting purposes. For use in a blast furnace coke needed an ash content of 10 to 20 percent, with around 50 percent cell space. As a safety factor the coke was expected to support a 90-foot charge without crushing. Fine coke particles injured the smelting process and were avoided by using a fork to feed the furnaces. If used as the sole fuel, coke produced clean slag and little flue dust. The composition of some cokes used in Colorado are given below (Table 2-2). The coke from El Moro in southeastern Colorado was generally considered the best coke produced locally.

Table 2-2. Coke Composition used in Colorado, modified from Hofman 1892:151.

Component	**Connellsville, PA**	**Grand River, CO**	**El Moro, CO**	**Crested Butte, CO**
Carbon	87.46	93.75	87.47	92.03
Moisture	0.49	-	-	-
Ash	11.32	5.49	10.68	6.62
Sulfur	0.69	0.76	0.85	-
Phosphorous	0.029	0.10	-	-
Volatile Matter	0.011	-	1.85	1.35

Charcoal

Charcoal was also a good fuel for smelting with some qualities superior to that of coke. It has better porosity making it a good oxidizing agent and required a lower blast pressure to burn properly. Its volume is three times as high as coke allowing for a loose charge that allowed quicker smelting. The main problem with charcoal was its inability to bear a heavy burden. The best charcoal available in the Western United States was generally from pinon pine and was considered adequate for smelting. However, charcoal derived from aspen, pine or fir was not suitable due to its high friability and some smelters refused to use it under any circumstances. A combination of coke and charcoal was often used giving the advantages of charcoal with the ability to properly support a charge. Mixtures of coke and anthracite or bituminous coals had been successfully used in some smelters, but such mixtures were not in wide use (Reno 1996:115-116).

Smelting consumed most of the charcoal production of Colorado. During 1887 three unidentified smelters in Leadville had an aggregate charcoal consumption of just under 2.4 million bushels out of a total state-wide production of approximately 8 million bushels. The smelters in Denver and Pueblo consumed the majority of the remainder (Ensign 1888:59-60). By comparison, the small smelter at Rico consumed 25,000 to 40,000 bushels per year. Although all smelters would have preferred to use coke, bad transportation links and high costs led to charcoal being the most common fuel in mountain smelters. Estimates for Leadville showed the use of coke as the only fuel would have increased smelting costs in many smelters by 15 to 25 percent (Ensign 1888:68-69).

More fuel was needed during the winter (approximately 5 percent) than the summer while elevation also had a significant effect. Studies showed that a charge at Salt Lake City at an elevation of 4,000 feet required only 14 to 17 percent fuel in a charge compared to 22 to 24 percent at Leadville at an elevation of 10,000 feet (Hofman 1894:154). This was another factor inhibiting the profitability of high-elevation smelters as 3 to 5 percent more fuel was required at Leadville than at Pueblo (Hixon 1908:73).

2.2.2 Copper-Gold Smelting

Most gold in Colorado is associated with copper minerals which required different processing techniques than lead-silver ores. During the 1860s and 1870s these copper-gold ores were most commonly processed in reverberatory furnaces. Some of the large smelters in Denver and Pueblo installed blast furnaces for the processing of copper ores to supplement their lead blast furnaces allowing them to process a larger variety of ores. The use of reverberatory furnaces, however, continued into the twentieth century with the large Argo Smelter in Denver using the process until it closed in 1906. This section first discusses the reverberatory furnaces as seen at the Boston and Colorado smelters at Black Hawk and Denver before continuing to a brief discussion of the modified blast furnaces used for copper reduction. For small smelting sites in the mountains, reverberatory furnaces are the most likely type to be encountered, as the large copper blast furnaces were restricted to the large smelters in Denver and Pueblo.

Copper Reverberatory Furnaces

The copper reverberatory furnace was used at the first successful smelters in Colorado. The type was pioneered at the Lyons Smelter and perfected at the Boston and Colorado Smelter, both at Black Hawk in Gilpin County. Other small smelting operations, such as Swansea Smelter in Cleark Creek County, used the process. This type of smelter was rarely used in most small smelting operations after the 1860s but is the most likely type to be encountered other than blast furnace types.

The smelter most associated with the use of copper reverberatory furnaces is the Boston and Colorado Smelter at Black Hawk that used a version of the process developed in Swansea, Wales. The products of this type of furnace was slag and matte, the matte collected the gold and silver in the charge. The Argo Works (Boston and Colorado) at Denver used essentially the same process as the original Black Hawk smelter of the 1860s and continued to use reverberatory furnaces until it closed in 1906. The furnaces were regularly rebuilt due to wear and their sizes were steadily increased which gave a progressive reduction in labor and fuel costs (Figure 2-12). The furnace design used at the Argo allowed for rapid charging and heated the air blast by routing it through the brickwork of the furnace. The charge was skimmed through four charging doors while the molten slag was conducted via launder to the exterior of the building where it was granulated in water for use as railroad ballast. The furnace was tapped once per week after at least 24 charges had been processed (Peters 1895:441-447,451).

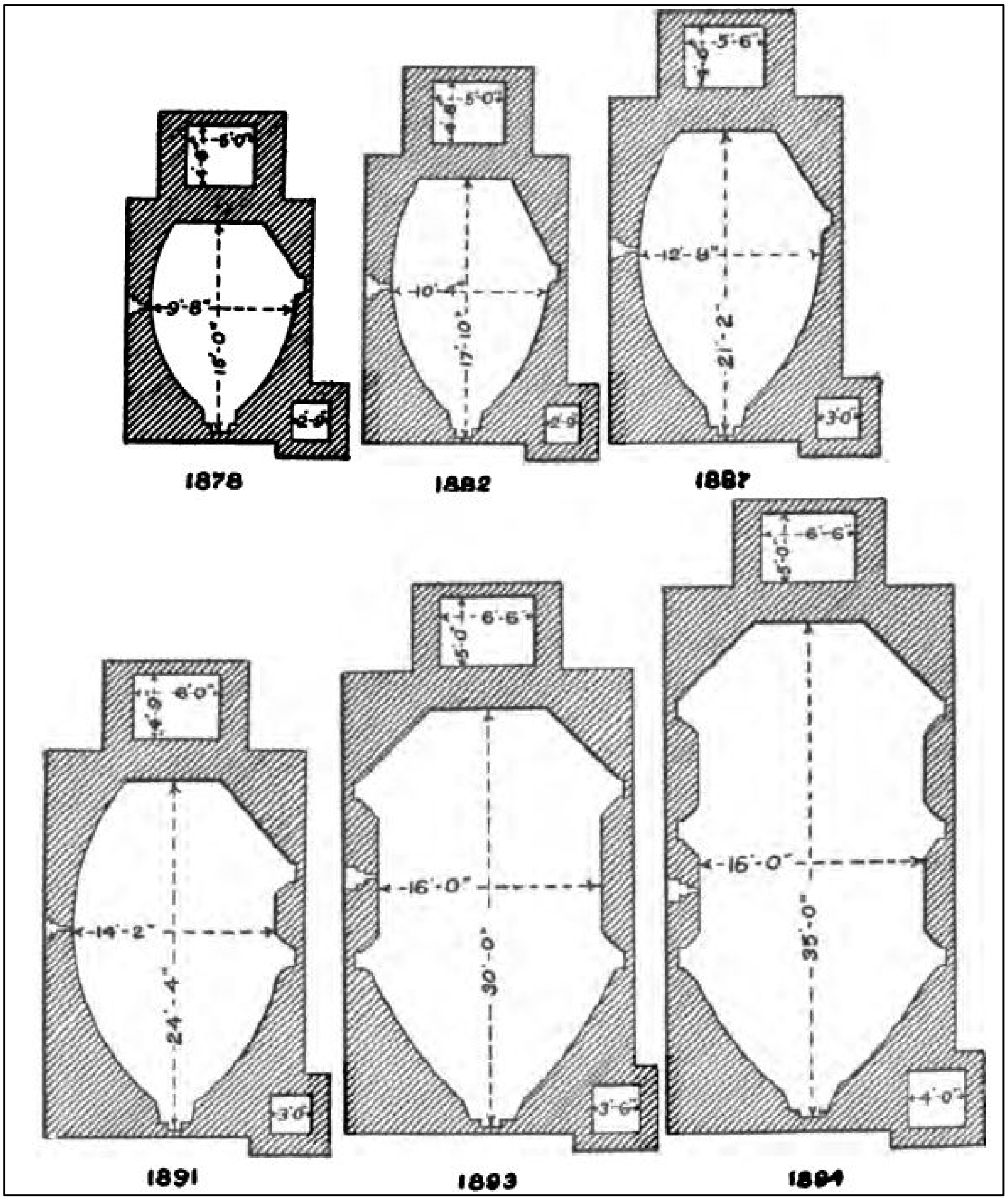
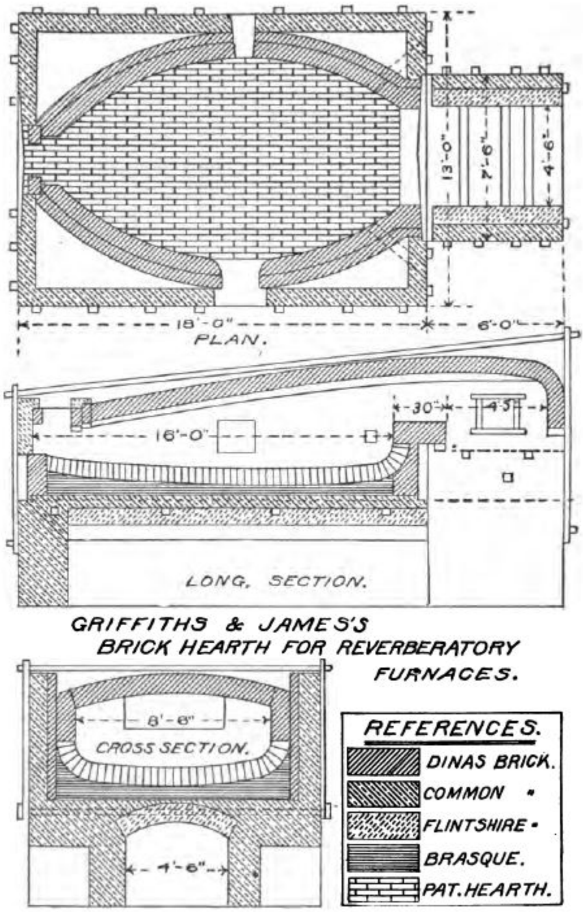


Figure 2-12. Evolution in size of reverberatory furnaces at the Argo Smelter. Illustration from Peters 1895:444.

A typical reverberatory furnace (Figure 2-13) was built with inside walls of common brick or inferior fire brick, a bridge wall at the rear and a front wall with a skimming door. The bottom of the hearth was an inverted arch built of fire brick that almost met the upper fire brick arch of the cooling vault. If a cooling vault was not included in the design, it was laid in a bed of steep. The early practice in reverberatory furnaces was to use two bottoms, but this was abandoned and only the one bottom was used as the sand layer between the two bottoms often caused problems with deforming the hearth floors (Peters 1895:464-466).

The bottom of a furnace for processing ores that make 15 to 30 percent of their weight in matte was 16 to 18 inches below the skim-plate, allowing the tap hole to be 8 inches above the deepest point of the furnace. This allowed 6 to 15 tons of matte to remain in the furnace, which served to insulate and protect the floor from the extreme heat of the furnace. The ore charges were dropped through the arch and floated on the top of the matte where the workers manipulated it with paddles to evenly spread the charge after which the doors were closed and luted. At the Argo the charge was fed through three hopper doors loading 12.5 tons of charge into a 35-foot furnace (Peters 1895:464; 469-470).



FIGS. 64, 65 AND 66.

Figure 2-13. Reverberatory furnaces design. Illustration from Peters 1895:468.

The construction of a reverberatory furnace began with the excavation of foundations at least 18 inches wider than the intended furnace. The foundation depth was at least four feet deep with permanent tile drains installed to ensure moisture would not collect under the furnace floor. Two brick walls with a spacing of five feet was built under the main part of the furnace which was covered with a brick arch of 4-inch common bricks covered with two layers of 4½ inch firebrick. The ash pit was built at the same height as this chamber. When the walls were within a foot of the future hearth floor an inverted arch was constructed. The arch was slightly arched longitudinally and well grouted with fire clay to prevent the arch would be lifted by molten charge materials (Peters 1895:476-477)

The hearth area was then enclosed by fire brick walls nine inches thick with a cladding of nine inches of common brick. A heavy cast iron plate was included at both ends of the hearth (conker plates) to strengthen the bridge wall. A horizonal cast iron skimming plate was placed on top of the conker plate at the front door. The bridge wall was built of fire brick with a 3-inch air passage along the conker plate. In some furnaces a large hole was left on the sides of the furnace to allow for greater air flow at the angle of the back wall with the fire box. This was only done if the furnace was anticipated to need a strongly oxidizing environment as required during the matte concentration. The fire box was built with nine-inch-thick fire brick walls, sometimes clad with common brick. Preferably, the furnace arch was constructed of a high-quality fire brick containing high amounts of silica as this wore longer than common fire brick. The arch had a rise of one inch per foot and pitched down abruptly near the anterior of the bridge wall until it was only 12 to 14 inches high at the front door skimming plate. The front of the arch near the door was often referred to as the “vulcatory” and was subject to rapid wear and required frequent repair and replacement. The flue opening was trapezoidal and located between the converging walls of the hearth (Howe 1885 32-33; Peters 1895:477-478).

In the large furnaces of the 1890s the traditional use of railroad rails as buck staves fell into disfavor as they lacked sufficient strength to support the larger walls. Instead reinforcement shifted to the use of steel I-beams (Peters 1895:479-480). A properly constructed reverberatory furnace required five different kinds of brick. Most of the superstructure was built of common red brick. The main arch, flue and most of the side walls of the hearth were made from silica fire brick. Parts of the furnace that were exposed to greater chemical or mechanical wear, such as the fire box, stack lining, and the lower parts of the furnace lining, were built of stronger basic (aluminous) brick. Lower quality good fire brick could be used to build the vault arches, the furnace walls below ground and parts of the furnace and stack that weren’t directly exposed to flame. All brickwork was laid in a thin mortal composed half of burned, and half of unburned fire brick ground to pass through a 30-mesh (0.3 inch) screen (Peters 1895:480-481).

In American practice reverberatory furnaces were usually served by individual stacks to avoid the unnecessary expense and complexity of building flues to connect multiple furnaces to one stack. These individual stacks were usually 60 to 65 feet high. If the stack served multiple furnaces it was generally at least 120 feet high as the cooling of the furnaces gases in the connecting flues reduced the effective draught. Tall stacks were generally round, while stacks up to 80 feet high could be square. The outer layers of brick in the stack could be set with standard lime mortar, but the interior layers required mortar of fire clay (Peters 1895:483).

Each furnace in a smelter was provided with at least 15 feet of open space on the tapping side and front to allow workers sufficient room to work. The charging side of the furnace required at least 12 feet of working room. All areas within the furnace building had drains of brick or cast-iron plates to channel moisture away from the furnaces (Peters 1895:483).

The floor of the hearth required careful preparation when built or rebuilt. The furnace was first heated to a light red color (this usually took about 12 hours of firing) and then covered with a layer of crushed sandstone or pulverized quartz. The material for the bottom either contained enough base to be somewhat fusible, or a small amount of slag was added to the sand to allow it to fuse slightly (Peters 1895:484). During the process the corners of the furnace were filled in and rounded to make the entire area easily accessible to the tools of the workers (Howe 1885:34).

The hearth bottom consisted of two different layers (Figure 2-14). The bottom layer was built of 6 to 10 tons of sand heated with a moderate fire while being constantly rabbled until all moisture was driven off. This layer was then worked with paddles until it was slightly concave in form. The doors of the furnace were then closed and sealed, and the furnace heated as high as possible for 6 to 14 hours until the layer fused. After the layer was cooled to a dark red heat a charge of 3,000 pounds of moderately basic slag was spread across the layer with paddles. The furnace was again sealed and heated for two hours until the layer liquified and was absorbed by the sand bottom. A further charge with more slag and a few hundred pounds of low grade (30 percent) matte was mixed and the whole heated until melted with the goal of saturating the hearth material with low grade matte to prevent higher grade matte from penetrating the hearth bed once work commenced. After the lower layer was completed, the upper layer was installed. This layer was more carefully worked and leveled with a gentle slope across the whole toward the tap hole. The layers were carefully cooled to prevent any cracking and at the end a small quantity of finely crushed slag was placed along the edges of the furnace at the junction of the hearth bed and the furnace walls and covered with a thick layer of fire clay and crushed quartz (fettling) to help prevent the charge from penetrating the furnace along the seams (Peters 1895:486-487). After these preparations were complete the furnace was ready for use.

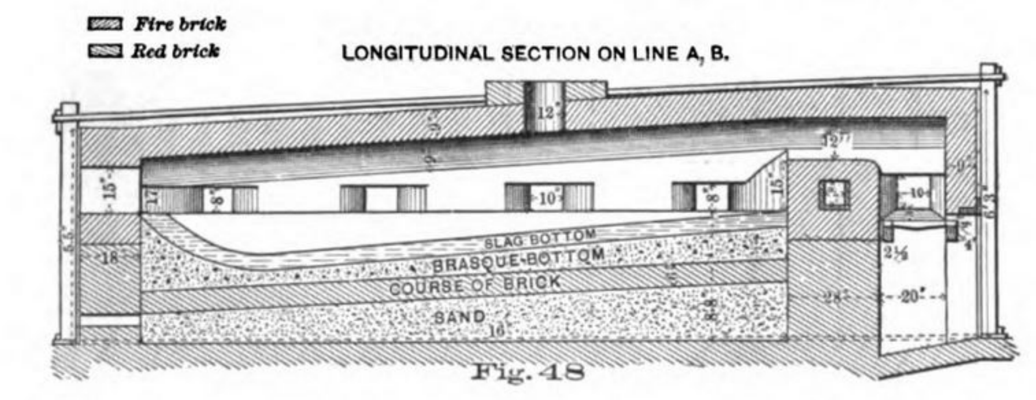


Figure 2-14. Cross-section of reverberatory furnace showing construction of hearth floor. Illustration from Hofman 1893:163.

Copper Blast Furnace

The main alternative to the reverberatory furnace for the reduction of copper-gold ores was the blast furnace. The use of blast furnace for copper ores was rare in Colorado. This is largely due to the relative rarity of gold ores in Colorado and the dominance of the Boston and Colorado company for the working of copper-rich ores (they continued to rely on reverberatory furnaces through the end of the century). Blast furnaces of this type were erected at some of the large Front Range smelters in Pueblo to augment their lead-silver blast furnaces, but the processing of copper-gold ores remained a small part of their business.

Reducing copper ores in the blast furnace was a more complicated process than reducing lead ores as several operations were required to remove sulfur from the charge as it was not economical to completely remove the sulfur by roasting. Instead the ore was roasted to remove as much sulfur as possible, then during the smelting process the remaining sulfur combined with the copper and iron in the ore to form a matte, the main objective of the smelt. The matte could successfully catch 90 percent of the copper, 96 percent of the silver and 99 percent of the gold assay values in the ore. To capture most of the gold and silver value, the amount of copper in the ores was limited (the Argo using ores averaging 3 percent copper). Higher concentrations limited the ability to concentrate large amounts of precious metals (Peters 1895:224-225).

Most American copper blast furnaces in the 1890s were water jacketed with only a few of the older brick Raschette furnaces (Figure 2-15) still in use. Water jacketed furnaces were superior in most ways to the older brick styles as they were cheaper to build, easier to maintain, and had fewer problems with the development of accretions on the interior walls. They could provide good service in conditions where the smelting process produced a minimum of corrosive products, otherwise the brickwork tendered to deteriorate rapidly and require frequent repairs (Howe 1885:85-88).

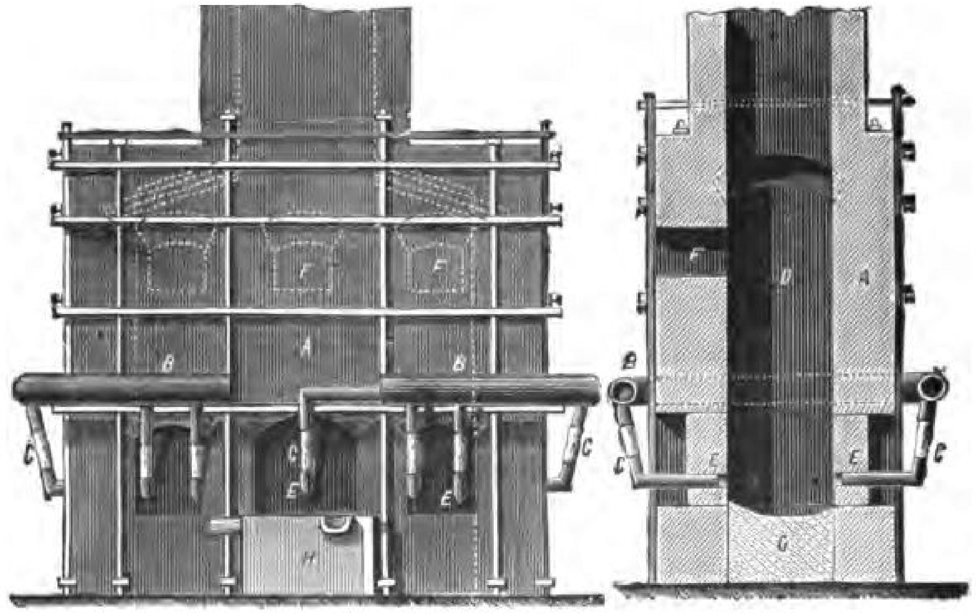


FIG. 44. ORFORD BRICK FURNACE. FIG. 45.

Figure 2-15. Brick copper smelting furnace. Peters 1895:321.

Water-jacketed copper blast furnaces were generally circular to oval with interior dimensions of 40 inches by 160 inches and equipped with 10 to 20 tuyeres. Molten slag and matte escaped from the base of the furnace, emptying into a brick-lined mobile forehearth. Slag from the forehearth poured in a constant stream into large pots and was removed either in large mule drawn slag pots or directed into a stream of water where it was reduced to a granulated form and drawn off with the water. In large plants the matte drawn from the furnace was sometimes tapped immediately into Bessemer converters for refining that reduced the charge to 99 percent pure copper. The Bessermized copper was then either cast into pigs for shipment, or as electric anodes for electrolytic refining if the copper contained precious metals (Peters 1895:243). Typical furnaces of the 1890s had a capacity of 100 to 160 tons daily.

As in lead-silver smelting, the water jackets used in copper blast furnaces were either cast iron or wrought iron. The wrought iron jackets were more common than cast iron models as they were generally more damage resistant in the higher temperature copper furnaces. Cast models tended to crack during rapid temperature changes and were harder to repair than wrought iron models (Howe 1885:89). The wrought iron water jackets were typically circular with the jacket extending from below the tuyeres to well up the side of the shaft, usually 6 to 9 feet above the tuyere level. The diameter of the furnace increased toward the top with an angle of approximately 1-inch per foot of vertical rise. The circular form of furnace was most useful for small to medium sized furnaces as the blast could only penetrate a charge to a depth of about 48 inches. Larger furnaces were built with a rectangular shape so that the blast could reach through the charge most efficiently while still handling large volumes of material. The furnaces produced black copper if working oxidized ores, or matte if working high-grade sulfide ores (Peters 1895:267)

The main problem experienced by wrought iron jackets was that many ores contained copper sulphates that corroded the upper part of the furnace. The problem was overcome by making the inner shell of the furnace out of copper which was more corrosion resistant (Peters 1895:269).

The base of the furnace was usually constructed of layers of firebrick or fireclay. The longevity of the base was dependent on the quality of the materials produced. Low grade matte tended to erode brick hearths causing their eventual failure. To avoid this problem the forehearth was developed. Forehearths were exterior hearths that allowed the furnace products to settle outside the furnace. These could be quickly replaced if needed and did not require the partial dismantling of the furnace for repairs that was required by interior hearths. The forehearth was essentially a cast iron box outside the furnace shaft that caught the molten materials. Once in the forehearth, the materials separated according to their specific gravities during lead-silver smelting. The simplest forehearth consisted of four cast iron plates, set on a cast iron base that was itself mounted on a wheeled base. The hearth included a removable cast iron spout for pouring off the furnace contents and a vertical slot on one side to accept the furnace tap hole. Forehearths were lined with protective materials ranging from a simple mixture of straw and clay for furnaces working high-grade matte, or a fire brick lining if the furnace produced an iron rich slag or worked low-grade matte (Peters 1895:284).

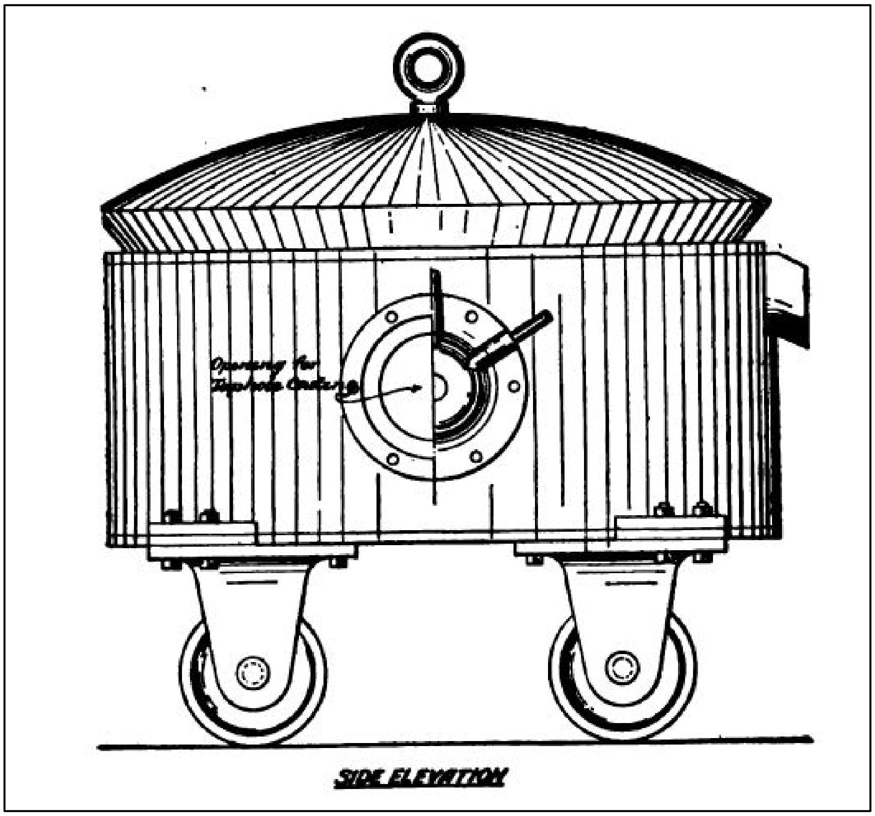


Figure 2-16. Example of a forehearth used in copper blast furnaces. Illustration from Peters 1895:291.

A specialized reverberatory forehearth was used for blast furnaces serving Bessemer converters. This consisted of a settling reservoir constructed like a simple reverberatory furnace. This allowed the matte tapped from the furnace to be maintained at a liquid temperature for feeding into the converter. The molten materials flowed from the furnace into the forehearth, with the slag flowing our immediately and the matte sent to the converter through a siphon or by using a ladle (Peters 1895:298-300).

If this type of forehearth was not used, or if it was necessary to store the matte, it was allowed to solidify. The solid matte was then be broken up and fed into a separate blast furnace for remelting when desired (Peters 1895:303). A specialized type of blast furnace using strong blast pressure, hot blast and high charge columns was used for the remelting of solidified matte for feeding into a Bessemer converter or for smelting ores consisting mostly of silica and metals under highly oxidized conditions (Peters 1895:306).

Copper blast furnaces were designed to partially oxidize the ores in addition to smelting them. This required a furnace design that allowed a light blast to penetrate the entire ore column. Furnaces of this type were rectangular, up to 14 feet long, but with a width of only 32 to 38 inches with perfectly perpendicular walls. Since the blast was light the tuyeres were increased in diameter to ensure an equal amount of air flowed in the furnace. The oxidizing conditions also required that the height of the ore column be reduced, with a height of 4 to 6 feet above the tuyeres level typical (Peters 1895:308-309). Matte from the furnaces was tapped periodically into slag pots of 1,000-pound capacity while leaving sufficient matte in the forehearths to continue the separation of the slag efficiently. The slag in small plants was generally removed by small slag pots, while larger plants either used large pots hauled mechanically or granulated their slag in a stream of water (Peters 1895:311).

Archaeologists are unlikely to encounter blast furnaces designed for copper smelting at most small sites. The possibility does exist, however, as historical records are not specific about the forms of blast furnaces used and the potential for their presence in the Colorado mountains should not be discounted. If ores within the district contain a significant amount of copper minerals, a close examination of blast furnace remains should be made to determine if this type of furnace was used.

2.2.3 Pyritic Smelters

The last type of smelting adopted in Colorado during the nineteenth century was pyritic smelting. This involved modifications to traditional blast furnace design in an effort to reduce fuel costs. The efficiency of pyritic furnaces led to a small revival of small smelter construction in the early twentieth century, but during the nineteenth century the type was limited to two experimental plants in Lake and Summit counties. The following discussion is intended to provide basic information for archaeologists that may encounter small twentieth century pyritic smelters during field investigations.

The last type of smelting introduced in Colorado during the nineteenth century was pyritic smelting. Pyritic smelting involved the use of a blast furnace similar to those used in lead-silver or copper smelting, but used the heat generated by the oxidation of sulfide ores to minimize or eliminate the need of additional fuel (CIW 1896:29; Lang 1896:42). During the 1890s two Colorado smelting companies experimented with the pyritic method but were unable to successfully adopt a fully pyritic smelting method, finding that some fuel still needed to be included in the charge.

The Colorado smelting community was enthusiastic about the potential of pyritic smelting due to the significant reduction in fuel costs that could be realized once the method was perfected. The coke charge used in conventional copper blast furnaces accounted for approximately 65 percent of total smelting costs, while the conversion to pyritic or semi-pyritic smelting could reduce the figure to around 20 percent. It also eliminated the need to roast the ore as the decomposition of the previously undesirable sulfur and iron could was now used as the primary source of heat for the furnace. This allowed for the elimination of the roasting and calcining departments, which accounted for 15 to 50 percent of the smelting expenses at conventional blast furnaces. The elimination of handling required by the roasting process had the added advantage of eliminating the loss of ore fines due to excessive handling (Peters 1895:380).

The pyritic process had not reached maturity by the turn of the century as coke was still required to smelt the ore charge. However, fuel savings were substantial and the use of hot blast and 1.5 to 5 percent coke in the charge often made it the most economical reduction method available. The pyritic method also proved to be the only smelting process that could efficiently handle heavy spar (baryta) materials leading to a brief recovery in some mining regions. Colorado was in the forefront of experimentation with pyritic smelting. In 1895 the two smelters experimenting with the method (the Bi-Metallic at Leadville and the Summit in Kokomo) accounted for half the pyritic furnaces in the country (Douglas 1895:30-31; Schnabel 1898:166; Peters 1895:392-393, 415).

The design of a pyritic plant was essentially the same as a conventional copper blast furnace with a hot-blast stove, blowing apparatus, forehearth and flue dust chamber (Peters 1895:417). Although any slag capable of easy running was acceptable, it required the ores to contain enough sulfur and iron to fuel the pyritic reactions (Peters 1895:419). Colorado had two early pyritic plants, both of which showed excellent recovery of gold and silver. The plant at Kokomo recovered 85 to 90 percent of the assayed silver value and 100 percent of the assayed gold content of the ore. The Bi-Metallic plant at Leadville was one of the largest pyritic smelters in the world at the turn of the century with a daily output of 250 tons that recovered 93 percent of silver and 95 percent of assayed gold values in the ores (Peters 1895:433, Tonge 1900:821).

2.3 Non-smelting Methods of Recovering Gold and Silver

The previous sections in this chapter have described the various types of smelting practiced in Colorado during the nineteenth century. Smelting was not the only method of separating gold and silver from the ores of Colorado. Various chemical means of processing ores were also practiced in Colorado during the period of study. This section briefly discusses the main types of chemical reduction practiced in the state that used mercury, chlorine, or cyanide for ore production. This is intended to provide a more complete view of the options available to mine owners during the period.

The main competitors to smelting for the reduction of complex ores were chemical processes that used either mercury, chlorine, or cyanide to capture the gold and/or silver which were then precipitated through various means. Free milling ores with native gold or silver were able to be processed by the use of simple amalgamation. More complex ores required additional treatment. The Washoe Process was developed in 1860 on the Comstock to process ores more rapidly than the old Spanish cazo process where crushed ore was mixed with salt and water in tubs and then boiled. The resulting amalgam was recovered after 10 to 20 hours of agitation and boiling. The Washoe Process added mechanization to the cazo process which was made more efficient by the addition of iron, often from the machinery itself. A modification of the process was developed in 1862 in the Reese River district of Nevada to work ores that were more refractory than those found on the Comstock. The processes differed mainly in adding a roasting step to the process with the addition of salt that transformed the silver sulfides in the ores to chlorides that were more easily worked (Meyerriecks 2003:131-142).

2.3.1 Chloridation

The Chlorination, or the Plattner Process was commonly used for the reduction of gold ores, but rarely silver ores as it was less efficient than other methods. The process was based on the tendency of chlorine to produce compounds with gold (gold chlorides). The process was originally developed by Karl F. Plattner in Germany during 1848 but was not introduced at a significant scale in the United States until around 1860. The process required careful roasting prior to treatment, which often formed half the processing costs due to the large amount of salt required to form a chloridizing roast.

After roasting the process entailed placing the ground ore into large leaching vats (typically holding around 3 tons of ore) with a false bottom of closely spaced boards to allow the chlorine gas to pass through the ore and to allow easier cleanup of the charges (a filter of quartz sand and gravel underlay the false floor which helped to prevent the filter from being disturbed during cleanup. The leaching tanks had an entry for the chlorine gas and an opening on the opposite side to allow for its removal (Wilson 1907).

Processing the ore took anywhere from 3 to 6 hours, during which time gold chloride was formed. In the early years removing the product required opening the vat and allowing the gas to dissipate (a dangerous process for the workers due to the danger of accidental inhalation of chlorine gas). The resulting liquid was drained into a settling tank and washed for several hours before being sent to precipitation tanks. The process could produce bullion up to 990 fineness. The entire process took at least four days, so most mills cycled vats in groups of four to maintain continuous production. Continual improvements to the process were made in the nineteenth century to speed up the process and to reduce costs (Wilson 1907).

The chlorination process was expensive, largely due to the required sulfuric acid, which was difficult and expensive to transport. The process also involved the use of highly toxic substances that were dangerous for workers. But it remained one of the main alternatives to amalgamation and smelting for the processing of ores until cyanidation was developed near the end of the century.

2.3.2 Cyanidation

The use of cyanide only began at the end of the nineteenth century, although it became the most common method of processing gold and silver ores during the early and mid-twentieth century. During the 1890s the use of cyanide is best shown at Cripple Creek. In the early years ore processing was dominated by the chlorination process, but cyanide milling started becoming more and more common after 1900 with the last chlorination mill closing in 1911 with cyanide controlling the whole process. Smelters had ceased to receive significant amounts of Cripple Creek ores by the mid-1890s.

The first patent (for the process was awarded to John MacArthur and Robert Forrest, who developed the process in England in 1887, with a US patent following in 1888 (U.S. Patent No. 418,137). It was first used in New Zealand (1889) and the Transvaal (1890) before the first use was undertaken in Utah in 1891 (Richards 1897). The process was much cheaper than chlorination as both cyanide and zinc, used to precipitate gold from the cyanide solution, were less expensive than the components needed for Chlorination. The process works best on free milling gold ores but can be used in the recovery of silver as well. The process was retarded by ores that were extremely fine (due to caking or lack of movement of the solution), or that contained contaminants, especially wood, etc. from mines or found in old tailings that tended to absorb the cyanide rather than allowing it to react with the ore. Finely crushed ore was seeped in a dilute solution of cyanide in wooden vats and then the pregnant solution was passed through boxes filled with zinc shavings that precipitated the gold. The zinc shavings were then dissolved with dilute sulfuric acid and the remaining gold particles collected by filter presses (ITC 31-1 to 32-13).

This chapter has given a detailed overview of the smelting processes used in the Colorado smelting industry to provide a base of knowledge for the reader going forward to understand the types of smelting furnaces available to Colorado metallurgists during the nineteenth century. In the following chapters on the history of smelting in Colorado these furnace types will be frequently referred to during discussions of specific smelting sites. The types of smelting practiced in

Colorado tended to evolve through time. Hearth furnaces were generally only used in the 1860s with most operations moving to blast furnaces for lead-silver ores in the early 1870s. Small smelters processing copper-gold ores depended on reverberatory furnaces throughout the period. Although blast furnaces came to dominate the smelting industry starting in the 1880s, it is entirely possible that some operations adopted hearth or reverberatory furnaces for lead-silver work during later periods. An understanding of the various smelting types detailed in this chapter can help investigators of smelting sites verify the type of furnace used at their sites.

3 Early Colorado Smelting

This chapter describes the early period of Colorado smelting and is broken into two main sections. The first section discusses the early history of mining and smelting in Colorado covering the period from 1861 to approximately 1885. The discussion begins with a review of the mining and smelting history of Colorado with separate sections detailing the development of transportation in Colorado, and the economic conditions that helped shape both the mining and smelting industries during the period. The chapter then proceeds to detailed examinations of four early smelting operations to provide examples of how some of how these works operated. The second part of the chapter (Section 3.4.5) is a discussion of the small mountain smelters of the state derived from numerous historical sources. Although by the nature of the available historical sources this section does not identify every smelter in the state, it is one of the first comprehensive examinations of the small smelters of the state.

The settlement and early history of Colorado was dominated by the quest to locate and exploit precious metal deposits. The first deposits to attract attention was the gold found in the streams and rivers descending from the mountains. As these deposits were rapidly exhausted attention shifted to identifying the lode deposits that were the source of the placer gold. The surface deposits of the early lodes were generally decomposed quartz and easily processed. As the enriched upper deposits were depleted however it became necessary to develop methods to treat the refractory ores found at greater depth. The inability to process the new refractory ores sent Colorado mining into a depression until a successful smelting industry was developed. This chapter will examine the early history of mining in Colorado and the concurrent development of the milling and smelting industries that processed the ores of the mines.

3.1 Early Exploration and Mining

One of the earliest known forays into Colorado was in 1761 when Juan de Rivera led an expedition north from Santa Fe to explore the San Juan Mountains north of present Durango (Athearn 1992). Records of the expedition do not mention the discovery of gold or silver deposits, but it seems likely that some precious metals were discovered in Baker's Park near the present town of Silverton. Early Anglo-American prospectors and miners in southern Colorado mention evidence of earlier Spanish mining at scattered locations, but any evidence of these early mines was destroyed by later mining activity. If the Spaniards worked mines in Colorado, they left no records and probably conducted their operations in secret to avoid taxation by the Crown. Other than the early expeditions like Juan de Rivera, Spanish government involvement in Colorado prospecting and mining is unknown (Smith 2000: 9-10).

During the following fur trade period there were no major gold discoveries despite the extensive and wide-ranging exploitation of the rivers and streams of the area.

Only two verified accounts from the period are known. During his imprisonment in Santa Fe explorer Zebulon Pike heard a rumor that a trapper named James Purcell had found gold in the South Park area around 1800. Unfortunately, Pike's journal was lost and did not resurface until the 1950s and the story was not widely known and failed to stimulate exploration of the state (Fell and Twitty 2008). The other discovery was made by a member of John C. Fremont's 1848 expedition, near the future site of Lake City. This discovery also failed to attract significant attention being overshadowed by the gold discoveries in California in 1848(Henderson 1926).

The first observation of gold in Colorado that had a significant impact on the state's history was made by California-bound prospectors in 1849. During the migration to California, John Beck and Lewis Ralston located faint colors in streams in the Denver area including. Although the quantity of gold observed was not sufficient to turn them away from California, many of them would return to Colorado in later years.

During 1858, a prospecting party led by William G. Russell left Georgia to investigate the gold discovery made by party member John Beck a decade earlier. The party arrived at the future site of Denver and began prospecting Cherry Creek in the spring (Rickard 1896:835-836). The Cherry Creek placer deposits were derived from paleo-river channels in the Castle Rock conglomerate and Dawson arkose formations of the Palmer Divide. They occurred in small pockets and consisted of fine gold that was difficult to recover. The party worked down the creek to its confluence with the South Platte River and then up Ralston Creek where the gold values increased. The source of these water courses originated in the mountains where geologically younger deposits contained greater quantities of gold. The placer deposits of the Front Range were fairly poor, but by chance an itinerant trader named John Cantrell passed through the Russell Party camp and purchased a bag of gravel from one of the banks. Cantrell took the gravel east where he panned it publicly to great fanfare. The exaggerated reports of the gold deposits led to the Pike's Peak gold rush of 1859 (Henderson 1926:27).

The large number of prospectors involved in the Pike's Peak rush rapidly depleted the gold deposits in the Denver area and the limited placer mining opportunities on the plains and prospecting parties soon followed the streams up into the mountains. Early in the year important placer mining areas had been discovered on Boulder Creek, North Clear Creek and on Idaho and Spanish bars on South Clear Creek. By August additional rich placer diggings were located in South and Middle parks (Rickard 1896:836-837). Although many of the "59ers" left in disappointment due to the overblown reports of the riches of Colorado and the harsh, isolated conditions of the area, others remained. In 1860 towns began to spring up in the mountains including Black Hawk and Central City along North Clear Creek, and Empire, Idaho Springs, Georgetown, and Silverplume on South Clear Creek. In South Park the towns of Tarryall, Buckskin Joe, and Fairplay were founded soon after. The year also witnessed gold discoveries at California Gulch at the future site of Leadville; Ten Mile Creek to the north, and along the Blue River at the future site of Breckenridge. Further gold deposits were found in the San Juan Mountains by Charles Baker in Baker's Park near the present location of Silverton, but little development in the San Juan Mountains occurred during this early period as placer gold in the park was limited and the early prospectors lacked the experience to identify the rich silver lodes of the Park. The low returns gave the region a bad reputation and further work in the San Juans was delayed by nearly a decade. This was compounded by the difficulty of transportation in the rugged mountains and the hostility of local Ute tribes (Smith 2000: 7-12)

Within the first few years the richest placer deposits were exhausted and the search for the parent lodes of the placers began almost immediately. The first lode deposit identified in Colorado was the Gregory Lode discovered by John Gregory at the Gregory Diggings. The ore body consisted of approximately 40 feet of decomposed pyrites, gossan, quartz and dirt overlying unoxidized deposits of quartz and pyrites that was referred to as the cap. The decomposed ore was extremely rich in gold (Hollister 1867: 64). The discovery of the lode led to the earliest documented milling activities in Colorado with an *arrastra* built to process the quartz in July of 1859. The arrastra was a simple milling apparatus adopted from Spanish practice but with roots extending to at least Roman times. It consisted of a circular floor of tough igneous or metamorphic stone blocks surrounding a central post pivot that was turned by horses or mules. One or two large drag stones were attached to a beam on the pivot. As the stones rotated a small amount of water was run into the arrastra and the movement of the stones reduced the ore to a slime that flowed out of the arrastra through an opening equipped with a screen (Young 1970:69-71). By September of the year a small steam-powered stamp mill was running at the lode (Henderson 1926). With the switch from placer to lode mining many of the earliest mining camps were abandoned after only a few years of life-giving rise to the first wave of ghost towns in the state.

Early lode mining concentrated in the two most heavily explored areas, the valleys of North and South Clear Creek. Both became well-known mining regions and dominated the Colorado mining scene throughout the 1860s. The mines of North Clear Creek (Gilpin County) were centered on the towns of Black Hawk and Central City. The South Clear Creek mines were strung along the valley with two main loci at the far ends. Idaho Springs (Idaho City) formed the east end of the South Clear Creek mining area and Georgetown/Silverplume the west end. However, smaller mining communities were located in between including Downieville, Dumont (Mill City), and Lawson. Throughout its history the Gilpin County mines produced mostly gold, whereas the Clear Creek County mines produced mostly silver.

A common feature of both areas was the presence of extremely rich free milling oxidized ores with simple arrastras and stamp mills. Although capture rates were high, sufficient gold remained in the tailings to be a valuable asset for future milling companies with more advanced technology. The rich surface ores were rapidly exhausted and it was quickly determined that the underlying ores were not amenable to simple amalgamation (Hollister 1867:64) and the recovery rate of many mills in Gilpin County declined from an initial eighty percent to twenty percent or less (Browne and Taylor 1867).

The rapidly dropping returns on the refractory ores led to desperation in the mining community encouraging the adoption of a variety of ineffective reduction methods. The phenomenon was termed “process mania” by Rossiter Raymond and dominated the period of 1864 to 1867. The processes were generally aimed at the removal of sulfur from ores to allow their processing by conventional amalgamation techniques. Most of these methods were at best experimental and many were downright fraudulent. The problem was compounded by the secretive nature of the inventors and the lack of experience on the part of the miners who were unable to accurately gauge the potential success of the methods. Some of the most notable processes attempted during the period included adaptations of the Keith Process, the Crosby and Thompson’s Process, Kent’s Process, Mason’s or Hagan’s Process, and Monnier’s which were various forms of attempting to desulfur the ores. Although some, like Keith’s, Kent, and Monnier processes, worked in the laboratory, they were completely unsuccessful when applied to Colorado ores. The Crosby and Thompson Process and the Mason's or Hagan's Process were processes rejected professionally in Europe that were attempted in Colorado. The remainder were largely fraudulent, or so poorly designed that there was no reasonable expectation they would work. One of the most questionable processes was the Bartola Process used at the Whale Mill where ores were exposed in vats to different chemical agents. The process was so poorly designed and misrepresented that Raymond stated:

> It is difficult to reconcile the history of this invention with the hypothesis of honesty on the part of the inventor… It may be said of Bartola's method that it was neither metallurgically nor economically successful on a large scale and its principle legacy to the Territory has been a large amount of wholesome experience and more or less useful second-hand equipment. (Raymond 1870:356-358).

Most of these questionable processes were abandoned by 1867 leaving the South Clear Creek valley littered with abandoned mills (Smith 1984a).

The failure to find a solution to profitably work Colorado ores led to an economic decline in Colorado that was worsened by unrelated outside factors. Prices in Colorado rose during the 1860s due to a combination of transportation difficulties and the effects of the Civil War. The high inflation during the war led to an initial flurry of investment in Colorado mining as gold mines were viewed as a safe commodity not subject to inflation. However, unscrupulous and/or overly optimistic mining companies made promises of profits that were not achievable, and investment rapidly dried up as it became clear that the mines did not yield profits commensurate with the level of investment. Transportation to the territory was already difficult, but the start of the Plains War of 1864 -1865 when violence between plains tribes and Anglo-American settlers made freighting and travel to Colorado both expensive and dangerous. In response many mines closed in the late 1860s creating a decline in production (Rickard 1896:840-842; Fell and Twitty 2008:11-12). The situation began to stabilize at the end of the wars and the arrival of railroads in the 1870s.

Gold had been discovered in the San Juan Mountains, perhaps as early as the eighteenth century, but the first well documented discovery was by the Baker party in 1860-1861. The party explored much of the San Juan Mountains, and although they found only a small amount of gold, they found rich silver deposits in many areas. Due to the isolated nature of the region and the hostility of the local Ute tribes the area could not be economically exploited, and the region was largely abandoned. Mining activity in the area revived in the 1870s when miners returned to Baker's Park (the Silverton area) in 1871.The area was still occupied by hostile Ute tribes determined to protect their territory and violent confrontations occurred between the groups. Political pressure by the mining interests led to the negotiation of the Brunot Treaty of 1873/1874 under which the Utes surrendered their claim to the area (Smith 1992:76-77). In an effort to learn more about the large area the government had just acquired the Wheeler and Hayden expeditions were dispatched in 1874 and 1876, respectively. The priority of both parties was to determine the mining potential of the area. With settlement now possible due to the treaty the communities of Silverton (1873) and Ouray

(1875) were established, however both towns were isolated and difficult to access. To address the problem (and make himself a handsome profit) Otto Mears began the construction of a series of toll roads to service the region. The earliest was the Saguache & San Juan Toll Road that connected the Arkansas River Valley with Silverton. During the construction of the road in 1872 a rich silver deposit was discovered near the future site of Lake City. The road reached Silverton in 1877 with a branch reaching Ouray in 1882 (Rickard 1896a:841-842; Fell and Twitty 2008:22).

3.2 Transportation

One of the most important factors in the development of mining and smelting in Colorado was the difficult nature of the terrain. Access to most mining areas was extremely difficult in the early years, making shipping materials in and out of new mining districts extremely expensive. These difficulties created the opportunity for the small mountain smelters to develop. Their role in producing an intermediate product that was cheaper and easier to transport than raw ore both allowed isolated mining regions to develop and stimulated the further development of Colorado’s transportation network. This section focuses primarily on the development of Colorado’s railroad network from the early 1870s to the turn of the century. Where possible the section discusses transportation improvements in chronological order. However, the discussion on railroads is grouped by railroad (listed in the order they were chartered) leading to some overlap of dates. This section provides an important overview of transportation issues that will be further developed in later chapters of the dissertation.

Improving the transportation network in Colorado became a priority immediately after mining in Colorado began. At first traffic followed small trails, which often followed prehistoric Ute trails through the areas. These trails were soon supplemented by the construction of wagon roads with the first toll company charters dating to 1859 (Figure 3-1). In the area depicted on the Denver 1° by 2° USGS quadrangle over 250 wagon road and toll roads were built in the area during in the mid to late nineteenth century, while approximately 100 were built around Leadville. The number of roads ultimately built in Colorado is unknown, but the region was soon crisscrossed by primitive roads (Scott 1999, 2004).

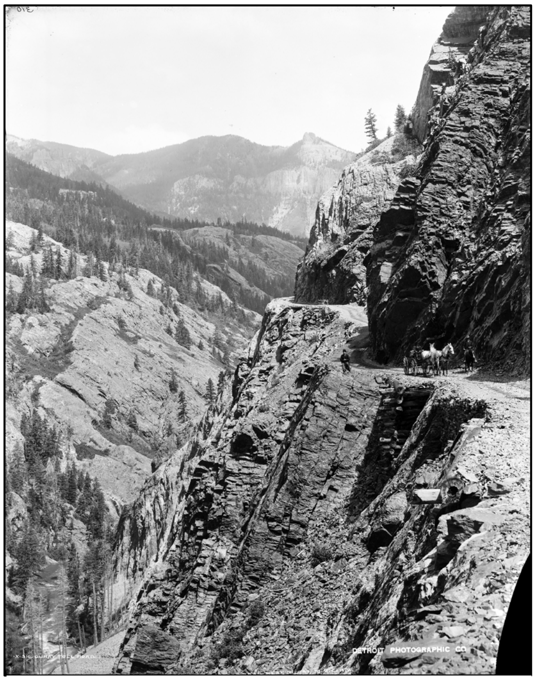


Figure 3-1 Otto Mears Road between Silverton and Ouray. Colorado Historical Society, CHS.J3659.

The importance of Due to the lack of a connecting road in 1875 ores from the mines on Middle Boulder Creek and Left Hand Creek required freighting a distance of approximately 45 miles out of the mountains to the plains, south to Golden (then called Golden City), and then back into the mountains to reach the

Boston and Colorado Smelter at Black Hawk for reduction when the distance as the bird flies was only 19 miles. Due to the failure of local smelting ventures, the mines of Clear Creek County had to ship ores 15 to 30 miles to Black Hawk. The mines of Park County were able to ship ores to the Boston and Colorado branch smelter at Alma, but the resultant copper matte had to be shipped 120 miles to Denver for transportation east. The company determined it was cheaper to close the smelter and require the mine owners to transport ore or concentrates to their Denver works. The mines of the Rosita District (near modern West Cliff in the Wet Mountains) needed to ship their ores 190 miles to the nearest smelter, whereas the mines of the San Juan Mountains were the worse off having to ship their ores and concentrates to Pueblo, requiring the crossing of ”two snowy ranges [in between] and spend ten days at least on the road before the furnaces are reached.” Raymond 1875:286-287.

Networks of wagon roads radiated from towns at the terminus of railroad branches to districts off the line. The Denver South Park and Pacific (DSP&P) end of track at Webster in the 1870s was the origin of at least eight wagon roads that served the Montezuma, Hall Valley, Fairplay, and Leadville areas.

The complimentary role of railroads and wagon roads allowed large areas to develop, but for a district to become truly successful it required a direct railroad link. The earliest section of railroad in the territory was a short (nine mile) segment of the Union Pacific (UP) transcontinental railroad that passed through the extreme northeastern corner of the territory enroute to Cheyenne. See Figure 3-2 through Figure 3-6 at the end of Chapter 3.2. To ensure that Colorado cities would be serviced by railroads William Loveland, a prominent early Colorado entrepreneur, had attempted to convince the UP to use a route through Golden, up the valley of South Clear Creek and over Berthoud Pass for the original transcontinental railroad route. However, a preliminary examination by UP chief engineer Grenville Dodge led to the immediate dismissal of the idea and the much easier path over South Pass in Wyoming was chosen. In cooperation with the Union Pacific Railway a group of influential Denver businessmen organized the Denver Pacific Railroad to connect Denver with the Union Pacific at Cheyenne in 1867. A dedicated connection to the east, was imminent as well as the Kansas Pacific was building toward Denver in 1869 (Poor 1976:40-43). Almost immediately additional railroad companies were chartered to connect the urban centers of Denver and Golden with the mountain mining communities.

Beginning with the construction of the Denver Pacific (DP) railroad, Colorado’s railroad network grew almost continuously until the early twentieth century. Numerous railroads were chartered or entered Colorado during this period but four accounted for most of the mountain railroad network: the Colorado Central (CC), Denver and Rio Grande (D&RG), Denver South Park and Pacific (DSP&P), and the Colorado Midland (CM). Other than the DP connection to Cheyenne, service out of the state was dominated by large national railroad companies including the Union Pacific (UP), the Atchison Topeka and Santa Fe (ATSF), and the Chicago, Burlington and Quincy (CB&Q). In later years the Denver and Rio Grande Western (D&RGW) built a connecting line west to the Union Pacific at Ogden by way of Salt Lake City. The state’s railroads ultimately played an important role in the development of Colorado’s smelting industry. The small smelting sites of the mountains tended to develop in the absence of railroads and withered with their arrival and the precipitous drop in transportation costs and time. The development of Colorado’s railroads were assisted by the development of the Colorado Coal & Iron Company (CC&I), the predecessor of the Colorado Fuel & Iron Company (CF&I) at Pueblo. The company had been founded with the support of William J. Palmer (president of the D&RG) in part to provide rails for his railroad.

The earliest of the Colorado chartered railroads was the Colorado Central which was chartered in 1866 (Abbott et al. 2007:20). The CC had originally intended to create a standard-gauge line between Golden and Cheyenne to connect with the Union Pacific transcontinental line. The railroad was founded under the urging of William Loveland, a local entrepreneur that wanted to make Golden the head city of the state. His plan to connect to Cheyenne received the support of the Union Pacific management who agreed to supply rails and rolling stock for the projected line (Le Massena 1987:23). Due to financial difficulties the CC proceeded slowly and was beaten to Cheyenne by the DP. In an effort to tap the rich mines of neighboring Clear Creek County, Loveland then decided to build a railroad from Golden to the mines at Black Hawk, adopting the new 3 foot narrow-gauge adopted by Palmer’s D&RG. The railroad reached Black Hawk and Boston and Colorado Smelter in 1873.

Further financial problems delayed further construction for several years. Despite promises to the contrary, the CC failed to extend a line to Georgetown as the narrow canyon of South Clear Creek guaranteed all traffic from the area was still forced to use their track at the confluence of North Clear Creek and South Clear Creek. Only with the threat of the construction of an independent railroad to Georgetown did they finally complete the branch line in late 1877 (Le Massena 1987:209, 305; Abbott et al. 2007: 334). The CC reached its maximum extent when it reached the mines at Graymont in 1884 with the creation of the famous Georgetown Loop. Although controlled by the Union Pacific, the CC remained independent until consolidated into the Union Pacific, Denver and Gulf railroad in 1890, that was in turn consolidated into the Colorado and Southern Railroad (C&S) in 1899.

Perhaps the most famous railroad in Colorado history was the Denver and Rio Grande, founded by William J. Palmer in 1870 with the intention of connecting Denver with Mexico City and serving as a north-south connecting line between the various east-west transcontinental lines. The D&RG began building south from Denver to Colorado Springs in 1871 (LeMassena 1974). At its height the D&RG operated approximately 4,000 miles of narrow-gauge track, but most was abandoned in the 1940s and 1950s (LeMassena 1974). The D&RG connected many important mining areas around the state including the coal mining areas of southeast Colorado and hard rock mining locations in the central, southwestern, and south-central regions. Most of these mining areas supported smelters prior to the arrival of the railroad, but most soon failed due to competition from the smelters of Denver and Pueblo when transportation costs decreased. Major connections made by the railroad included the mining communities of Leadville in 1880, Gunnison in 1881, Silverton in 1882, and Aspen in 1886 (Wilkins 1974).

The main competitor of the D&RG during the 1870s and early 1880s was the Denver South Park and Pacific Railroad organized by Governor John Evans in 1872. The railroad was chartered with the intention of building southwest from Denver to reach the mines of South Park and the San Juan Mountains. Construction began from Denver up the canyon of the South Platte River in 1873 but was almost immediately halted due to a lack of funding during the Panic of 1873. The railroad stalled at the town of Morrison only 15 miles from Denver until late 1876 when construction within the canyon resumed. The railroad began a race with the D&RG for the Leadville traffic, and the speed of construction rapidly accelerated reaching the eastern foot of Kenosha Pass in January of 1879. When the pass was summited a week later it was the highest stretch of railroad in the country. The DSP&P built across South Park interconnected with the D&RG at Buena Vista in 1881 providing service to Leadville. It continued its expansion reaching the mining centers of Fairplay, Gunnison, Breckenridge and

Alma in 1882 by which point the railroad had reached its maximum extent. (Poor 1976:122-152).

The company provided significant competition for the D&RG for several years but was unable to duplicate Palmer's success and remained in its shadow. The DSP&P was reorganized as the Denver, Leadville, and Gunnison in 1889, and joined the CC network in the Denver, Leadville and Gulf railroad in 1898 and the C&S in 1898. For simplicity the maps of this section retain the DSP&P designation regardless of corporate reorganizations. Most of the DSP&P system served communities also served by the D&RG. Of the major regions served by the railroad, only the South Park area remained its exclusive preserve. Most of the CC and DSP&P network remained in use through the early twentieth century, but declining mining traffic and competition from the trucking industry led to the abandonment of C&S entire narrow-gauge mountain network by 1937.

The last of the major mountain lines was the Colorado Midland. The railroad was chartered at Colorado Springs during 1872 with the intention of building a direct standard gauge route across the Colorado mining regions enroute to the Colorado River near Grand Junction. The railroad suffered from a difficult line, poor access to capital, and incompetent management that made its success unlikely from the start (Beebe and Clegg 1962:106). The railroad had extreme difficulty raising capital due to pressure from the better-established D&RG, only beginning construction west from Colorado Springs to Leadville in 1887. The

D&RG immediately began a ruinous competition with the railroad, upgrading their line between Pueblo and Leadville to three rails so it could run both narrow- and standard-gauge cars between the city. The CM reached the mines of Aspen in February of 1888 but went into receivership during the Silver Crash of 1893 and was acquired by a partnership of the D&RG and the Denver and Rio Grande Western in 1899. Sole ownership was soon acquired by the D&RG, who operated the railroad until 1918 when it was finally dissolved (Bebbe and Clegg 1962:110). In the effort to operate the shortest line possible, the railroad ran over some of the highest passes of any Colorado railroad.

The development of Colorado's transportation network was critical to the development of the state's mining industry. The expansion of the railroad network led to the initial development of, and the rapid decline of the small-scale smelting industry in the Colorado Rockies. The full implications of transportation to the failure of the industry is discussed further in Chapter 5.

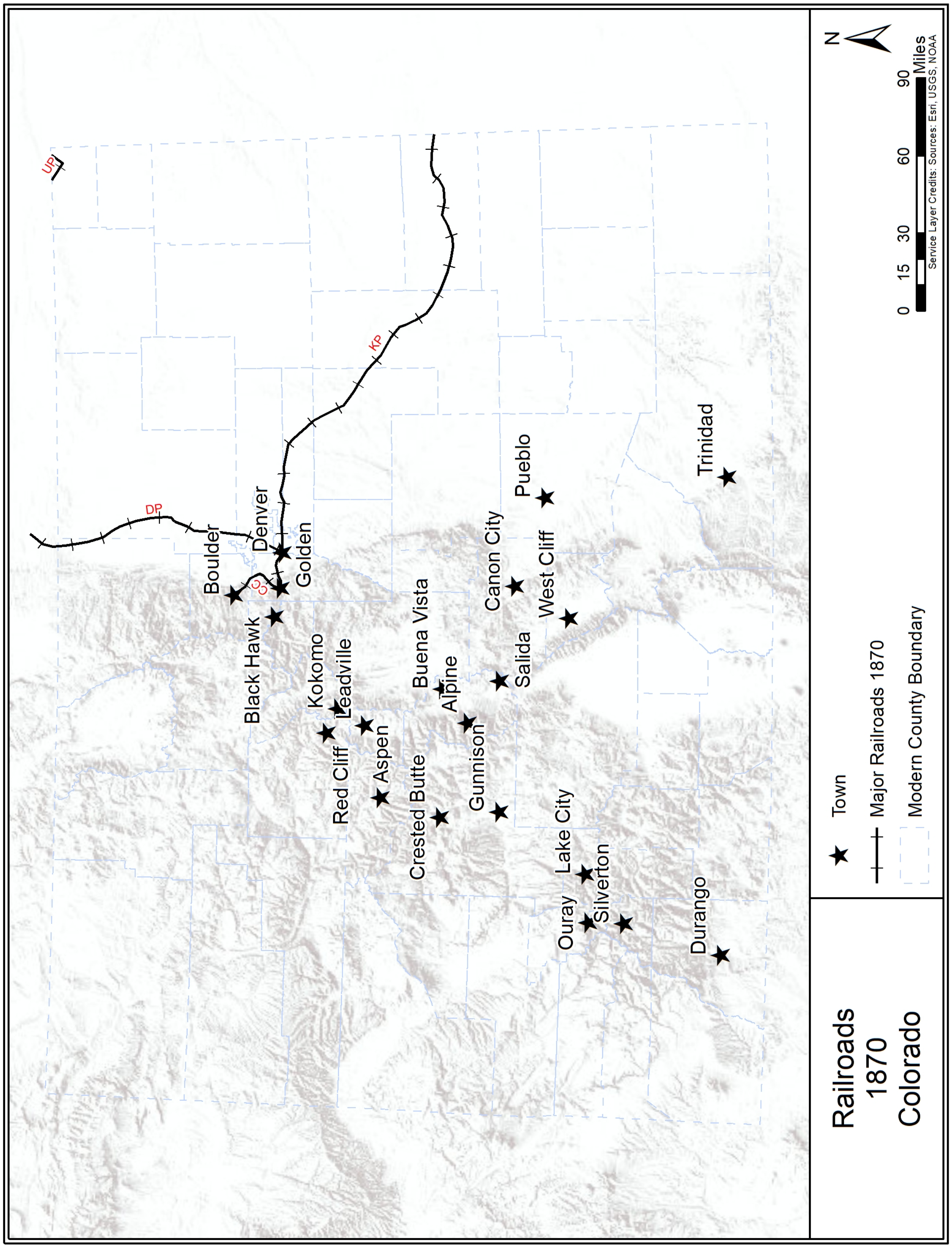


Figure 3-2. Colorado Railroads - 1870. Adapted from Robertson 1991.

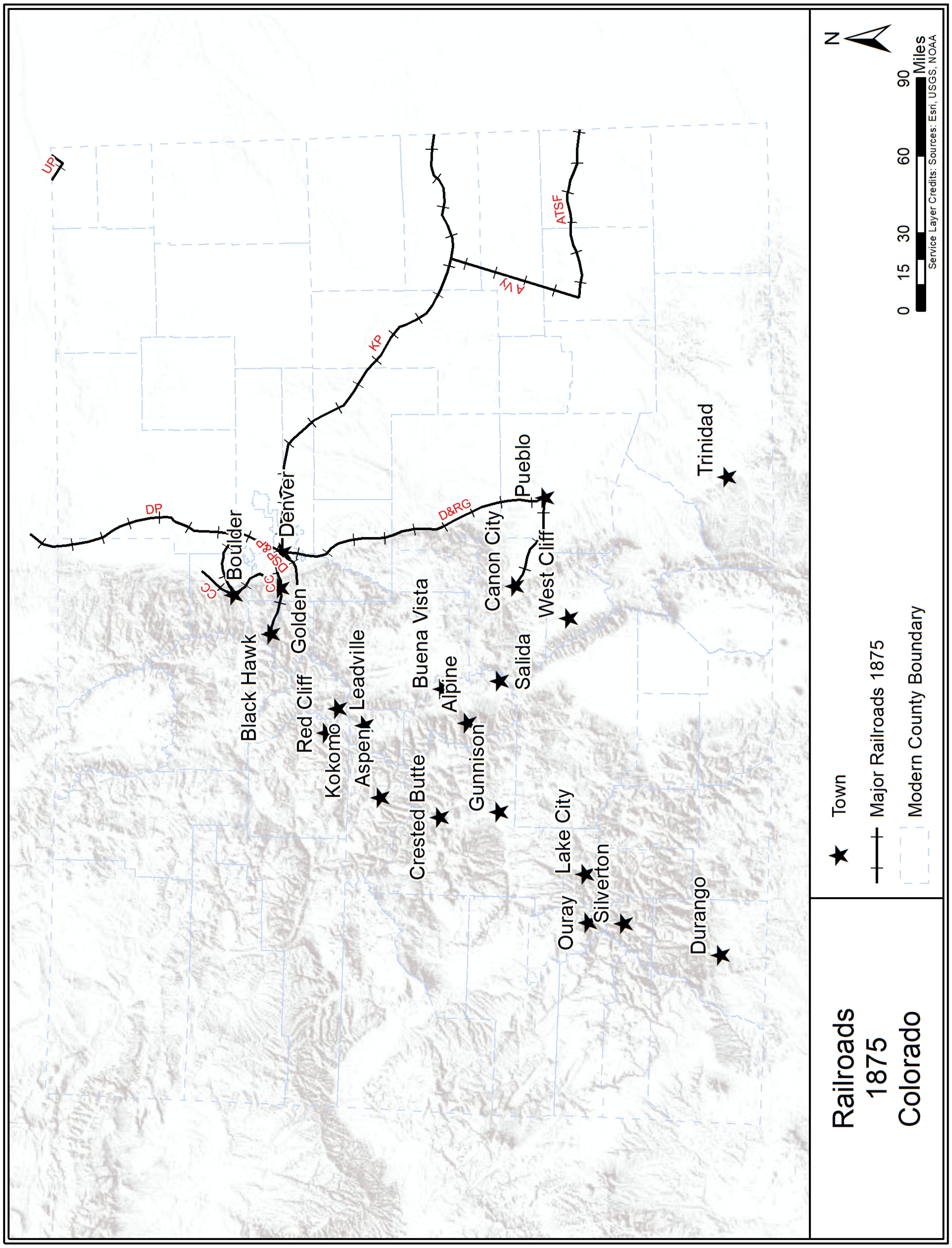


Figure 3-3. Colorado Railroads - 1875. Adapted from Robertson 1991.

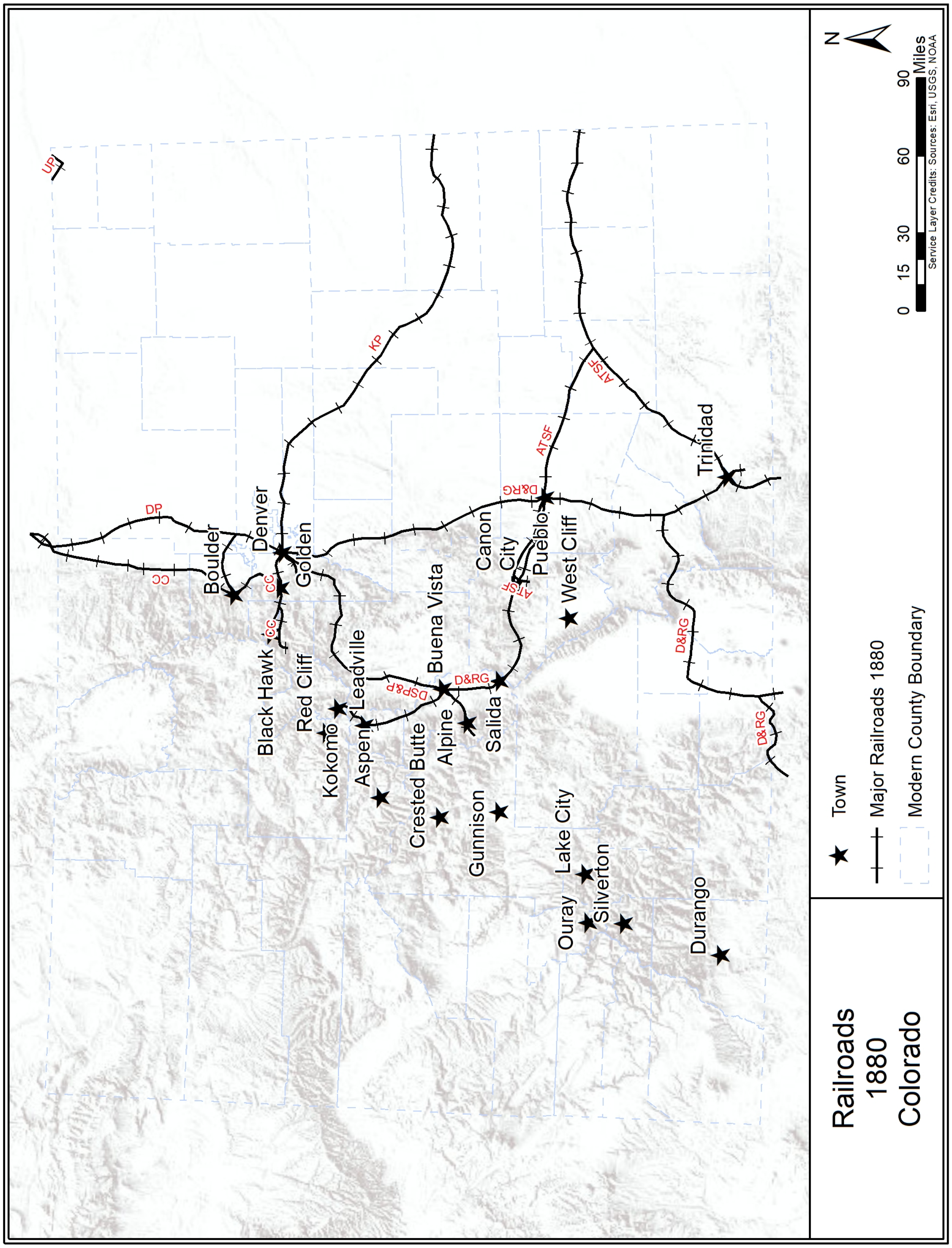


Figure 3-4. Colorado Railroads - 1880. Adapted from Robertson 1991.

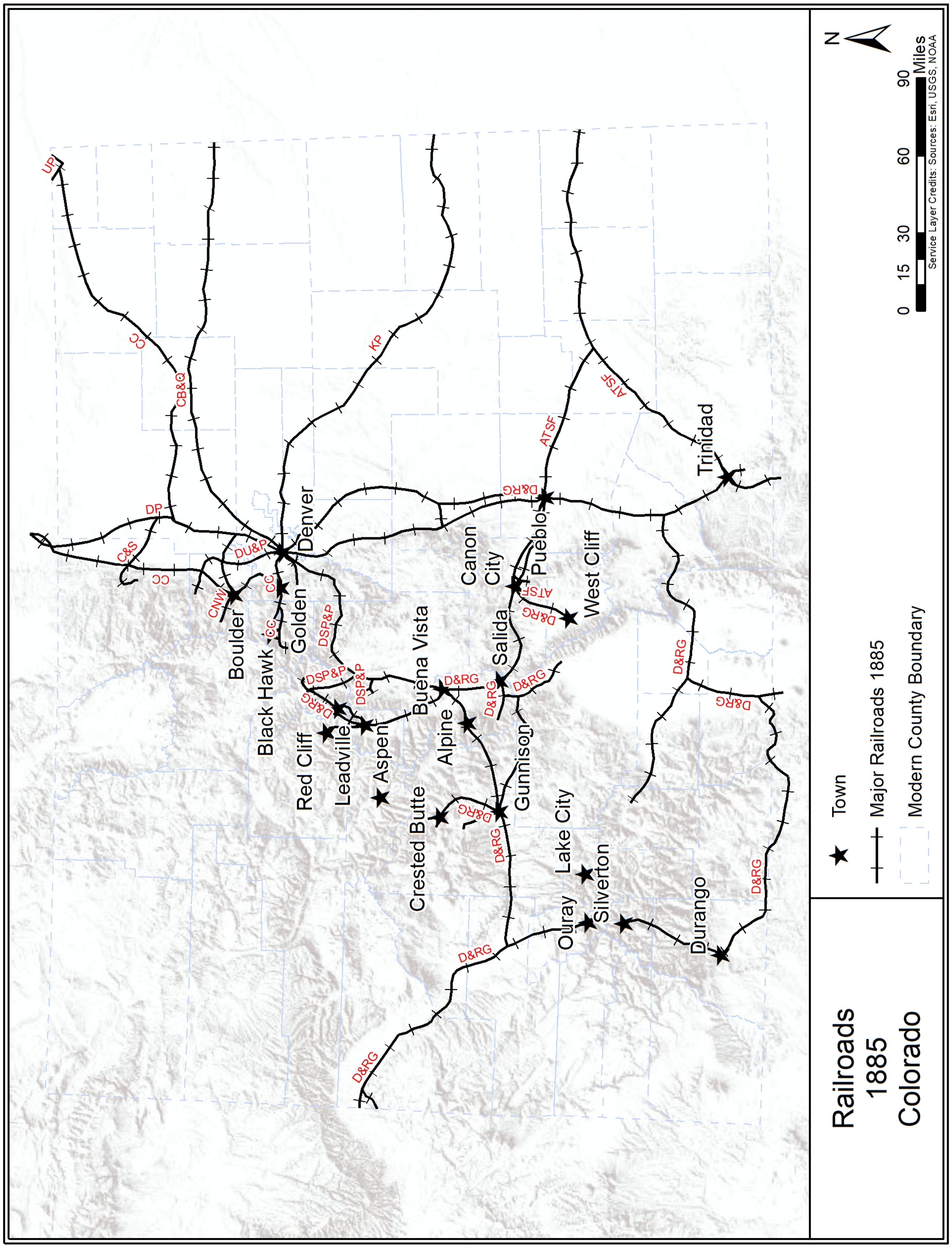


Figure 3-5. Colorado Railroads - 1885. Adapted from Robertson 1991.

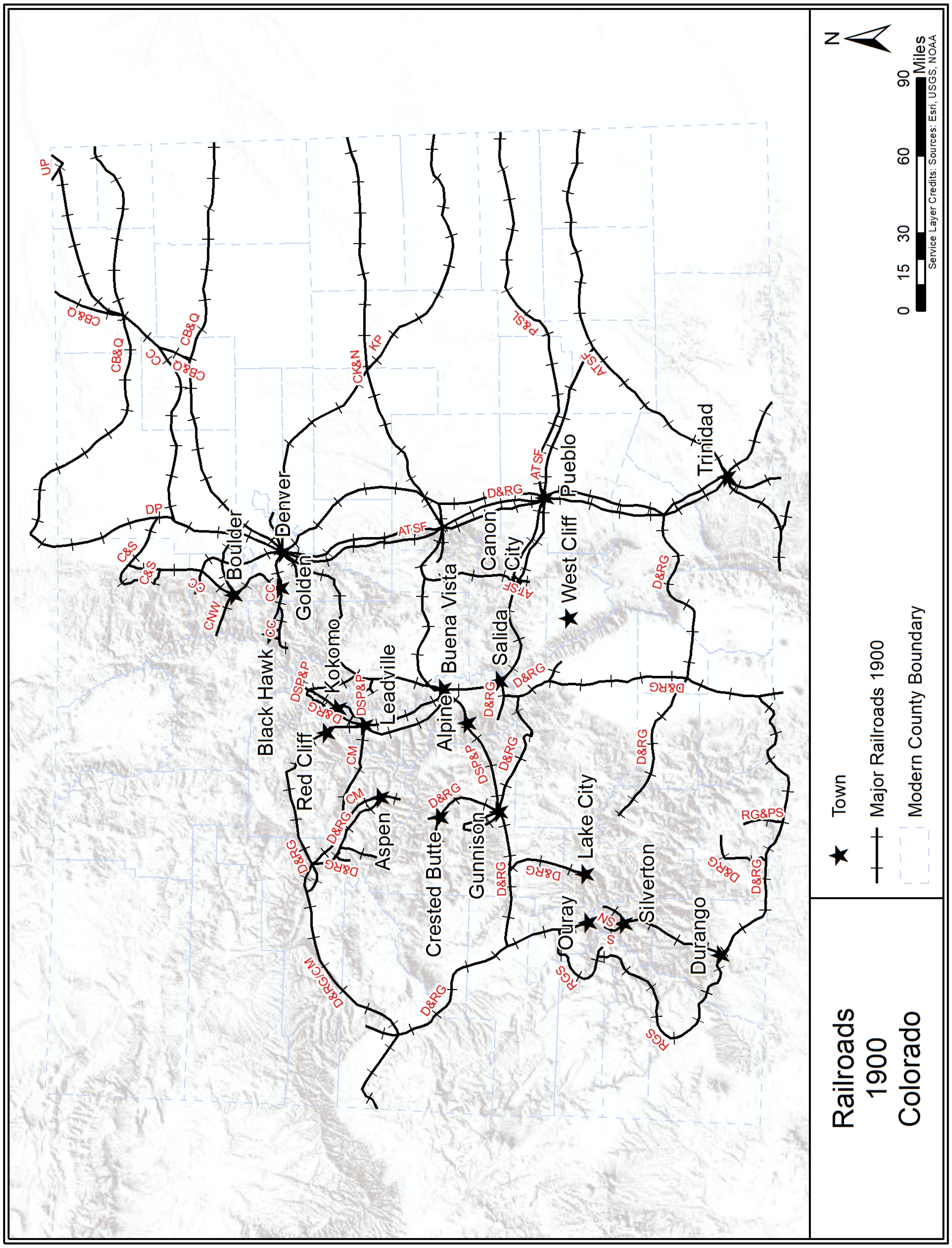


Figure 3-6. Colorado Railroads - 1900. Adapted from Robertson 1991.

3.3 Economic Conditions

Of similar importance to the development of Colorado's smelting industry as transportation, were economic events occurring on the national level. The nineteenth century saw a series of economic crises that shaped both public and government views on the precious metals industry of the western United States. The extreme volatility of the American economy during this period led to the rise and fall of mining industries, especially those involving the exploitation of silver (Smith 2000:84). In order to place these issues in context, the following section will briefly examine the history of economic events in the United States during the last half of the century, and the main pieces of legislation that most affected mining and smelting industries.

The second half of the nineteenth century saw a series of financial panics or depressions. These panics are often considered to be the result of a lack of federal regulation of the economy. Financial panics are "socioeconomic events, often psychologically driven, in which a more or less irrational fear and sense of futility sweeps through investors or some other group." (Thomas 1999:316). These panics usually followed a period of economic optimism and industrial over-expansion and usually led to an economic depression.

The first of these panics occurred in 1857 as a result of the failure of a number of banks in the northern and western portions of the United States. The South was largely unaffected due to its emphasis on cotton production and the benefits of a protective cotton tariff. One of the main results of the panic was that the northern and western portions of the nation turned to the Republican Party as an alternative to the southern-controlled Democratic Party and the issues of the economy and slavery were to be major issues during the 1860 election that brought Lincoln into power and ultimate causing the Civil War. The costs associated with the Civil War had plunged the federal government into deep debt. To stabilize the volatile economic situation and raise money for the war effort, Congress created the national banking system in 1863 (Thomas 1999:773).

The second major financial panic occurred in 1873. In the late 1860s and early 1870s speculators ignored increasing trade deficits and focused almost all investment activities on railroad companies which comprised the majority of Wall Street transactions during this period (Thomas 1999; Olson and Wladaver-Morgan 1992:154). Many economic historians consider the 1873 panic as the beginning of a twenty-year period of economic instability, extending up to the depression of 1893 (Olson and Wladaver-Morgan 1992:154). An increasing trade deficit, combined with a lack of domestic investments, led to 4,000 businesses failing in 1872. The panic started in earnest in 1873 with the failure of several major New York banking firms. In the aftermath of these bank closures, Wall Street closed for 10 days. By 1875 over 500,000 out of 10 million workers lost their jobs. In 1876 and 1877 an additional 18,000 businesses failed (out of a total of 252,000), including most of the nation’s railroads and iron mills.

Wages also declined during the period, which led to a series of increasingly violent strikes. The economy only began to recover in 1878 (Thomas 1999; Barabba 1975a, 1975b).

By the 1880s the nation's investors had already forgotten the lessons of the 1873 panic and made investments in railroads, silver mines, industrial plants and foreign enterprises that far exceeded any possible financial returns. This led to a drop in the price of commodities and the start of a third financial panic in 1883 (Thomas (ed) 1999:773; Olson and Wladaver-Morgan 1992:154). Silver miners aided by overproducing wheat farmers pushed for a silver standard to combat declining prices. In addition, Eastern industrial growth outpaced gold production, leaving insufficient gold in banks to cover accounts. A slight economic recovery in the late 1880s was almost immediately countered by a sudden slump in the British economy in the 1890s. Investment of British capital dropped, and foreign investors sold US securities causing a Wall Street collapse and a substantial export of gold reserves. In the midst of this crisis President Benjamin Harrison promised to help relieve silver producers from declining silver prices, which led to the passage of the Sherman Silver Purchase Act of 1890 that bolstered the declining value of silver revitalizing the mining and smelting industries of Colorado. The panic accelerated in 1893 when the US gold reserves dropped below the legally set $100 million minimum level. During the panic, 4,000 banks failed, 14,000 (out of 350,000) businesses closed their doors and over 4 million (out of 19 million) workers were unemployed. During President Grover

Cleveland’s second (non-consecutive) term, Congress repealed the Sherman Silver Purchase Act to stop the drain on US gold reserves (Hofman 2002). In combination with the decision by the British government to stop minting silver coinage in India, the repeal of the Sherman Act led to plummeting silver prices and devastated large portions of the Western economy, which in turn again led to violent strikes in 1893 and 1894 although silver production continued to rise (although largely as a byproduct of base metal (zinc, lead, and copper) production (Meade 1899)). Cleveland arranged for eastern bankers (like J.P. Morgan) to purchase special US bonds to replenish the national gold reserves. This, combined with poor European harvests in 1897 led to an influx of foreign gold, helping the wheat farmers of the Midwest. Improvements in the gold mining industry (mostly the widespread adoption of cyanide leaching) helped end the depression by 1898 (Barabba 1975a,1975b).

Economic conditions on the national level had a great influence on the development of Colorado’s smelting industry. The panics of 1873, 1883, and 1893 had major impacts on the industry. The Panic of 1873 largely halted railroad construction and industrial expansion in Colorado for several years, leaving much of the state’s mining industry idle. After a brief recovery in the late 1870s the following Panic of 1883 led to calls for legislative action to support sagging silver prices and the eventual passage of the Sherman Silver Purchase Act which created a recovery of the state’s mining and smelting industries. The subsequent repeal of the act during the Panic of 1893 led to a major decline in the price of silver and the development of the ASARCO smelter trust at the end of the period of study in an attempt to stabilize prices.

3.4 Early Smelting

This section covers the main period of interest for this dissertation. This period, from approximately 1875 to 1885, marks the expansion of small smelting enterprises throughout the state. These smelting concerns were major drivers of the development of Colorado. This section is broken into two main areas of discussion. The first provides a historical background of the smelters of this period with specific attention paid to four early smelting companies that developed in Gilpin, Summit, and Park counties. These smelters provide examples of two of the earliest companies (The New York and Colorado, and the Boston and Colorado), and two more typical examples of early smelters (The Boston Silver Mining Association and the Mountain Lincoln Smelting Works). The second section (beginning at 3.4.5) is an examination of the small smelting operations identified throughout the state during the study. The smelters are broken down by county and provide the first comprehensive look at the distribution and identity of small smelting operations in the state.

United States Geological Survey member Henderson (1926:177) estimated that up to 300 small smelters were built throughout Colorado during the nineteenth and early twentieth centuries. Precious metal smelters were found throughout the

Colorado mountains and at a few locations on the Front Range. Prior to the development of a local smelting industry, Colorado mines were dependent on smelters found in the Midwest, along the eastern seaboard, Wales, and Germany for markets for their ores. The main impetus for the development of a smelting industry in the Rocky Mountains was the extreme difficulty and expense of shipping ores to these distant smelters. Prior to the development of a local industry only the richest ores could be profitably processed due to the costs of transportation and treatment. For mines with lower grade deposits, only the development of a local ore markets allowed them to be profitable. The establishment of a smelter in a community had tangible effects for the region. A local smelter was viewed as a sign that the district had “arrived” and that future prosperity was assured, although many of the smelters were lucky to survive their first season. The need for a local industry was recognized at an early date and attempts to develop smelting in Colorado began only a few years after the initial rush.

The early smelters that developed were located near the mines they were intended to support, and in many cases were built to support an individual company’s mines. Examples of smelters of this type are the Hall Valley, Dudley and McFerran smelters in Park County. It seems that every mining region was home to at least one smelter prior to its connection to a railroad.

The initial excitement about local smelters soured through the 1870s as the difficulty of successfully operating these small industries became clear. An example of the negative view that came to plague small smelters came from the mining community of Silverton in the San Juan mountains that had been home to several small smelters in the 1870s and early 1880s. A local newspaper stated that:

> History and experience has demonstrated that local smelters are a fraud. Silverton will corroborate our statement inasmuch as they had to go to England to secure a purchaser for the Martha Rose. (SMW 1 June 1883:3).

The owners of the Martha Rose in Silverton were forced to expand their search for a purchaser to England where a lack of familiarity with the conditions of Colorado might induce individuals to invest in a small, marginal smelting enterprise.

Most of the Colorado metals industry, including its early smelters, were found in the northeast to southwest trending Colorado Mineral Belt that stretched between Boulder and the San Juan Mountains (Figure 3-7). The Colorado Mineral Belt is a complex series of intrusive episodes associated with the subduction of parts of the Farallon plate during the Laramide uplift (Chapin 2012). Few significant mining districts were located outside the Mineral Belt, although a few smaller districts occur in isolated areas with the proper geological setting. A few early smelters functionally equivalent to the mountain smelters were also located in the Front Range communities of Boulder and Golden in the early 1870s. The Golden smelters were unable to compete for the best ores with the well-regarded Hill smelter although smelting in the city continued intermittently through the turn of the century (Cecil 1952).

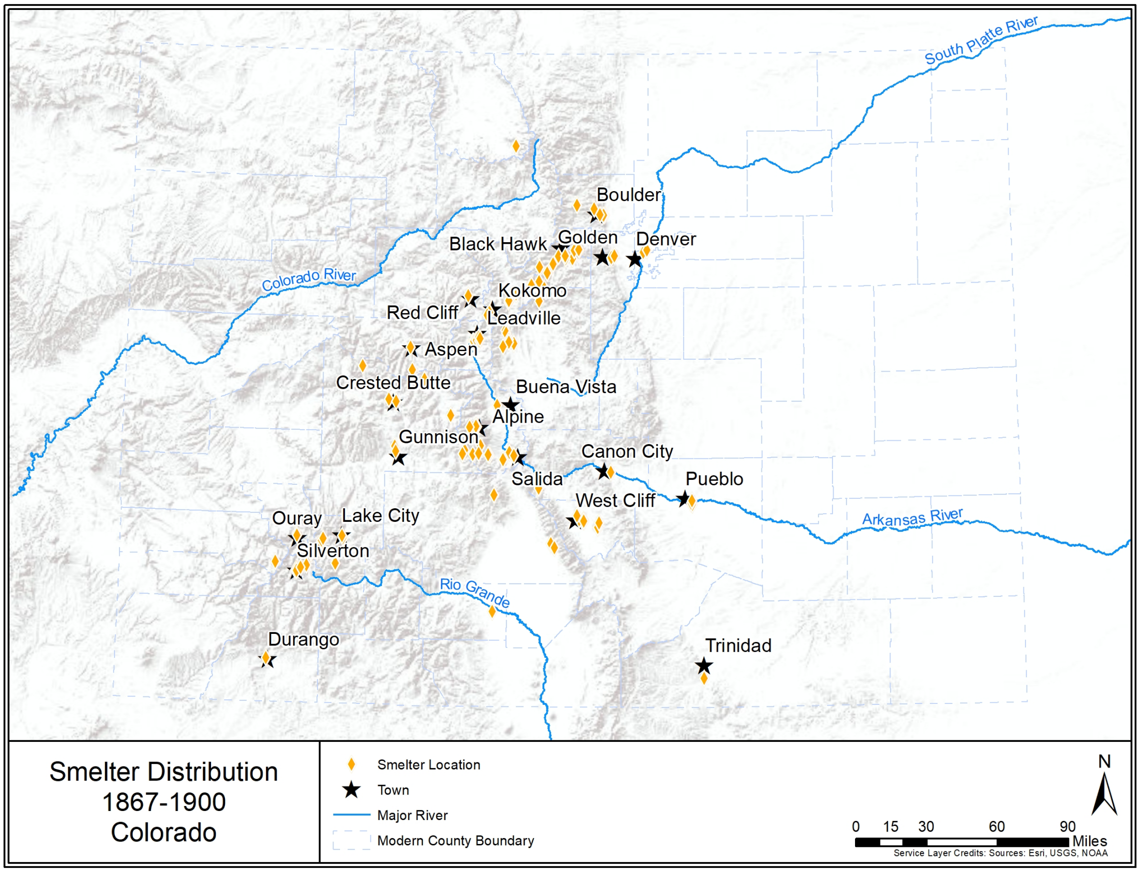


Figure 3-7. Map of smelter locations mentioned in text.

The earliest center of smelting in Colorado was one North Clear Creek and South Clear Creek in Gilpin and Clear Creek counties respectively. The earliest known smelter in Colorado was a small lead smelter at Nevadaville (just outside Black Hawk in Gilpin County) used to smelt lead to supply ammunition to the First Colorado Cavalry in 1861. It was converted to a lead-silver smelter the same year but burnt to the ground during its first firing (Ronzio 1966). The following section discusses the smaller smelters found in the mountainous portions of the state. Due to the limited information about most mountain smelters the following section will first discuss some of the better documented small smelters of the region and then discuss smelters by county. The larger smelters on the Front Range and at Leadville will be discussed in the following chapter.

Most information on these local smelters exists only in historic newspaper articles and occasional articles in technical journals including *Engineering and Mining Journal, Mining and Scientific Press* and even *Scientific American.* Most of these articles refer to larger, well-financed firms unless a local correspondent took a particular interest in an operation. In the newspapers of the era there is often little more information than a mention that a smelter had recently blown in or was in the planning stages, but in some instances provide detailed descriptions based on tours of the facilities. Another useful source are the books written by Muriel Sibell Wolle from the 1940s to 1970s. Wolle was an art professor at the University of Colorado who was fascinated by the towns, mines, and remains of the western mining industry. Over a period of nearly 50 years she visited locations throughout the state and sketched, painted and photographed many sites that no longer exist. She conducted her research at a time when informants who had lived and worked in the communities were still alive and her books contain information gathered from eyewitnesses to the early period of Colorado. Her books sometimes provide the only commonly available reference to these areas. At many of the locations she visited she noted the existence of smelter ruins identified by local informants. Although many visitors fail to identify smelters when visiting sites (smelters rarely entering into the thoughts of many visitors), Wolle was extremely knowledgeable about the mining period and appears to have clearly understood the distinctions between the two types of properties and her identification of smelter sites seems reliable.

A further factor complicating the determination of a smelter’s identity was their complex operational histories. It was common for smelters to change hands, often after only operating for a few months, with the new owners renaming the plant. Period newspapers also had the tendency of interchangeably uses the name of the owner, manager, or the smelter location as its name further clouding the picture. This makes the exact identification of a smelter a difficult task. Period newspapers often include brief articles indicating that construction of a smelter was planned, or that property to build a smelter had been acquired and it is often unclear whether the plant was built. In these instances, potential smelters have been left out of the discussion or is clearly identified that the information about its use is questionable. Other articles discuss a smelting operation without providing sufficient information to locate the smelter using names and landmarks that have since fallen out of common usage. Such references are also not included in the following discussion.

Smelter construction in Colorado peaked during the late 1870s and early 1880s. The founding of small mountain smelters dropped off significantly by the mid-

1880s as railroads reached most of the major mining areas making it difficult for the small companies to compete with the plants on the Front Range. The exception was a brief period of construction of small semi-pyritic and pyritic smelters in the 1890s and 1900s, although competition with the increasingly effective chlorination and cyanide plants led to most closing within a few years. The cut-off for the discussion of smelters in this document is set at 1900, and at least a few smelters (mostly new pyritic plants) erected in the very late 1890s and 1900s are not included in this discussion. In instances where smelters have been recorded archaeologically the Smithsonian trinomial number and a summary of the site description from the Colorado Office of Archaeology and Historic Preservation (OAHP) is included.

To provide a context for smelters of this type this section examines the histories of four smelting companies in the Colorado mountains. Two of these, the New York and Colorado Mining Company and the Boston and Colorado Smelting Company, were located in the town of Black Hawk in Gilpin County. The Boston Silver Mining Association was at the small community of Sts. John in Summit County and the Mount Lincoln Smelting Works was at the town of Dudley in Park County.

3.4.1 New York and Colorado Mining Company

The New York and Colorado Mining Company was established by James E. Lyon, a prominent entrepreneur in the early years of Black Hawk who had interests in numerous area industries and mines, including the famous Gregory Lode. Frustrated by the inability of local amalgamation mills to recover a significant portion of the gold content in his mine's ores he shipped a lot of ore from the Gregory Lode to a smelter in New York City in 1865 to see if they could recover a higher percentage of the assay values. Lyon was thrilled that the smelter was able to produce a return of $250 per ton, much higher than the amalgamation mills could recover. In response he decided to open a smelter in Colorado, and after securing backers (including George Pullman of later railroad fame) organized the New York and Colorado Mining Company. While in New York Lyon recruited a pair of European metallurgists to help in the construction and management of the smelter. Upon his return to Colorado he also took on Nathaniel P. Hill, a chemistry professor at Brown University who came west to examine mining properties as a consultant (Smith 1992:37-38).

Lyon's initial attempt at smelting involved the use of a Scotch hearth to smelt the ore and a cupola furnace to refine the resulting bullion. By 1867 the works included three reverberatory roasting furnaces of 20 to 25-ton capacity and three Scotch hearths for reducing lead ores. During his initial run he produced the first bar of silver bullion in state history (Henderson 1926). Despite his initial success, Lyon's smelter was poorly designed and laid-out. Although he soon rebuilt his smelter to use the Swansea Process that was later adopted by N.P. Hill, he experienced little success. He managed to produce around 100 tons of copper matte that was shipped to Swansea, Wales for refining. The combined reduction, transportation, and refining costs forced the company to operate at a loss and it soon closed. When the smelter was dismantled an additional 100 tons of matte was recovered that had seeped through the poorly built furnaces and collected in the masonry. If the additional matte had been recovered during processing the smelter may have made a profit and could have been the first successful smelter in the territory (Raymond 1870:359). Instead success was reserved for the smelter of N.P. Hill.

3.4.2 Boston and Colorado Smelting Company

One of the most important figures in the history of smelting in Colorado was Nathaniel P. Hill. As the unoxidized ores of his mines were depleted, Hill sought a way to increase the yields and became involved in James E. Lyon's attempt to build a smelter.

Hill observed the operations of Lyon's smelter with interest and returned to the east to New York to study metallurgy in more detail. He soon settled on the Swansea Process as the best option for Gilpin County ores. The Swansea process uses the copper and iron sulfides within ore to trap the gold and silver. The resultant material is known as copper matte, which requires additional refining operations to separate out the various metals. Determined to make the process successful Hill traveled to Wales in 1866 to observe the process and consult with professionals. He purchased 70 tons of ore from the Bobtail Lode and had it shipped to Swansea where he observed the full reduction process spending three days at the smelters of Swansea. The ore treatment was successful and in early 1867 he was the driving force behind the creation of the Boston and Colorado Smelting Company intended to process ores in Colorado (Fell 2009:25).

Hill was a cautious businessman and decided to proceed slowly with the business. The initial plans did not include a refinery as its early matte output was not sufficient to support one. Instead, they negotiated a contract with the company of Vivian and Sons in Swansea, Wales to refine their matte. The company purchased a four-acre tract adjacent to Lyon’s smelter in Black Hawk. The plant (Figure 3-8) was erected under the direction of Hermann Beeger, a professional metallurgist trained at the famous German mining school at Freiberg who had worked in smelters in both Swansea and on the Continent (Fell 2009:27-28).

To supply his new smelter, Hill purchased both raw ore from area mines and tailings from local stamp mills. The tailings from the earlier milling activities were quite valuable to the smelter as the amalgamation process had failed to recover a large amount of the gold in the processed ore that could be recovered through smelting. The materials were first roasted to remove excess sulfur. Raw ore was roasted in open piles for a period of six weeks while mill tailings, which were too fine for heap roasting, were instead roasted for 24 hours in calcining furnaces (Egleston 1877:8-9).

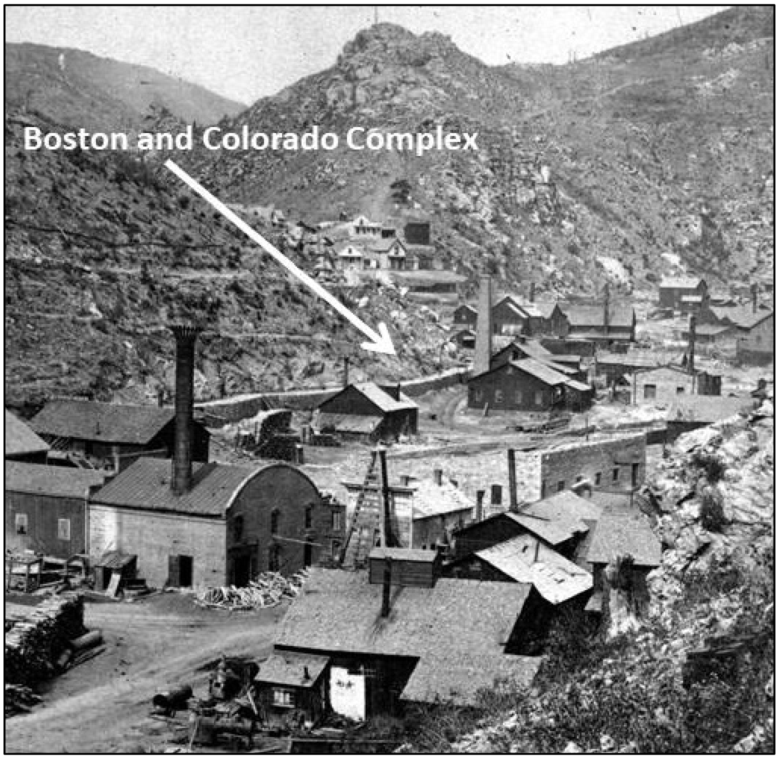


Figure 3-8. View of Boston and Colorado Smelter: Stereo card ca. 1870-1880. Denver Public Library Western HistoryX-17639.

The success of the plant stimulated a revival in the mining industry of Gilpin County which had gone into decline in the late 1860s. His position as the first successful smelter manager allowed him to develop an effective monopoly on the purchasing of ores of Gilpin County and he expanded the plant in the 1869 and 1871 to a total of three reverberatory furnaces with an aggregate production of 25 tons per day (Raymond 1870:362-363). In 1873 the Boston & Colorado's refining contract with Vivian & Sons expired. Due to their demand for higher reduction rates Hill decided to build his own refinery at Black Hawk, which was completed by the end of the year (Fell 2009: 42). By the middle of the decade the

Black Hawk works was responsible for almost half of Colorado’s precious metals production by value. Other companies at Empire, Golden and Denver tried to emulate Hill’s success building smelters using the Swansea process, but were not successful (Fell and Twitty 2008:12-14).

While Lyon and Hill had concentrated on the development of methods to treat the gold, silver, and copper deposits of Gilpin County, in neighboring Clear Creek County the focus rapidly switched to attempts to wrest silver from its ores. The early attempts to reduce the local silver ores involved the use of Scotch hearths and that had been used by some of the miners during smelting in the lead producing areas of the Midwest. However, these technologies had been developed for use in areas where lead was the primary metal of interest. These furnaces proved to be poorly suited to recovering silver from lead ores. The relatively lead poor ores of Colorado were not particularly amenable to the smelting methods developed in the non-argentiferous galena mines of the Midwest (Raymond 1870:375). Due to the lack of success with these furnaces there was a rapid abandonment of Scotch hearths to blast furnace technologies in the 1870s.

Blast furnaces for refining had originally been developed in central Europe and then exported to the United States where the technology was improved and adapted to local needs. Early development of blast furnaces for lead-silver reduction was concentrated in Utah and Nevada. Concurrent, but more limited, development of blast furnaces was conducted in Colorado (Canby 1913:363-368).

3.4.3 Boston Silver Mining Association

Among the earliest lead-silver furnaces in the state were at Sts. John and at Dudley. The smelter at Sts. John's (Figure 3-9) was built in 1865 by Cornish mining engineer John Collom for the Boston Silver Mining Association. Due to high transportation costs in the isolated Montezuma District, the company wanted to process the ores onsite. Collom built a plant using six Scotch hearths and produced one ton of lead-silver bullion in 1867 that was shipped to Edward Balbach & Sons in Newark, New Jersey for refining. An additional nine tons of bullion was shipped in 1868. However, it soon became obvious that the Scotch hearths were inefficient at smelting the lead-silver ores of the area. Scotch hearths generally require a lead content in the charge of at least 60 percent, but even with concentration Collom was unable to raise the lead content of his charges above 50 percent which resulted in the loss of much of the silver in the slag. The transportation costs from Sts. John's to the refinery in New Jersey were also extremely high (approximately $83 per ton) allowing only the richest of the company's ores to be processed. To improve efficiency Collom installed a blast furnace at the plant in 1869 that remained in use into the 1870s (EMJ 1877a:221; Fell 2009:57-58).

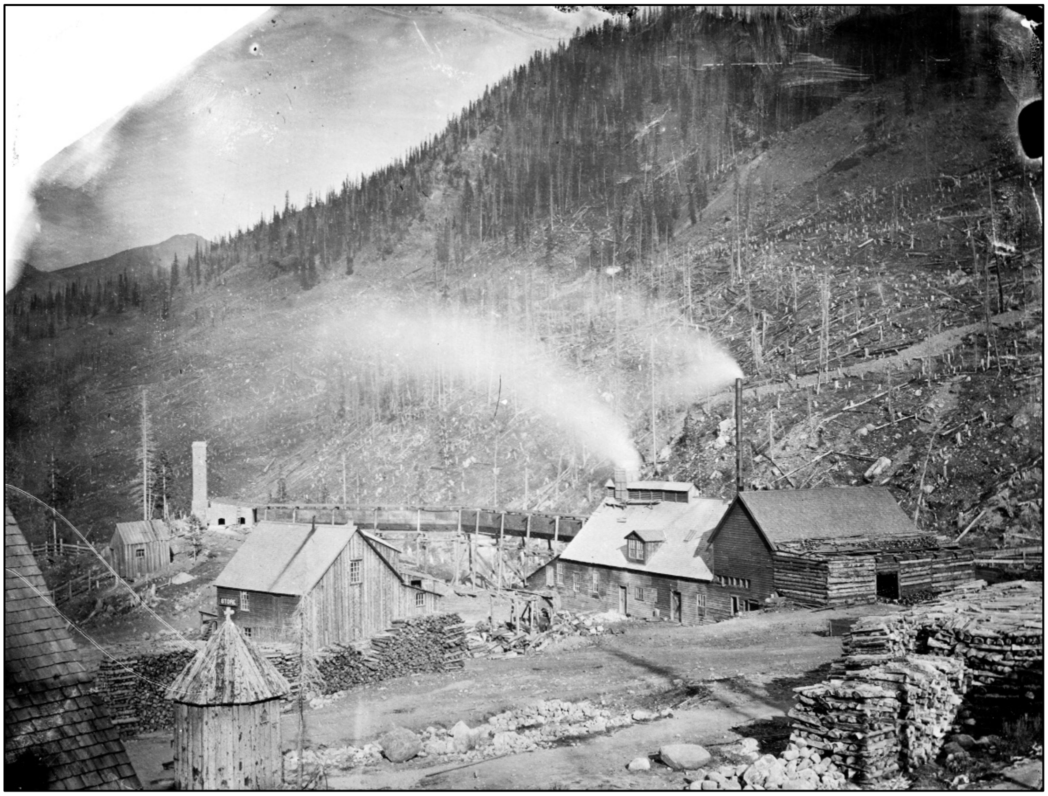


Figure 3-9. Smelter at Sts. John ca. 1870-1880 showing furnace in left background, roaster in right mid-ground, and piles of cordwood at lower right. Colorado Historical Society X-13495

3.4.4 Mount Lincoln Smelting Works

The smelter at Dudley (a few miles upstream from the town of Alma) was built by Edward D. Peters for the Mount Lincoln Smelting Works Company in 1872. Peters was a young metallurgical engineer who had recently graduated from the Konigliche Sachsische Bergakademie at Freiberg, Saxony. He erected a Piltz pattern blast furnace in the plant to reduce the lead-silver ores from the mines on Mount Bros and Mount Lincoln. After some initial difficulties Peters modified the furnace and was soon producing bullion at the rate of 10 tons per day (EMJ 1877a:221). Unfortunately, his reduction costs were extremely high at around

$64 per ton of ore treated and it proved unable to compete successfully with a branch smelter of the Boston and Colorado (Figure 3-10) that opened nearby at Alma using the Swansea process already in use by the company's smelter in Black Hawk. In response Peters redesigned the smelter to also use the Swansea Process (Peters 1874:310-314), but by the time the conversion was completed the Alma smelter had monopolized the local production of pyritic ores and the Dudley failed in 1875 (Simmons 1992:121). The Dudley smelter had the disadvantage of opening with preexisting competition as the Alma smelter had opened the previous year. The Alma smelter was essentially a copy of the original Boston and Colorado smelter at Black Hawk. The copper-silver matte produced in Alma was freighted to Black Hawk for assaying before shipped to Swansea, Wales for refining. After the Dudley smelter closed, the Alma processed up to ninety percent of South Park ore production before its closure in 1879 (Fell 2009:38-39) despite attempts at competition by other small local smelting plants.

Figure 3-10. Boston and Colorado Smelter at Alma, date unknown. Colorado Historical Society X-5650.

3.4.5 Small Smelter by County

This section provides brief summaries of the smelting sites identified during the creation of this dissertation. The section is organized by county to provide an organizational framework for the discussion. Smelters within counties are generally discussed in chronological order of founding, but where distinct clusters of smelters are identified, they are discussed as groupings within the county. The smelters in this section are unified by their small size (one or two furnaces of 10 to 50 tons capacity) and (generally) early dates. The larger smelters on the Front Range and at Leadville are discussed later in Chapter 4. Maps showing a more detailed view of the distribution of smelters are included here for reference in the following sections (Figure 3-11-Figure 3-13). These small smelters and the reasons for their failure are the main focus of the dissertation. The discussion provided in Chapter 5 refers to several the smelters in this section as examples of the causes of failure in Colorado’s small-scale smelting industry.

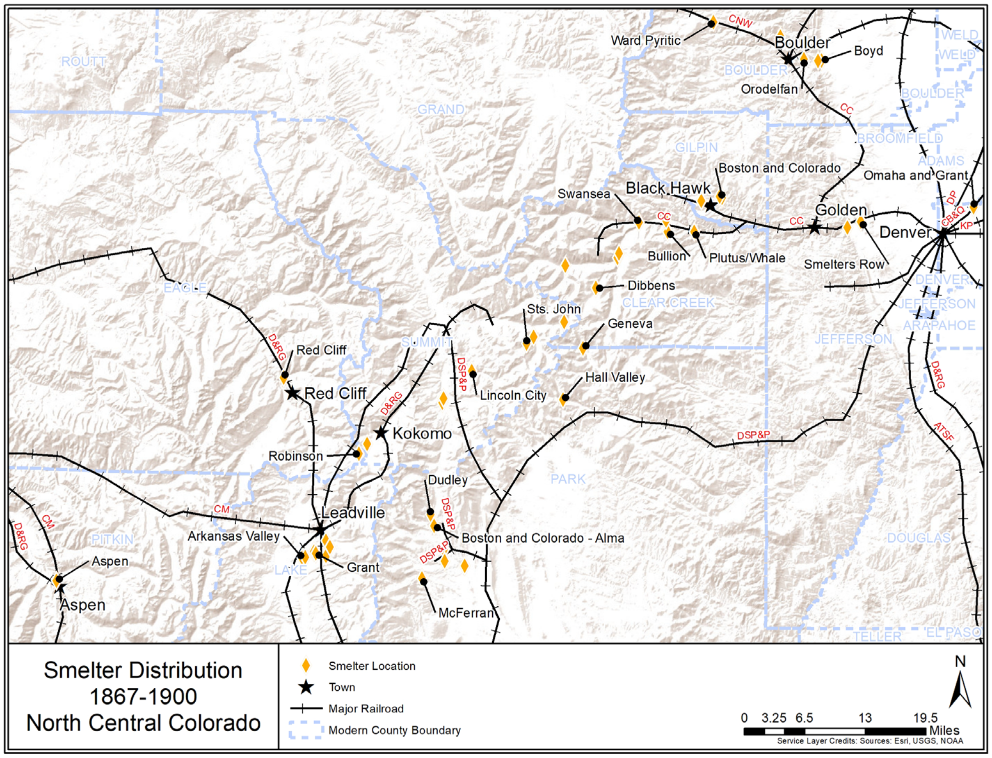


Figure 3-11. Smelter map, north-central region.

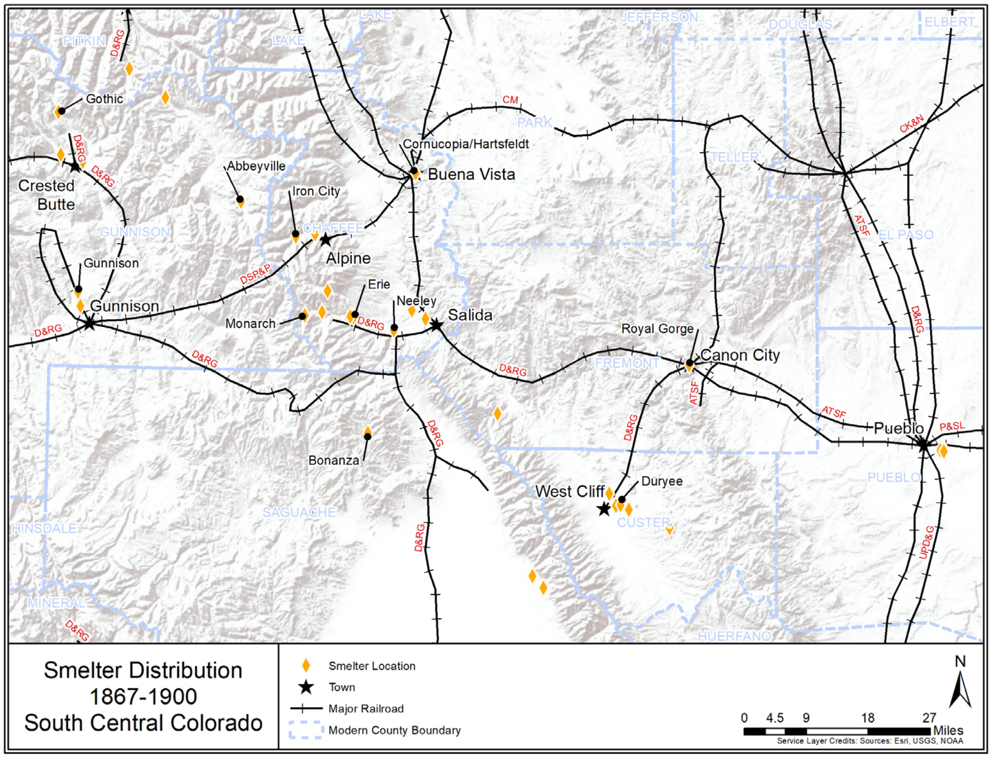


Figure 3-12. Smelter map, south-central region.

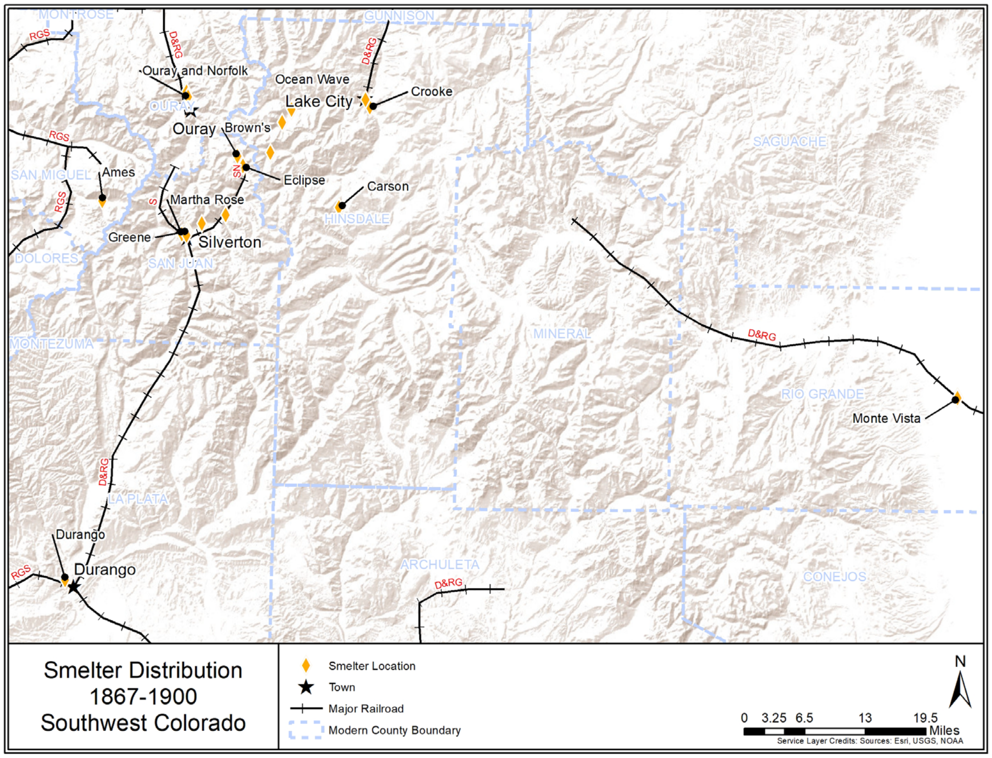


Figure 3-13. Smelter map, southwest region.

Boulder County

The mines of Boulder County were discovered during the first wave of the 1859 rush. Prospectors chasing placer gold up the streams into the mountain front soon located lode deposits at Gold Hill, Nederland, Ward, and Caribou creating a demand for local smelting works. The Boulder smelters were somewhat protected from competition due to the rugged terrain between the mines and the Boston and Colorado smelter at Black Hawk. To reach Black Hawk ores from Gold Hill required 50 miles of freight down the canyon to Boulder, then south to Golden, and then upstream to Black Hawk, a linear distance of only 19 miles.

At least five smelters were built in the Boulder County during the nineteenth century, two within the city itself. The earliest was the Boyd Smelter (5BL5094/5BL7094) built in 1874. It opened with a single 10-ton capacity blast furnace with water powered machinery (EMJ 1877a:221). Although small with only a 15 to 20-ton daily capacity it survived far longer than most if its contemporaries around the state, operating until ca. 1890. It is one of the few smelters located in an urban setting that may retain significant archaeological potential as part of the site was intentionally buried by the city in the 1990s to protect it during the construction of the adjacent city improvements, which included the new Boulder County Justice Center, a skateboard park and a bike path. Features reported during the burial included several foundations, portions of walls, and part of the millrace and head gate. The second smelter built in

Boulder was the Whitney-Thompson Smelter. The smelter was near the Boyd and operated during the early 1880s (Salida Mail [SM] 26 April 1884:1). No figures for production or the output of the plant were located.

Further west of Boulder along the valleys extending toward the mines two additional smelters were built. The earliest were the Hunt and Barber Works built at the town of Orodeelfan at the mouth of Fourmile Canyon on the road to Crisman. The smelter operated four blast furnaces and was intended to process the ores from the mines of the Gold Hill District. The operational dates of the smelter are unknown, but the smelter was sold at auction in early 1880 (Boulder News and Courier [BNC] 2 January:1880:2; EMJ 1880b:264; Wolle 1971:488). The general pattern of smelting developed in Colorado indicates it was probably built and operated in the early 1870s. The Phillips Smelter was built near the town of Salina in 1880 (Boulder News and Courier [BNC] 2 January 1880:2) but beyond the articles reporting its blowing-in no further information could be located. These two smelters likely had short lives as the local mines were not large producers. The limited ore supplies available made competition fierce and they likely had difficulty competing with the established Boyd Smelter in Boulder. Their location within the canyons presented additional difficulties as forests in the area were fairly thin and local fuel supplies were limited.

The last smelter in Boulder County was a pyritic smelter built at the turn of the century at the town of Ward. The Ward smelter (5BL9700) was built in 1898 in the same year that the Colorado and Northwestern Railroad reached the community. The mining industry of Ward had been in decline for years due to the exhaustion of high-grade ores and it was hoped the new smelter could revive the area. Although production information about the smelter is unknown, it failed quickly and had been abandoned by the time the railroad was abandoned in 1919 (San Juan Prospector [SJP] 5 November 1898:6; Rosenberg 1977).

Chaffee County

Chaffee County is along the upper Arkansas River valley and included mining districts in the Sawatch Range on the west and the Mosquito Range on the east. The county served as a gateway to the rich mines of the Leadville area in neighboring Lake County. Chaffee County received early railroad service in the 1870s as the easiest route to Leadville with both the DSP&P and D&RG passing through the center of the county. Branch lines were rare in the area, and the only significant east – west trending lines were the DSP&P mainline up Chalk Creek to Gunnison and the D&RG branch line over Monarch Pass to Gunnison that started south of Salida. Information pertaining to at least 13 small smelters was found during research, and one late large smelting plant was built at Salida after the turn of the century.

Salida was home to one smelter during the period of study. The Smith and Gray Smelter was blown-in on June 31, 1882 (CDC 30 June 1882:4). Little other information about the smelter was located but it likely failed quickly. The late smelter in Salida was the Ohio-Colorado Smelting Company that built a large modern plant at the west edge of town in 1902 outside the period of the study. The smelter operated until 1920 and most of its facilities were demolished soon thereafter. The main 365-foot brick chimney survives as a historic site to this day and is listed on the NRHP.

The Neeley Smelter was built at Poncha Springs five miles west of Salida in 1880 (MM 12 June 1880:4). The smelter had a single charcoal fueled water jacket blast furnace with a 30-ton daily capacity. The furnace was housed in a 40 foot by 48-foot building with an attached 20 foot by 40-foot boiler room. A 40 foot by 60-foot ore platform outside the buildings was used for the production of furnace charges (MM 1 January 1881:2). The smelter failed quickly and was out of blast by 1882 due to mismanagement and financial difficulties. The machinery of the plant was purchased by the Salida Mining and Milling Company and shipped to Cañon City (Fremont County) where it was incorporated into the new Royal Gorge Smelter (MM 25 February 1882:3; LDH 19 February 1882:2; MM 17 June 1882:1).

In the central part of the county a smelter was built at Buena Vista, the junction point of the DSP&P and D&RG railroads to Leadville. The Cornucopia Mining Company erected a small smelter at the town under the ownership of the Hartsfeldt Portable Smelting Furnace and Mining Company to test a new, portable blast furnace design of their own invention with a daily capacity of 20 tons (BVD 13 October 1885:3, SM 10 September 1886:1). The plant was built on a 10-acre site along the Arkansas River. The furnace was supplied with the understanding that a successful two-week run would be completed prior to payment to the inventor (SM 14 January 1887:7). Early tests of the furnace showed it worked well on lead rich ores but had difficulty with ores that had high silica content (SM 18 February 1887:3). The furnace ultimately proved to be a failure and was listed at a sheriff's sale in April of 1887 (BVD 28 April 1887:3). Although Buena Vista was an attractive location for a smelter, it was already connected by rail to well-established smelters in Pueblo and Leadville. It was unlikely at this stage for a small furnace using untried technology to compete successfully with well-capitalized firms.

Fourteen miles southwest of Buena Vista a cluster of three smelters were built in the Chalk Creek Mining District of the Sawatch Range. The district contained a number of rich mines around the towns of Alpine and St. Elmo and the smelters were erected to work their rich silver ores. The earliest was the Kansas City Smelter built at Alpine in 1871 that was renamed the Alpine Smelter in 1884. The smelter had a daily capacity of 20 tons and a workforce of 25 men (BVD 9 October 1884:4). A second unidentified smelter was erected at Alpine prior to 1883 but was unable to acquire sufficient fluxes to work the area ores successfully and was soon converted into a concentration and sampling works (BVD 8 July 1885:2). The third smelter was built at the town of Iron City (just outside St. Elmo) in 1880 and remained in operation until 1883 (Mountain Mail

[MM] 26 March 1881; MM 22 July 1882:1; BVD 15 March 1883:3). All three smelters were built within five miles of each other and must have experienced ruinous competition with each other. All operated intermittently as ore supplies from the mines were unable to dependably supply the works (SM 3 July 1885:5). All three were doomed to failure when the DSP&P mainline was built through the district in 1881 on its way to Gunnison. The arrival of the railroad greatly reduced freight rates that improved the profitability of area mines and allowed them to ship their ores to the large Front Range mills that could offer more competitive reduction rates (BVD 8 July 1885:2).

The town of Maysville 10 mile west of Salida as home to two smelters. The mines around Maysville were found in the early 1870s and the town was an important center of mining activity for a time although the mines proved to be only moderate producers. The earliest smelter in town was the Shaveno Smelter of the Shaveno Mining and Reduction Company. The smelter was blown-in during June of 1880 (MM 5 June 1880:1; GC 17 June 1880:1). A competing smelter, the Erie, owned by the Erie Smelting Company opened later the same year. The Erie had a daily capacity of 50 tons and was shipping bullion by the fall (MM 18 September 1880; GC 5 August 1880:3; MM 23 October 1880:3). No further references to the Shaveno Smelter was found and it appears to have rapidly failed due to competition from the larger Erie. A second Shavano smelter was reportedly under construction at the town of Shavano ten miles north of Maysville in the same period (MM 7 August 1880:2). It is unclear if this is a separate company or the smelter decided to immediately relocate when the Erie was constructed. The smelter at Shavano apparently never entered production although it was briefly reopened as the Patridge Smelter in 1881 (MM 26 March 1881:3). This attempt also failed, and no bullion was ever shipped.

The Erie Smelting Company operated their smelter directly until 1882 despite difficulties in the winter of 1880 when the freezing of the river forced the company to install a small boiler to continue year-round operations (MM 27 November 1880:3; MM 18 December 1880:3; MM 1 October 1881:4; MM 27 May 1882:3). After that date the company decided to lease the smelter to a succession of lease holders that in the words of a local newspaper "knew about as much about smelting as a toad does about dancing Fishers Horn Pipes. (BVD 23 August 1883:3)" The smelter was worked periodically through 1885 when it finally closed.

Two smelters were built at the base of Monarch Pass in the Garfield/Monarch District. The first was built at the town of Arbourville at the east foot of the pass in 1880 with a capacity of 25 to 30 tons per day (MM 20 November 1880:1; GC 9 September 1880:1; GC 25 November 1880). Arbourville was short-lived and was most famous for having the only brothel in the area and the smelter appears to have failed almost immediately with the last mention of its operations from 1881 (MM 27 August 1881:3). The second smelter was the Madonna Smelter constructed at the Madonna Mine for the express purpose of processing the mine's ores. The smelter entered blast in 1881 and closed in 1882 after an expansion to 50 tons capacity (SM 5 June 1900:1; MM 1 July 1882:3; EMJ 1882h:138). Unlike most small smelters its closure did not directly reflect problems with the smelter itself. The owners of the Madonna brought in noted metallurgist Anton Eilers as a consultant to improve the efficiency of their smelting operation. Instead he convinced the owners to build a large smelting plant in Pueblo with its more central location and better transportation facilities. The Colorado Smelter at Pueblo became one of the largest smelters in Colorado. The original smelter was torn down to make way for a tramway in 1884 (SM 28 June 1884:4).

On the west side of Monarch Pass a small smelter was built at the town of Argenta/Tomichi on the flank of Bald Mountain. The smelter opened in 1882 but burned the following year and was never reopened (Wolle 1971:172). A second Tomichi smelter was opened at the nearby town of White Pine in 1901 (SM 7 January 1902:3) outside the period of study.

The success of the smelters of Chaffee County was a mixed bag. Most of the smelters followed the common pattern of a brief life before failing either to competition or declining production in the quantity and/or quality of ores from local mines. The experimental Hartsfeldt furnace at Buena Vista is unusual as an attempt to introduce innovative technology on a small scale to the Colorado smelting scene. Most significant alterations to smelting furnace design was undertaken by the better capitalized firms of the Front Range. The potential for a small, semi-portable smelter was highly attractive to mining companies in the state. Unfortunately, the technology used in the furnace appeared to be ill suited to Colorado ores and despite two years of continual efforts was unable to work successfully. The small Madonna Smelter, although of little importance itself, was the direct predecessor of the large Colorado Smelter in Pueblo. It is the only instance where a small company smelter evolved into a large, powerful smelting firm on the Front Range. The other players that came to dominate the Colorado smelting industry were either built from the start as new companies, were the outgrowths of early technological leaders (the Boston and Colorado Argo Smelter at Denver), or from previously well-capitalized companies (the Grant Smelter at Denver).

Clear Creek County

Clear Creek County was one of the earliest placer and lode mining areas of Colorado. Placer mining along the creek began in 1859 with the discovery of the Jackson Diggings at Idaho Springs. Active placering extended from the confluence of North and South Clear Creeks east of Idaho Springs upstream to the confluence of South Clear Creek and Fall River. The heart of the area was the Jackson Diggings at the confluence with Chicago Creek at Idaho Springs. The Jackson Diggings consisted of a series of terraces (bars) in and adjacent to South Clear Creek and its tributaries (Henderson 1926:31). The most productive area was at Spanish Bar (the area from the entry of Fall River to a point below the Stanley Mine), but due to the high stream velocity and the large number of large boulders in the stream bed most of the bedrock contact was not explored. Regardless in the early 1860s at least 50 sluices were in use on Spanish Bar alone (Cushman 1876:8). Placer mining operations continued in Clear Creek County until at least 1913, but most production was made between 1859 to 1863. Rich lode deposits were soon found on the slopes adjacent to Spanish Bar, and the rich oxidized surface ores from the Lincoln, Whale (Stanley), Hukill and other lodes supported a 20-stamp water powered mill from 1861 to 1863. Additional placer and lode deposits were discovered between Spanish Bar and Dumont (Mill City) and near Georgetown (Rickard 1896a:837; Henderson 1926:31), but the deposit was overshadowed by those further downstream, and there was little development at the time.

A total of three mining districts were formed in the county in 1859: Empire, Georgetown, and Idaho Springs. Prospecting in the valley was carried out on an extensive scale with Spanish Bar alone supporting 12,530 lode claims in 1861. The lodes gave good returns and amenable to processing by simple by stamping and amalgamation, but the gold was increasingly replaced by silver with depth and became refractory (Cushman 1876:6). The richest gold mines of this early period were found in the Empire District. These mines contained extremely rich surface ores of decomposed quartz that could be easily worked by sluicing and stamping (Rickard 1896a:837). The C.H. Martin claim was fairly typical with a surface mined area 500 feet long, 40 feet wide and 30 feet deep where the ore was worked by sluicing. The mine produced approximately $150,000 in gold before the cap of iron pyrites was reached (Cushman 1876:79). When the refractory ores were reached a number of amalgamation mills were built to process the ore. None of the mills was successful and the last serious work at Empire was abandoned in 1875. Total production for the Empire mines from 1859 to 1865 (when the last of the decomposed surface ores were exhausted) is estimated at $1.5 million (Henderson 1926:31).

The first silver claim in Colorado was located on Glacier Mountain in September of 1864 by prospectors working out from the Empire District and the Belmont Lode on McClellan Mountain (about 8 miles from Georgetown) was discovered a few weeks later (Henderson 1926:32). Assays on the ores of the lodes during the winter of 1864 gave results of $200 to $500 per ton in silver creating a rush to the newly created Argentine District in 1865. By the end of the year hundreds of lode claims had been made in the Georgetown area (Cushman 1876:8). The mines were in the mountains surrounding the twin towns of Georgetown and Elizabethtown (soon consolidated into the single town of Georgetown) which developed as the supply and smelting center for the nearby Argentine and Griffith districts. Important mines in the area included the Baker, Brown, Coin, Dives, Equator, Griffith, Pelican and Terrible mines. The silver industry of Georgetown continued to grow steadily through the remainder of the 1860s and 1870s (Rickard 1896:327; Henderson 1926:32).

By 1875 mining in Clear Creek County was concentrated in the Georgetown area. Valuable mines like the Hukill, Seaton, and Victor continued to operate near Idaho Springs and Spanish Bar, but none of the mines of that area compared in the size or productivity to the giants of the Georgetown area. Between Idaho Springs and Georgetown rich silver mines were also found on Red Elephant Hill in 1876 and adjacent mountains around the towns of Lawson and Dumont. Major mines in this area included the Free America, Albro, Blue Ridge, Senator and Syndicate mines, which produced rich silver ores through the end of the 1880s.

Attempts to process the silver ores began almost immediately, but rapidly ran into the same problems seen in other districts. Although some of the oxidized surface silver ores of the Georgetown mines assayed as high as $3,000 per ton, the initial smelting techniques that were familiar and successful in Missouri and the Midwest were inefficient in recovering silver. Early attempts to build smelters to support the mines were concentrated around Georgetown (Figure 3-14). In the early 1860s the Argentine Silver Mining and Exploration Company built a Scotch hearth near Georgetown, while the Bohemia Smelting Company built a reverberatory furnace nearby. However, neither proved capable of processing local ores. The first smelter in Clear Creek County to show any success was built by the Georgetown Silver Smelting Company in 1866-1867 at a cost of $25,000 (Cushman 1876:8). The company built a reverberatory furnace and cupelling unit for refining and ran a short campaign in 1867 that produced 558 ounces of silver bullion but encountered technical problems (Rocky Mountain News [RMN] 14 May 1867:1; RMN 2 August 1867:4). A novel smelting attempt was made by a group of Mexican prospectors who built a small adobe furnace consisting of a simple cupola with a single tuyere at the rear. The molten silver was collected from a tap hole at the front and collected in a basin where it was scarified (RMN 2 August 1867:4), but production was low and inefficient, and the smelter was soon abandoned.

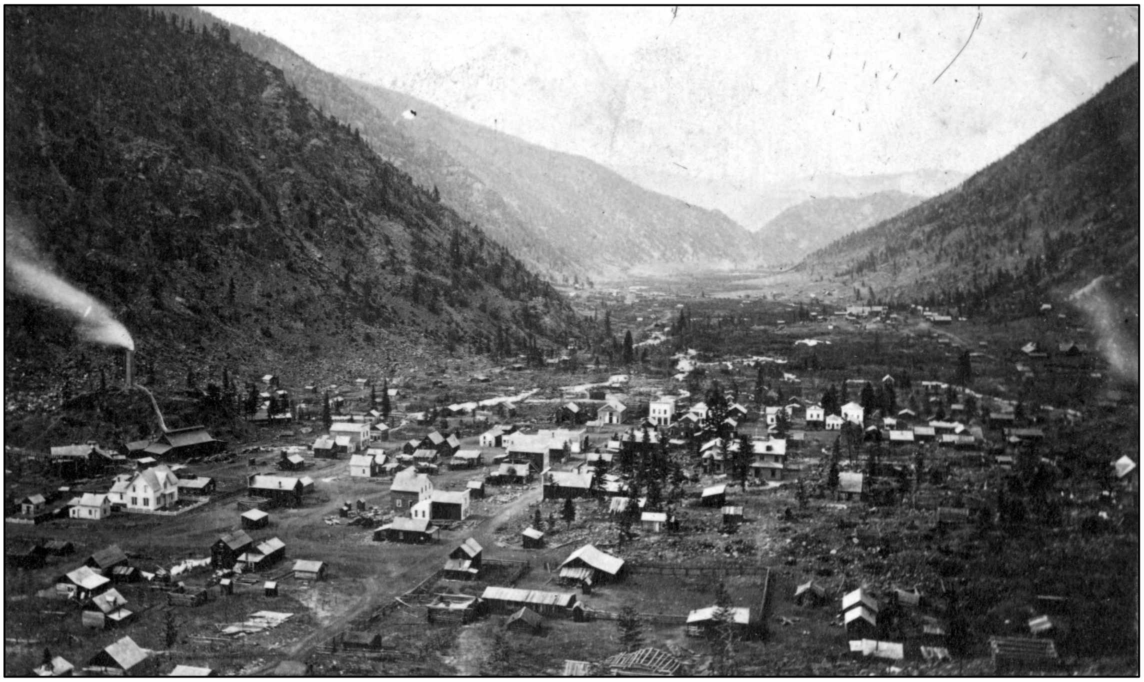


Figure 3-14. Georgetown in 1867 showing smelter in far-left middle ground. Colorado State Historical Society CHS X-1014.

Another early attempt was by an entrepreneur from the Central City area who built a water powered smelter on South Clear Creek and hired “professor” Fred Dibben to work the smelter (Figure 3-15). His work was unsuccessful until a formerly enslaved man Lorenzo Bowman who had 20 years’ experience in the

Missouri lead mines offered to try and correctly mixed a charge and smelted the ore. Lorenzo later helped organize the Red, White and Blue Mining Company (owned largely by the African-American community of Denver and included Frederick Douglas as an investor) that built a Scotch-hearth smelter 1.5 miles above town to work ores of their mines in 1867 (Spude 2003:111).

Figure 3-15. Dibbens Smelter near Argentine, ca. 1900-1920. CSH X-61397

The company then leased the plant to two German mining engineers, Schirmer and Brückner, who remodeled the plant and installed the experimental cylinder roasters of Brückner's design. The redesigned plant was able to recover up to 95 percent of the assayed value of the Georgetown ores, but recovery dropped dramatically when they began testing the underlying sulfide ores. The group had difficulty running the plant through the winter and it reverted to its previous owners who ran it semi-successfully in 1868 before closing in 1869. The inefficiency of the reverberatory furnace in treating the relatively lead-poor ores of the area mines was largely responsible for the plant's failure (Spude 2003:113-114).

Another smelter was built in Georgetown by the Brown Silver Mining Company in 1867. The mine owners built the smelter to avoid what they considered to be excessive reduction rates for their ores. The resulting smelter had a reverberatory furnace with both ore roasting and bullion refining units. The ores were concentrated by hand sorting the ore and then feeding the ore through a Blake jaw crusher and a 20-stamp mill before dressing ore on a buddle. The concentration usually reduced six tons of ore to one ton of concentrates averaging 200 ounces of silver per ton. The concentrates were then calcined in a double reverberatory furnace and smelted in a "common lead furnace, with the usual fluxes". The resulting lead-silver bullion was then refined in a cupellation furnace of a type "in general use in England and in western Nevada." The product was buttons of silver weighing 500 to 600 pounds (Cushman 1876:8-9). However, the ores produced by the company mines proved to be too low in lead content to allow efficient silver recovery, and in response they imported galena rich ores from mines in Gilpin County to raise the lead content of their charges. This was ultimately unsuccessful, and the company attempted to stay in business by importing pig lead from Chicago, but the extremely high transportation costs (raising reduction costs to $120 per ton) made the smelting process uneconomical and the smelter closed in 1870 (Fell 2009:61-61).

In addition to these early smelting works a number of amalgamation mills were built in the canyon. The earliest was a small six stamp mill about a mile below Georgetown that operated for about two years. Another notable mill was the Mount Alpine, or What Cheer, mill that was the first works in the state to use the Brückner cylinder roaster on a practical scale (Cushman 1876:10). At least 15 other reduction mills were built in the South Clear Creek Valley in the early to mid-1860s. These included mills from the “process mania” period such as the large brick mill at the Whale Mine on Spanish Bar that attempted to use the Bertola Process on a large scale and the Mason Furnace at Mill City (Dumont) that attempted to oxidize and desulfurize the ore by using a super-heated steam bath. A traditional smelter (the Swansea Smelter) was opened at Empire Junction managed by Mr. Richard Pierce (Cushman 1876:11).

The desperation to successfully treat the refractory ores of the area can be shown by the investment made at the Whale Mill (Figure 3-16). Using the experimental, and ultimately unsuccessful, Bertola process, the company built a brick mill with a core 138 feet long by 75 feet wide with two wings, each of 75 feet by 50 feet (Cushman 1876:84) all aligned parallel to South Clear Creek. The mine was designed to hold 128 300-pound stamps with an iron Chilean mill for each stamp battery. Tanks caught the processed ore to be treated by the Bertola Process. Each wing of the mill had 50 Bertola pans, where ore was ground and amalgamated after being subjected to a chemical steam bath. Six hundred feet above the mill a large dam was built across Clear Creek to give a 12 to 14-foot fall to feed two turbine wheels (one at each end of the building). After the failure of the Bertola Process the mill was briefly converted into a traditional smelter equipped with reverberatory furnaces but quickly failed (Cushman 1876:11).

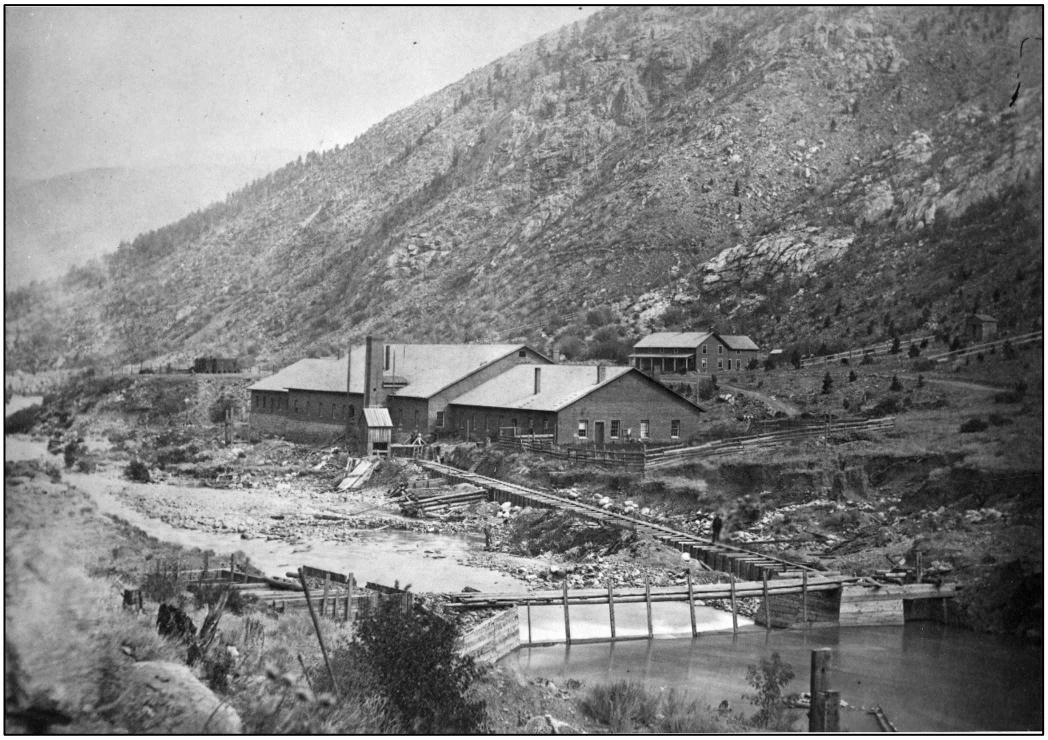


Figure 3-16. Whale Mill at Spanish Bar ca. 1870-1875. CHS.X-4592

A smelter using use the Swansea Method was erected at Empire Junction in 1872 by the Swansea Smelting and Refining Company under the management of Richard Pearce, a graduate of the Royal School of Mines who had worked at one of the largest smelters in Swansea, Wales. The company purchased the buildings of a previous company that had unsuccessfully attempted the Swansea method along South Clear Creek. The plant employed experienced workers from Cornwall and attempted to combine the local gold pyrites from the Empire District with the silver ores from Georgetown to create a copper matte that was shipped to Wales for refining. The method did not work well, and the smelter ran only a single month during the year as the local ores did not contain enough copper to create a successful matte. Further difficulties arose due to the high competition for top quality ore from the competing Boston and Colorado works in Black Hawk, ore buyers from Welsh smelting companies, and competition from the newly erected works of the United States General Mining and Smelting Company elsewhere in the valley (Fell 2009:43-44). The failure of the smelter was guaranteed when Hill convinced Pearce to come work for his company.

At the time Cushman was researching his book on the mines of Clear Creek County in 1876, no smelters were still operating in the valley although a number of chlorination and amalgamation works (the Stewart Silver Reducing Company, the Pelican Mill, and the Fudd and Crosby Reduction Works), three concentration mills (The Silver Queen Concentration Works, the works of the Collom Ore Dressing Company, and Mr. George Teal mill), and three major sampling works (Messrs.' G.W. Hall & Company's Sampling Works, the Rocky Mountain Concentration and Sampling Works, and the Church Brothers Sampling Works) were in operation (Cushman 1876: 9-12).

Local smelting ultimately failed due to inefficient plants and high competition for high-grade ores. Outside firms were usually able to outbid local companies. As ore values declined the eastern and European companies dropped out of the competition and the Boston and Colorado company developed a virtual monopoly on Clear Creek ores.

Silver production in Clear Creek County experienced two peaks, one in 1880 and one in 1894. Production remained steady until 1904 before entering a steady declined. The well-developed silver mines of the Argentine and Griffith districts remained in production, but base metals (primarily zinc) became increasingly important to their profitability. The gold mines near Idaho Springs remained in use intermittently into the 1930s. From 1858 to 1920 aggregate production for Clear Creek County was valued at $89,894,724 comprising $22,515,268 in gold (3.38 percent of Colorado’s total), $57,625,615 in silver (9.24 percent of Colorado’s total) making it the sixth most productive county in Colorado (Henderson 1926:86-87).

Clear Creek County was one of the early mining districts in the state, with both placer and lode deposits found during the original 1859 rush. Some of the earliest attempts to open smelting plants in Colorado were made in the county, although ultimately none were successful. The local plants had difficult competing for choice ores with the Boston and Colorado Smelter in Black Hawk (in Gilpin County), and later the large smelters of Denver. The mines of Clear

Creek County were some of the earliest to be served by railroad with the Colorado Central reaching the area in the mid-1870s from Golden. Like most Colorado mining areas most values were in silver, which contrasted with the deposits of neighboring Gilpin County whose mines mostly produced gold. The valley was the main victim of the “process mania” of the 1860s and the resulting skepticism limited the potential for the development of a local smelting industry with most ores being either processed by local amalgamation and chlorination plants or shipped to smelters in Black Hawk, Golden, or Denver. The known smelters were concentrated in the area between Idaho Springs and Georgetown, although one article mentioned the construction of a smelter at Idaho Springs (the Osbloston Smelter) (BVD 6 May 1885:1).

Some of the earliest smelting attempts in Colorado happened around Georgetown. Early mining in the county had concentrated in the gold mining areas of Idaho Springs and Empire where oxidized surface ores could be exploited using relatively simple techniques. However, the discovery of silver deposits near the head of South Clear Creek in the Argentine and Georgetown/Silverplume districts required the development of a way to process the more complex silver bearing ores.

Early newspaper accounts indicate that a number of small hearths for processing silver ores were built by Mexican miners in the area in the 1860s. Due their usefulness the Mexican population of the areas was initially well regarded in comparison to most areas of the state, but when it became apparent that the hearth furnaces were not profitable their welcome in the district declined and most moved on to other areas. None of these early Mexican smelters have been located. Other Georgetown smelters were discussed in Chapter 1 and include the Georgetown Silver Smelting Company and the Brown Smelter, both established in 1867.

In the neighboring Argentine District southwest of Georgetown was the small Dibbens Smelter (5CC1279). This was a Scotch hearth and one of the earlier attempts to build a smelter in the County. The smelter was only in use for a short period before conversion to an amalgamation works. The smelter used waterpower and it does not appear that a boiler was installed. The smelter was recorded by the United States Forest Service (USFS) in 2003 and determined eligible under criteria A and D. The industrial portion of the site consists of the mill foundation and the adjoining stone smokestack. Unfortunately, the site is in an area popular with recreationalists who reported evidence of mercury contamination. The USFS conducted limited archaeological data recovery during the following environmental cleanup operation. Archaeological deposits within the mill were removed which has likely destroyed the data potential for the site, although the smelter stack was preserved.

The Swansea works were built at Empire Junction using the same reverberatory process used at the slightly later Boston and Colorado works in Black Hawk. As built in 1872 the plant processed 8 tons per day and was equipped with two Gerstenhofer calcining furnaces, and two reverberatory smelting furnaces. The resulting matte from the operation was shipped to Swansea, Wales for refining (Stone 1918:312). Ultimately it proved unable to successfully compete with the Boston and Colorado and soon closed. In order to find usable ores, the company had even imported ores from the mines in the Boulder County to mix with the lean local ores (Colorado Miner [CM] 11 November 1876:3). Hill convinced Richard Pierce, the head metallurgist of the Swansea Works, to work for him and many of his English workers followed suit. Pierce served the rest of his career working for Hill and was largely responsible for the success of the operation. The exact location of the works has been difficult to locate due to disturbance from to the construction of US Highway 40 and Interstate 70. This has made it difficult to correlate historic maps and descriptions to the modern arrangement of the area. The works were approximately 1,000 feet west of the junction of the historic alignment of US 40 and the road to Georgetown. Portions of the slag dump and some foundations were still visible into the 1970s (Wolle 1971:39), but the remains are no longer visible from public right of ways or on aerial photographs. It appears that at least part of the site underlies a large Colorado Department of Transportation maintenance yard.

The Whale Mill was further east at Spanish Bar and was discussed in Chapter 1 as a good example of the process mania of the 1860s. A large amount of capital was expended building a large brick mill to use the unsuccessful Bertola process.

The mill was briefly converted to use reverberatory lead furnaces, but these were also unsuccessful at treating the ores of the mines and it was ultimately abandoned. The smelter was briefly reopened by the Plutus Mining Company (successor of the Whale and predecessor of the Stanley Mine) in the mid-1880s, operating at 50 tons capacity a day but closed by early 1886 (EMJ 1885d:262; BVD 21 February 1886:1; Stone 1918:313). Based on historic photographs and Sanborn Fire Insurance maps it is clear that the site was destroyed in the 1960s when South Clear Creek and Stanley Road were realigned during the construction of Interstate 70. The smelter location was just west of the existing Stanley Mine property outside Idaho Springs.

The Bullion Smelter (5CC352) was built in 1875 by the Bullion Smelting Company to treat the ores of the Freeland and Lone Tree mines. The company was organized by John M. Dumont and George G. Vivian, prominent mine owners in the county. The smelter had a capacity of 24 tons per day and had smelted 6,500 tons of ore during 1883 (EMJ 1884b:48). The smelter was recorded in 1976 and no NRHP evaluation was given. No site description was included beyond a photograph of a slag pile. OAHP records indicate the smelter is along Trail Creek downslope from the main Freeland Mine shaft to the southwest of Idaho Springs.

A small smelter was built by the Baker Company at Bakersville (modern Graymont) in 1869 to process ores from their mine on Kelson Mountain. The smelter produced between 15 and 65 tons daily until it was destroyed by a fire in July of 1871. It was not rebuilt (Lovering 1935:69) and was likely destroyed by the construction of I-70.

The last smelter identified in the county was an unidentified smelter was built at Dumont (Mill City) in the early 1870s near the junction of Mill Creek and South Clear Creek (Wolle 1971:112). The town had a number of amalgamation and reduction mills in the 1870s and 1880s, the foundations of some of which are still visible. Reference to the smelter was only found in one of Wolle's books and she may have misidentified a mill as a smelter. Wolle was an excellent research with an attention to detail but given the lack of corroborating evidence of a smelter in such a well-documented mining area she may have confused a conventional reduction mill for a smelter at this location.

Custer County

Custer County is in the Wet Valley between the Wet Mountains on the east and the Sangre de Christo Range on the west. The region contained productive silver mines at Rosita and Silver Cliff/West Cliff, but access to the outside was difficult. The D&RG built a narrow-gauge line to West Cliff in 1881 following Grape Creek, but it was abandoned in 1889 due to repeated flood damage and service was not restored until a new line was built up Texas Creek in 1901. The Custer County mines are unusual as most of the silver deposits are concentrated in small areas where breccia chimneys rise from the underlying caldera. Due to expense of shipping ores from the district a number of small smelters were built in the county, although none lasted long. No smelters in the county have been professionally recorded.

At least four smelters were built at Silver Cliff in the late 1870s and early 1880s. The Chambers Smelting Furnace was built just outside town in 1879 to process ores from of the Bull-Domingo (one of the largest mines in the district) and neighboring mines. The plant had a capacity of 20 tons per day and used a standard Fraser and Chalmers design with a Blake Crusher, Cornish rolls, two reverberatory ore roasting furnaces, and a water jacked blast furnace (EMJ 1880f:190; Emmons 1896:417). During a one-week period in April it produced 100 bars of bullion, each weighing 105 pounds (CDC 24 April 1880:4). The smelter operated for a period of 18 months before closing (Emmons 1896:417). This may be the same smelter identified as the Stacy and Knight Smelter, which was offered for sale in late 1880, although the location of the Stacy and Knight was not identified (Georgetown Courier [GC] 2 December 1880). The second smelter in the area was the St. Joseph Smelter, built along Grape Creek (CDC 6 September 1878:4) just outside of town in 1879 although it never entered production. The smelter was designed by a Catholic priest who constructed a five-stamp mill, roasting kiln, calcining furnace and a matting furnace before running out of funds (Emmons 1896:417). The Silver Cliff Smelter was built three miles north of town along Grape Creek in 1880. The smelter used a water-jacketed blast furnace with a daily capacity of 15 tons. Either due to bad management or poor design of the equipment the smelter froze continuously and was soon abandoned. The idle works were then destroyed by fire in 1883 (Emmons 1896:417). The final furnace built in the city was the experimental Duryee Furnace, constructed in 1880. The company attempted to use a new smelting technique where a revolving iron furnace four feet in diameter and 30-feet long was used to roast and smelt the ore in a single operation (Daily Herald [DH] 8 June 1882:4). The furnace was heated using petroleum byproducts with the belief that the precious metals would volatilize and could then be collected using a series of long dust chambers. The owners of the plant experimented with the process for three years, including lengthening the furnace to 50 feet, but ultimately could not make the process successful. No production of precious metals was reported after an expenditure of approximately $150,000 (approximately $3.7 million in 2018) (BVD 13 September 1883:1; Emmons 1896:417).

The Rosita District had been located prior to the Silver Cliff area (1872), but only a fitful attempt at smelting was made at the location, although a number of conventional reduction works were built in the area. The James Cupola Furnace was the earliest smelting attempt in the valley, built in 1873 (CDC 7 September 1873:4). The plant used a furnace design that was generally used in foundries for the remelting of pig iron. Not surprisingly the furnace was completely unsuccessful at processing the silver ores of the region and after a few tries and attempts at modifications was abandoned in less than a year (CDC 25 November

1873:4; CDC 27 November 1873:4; Emmons 1896: 416). Attempts were made to restart the smelter (now named the Pennsylvania) in 1876 by professor Mallet (CDC 14 December 1876:4) and again in 1880 as the Invincible with a new water-jacket blast furnace but with little success (EMJ 1880c:324; MM 25 December 1880:1). Professor Mallet gained a bad reputation and it was noted the works were in bad repair, his workers were not paid for overtime and neglected to pay many of his bills (CDC 1 February 1877:4), although he was able to install a new rotary roasting furnace (CDC 8 April 1877:4). The smelter was offered for sale in the Colorado Daily Chieftain in 1878 for only $1,000 as it used an old fashioned and ineffective method. The seller offered to rebuild it as a leaching works for an additional $3,500 (CDC 7 February 1878:2).

The last smelter identified in the County was a small 10-ton capacity water jacketed blast furnace intended for the Star Mine along Oak Creek. The materials for the smelter arrived onsite in 1882 and construction started. However, construction was apparently never completed, and it was never blown-in (EMJ 1880e:154; Emmons 1896:419).

Dolores County

The mining industry in Dolores County was concentrated around the town of Rico, a major mining center during the 1870s and 1880s. A total of three smelters were built in and around the community during this period. The earliest was a small adobe smelter built in 1872 but failed rapidly. The other smelters were built in the 1880s. The Grand View Smelter was built on the east bank of the Dolores River in 1880 at the north edge of town. The machinery for the smelter was freighted in from Alamosa (230 miles away by modern roads) and it was blown-in November 17, 1880 (Dolores News [DN] 30 July 1881:3; Hall 1895:121). It operated at a capacity of 35 tons daily during the autumn of 1885 (Delta Chief [DC] 23 September 1885: 2). Prominent metallurgist H.O. Hofman took over management of the works in 1883 (EMJ 1883c:54). The works were still in operation in the spring of 1887 (BVD 8 June 1887:4; BVD 30 June 1887:1). It produced between 400 and 500 tons of bullion during 1887 (BVD 6 October 1887:1). It appears to have fallen out of use for nearly a decade but was back in operation in 1892 producing bullion from the slag of its earlier years of operation (SCR 30 March 1892). The smelter is depicted on the Sanborn Fire Insurance maps of Rico for 1886 and 1890. The other smelter in town was the Pasadena Smelter built in 1882 (Hall 1895:122) which was intermittently in production until at least 1885 (SM 12 July 1884:2; SM 21 March 1885:1). The smelter installed a reverberatory furnace in September of 1884 (EMJ 1884h:179). Over a two-week period during the winter of 1884-1885 the smelter produced 30 tons of bullion with a total of 50 tons of bullion on hand (BVD 6 November 1864:2; DN 17 January 1885:2). By the summer of 1885 it was operating at 20 to 25 tons per day and had produced $200,000 worth of bullion since opening (DN 11 July 1885:2) The Rio Grande Southern Railroad did not reach Rico until 1891, by which time the smelters had closed, and local ores were then transported to the Durango Smelter for processing.

Eagle County

Although there were scattered mining districts in the central part of the county, the main productive mines were concentrated in the Gilman District. Only one smelter is known to have operated in the county. The Red Cliff smelter was built by the Battle Mountain Mining and Smelting Company in 1880 with one blast furnace with a 25-ton daily capacity (DCM 6 March 1880; EMJ 1882f:190) to process the ores of the company’s mines. Ore from other mines in the district were generally shipped to the smelters at Leadville. The smelter was operated successfully for a few years, but with the arrival of the D&RG at Red Cliff in 1882 it became cheaper to ship the ores outside the district for processing and the smelter was closed (Hall 1895:124).

Fremont County

Mining in Fremont County concentrated on the exploitation of coal deposits, but a few small mining districts working silver deposits were also created. Information has been found for two smelters in the county. An unnamed smelter was identified as under construction at the east end of Hayden Pass along Texas Creek (Fairplay Flume [FF] 1 April 1880). No significant historic mining production is known from the vicinity, although a small amount of gold and other metals was mined in the area in the mid-twentieth century. The location for the smelter given in the article is vague and it is impossible to determine exactly where it was built. The smelter could have been constructed to process ores from the Silver Cliff area further up Texas Creek in Custer County, but the distance to that area and the existence of local smelters at Silver Cliff make such an undertaking unlikely. The main smelter in the county was the Royal Gorge Smelter at Canon City (Figure 3-17). The smelter blew in March 15, 1883 with two water jacket furnaces processing ore from Oriental City (FF 15 March 1883:2; FCR 10 March 1883:4; EMJ 1883a:47). The initial operators of the smelter had difficulty making a profit and sold the works to the American Smelting Company (headquartered in Leadville) in early 1884 (SM 2 February 1884:4; SM 3 May 1884:3). At the time of sale, the smelter had a capacity of 50 tons per day and power was supplied entirely by water with no boilers installed. The smelter remained in use through at least 1886 when it was processing ores from Gunnison, Lake and Pitkin counties (CC 10 May 1886:5), but it appears to have failed soon thereafter. An attempt to rebuild the smelter and restart it in 1888 appears to have failed (BVD 5 April 1888:2). The last mention of the smelter was in 1907 when road crews encountered slag from the old smelter (that assayed high in gold), but the works had been abandoned for around 20 years at that point (Canon City Record [CCR] 15 August 1907:1). The smelter is depicted on the Sanborn Fire Insurance maps of Cañon City for 1883-1895.

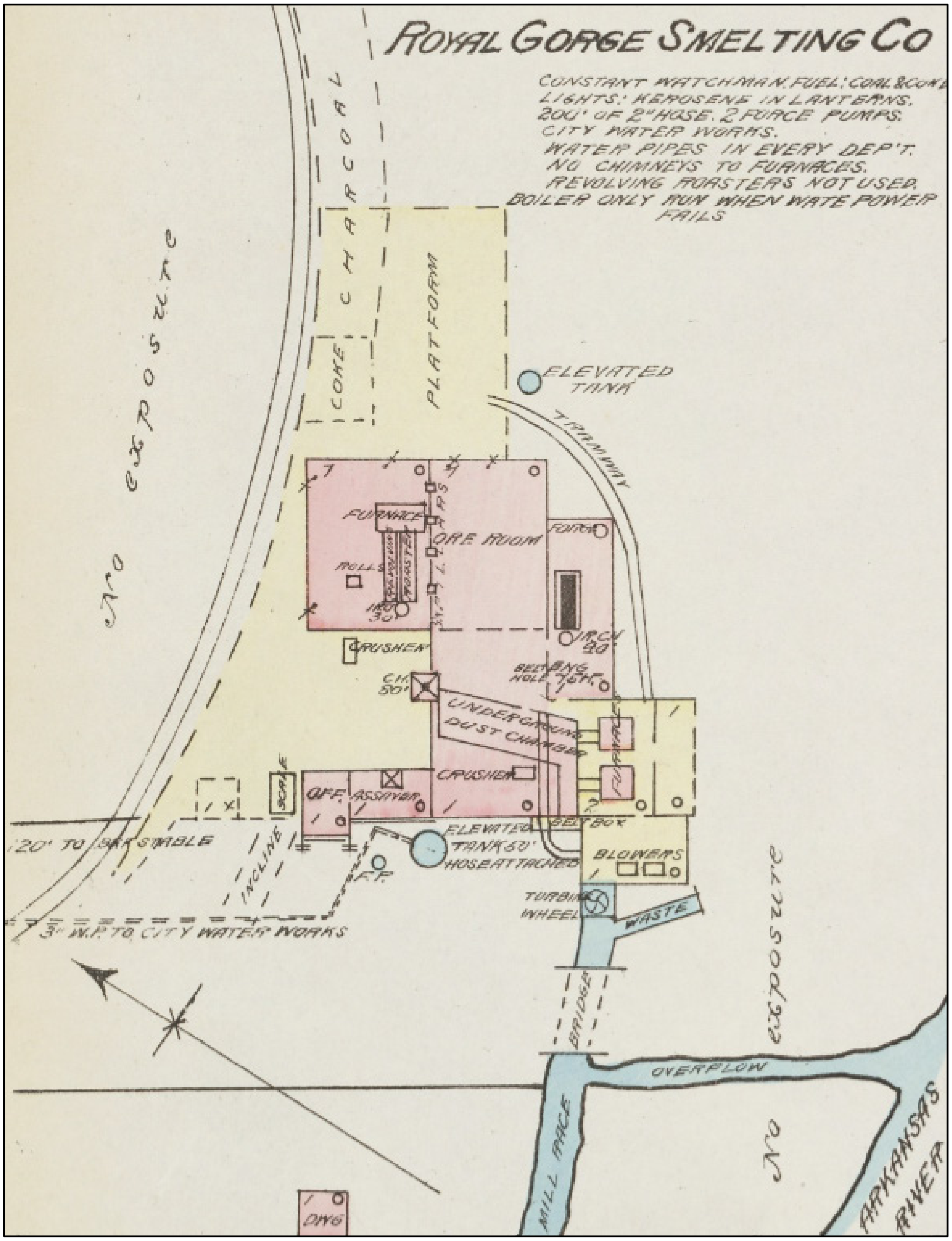


Figure 3-17.Royal Gorge Smelter. Sanborn Insurance Map, Canon City, 1883.

Gilpin County

Like Clear Creek County, the Gilpin County mines were located during the original 1859 gold rush. Prospectors followed rich placer deposits up North Clear Creek and found the Gregory Lode, the first lode deposit found in Colorado. The county was the main gold producing area of the state until the discovery of Cripple Creek. Although the earliest smelters in Clear Creek County predate those of Gilpin County by a few years, Gilpin can claim the first commercially successful smelter in the state, Nathaniel Hill's Boston and Colorado Smelter at Black Hawk.

Three smelters have been identified in the county. The earliest was a small smelter built by Caleb S. Burdsall at Nevadaville in 1861. The smelter was destroyed by fire within a month of operation before having a chance to prove itself and was not rebuilt (Stone 1918:310). The second smelter was the New York and Colorado Smelter built in the early 1860s by James Lyon. As a pioneer smelting endeavor Lyon was forced to make continual changes to his methods in an attempt to process the sulfide ores that were becoming common in the district as the oxidized surface ores were depleted. Lyon started with a Scotch hearth, which was unfortunately better adapted to the processing of silver ores than the gold ores of the area. He switched to the use of reverberatory furnaces similar in design and method to those later adopted by Nathaniel Hill (who worked for a time at Lyon's smelter prior to entering the business on his own and used is experience with Lyon to help determine the best smelting methods to work Colorado ores) but was unable to make the smelter economically feasible. The exact location of Lyon’s smelter within Black Hawk is unknown, but due to the limited space available in the canyon all traces of the smelter has likely been destroyed later construction.

The main smelter in the county was the Boston and Colorado Smelter (5GL2005) which is discussed in Chapter 1. The smelter was built in 1867 and remained in use until 1879 when the company built the new Argo plant in Denver. The Black Hawk works were retained by the company and converted into a sampling works to purchase ore supplies for shipment to Argo. It is unlikely that any intact remains from the smelter remain. The slag from the smelter was mined and shipped to Front Range smelters in 1930 to recover the remaining gold values. The smelter site was recorded by J.R. Baker of the University of Colorado in 1975. The only surviving feature of the site was the stone smokestack that was on the adjacent hillside. At the time of the 1975 recording the landowner planned on dismantling the stack for building material (Baker 1975). The site was in the approximate location of the Ameristar Casino and any remaining trace was destroyed by construction in the area.

Gunnison County

The Gunnison country was a major mining region of Colorado but was difficult to access due to rugged mountains along its borders. The major mining areas were concentrated along the north edge of the county near the boundary with Pitkin County, and in the east near the border with Chaffee County. The town of Gunnison is roughly in the center of the county and served as the main supply center. Gunnison was served by both the D&RG and the DSP&P railroads starting in 1881. Two smelters were built around Gunnison in the early 1880s, but both soon failed. At least six other smelters were built in the county to serve isolated mining camps.

The two smelters around Gunnison were the Gunnison Smelter (5GN1510) and the Jumbo Smelter. The Gunnison Smelter was started by the Mingo Furnace Company, which rapidly abandoned the effort and it was completed by the Shaw and Patrick company in 1884 with a capacity of 25 tons per day. The smelter was built along the East River north of town. (SM 2 February 1884:4; EMJ 1884i:235). It entered operation but failed by the end of the year. The works lay abandoned until reopened as the Gunnison Smelter in 1886 (BVD 10 February 1886:2). The plant was as unsuccessful the second time and also closed in less than a year (BVD 3 November 1886:1). The smelter is depicted on the 1886 Sanborn Fire Insurance map of Gunnison. The site was recorded in 1979 and visible remains consisting of a raised earthen platform, slag mounds and a brick smokestack (Sullenberger 1979). Since 1979 a residential complex has been built at the site location. The smokestack has been demolished and no evidence of the site is observable from public right of ways or aerial photographs. Based on aerial photographs the smokestack may have survived until 1994 but was clearly demolished by 2005.

The Jumbo Smelter was built at the northeast edge of town, probably in the early 1880s. The date of construction could not be located, but it was in operation in 1885 (BVD 21 October 1885:1; WPC 16 October 1885:2; BVD 9 December 1885:4). A one week run in October produced 347 bars of bullion with an aggregate weight of 29,495 pounds (WPC 23 October 1885:4). The smelter added a second stack in February of 1886 (BVD 10 February 1886:2), but by the time of its depiction on the 1886 Sanborn Fire Insurance map of Gunnison is noted as abandoned.

In the northern part of the county a smelter was built at Marble in 1884 (SM 26 July 1884:3), but no information about its operation was located. It was rebuilt by the Hoffman Smelting and Refining Company in the late 1890s. The bullion from the plant was sent to Pueblo for refining (AE 25 November 1897:3).

Crested Butte served as a supply center for mines in the northern part of the county and a smelter was built there by Howard E. Smith in 1879 (GC 22 January 1880:3), but it proved inadequate to support the local mines. A second smelter was built nearby at Rock Creek in early 1880 (GC 22 January 1880:3) which operated intermittently through at least July of 1884 (Salida Mail [SM] 26 July 1884:3). The closure date of the smelters is unknown, but precious metal mining in the Crested Butte area was short lived declining significantly by the mid-1880s. The precious metals industry of the community was rapidly supplanted by the coal industry and the area became an important coal producing areas of Colorado by the early 1880s. The region continued as a major coal and coke producer for the Colorado Fuel and Iron Company into the 1950s.

A small smelter was built at the town of Gothic in 1880. Late in the year the machinery for a 40-ton capacity smelter was shipped to the town and it was blown-in before the end of the year (MM 20 November 1880:1; GC 22 January 1880:4; GC 25 November 1880:1). It operated intermittently until at least 1884 (Salida Mail [SM] 7 June 1884:1). The boom days of Gothic were brief, and the silver found there was mostly in the form of wire silver that needed little processing. The final smelter in the northern part of the county was built in 1881 at Bowman in Taylor Park (Wolle 1971:187). No information was located for the smelter and it likely operated for only a short time. Mining was never very profitable in Taylor park due to poor transportation (the area was linked to the outside by only a long wagon road to Gunnison, and a difficult wagon road over Cottonwood Pass to Buena Vista). It also suffers some of the worst winter weather in the state which made year-round production difficult.

In the eastern portion of the county a smelter was built in 1880 at Abbeyville (one mile north of Tin Cup) by C.F. Abbey. The smelter had a capacity of 20 tons per day (GC 1 July 1880:1) and was blown in during November of that year (GC 25 November 1880:1). The smelter operated until 1884 when the population of

Abbeyville relocated to Tin Cup (BVD 15 March 1883:1; Wolle 1971:182). An attempt was made to build near Tin Cup in Virginia City but was described as “exists only in name, being simply a heap of materials put together so badly that on the first trial it broke down, the roof of the furnace is falling in, and the bottom allowing the metal to leak out.” It apparently never operated at its first test and was sold at a sheriff’s auction in 1884 for $52.25 (Chadwick 1881:75; EMJ 1884f:448).

Hinsdale County

Mining in Hinsdale County was concentrated from Lake City west to the border with San Juan County. Silver was discovered in the area in 1871, but transportation was limited to a few toll roads. To support the mines four or five smelters were built in the county. The two largest smelters were built at Lake City (the Crooke and Ocean View smelters) in 1877. The Crooke Smelter started production in July and the Ocean Wave in September (CDC 24 June 1877:1; CDC 13 July 1877:1; CDC 27 September 1877:4). Both were moderately successful until the mid to late 1880s. Two other smelters were built south of the city along the Lake Fork Gunnison River, while a third may have been built along Henson Creek. All the county smelters had failed by the time the D&RG reached the city in 1889 and all ores after this point were shipped out of the county for processing.

The Crooke Smelter (5HN1077) was built in 1877 with an initial capacity of 50 tons of ore per day (EMJ 1877a:221) and in its first year of production the smelter produced 300 tons of bullion with a value of $48,000 (SW 5 January 1878:2). The smelter ran successfully for several years before the company was sold to an English firm in May of 1882 (EMJ 1882e:8): The company went into bankruptcy in 1885 (EMJ 1885e:343) but continued to operate intermittently until at least 1886, although it had been forced to import pig lead from Joplin, Missouri (freighted 115 miles from the rail head at Alamosa) to continue operating due to the low lead content of local ores (SS 23 March 1889:1). The site was recorded in 2007 and was described as heavily disturbed due to the construction of a new hydroelectric facility and adjacent residential development. Although a few bedrock platforms from the smelter remain, the only undisturbed feature is the base for a steam engine. The site recorder recommended that the site no longer retained significant data potential. The Ocean View Smelter was built outside Lake City along the road to Capitol City (Silver World [SW] 15 December 1877). The company made its first shipment of 25 tons of bullion in September of 1878 with a silver content of 250 to 300 ounces per ton (EMJ 1878e172). Although it is unclear if the smelter was in use continuously, it was still operating in 1893 when Lake City negotiated with the company for power to supply street lighting (SM 1 September 1891:4). The smelter appears to have closed before the turn of the century, and the building was remodeled as either a chlorination or cyanide works in 1911 (Ouray Herald [OH] 13 January 1911:5).

The two smelters along the Lake Fork were the Carson and Welch's smelters. The Carson Smelter was a small plant built at Carson, a small town above timberline. The smelter was built to process ore from the St. Jacobs Mine, but was soon abandoned when the mine management decided to lease out the property rather than run it directly. The machinery from the plant was moved to Lake City and was probably incorporated into the Crooke Smelter (Wolle 1977:260-262). Welch's Smelter was built in the early 1870s in Burrows Park at the head of the Lake Fork. The smelter operated for a few years before the equipment was removed and installed at the works of the Lee Mining and Smelting Company at Capitol City (SW 27 July 1878; SW 24 August 1878). Mr. Greene, proprietor of the Greene Smelter in Silverton, broke ground for a smelter 10 miles above Lake City on Henson Creek and had machinery onsite (CDC 26 January 1877:4; SG 5 May 1877:7; CDC 31 May 1877:4), however no further information about the smelter was located.

Jackson County

There was little precious metals mining in Jackson County, although a few small districts were located along the edge of North Park. Wolle (1971:270) noted observing the remains of a smelter at the ghost town of Teller City, but no other references to smelters in the county were located.

Jefferson County

Precious metals production in Jefferson County was limited to a small amount of placer mining in 1859 and the early 1860s along Clear and Ralston creeks. However, the city of Golden served as an early smelting center. Golden was the terminus of the Colorado Central railroad which monopolize rail access to the mines of Clear Creek and Gilpin counties. Five smelters operated in Golden between 1872 and 1920. Most were built along the Colorado Central in the Clear Creek valley at the east edge of the city, known locally as Smelter's Row. The smelters operated with varying degrees of success until the turn of the century but were never able to compete with the large smelters of Denver and Pueblo. The early works were the Golden Smelting Works, the Colorado Dressing and Smelting Company, the French Smelting Works and the Malachite Mining Company. The Golden Smelting Works (Figure 3-18) were established by the partnership of Bagley and Sons in 1872. Unlike many smelting works they experimented with the use of lignite for fuel, fed by an air-blast mechanism. The use of local lignite was estimated to save $30 per day in fuel costs compared to their original wood fuel (EMJ 1876d:397; EMJ 1876e:397). The smelter started using blast furnace technology but converted to a copper matte plant in 1880. The smelter was the longest lived of the Golden companies and was the only one that operated between 1884 and 1888 (EMJ 1877a:221; Stone 1918:313). The works covered two acres along Clear Creek and processed 25 tons per day (Cecil 1952; Pueblo Daily Chieftain [PDC] 15 August 1874:3). The Colorado

Dressing and Smelting Company was established by the Colton Company in 1876 for the express purpose of treating the table concentrates produced at the company mines in Idaho Springs and Black Hawk. The works opened with two roasting furnaces and one reverberatory smelter of 15 tons capacity. The smelter produced copper matte for shipment out of state for processing (EMJ 1876:517). The French Smelting works were built in 1876 by Jacques Gaillordon with a capacity of 60 tons per day (EMJ 1880d:258). Other smelters in town included the Trenton Dressing and Smelting Works, a stone and brick smelter built at the entrance of Clear Creek Canyon built in 1877. The works appear to have closed within a few years and reorganized as the Valley Smelting Plant in 1879 which had a processing capacity of 15 tons and a one week run in early 1880 produced $11,453 in bullion (EMJ 1880b:264). A small smelter with a 5-ton daily capacity was built by the Malachite Mining Company to process the production of the company mines. The latest smelter built was a semi-pyritic plant built by the Clear Creek Mining and Reduction company in 1901, probably on the site of either the French Works or the Colorado Dressing Company (Cecil 1952; CM 8 March 1879:2).

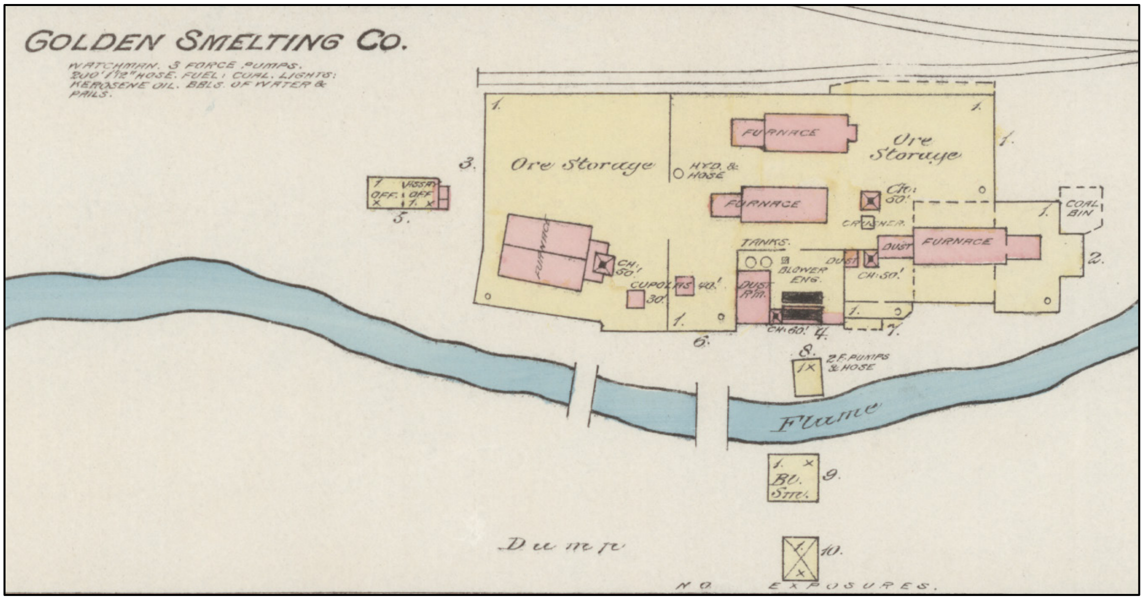


Figure 3-18. Golden Smelter. Sanborn Insurance Map, Golden, 1886.

La Plata County

Mining in La Plata County was limited with a few small districts with minimal production, and these produced most of their output in the early twentieth century. However, the town of Durango was a major supply center for the region with good transportation connections through the D&RG to mining districts, fuel and ore supplies throughout the state. Durango was home to the largest smelter in the Four Corners region. The Durango Smelter was a contributing factor to the closure of smaller smelters in the San Juan Mountains. However, the Durango plant did have limitation as the high snowfalls in the San Juan Mountains led to periodic shutdowns due to the inability of trains to move ores from Silverton which provided the bulk of its ore supply (DN 8 March 1884:2).

The Durango Smelter originated as the Greene Smelter located in Silverton. The Greene Smelter was acquired by the San Juan and New York Company and the equipment of the plant was shipped to Durango where it became the core of the new smelter. The San Juan and New York expanded continually until it became part of ASARCO at the turn of the century. The smelter operated until November of 1930 when it closed due to the decline of mining in the San Juan region. Most of the plant buildings were demolished in the following decade. The plant was rebuilt on a smaller scale during World War II to process uranium ore for the Manhattan Project and continued as a uranium smelter until 1963 when most of the plant was demolished. The last remnant of the complex was the brick smokestack that was recorded as HAER No. CO-38 by Duane Smith (1984b) prior to its demolition during the remediation and capping of the site by the Department of Energy.

A second small smelter was located at Animas City just outside Durango during the mid-1880s (CDC 9 May 1888:4), but little information pertaining to the smelter was located.

Las Animas County

Mining in Las Animas County was dominated by coal mining which was processed onsite into the El Moro coke used by many Colorado smelters. One smelter (the St. Helens) was built at Trinidad in 1889 by the Copper King Mining, Refining, and Smelting Company (WPC 18 October 1889:2; CDC 18 January

1890:6). The smelter had a daily capacity of 300 tons and used a matting process that differed from the Austin process in an unspecified way, but the company had trouble getting the proper ore mix to make the process successful (SiS 23 December 1893:3). The plant appears to have closed within a few years.

Ouray County

Ouray County had a number of rich mines including the Camp Bird which was one of the richest gold mines outside Cripple Creek. Information on smelters in the district is limited but at least one, and possibly two smelters were built around Ouray in the 1870s. The district was isolated and difficult to access until the D&RG reached the city in 1887. The earliest smelter in the county was the Long and Strout Smelter owned by the San Juan and St. Louis Smelting Company. This was a small smelter of 5-ton daily capacity that was built in August of 1877 (SW 11 August 1877; CDC 14 November 1877:4). No other information about the plant was located, but its small size indicates it was either intended to process the ores of a single company, or possibly served as a pilot plant to test the amenability of local ores for processing. References to a second smelter appear in 1878 (SW 9 March 1878:2) when a “company from Ohio” was planning to build a smelter near Ouray. The location under consideration was 1 to 1.5 miles south of Ouray at the hot springs along the Uncompaghre River. It was intended to run the works through the winter using the water from the springs for power. This was probably the smelter scheduled for construction by the Star Milling and

Smelting at Ouray in 1880 which was to include both a sawmill and concentrator (Solid Muldoon Weekly [SMW] 24 September 1880:3). The smelter was renamed the Ouray and Norfolk Smelter in the mid-1880s. The smelter appears to have been poorly designed as substantial amounts of matte were recovered during the demolition of the smelter in 1888. Partway through the demolition 200 sacks of matte averaging 250 ounces of silver per ton was already recovered from the ruins with expectations of an equal amount remaining (SMW 23 March 1888:3).

Park County

The mining areas of Park County were some of the earliest and at the time most isolated in the territory. During the 1860s and early 1870s South Park was only accessible by long wagon roads originating on the Front Range near Denver. The county includes South Park itself, and the bounding mountain ranges on the north, west and east. On the south a low range of hills separating the park from the Arkansas River drainage. Mining in the county was centered in the area around Fairplay and Alma, but other districts were located in the Mosquito Mountains along the west edge of the county and small outlying districts were located along the borders of Clear Creek and Summit counties. Due to the limited transportation options during the early years a number of small smelting enterprises developed in the county to support the industry.

A number of smelters were built in the area around Alma which supported the rich mines on Mount Bross and Mount Lincoln. The earliest was the Alma

Smelter (5PA340), a branch smelter opened by the Boston and Colorado Smelting Company to process ores that could not be economically shipped to Black Hawk. Most of the original Alma smelter was demolished in 1909 by the Colorado Gold Mining and Smelting Company to erect a short-lived smelter onsite (Herald Democrat [HD] 26 August 1909:3). The operation appears to have operated for a single year despite the installation of a state-of-the-art blast furnace and electrically powered equipment due to an insufficient ore supply from area mines (Rosenberg 1976). However, two of the original 1870s buildings from the Boston and Colorado smelter remain intact. The frame company office is currently in use as a retail store, while the limestone engine house is used as a residential structure. The buildings have been listed as a Park County Historical Landmark since 2014 and the buildings are described as rare surviving examples of industrial buildings from the heyday of mining in the county.

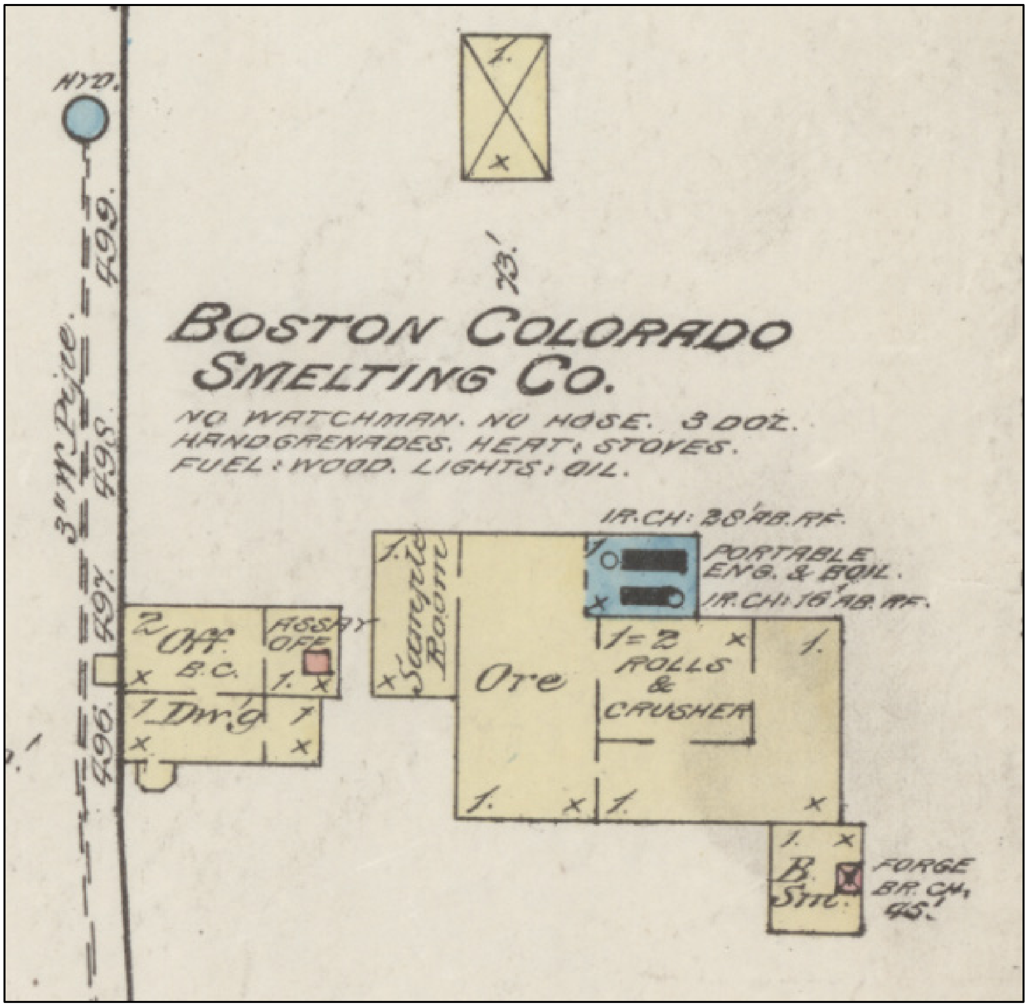


Figure 3-19. Boston and Colorado Smelter, Alma Branch. Sanborn Insurance Map, Alma, 1886.

Two other smelters in town was the Fanney Barrett, located just south of the Boston and Colorado works, and the Stevens. Both smelters were unpopular with local miners due to their high reduction costs (EMJ 1881g:435). One smelter was built at the small town of Dudley north of Alma. The Dudley Smelter (5PA334) was built a short distance north of Alma and was an early competitor of the Boston and Colorado works entering blast in November of 1872. The smelter is discussed in Chapter 1 as the Mount Lincoln Smelting Works. The smelter appears to have been highly inefficient and when the dump was reprocessed in

1882 it yielded $200 in silver per ton of slag (FF 7 September 1882:4). The site was recorded in 1976 (Warren 1976) and the description was limited to “Only a part of the foundation, rotting timbers, and the pile of slag…”. The single photograph in the site form shows foundation walls at least 7 to 8 feet high. The site was recommended as not eligible for the NRHP.

The Muchworth and Holland Smelter was southeast of Alma at the small town of Holland at the mouth of Pennsylvania Gulch. It was built by the Chicago and New York Mining and Smelting Company in 1879. The smelter used a blast furnace to process ores from the immediate vicinity but was not successful having difficulty processing the local ores (FF 15 May 1879; FF 14 August 1879:2; FF 20 May 1880:3; FF 18 December 1879). A second attempt was made in May of 1880, but the available ores were too low in lead content and it was forced to shut down after producing only 20 bars of bullion (FF 20 May 1880:3). The company was purchased by Messrs. B.D. Moore and Company in September and a third attempt to operate the smelter was made by September which was reported as successful with 165 bars of bullion on hand and the capacity of the furnace had been expanded to 50 tons per day (FF 16 September 1880). The date the smelter closed is unknown, but it was likely in the mid to late 1880s (Simmons 1992:123).

The South Park Smelting and Reduction Works, also known variously as the McFerran Smelter, the East Leadville Smelter or the Horseshoe Gulch Smelter was built at the town of East Leadville, that was platted by prominent local mine owner Judge H.B. McFerran in 1879. The smelter included a concentration works and a cupola smelter with a daily capacity of 10 tons. The smelter components incorporated equipment from an earlier smelter (the Lunt) the location of which is unknown (FF 4 September 1879:3). The smelter was mainly intended to smelt the ores of McFerran's Peerless mine, but also purchased ores from other area mines (FF 25 September 1879:3; FF 29 January 1880:3). The used equipment was not dependable, and the water jackets of the furnaces sprang leaks and had to be shipped to Denver for repairs in the spring of 1880 (FF 15 April 1880:3). The smelter was sold to Messrs. Russell, Allen and Wolcott of the Crusader Mining Company in the summer of 1880 who ran the smelter for a short time that summer, adding a new 35-ton capacity furnace, but the smelter was in very poor condition by the time they took possession and they had many difficulties keeping it operational. The group was forced to import iron ore from Brecce Hill at Leadville for use as flux, but the high transportation costs over Mosquito Pass seriously impacted the smelters profitability (FF 22 July 1880:2; FF 5 August 1880:2; FF 19 August 1880; FF 2 September 1880:3). The company went bankrupt in the fall of 1880 (FF 4 November 1880:3) and the works were destroyed by arson in the spring of 1881 and was not rebuilt (FF 7 April 1881:2). The exact location of the smelter is unknown as there is some confusion about the identification of the historic ghost towns of Horseshoe Gulch, with the towns of East Leadville, Horseshoe, Sacramento, and Leavick often used interchangeably. The remains of a smelter was observed at the site of Leavick by Wolle (1971:96), but it is unclear if this was the remains of the McFerran smelter or a separate unidentified smelter.

The Duquesne Smelter (5PA299) was built at the mouth of Sacramento Gulch west of Fairplay blowing-in for the first time in February of 1880 (FF 18 September 1879:3; FF 16 October 1879:3; FF 5 February 1880:3; EMJ 1880a:105). The smelter failed by April with a total production of only 10 tons of bullion due to the “financial embarrassment” of the management (FF 5 February 1880; FF 15 April 1880:3). The smelter was recorded by the USFS in 1976 and the remains were described as only “structural debris, ashes, brick and slag remain.” The 1985 reevaluation of the smelter stated it “...is significant only as an example of several in South Park that failed because of obsolete technologies or inadequate or short-lived ore supplies in lesser mining areas like Sacramento.” (Gardner 1985).

The last smelter in the western part of the county was the Stone Smelter erected at the town of Fairplay by Colonel W.B. Stone (company president). The exact date the smelter opened is unknown but it produced 50 bars of bullion with a content of 200 ounces of silver per ton in 1882. The smelter was contracted with the Criterion Mine for lead rich ores (Rocky Mountain Sun [RMS] 15 July 1882:4). The location of the smelter within Fairplay is unknown.

The last two smelters identified in the county are on the east border of South Park on Kenosha Pass near the historic towns of Grant and Webster. Both smelters were built by the same company, the Hall Valley Silver-Lead Mining and Smelting Company, Ltd., to process ores from their mines at the heads of North Fork of the South Platte River and Geneva Creek respectively. Both were built prior to the construction of the DSP&P railroad across the pass and were connected to the outside world by long wagon roads to Denver, or shorter roads crossing steep passes into Clear Creek and Summit counties. The veins exploited by the company mines had very similar makeup and appear to be components of the same deposit that is like those found in the Montezuma District just over the border in Summit County. The Hall Valley Smelter (5PA313) was the earlier of the two (built in 1873) and the best documented. The smelter was constructed to reduce transportation and treatment costs for the mines on Whale Mountain. The smelter is described in greater detail in Chapter 1. The blast furnaces built at Hall Valley had great difficulty treating the local ores which were rich in barite. The specific gravity of the barite and the silver bearing minerals were too similar to allow for a good separation of the ore and gangue and the smelter rapidly failed. The smelter site was acquired by the Comet Consolidated Mining Company in 1883 and there is some indication that an attempt was made to convert the smelter to an amalgamation or chlorination plant. However, these efforts proved no more capable of processing the ore and all large-scale operations in the valley halted. Only after the installation of a floatation mill near the mines in 1917 was the ore successfully processed. The floatation mill appears to have operated until 1921 (Lovering 1935:67).

The second smelter owned by the Hall Valley Company was the Geneva Smelter (5PA317) built north of Grant at the junction of Geneva and Smelter gulches. The first plans for the construction of the smelter were made as early as 1876 (DCM 11 November 1876:3). The smelter was built three miles from the mines, which had previously been shipping their production to the Boston and Colorado works at Black Hawk. Herman Beeger was hired to design the smelter which had a capacity of 15 tons per day (CM 31 August 1878:3). The location below the company's mines was chosen due to better access to wood, which was the main fuel used by the works. The exact date of construction is unknown, but by the summer of 1879 it had a 40-foot by 32-foot furnace building, a 55-foot by 40-foot "main building", a 40-foot square sawmill and 500 cords of wood on hand for fuel (DCM 16 August 1879:). The smelter was intended to process ores from the Baltic and Revenue mines at the head of the creek which were originally hauled to the Hall Valley Smelter for treatment (GC 8 May 1879:3). Despite the failure of the Hall Valley Smelter the company persisted in using similar smelting methods at Geneva that also proved unable to process the functionally identical ores from these mines and the smelter failed by 1881 (Lovering 1935:69). The smelter was recorded in 1977, but the site description was limited to "Little remains except stone foundations and a small slag pile from the ore treated here." The site was recommended eligible for the NRHP due to its data potential (Rosenberg 1977b).

Pitkin County

Mining in Pitkin County was concentrated around the town of Aspen. Due to the area’s isolation and the difficulty of shipping ores out of the district there were at least two attempts to construct smelters in the county. There appears to have been an increasing reluctance by Colorado entrepreneurs to enter the smelting business by the mid-1880s. It was becoming obvious that smelting was a difficult and often unprofitable business and the area was hopeful that the arrival of the railroad would provide better other options. In the early years of the town the mines were able to remain profitable shipping high-grade ores over Independence Pass to the smelters at Leadville. Shipping low grade ores became possible with the arrival of the D&RG at Aspen in 1887.

To meet the demand in the interim several small smelters were opened in the county. The name of the first smelter at Aspen is unknown, but construction on it began in 1881 but had not yet opened by March of 1884 while the owners continued to attempt to acquire mining properties on Aspen Mountain (LD 16 June 1881:4; CaC 15 March 1884:2). The smelter entered production after it was sold to a group of investors from the Colorado Midland Railroad but closed in 1888 (BVD 19 January 1888:1). The second was built by the North Texas Smelting Company with a 50-ton daily capacity in 1882 (EMJ 1882j:259) but closed before significant production was made (RMS 21 June 1884:2).

The third, and only successful smelter was the Aspen Smelter built ¾ of a mile from town which opened in 1883. The works had a capacity of 40 tons per day and was equipped with Blake crushers, Cornish rolls and used both waterpower and a small boiler produced by the Colorado Iron Works. By 1885 the plant had produced 550 tons of bullion and had replace the original water turbine with a Pelton wheel (RMS 14 March 1885:4; CC 19 July 1884:5; EMJ 1884g:78). The head metallurgist for the company was W. B. Devereux who had patented several improved pieces of smelting equipment he designed for the smelter (RMS 4 August 1883:2) The plant operated for much of the 1880s but closed before the end of the decade (AWT 8 February 1890:2). The smelter is depicted on the Sanborn Fire Insurance map of Aspen for 1886.

A smelter was built at Ashcroft a community further up the Roaring Fork with more limited transportation facilities in 1880 by Messrs. Kellogg and Company (Rocky Mountain Sun [RMS] 30 July 1880), although the machinery for the smelter did not arrive until late the following summer (AWT 30 August 1881:2).

Rio Grande County

Rio Grande County is in the western San Luis Valley and its economy was always dominated by agriculture. However, its western border extends into the San Juan Mountains including the Summitville Mining District. Most of the district's ores were shipped out of the county and only one smelter has been identified. A small smelter was built at the town of Monte Vista by professor

Yonley and Company in 1880 (FF 7 October 1880) on high ground at the south edge of town. No records of production were located, and it appears to have closed quickly.

Saguache County

Saguache County is at the north edge of the San Luis Valley bordering Chaffee and Gunnison counties on the north and extends to the crest of the Sangre de Cristo Range on the east. Precious metal mining in the county was concentrated in two areas: the Bonanza District in the north central part of the county and in the Sangre de Cristo Range around Crestone. In later years the Bonanza area became a significant copper producer and the Orient District north of Creston became a major iron supplier for CC&I/CF&I.

A total of four smelters have been identified in the county. Two of the smelters were built in the Bonanza District. The first was built by the U.S. Mining Company of Pittsburg in Bonanza City in 1880 (SM 10 July 1885:4; Mountain Mail [MM] 30 October 1880:1; MM 25 December 1880:1). By 1882 the smelter was producing up to 150 bars of bullion per day (Leadville Daily Herald [LDH] 10 August 1882:2; Colorado Daily Chieftain [CDC] 25 January 1882:2) but was handicapped by the inability to procure sufficient lead rich ores (MM 21 January 1882:3). The smelter remained in operation into 1885 before closing down when the districts highest-grade ores were exhausted (Wolle 1977:227, 1971:299). A second smelter, the Weems Bonanza Smelter, was built just outside Bonanza in 1895 by the New

York Smelting Company. The company modified a large abandoned mill originally built in 1884 where they installed a pyritic smelter stack. The smelter was blown in August 15 with a capacity of 100 to 120 tons daily. A 10-day trial run of 1,000 tons of ore produced a matte averaging 40 percent copper with 750 ounces of silver, and four ounces of gold (Saguache Crescent [SC] 15 August 1895:3; 26 September 1895:3). The smelter appears to have closed after a short run.

In the Sangre de Cristo Range at least two small smelters were built. The first was a small smelter was built at Crestone in 1885 that is known only from a travel log (Warner 1885a:1, Warner 1885b:1). The second smelter at the town of Oriental by a Mr. Dorkensly in 1880. The machinery of the smelter was purchased from the Shaveno Smelter at Maysville in Chaffee County after it closed (Saguache Chronicle [SC] 8 October 1880:4).

San Juan County

San Juan County is entirely within the San Juan Mountains centered on the town of Silverton. Mining occurred in all parts of the county but was concentrated in the mountains northeast of town. Prior to the arrival of the D&RG transportation outside the county was difficult and several small local smelters developed to serve the mines. Most were concentrated in Silverton, though others were built up the Animas River past the town of Animas Forks. The earliest smelter in the area was the Greene Smelter that was built at Silverton in 1875 by the San Juan and New York Mining and Smelting Company. All materials for the construction of the smelter were shipped into Silverton by burro due to the lack of a passable road into the district. It was first blown in on July 6 with a production of 4 tons of bullion per day, and by July 10 had produced 150 small bars of bullion (EMJ 1876f:77; Quite So 1875:2) and by September 40 tons of bullion worth $15,000 was shipped east for refining (CDC 8 September 1875:4; CDC 24 September 1875:4). During 1877 it produced 400 tons of bullion averaging 240 ounces of silver per ton (CSG 8 December 1877:4). In 1880 the plant consisted of two roasting furnaces, a 36-inch round water jacketed blast furnace with a 10 ton per day capacity, a 5 foot by 4-foot rectangular water jacketed furnace with a capacity of 15 tons per day, Sturtevant and Blake blowers, two Blake jaw crushers and a set of Cornish Rolls. It reported saving 92 percent of the assayed silver content of the ore (San Juan & New York 1880). The smelter remained in operation until 1881 when the smelter was sold, dismantled, and shipped to Durango to form the core of the Durango Smelter.

A competing smelter, the Silverton Smelting Works was built at about the same time as the Greene Smelter producing 345 tons of bullion averaging 260 ounces of silver per ton by the end of the 1877 (CSG 8 December 1877:4). By the following summer the smelter was offered for sale due to the “financial embarrassment” of the company. The company’s failure was attributed to the owner’s speculative mining investments rather than any problems with the smelter itself (Dolores News [DN] 28 August 1879:2). A third smelter in the city was the Rough and Ready Smelter built by Calder, Rouse, and Holmes in 1875 and later sold to Messrs. Mather, Smith and Perkins of New York (CSG 25 September 1875:1). The smelter was unsuccessful and was converted to a sampling works in 1878. By 1884 it had been abandoned and was described as an “ornamental burden” for the city (CaC 15 March 1884:2; CSG 6 July 1878:3).

A fourth Silverton smelter was the Martha Rose Smelter (5SA1177) built by the Silverton Smelting and Mining Company in 1882 (Solid Muldoon Weekly 1 June 1883:3; Wolle 1971:431). The smelter was not profitable and closed in 1884 after it was sold to an English Company for $25,000 (EMJ 1884f:448). The smelter was reopened in the 1890s as the Walsh Smelter using the pyritic method (SiS 21 April 1894:2; Sis 18 May 1895:2) and enjoyed success for a number of years before closing in the early twentieth century. The Martha Rose/Walsh Smelter was recorded in 2005 and is one of the few smelters in the state that has been recorded to current professional standards.

Much less information is available for the other smelters in the county. Brown’s Smelter was built at Animas Forks in 1875 (CSG 25 September 1875) but was completely destroyed by an avalanche in 1877 at a loss of $30,000 and was not rebuilt (CSG 13 April 1877:4; CDC 20 April 1877:4). An unidentified smelter was built at Howardsville in 1875 (CSG 25 September 1875; Silver World [SW] 9 October 1875). This maybe the reverberatory smelter built by Spencer and Dunhem at the mouth of Minnie Gulch, or these may have been two separate smelters (SW 9 October 1875). A small smelter using a hearth furnace was under construction at Howardsville by a Mr. Innis during the same period (SW 9 October 1875). The Crooke Brothers (owners of the Crooke Smelter in Lake City) let out bids for construction and freighting of equipment to a smelter site a few miles north of Silverton at the mouth of Boulder Gulch in 1878 (CSG 6 July 1878:3; CSG 31 August 1878:2). The removal of their works from Lake City was apparently motivated by a desire to avoid taxes levied on the smelter by Lake City (Dolores News [DN] 28 August 1879:2). Two additional smelters were located near the headwaters of the Animas River. The Brown Eply Smelter (5SA556) and the Eclipse Smelter (5SA566) were recorded in the late 1990s. At the time no archival information was located pertaining to the smelters beyond their depiction on an 1891 map of the area. The recorder believed the two smelters were built in the 1890s and closed around 1904 when the Silverton Northern railroad reached the area (Baker 2000a; Baker 2000b). At least the Eclipse Smelter predates the 1890s and was in operation by August of 1881 (EMJ 1881f:136), with 100 tons of matte on hand in 1882 (EMJ 1882g:299). The last known smelter built in the county was the Kendrick and Gelder Smelter, built at the mouth of Cement Creek in 1900, renamed the Ross Smelter in 1906 (Wolle 1971:432). The smelter appears to have failed soon after this date.

San Miguel County

Mining in San Miguel County was concentrated in a band starting northeast of Telluride and extending southwest to the Ophir area. Gold and silver deposits were identified in the area in 1875 and a few of the large mines remained in production into the 1950s. Ore reduction methods for the county concentrated on chemical methods (amalgamation, chlorination and cyanidation). It appears that only one small smelter, the Ames Smelter, was built in the county at Ophir in 1882, but was almost immediately sold at a sheriff's sale). The competing Boston and Ophir company smelter opened in the same year, but it remained in operation for only a few years (EMJ 1882h:137; EMJ 1883e:87: Wolle 1971:390).

Summit County

Summit County is unique in Colorado for the continued dominance of placer mining throughout the nineteenth century. The area around Breckenridge on the Blue River and in adjacent French Gulch supported conventional placer mining in the nineteenth century and large dredge operations into the early twentieth century. Lode mining in the county was concentrated in the eastern part of the county near Chihuahua and Montezuma (extensions of the Peru-Argentine district in Clear Creek County), in the southwestern part of the state in the Ten Mile District around Kokomo and Robinson, and in the area bordering Mt. Bross and Mt. Lincoln in the south-central part of the county. The early isolation of the county led to the construction of a number of smelters, including one of the earliest at Sts. John.

The Sts. John smelter was discussed in Chapter 1 and is one of four smelters in the Montezuma District. The earliest version of the smelter consisted of a Scotch Hearth built by John Coley. The stack of the smelter is still standing. Elsewhere in the Montezuma District smelters were built at Montezuma and Decatur. An unidentified smelter was under construction at Decatur in August of 1879 (CM 30 August 1879:3). No other reference to this smelter was located, and it is unclear if it entered production. The firm of Aldrich and Hill remodeled the Sisapo Mill at Montezuma into a 25-ton per day smelter under the technical direction of professor Yonley at a cost of $10,000 in 1880 (CM 17 April 1880:3, GC 22 April 1880:4). The smelter began roasting ores in preparation for smelting in July (CM 10 July 1880:3) and entered operation in September, producing 10 to 20 tons of bullion per day using charcoal and coke for fuel (CM 10 July 1880:3; CM 11 September 1880:3). The smelter was still in operation in early 1881 (GC 17 March 1881:3).

The Ten Mile District is in the southwestern part of the county and was located by prospectors crossing Fremont Pass from Leadville. The district was a producer of gold, silver, lead and zinc. The most profitable period of mining was in the 1880s, but mining continued into the early twentieth century. The great molybdenum deposit at Climax was discovered in the 1880s but did not serve a practical purpose until WWI when large scale mining of the deposits began. The Climax mine remains in production in the early twenty-first century.

The first smelter in the district was built at Kokomo in the spring of 1879 by Grant, McNair and Wormsey (the Pittsburg Mining and Smelting Company) and was named the Pittsburg Smelter (GC 5 June 1879:3). Local miners viewed the smelter as so important to the success of the district that they contributed $650 to help defray the transportation costs of moving the machinery to the site (CM 7 June 1879:3). At the time of construction, the nearest railhead to the site was the end of track for the DSP&P at the town of Webster at the east base of Kenosha Pass approximately 80 miles away. Webster was notorious as a bottleneck for freight outfits and in addition to the machinery for the Pittsburg, the equipment for a second smelter belong to a Mr. Raymond (for the Robinson Smelter) was also awaiting transportation to Kokomo (GC 12 June 1879:3). Construction of the Pittsburg Smelter began in early June (CM 21 June 1879:3) and was completed in early July with the machinery arriving on July 5 (Leadville Daily Chronicle [LDC] 7 July 1879:1; CM 5 July 1879:3). The main building of the smelter was 30 x 40 feet and included a blast furnace with a capacity of 40 tons per day with ancillary equipment powered by a 35 hp steam engine (CM 5 July 1879:3). The smelter went into blast in October and produced 150 tons of bullion during an 18-day campaign (GC 6 November 1879:3). The first run indicated that further improvements to the methods were needed and it shut down while changes to the equipment were made. It became apparent that the plant had started somewhat prematurely and efforts to improve transportation and storage facilities for the plant were underway to enable it to reach full capacity. During a run in late 1880 the water jacket of the furnace burst and it was forced to sell its accumulated ores to the Robinson (CM 22 November 1879:2; EMJ 1880g:319). Less information is available about the Robinson Smelter built at the nearby town of Carbonateville in 1879. The furnace had a daily capacity of 80-tons per day and had signed a contract for 50,000 bushels of charcoal at 18 cents per bushel in November of that year (CM 29 November 1879:3; GC 26 February 1880:3). The smelter had an initial capacity of 30 tons of ore per day and could not meet local demand but was forced to import low-grade bullion from Leadville due to the lack of lead in local ores (EMJ 1881c:165; EMJ 1881d:97). The smelter was closed, and the machinery shipped to Leadville in late 1884 (EMJ 1884j:432). A third smelter in the Ten Mile District was built in early 1880 by Thomas and A. Greer of New York City with D. Doncaster as superintendent. The plant was designed with a capacity of 30 tons with machinery ordered from manufacturers in Chicago (GC 26 February 1880:3). The exact location of this smelter is unknown.

The last smelting area in Summit County was around Breckenridge where at least three smelters were built. The earliest was built at Lincoln City four miles east of Breckenridge in 1879. The smelter was under the direction of Captain Smith and made a test run of 50 tons of ore to determine if the operation would be profitable (required local ores to yield at least 50 ounces of silver per ton) (CM

21 June 1879:3). The smelter remained in operation until early 1880 (GC 20 March 1880:3). The smelter is depicted on the Sanborn Fire Insurance Map of Breckenridge in 1883. This was followed by the Fuller Placer Mining Company with funding provided by Boston and New York businessmen, acquired a 15-acre plot across the Blue River from Breckenridge in 1880 and built the Cataract Gulch Smelter early in the year. They erected a 50-foot square, two story main building for the smelter with two 50 x 25-foot sheds for roasting furnaces. The 20-ton daily capacity blast furnace was purchased from Fraser and Chalmers of Chicago. Room had been included in the building for the addition of a second furnace at an early date if the smelter proved successful. Power for the plant was provided by a combination of waterpower from Alpine Creek and a backup steam plant for times of low water. The plant worked ores from the company mines although 50 percent of the plant capacity was reserved for use on custom ores (DCM 17 January 1880:CM 17 January 1880:1). The buildings were sheathed in sheet iron siding, had large ventilators on the roofs and were painted a “handsome” brown color (CM 29 May 1880:1). A third smelter was built near town in July by the Wilson Smelting Company with a projected capacity of 50 tons per day (GC 8 July 1880:3). The final smelter

This section provided an overview of the small smelting operations in the Colorado mountains. Further research would certainly reveal additional smelters in many areas. These smelters would almost uniformly be considered failures. These smelters were generally small, poorly capitalized, short-lived plants based on blast furnace technology. Some managed to survive in relative isolation for a short time, but many failed within one or two years. The main period of construction for the smelters is around 1880, probably due to the introduction of more experienced smelting workers with the development and collapse of the large concentration of smelters at Leadville in 1879 and early 1880. The reasons for these failures are discussed in Chapter 5. These small smelters set the stage for the later large smelters that developed at Leadville and along the Front Range and discussed in the following chapter.

4 Late Smelting – Leadville and the Front Range

This section discusses the large, well-financed smelters that were built in Denver, Leadville, and Pueblo starting in the early 1880s. These smelters were the primary competition for the small smelters in the mountains. The discussion here allows these larger smelters to be compared to the small smelters discussed in Chapter 3 and are important to the discussion of the failure of small smelters in Chapter 5. The initial concentration of large smelters was at Leadville in the central portion of the state, but it was soon eclipsed by larger plants built at the Front Range communities of Denver and Pueblo. This chapter briefly examines changes in the mining industry during the later part of the nineteenth century and its impacts on the smelting industry. It then discusses the three main smelting centers of the state: Leadville, Denver, and Pueblo to provide a comparison of the size of these plants and the smaller smelters discussed in Chapter 3.

The decline in silver prices in the 1890s impacted silver mining on a global scale. The industry which had previously been in a state of near constant expansion stagnated. Many smaller mines closed in response to the fall in prices, but aggregate production from 1893 to 1897 remained constant. In Colorado many large silver mines remained in production but no major new mines were opened after 1893 (Rickard 1896b) and these mines only remained profitable due to improvements in smelting and chemical means of production that reduced prices. Silver and gold production as a byproduct of base metal smelting become the main source of these metals, accounting for two-thirds of world production. By 1896 the majority of U.S. silver production was a byproduct of lead mines (58.8 percent), 34.4 percent came from copper mines, and only 6.8 percent came from straight silver mines. The 22.6 percent decline in silver prices in the period was compensated for by a 29.2 percent increase in the price of lead and a 10.1 percent increase in the price of copper (Meade 1899).

The Colorado mining industry responded to lower silver prices by various attempts to increase efficiency and lower prices. The most notable was the construction of a series of combined drainage and haulage tunnels meant to serve large numbers of mines. Many of these projects were initiated in the 1890s, but the height of their construction occurred from 1900 to 1910. Major examples of these tunnels include the Yak Tunnel at Leadville serving mines on Breccia, Carbonate, and Iron hills. The Argo and McClelland tunnels in Clear Creek County (Griswold and Griswold 1996:2205-2206; PCM 1905:215; Twitty 2014). Although the tunnel projects extended the life of some mines, they failed to generate the great revival in mining that was originally intended.

The decline in silver prices led to a renewed interest in the state’s gold mines. Old mines in the Idaho Springs area were reopened but the best deposits were long since depleted. Even the dependable gold mining areas of Gilpin County were eclipsed by the rise of the last of Colorado’s great mining regions, Cripple Creek.

A short rush to the area had occurred in the 1880s, but poor showing and fraudulent reports on the richness of the finds gave the area a bad reputation. It was not until the discovery of gold on the west flank of Pike's Peak by Bob Womack in 1890 that attention returned to the area. Cripple Creek soon became the preeminent mining district of Colorado (Rickard 1896a:846-847).

Although the Cripple Creek region produced significant amounts of ore into the early twentieth century, this had little impact on the state smelting industry. The use of chlorine and the new cyanide process proved capable of treating the gold ores more cheaply than smelting. Combined with the reduction in the production of gold and silver ores around the state the smelting industry fell into decline. Attempts to reduce wages in both the mines and smelters to improve profits led to an increasing number of bitter strikes in Cripple Creek, Leadville, and the San Juans that led to the permanent close of many mines and some smelters. Mining production in Colorado peaked in 1900, but gold and silver had declined in importance. The exploitation of base metal deposits such as molybdenum, tungsten, zinc, and vanadium became the new focus of mining. Increased demand during the First World War temporarily buoyed mining but demand for metals rapidly declined after the Armistice. By the 1920s even Cripple Creek faltered as gold values declined (Fells and Twitty 2008:38-39).

In the smelting industry, stagnant mine production and over-competition between the smelting companies created an interest in stabilizing reduction prices. In

1899 a group of prominent smelter owners formed ASARCO, a smelting trust intended to regulate smelting prices. The trust soon included most of the major smelters of Colorado and expanded into other states. Most of Colorado's smelters were determined redundant and were eventually closed except the Durango Smelter (closed 1930), Arkansas Valley Smelter (closed 1960), Globe Smelter (closed 2006), and the independent Pueblo Smelter (closed 1921). The Pueblo Smelter remained in production until the Great 1921 Flood caused extensive damage to the plant. The smelter was not reopened, and the surviving equipment was sold off the next five years after the flood (Fry 2007:107).

With the fall in ore production across the state the extensive narrow-gauge network in the mountains began to be abandoned. The Colorado Southern and Denver and Rio Grande railroads began to abandon much of the mountain rail network in the late 1920s and early 1930s. Such ore as was still produced was shipped by the rapidly expanding highway network.

Although the small smelters of the 1870s and 1880s provided the initial support for the Colorado mining industry, it was rapidly displaced by concentrations of larger, well-capitalized firms by 1885. Except for Leadville, these new smelters were built on the Front Range at Denver and Pueblo. These large smelters were able to take advantage of their communities' roles as hubs of the state's railroad network allowing them ready access to fuels, fluxes, and ores from around the state. This allowed them to have significantly reduced reduction charges than the small smelters in the mountains (Anon 1886:9053).

Leadville

Leadville is at the center of Lake County in central Colorado. The mines surrounding the city were the heart of Colorado mining in the late nineteenth century. The first prospectors were attracted to the area by rich placer gold deposits in California Gulch and the town of Oro City grew up at the deposits in 1860. The discovery of the incredible silver deposits of the region did not occur until 1876 when a rush back to the area occurred but immediate work was hampered by the lack of local reduction facilities (EMJ 1876c:176). The population of the county rose from 200 in 1877 to over 15,000 by 1880, Leadville becoming either the second or third largest city in the state.

There was a serious push to make Leadville the state capitol and it rapidly became the largest mining and milling center of the western United States with 15 smelters operating in the city by the early part of 1880. The resulting influx of capital and experienced mining engineers and metallurgists made it one of the largest smelting centers of the world at the time. By the early 1880s Leadville had surpassed the Comstock as the country’s most productive silver producing region, and for a time led the country in lead production as well (Emmons 1886:614).

The Leadville area has been one of the most productive metal producing areas in the world. Estimates of production through 1999 totals 265 million ounces of silver, 3.3 million ounces of gold, 110 million pounds of copper, 2.35 billion pounds of lead, and 1.94 billion pounds of zinc (Cappa and Bartos 2007:31). In its earliest years the city lacked rail service and shipment of ores out of the county was extremely expensive. In response to transportation difficulties and the vast production of the area Leadville became the site of a unique concentration of smelting establishments in 1878-1879. This was one of the largest concentrations of smelters in the world at the time, although most failed within a few years due to over competition, poor planning and poor management. By chance the USGS decided to report on the geology and mining of the area and arrived at the height of the smelting industry's expansion. As part of the investigation an experienced metallurgist named Anton Guyard accompanied the geologists to the city and produced a detailed examination of smelting as practiced in the city in late 1879 to early 1880 (Emmons 1886).

By late 1880 a number of the plants had already closed, and only a few survived to the end of the century. By the late 1880s only the American, Arkansas Valley, Harrison, and Elgin smelters were still in operation (Stone 1918:315). The Arkansas Valley Smelter (the successor of the Billings and Eilers) was the last smelter to operate in the city and ran almost continuously between 1879 and 1960.

During the 1980s and 1990s an 18 square mile area around Leadville became part of the California Gulch Superfund site (EPA 2019). Areas slated for remediation included many of the smelter sites around the town. A limited investigation of mines, railroads, and smelter sites was conducted. Out of the major smelters from the 1870s and 1880s, two were on private land where access was denied, four were relocated but not recorded, and five were not relocated. Only the Arkansas Valley Smelter (5LK892), the Elgin Smelter (5LK893), and the Grant Smelter (5LK894) were recorded and submitted to SHPO. The information in these recordings is minimal. Only the Arkansas Valley was determined eligible due to the heavy impacts at the other sites.

Of the fifteen works erected in the Leadville area in the 1870s and 1880s, only the Harrison and Grant smelters were within town proper, the remainder were outside town along California Gulch, Big Evans Gulch, or at individual mines.

West of town along California Gulch were the Arkansas Valley, Lizzie, and Malta smelters. To the east were the Leadville, La Plata, American, Billings and Eilers, and California smelters. At the north edge of town, a second line of smelters ascended Big Evans Gulch including the Elgin, the Raymond, Sherman and McKay, the Gage, Hagaman and Co., the Cummings and Finn, and the Ohio and Missouri smelters. The Adelaide and Little Chief smelters were east of town on Iron Hill and Fryer Hill, respectively (Emmons 1886:625).

The remote location of Leadville prior to the arrival of the railroads made the early exploitation of the mines difficult. To take advantage of the situation, the Malta Smelting and Mining Company built the areas first smelter at the town of Malta, a few miles west of Oro City in 1876 (Griswold and Griswold 1996: 127). The company opened with a reverberatory roasting furnace and a single blast furnace but prices to import raw materials were extremely high. Due to the lack of acceptable local substitutes brick was imported from England at a price of $0.45 each (LC 30 May 1879:2; Hayes 1876:423). Due to the primitive state of the mines and low ore output the smelter operated only intermittently in 1877.

The Malta was soon followed by the Harrison Works. Built by A. Meyer, an ore buyer for the St. Louis Smelting and Refining Company. The Harrison was built as a subsidiary smelter due to the expense of shipping ores from Leadville to the main company smelter at St. Louis. The Harrison processed lower-grade ores. The company's freight teams continued to ship the high-grade ores to the railroad head at Colorado Springs, and the ores then shipped by rail to St. Louis. The freight teams made the return trip to Leadville carrying coke from El Moro to feed the company furnaces (Fell 2009:80). The plant originally had a capacity of 30 tons per day and a workforce of 40 men (EMJ 1878b:276), expanded to 60 tons capacity in 1878. The prominent position of the smelter led to the essential abandonment of Oro City and the establishment of Leadville around the works. The Harrison continued to expand, adding a second blast furnace in 1878. Out of a desire to reduce transportation costs, the smelter management helped convince John Evans of the DSP&P to connect the city by rail (Emmons 1886; Evans 1878; EMJ 1877d:352).

The Malta and Harrison soon proved inadequate for the ore output of the area. Two more smelters were built in 1878, with an additional 11 built the following year. The Malta smelter failed in 1878 due to poor design and a lack of capital to fund improvements. The works were sold to J.B. Dixon who hired metallurgist Franz Fohr as supervisor and were soon shipping large quantities of bullion to eastern refineries. Despite the improvements made by Fohr the smelter had failed by the end of the year (EMJ 1878b:154).

The largest of the Leadville smelters for the period was the Grant Smelter, built by James B. Grant in 1878. Grant was a Freiberg-trained metallurgist who became convinced of the potential profitability of opening a smelter at Leadville after examining a number of the area mines in 1877. The company purchased Piltz pattern water-jacketed blast furnaces from Frazer and Chalmers, and the smelter entered blast on October 3. By the end of the year the plant had produced 300 tons of bullion that were shipped to Omaha for refining.

The plant grew rapidly, reaching eight furnaces by 1880. His success allowed him to secure the output of Horace Tabor’s Little Pittsburg mine for the last half of 1879. Grant added two Raschette blast furnaces at the Council Bluffs Iron Works to increase capacity, but both turned out to be both late and ineffective and were soon supplemented by two additional Piltz pattern furnaces. By the end of 1879 the smelter accounted for ¼ of Leadville's bullion output (Kent 1880:101-105).

At roughly the same time that Grant had decided to construct his smelter a partnership of former ore buyers of the Omaha Smelting and Refining Company (Nathaniel Witherell and Theodore Berdell) opened the La Plata Smelter, entering blast on a 170-day campaign a few days after the Grant opened (LDH 24 November 1883:3). The company expanded opening a third furnace in 1879, increasing the plant capacity to 90 tons per day (LDC 30 May 1879:2). By 1881 the company was shipping 500 tons of bullion per month. Bullion from the smelter was shipped to the Balbach Refinery in New Jersey for further processing (EMJ 1881e:318).

The Grant Smelter was recorded in 1995. The site description for the largest plant in Leadville during the 1880s was limited to "The site has been removed except for the slag pile." The site was recommended as not eligible for inclusion in the NRHP due to the lack of standing structures and limited archaeological potential.

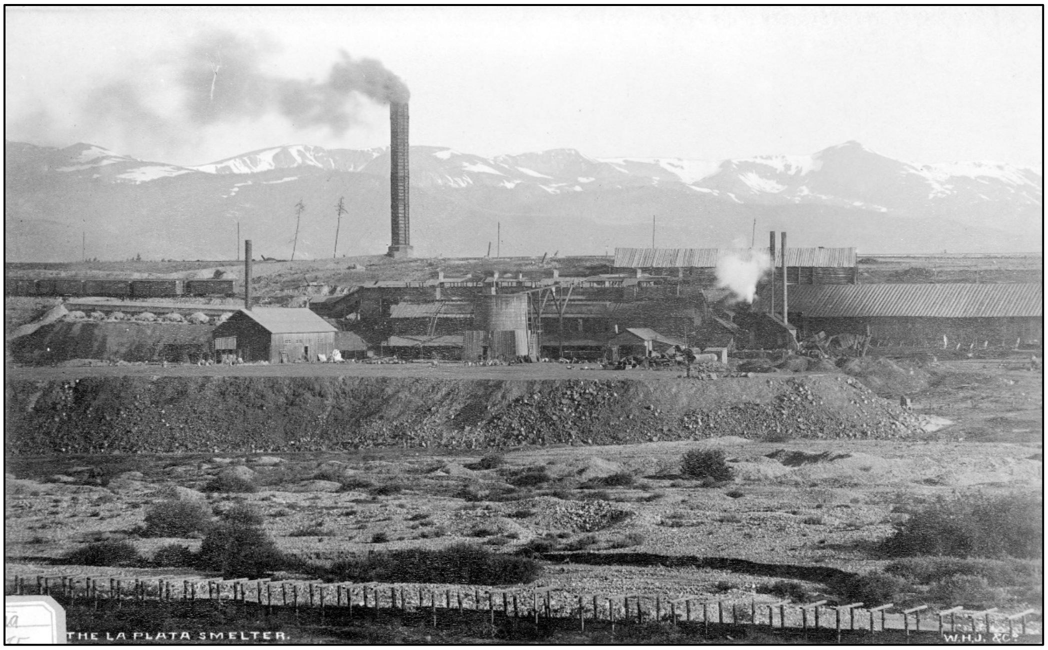


Figure 4-1. La Plata Smelter at Leadville, 1882, Denver Public Library Western History WHJ-685.

The last of the first-tier smelters of Leadville was the Billings and Eilers Smelter built in May 1879 (LDC 16 May 1879:3). Gustav Billing and Anton Eilers had been part owners of the Germania Smelting and Refining Company of Salt Lake City. They sold their interests in the Germania to help fund the opening of their new smelter in Leadville. Eilers was a well-respected metallurgist who had assisted Rossiter Raymond in compiling his annual reports of the mining statistics of the United States. A meticulous metallurgist, Eilers had authored several articles on the inefficiency of many American smelting companies and championed the adoption of more scientific methods (Eilers 1874:98-99; Eilers 1875:25). The company opened with one blast furnace but added a second within a year, becoming the third largest smelting works in the city (LDC 16 May 1879:3; Kent 1880:97-98).

Ten additional smelters opened in 1879 but all were smaller than the Harrison, Malta, Grant and Billings and Eilers works. Combined these smaller smelters accounted for only 1/3 of Leadville’s bullion production in 1879, but the American, Cummings and Finn, and Elgin companies soon become major players (Fell 2009:97-98).

The American Mining and Smelting Company was chartered in March 1879 and included several prominent railroad executives among its shareholders. The company hired well-known metallurgist Otto H. Hahn to run the works. The smelter entered blast on June 5, and a second furnace was added by the end of the year. The competing M.J. Cummings and Nicholas Finn Company built their smelter under the direction of Thomas McFarlane, the previous manager of the Wyandotte Smelter in Michigan. The furnace entered blast on July 25 with two furnaces with an aggregate capacity of 50 to 60 tons. Although hampered by a lack of water and difficulty in acquiring coke, the company expanded with the addition of new furnaces in late 1879 and early 1880 (LDC 30 May 1879:2). The Elgin Mining and Smelting Company opened at the same time, entering blast on June 24. The Elgin was the first smelter built north of town along Big Evans Gulch (Kent 1880:100-101). The Elgin Smelter was recorded during the same project and was described as “A sparse and disturbed scatter of slag and very deteriorated brick piles. Very sparse historic materials; no evidence or reference to domestic habitation occurring at this location. Several very deteriorated piles of brick (red and fire), with iron chimney remains, probably indicate furnace locations. No evidence of machinery. A slag "pad" to the west is of unknown function and age. A fragment of railway, (one rail and 304 ties) protrudes from the slag just north of the brick piles."

Figure 4-2. American Smelter at Leadville, ca. 1880s. Colorado Historical Society. CHS.J39

The remaining small plants built in 1879 suffered from a combination of poor design, bad management, improper metallurgical techniques, and inadequate capital. These smelters had far more in common with typical small mountain smelters than with the large with the preceding Leadville smelters. They were small, with single furnaces of 25 to 30-ton capacity (the Lizzie was somewhat larger with two furnaces with an aggregate capacity of 80 tons) (LDC 30 May 1879:2). These smaller smelters failed to consider the highly competitive field they were entering and were overly optimistic about their ability to acquire quality ores and fuels. The rapid failure of these small smelters likely produced a number of moderately experienced smelter workers who then expanded to mining regions across the state leading to the wave of small smelting operations opened in the early 1880s.

The large number of smelters built at Leadville in 1879 was considerably in excess of ore production at that date resulting in a sharp competition for the limited ore supplies. As the railroad had yet to reach the city, fuel costs were high with the price of coke at $25 per ton. After winter hit, transportation to the city became extremely difficult and the price increased to $60 a ton when available. The superior El Moro coke became nearly impossible to find and even the inferior coke from Como in South Park was expensive. Only the best funded companies were able to work through the winter, and even they were forced to curtail production (except for the Grant Company, which had the foresight to stockpile sufficient fuel to last through the winter). With the arrival of the railroad the following year fuel prices dropped with coke ranging from $10 to $23 per ton (Emmons 1886).

The intense competition fostered by the large concentration of smelters at Leadville, combined with the difficult conditions of 1879 led to the failure of most of the smelters. The Leadville, Lizzie, and Raymond, Sherman and McKay smelters failed by the end of 1879. The Gage and Hagaman closed in early 1880 due to its inability to acquire enough lead rich ores. By the end of 1880 the Adelaide, California, Little Chief, Ohio and Missouri, and Malta smelters had also failed. The surviving smelters were the better-capitalized and managed companies (Emmons 1886:626).

During the 1880s the surviving large Leadville smelters were at the forefront of smelting technology and the community contained some of the country's most respected metallurgists who experimented with the latest techniques. To remain competitive with the large smelters on the plains, they incorporated some of the best available methods, such as dust chambers and water jacketed furnaces. In addition, they tested and controlled the contents of their slags, and had excellent recovery rates on precious metals as shown in Emmons study of Leadville.

Of the surviving plants, the Grant remained the largest. It was remodeled from 1880 to 1882 replacing their older furnaces with new models increasing the plants reduction capacity from 160 to 350 tons per day allowing them to reduce reduction prices. The increased efficiency allowed it to compete with the first of the large plants in Denver and Pueblo that were beginning to compete strongly for Leadville's best ores (EMJ 1883d:61). The smelter continued to dominate Leadville's production until a fire destroyed the entire plant in 1882 (CDC 26 May 1882:1). To meet their existing contracts, the company was forced to lease the defunct Elgin Smelter. Rather than rebuild the plant in Leadville, the company decided to build a completely new plant at Denver (LDH 29 June 1882:3).

The Billings and Eilers continued to expand during 1880, adding two additional blast furnaces, dust chambers, and adopted electrical lighting. After the destruction of the Grant Smelter it became the largest in the city. On June 1, 1882 the Billings and Eilers partnership was dissolved. Billing retained the smelter, reorganized as the Arkansas Valley Smelting Company (Figure 4-3, Figure 4-4) with the help of investors from St. Louis and Kansas City. Eilers took a cash settlement that he used as part of the start-up capital for the new Colorado Smelter at Pueblo. The Arkansas Valley continued to expand, reaching a capacity of 250 tons per day by the end of 1882. Although the plant had problems competing for the best ores with the Denver and Pueblo smelters it ended up as one of the last smelters in Colorado. It outlived all but the Globe Smelter at Denver and closed in 1960 (Fell 2009:113-116; Patrick nd).

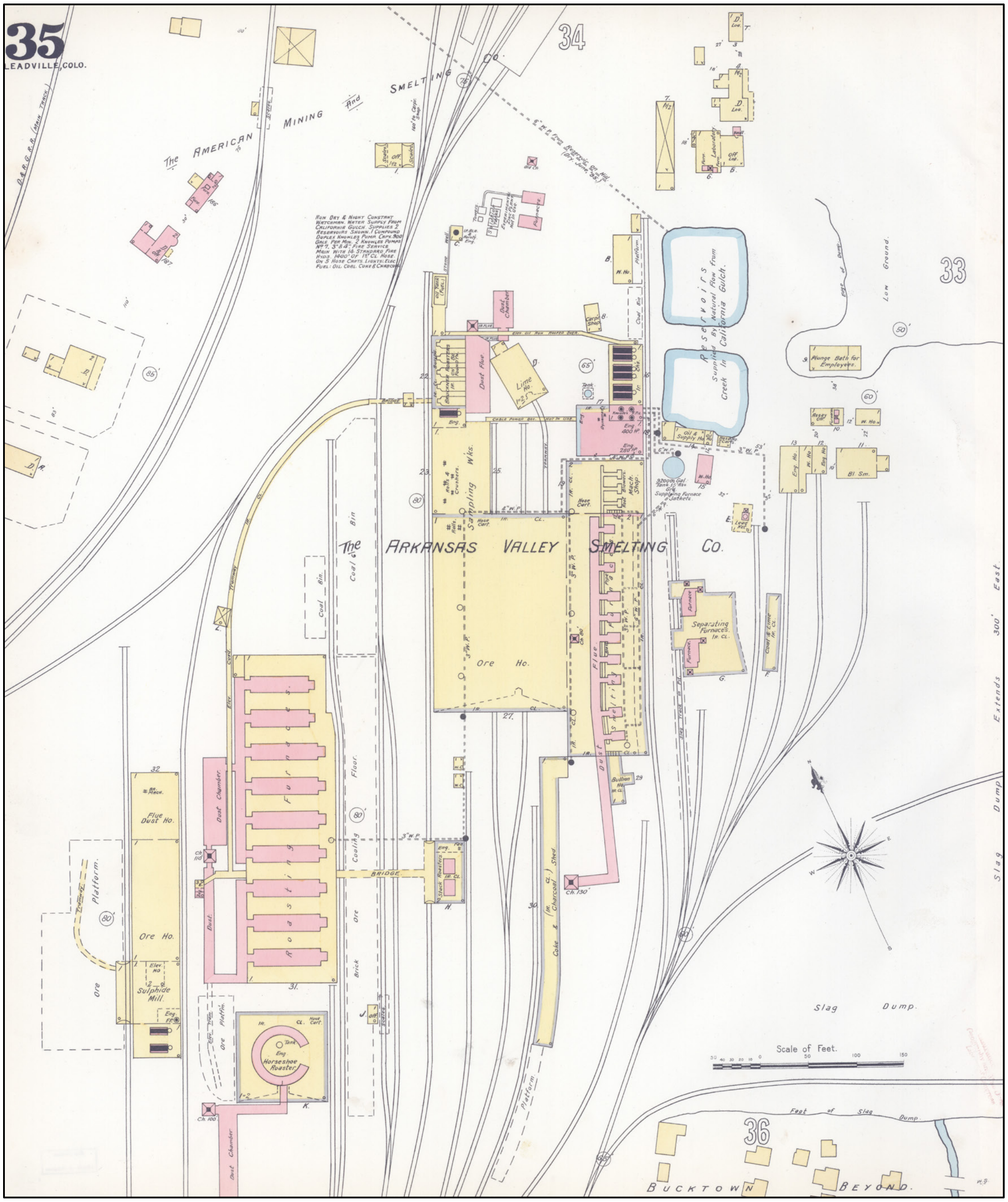


Figure 4-3. Arkansas Valley Smelter. Sanborn Insurance Map, Leadville, 1893.

Figure 4-4. Arkansas Valley Smelter ca. 1900, Colorado Historical Society, CHS-X-61428

Although the Grant and the Arkansas Valley dominated the Leadville smelting scene by the La Plata and Harrison Works continued to operate into the late 1880s. Both works installed improvements and upgraded their plants in the early 1880s, but were ultimately unable to compete with Arkansas Valley Smelter or the Front Range smelters that were already siphoning off half of Lake County's ores by 1883 (EMJ 1883d:61; Fell 2009:116-118).

Like most of Colorado's smelters, the Leadville plants sent their bullion to the Midwest or East Coast for refining. Transportation costs to these distant refineries accounted for much of the smelter costs. Transportation to the refineries varied from $27 to $35 per ton. The average value of bullion produced in Leadville during 1880 was worth $30 to $78 per ton. Further refining charges were included on top of the transportation costs. These costs were either a flat $14 to $15 per ton or part of the metal content of the bullion. A royalty of 3 ounces of silver and 100 pounds of lead per ton of bullion was typical. Due to the volatility of silver prices it was common practice for Leadville smelters to stockpile bullion in anticipation of increased prices. One smelter in August of 1880 had stockpiled 1,453,250 pounds of bullion (Emmons 1886:692-693). During periods of low prices this dramatically reduced cash flows as both ore and fuel purchases were still required during these lulls in selling.

By 1884 Leadville smelters were having increased trouble competing with the smelters of Pueblo and Denver. The La Plata Mining and Smelting Company reorganized in 1883 due to financial misdealing's by the American company management and was reorganized as an English company, the La Plata Mining and Smelting Company, Ltd. However, by 1883 the smelter had the oldest machinery in town and was forced to invest heavily in new equipment. This, combined with declining ore output by the company mines, caused the smelter to run at reduced capacity in 1884. The company attempted to compensate by installing Leadville's only refinery, but this proved unprofitable and was quickly discontinued (EMJ 1885a:221; EMJ 1885b:294). The company struggled on for a few more years before closing in 1887. The Arkansas Valley was forced to modernize in 1885 with the construction of new furnaces but profits continued to decline despite the increased production due to continually declining silver and lead prices. (Fell 2009:121-125).

Denver

Although its ascendancy over Pueblo wasn’t clear until the early 1920s, Denver was Colorado’s leading city and one of its leading industrial centers. Denver was the political capital of Colorado and home to major foundries and four equipment manufacturers (EMJ 1883b:259). Being in Denver gave industrialists ready access to the ears of prominent politicians and bankers greatly easing the difficulty of conducting business. The city was the main railroad hub of the state, served by the Colorado Central, Denver & Rio Grande, Denver, South Park & Pacific, Union Pacific, Kansas Pacific, and Atchison, Topeka & Santa Fe railroads. This allowed the smelters of the city to access ores from throughout the Rocky Mountain region, charcoal from the mountains, raw coal from throughout the state, and coke from Pennsylvania and El Moro, Colorado.

The smelting industry of Denver was dominated by the large Argo, Grant, and Globe smelters but at least one small smelter, the Swansea, was also built in the city during the early 1880s (EMJ 1884d:109). The smelter was a mile southeast of Utah Junction (the junction between the north-south Union Pacific line and the westward Colorado Central line to Golden). The plant was operated for only a few years before failing.

The first of the large smelters of the city was the Argo, built on an 80-acre site along the Union Pacific tracks just north of town in 1878 and opened with a workforce of 240 men and a monthly production of $200,000 per month (EMJ

1878d:154). The Argo was built by the Boston and Colorado Smelting Company as a replacement for their original smelter at Black Hawk that was in too confined an area to allow for further expansion. N.P. Hill decided to move the smelter to Denver to take advantage of the better transportation facilities available in the city. The smelter processed ores from Clear Creek, Gilpin, Lake, and Summit counties, but soon treated ores from states south and west of Colorado (BVD 22 December 1887:1). Due to the decreasing copper content of Colorado ores by the 1880s the company opened a subsidiary smelter at Butte, Montana to guarantee a sufficient supply of silver-copper matte for their furnaces (Henderson 1926:137). The facility operated continuously until 1909 when the company refinery burned down. Due to falling revenues it was decided to close the smelter rather than rebuild the refinery. Most of the structures were demolished in the next few years (DWE 11 November 1909:2; CT 12 May 1910:1), but a few buildings survived into the 1930s (HCD 1909). The site was gradually redeveloped, and no trace of the smelter remains.

The second of the large Denver smelters was the Grant, or Grant-Omaha (Figure 4-5. The original Grant Smelter was the largest smelter at Leadville but was destroyed by fire in 1882. Rather than rebuild at Leadville, the Omaha-Grant Company decided to rebuild in Denver for the same reasons as the Boston and Colorado. Construction on the new smelter began in 1882 and contained four new water-jacketed blast furnaces with an aggregate capacity of 200 tons daily. Well-regarded metallurgist Malvern W. Iles was employed as the superintendent

(RMS 26 August 1882:2; FF 5 October 1882:1; Frost 1883:163). By 1885 the smelter was operating 30 roasting furnaces supply 10 blast furnaces (BVD 14 October 1885:4). As part of the larger company, the Grant processed local Colorado ores and the company's main smelter at Omaha handled ores from the Idaho, Montana, and Utah markets (EMJ 1885c:244) in addition to providing refining services for the Grant. The main source of the smelter's ores continued to be Leadville, supplying 60 percent of the ores used in the 1880s. They eventually proved unable to compete with the Pueblo Smelting and Refining Company for ores high in lead causing problems in the mixing of efficient charges (Henderson 1926:146). The smelter continued to grow and by 1887 employed 425 men and had a daily capacity of 400 tons (BVD 1 September 1887:1; SCR 9 June 1887:2) and claimed to be the largest smelter in the world (BVD 8 June 1887:4).The smelter closed in 1903 when the owners decided to close the plant rather than meet the demands of striking workers. The buildings of the facility were gradually demolished over the years until only the 250-foot brick smokestack remained. Due to safety concerns the stack was demolished in 1950 despite opposition from an early historic preservation effort. The site is now occupied by the Denver Coliseum (Metz 2014).

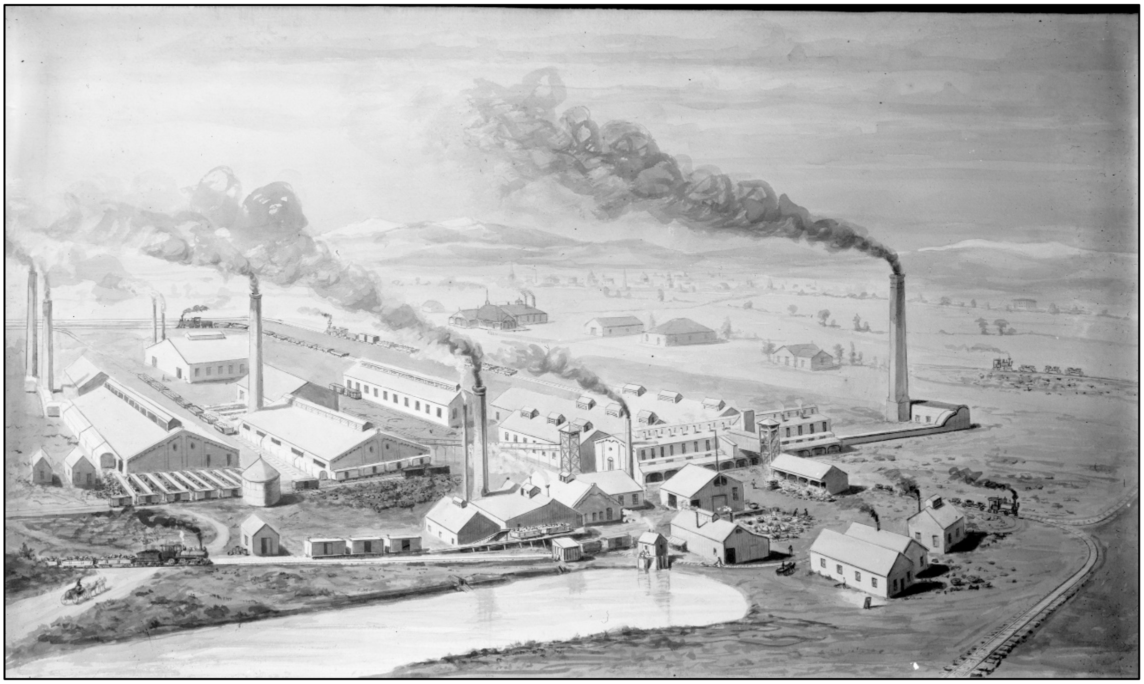


Figure 4-5. Grant Smelter at Denver ca. 1910, Colorado Historical Society, CHS-B395.

The final smelter of Denver was the Globe (originally the Holden) Smelter (Figure 4-6; Figure 4-7). The Globe (5DV348) was built in 1886 across the South Platte River from the Grant. The smelter entered blast on October 6, 1886 with four blast furnaces with an aggregate capacity of 150 tons daily (RMS 10 April 1886:2, CRJ 26 May 1886:4). The smelter was originally built at the direction of Edward Holden who had previously managed the Holden Sampling Works in Leadville (Griswold and Griswold 1996:1643). Holden's management of the plant was unsuccessful, and he was replaced by David Sheedy in 1887 and the company reorganized as the Globe Smelting and Refining Company (Sheedy 1923). Due to declining lead content in Colorado ores by the late 1880s the smelter actively sought ores from Idaho mines to better balance their furnace charges. The company eventually expanding its reach and processed ores from as far away as Mexico and Canada (Henderson 1926:148, 154). By the turn of the century the plant had a daily capacity of 800 to 1,000 tons per day. Flux for the furnaces included limestone quarried at Morrison, iron and manganese ores from Leadville, and fuel was sourced from coke ovens at El Moro. The smelter was Colorado's longest-lived, remaining in production until 2006 under the control of ASARCO. The smelter was declared a Superfund site in 1993 leading to its eventual closure. The plant was demolished in 2012 marking the end of the last of Meyer Guggenheim's smelters. The site has since been remediated and no original structures remain. An attempt to record the site was made in 1983 but ASARCO denied access and the recording was limited to photographs taken from outside the company fence.

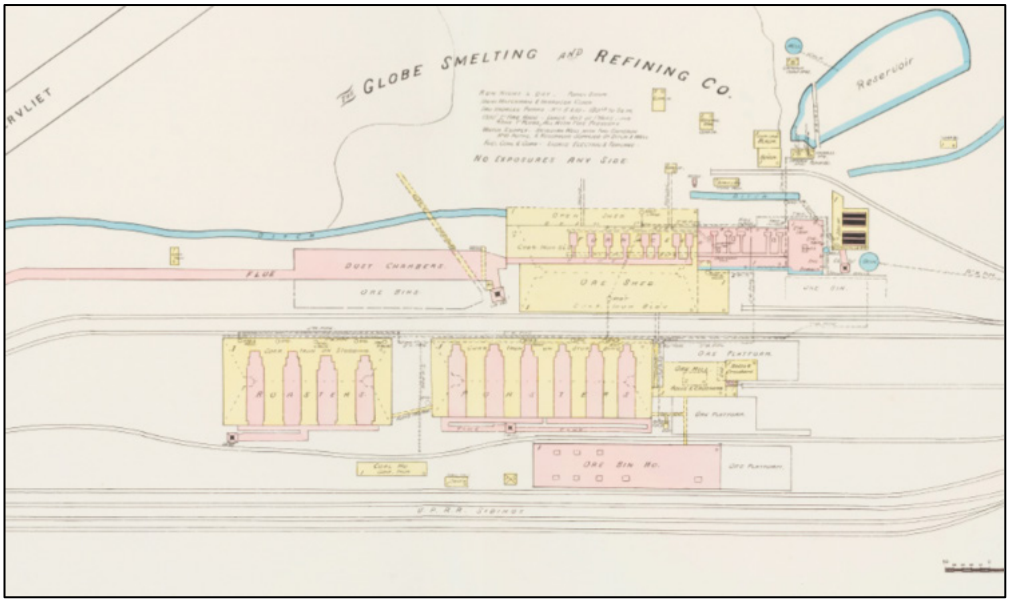


Figure 4-6. Globe Smelter. Sanborn Insurance Map, Denver, 1890.

Figure 4-7 Globe Smelter late nineteenth century, Colorado Historical Society CHS.J20.

Pueblo

During the later nineteenth century, Pueblo was Denver's main rival in terms of population and industrial capacity. During 1882 the city shipped $28 million in gold and silver to eastern refineries, double the production of Denver (EMJ 1882i:164). Home of CF&I, the largest steel mill west of the Missouri prior to the construction of the Geneva Steel Works at Salt Lake City in the 1940s, the city was also home to three large smelters, numerous foundries, and mining equipment manufacturers.

Smelting in Pueblo may date further back than any other location in Colorado. Early residents of the city reported a large plaza was reported near the old government corral in downtown. Two adobe smelting furnaces were reported at the site with interior linings of brick and granite blocks. Smelting slag was observed around the furnaces and ore similar to that found near Rosita (where early miners reported an old shaft predating Anglo-American use of the area). A second, larger smelting works was reportedly identified near the headwaters of Culebra and Trinchera creeks on the west slope of the Sangre de Cristo Mountains in 1864. The site was reported to contain ruined buildings, abandoned shafts, and slag heaps the size of houses (CDC 14 February 1875:4).

The large plaza at Pueblo probably refers to the remains of El Pueblo, a trading post occupied from 1842 to 1856. The fort was mostly used to trade liquor with local native tribes. If the furnaces were built by the inhabitants of El Pueblo, they would likely date to the 1850s after the original fur trading function of the fort had been abandoned. Archaeological investigations conducted on El Pueblo in the 1990s revealed no evidence of smelting related features (Buckles 2006). The possible smelter in the Sangre de Cristos is on the Sangre de Cristo Grant, awarded by the Mexican government to Stephen Luis Lee and Narcisco Beaubien in 1843. The area of the grant contains St. Luis, the oldest town in Colorado (founded in 1851). A smelter operating in the area likely dates to the 1840s or 1850s prior to the sale of the grant to former governor Gilpin and his partners in 1863.

By the early 1870s Pueblo was served by the north-south running Denver and Rio Grande and the east-south running Atchison, Topeka and Santa Fe (ATSF). Prior to the establishment of the three large smelters in town, three abortive attempts were made in the late 1870s. Little is known about the small Pueblo Sampling Works built in 1878, but the Pueblo Reduction Works built in 1879 lasted less than a year before burning down in 1880 (Fry 2000:1-2). A third small smelter, the Massachusetts, or New England, Smelter was built in 1884 on land donated by CC&I on a high bluff overlooking the Arkansas River. Work on the buildings began in May of 1884 and the machinery was installed in November (SM 17 May 1884:1; CDC 23 November 1884:2; EMJ 1884c:89). The opening of the plant was delayed due to a freak lightning strike that demolished the company's brick chimney several hours after completion (BVD 3 July 1884:2), and the plant did not enter blast until September 1885 (FF 24 September 1885:2; BVD 23 September 1885:1). The smelter ran without notable success until early 1889 when it closed and was sold the Philadelphia Salt Company for $21,100 (CDC 27 February 1889:10; CDC 1 March 1889:2; CDC 2 March 1889:3).

The first of the large Pueblo plants was the Pueblo Smelter (Figure 4-8) built by the Pueblo Smelting and Refining Company in September of 1878. The company was headed by metallurgists Mather and Geist who had previous run a smelter in Utah. The smelter was built on six acres of land along the Arkansas River east of Santa Fe Avenue (Fry 2000:2-6). The smelter started with a single 20-ton capacity water-jacketed blast furnace supplied with Leadville ores. Prior to the completion of the D&RG to Leadville the company employed 200 freight teams to transport ores from Leadville to the railhead at Canon City (120 miles) then shipping the remaining 40 miles by rail. The smelter also purchased ores from the mines of Rosita, from the San Juan Mountains, and from districts in the northern part of the state (CDC 5 September 1878:4). Limestone flux was quarried just outside town and iron ore imported from the Iron Mountain area. The bullion produced by the smelter was shipped to Omaha for refining (CDC 12 September 1878:4). In the 1880s it was one of the largest smelters in the country (CDC 26 November 1889:6).

By 1882 the works was producing 1,000 tons of lead per month. To try and save money on shipping the lead to manufacturing companies, the company erected its own lead pipe factory adjacent to the smelter. At the time of its construction it was the largest pipe factory between the Missouri River and California. Machinery to manufacture sheet lead was added within a year (CC 2 April 1882:4).

To improve the capability to work more ores, a reverberatory furnace was added to process copper matte in 1888 and a semi-pyritic blast furnace with a 600-ton daily capacity was added in 1899 (Fry 2007:27-31). In 1888 the smelter had a daily capacity of 5,000 tons per day with a production of 4.5 to 5.0 million oz. of gold and silver and 150 carloads of pig lead per month (CDC 6 May 1888:14).

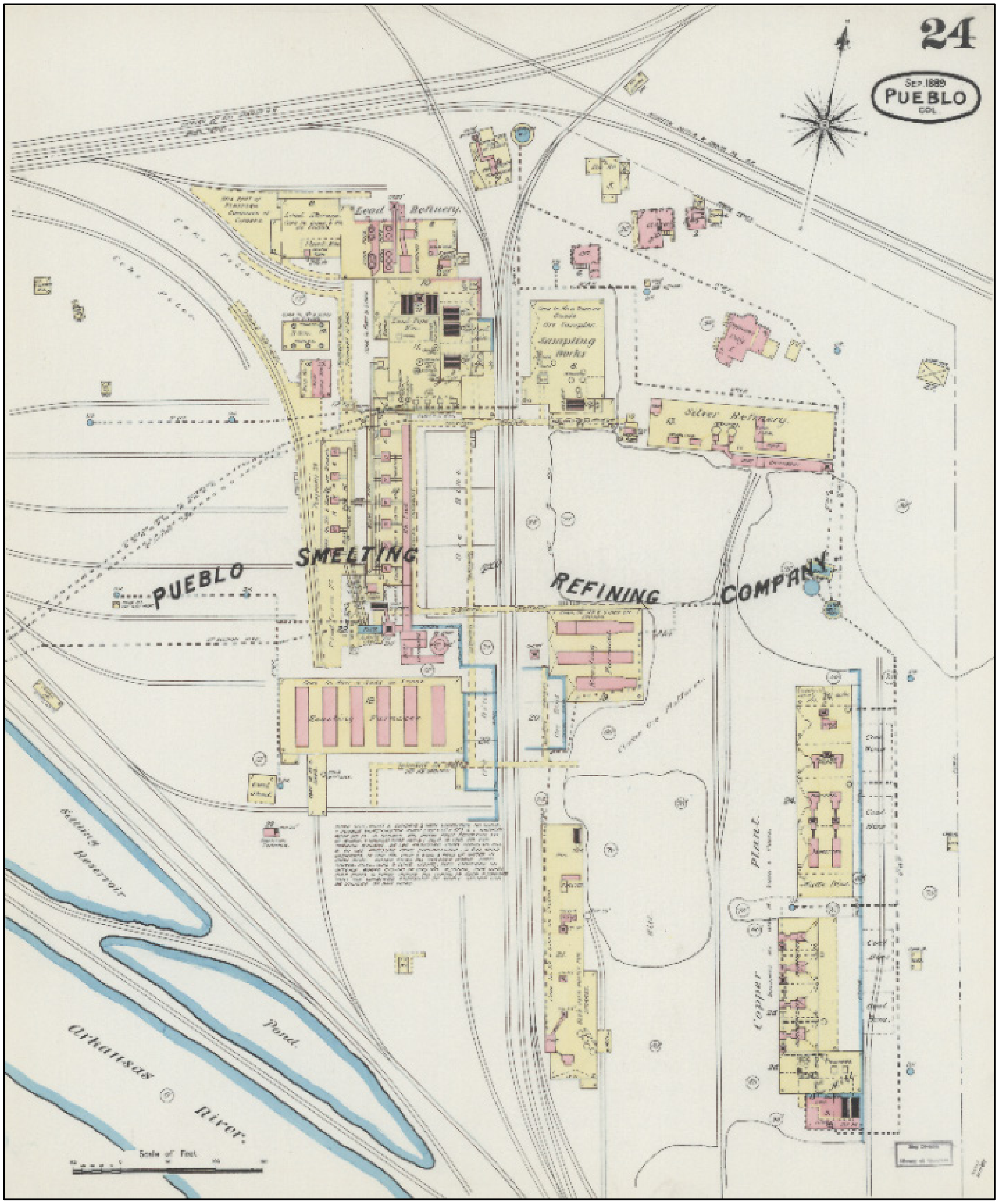


Figure 4-8. Pueblo Smelter. Sanborn Insurance Map, Pueblo, 1889.

The Pueblo Smelter was soon followed by the Colorado Smelter, built on land donated by CC&I in 1878. The smelter was often referred to as the Eilers Smelter after its manager, Anton Eilers, who had previously run the Germania Smelter in

Utah. The smelter was built by the owners of the Madonna Mine at Monarch (Chaffee City) to replace their small company smelter at the mine at the urging of Eilers who was brought in as a consultant to improve the capacity of their earlier smelter. Eilers convinced the D&RG to build a spur line to the Madonna Mine, at which point a central smelter at Pueblo became a cheaper alternative to improving the local smelter despite adding 120 miles of shipping (Fry 2007:4). In addition to general manager Eilers the company included prominent mining engineer Rossiter W. Raymond as vice president.

Although the smallest of Pueblo's large smelters (CDC 1 January 1885:5), it was still in the upper rankings of the state and boasted one of Colorado's few silver refineries (CDC 1 January 1890:12). The smelter was directly served by a siding of the D&RG and was built along a 40-foot deep ravine that was used to dispose of the company's slag. The plant opened with four blast furnaces, each with an average capacity of 14.5 tons of bullion daily. From its opening in 1883 to the end of 1887 the smelter produced 37,659 tons of bullion containing 4,436,100 oz. of silver and 11,887.25 oz. of gold, with a value of over $7 million (over $184 million in 2019 dollars). The smelter consumed $60,000 in coke, $27,000 in charcoal, $10,000 in raw coal, and $10,800 in limestone during the year 1887 (CDC 6 May 1888:10). In 1899 the smelter was one of the first to join ASARCO and was closed by the combined in 1908.

The last of Pueblo's major smelter was the Philadelphia Smelter, built in May 1888. The smelter was a joint venture between Edward Holden and his friend Meyer Guggenheim. Holden withdrew from the company at an early date and most of the major positions within the company were filled by Meyer's sons, two of whom had studied metallurgy. The plant was built along the east side of CC&I near the failed Massachusetts Smelter (BVD 3 July 1884:2; BVD 9 December 1885:1).

The Philadelphia supplied much of its own ore from the Guggenheim-owned mines at Leadville (Fry 2007:57-62). The plant began roasting ores in November 1888 in preparation of blowing-in the furnaces, which occurred on December 19. The smelter opened with two blast furnaces, with an additional four already under construction. The combined six furnaces had a daily capacity of 600 tons (BVD 20 September 1888:1). During its first year it produced 19,112 oz. of gold, 2,381,009 oz. of silver, 44,034 lb of copper, and 16,332,520 pounds of lead (CDC 26 November 1889:6; CDC 1 January 1890:7). By the 1890s the smelter still operated mostly on Leadville ores, but was also purchasing ores from Cripple Creek, Arizona, Idaho, New Mexico, and Utah (Fry 2007:64).

Although the decline in silver prices in the 1890s hurt the pueblo smelters, their decline was more clearly a result of the formation of ASARCO in 1899. ASARCO rapidly gained control of most of Colorado's smelters including the Pueblo and Colorado smelters at Pueblo, the Globe and Omaha-Grant smelters at Denver, the Arkansas Valley and Bi-metallic smelters in Leadville, and the Durango Smelter. The only major smelters not to join ASARCO immediately were the Argo in Denver (which closed in 1903), and the Philadelphia Smelter at Pueblo. The Guggenheims eventually sold out to the trust in 1901 for 50 percent of ASARCO's stock (Fry 2007:64).

Although the small smelters described in Chapter 3 existed in far greater numbers than the large smelters and had more immediate access to ore supplies (with the obvious exception of Leadville) they were ultimately unable to compete with the larger works. Leadville was the first major smelting center of the state, with an extraordinary concentration of large smelters built in the city. The city became an intermediate rail nexus in the mountains providing access to a variety of ores from mining districts throughout the region. This allowed the surviving large smelters of the city to remain at least marginally competitive against the large smelters that developed in Denver and Pueblo. The unique mixing of large and small smelters at Leadville in 1879/1880 is an interesting example of the competition between large and small companies played out at a local scale. Many of the problems faced by more isolated small smelting operations can be seen at Leadville during this period. The history of the large smelters in this section provides details of the scale of competition faced by the small, local smelting companies as discussed in the following chapter.

5 Success and Failure

The small smelters of Colorado discussed in Chapter 3 were critical to the development of Colorado through their support of the state's mining communities. These small industries sprouted up in most of the state's mining districts during the late 1870s and early 1880s, but almost universally failed around 1885. These small smelting firms were able to develop and survive while protected by their isolation and expensive transportation costs, and then failed when transportation costs were lowered, and they were forced into direct competition with larger and more efficient smelters on the Front Range. This chapter discusses the causes and patterns of this failure through the examination of case studies from previous research on failure in frontier industries and three examples from the Colorado smelting industry.

Previous studies of the Colorado smelting industry have been rare. The notable exception is James E. Fell, Jr.'s book *Ores to Metals.* Fell's book is a detailed corporate history of Colorado smelting with a focus on the large smelters of Leadville and the Colorado Front Range. He covers some of the better documented early mountain smelters in his discussion of early smelting, including the Boston and Colorado Smelter at Black Hawk, and several of the smelters in Park County. The present document approaches the Colorado smelting industry from a different viewpoint. The focus of this study is on the history and distribution of small smelters in Colorado's high country. The reign of the small mountain smelters was brief, but they were an important part of Colorado’s transition from a collection of largely isolated mining districts to an industrial state closely integrated with national and international markets. The important role of these smelters and the reasons for their rapid obsolescence and failure have not been studied in detail. This is study is intended to provide a framework to assist in the study of other small frontier industrial enterprises in Colorado and the Rocky Mountain region.

The Colorado smelting industry developed in the mid-1860s at roughly the same time as small smelting operations were developed in Nevada and Utah, but earlier attempts at smelting in the western United States did occur prior to the 1860s. The Latter-day Saints of Utah had established a short-lived iron smelting industry in southwestern Utah in the 1850s (Shirts and Shirts 2001) but largely ignored the state’s silver deposits. Potentially earlier Spanish or Mexican smelters in southeastern Colorado may date to the 1840s or earlier (CDC 14 February 1875:4)

The main expansion of Colorado’s small smelters occurred in the late 1870s. By this period many of the most obvious problems in adapting European smelting technology to work in the American West was already addressed by prominent metallurgists such as Albert Arents and Otto Hahn in Nevada (Bailey 2002). In theory, Colorado should have avoided many of the problems experienced by the earlier Nevada smelters, but problems remained common throughout the mid-1880s.

There were many differences in the nature of the ore deposits, geography, and environmental conditions of these early smelting regions but they all had to contend with the isolated frontier nature of the West. Compounding the difficulty of working in these new regions was the often-limited technical knowledge of many early smelter owners and workers. The easily processed placer gold that initially spurred mining in Colorado could be mined, processed, and collected with simple methods that had been in use for centuries (Agricola 1950). The best placer deposits were rapidly depleted, and work expanded to the highly oxidized surface lodes that had spawned the placer gold. These too could be easily worked with simple methods. These deposits were also rapidly depleted, and the ores transitioned to unoxidized sulfide ores that were not amenable to simple processing methods. Although the richest ores could be mined and shipped to distant smelting works at a profit, the majority could not. This spurred the need for a local method of ore processing. A large number of amalgamation, chlorination, and small smelting works rapidly sprang up in most districts.

An estimate made by the United States Geological Survey in the late 1920s put the number of smelters built in Colorado between 1861 to the 1920s at over 300 (Henderson 1926:177). Presently available data makes it impossible to corroborate this estimate. Although the actual number is probably lower due to the confusion arising from changes in ownership and smelter names, the USGS estimate is probably relatively close. It is clear that the smelters identified in earlier chapters represent only a fraction of the small smelters built in Colorado. At the height of small smelter construction from about 1875 to 1885 small smelters were built in all the major mining districts, and in many the small ones. All of them ultimately failed, most of them quite rapidly. The following section examines industrial failures using examples from previous research and examples from smelting operations within Colorado. Information from the preceding chapters is analyzed to identify patterns and themes of failure in the Colorado smelting industry.

5.1 Failure

The failure of industrial enterprises in frontier settings in the American West is a dominant theme in its economic development. The short life and quick failure of most small mines and industries in the western United States is recognized at an intuitive level by most students of early industry in the region. The phenomenon, however, has received surprisingly little direct study in historical and industrial archaeology. The fields of economics and the history of technology have paid more attention to the concept of failure in businesses, illustrating its importance in the development of successful industries and technology (Basalla 1988; Petroski 1992). Gooday (1998) discussed differing views on the definition of failure in the history of technology noting that the success or failure of a technology is a social construction and can have little to do with the technology itself. During the early stages of Colorado smelting furnaces designs were adopted from regions with drastically different geological conditions proving to be a poor fit for the needs of Colorado (e.g. Hearth furnaces were highly successful in Missouri but proved poorly adapted to working the ores of Colorado). The state's smelters eventually settled on blast furnaces as the best fit for local conditions, but despite this ended up as economic failures that failed to produce significant or dependable profits to their owners. In contrast, only a few studies in archaeology have directly addressed the phenomenon of failure, notable exceptions being excavations at a few mining sites in Michigan and Arizona, and the study of a small copper smelter within Isle Royale National Park (Landon and Tumberg 1996; Gordon and Malone 1994:207-210).

The general neglect in the study of patterns of failure in archaeology are unfortunate as the phenomenon is interesting and is the dominant pattern seen in industrial operations across the country. Three of the best examples in the literature dealing with the topic of failure deal with the failure of iron industries in Washington and Pennsylvania, and the study of the failure of a small mining district in Montana. The following section briefly examines these studies and discusses the parallels between their problems and those experienced by the Colorado smelting industry.

Irondale, Washington

Diane Britton (1991) examined the history of an iron and steel venture at Irondale, Washington. The idea for the industry was formed by a group of Seattle business leaders after a rich iron deposit was discovered across Puget Sound from the city. The businessmen hoped a local iron industry could reduce the expense associated with importing iron and steel to the city from more developed parts of the country, as well as earn themselves a tidy profit from the works.

Despite the best efforts of the company, success was fleeting, and the works operated intermittently from its founding in the early 1880s until 1919. The works were sound in principle as they were built near the ore deposits. To help reduce expenses, the company invested in the development of supporting industries including its own brickworks to supply construction materials, and a substantial charcoal works to provide fuel. Problems were rapidly experienced by the company as the charcoal produced from the local forests proved to be ill-suited to iron smelting. In addition, the iron ore deposit proved to be shallow and was soon depleted. The company was then forced to import both ore and fuel for the works at great expense (Britton 1991:38, 143).

Transportation costs also were higher than initially hoped. The workers were dependent on shipping on Puget Sound to import raw materials and export their iron. Although cheaper than transportation by land, shipping costs proved to be high and the unpredictable weather on the sound could shut down shipping with little notice, led to periodic closures of the plant due to lack of supplies. The continual problems experienced by the furnace discouraged potential investors and the company was always short on capital and unable to afford to incorporate improved technology in the plant, or to fund necessary expansion (Britton 1991:39, 142-145).

Similar patterns can be observed at small Colorado smelters. Like at Irondale, many Colorado smelters held unrealistically optimistic views on both the quantity and quality of local resources. When ore or fuel supplies were exhausted or proved unsuited to the technology used at their plants, the Colorado companies were forced to import ore and fuel from long distances or close down.

Transportation difficulties were also shared by the two regions. Irondale's location on Puget Sound led to hopes for cheap transportation costs, but ultimately ended up as a major drain on company finances. The unpredictable nature of the shipping only made matters worse. Colorado's companies had no such expectation of cheap transportation unless a railroad already served the area or where one was expected to arrive soon. Even in locations with rail access, severe winter weather often led to temporary closure of rail lines for weeks at a time leading to ore and fuel shortages. Finally, both Irondale and Colorado smelters suffered from a continual lack of capital, making it difficult or impossible to make necessary investments and improvements to their facilities to meet changing conditions.

Juniata District, Pennsylvania

Scott Heberling (2017) conducted an archaeological study of two small iron works in the Juniata District of Pennsylvania. The works were originally founded in the 1830s and operated intermittently for several decades. The two ironworks were typical of frontier industries and seemed to have a number of factors in their favor. The works were both near ore supplies, had local access to fuel and fluxes, and had an adequately developed transportation network that allowed them to ship their products to finery forges at acceptable prices (Heberling 2017:26). The two works were actually adjacent to each other and provide an excellent case study to examine how minor differences can make or break small industries with low profit margins. Although the furnaces were built earlier and in a different part of the country from Colorado, they still share a number of similarities and parallels can be made between the two areas.

Like the Colorado smelters they were built as close to the ore supplies as possible to minimize transportation costs. The relative inefficiency of transporting goods by wagon worked against the creation of centralized smelting sites until improvements in transportation were developed. In the case of Juniata, a major canal was built nearby that allowed for their products to be shipped to refineries at a reasonable price. They were also similar in producing an intermediate material (pig iron) that required further refining at a separate company. This allowed both the iron works and the Colorado smelters to avoid the investment in expensive refining works but left them at a disadvantage in having to market their products to middlemen (Heberling 2017:28).

The two smelters were the Winchester and Rockhill works. The smaller Winchester works is the most similar to the Colorado smelters and will be the main focus of the discussion. The two smelters were built along Blacklog Creek and shared the same tailrace as an older gristmill. This left the two ironworks in a vulnerable position as the gristmill had priority for waterpower during period of low water. The Winchester was the worst off of the works as it lay at the end of the race and suffered additional problems. Although water supplies were initially adequate, deforestation associated with charcoal production led to alternating drought and flood cycles and the smelters suffered from an erratic water supply as a result. The Winchester, located at the end of the race where it flowed back into the creek, suffered during both period of high water and low water. During drought it had the lowest priority, and during period of high-water backflow from the creek flowed up the race and stop the company's undershot waterwheel. Both smelters were also constrained by geography, located on a narrow shelf between the creek and a steep hillside. This limited both their ability to expand or make significant changes to their plants. Both companies did benefit from dependable fuel supplies through the ownership of charcoal plantations (Heberling 2017:40-41).

Historical information about the Winchester is limited, a situation common with most small Colorado smelters. Information about the site was limited to brief entries in local histories, and asides in correspondence from the adjoining Rockhill works. The Winchester operated only intermittently for its 20-year life, run by a series of short-term leases, and it was idle more than it was in use throughout its life. In contrast, the better situated Rockhill works were more successful, operating for almost 40 years (Heberling 2017:44).

Both works did suffer from many of the same problems. Although the Rockhill had a more dependable water supply than the Winchester, there were still periodic interruptions and it also suffered from the constrained site, making expansion difficult. Both smelters also had to contend with poor management. The owner of the Rockhill viewed the ironworks as a side-line from his other business interests, had little knowledge of iron making, and his oversight of the works was poor. The Rockhill operated continuously with fair success until the Civil War when it was temporarily abandoned. The works were reopened in the 1870s when a railroad was built nearby, reducing costs for materials and shipping, stayed in production until 1909 (Heberling 2017:32-34).

Of the two smelters, the Winchester appears to be a clear instance of failure with much in common with smelters in Colorado. The works ran only intermittently, had low production totals, changed ownership often, and was abandoned quickly compared to other ironworks in the area. In contrast, the Rockhill Furnace operated or nearly 40 years, outliving most of its local competitors. This was despite chronic shortages of capital and the production of a relatively low grade of iron. When compared to the larger, vertically integrated ironworks that grew up elsewhere in the district it was clearly not a very profitable or successful business (Heberling 2017:44). By the 1850s the larger iron firms of Pennsylvania were in the early stages of vertical integration. These companies began to control the blast furnaces, refining mills, and rolling factories. This allowed them to control all aspects of the iron production process. Although full vertical integration was not achieved in Colorado a similar development is seen during the 1880s when some of the larger companies began to add refineries to separate out the precious metals and build associated industries to dispose of some of the base metals (CC 2 April 1882:4). Other large Colorado smelters were part of larger smelting companies that controlled out of state refineries, providing a ready market for their metals (Henderson 1926:146).

Hot Spring District, Montana

Jeffrey Safford’s (2004) history of the Hot Spring Mining District of Montana. The district is typical of many of the small mining districts of Colorado. Following the initial discovery of gold, it was the subject of vastly exaggerated accounts regarding the quality and quantity of the ore in the district’s mines (Safford 2004:18-20). The reputed mineral wealth of the district led to an initial flurry of excitement with prospectors locating placer and lode claims throughout the area.

The oxidized surface ores of the district were indeed rich, assays showing some of the highest gold content known in Montana at the time. The enthusiastic miners made a common bad assumption that the gold content of the district's veins would steadily increase with depth. Similar optimistic views had been expressed, and crushed, in both California and Colorado by this point. The miners at Hot Spring, however, failed to heed the lessons the painful lessons learned in these more established mining regions, and the rich oxidized surface ores at Hot Spring rapidly gave way to refractory ores (at a shallow depth) that were both harder to process and contained less gold (Safford 2004:89-90).

Before this problem became clear, investors from the eastern United States were induced to develop the unproven ore deposits found in the Hot Spring mines. The territory's newspapers assured everyone that the district was the richest in the state and further exploration would continue to locate more, rich gold deposits. It soon became clear that the ores of the district were more difficult to process than anyone had anticipated. To address the problem a number of companies-built reduction mills in an attempt to successfully exploit deposits that were still regarded as rich in gold. The milling efforts ultimately proved unsuccessful, and the district that was once hailed as the richest in the territory became known as one of the worst after only a few years and it rapidly went into decline (Safford 2004).

The similarity between the milling operations of Hot Spring District and small Colorado smelters is the excessive optimism of local industrialists. Many of these small companies invested large amounts of money in physical plants without a good idea of the ultimate value or longevity of a mining district. Many small Colorado districts went through similar life cycles of over-optimism followed by realism and abandonment.

5.1.1 Colorado Examples

Three examples were selected from the small smelters of Colorado to compare to the studies of Irondale, Juniata, and Hot Spring District discussed above. The first two examples are from Silverton. The Greene Smelter is an example of one of the rare success stories in the history of small local smelters in Colorado that developed into a large and successful plant. The Martha Rose Smelter was a small operation that attempted to fill the gap left after the Greene Smelter relocated to Durango and rapidly failed. The final example is from Hall Valley, an isolated smelter dedicated to processing the output of a single company’s mines. These examples demonstrate some of the problems experienced by the small smelters of Colorado and provide case studies used in the following section to discuss patterns of failure in Colorado’s small smelters.

The Greene/San Juan and New York Smelter

The Greene Smelter was one of the more successful small smelters in Colorado. It was built at the town of Silverton by the San Juan and New York Mining and Smelting Company in 1875. The Greene was one of the pioneer smelters of the San Juan region and all the materials for its construction had to be hauled by burro teams from the nearest railhead over 160 miles to the east (Quite So 1875:2). Due to the difficulty and expense of transportation, the company conducted a failed experiment using local sandstone as a hearth lining in place of expensive fire brick. The company was also forced to use local charcoal for its smelting operations but felt that the charcoal was poorly adapted to use in smelting furnaces (EMJ 1877c:439).

The smelter ran successfully, and its capacity was steadily increased from an initial production of 4 tons of bullion daily in 1876 to 10 tons in 1877 (EMJ 1876b:77; CSG 8 December 1877:4; EMJ 1877b:221). The furnace remained in blast until 1881 when the board of directors (which included three directors of the Denver and Rio Grande Railroad) decided to relocate the smelter to the town of Durango (EMJ 1881b:34).

The relocation took advantage of the superior transportation facilities of Durango. It was much cheaper to ship Silverton ores down to Durango than it was to ship coke, fluxes, and additional ores from other districts upslope to Silverton. The more central location of Durango greatly eased access to raw materials from throughout the region. Its close relationship with the Denver and Rio Grande guaranteed it favorable shipping rates. Soon after reopening, the smelter accounted for 13.5 percent of Colorado’s bullion production (EMJ 1882b:8) and was considerably expanded in later years (EMJ 1882:8; EMJ 1884:392-393) coming to dominate the smelting of San Juan region ores until its closure in 1930.

The Martha Rose Smelter

The history of the Martha Rose Smelter is fairly typical of small smelters in Colorado. The Martha Rose was built in 1882 in Silverton (SMW 1 June 1883:3) in the wake of the relocation of the Greene Smelter to Durango. The smelter entered a field that already included several other small smelters distributed along the Animas River from Silverton to Animas Forks that were taking advantage of increased ore production in the area. The company had planned ahead to try and reduce costs by purchasing its own coal mine and coking the coal-inhouse, but production costs for the coke were high (EMJ 1882c:177). The smelter ran into trouble almost from the start. The smelter blew-in during September, but by the end of the year had only managed two or three short campaigns of 2 to 4 days duration. Total bullion production by the end of the year was only 11 tons. The initial problems with the furnace caused an immediate shortage of operating capital, and the low production, high fuel costs, and high labor costs of Silverton made it impossible for the smelter to offer reduction costs competitive with the better located San Juan and New York Smelter in Durango (EMJ 1882d:351).

Like many small firms with limited capital they were unable to correct the deficiencies in their plant or compete with outside companies, forcing the works to close in 1882. The problems inherent in operating a small local smelter were becoming evident by this point and no local offers for the plant were made. Ultimately, the smelter was sold to an English firm, but never reopened (SMW 1 June 1883:3).

Hall Valley

A final example of a small Colorado smelter is the Hall Valley Smelter of Park County (Appendix C). Hall Valley is a glacial valley containing the headwaters of the North Fork of the South Platte River. The company's mines were high on the edges of the cirque at the head of the valley. Silver deposits were identified in the valley in the 1860s. An English Company, the Hall Valley Silver-Lead Mining and Smelting Company, Ltd., was formed to work the Whale lode and adjacent mines (Jernegan 1875:246). Initial shipments of the ore to the Boston and Colorado Smelter at Black Hawk proved to be unprofitable due to transportation costs and the company decided to erect a smelter near its mines in 1873. The works entered blast in July 1876, but its initial run ran into problems and only a small amount of base bullion was produced (EMJ 1876a:49).

Success for the company smelter was elusive as the machinery was poorly adapted to smelting the barite-rich lead ores of the district. The company added a reverberatory roasting furnace to help process the ore and concentration machinery was installed to separate out as much barite as possible. These processes caused a significant loss in silver values prior to smelting, but this was unavoidable as the barite caused the creation of a dense, stiff slag that was difficult to separate from the liquid bullion from the furnaces (Jernegan 1877:221).

The smelter contained three 23-foot tall Piltz pattern blast furnaces manufactured in Freiberg, Saxony and shipped to the smelter site at great expense. The aggregate capacity of the smelter was 40 tons per day (Jernegan 1877a:221). The furnaces had been designed to smelt iron ores and proved ill-suited for use on argentiferous lead deposits. The extreme height of the stacks caused the bog iron flux used by the company to reach a metallic state prior to reaching the smelting zone, forming accretions on the furnace walls 8 to 10 feet above the tuyere zone. This caused short runs with frequent shutdowns to remove the accretions (Jernegan 1877:221; Gignoux 1877:147).

The original manager, a Mr. Painter, convinced the company to invest in the addition of the roasting unit and to cut one furnace down to a height of 12 feet but left the company in 1876 prior to making a trial run with the modified furnace. His successor managed a successful run using charges prepared by Painter but lacked the technical knowledge to successfully duplicate his charge ratios and the furnace was blown-out when the existing charges were exhausted (Bell 1877:50; Gignoux 1877:147).

After expending $500,000 on the development of their mines and smelters the Hall Valley Company entered bankruptcy. Although the company was able to discharge its debts, it did not restart the smelter and it is not shown on an 1881 list of active smelters in Park County (EMJ 1878a:240; EMJ 1881a:435). The plant was briefly leased by the Sts. John Mining Company in 1878 when winter shutdown their own works (EMJ 1878c:190). The smelter was purchased by the Quincy Reduction Company and conventional reduction machinery was installed in some of the abandoned smelter buildings during the fall of 1882 (EMJ 1882a:208). The facility is last mentioned as operating as a concentration works under the ownership of the Comet Consolidated Mining Company in the mid to late-1880s (Rosenberg 1977c). An updated recording of the site is included in Appendix C.

Common patterns contributing to the failure of small industries detailed in the earlier examples of the chapter are apparent at Hall Valley. The Hall Valley company decided that the argentiferous lead deposits owned by the company could probably be treated by blast furnaces but lacked the technical knowledge of metallurgy required to choose the correct type. Furnaces designed for use in iron smelting were purchased and shipped from Europe at great expense to a remote valley in the Colorado wilderness. The absentee owners of the company repeatedly ignored the advice of their on-site metallurgist to modify the furnaces to better suit the ores of the district (Gignoux 1877:147), instead enforcing the adoption of less expensive but unsuccessful options which led to the closing of the plant. The patterns of failure observed in these examples are more fully discussed in the following section.

5.1.2 Common Themes of Failure

The previous section examined five examples of small industrial enterprises in Colorado, Montana, Pennsylvania, and Washington. These case studies provide an overview of the types of failure observed in some frontier industries. Although each has unique factors contributing to their failure, several trends can be observed throughout. This section examines these failed enterprises to identify common themes and patterns of failure embodied in the small smelters of Colorado including technological, economic, and transportation difficulties.

At Hot Spring District three major companies constructed mills to process the district’s ores. The poorly capitalized Ragland, Cope and Napton partnership installed a 15-stamp mill at the district in August 1862. The better capitalized New York and Montana Mining and Discovery Company (NY&MM&D) erected a large 40-stamp mill shipped from Brooklyn, New York. Both companies chose standardized mill designs, the NY&MM&D in particularly hoping that the simple design of the mill would allow for the easy maintenance and repairs necessary in the primitive conditions of the district. Their choice of such a large mill purchased on the East Coast expended much of the company's capital just on shipping charges (the shipping costs alone were double the cost of the smaller Ragland and Cope mill). This put the company on a shaky financial footing before the mill was even erected. The third company, the Clark and Upton Mining Company, soon entered the field with a daring, but ill-informed, state of the art mill. In comparison to the simple water-powered stamp mills of the other companies, the Clark and Upton installed a complicated steam-powered plant that relied on hydraulically powered stamps to crush the ore. Unsurprisingly, the machinery proved to be overly expensive, complex, under-powered, and was highly unreliable (Safford 2004:107).

All three companies expended large amounts of capital on processing equipment prior to the proper understanding of the characteristics of local ore deposits. The choice of simple crushing and amalgamation mills proved completely unsuited to the processing the sulfide ores underlying the shallow oxidized deposits. The tendency of companies to invest heavily in machinery to process unproven and poorly understood mineral reserves was common in many districts of the western United States (Comstock 1881:284). In Colorado, many small smelters were erected by partnerships of eastern investors at the urging of highly enthusiastic local entrepreneurs. These local entrepreneurs often lacked the technical background necessary to make informed decisions on the highly technical details of ore reduction methods.

Most of the mills at Hot Spring District used cheap and simple technology that, while reliable in a frontier setting, proved to be poorly suited for local conditions. At the extreme end of the spectrum was the Clark and Upton Company that chose an overly complex and unreliable mill that, although at the cutting edge of technology, was similarly ineffective.

Colorado smelters followed a similar pattern. When conventional processes failed, local industrialists turned to technologies they thought might allow them to process their ores. The early years of the industry show a clear technological evolution in smelting techniques. The early hearth smelters familiar to Midwestern miners rapidly gave way to lead-silver reverberatory furnaces, and finally to blast furnaces and copper matte reverberatories. Due to the prevalence of argentiferous lead deposits in Colorado most firms eventually settled on blast furnace technology due to their proven record of successfully working such ores. Blast furnaces had low up-front costs, low operating expenses compared to reverberatory furnaces, and were easy to procure. Machinery to outfit a new smelter with blast furnace technology were available from manufacturers in Denver, Pueblo, or further east. Although blast furnaces were relatively technologically simple compared to reverberatories skilled metallurgists were still required to superintend the works. The Martha Rose and Hall Valley smelters are good examples of companies that faced these types of problems.

The availability of power was also be a limiting factor for small furnaces. As at the Winchester and Rockhill furnaces, many of the Colorado works were dependent on waterpower. This had the advantage of lower initial costs, and extremely low recurring costs during operations. Early smelters often overlooked the seasonal nature of the water supply in the Rockies. Mountain streams are largely dependent on snowmelt for their flow. Combined with freezing during the winter water levels in most streams decline in later summer and the fall, and often proved insufficient to power the smelter machinery. Most water powered smelters that survived their first year were forced to install backup boilers to allow year-round operation. This added expense was likely impossible for many of the poorly financed smelters to absorb. This situation was observed at Maysville in 1880. During the first winter of smelting activity at the town, the Arkansas River froze bringing the town's two smelting works to a halt. The better financed Erie Smelter was able to install a boiler to continue operations through the winter. The less well financed Shaveno Smelter failed to reopen in the spring (MM October 1880:3).

Another cause of failure was the difficult logistical arrangements needed to run a smelter. The impact of poor transportation infrastructure serving isolated western mining districts could be especially difficult to overcome. Freight costs impacted a smelter at all levels. The initial cost of transporting machinery to a site could consume much of a company's finances as shown by the experience of the NY&MM&D company in Hot Spring District, Montana (Safford 2004:34).

Transportation to many Colorado districts was more difficult than travel to Hot Springs, since much of the distance to Hot Spring District could be traveled by river during parts of the year. The early smelters in Clear Creek and Gilpin counties had to freight equipment and construction supplies overland from the railheads in Nebraska and Kansas. Local sources of firebrick and mining equipment did not become available until the late 1870s, increasing both up front and maintenance costs. Freight for the 70-mile trip between Leadville and Alma (the location of the nearest smelter prior to 1878) was $27 per ton in 1877 (EMJ 23 January 1887:55) The greatly reduced cost of railroad shipping is shown by the rates charged to the Aspen Smelter. In 1884 The cost to ship bullion by wagon from Aspen to Granite over Cottonwood Pass, approximately 45 miles, cost $25 per ton. The cost to ship the bullion from railroad at Granite to Denver, 140 miles, was $5.00 (EMJ 1884g:78). The high transportation costs not only increased the prices paid for smelting materials, but prices for food, clothing, and other essentials were all greatly increased by transportation costs. This in turn led to a high cost of living in the mountain communities and resultant high labor costs. Transportation prices further impacted the profitability of smelters after smelting was completed by elevating the prices for refining.

High costs of living in the mountains required the payment of high wages compared to more accessible regions on the Front Range. After a smelter was built, proven, and in production the resultant bullion or matte required shipment to refineries along the Missouri or East Coast. Only after the bullion was refined was the smelter finally paid for their work (Grabill 1908).

5.1.3 Smelters as Small Businesses

Failure, as observed in the previous section, is also common in the modern small business environment. The difficulty of small firms to compete with “big business” is common in both instances and historical and modern small businesses share some similar factors in their failure. Although the term “small business” was not used in the nineteenth century prior to the development of “Big Business” in the latter half of the nineteenth century (Waterhouse 2019:3) and would not become popular until the mid-twentieth century (Dannreuther and Perren: 2013), many of the Colorado smelters can be viewed in these terms. Their short lives were generally due to competition from the incipient Big Businesses of the Front Range and Leadville. The struggle of the small smelters against the large is similar to struggles observed between contemporary start-up companies and large corporations. The study of the interaction between the small smelters of Colorado and their larger competitors can shed a light on the early stages of this competition that may be useful to studies of contemporary small business.

From the beginning, the Colorado smelting industry faced competition from larger, better financed companies in other parts of the country. Like most contemporary start-up companies, most Colorado smelters were small, under-capitalized firms that were inefficient and overshadowed by a small number of firms that managed to perform well (Nightingale 2013:2). The Colorado smelting industry was temporarily insulated from serious competition with the large firms from approximately 1870 to 1879 when the first large firms began to form at Leadville. Local competition with small firms was ongoing prior to the rise of the large firms, mainly with the impressively successful Boston and Colorado Smelter at Black Hawk, the first really successful start-up industry in the state.

Although the Boston and Colorado was a singularly successful small smelter that evolved into a major player it was soon surpassed by larger firms that were in the initial stages of vertical integration. The Grant Smelter and the Harrison Reduction Works were both built during the Leadville smelter building craze of 1878-1879. The smelters were built by local businessmen with the assistance of the Omaha Smelting and Refining Company and the St. Louis Smelting and Refining Company, respectively (Emmons 1886). Colorado smelters of the time produced bullion and matte for shipment to distant refineries that conducted further processing. The Grant and Harrison smelters represent an early step in the formalizing of the process with initial smelting carried out by the local firms with refining carried out at allied refineries. The advent of fully integrated Colorado smelters soon followed.

The Colorado Smelter and the Philadelphia Smelter at Pueblo were the most notable businesses in this regard. Like the Boston and Colorado and New York and San Juan smelters, the Colorado was one of the rare big-time success stories in small smelting. The company evolved from the small Madonna mine owned smelter that evolved into a large central plant at Pueblo. The Colorado soon controlled its own mines, smelted the company's ores, and added one of the earliest refineries in the state allowing the company to control the entire process from mining the raw ore to producing the final gold and silver bars. The Philadelphia Smelter was similar, built by Meyer Guggenheim to smelt the ores of his large silver mines at Leadville. The success of his smelter eventually allowed Guggenheim to transition from a mine owner to having a controlling interest in the large smelter trust ASARCO.

The economic power of the large smelters attracted prominent individuals, and the company boards often included important railroad men that further strengthened their dominance of the smelting industry through setting favorable shipping rates for their allied smelters. The heavy competition from these new, large companies combined with the development of a large railroad network that allowed for the economical transportation of ores and concentrates from mines directly to the large smelters. Colorado's smelting industry was already considered overbuilt by 1884, with many large works operating at low capacity and many small works shuttered (EMJ 1884e:146) and most of the small smelters were failing 1885.

Given the obstacles facing small smelters, perhaps it is not surprising that they tended to fail as quickly as they did. Modern small businesses are similarly prone to failure. Although estimates vary, almost half of new small businesses fail within two years, and the majority fail within five years (Rannie 1985:157; Waterhouse 2019:6). Small companies are handicapped in their competition with larger firms due to their limited startup capital, and the difficulty of raising additional capital. Their limited financial resources make it difficult to invest in new technologies, and they lack the financial strength to exert their will beyond their local markets (Nightingale 2013:317-318). Small smelting operations were dependent on the ores produced in their local districts. This restricted their ability to make efficient smelting charges leading to inefficient and expensive reduction costs. In contrast, the large smelters on the Front Range and at Leadville could access ores from many regions at low prices allowing for cheaper and more efficient smelting.

The small Colorado smelters were in a similar situation. New start-ups, they were unable to compete with better established companies, like the Boston and Colorado that had already developed sufficient operating capital and a dominant market share. Competition required that no mistakes be made during the initial development of a smelting company, or they tended to end up like the Dudley Smelter where the initial mistake of using a blast furnace instead of a reverberatory furnace placed the smelter in a position where it could not recover and compete effectively with the Boston and Colorado branch smelter.

The limited financial reserves of small businesses also tend to make them less innovative than larger firms, contrary to popular misconceptions and the small smelters of Colorado were similarly responsible for few technological developments. Small businesses in general are poorly suited to innovate. Their management is often poor, and generally content with tried and true methods of conducting business. Most innovations are made by larger firms with the capital reserves to allow for experimentation and the adoption of new technology, although the American precious metal smelting industry as a whole was responsible for few significant large-scale innovations in technology (Burt 2000; Nightingale 2013:3-5; Rannie 1985:147).

If anything, the modern data overemphasizes the survival rate of small businesses. Modern researchers have yet to develop a commonly accepted definition of what constitutes a small business making comparisons between businesses difficult. Some researchers use the metric of the number of employees as a proxy, but this is not consistent across regions. Within the United States small businesses are often defined as those with less than 500 employees, whereas studies in Europe use far lower numbers, some considering small businesses those that employ less than 20 people. The data also has an element of survivor bias as many firms survive for such a short time that they fail to enter in the data sets and are not counted toward the calculation of failure rates. Standards for when a firm is established are also unclear. One metric is that a business has been founded when its monthly cash flow manages to pay salaries and all company expenses for a period of at least six months during a year. Many small businesses (and historical small smelters) never meet that criteria and therefore would not enter the statistics (Nightingale 2013:5-12).

The small smelters of Colorado show many of the traits of modern small businesses. They are characterized by low starting capital, limited cash flows, and a small work force. Due to the lack of capital, coupled with a limited understanding of smelting, the companies were forced to make do with inexpensive and readily available technology. Combined with the high price of supplies and labor in most mountain camps they tended to invest in blast furnaces regardless of whether they were the best suited for a given area. In many instances, and as shown at Hall Valley the onsite metallurgist understood the limitations of the smelting plant as but was unable to convince the company to expend further money on improvements. After the heavy initial investment in construction, company directors and shareholders often proved unwilling to invest further in a plant until it generated a profit, creating an untenable situation as shown at Hall Valley (Gignoux 1877:147) or at the NY&MM&D in Montana (Safford 2004:34). Management was most concerned with generating profits and preferred to enjoy what revenue was produced with the current plant or wash their hands of the business entirely. Only in extremely rare instances were innovative approaches to problems observed at small works, and these were usually minor improvements at successful operations.

In more-or-less ideal conditions, these local smelters could enjoy limited success, as was the case of Lake City's Crooke Smelter or the smelter at Aspen. Yet these smelters inevitably became victims of their own success: profitable in their niche market but unable to expand into new ones. The Hall Valley Smelter was built to serve its own mines that were too distant from existing smelting centers to be profitable. Although the company was relatively well financed, capable of investing $500,000 on the companies mines and smelters (the company built a second, similar smelter in the next valley over on Geneva Creek), its management demonstrated little understanding of metallurgy. It purchased a set of furnaces without verifying that the furnaces were appropriate for the ore from the company mines. After the great expense of purchasing the equipment, shipping it to Colorado, and building the smelter, the management refused to heed the advice of their metallurgist on the ground and refused to expend money to modify the blast furnaces. The failure of the company to adequately modify their plant to match local conditions led to its bankruptcy and eventual sale of the mines and smelter.

Survival for the small smelters of Colorado relied on a degree of isolation from the major centers of the state, a temporary condition that disappeared within a few years. They required a transportation network that was advanced enough to allow for the movement of ores and supplies within the district and shipment of their bullion or matte to outside refineries. At the same time, the network had to be primitive enough to insulate the smelters from outside competition. This delicate balance would be disrupted by the dramatic reduction in transportation costs associated with the arrival of a railroad in the region that allowed for concentrates to be shipped and processed more cheaply at locations outside the district. Conditions only worsened if competing smelters were built in the same district, as this often turned out to be the case.

6 Conclusions

I have provided a research context for small-scale smelting in Colorado, including an overview of the technologies used in the smelting industry, the history of the industry, and the prevalence of (and potential causes and patterns contributing to the failure of) small-scale smelting in the state. This final chapter addresses three main topics: evaluating the significance of individual smelter sites, their research potential, and heritage issues related to the sites. The application of the NRHP criteria for determining the significance of small smelters sites is illustrated using the example of the Hall Valley Smelter initially discussed in chapters 3 and 5. I also discuss potential research avenues that could be addressed by further archaeological examination of smelter sites using the Hall Valley example. The chapter concludes with a discussion of the challenges of preserving the tangible remnants of Colorado's smelting heritage and the importance of integrating the history of the smelting industry more fully into the historical study of Colorado.

The metal industry of Colorado involved the integration of many related industries, working toward the common goal of producing metals for profit. Although the mines are the most obvious part of the metal production process from both a visual and historical perspective, the process also involved mills to sort and concentrate the ores, processing plants to make the initial separation of metals from the ores (including both chemical works and smelters), the transportation network, water storage and conveyance features, quarries for fluxes and building material, charcoal pits and ovens, and the towns and cities that provided services needed to support the industry.

Although these various components of mineral districts are usually treated separately for management purposes, they should be examined at a landscape level to better understand the industrial landscape in which the smelting industry was embedded (Francaviglia 1991; Hardesty 2010; Stöllner 2014). A mining district consisted of a wide range of industrial and support system that were interwoven together over a large area. The individual sites (mines, smelters, saw mills, etc.) within a district were connected by the flow of people and goods constantly moving between the individual components of the district. Viewing the district as a landscape allows the disparate components of the industrial system in a district to be viewed as a whole, allowing for an analysis determining the interaction between intentional human design and geographic constraints in the evolution of an industrial area. Many types of landscape analysis can support this approach (c.f. Anschuetz et al 2001). As the focus of the present study is directed toward the distribution of smelting operations on the state level, examination on a more local level should incorporate a landscape approach as this will allow for the examination of important social issues. The organization of the landscape, including associated habitation sites, is a physical manifestation of social hierarchy, class, ethnicity, and power. Examining sites individually limited the ability to examine important questions on the interrelationship of these issues in the development of western mining districts (Cimino 2009; Cowie 2011).

In some ways, landscape studies in Colorado should be easier than in some regions. The dispersed nature of mineral deposits in western states allows mining districts to be viewed as “islands,” or patches of resources. Although connected to the outside world, the communities and industrial facilities in mining districts developed as self-contained entities with their own towns, mines, mills, smelters, and ancillary facilities (Hardesty 1999:215). These islands were separated from each other by rugged terrain lacking economically valuable mineral deposits, creating clear boundaries allowing the definition of relatively small industrial landscapes that can be used for management purposes.

In Colorado, attempts to manage industrial landscapes at this level are rare. Major federal land-owning agencies such as the United States Forest Service and Bureau of Land Management control large, contiguous blocks of land that could be managed in a comprehensive way. These agencies, however, are chronically under-staffed, under-funded and realistically lack the ability to develop a new and comprehensive method of dealing with their cultural resources. Most archaeological and historical projects on federal lands are conducted by private companies in response to the Section 106 process leading to surveys and site assessments that are restricted to tightly delimited areas (King 2004; Sebastian 2009; McManamon et al. 2016). This results in industrial and historical sites being recorded in a piecemeal fashion that prevents them from being viewed as part of an integrated industrial system.

to the history of Colorado or the local area. The lack of attention makes determining the relative importance of these sites difficult to determine increasing making it hard to prioritize the preservation of the sites. Realistically, only a portion of the industrial sites near mountain communities can be preserved, requiring that preservation activities be focused on the most important remaining examples.

6.1 NPS Eligibility and Integrity

In an attempt to rationalize and prioritize the preservation of cultural resources in the United States, the National Park Service (NPS) has developed a scheme to assess the relative significance of sites in an organized manner. This was enacted in support of the National Historic Preservation Act (NHPA) that was established in 1966 as 36 Code of Federal Regulations 800. The act stated that federal agencies must “Take into account” the potential effects of their activities on “historic properties,” that is properties considered eligible for listing on the National Register of Historic Places (NRHP) (King 2004:81-84).

The NPS has published guidance to assist individuals in determining the significance of cultural resources. The main guidelines are in National Register Bulletin (NRB) 15 *How to Apply the National Register Criteria for Evaluation*

(NPS 1997a). Further guidance that is applicable to Colorado smelters were published in NRB 36 *Guidelines for Evaluating and Registering Archeological Properties* (NPS 2000), and NRB 42 *Guidelines for Identifying, Evaluating, and Registering Historic Mining Properties* (NPS 1997b). Further clarification on eligibility requirements and historical themes for the Colorado smelting industry were discussed in a multiple property documentation form, *The Mining Industry of Colorado* by James Fell and Eric Twitty (2008). The document stressed the importance of smelters in the national development of smelting, their contributions to the mining industry, the economic development of Colorado, and its role in social development in the state. These guidelines identify four criteria that sites may possess significance under, labeled criteria A – D.

Sites maybe significant under one or more of these categories. Significant sites must also be assigned to a period of significance. Sites may have multiple periods of significance if its use changed and the new activity was also determined to be significant. For instance, a small smelting site may have an early period of significance during its use as a smelter, and a later period of significance when it was used as a concentration works. Modifications to a site from outside its period(s) of significance can negatively affect the integrity of a site and render an otherwise significant site not eligible for listing.

Criterion A

To be significant under Criterion A sites must be directly associated with an event that made an important contribution to the ‘broad patterns of our history.’ To be significant under this criterion the importance of the site must be demonstrated within a specific geographical context and relevant historical themes (mining, settlement, etc.). It is necessary to demonstrate the strength of the site’s connection with the appropriate historical events, and it must retain sufficient integrity that the intra-site patterning of artifacts and features is preserved sufficiently to illustrate the relationship to the historical event.

Themes of potential relevance under this criterion can include its importance in the history of engineering, the development of big business, labor relations, ethnic heritage, or any of a wide range of other historically important topics. At the Anaconda Smelter site, the smelter smokestack was determined eligible under this Criterion due to the importance of the smokestack in the history of environmental law and as an example of an early attempt to mitigate the harmful effects of smelting (Quivik 2007:48). Small mountain smelters may be eligible under this criterion if it can be demonstrated that its operation stimulated the local mining industry, contributing to the settlement and industrial development of a district.

Criterion B

To be significant under Criterion B a direct relationship must be demonstrated between the site and a historically significant individual. It is necessary to develop a sufficiently detailed historical context to clearly demonstrate the importance of the individual and his association with the site. For a smelting site significance under this category would require the works be the location where the individual accomplished important work, such as developing a new piece of technology or smelting technique, be a smelter that he designed, or a location that significantly influenced his career. The Dudley Smelter at Alma could be potentially significant under Criterion B as one of the earliest smelters operated by Edward D. Peters. His lack of success using argentiferous lead blast furnaces at the site and his attempt to switch to a copper reverberatory method may have influenced his later career and his becoming a noted expert in copper smelting technology.

Determining eligibility under Criterion B may require significant research, as the importance of a site and the individuals involved may not be immediately obvious. Additional research on a group of small, non-descript mining sites in southern Nevada demonstrated it was associated with a nationally prominent geologist. It was the location of one of the earliest attempts to locate mineral deposits not visible on the surface through use of scientific geological modeling and testing that later became standard in the mining industry (Valentine 2008).

Criterion C

To be significant under Criterion C a site must retain the characteristics of a "type, period, or method of construction." Sites lacking standing architecture may still be eligible under this criterion if it displays a pattern of features characteristic of a type of industry (such as nineteenth century smelters). The features should demonstrate the original plan of the works or demonstrate the evolution of the site over time. Sufficient site integrity must remain to clearly illustrate the design and function of the site, including workflow and the movement of materials through the site.

A major difficulty in applying Criterion C to a given smelting site is the lack of comparative data between the site and other similar sites in the state. This makes it difficult to determine the importance of a site as the condition and surviving features of similar sites is currently unknown. If it can be demonstrated that the site was an early example of the type, one of the last, or demonstrated a new or novel approach to smelting it may be significant under this criterion (Hardesty 1990:48-50; Quivik 2008:49).

Criterion D

Most eligible smelting sites will likely be significant under Criterion D where the site must have provided, or have the potential to provide, significant data capable of addressing research questions shaped by relevant research topics and themes in archaeology. Significant avenues of research that could potential be addressed can include questions on technology, economics, land-use patterns, social organization, and cultural interaction with the environment. To have the potential to answer these questions it is necessary that the site retain sufficient integrity. It is important to assess whether natural and cultural site formation processes have left sufficient intact deposits to address these research questions.

One underestimated avenue of research on smelting sites is their waste deposits. The waste piles associated with an industrial operation has the potential to provide significant information about a smelter. Chemical analysis of the waste can potentially provide information about the methods used and the efficiency of the operation. Some of this data may already be available for particular sites as a result of chemical testing of the remains in the course of environmental remediation actions (White 2003). The methods used to dispose of the waste may also indicate the amount of foresight used by the management, or how they viewed the longevity of the works. Disposal of waste was a major consideration at smelting sites if long-term use of the facility was anticipated (Quivik 2007:38).

Aspects of Integrity

For a site to be eligible for inclusion to the NRHP must retain integrity, in addition to having significance under one or more the eligibility criteria. Even the most historically significant site may not be eligible for listing if there has been too much disturbance to the resource. For listing, a site must retain most of the aspects of integrity. In specific instances arguments can be made to limit the importance of certain impacts to site integrity, but these must be made on a case-by-case basis (Hardesty 1990:50). To evaluate how intact a site is the NPS developed seven aspects of integrity relevant to archaeological sites.

Design

Integrity of design requires that the original design, or layout, of a site remain evident. For archaeological sites this requires that artifact and feature patterning within the site are sufficiently intact to convey the original layout and industrial processes at the site at the site. In the case of sites that were used for a long period, or multiple periods, this can include the ability to trace the evolution of the site plan through time.

Materials

Integrity of materials requires that the original physical elements of the features or structures of the site remain intact. In reference to archaeological sites, integrity of materials refers to the completeness of the artifact and feature assemblage of the site. Features from outside the period of significance, or significant artifact loss, can compromise this aspect of integrity.

Workmanship

Integrity of workmanship requires that the original construction methods of a structure or site remain evident. Methods of construction that are typical of the period of construction or that provide clues to the ethnicity of the designer and builders of the feature or site are particularly important. Integrity of workmanship requires that the methods of construction for site features remain in evidence. For archaeological sites this is indirectly inferred from the features remaining. The features need to allow for the reconstruction of the original methods of construction or site use.

Location

Integrity of location is rarely of great importance in the treatment of archaeological sites. It is most commonly significant in situations where historical buildings or equipment are removed from their original location. The relocation of historical buildings to architectural parks like South Park City in Fairplay, is an example of where this aspect of integrity can come into play.

Setting

Integrity of setting is an assessment of whether the landscape surrounding the site remains similar to its appearance during the period of significance for the site. Elements of the setting that may be relevant include man-made features like homes, highways, or transmission lines or significant changes to vegetation communities in the area. A small farm complex encompassed by urban sprawl is an example of where integrity of setting could be compromised. On a larger scale the historical community of Georgetown is now overshadowed by the massive fill built to carry Interstate-70 along the north edge of town. For many archaeological sites the integrity of setting is of little importance as the significance of the site is primarily based on the data potential of the site.

Feeling

Integrity of feeling can be difficult to quantify. Feeling is the ability of a site to express or elicit a historical or aesthetic sense conveying the historical importance of the site. There are few hard rules on assessing integrity of feeling, and it must be determined on an individual basis. Generally, the isolated rural nature of many small smelting sites creates a sense of the boom-bust cycle of western industrial sites, contributing to the retention of integrity of feeling.

Association

Integrity of Association refers to the ability of a site to convey the link between the historically important event or individual listed under criteria A or B. For archaeological sites this aspect of integrity is sometimes used to define the ability of the site to contribute data to significant research questions identified under the eligibility discussion for Criterion D.

Research Considerations

Despite the generally good knowledge of smelting technology from the period, there are significant questions that can be answered by studying small smelting sites. There are have been no excavations of smelting sites in Colorado to date, and all information about them is derived either from incomplete historical documents or cursory surface recordings. Given the short life of most of these smelters they provide an excellent opportunity for archaeology study. Beyond their mere historical value, these sites have scientific value. Study of these sites can be used to answer questions relevant to fields such as the history of technology (Basalla 1988; Blockley and Henderson 1980; Burt 2000; Petroski 1992a, 1994), economics (Knott and Posen 2005; Nightingale and Coad 2013; Dannreuther and Perren 2013), and anthropology (Pfaffenberger 1990, 1998) These sites have the potential to answer important questions about Small sites such as these have less complex deposits than large smelting sites have. Many were abandoned and never reoccupied and providing a single component that can be easily analyzed and patterns of site use and the types of technology and patterns of workflows within the sites would be relatively easy to determine (White 2016). At most of these sites' equipment was likely salvaged for reuse elsewhere or collected during various scrap drives and cleanup operations in later years (Hardesty 2000). A study of several small sites could help detect patterns of equipment reuse and contribute to the study of post-abandonment site formation processes on small industrial sites. Even if little of the manufacturing portion of a site remains intact the waste deposits can provide information about the processes at the sites. Although slag at larger sites were often reused after abandonment, in small mountain smelting locations there are still likely deposits onsite. These wastes can be analyzed to provide significant information. A chemical analysis of the slag can provide information on the type of process used and the efficiency of the operation (White 2003). Often information about smelting sites is very limited and little or no information about the types of furnaces installed, the flow of materials through the site, or the layout of the plant are known. The investigation of any smelting site will provide valuable information that can be used to develop an archaeological signature of smelter design in Colorado. Such information could then be compared to investigations of smelters in better documented areas like Nevada to see if there are unique adaptations to the high-altitude environment of Colorado.

Hall Valley – An Example NRHP Eligibility Nomination

As an example of the way the NRHP and integrity criteria can be applied to smelter archaeological sites we will examine the Hall Valley smelter (5PA313), initially discussed in chapter 5. I surveyed the site in the fall of 2018 because the site appeared to be a good example of a small mountain smelter with unusually good documentation in historical records. Like most of the smelting sites recorded in Colorado, an archaeological survey team documented Hall Valley's smelter in the 1970s. The form submitted to Colorado SHPO contained very little information about the site, although it was recommended eligible under Criterion D for its research potential. While my initial expectations for the site were low, I was surprised at the well-preserved nature of the smelter site and the valley's industrial landscape. This site should be recorded as part of an integrated study of industrial operations throughout the valley including the mines at the head of the valley and any undiscovered ancillary facilities. While this survey was only intended to assess the research potential of the site as an illustration for this dissertation, it revealed the need for a much more comprehensive review of the valley's industrial landscape.

With the assistance of Megan Mueller, we identified and mapped fifteen new features: a mill race, five foundations, a depression, an artifact concentration, a privy pit, a large platform, a slag pile, an unidentified piece of machinery, a large mound of burnt fire brick, a wagon road, and a modern road. Although no standing structures remain at the site, these features have the potential of providing a great deal of information about the layout and activities at the site (detailed information on the site is included in Appendix C).

The physical features of the site, combined with historical maps and a historical photograph, allow for the correlation of the features with most of the major components of the smelter. The short life of the smelter and its isolated location has preserved much of the evidence of the original layout of the smelter allowing for a reconstruction of work flows at the site. This allows the examination of the entire feature system for the site. As defined by Hardesty (2010:16-20) a feature system consists of all the related components of an industrial operation. The following discussion provides an example of an NRHP recommendation for a small smelter site.

- Criterion A – The Hall Valley Smelter is not eligible for the NRHP under Criterion A. The smelter was built during the mid-1870s after several other smelters were built in the Park County. It was not an early example of these establishments in Park County or the state. The smelter was associated directly with a small mining district controlled by a single company. Neither the company nor the district contributed significantly to the economic development of the county. The design and use of the smelter did not lead to any improvements or developments of smelting technology or engineering.
- Criterion B – The smelter is not eligible for the NRHP under Criterion B. The existing historical records pertaining to the smelter do not directly associate it with the life or work of a prominent individual in history. Although it was the subject of several articles in the *Mining and Engineering* journal during its brief period of operation, none of the individuals involved were well known or responsible for significant or enduring contributions to the field of smelting or played a significant role in local or state history. The individual most closely associated with the operation of the smelter, a young metallurgist named Jernegan, died in an

accident a few years after his association with the smelter and did not achieve a degree of prominence in the field.

- Criterion C – It is difficult to assess the potential eligibility of the site under Criterion C. No smelting sites have been professionally investigated in Colorado and there is no existing body of data to use as a comparison to determine whether the site has any unique or innovative features. The primary potential of the site under this criterion is as an example for comparison with other sites as they are evaluated. Most of the site's features can be defined pertaining to their functions in the site making it possible to trace the movement of materials through the industrial operation. The locations of the ore house, fuel storage, the platform for making furnace charges, the smelter building, and the slag dump were all identified during our visit. Features related to some parts of the smelting process were not identified, including the roasting facilities, the workshop, and the assay office. Further archaeological investigation of the site is needed to locate the unidentified portions of the complex. The site has the potential to provide an example of the typical layout of a small Colorado smelter during the 1870s. It is not, however, one of the earliest examples of smelting in the state and did not contribute to the development of smelting technology or practice in Colorado and is likely not eligible for the NRHP under Criterion C.

- Criterion D – The Hall Valley smelter is eligible under Criterion D. The site has had few modern impacts and retains considerable potential to answer questions related to the transfer of smelting technology to Colorado, the sequence of technical decisions over time, and the environmental impacts of small-scale smelting operations. Excavations within the foundations could provide important information on the details of how small smelting plants were organized. Given the lack of surface or subsurface investigations of smelting sites in Colorado this would provide important comparative information for future investigations of smelting sites. Due to the short life of the smelter there was no significant change to the smelting equipment or processes at the site and it should provide a good example of the data potential of similar smelting sites in the mountains. One of the foundations onsite is from a habitation structure. A nearby privy and a collection of domestic refuse indicates the site has the potential to provide information about the lives and ethnicity of the smelter workers. No information pertaining to the workforce was located in historical records and excavation and analysis of these features will yield information about the daily lives of workers and may clarify whether workers were brought from Britain to work at the site. Additional information may be derived from an analysis of the fuel and waste products at the site, reconstructing the actual technical process used and it’s variation over time. The source of the coke used by the company is unknown. Analysis of coke remaining on the site could be compared to the composition of coke produced at manufacturing facilities in Colorado and Pennsylvania to identify a likely source. The slag deposits also contain significant data. The historical records indicate that the smelting process used at the site was inefficient and subject to frequent stoppages. Analysis of the slags could be used to quantify the components of the smelting charges and identify potential problems that arose during smelting. This could be combined with a wider analysis of slags from other smelting sites around the state to identify similarities and differences between blast furnace operations across Colorado. Finally, the smelter did not include dust chambers in its design, or other means of capturing the flue dust generated during firing. Sediment samples in the valley should contain lead and other heavy metal deposits from the smelter. This could be used to determine the rate and extent of industrial pollution generated here and at similar sites.

The isolated nature of the location has led to the preservation of most of the aspects of integrity.

- Integrity of design for the site is intact. There has been little modern development at the site, limited to the construction of a modern Forest Service road along the north and west boundaries of the site. The site features are mostly undisturbed and continue to convey the original layout of the site.

- Integrity of materials is largely intact, as there has been little disturbance of the site's features. The proximity of the site to the Hall Valley campground and the low overall artifact density indicates that some artifact collection has occurred. There are, however, still artifacts pertaining to the industrial processes at the site (portions of the blast piping, iron chimney, etc.), as well as a concentration of cans and other domestic artifacts from the occupation of the site.
- Integrity of workmanship is intact. The features are in sufficiently good condition for the original construction methods to be readily identified. The dry-laid stone foundations are well constructed and well preserved.
- Integrity of setting is largely intact. The landscape retains the isolated character that existed at the time of occupation. The primary impact to the setting is that the density of the modern forest is much higher than it was historically, limiting the viewshed from the site.
- Integrity of feeling for the site is intact. The appearance of the slag pile and large foundations in a natural setting evokes a feeling of the boom-bust cycle typically associated with western mining and industrial sites. The juxtaposition of industrial features with the apparently undisturbed natural setting of the site facilitates reflection on the history of the area and the transient nature of human activities.

- Integrity of association is intact. Although the site is not eligible under criteria A or B, it does retain the ability to answer the research questions listed under Criterion D
- Integrity of location for the site is also intact. No features, structures, or other site components have been relocated.

The Hall Valley example demonstrates the types of information that can be derived from these small smelting sites and their potential significance in the history of a region. The site has the advantage of being in an isolated area on federal land with little danger from future development. Many small sites are not as fortunate in their prospects for preservation. In the following section I examine the problems of preserving and interpreting smelting sites in Colorado.

6.2 Heritage Issues

The smelters of Colorado have been largely forgotten. With the continued influx of people from outside the state the proportion of the population that have a connection to the industrial period of Colorado's development decreases by the year. Although abandoned industrial sites have gained some appreciation as part of peoples heritage and their potential for reuse, preserving their historical potential (Storm 2008), most of the remains of the standing remains of Colorado's smelting industry disappeared long ago. Consequently, the preservation of Colorado's industrial heritage is not a large priority beyond the local level and is becoming increasingly marginalized as other preservation interests come to the fore. Even the records of the Colorado Office of Archaeology and Historic Preservation are limited pertaining to the Colorado smelting industry, and most of these projects date to early reconnaissance work in the late 1970s and early 1980s. These records contain limited information, and in most cases no attempt was made to evaluate the research potential or integrity of the sites.

A major EPA cleanup operation was conducted at several large smelting sites at California Gulch outside of Leadville (Woodward-Clyde 1992). The archaeological work conducted was minimal and failed to produce significant information about the sites. The sites have now been largely reclaimed, remaining slag heaps capped and are no longer recognizable as smelter sites. The Globe Smelter in Denver remained in operation until 2006, producing silver and gold only as byproducts of base metal production that become the focus of work in the 1920s. All the buildings of the plant were demolished documentation and the area has been remediated. At Pueblo both the Pueblo and Colorado smelting works were demolished at an early date and the areas partially remediated. A section of slag dump, foundations and walls at the Colorado works remain but are scheduled for remediation by the EPA and their future is uncertain. The Philadelphia Smelter in Pueblo was adjacent to the east side of the Colorado Fuel and Iron (CF&I) plant and was incorporated into the steel works property after abandonment. None of the smelter buildings remain standing and it appears only fragmentary concrete piers and foundations remain (Tate 2019).

The interpretation of most Colorado smelters is also impeded by the lack of surviving records from their period of operation. Although a few ledgers from small smelters have survived in the collections of History Colorado, no significant records from the larger smelters were located. Smelting was a controversial business, and mine owners often complained of high smelting costs, which miners attributed to the greed of the smelter owners (Adkinson 1908; Grabill 1908; Turnbull 1916). This perception was partially derived from the fact that smelting was a complicated and expensive business. In addition to the costs of the ores, smelters had to contend with the costs of fuel, fluxes, transportation, refining, and marketing. These costs were rolled into the reduction costs that were paid per ton of ore. Due to the complains on smelting costs, smelters were loath to let their records become public knowledge. The potential for the old papers of a company to be used to tarnish the reputations of the prominent company owners and management were recognized at the time and most records were likely destroyed after the smelters closed. A letter found in the papers of N.P. Hill, Jr., the son of the long-time proprietor of the Boston and Colorado Smelter, shows the likely disposition of that company's papers:

> Mr. Hale has informed me that we have a large quantity of books of account in that office building also old letter books and old letters received from the Boston office and other places. We had a prudent management, and doubtless a great many old papers were kept. Mr. Hale thinks that there are no deeds of real estate and no valuable papers. If you see no

> objection, I wish you would have the useless books and papers destroyed. I assume that they could be sold as old junk, but I also feel strongly that we would not like to have our old papers scattered about. Some newspaper might misunderstand them and write up an erroneous story which would give us disagreeable publicity. Therefore, I favor burning up the useless old books and papers. I suggest that you communicate with Mr. Jesse D. Hale and get information from him as to what books and papers are now in the old office building. If you see no object, have them burned up. (HCD 1909)

Damage to the physical remains of the smelters were also perpetrated by company management. Every attempt was made to maximize the final payout to stockholders by disposing of anything of potential value. Buildings were destroyed for salvage if they could not be sold for use off the site (HCD 1909). The large quantities of slag, however, were of some potential value and were sold where possible. Outside contractors approached the Boston and Colorado Company about reprocessing some of the slag to recover any remaining gold and silver that had been missed by earlier smelting attempts. At the Argo a Mr. Stanley Barrows (HCD 1913a) and Mr. Paul Wilson signed a contract to sort through remaining slag and materials on site, providing the company with a percentage of any profits realized from the work (HCD 1913a). Unfortunately, the Argo was an efficient smelter and the materials they recovered contained little metal. During Mr. Wilson’s 90-day lease to salvage materials a load of copper bars and copper matte were recovered from the site and shipped to smelters for processing. The ASARCO smelter in Omaha paid $10.66 for the matte, and the Garfield Smelter at Salt Lake City paid $14.18 for the load of copper bars. At a 20 percent royalty the Boston and Colorado company realized a profit of $4.97 for the work. (HCD 1913b; 1913c). No further attempt was made to recover metals from the remaining materials onsite and the remaining slag was disposed of to a local sand and gravel dealer at a price of $0.10 per cubic yard (HCD 1924). Slag was still being sold to interested parties as late as 1940 when the Highway Department of the City and County of Denver purchased slag for use as road fill at a cost of $0.25 per cubic yard (HCD 1940).

Sites in some of the smaller mountain communities may retain archaeologically important deposits but several of these sites were destroyed in the late 1970s and early 1980s due to a lack of local interest in their preservation. Many of the remaining sites near towns are threatened by burgeoning urban development. At Alma two buildings from the original Boston and Colorado company's branch smelter but are the only smelting structures remaining in the county. Although isolated, Alma is experiencing urban development as a satellite community of Breckenridge and the sites are also in danger of destruction. The site of the Gunnison Smelter was intact until the 1970s but has since been destroyed by the creation of a residential neighborhood. The Jumbo Smelter at Gunnison was located near Western State College and was destroyed by earlier expansion of the city. Of the two smelters built in Boulder, portions of the Boyd Smelter were encountered during the construction of a bike path and was purposely buried by the city to preserve the remains. The location of the second smelter in town is unknown but was likely destroyed by urban development. At Golden the smelters were located along Clear Creek at the east edge of town. The sites were likely destroyed by the construction of a variety of light industrial companies in the area east of the Coors Brewery. None of the early smelters of Georgetown remain intact, destroyed by development during Georgetown's boom years, or by disturbance associated with the construction of I-70 through the valley.

The least endangered sites are those smelters outside modern urban areas. Some of these were in isolated areas near mines, while others were in short-lived mining communities that have since become ghost towns. A few sites in these areas retain some architectural components such as the brick smelter stacks at Sts. John in Summit County, and along Henson Creek in Hinsdale County. Examples of smelters in largely undeveloped areas the Dudley, Hall Valley, and Geneva Gulch smelters of Park County and a series of small smelters along the Animas River above Silverton. Such sites exist across the state.

An issue in motivating the public to recognize the importance of Colorado's industrial heritage is the lack of visually striking structures at most smelting sites. The mountain smelters were generally small, short-lived, and have been long abandoned. In contrast, many of Colorado's mining districts had significant mining activity stretching into the first decades of the twentieth century. These districts often retain highly visible headframes, shaft houses, and large waste rock piles that dominate the landscape. Late historic mills often left large concrete foundations that provide a more visible connection to the mining era. In contrast, the mountain smelting sites s were mostly abandoned in the 1880s or had relatively flimsy buildings that were salvaged for materials or long since rotted away. They also generated fairly small amounts of waste materials that are far less visible on the landscape. This is compounded by the lack of connection between the modern population and historic industries. Unlike at Anaconda in Montana or Ducktown in Tennessee, smelting has not been a significant industry in Colorado for many generations. Current populations no longer have a direct link to smelting and fail to see it as an important part of their historical heritage while the romance of mining has made many communities embrace their history as mining locales. The competition to preserve the small smelting sites that have been reduced to archaeological resources can be difficult to justify to agencies and local governments when large, tourist-attracting remains from later periods of industry are available.

Part of the problem with engaging people with Colorado's smelting heritage is the early date of its failure. Unlike in some regions where smelting related sites and landscapes retain striking visual remains as the large smokestack at Anaconda, Montana, the denuded landscape of Ducktown, Tennessee, or the intact smelter at Hancock, Michigan (Morin 2009; 2013), Colorado lacks such striking reminders of the industry. The only similar site in Colorado is the 365-foot brick smokestack of the Ohio-Colorado Smelting Company at Salida. The stack is listed on the National Register, but the plant only operated for an 18-year period before closing in 1920 and the local community of Salida has little interest in celebrating this part of its heritage. Other standing smelting structures are limited to a few buildings at Alma, and the smokestacks at Sts. John in Summit County, and one on Henson Creek near Lake City. None of these structures are well known.

The most obvious visual legacy of the early smelting era are the piles of slag generated by the works. Unlike the large smelters of Montana, however, the sites of Colorado smelters contain much less slag due to their short-lives, recycling for other functions, and environmental remediation. Although a few smelting sites such as the Arkansas Valley Smelter in Leadville and the Colorado Smelter in Pueblo retain significant mounds of slag, they are not generally viewed as a heritage resource. In Pueblo the Colorado Smelter slag deposit is so close to CF&I that even the local population generally assumes it is associated with the steel mill (which has miles of linear slag piles on its property), rather than with a lead smelter. The waste mound for the Pueblo Smelter is remediated and looks like an oddly shaped hill rather than an industrial feature when viewed by traffic on Interstate-25.

Although the waste deposits of the small mountain smelters do not dominate the landscape as they do in other smelting regions, they can be striking at a smaller scale. The dark, obsidian-like slag mounds strongly contrast with native soils, or the yellowish-sulfide rich soils that mark the locations of concentration and chemical mills. Normal mine and milling wastes are so ubiquitous in Colorado that many recent residents fail to recognize their origin. Smelter slag on the other hand is obviously artificial in origin and attracts attention.

Confrontation with a deposits of smelter slag in seemingly pristine areas often causes a moment of confusion and reflection as people are confronted with unexpected evidence of previous human interaction with environment (Hardesty 2001:66).When people encounter these deposits of toxic waste in idyllic forested areas in the mountains, it serves as a reminder that some sort of industry was practiced and that human industry and the natural environment have a complex history (Hardesty 2001; Quivik 2007). Such surprise encounters can spur a variety of reactions ranging from excitement of finding a hidden bit of history, to a deep-seated revulsion at the reminder of the environmental costs of human industry. In either case, the waste deposits have the potential to spur reflection on Colorado’s history that might not have otherwise happened.

These two views were brought sharply into view a few years ago during a conversation with an EPA project manager at Leadville. The manager was discussing previous remediation efforts in California Gulch, pointing out several large mine waste piles that had been recontoured and capped. She was still surprised at the strong criticism they had received from local residents who were upset that the EPA had so callously altered the landscape of their town. The manager was still uninterested in the historical value of the mining landscape but was taking greater care to match the original appearance of remediation sites in the future. Compromises between preservation and environmental remediation have been made in the past, notably at Anaconda, Montana where the EPA agreed to allow ground slag as sand traps on a golf course built to cap some of the tailings onsite (Morin 2009).

In an ideal world it would be possible to accommodate modern development and the preservation of our industrial heritage but increasing population expansion in Colorado makes this a difficult goal. The metal deposits that attracted Euro-Americans to Colorado were usually located in rugged, high-altitude areas. Although the beauty of these areas was not lost on historical populations, they were most concerned with the difficulties the terrain presented for transportation, work, and comfortable living. In recent years this same terrain has become a major draw due to their beauty and recreational potential. Many historical communities have experienced a dramatic increase in population in the last 20 to 30 years which has served to revive their economies but with significant negative effects on historical resources.

Rapidly rising cost of living has forced many of the original inhabitants of these communities out, breaking direct ties between the community and its history. Other than the restoration of downtown areas to a quaint approximation of their historical appearance, these communities bear little resemblance to their historical selves. As the communities continue to grow many historical buildings and historical archaeological sites are being destroyed.

6.3 Concluding Remarks

Colorado's gold and silver smelting industry sprang into existence in the late 1860s, experienced vigorous growth in the late 1870s, continued its output through the 1890s, then entering decline and had largely ended by the 1920s. The industry was to a large extent responsible for the economic development and settlement of Colorado. The industry allowed mines and their associated communities to develop in isolated mountain valleys throughout the state that would not have otherwise been settled. Although often maligned by the very miners they served, the smelting industry allowed the state to thrive. Depletion of local resources and changing economic and political forces at the national and international levels devalued silver, the main product of Colorado led to a decline in output of ores valued strictly for their precious metals. Mining in Colorado ultimately survived these changes but relegated precious metals to merely a byproduct of base metal production. Colorado smelting mirrored this trend, shifting to the processing of base metals aimed at industrial uses. The few smelters surviving into the mid-twentieth century (e.g. the Arkansas Valley and Globe smelters) no longer depended on the gold and silver content of the ores.

This document explored the rise and fall of the smelting industry, with an emphasis on the small smelters in the mountains. Like the iron industry of Pennsylvania (Heberling 2004:44), failure was the dominant pattern in the Colorado smelting industry and success was relatively rare. Ultimately, all the

Colorado smelters failed. The last, the Globe Smelter of Denver, closed in 2006, but had switched to the smelting of base metals decades before. Although most smelters had a short life span, and failed to produce a profit for their shareholders, they had a profound impact on the history of Colorado over the 150-year life of the industry. The small smelters served a key role in the development of the Colorado mining industry, and the history of the state. Although mostly failures in their own right, they were successful in providing a key market for local ores that stimulated the development of Colorado. As asserted by Gooday (1998), the definition of 'failure' itself fails to provide the interpretive flexibility to understand the process. Like most small business ventures only a tiny percentage could be considered traditional success stories. The impact of these small smelters had an importance extending beyond their profitability or growth. They were a critical component of Colorado's economy and shaped its present appearance.

The metals industry of Colorado also provides an excellent case study to view the development of entirely new industrial landscapes. Within a space of less than 20 years Colorado grew from a small and scattered population of Euro-Americans occupying a few trading posts to a population in the tens of thousands centered around industrial enterprises. The precious metals industry spurred the construction of railroads in terrain that was often considered utterly impractical for their construction. This led to a series of engineering accomplishments of the highest and steepest railways (Poor 1976:135). Many of the narrow-gauge routes of Colorado were considered engineering marvels in their day, and all were spurred by the bonanza in the mountains that was stimulated by the smelting industry.

Without the smelting industry most of the state’s mining districts would not have been sufficiently profitable to justify connection by rail, but the arrival of the railroad, while advantageous for the mining district, spelled the demise of local smelting operations. In a sense, the small local smelters required a very specific and transitory set of transportation conditions to survive. If they started to have success, smelters tended to create the conditions for their own decline. They existed as producers of an intermediate material (bullion or matte) that allowed the mines of a district to profitably sell ore and increase production. The increased production in turn increased the attractiveness of the district to outside business, encouraging the development of improved transportation routes. The drastically decreased costs of moving materials in and out of a district led to direct competition by local smelting firms with the larger smelters outside the district, competition they could not hope to best. The “sweet spot” occupied by local firms was inherently short-lived. Their role in the development of Colorado’s transportation network was an unintended consequence of their success that continues to this day. Most of the roads in Colorado’s mountains follow the routes of historical wagon roads or railroads that indirectly owed their existence to the smelting industry.

Colorado’s population has undergone tremendous growth in the last 30 years. The large smelters of the Front Range are destroyed or inaccessible for study leaving the small smelters of the mountains as the last examples of the industry. The rapid expansion of Colorado’s mountain communities during this time has been breath-taking with mountain towns like Aspen, Breckenridge, and Gunnison growing from sleepy communities to growing cities surrounded by ever expanding belts of homes and condominiums. Some communities, like Silverton, have survived largely intact to date, but the efforts of the inhabitants of that city to block the creation of a ski area near their town is probably doomed to failure. In another 20 or 30 years the town may become another Telluride and the smelting sites around the community will be destroyed.

Less than half of the 300 smelters estimated by the USGS to be built in Colorado were identified during this study, and many of those have likely been destroyed by urban development in the last few decades. Smelters always existed in smaller numbers than the better documented and studied mines and mills of Colorado. The preservation and excavation of at least a sample of these sites must be undertaken soon before more of them are destroyed. The information contained in these sites is irreplaceable and their important role in Colorado’s history should be emphasized in future historical interpretations of the mountain communities.

During the discussions in this document we have examined the technology and history of Colorado’s smelting industry. We have also attempted the first systematic examination of the state’s mountain smelters. Although a preliminary effort the information provides a body of data researchers can use in future studies on interrelationships between smelting and other facets Colorado’s archaeology and history including the development of mining districts, transportation networks, and other aspects of the state’s nineteenth century economy. It also highlights the importance of examining the phenomenon of failure in Colorado’s smelting and allied industries. Although the phenomenon has been examined in other fields as discussed in Chapter 5, insufficient attention has been paid to the process in historical and industrial archaeology in the state. Further study here could have implications for the study of the failure of industrial operations in other areas.

The Hall valley Smelter site demonstrates the rich archaeological potential of small smelting sites. Due to the short life of this class of smelter, it is possible to observe most, or all, of the components of the feature system of the operation. Due to little remodeling of small smelters information on the flow of materials through these sites remain mostly intact allowing for a reconstruction of the industrial process in a way not possible at larger sites.

The needs of the mining industry spurred developments in the related smelting industry, allowing both to flourish. Small smelting businesses spread across the state, usually poorly funded and poorly managed just like their related mining ventures. This has left a legacy of industry that both attracts and repels modern viewers. If properly interpreted the legacy of Colorado’s smelting industry has the potential to educate the public on historical topics involving engineering, metallurgy, commerce, western settlement, and the environmental consequences of metal production reinforcing the importance of industry to the development of the modern world.

7 Reference List

Abbott, Dan, Dell A. McCoy, and Robert W. McLeod

2007 *Colorado Central Rail Road – Golden, Central City, Georgetown.* Sundance Publications, Ltd., Denver.

Adkinson, H.

1908 Ore Contracts from a Producer's Point of View – How Ore Contracts Are Made. Treatment Charges. Benefit of Competition. Some Actual Examples and the Results Worked out. *Engineering and Mining Journal.* 85(20):992-996.

Agricola, Georgius

1950 *De Re Metallica.* Trans. Herbert C. Hoover, Lou H. Hoover. Dover Publications, Inc. New York

Anchuetz, Kurt F., Richard H. Wilshusen, and Cherie L. Scheick

2001 An Archaeology of Landscapes: Perspectives and Directions. *Journal of Archaeological Research.* 9(2):157-21.

Anonymous (Anon)

1886 Silver and Lead Smelting in Colorado. *Scientific American Supplement, No. 567.* November 13, 1886. P 9053-9054.

Athearn, Frederic J.

1992 *A Forgotten Kingdom: The Spanish Frontier in Colorado and New Mexico, 1540-1821.* Second edition. Colorado Bureau of Land Management.

Bailey, Lynn R.

2002 *Shaft Furnaces and Beehive Kilns – A History of Smelting in the Far West, 1863-1900*. Westernlore Press, Tucson.

Baker, J.R.

1975 HAER Inventory card for 5GL2005. June 29, 1975.

Baker, Steven G.

2000a Colorado OAHP site form for 5SA.556. Brown Eply Smelter. September 1999.

2000b Colorado OAHP site form for 5SA.566. Eclipse Smelter. August 1999.

Barabba, Vincent P.

1975a *Historical Statistics of the United States – Colonial Times to 1970, Bicentennial Edition.* Part I, U.S. Government Printing Office, Washington.

1975b *Historical Statistics of the United States – Colonial Times to 1970, Bicentennial Edition.* Part II, U.S. Government Printing Office, Washington.

Basalla, George

1988 *The Evolution of Technology.* Cambridge University Press, New York.

Beebe, Lucius, and Charles Clegg

1962 *Rio Grande – Mainline of the Rockies.* Howell-North, Berkley, CA.

Bell, Henry S.

1877 Notes – Metallurgical Campaign, Hall Valley, Colorado. *Engineering and Mining Journal*. Vol. 24:50

Blockley, D.I. and J. R. Henderson

1980 Structural Failures and the Growth of Engineering Knowledge. *Proceedings of the Institute of Civil Engineers.* 68(1):719-728.

Britton, Diane F.

1991 *The Iron and Steel Industry in the Far West. Irondale, Washington.* University Press of Colorado, Niwot.

Browne, J. Ross and James W. Taylor

1867 *Reports upon the Mineral Resources of the United States.* Government Printing Office, Washington.

Buckles, William G.

2006 *The Search for El Pueblo – Through Pueblo to El Pueblo, An Archaeological Summary.* Second edition. Colorado Historical Society.

Buena Vista Democrat (BVD) [Buena Vista, Colorado]

1883 “Tin Cup Notes” 15 March :1. Buena Vista, Colorado.

1883 Short news items 15 March:3. Buena Vista, Colorado.

1883 Notes on area mines and smelters. 26 April:1. Buena Vista, Colorado.

1883 “About the county and elsewhere” 23 August 1883:3. Buena Vista, Colorado.

1883 “State News” 13 September:1. Buena Vista, Colorado.

1884 “State News” 3 July:2. Buena Vista, Colorado.

1884 “Colorado Condensed” 6 November 1874:2. Buena Vista, Colorado.

1885 “Alpine and St. Elmo” 8 July:2. Buena Vista, Colorado.

1884 “Alpine Notes” 9 October:4. Buena Vista, Colorado.

1885 “Alpine and St. Elmo” 8 July:2. Buena Vista, Colorado.

1885 “Smelter at Buena Vista” 13 October:3. Buena Vista, Colorado.

1885 “Colorado Condensed” 6 May:1. Buena Vista, Colorado.

1885 “Colorado Condensed” 23 September:1. Buena Vista, Colorado.

1885 “Grant Smelter” 14 October:4. Buena Vista, Colorado.

1885 “Colorado Condensed” 21 October:1. Buena Vista, Colorado.

1885 “Colorado Condensed” 9 December:1. Buena Vista, Colorado.

1885 “Mining Notes” 9 December:4. Buena Vista, Colorado.

1886 “General Items” 10 February:2. Buena Vista, Colorado.

1886 “State News” 21 April:1. Buena Vista, Colorado.

1886 “State News” 6 October:1. Buena Vista, Colorado.

1886 “Mining Matters” 3 November:1. Buena Vista, Colorado.

1887 “Sheriff’s Sale” 28 April:3. Buena Vista, Colorado.

1887 “Mining Matters” 8 June:4. Buena Vista, Colorado.

1887 “Mining Matters” 30 June:1. Buena Vista, Colorado.

1887 “Mining Matters” 1 September:1. Buena Vista, Colorado.

1887 “Mining Matters” 6 October:1. Buena Vista, Colorado.

1887 “Mining Matters” 10 November:1. Buena Vista, Colorado.

1888 “Colorado Condensed” 19 January:1. Buena Vista, Colorado.

1888 “Colorado Condensed” 20 September:1. Buena Vista, Colorado.

Burt, Roger

2000 Innovation or Imitation? Technological Dependency in the American Nonferrous Mining Industry. *Technology and Culture*. 41(2):321-347.

Canby, R.C.

1913 Development of the American Water-jacket Lead Blast-Furnace. *Bulletin of the American Institute of Mining Engineers*. Vol 75., March.

Cappa, James A. and Paul J. Bartos

2007 *Geology and Mineral Resources of Lake County, Colorado.* Colorado Geological Survey, Division of Minerals and Geology, Department of Natural Resources, Denver, CO.

Castle Rock Journal (CRJ) [Castle Rock, Colorado]

1886 “The Holden Smelter” 26 May:4. Castle Rock, Colorado.

1886 “Colorado Condensed” 6 October:1. Castle Rock, Colorado.

Cecil, Morton S.

1952 *The Smelting Industry in Golden, Colorado.* Paper submitted to the Colorado Metallurgical Society Best Paper Contest March 15, 1952. In Denver Public Library Archives

Chadwick, Frederick

1881 Smelting Operations in the Tin Cup District, Gunnison County, Colorado. *Engineering and Mining Journal.* 31:75.

Chapin, Charles E.

2012 Origin of the Colorado Mineral Belt. *Geosphere*. 8(1):28-43

Cimino, Stephanie L.

2009 *Managing Change: Integrating Cultural Landscape Values and Industrial Heritage Preservation.* Unpublished Master’s Thesis. Interdisciplinary Studies Program, University of Oregon.

Colorado Daily Chieftain (CDC) [Pueblo, Colorado]

1873 “From Hardscrabble” 7 September:4. Pueblo, Colorado

1873 “Hardscrabble” 25 November:4. Pueblo, Colorado.

1873 Short news items. 27 November:4. Pueblo, Colorado.

1874 “Territorial News” 15 August:3. Pueblo, Colorado.

1874 “Rosita Items” 14 December:4. Pueblo, Colorado.

1875 “A Ruined Plaza. Mining and Smelting in Former Times” 14 February:4. Pueblo, Colorado.

1875 “Silverton” 8 September:4. Pueblo, Colorado.

1875 “Mining news from around the state” 24 September:4. Pueblo, Colorado.

1877 “Lake City Mining Notes” 26 January:4. Pueblo, Colorado.

1877 “City and Vicinity” 1 February:4. Pueblo, Colorado.

1877 “Animas Forks” 13 April:4. Pueblo, Colorado.

1877 “Rosita” 8 April:4. Pueblo, Colorado.

1877 “Eureka District” 20 April:4. Pueblo, Colorado.

1877 “Lake City” 31 May:4. Pueblo, Colorado.

1877 “A Big Strike in Burrows Park” 24 June:1. Pueblo, Colorado.

1877 “Miscellaneous” 13 July 1877:1. Pueblo, Colorado.

1877 “Lake City” 27 September:4. Pueblo, Colorado.

1877 “Ouray” 14 November:4. Pueblo, Colorado.

1878 “Col. Sellers in Colorado – Cheap Smelter” 7 February:2. Pueblo, Colorado.

1878 “Smelting Works – Another Business Enterprise for Pueblo” 8 June 1878. Pueblo, Colorado.

1878 “City and Vicinity” 24 August:4. Pueblo, Colorado.

1878 “City and Vicinity” 5 September:4. Pueblo, Colorado

1878 “Ula” 6 September:4. Pueblo, Colorado.

1878 “The Dollar of our Dads. Where the Silver Comes From” 12 September:4. Pueblo, Colorado.

1880 “Silver Cliff Items” 24 April:4. Pueblo, Colorado.

1882 “Lead Pipe Works. Pueblo Smelting and Refining Co. Starting up their Lead Pipe Works” 2 April:4. Pueblo, Colorado.

1882 “Disaster. Grant Smelter, at Leadville, Burned to the Ground” 26 May:1. Pueblo, Colorado.

1882 In a section of brief one sentence news notes. 30 June:4. Pueblo, Colorado.

1884 “Mine, Smelters and Mineral” 23 November:2. Pueblo, Colorado.

1887 “Home Happenings” 8 March:4. Pueblo, Colorado.

1888 “A New Smelter for Denver” 15 January:5. Pueblo, Colorado.

1888 “The Holden Smelter” 30 March:1. Pueblo, Colorado.

1888 “A Model Smelter”6 May:10. Pueblo, Colorado.

1888 “A Smelting Center” 6 May:14. Pueblo, Colorado

1888 “City of Durango – Something about the Metropolis of Southwestern Colorado” 9 May:4. Pueblo, Colorado.

1888 Untitled news briefs 27 November:2. Pueblo, Colorado.

1888 “The Philadelphia Smelter” 19 December:4. Pueblo, Colorado.

1889 “Pueblo an Ore Center” 27 February:10. Pueblo, Colorado.

1889 “Interesting Reading” 1 March:2. Pueblo, Colorado.

1889 “Town Topics” 2 March:3. Pueblo, Colorado.

1889 “Great is Pueblo” 26 November:6. Pueblo, Colorado.

1890 “A Great Smelter” 1 January:7. Pueblo, Colorado.

1890 “A Model Smelter” 1 January:5. Pueblo, Colorado.

1890 “Silver Bricks” 1 January:12. Pueblo, Colorado.

1890 “State Notes” 18 January:6. Pueblo, Colorado.

Colorado Iron Works (CIW)

1896 *Some Details as to Smelting Practice and Equipments for the Reduction of Gold, Silver, Lead, and Copper Ores.* Colorado Iron Works, Co., Denver.

Colorado Miner (CM) [Georgetown, Colorado]

1876 “Arapahoe County” 11 November:3. Georgetown, Colorado.

1878 “Smelting Works” 31 August:3. Georgetown, Colorado.

1879 “Kokomo – Items from the New Carbonate Metropolis” 7 June:3. Georgetown, Colorado.

1879 Short discussion on smelters. 21 June:3. Georgetown, Colorado.

1879 Local news items. 5 July:3. Georgetown, Colorado.

1879 “Kokomo – The Mining Metropolis of Summit. Past, Present, Prospective.” 19 July: 2. Georgetown, Colorado.

1879 “Our Mining Interests – Geneva Consolidated Silver Mining and Smelting Company”. 16 August:3. Georgetown, Colorado.

1879 “Kokomo – Items from the Ten Mile Metropolis” 23 August:3. Georgetown, Colorado.

1879 “Decatur” 30 August 1879:3. Georgetown, Colorado.

1879 “Carbonates – The Mines About Kokomo – The Kokomo Smelter” 22 November:2. Georgetown, Colorado.

1879 “Ten Mile Notes” 29 November:3. Georgetown, Colorado.

1880 “Breckenridge Letter” 17 January:1. Georgetown, Colorado

1880 Brief description of works ongoing at Canon City Smelter. 21 February:2.

1880 Brief discussion of mining throughout state. 6 March 1880:32. Georgetown, Colorado

1880 Brief discussion of mining throughout state. 20 March 1880:3

1880 “Decatur and Chihuahua” 17 April 1880:3.

1880 “Breckinridge’s Great Boom” 28 May:1. Georgetown, Colorado.

1880 “Montezuma” 10 July:3. Georgetown, Colorado.

1880 “Convinced at First Site” 11 September:3. Georgetown, Colorado.

1880 “Mining News – The Robinson Smelter” 13 November 1880:1.

Colorado Springs Gazette (CSG) [Colorado Springs, Colorado]

1875 “Mining Notes” 25 September 1875:2. Colorado Springs, Colorado.

1877 “Round the State” 8 December 1877:4. Colorado Springs, Colorado.

1878 “From San Juan” 6 July 1878:3. Colorado Springs, Colorado.

1878 “From San Juan” 31 August 1878:2. Colorado Springs, Colorado.

Comstock, Theodore B.

1881 The Causes of Past Failures in the San Juan Country. *Engineering and Mining Journal.* 32:284.

Cone, N.H.

1876 Bruckner Cylinders. *The Engineering and Mining Journal*. XXI:321.

Cowie, Sarah E.

2011 *The Plurality of Power: An Archaeology of Industrial Capitalism.* Springer, New York.

Croll, H.V.

1898 Silver Lead Blast Furnace Construction. *The Engineering and Mining Journal*. May 28. Pp 639.

Cushman, Samuel

1876 *The Mines of Clear Creek County, Colorado*. Times Steam Printing House, Denver.

Dannreuther, Charles and Lew Perren

2013 *The Political Economy of the Small Firm*. Routledge, Oxfordshire.

Delta Chief (DC) [Delta, Colorado]

1885 “State News” 23 September 1885:2. Delta, Colorado.

Dolores News (DN) [Rico, Colorado]

1881 “Local Intelligence” 30 July:3. Rico, Colorado

1884 “Smelter Closed Down” 8 March:2. Rico, Colorado

1885 “Mining News – The Mid-Winter Run of the Pasadena Smelter and it’s Great Success” 17 January:2. Rico, Colorado.

1885 “Mining Matters” 11 July:2. Rico, Colorado.

Douglas, James

1895 *Cantor Lectures on Recent American Methods and Appliances Employed in the Metallurgy of Copper, Lead, Gold, and Silver.* Will Trounce, London.

Dwight, Arthur S.

1906a Modern Silver-Lead Smelting. In *Lead Smelting and Refining with some notes on Lead Mining.* Pp.73-80. Ed. Walter R. Ingalls. Engineering and Mining Journal, New York.

1906b Mechanical Feeding of Silver-Lead Blast Furnaces. In *Lead Smelting and Refining with some notes on Lead Mining.* Pp.81-95. Ed. Walter R. Ingalls. Engineering and Mining Journal, New York.

Egleston, T.

1877 *The Boston and Colorado Smelting Works.* Sherman & Co., Printers, Philadelphia.

Eilers, A.

1874 Avoidable Waste at American Lead Smelting Works. *Engineering and Mining Journal.* 18:98-99.

1875 Progress of the Silver-Lead Metallurgy of the West during 1874. *Engineering and Mining Journal.* 19:25.

1881 Metallurgy at Leadville. *The Engineering and Mining Journal.* April 9. Pp246-247.

Eissler, M.

1891 *The Metallurgy of Argentiferous Lead – A Practical Treatise on the Smelting of Silver-lead Ores and the Refining of Lead Bullion.* Crosby Lockwood and Son, London.

Emmons, Samuel F.

1886 *Geology and Mining Industry of Leadville.* Monographs of the United States Geological Survey, Volume XII.

1896 *The Mines of Custer County, Colorado.* USGS 17th Annual Report, Part 2. US Government Printing Office, Washington.

Engineering and Mining Journal (EMJ)

1876a Mining Notes – The Hall Valley Smelting Works. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.22:45.

1876b Mining Notes from Colorado, Missouri, Montana, Nevada, and North Carolina. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.22:77.

1876c Lake County, Colorado. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.21:176.

1876d Mining Notes from Colorado and Utah. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.21:517.

1877a The Metallurgical Works of Colorado. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol. 23:221.

1877b The Metallurgical Works of Colorado. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol. 23:221

1877c Mining News – Colorado – Silverton Smelting Works, Silverton, San Juan County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol. 23:439

1877d The Lead Mines at Oro City, Colorado. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol. 23:352.

1878a Mining News – Colorado – Park County – Hall Valley Company. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.25:240.

1878b Leadville, Colorado's Latest Excitement. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol. 25:279, 293.

1878c Notes – Mining News Colorado – Summit County *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol. 26:190.

1878d Mining News – Colorado – Miscellaneous. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol. 24:154.

1878e Mining News – Colorado. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol. 24:172

1880a General Mining News – Colorado – Park County. Duquesne Smelting Works. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.29:105.

1880b Bullion. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.26:264.

1880c General Mining News – Colorado – Custer County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.29:324.

1880d General Mining News – Colorado – Jefferson County *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.29:258.

1880e General Mining News – Colorado – General Notes. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.29:154.

1880f General Mining News – Colorado – Custer County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.30:190.

1880g General Mining News – Colorado – Summit County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.30:319.

1881a General Mining News – Colorado – Park County. List of smelters in operation. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol. 32:435.

1881b Durango – the New San Juan Metropolis. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.32:34.

1881c General Mining News – Colorado – Summit County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.31:165.

1881d General Mining News – Colorado – Summit County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.31:97.

1881e The La Plata Mining and Smelting Company. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.31:318.

1881f The San Juan Region, Colorado. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.32:136.

1881g General Mining News – Colorado – Park County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.32:435.

1882a General Mining News – Colorado – Park County – Hall Valley. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.34:208.

1882b General Mining News – Colorado – San Juan County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.33:8.

1882c General Mining News – Colorado – San Juan Country. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.34:177.

1882d General Mining News – Colorado – San Juan Country. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.34:351.

1882e General Mining News – Colorado – San Juan Country. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.34:280.

1882f General Mining News – Colorado – Summit County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.34:190.

1882g General Mining News – Colorado - San Juan County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.34:299.

1882h General Mining News – Colorado – San Juan Region. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.34:137-138.

1882i General Mining News – Colorado – Pueblo County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.34:164.

1882j General Mining News – Colorado – Pitkin County *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.34:259.

1883a General Mining News – Colorado – Chaffee County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.35:47

1883b Denver as a Distributing and Manufacturing Center. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.35:259.

1883c General Mining News – Colorado – Dolores County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.35:54.

1883d Front matter of issue. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.35:61.

1884a General Mining News – Colorado – La Plata County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.37:392-393.

1884b General Mining News – Colorado – Clear Creek County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.37:48.

1884c General Mining News – Colorado – Pueblo County – New England and Colorado Mining and Smelting Company. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.37:89.

1884d General Mining News – Colorado – Arapaho County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.37:109.

1884e General Mining News – Colorado. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.37:109.

1884f General Mining News – Colorado – Gunnison County *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.37:448.

1884g General Mining News – Colorado – Summit County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.38:78.

1884h General Mining News – Colorado – Dolores County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.38:179.

1884i General Mining News – Colorado – Gunnison County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.38:235.

1884j General Mining News – Colorado – Summit County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.358:432.

1885a General Mining News – Colorado – La Plata County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.40:221.

1885b General Mining News – Colorado – Lake County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.40:294.

1885c General Mining News – Colorado – Lake County - Grant Smelter. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.40:244.

1885d General Mining News – Colorado – Clear Creek County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.40:262.

1885e General Mining News – Colorado – Hinsdale County. *Engineering and Mining Journal.* Scientific Publishing Co., NY Vol.40:343.

1893 The General Arrangements of a Lead Smelting Plant. *Engineering and Mining Journal* IV. Jan – June 1893. Scientific Publishing Co, NY. Pp246.

1911 Editorial Correspondence – Denver. *Engineering and Mining Journal* Vol. 92. Scientific Publishing Co., NY. Pp656

Ensign, Edgar T.

1888 *Biennial Report of the Forest Commissioner of the State of Colorado for the years 1887 and 1888*. Collier & Cleveland Lithographic Company, State Printers, Denver.

Environmental Protection Agency (EPA)

2019 *Superfund Site: California Gulch Leadville, CO.* Electronic document, accessed 10/10/2019. https://cumulis.epa.gov/supercpad/siteprofiles/index.cfm?fuseaction=second.Cleanup&id=081478bkground

Evans, John

1878 Letter to Edward Harrison, 4 July. Manuscript, Edwin Harrison Collection, Colorado State Historical Society, Denver.

Fairplay Flume (FF) [Fairplay, Colorado]

1879 “Personal” 14 August:2. Fairplay, Colorado.

1879 “The East Leadville Smelter” 4 September:3. Fairplay, Colorado.

1879 “The Horseshoe Works” 25 September:3. Fairplay, Colorado.

1879 “Starting the Works – The East Leadviille Smelter” 4 September:3. Fairplay, Colorado.

1879 “The New Smelter” 18 September:3. Fairplay, Colorado

1879 List of local news items 16 October:3. Fairplay, Colorado.

1880 List of local news items. 29 January:3. Fairplay, Colorado.

1880 “A Perfect Success – Starting of the Duquesne Smelting Works” 5 February:3. Fairplay, Colorado.

1880 List of local news items. 15 April:3. Fairplay, Colorado.

1880 “Horseshoe Happenings” 15 April:3. Fairplay, Colorado.

1880 “The Holland Smelter” 20 May:3. Fairplay, Colorado.

1880 “Horseshoe Gulch” 22 July:2. Fairplay, Colorado.

1880 List of local news items. 5 August:2. Fairplay, Colorado

1880 List of local news items. 2 September:3. Fairplay, Colorado.

1880 List of local news items. 16 September:3. Fairplay, Colorado.

1880 List of local news items. 4 November:3. Fairplay, Colorado.

1881 “Firing up a Smelter” 7 April:2. Fairplay, Colorado.

1885 “Colorado Condensed” 24 September 1885:2. Fairplay, Colorado.

Fell, James E. Jr.

2009 *Ores to Metals: The Rocky Mountain Smelting Industry.* University Press of Colorado, Boulder.

Fell, James E. Jr. and Eric Twitty

2008 *National Register of Historic Places Multiple Property Documentation Form: The Mining Industry in Colorado*. Colorado Office of Archaeology and Historic Preservation, Denver.

Francaviglia, Richard V.

1991 *Hard Places: Reading the Landscape of America's Historic Mining Districts*. University of Iowa Press, Iowa City.

Frost, O.J.

1883 The Grant Smelting Works. *Engineering and Mining Journal.* 35:163.

Fry, Eleanor

2000 *Smelters of Pueblo.* Pueblo County Historical Society.

Gardner, Hugh

1985 Colorado OAHP site form for 5PA299. Duquesne Smelter. September 1985.

Georgetown Courier (GC) [Georgetown, Colorado]

1879 "The Revenue Mineral Company" 8 May:3. Georgetown, Colorado.

1879 "Kokomo" 5 June:3. Georgetown, Colorado.

1879 "Kokomo! – Local News" 12 June:3. Georgetown, Colorado.

1879 Local news items. 6 November:3. Georgetown, Colorado.

1879 "Kokomo Letter" 13 November:2. Georgetown, Colorado

1880 Brief discussion of smelting in Crested Butte district. 22 January:3. Georgetown, Colorado.

1880 “Kokomo Items” 26 February:3. Georgetown, Colorado.

1880 Brief article on Chihuahua and Montezuma. 22 April:4. Georgetown, Colorado.

1880 Brief discussion of Mayville Area. 17 June:1. Georgetown, Colorado.

1880 “Condensed Mining News” 1 July:1. Georgetown, Colorado.

1880 “Breckenridge” 8 July:3. Georgetown, Colorado.

1880 “Breckenridge” 8 July:8. Georgetown, Colorado.

1880 “Condensed Mining News” 9 September:1. Georgetown, Colorado.

1880 “A Letter from Mr. A. J. Randall, Maysville, July 31.” 5 August:3. Georgetown, Colorado.

1880 “Chaffee County” 25 November:1. Georgetown, Colorado.

1880 Short description of local business. 2 December:1

1880 “Peru District” 17 March:3. Georgetown, Colorado

Gignoux, Charles C.

1877 Metallurgical Campaign at Hall Valley, Colorado – Give Credit to Whom Credit is Due. *Engineering and Mining Journal*. Vol.24:147.

Gooday, Graeme

1998 Re-writing the ‘book of blots’: Critical reflections on histories of technological ‘failure’ *History and Technology, an International Journal.* 14(4):265-291.

Gordon, Robert B. and Patrick M. Malone

1994 *The Texture of Industry – An Archaeological View of the Industrialization of North America.* Oxford University Press, New York.

Grabill, Clarence A.

1908 Ore Contracts from the Smelter’s Standpoint. *Engineering and Mining Journal.* 86:73-77.

Griswold, Don L. and Jean Harvey Griswold

1996 *History of Leadville and Lake County, Colorado – From Mountain Solitude to Metropolis*. Volume 1 and 2. Colorado Historical Society. Johnson Printing Company, Boulder.

Hall, Frank

1895 *History of the State of Colorado Embracing Accounts of the Pre-Historic Races and their Remains; The Earliest Spanish, French, and American Explorations; the Lives of the Primitive Hunters, Trappers and Traders; the Commerce of the Prairies; the First American Settlements Founded; the Original Discoveries of Gold in the Rocky Mountains; the Development of Cities and Towns, with the Various Phases of Industrial and Political Transition, from 1858 to 1890*. In Four Volumes. Volume IV. Blakely Printing Company, Chicago.

Hardesty, Donald

1985 Chapter 9 Evolution on the Industrial Frontier. *The Archaeology of Frontiers and Boundaries.* Academic Press, Inc. Cambridge.

1990 Evaluating Site Significance in Historical Mining Districts. *Historical Archaeology.* 24(2):42-51.

1999 Archaeological Models of the Modern World in the Great Basin: World Systems and Beyond. *Models for the Millennium Great Basin Anthropology Today.* University of Utah Press, Salt Lake City.

2000 Speaking in Tongues: The Multiple Voices of Fieldwork in Industrial Archeology. *IA: The Journal of the Society for Industrial Archeology* 26(2):43-47.

2001 Issues in Preserving Toxic Wastes as Heritage Sites. *The Public Historian.* 23(2):19-28.

2006 Industrial Archaeology, Landscapes, and Historical Knowledge of Sustainability. *USDA Forest Service Proceedings RMRS-P-42CD.* Monitoring Science and Technology Symposium: Unifying Knowledge for Sustainability in the Western Hemisphere Proceedings.

2007 Perspectives on Global-Change Archaeology. *American Anthropologist* 109(1):1-7.

2010 *Mining Archaeology in the American West – A View from the Silver State.* University of Nebraska, Lincoln.

Hardesty, Donald and Eugene M. Hattori

1982 *Archaeological Studies in the Cortez Mining District 1981.* BLM, Nevada Technical Report No. 8 and No. 9.

Hay, Albert H.

1920 *A Glossary of the Mining and Mineral Industry.* Department of the Interior Bulletin 95. Government Printing Office, Washington.

Hayes, Maurice

1876 Lake County, Colorado, Mining Notes. *Engineering and Mining Journal.* 22:423.

Heberling, Scott D.

2017 An Archaeology of Failure: An Example from the Juniata Iron District of Pennsylvania *IA: The Journal of the Society for Industrial Archeology*. 41(1&2):25-48.

Henderson, Charles W.

1926 *Mining in Colorado: A History of Discovery, Development and Production.* U.S.G.S. Professional Paper 138. Government Printing Office, Washington.

Hixon, Hiram W.

1905 The Evolution of Tap Jackets and Spouts. *Engineering and Mining Journal* Vol. 79:673.

1908 *Notes on Lead and Copper Smelting and Copper Converting.* Fourth Edition. Hill Publishing Company, New York.

Hoffman, Karen S.

2002 "Going Public" in the Nineteenth Century: Grover Cleveland's Repeal of the Sherman Silver Purchase Act. *Rhetoric and Public Affairs.* 5(1):57-77.

Hofman, H.O.

1893 *The Metallurgy of Lead and the Desilverization of Base Bullion.* Third edition. The Scientific Publishing Company, New York.

1918 *Metallurgy of Lead.* First edition. McGraw-Hill Book Company, Inc. New York.

Hollister, Orvando

1867 *The Mines of Colorado.* Samuel Bowles & Co., Springfield, Massachusetts.

Howe, Henry M.

1885 *Copper Smelting.* United States Geological Survey. Government Printing Office, Washington.

Iles, Malvern W.

1902 *Lead-Smelting. The Construction, Equipment, and Operation of Lead Blast-Furnaces and Observations on the Influence of Metallic Elements on Slags and the Scientific Handling of Smoke*. John Wiley & Sons, New York.

1906 Cost of Smelting and Refining. In *Lead Smelting and Refining with some notes on Lead Mining.* Pp. 96-103. Ed. Walter R. Ingalls. Engineering and Mining Journal, New York.

International Textbook Company (ITC)

1909 *A Textbook on Metallurgy of Gold, Silver, Copper, Lead and Zinc*. International Textbook Company, Scranton.

Jernegan, M.E.

1875 The Whale Lode, of Park County, Colorado Territory. *Engineering and Mining Journal* Vol. 19: 246.

1877 Notes on a Metallurgical Campaign at Hall Valley, Colorado. *Transactions of the American Institute of Mining Engineers.* Volume V, May 1876-February 1877.

Kelley, Robert L.

1954 Forgotten Giant: The Hydraulic Gold Mining Industry in California. *Pacific Historical Review.* 23(4):343-356.

1956 The Mining Debris Controversy in the Sacramento Valley. *Pacific Historical Review.* 25(4):331-346.

Kent, L.A.

1880 *Leadville, the City, Mines and Bullion Product. Personal Histories of Prominent Citizens. Facts and Figures Never Before Given to the Public.* Daily Times Steam Printing Company and Blank Book Manufactory, Denver.

King, Joseph E.

1984 *Colorado Engineering Context.* Office of Archaeology and Historic Preservation, Colorado Historical Society, Denver.

King, Thomas F.

2004 *Cultural Resource Laws and Practice.* Second Edition. Alta Mira Press, New York.

Knight, Samuel

1898 Federal Control of Hydraulic Mining. *The Yale Law Journal.* 7(9):385-392.

Knott, Anne Marie and Hart E. Posen

2005 Is Failure Good? *Strategic Management Journal*. 26:617-641.

Lakes, Arthur

1906 *Prospecting for Gold and Silver in North America*. Third edition. International Textbook Company, Scranton.

Landon, David, Patrick Martin, Andrew Sewell, Paul White, Timothy Tumberg, and Jason Menard

2001 "…A Monument to Misguided Enterprise": The Carp River Bloomery Iron Forge. *IA. The Journal of the Society for Industrial Archeology.* 27(2):5-22.

Landon, David B. and Timothy A. Tumberg

1996 Archeological Perspectives on the Diffusion of Technology: An Example from the Ohio Trap Rock Mine Site. *IA. The Jounral of the Society for Industrial Archeology.* 22(2):40-57.

Lang, Herbert

1896 *Matte Smelting Its Principles and Later Developments Discussed with an Account of the Pyritic Process.* The Scientific Publishing Company, New York.

Lawrence, Susan, Peter Davies and Jodi Turnbull

2016 The Archaeology of Water on the Victorian Goldfields. *International Journal of Historical Archaeology* 2017(21):49-65.

Leadville Daily Chronicle (LDC) [Leadville, Colorado]

1879 "Another Smelter Started" 16 May:3. Leadville, Colorado.

1879 "The Smelters" 30 May:2. Leadville, Colorado.

1879 "Kokomo" 7 July:1. Leadville, Colorado.

Leadville Daily Herald (LDH) [Leadville, Colorado]

1882 "The Mines – The Building of the Grant Smelter at Denver Begins" 29 June:3. Leadville, Colorado.

LeMassena, Robert A.

1974 *Rio Grande… to the Pacific.* Sundance Publications, Ltd. Denver.

Lovering, T.S.

1935 *Geology and Ore Deposits of the Montezuma Quadrangle, Colorado.* USGS Professional Paper No. 178. Government Printing Office, Washington.

1950 *Geology and Ore Deposits of the Front Range, Colorado.* USGS Professional Paper No. 223. Government Printing Office, Washington.

Martin, Patrick

1990 Mining on Minong: Copper Mining on Isle Royale. *Michigan History*. 74 (3):19-25.

McManamon, Frank, John Doershuk, William Lipe, Tom McCulloch, Chris Polglase, Sarah Schlanger, Lynn Sebastian, and Lynne Sullivan

2016 Using Values to Manage Archaeological Resources at a Landscape Scale. *Advances in Archaeological Practice.* 4(2):132-148.

Meade, Edward S.

1899 The Present Production of Silver and Its Probable Future. *The Annals of the American Academy of Political and Social Science.* November.

Metz, Randel

2014 *World's Tallest Smokestack Comes Tumbling Down.* Electronic document accessed 11/29/2019. https://history.denverlibrary.org/news/worlds-tallest-smokestack-comes-tumbling-down

Meyerriecks, Will

2003 *Drills and Mills, Precious Metal Mining and Milling Methods of the Frontier West*. Second Edition. Self-Published.

Mitick, Ellsworth C.

1947 *The Development of Mining Machinery Manufacture in Colorado.* Thesis presented to the University of Denver.

Morin, Bode

2009 *Reflection, refraction, and rejection: copper smelting heritage and the execution of environmental policy*. Unpublished doctoral dissertation. Department of Social Sciences, Michigan Technological University.

2013 *The Legacy of American Copper Smelting – Industrial Heritage versus Environmental Policy*. University of Tennessee Press, Knoxville.

Mountain Mail (MM) [Salida, Colorado]

1880 “Referring to Shavano” 23 October:3. Salida, Colorado.

1880 “Our Kirber Camp Letter” 30 October:1. Salida, Colorado.

1880 “Maysville Locals” 20 November:1. Salida, Colorado.

1880 List of short state news stories 18 December:1. Salida, Colorado.

1880 Discussion of local mining news. 29 December:3. Salida, Colorado.

1880 “About Rosita” 30 December:1. Salida, Colorado.

1881 “Smelter” 1 January:2. Salida, Colorado.

1881 “Maysville Nuggets” 26 March 1881:3. Salida, Colorado.

1881 “Junctionalities” 27 August 1881:3

1882 Discussion of Bonanza district 21 January:3

1882 Short article on Neely Smelter. 17 June:1. Salida, Colorado.

1882 “Local News” 8 July:2. Salida, Colorado

Mrozowski, Stephen A.

2006 Chapter 2. Environments of History: Biological Dimensions of Historical Archaeology. *Historical Archaeology*. Ed. Martin Hall and Stephen W. Silliman. Blackwell Publishing, Carlton.

Munroe, E.M.

1881 On the Weight, Fall, and Speed of Stamps. *Transactions of the American Institute of Mining, Metallurgical, and Petroleum Engineers*. IX:89-99.

National Park Service (NPS)

1997a *How to Apply the Register Criteria for Evaluation.* National Park Service. Bulletin 15

1997b *Guidelines for Identifying, Evaluating, and Registering Historic Mining Properties.* National Park Service. Bulletin 42.

2000 *Guidelines for Evaluating and Registering Archeological Properties.* National Park Service. Bulletin 36.

Nightingale, Paul, and Alex Coad

2013 Muppets and gazelles: political and methodological biases in entrepreneurship research. *Industrial and Corporate Change.* 23(1):113-143.

Olson, James and Susan Wladaver-Moran

1992 *Dictionary of United States Economic History*. Greenwood Press, Westport.

Pacific Coast Miner (PCM)

1905 McClelland Tunnel. *Pacific Coast Miner.* 7(12):215

Patrick, W.B.

n.d. *Report on the Globe Smelter*. ASARCO corporation.

Peters, Edward Dyer

1874 The Mount Lincoln Smelting Works, At Dudley, Colorado. *Transactions of the American Institute of Mining, Metallurgical and Petroleum Engineers*. 2:310-314.

1895 *Modern Copper Smelting. Seventh Edition*. The Scientific Publishing Company, New York.

Petroski, Henry

1992a *To Engineer is Human – The Role of Failure in Successful Design.* Vintage Books, New York.

1992b History and Failure. *American Scientist*. 80(6):523-526.

1994 *Design Paradigms: Case Histories of Error and Judgement in Engineering.* Cambridge University Press, Cambridge.

Pfaffenberger, Bryan

1990 The Harsh Facts of Hydraulics: Technology and Society in Sri Lanka's Colonization Schemes. *Technology and Culture.* 31(3):361-397.

1998 Mining communities, chaines operatoires, and sociotechnical systems. In *Social Approaches to an Industrial Past: The Archaeology and Anthropology of Mining,* edited by Bernard Knapp, Vincent Pigott and Eugenia Herbert. Routledge, New York.

Poor, M.C.

1976 *Denver South Park & Pacific.* Memorial Edition, Rocky Mountain Railroad Club, Denver.

Quite So

1875 Silverton Items. *Colorado Springs Gazette* 10 July 1875:2. Colorado Springs, Colorado.

Quivik, Frederic L.

2000 Landscapes as Industrial Artifacts: Lessons from Environmental History. *IA: The Journal of the Society for Industrial Archeology*. 26(2):55-64.

2007 The Historical Significance of Tailings and Slag: Industrial Waste as Cultural Resource. *IA: The Journal of the Society for Industrial Archeology* 33(2):35-52.

Rannie, Al

1985 Small firms, big problems: the political economy of small business. *Capital and Class*. 9(1):140-168

Raymond, Rossiter W.

1870 *Statistics of Mines and Mining in the States and Territories West of the Rocky Mountains for 1869*. Government Document No. 207. Government Printing Office, Washington.

1881 *A Glossary of Mining and Metallurgical Terms.* American Institute of Mining Engineers, Easton, PA.

Reno, Ronald L.

1996 *Fuel for the Frontier: Industrial Archaeology of Charcoal Production in the Eureka Mining District, Nevada 1869-1891*. Unpublished doctoral dissertation, University of Nevada Reno.

Richards, Joseph W.

1897 The Cyanide Process for the Treatment of Gold Ores. *Early Publications of the Lehigh Faculty.* Paper 123.

Richards, Robert H.

1909 *A Textbook of Ore Dressing.* McGraw-Hill Book Company, New York.

Rickard, T.A.

1896 Gold Mining Activity in Colorado. *The North American Review.* Volume 162 (473). Pp 473-480.

Robertson, Donald B.

1991 *Encyclopedia of Western Railroad History: The Mountain States, Colorado, Idaho, Montana, Wyoming.* University of Michigan, Ann Arbor.

Rocky Mountain News (RMN) [Denver, Colorado]

1867 “Georgetown – Mines, Furnaces, Improvements, Prospecting, etc., etc.” 14 May:1. Denver, Colorado.

1867 “Daily News” 2 August:4. Denver, Colorado.

Rocky Mountain Sun (RMS) [Aspen, Colorado]

1882 “Water Jacket Furnaces” 15 July:4. Aspen, Colorado.

Ronzio, Dick

1966 Colorado Smelting and Reduction Works. *The Denver Westerners Monthly Roundup.* April. XXII (4).

Rosenberg, Robert D.

1976 Colorado OAHP site form for site 5PA340. Alma Smelter. November 1, 1976.

1977a Colorado OAHP site form for site 5BL9700. Ward Smelter. May 24, 1977.

1977b Colorado OAHP site form for site 5PA317. Geneva Smelter. October 19, 1977,

1977c Colorado OAHP site form for site 5PA313. Hall Valley Smelter. October 20, 1977/

Safford, Jeffrey J.

2004 *The Mechanics of Optimism: Mining Companies, Technology, and the Hot Spring Gold Rush, Montana Territory 1864-1868.* Mining the American West Series. University Press of Colorado, Boulder.

Saguache Chronicle (SaC) [Saguache, Colorado]

1880 “Christonie Camp” 8 October:4. Saguache, Colorado.

Salida Mail (SM) [Salida, Colorado]

1874 “State and General” 2 February:4. Salida, Colorado.

1884 Discussion of local mining news. 2 February:4. Salida, Colorado.

1884 “State and General” 17 May:1. Salida, Colorado.

1884 “State and General” 17 May:3. Salida, Colorado.

1884 Discussion of mining and smelting fees. 24 May:3. Salida, Colorado.

1884 “State and General” 7 June:1. Salida, Colorado

1884 Discussion of mining in county. 28 June:4. Salida, Colorado.

1884 “San Miguel County” 12 July:2. Salida, Colorado.

1884 “State and General” 26 July:3. Salida, Colorado.

1885 “Mines and Mining” 7 March:2. Salida, Colorado.

1885 “A Mountain Trip” 10 July:4. Salida, Colorado.

1885 “Alpine Notes” 3 July:5. Salida, Colorado.

1885 “Domestic Gleanings” 21 March:1. Salida, Colorado.

1886 Discussion of local mining news. 10 September:1. Salida, Colorado.

1887 “The Smelter at Buena Vista” 14 January 1887:7. Salida, Colorado.

1887 “In and Out of Chaffee” 18 February:7. Salida, Colorado.

San Juan & New York

1880 *Report on the Silverton Reduction Works and Hazelton Group of Mines.* San Juan and New York Mining and Smelting Company. Denver Public Library, Western History Collection.

Schnabel, Carl

1898 *Handbook of Metallurgy, Vol. I.* Trans. Henry Louis. McMillan and Co., Ltd. London.

Scott, Glenn R.

1999 *Historic Trail Map of the Denver 1° by 2° Quadrangle, Central Colorado.* Geological Investigations Series I-2639. United States Geological Survey.

2004 *Historic Trail Map of the Leadville 1° by 2° Quadrangle, Central Colorado.* Scientific Investigations Map 2820. United States Geological Survey.

Sebastian, Lynne

2009 Deciding What Matters: Archaeology, Eligibility, and Significance. In *Archaeology and Cultural Resource Management, Visions for the Future,* edited by Lynne Sebastian and William Lipe, pp. 91-114. School for Advanced Research Press, Santa Fe.

Sheedy, Dennis

1923 Untitled autobiography presented to Denver Public Library January 17, 1923. Denver Public Library, Western History Section.

Shirts, Morris A. and Kathryn H. Shirts

2001 *A Trial Furnace – Southern Utah's Iron Mission*. Bringham Young University Press, Provo.

Silver Cliff Ruster (SCR) [Silver Cliff, Colorado]

1892 "News of the Mines" 30 March:2. Silver Cliff, Colorado.

Silverton Standard (SiS) [Silverton, Colorado]

1893 Brief article discussing Trinidad smelter. 23 December:3. Silverton, Colorado.

Simmons, Virginia McConnell

1992 *Bayou Salado – The Story of South Park*. Revised Edition. Virginia McConnell Simmons.

Smith, Duane

1984a Decade of Frustration: Colorado and California Silver Mining in the 1860s. *Southern California Quarterly.* 56(2):135-158. Summer. University of California for the Historical Society of Southern California.

1984b Colorado OAHP site form for site 5LP1479. Durango Smelter. June 10, 1984.

1988 San Juan and New York Mining and Smelting Company, Smelter Stack on State Route 160 Durango, La Plata County, Colorado. HAER No. Co-38

1992 *Rocky Mountain West – Colorado, Wyoming, and Montana 1859-1915*. University of New Mexico Press, Albuquerque.

2000 *The Song of the Hammer and Drill: The Colorado San Juans*, 1860-1914. University Press of Colorado, Boulder.

2009 *The Trail of Gold and Silver – Mining in Colorado, 1859-2009*. University Press of Colorado, Boulder.

Solid Muldoon Weekly (SMW0 [Ouray, Colorado]

1880 “Brief article about new smelter being built in Ouray” 24 September:3. Ouray, Colorado.

1883 “The Ruling Passion” 1 June:1. Ouray, Colorado.

1888 “Mines and Mining” 23 March:3. Ouray, Colorado.

Spude, Robert L.

2003 The Ingenious Community: Georgetown, Colorado, and the Evolution of Western American Silver Milling and Metallurgy, 1864-1896. *Mining History Journal.* Pp110-132.

Stöllner, Thomas R.

2014 Chapter 7 Methods of Mining Archaeology (Montanarchäologie) *Archaeometallurgy in Global Perspective.* Ed. B.W. Roberts, C.P. Thornton. Springer Science+Business Media, New York.

Stone, Wilbur Fisk

1918 *History of Colorado.* Volume I. S.J. Clarke Publishing Company.

Storm, Anna

2008 *Hope and Rust – Reinterpreting the industrial place in the late 20th Century.* Stockholm Papers in the History and Philosophy of Technology, Royal Institute of Technology, Stockholm.

Sullenberger, M.

1979 Colorado OAHP site form for site 5GN1510. October 8, 1979.

Tate, Jeffrey

2019 Employee of EVRAZ Rocky Mountain Steel. Personal communication.

Thomas, Carson

1999 *Gale Encyclopedia of U.S. Economic History*. Gale Group, Detroit.

Thrush, Paul W. and the Staff of the Bureau of Mines

1968 *A Dictionary of mining, mineral, and related terms.* United States Department of the Interior. Maclean Hunter Publishing Company, Chicago.

Tonge, Thomas

1900 The Fourth Era of the Leadville Mining District. *Engineering Magazine* XIX April to September 1900. Pp 809 – 824. New York

Turnbull, J.M.

1916 Relations Between Custom Smelters and Small Mine Owners. *Mining and Engineering World.* 45(1):47-49.

Twitty, Eric

2014 *Historic Context Interstate-70 Mountain Corridor.* Mountain States Historical and CH2M Hill, prepared for Colorado Department of Transportation.

Ubbelohde, Carl, Maxine Benson, Duane Smith

2006 *A Colorado History*. Ninth Edition. Pruett Publishing Company, Boulder.

Valentine, David

2008 Digging a Little Deeper at Alunite. *Nevada Archaeologist* 23:23-36.

Van F Furman, H

1895 Melting and Refining Gold Bullion. *The School of Mines Quarterly*. XVI Nov 1894-July 1895. Pp 25 -31. Columbia College, NY.

Warner, Frank P.

1885a A Tale of a Missourian and his Nine Friends. *Sierra Journal* 24 December 1885:1. Rosita, Colorado.

1885b A Tale of a Missourian and his Nine Friends. *Sierra Journal* 31 December 1885:1. Rosita, Colorado.

Warren, Harold M.

1976 Colorado OAHP site form for site 5PA334. Dudley Smelter. March 28, 1976.

Waterhouse, Benjamin C.

2019 The small business myth – Small businesses enjoy an iconic status in modern capitalism, but what do they really contribute to the economy? *Aeon Essays.* Electronic document accessed 8/5/2019. https://aeon.co/essays/what-does-small-business-really-contribute-to-economic-growth

White, Paul J.

2003 Heads, Tails, and Decisions In-Between: The Archaeology of Mining Wastes. *IA, The Journal of the Society for Industrial Archeology.* 29(2):47-66.

2016 The Archaeology of Underground Mining Landscapes. *Historical Archaeology.* 50(1):154-168.

2017 *The Archaeology of American Mining.* University of Florida Press, Gainesville.

White Pine Cone (WPC) [Gunnison, Colorado]

1889 "Mining Matters" 18 October:2. Gunnison, Colorado.

Wilkins, Tivis

1974 *Colorado Railroads – Chronological Development.* Pruett Publish Company, Boulder.

Wilson, E.B.

1907 *The Chlorination Process.* John Wiley & Sons, New York

Wolle, Muriel Sibell

1971 *Stampede to Timberline – The Ghost Towns and Mining Camps of Colorado*. Sage Books, The Swallow Press, Inc. Chicago.

1977 *Timberline Tailings – Tales of Colorado's Ghost Towns and Mining Camps*. Sage Books, The Swallow Press, Inc. Chicago.

Woodward-Clyde

1992 Smelter Site Reconnaissance California Gulch Site Leadville, Colorado. Prepared for ASARCO, Inc.

Young, Otis E.

1970 *Western Mining: An Informal Account of Precious-metals Prospecting, Lode Mining and Milling on the American Frontier from Spanish Times to 1893*. University of Oklahoma Press, Norman.

A Copyright documentation

All images in this document are either from the public domain from sources that are no longer under copyright, or from Colorado archives that gave permission for their use in this document (documentation provided after list of figures).

Figure 3-1 “Otto Mears Road between Silverton and Ouray” History Colorado Hart Research Library No. CHS-J3659.

Figure 3-8 “View of Boston and Colorado Smelter” Stereocard ca. 1870-1880. Chamberlain Photographic Collection. Denver Public Library Western History Collection No. X-17639

Figure 3-9 “Smelter at Sts John” ca. 1870-1880. Denver Public Library Western History Collection No. X-13495

Figure 3-10 “Boston and Colorado Smelter at Alma” date unknown. Muriel Sibell Wolle Estate. Denver Public Library Western History Collection No. X-5650.

Figure 3-14 “Georgetown in 1867 showing smelter in left foreground” Chamberlain Photographic Collection. Denver Public Library Western History Collection No. X-1014.

Figure 3-15 “Dibbens Smelter near Argentine” ca. 1900-1920. Randall album. Denver Public Library Western History Collection No. X-61397.

Figure 3-16 “Whale Mill at Spanish Bar” ca. 1870-1875. Reed and McKinney collection. History Colorado Hart Research Library No. CHS.4592.

Figure 4-1 “La Plata Smelter at Leadville” 1882. William H. Jackson Sample Album, Colorado Book III, No. 189. Denver Public Library Western History Collection No. WHJ-685.

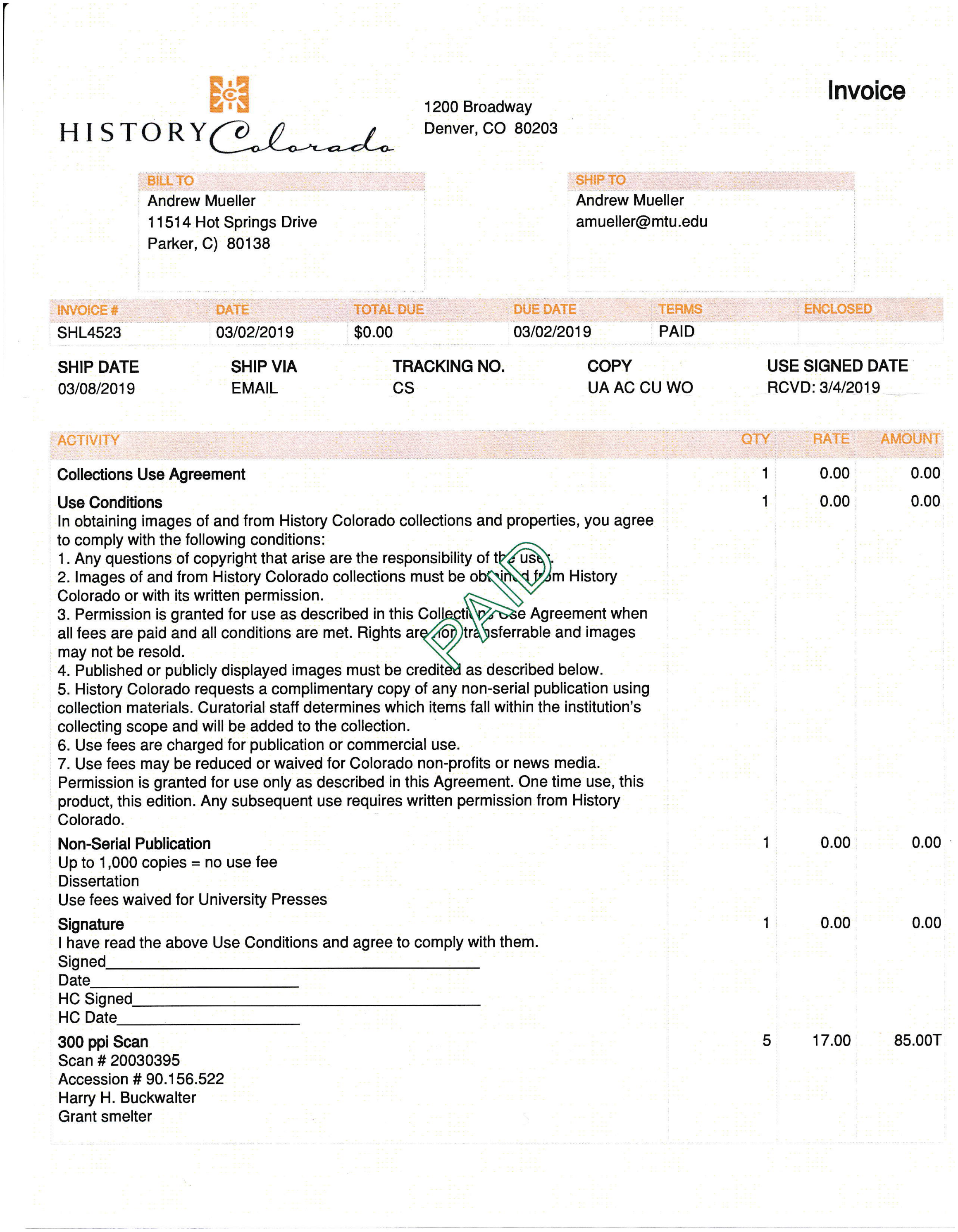
Figure 4-2 “American Smelter at Leadville” ca. 1880s. William H. Jackson Collection. History Colorado Hart Research Library No. CHS.J394.

Figure 4-4 “Arkansas Valley Smelter” ca. 1900. Denver Public Library Western History Collection No. X-61428.

Figure 4-5 “Grant Smelter at Denver” ca. 1910. Buckwalter Collection. History Colorado Hart Research Library No. CHS-B395.

Figure 4-6 “Globe Smelter” Late nineteenth century. History Colorado Hart Research Library No. CHS.J20.

Permission Letter – History Colorado



HISTORY Colorado

1200 Broadway
Denver, CO 80203

Invoice

BILL TO	SHIP TO
Andrew Mueller 11514 Hot Springs Drive Parker, C) 80138	Andrew Mueller amueller@mtu.edu

INVOICE #	DATE	TOTAL DUE	DUE DATE	TERMS	ENCLOSED
SHL4523	03/02/2019	$0.00	03/02/2019	PAID	

SHIP DATE	SHIP VIA	TRACKING NO.	COPY	USE SIGNED DATE
03/08/2019	EMAIL	CS	UA AC CU WO	RCVD: 3/4/2019

ACTIVITY	QTY	RATE	AMOUNT
Collections Use Agreement	1	0.00	0.00
Use Conditions In obtaining images of and from History Colorado collections and properties, you agree to comply with the following conditions: 1. Any questions of copyright that arise are the responsibility of the user. 2. Images of and from History Colorado collections must be obtained from History Colorado or with its written permission. 3. Permission is granted for use as described in this Collections Use Agreement when all fees are paid and all conditions are met. Rights are non transferrable and images may not be resold. 4. Published or publicly displayed images must be credited as described below. 5. History Colorado requests a complimentary copy of any non-serial publication using collection materials. Curatorial staff determines which items fall within the institution's collecting scope and will be added to the collection. 6. Use fees are charged for publication or commercial use. 7. Use fees may be reduced or waived for Colorado non-profits or news media. Permission is granted for use only as described in this Agreement. One time use, this product, this edition. Any subsequent use requires written permission from History Colorado.	1	0.00	0.00
Non-Serial Publication Up to 1,000 copies = no use fee Dissertation Use fees waived for University Presses	1	0.00	0.00
Signature I have read the above Use Conditions and agree to comply with them. Signed____________________ Date____________ HC Signed____________________ HC Date____________	1	0.00	0.00
300 ppi Scan Scan # 20030395 Accession # 90.156.522 Harry H. Buckwalter Grant smelter	5	17.00	85.00T

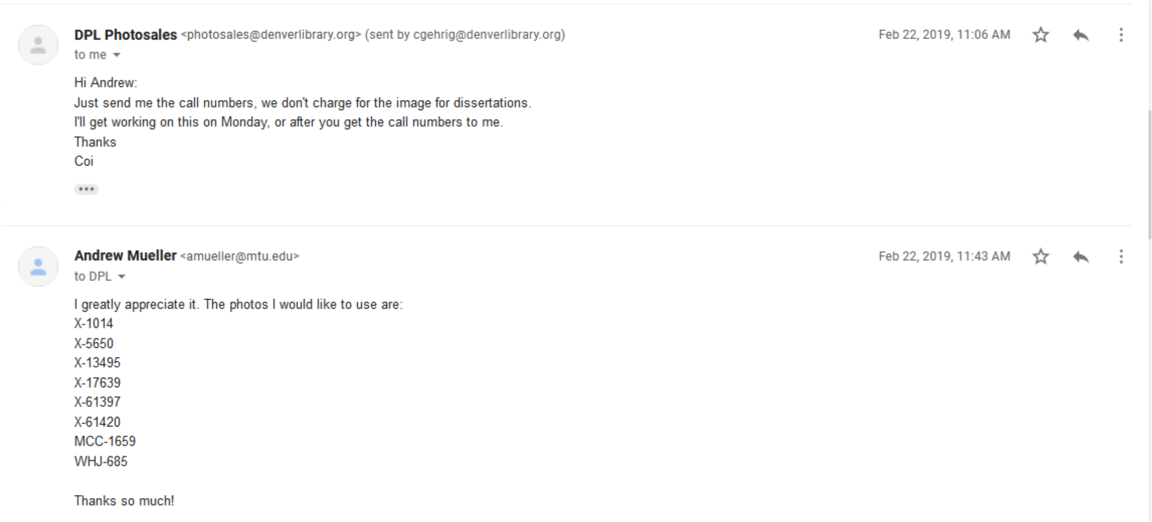
PAID

ACTIVITY	QTY	RATE	AMOUNT
Scan # 20102005 Accession # 86.200.1878 William Henry Jackson Denver Globe Smelter Scan # 10031802 | 10042054, 20004592 Accession # 95.200.123 Reed & McKenney , Reed & McKinney Whale Mill, Clear Creek County Scan # 20100395 Accession # 86.200.415 William Henry Jackson American Smelter Scan # 20103659 Accession # 86.200.6706 William Henry Jacoson Ouray toll road 300 ppi scan to email Email to: amueller@mtu.edu			
Photo Credit Credit must accompany the image in the caption, on the credit page, on the webpage where the image appears, or on the credit screen. Preferred credit for image(s) to read: "Subject, date. Photo by ___ (if known). History Colorado). Accession number"	1	0.00	0.00
Sales Tax Local & State	85	0.0831	7.06
Shipping EMAIL amueller@mtu.edu	1	0.00	0.00

SUBTOTAL	92.06
TAX (0%)	0.00
TOTAL	92.06
PAYMENT	92.06
BALANCE DUE	**$0.00**

Denver Public Library – Western History Section

The library did not provide a hard copy letter of permission, so a portion of the relevant email is included below.



DPL Photosales <photosales@denverlibrary.org> (sent by cgehrig@denverlibrary.org) Feb 22, 2019, 11:06 AM

to me

Hi Andrew:
Just send me the call numbers, we don't charge for the image for dissertations.
I'll get working on this on Monday, or after you get the call numbers to me.
Thanks
Coi

Andrew Mueller <amueller@mtu.edu> Feb 22, 2019, 11:43 AM

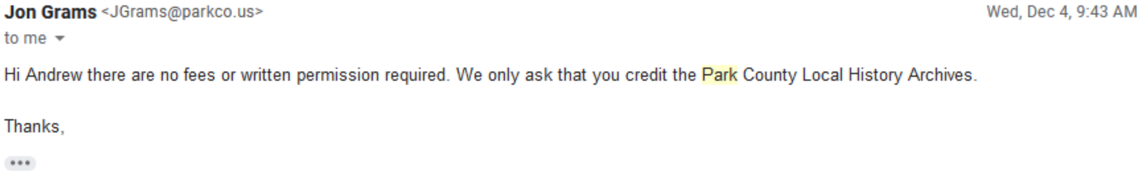
to DPL

I greatly appreciate it. The photos I would like to use are:
X-1014
X-5650
X-13495
X-17639
X-61397
X-61420
MCC-1659
WHJ-685

Thanks so much!

Park County Archives

The archives does not require permissions to use images from their collection.



Jon Grams <JGrams@parkco.us> Wed, Dec 4, 9:43 AM

to me

Hi Andrew there are no fees or written permission required. We only ask that you credit the Park County Local History Archives.

Thanks,

B Ore Reduction and Smelting Technology

Prior to use in a smelter most ores required crushing to bring it to a size that could be effectively and efficiently reduced. There were several crushing methods available including the use of hand breaking (*cobbing*), jaw breakers, rolls, and stamps. Initial breaking was generally undertaken by various forms of jaw breakers. Finer breaking at latter stages was generally accomplished by cobbing or rolls. Stamps were rarely used for ore reduction in Colorado and were instead generally used as part of the amalgamation process in ore mills with the stamps crushing ores in the presence of mercury to extract the gold with little additional processing (Munroe 1881:94).

Hand Breaking

Although not as common as mechanized breaking, hand breaking was still used to some extent in Colorado. Cobbing by hand was accomplished with the use of specialized hammers, the most common were cobbing hammers, spalling hammers and sledgehammers. Simple sledgehammers were most often used to break ore down to a size that could be fed into the mechanized ore crushers used at almost all works. These hammers varied from 10 to 30 pounds, the weight depending on the type of rock being broken (softer rock required a lighter hammer than hard rock to minimize pulverizing the ore into particles too small for easy handling and processing), although at higher elevations lighter hammers were usually used to lower the stress of working at altitude. Spalling hammers were also two-handed but were intended to break ore to a uniform size while producing the minimum amount of fines. Finally, the cobbing hammer was a one-handed hammer used to separate valuable ore from gangue. Although mechanical ore breaking was much cheaper for large quantities of material, hand breaking did have its advantages. A skilled worker could remove much of the barren rock during the breaking process reducing the amount of material that would be run through the plant. Hand breaking also produced less fine material, which was difficult to process and often led to significant losses of metal contents during handling and processing (Richards 1909:9-12).

Jaw Breakers

The most common form of mechanical breaker used in nineteenth century Colorado mining were jaw breakers of the Blake and Dodge patterns. These breakers were used in the initial reduction process to break ores to a coarse consistency that could be further reduced by additional breaking equipment if needed.

The Blake Crusher (Figure B- 1) was the earliest of the jaw crushers, having been patented in 1858 (U.S. Patent # 20,542). It had a moving lower jaw that applied the greatest amount of force on the smallest pieces of ore. The amount of power needed to operate the crusher varied depending on the type of ore, the speed of the machine, and the fineness of crushing desired (Meyerriecks

2003:201-202). Ores run through Blake crushers were generally broken to a final size of 1 to 4 inches. The Blake design had the added advantages that it was self-feeding and cleaning. Blake crushers were available in a wide range of sizes and capacities (Richards 1909:13-17). Blake crushers were the most common types and were the main crushing apparatus used in the Leadville smelters (Emmons 1886:629-630).

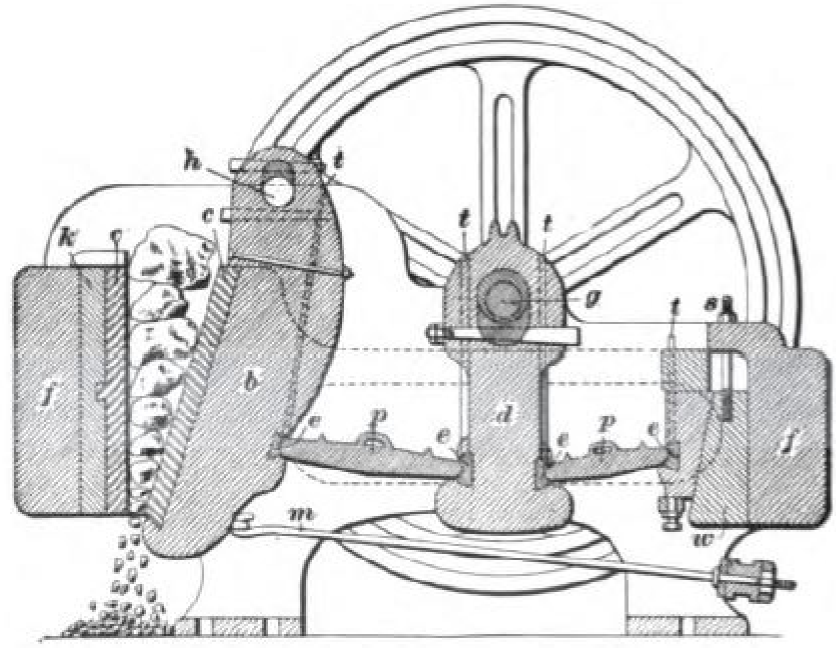


Figure B- 1. Blake Jaw Crusher. Illustration from International Textbook Company (ITC) 1902:25-2.

The Dodge crusher was similar in design to the Blake, but rather than the lower jaw, the upper jaw was the moving piece. This had the effect of applying the greatest amount of force to the largest pieces of ore. The Dodge was normally used as the second stage of the crushing process and were often used to further reduce the coarse ore produced by the Blake crushers (Richards 1909:23-25).

Rolls

If further crushing was required after the ore passed through the Blake and Dodge crushers, the ore was often passed through a set of rolls as the final stage of crushing. The crushing rolls (Figure B- 2) consisted of two iron or steel cylinders held in tension by either rubber or steel springs at a proper spacing to reduce the ore to a desired size. The typical diameter of the rolls themselves was 2 to 5½ inches. The rolls were usually constructed with cast iron cores fitted with replaceable shells (tires) of chilled cast iron or steel. Tires made of chilled cast iron had the advantage that it was inexpensive but wore out more quickly than steel tires and required frequent replacement. The earliest form of rolls were the Cornish rolls that operated at a speed of 30-40 feet per minute. By the 1890s the design of rolls had been greatly improved and could operate at speeds of up to 800–1,000 feet per minute. Rolls were most efficient at breaking brittle minerals such as pyrites that were commonly found in Colorado mines but had difficulty with softer ores containing native gold or copper as the rolls tended to flatten rather than break the ores causing caking that made them more difficult to process. Soft ores also had a tendency to adhere to the roll surfaces causing stoppages or equipment damage. However, when run at the correct speed on suitable ores rolls allowed for the fastest breaking with the least production of fines of any mechanical crushing method (Richards 1909:47-64).

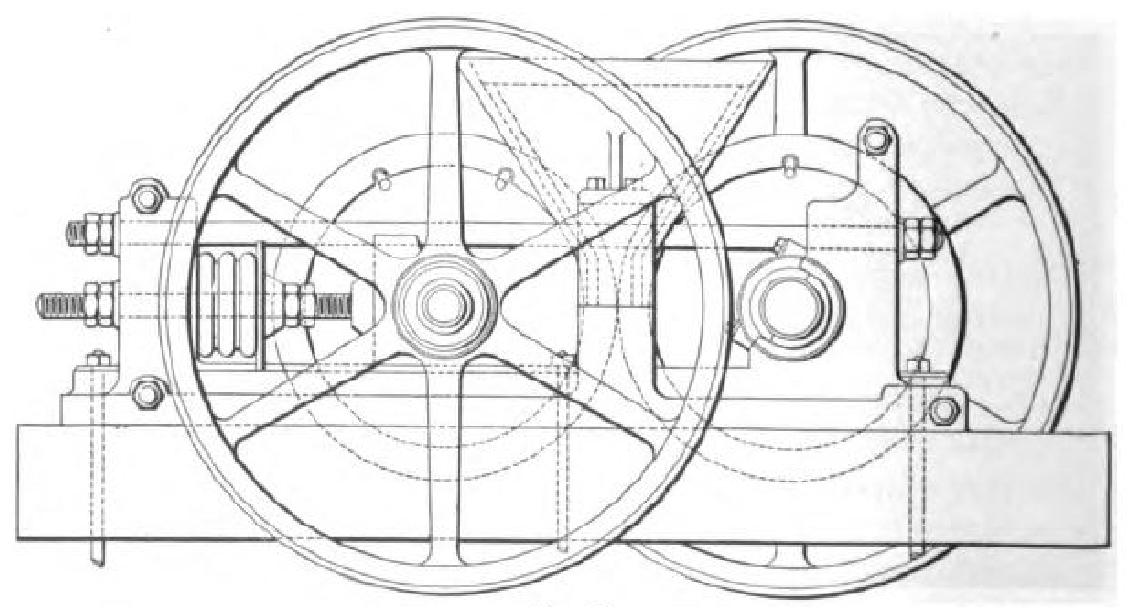


Figure B- 2. Crushing Rolls. The large spoked wheels are drive wheels powered by belts. The rolls themselves are the smaller interior circles in the drawing. Illustration from ITC 1902:25-12.

Stamps

The use of weights on vertical wooden beams for crushing was used quite early in the mining industry with the first known versions depicted by Agricola in the sixteenth century (Agricola 1950:279-280). Stamps (Figure B- 3) were rarely used in smelting plants (although one plant in Leadville did use a 3-stamp mill in the late 1870s). The typical stamp mill consisted of a series of stamp rods raised by the action of cams and allowed to fall under the force of gravity. The wooden rods were tipped at the bottom with cast iron shoes which fell onto iron dies sitting in the bottom of a cast iron mortar box. The mortar box in turn sat on stamp blocks (generally made of wood) resting on a sturdy masonry foundation. The mortar boxes included walls consisting of perforated iron sheet or hardware cloth that allowed the ore to escape the stamps after it had been reduced to the proper size (Meyerriecks 2003: 195-196; Richards 1909:84-101).

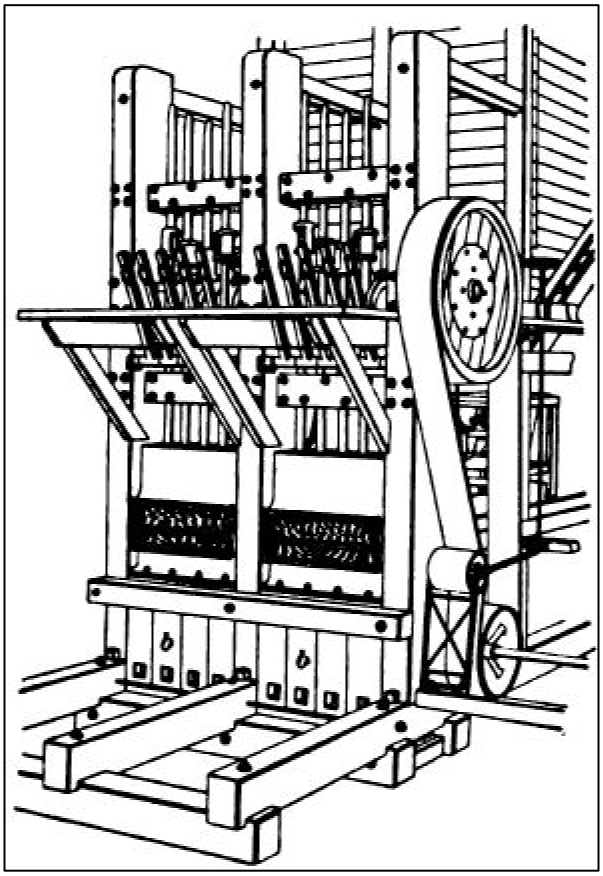


Figure B- 3. Stamps. Illustration from ITC 1902:25-27.

Ore Roasting

With few exceptions most Colorado ores required initial roasting prior to processing in the smelter. Depending on the nature of the ore, and finances of the company, there were several options for roasting or calcining ore. These were roasting in heaps, roasting in stalls, roasting in reverberatory furnaces, and roasting in mechanical roasters.

Roasting was a process where the ore was heated to high temperatures, but below the melting temperature of the ore. This process served to oxidize the ore driving off the sulfur and other unwanted elements that were chemically bound with the silver, copper, and lead in the metal bearing minerals of the ore.

As the metal bearing minerals in most ores had undesirable components, most smelters had large roasting yards. Roasting yards were prepared by leveling the site and removing all topsoil and organic matter. The area was then covered with a layer of gravel, slag or coarse tailings to form a platform 2-inches higher than the surrounding ground surface. This layer was then topped by a layer of compacted clayey loam or gravel which was in turn covered to a depth of three to four inches by a layer of ore fines from the crushing machinery. This final layer was intended to minimize the chances of contaminating the roasted ore with other materials during handling. Initially, little attention was spared for the location of the roasting yard beyond its proximity to the charging floor, but later in the century as the first successful environmental lawsuits were brought by farmers and ranchers against the smelters at Anaconda, Montana, more attention was spent on building the yards so that prevailing winds and other environmental conditions would minimize impacts of the roasting on the surrounding area (Quivik 2007).

For efficient roasting the ores were coarsely crushed to help assure a uniform roasting. Although the roasting process did not require a fine control over particle size, in other operations this was more critical, and the use of classifiers was common. A classifier was a device for the sorting of sand and smaller sized particles through the use of water allowing progressively smaller size particles to settle out in a series of classifying columns (Richards 1909:219). Prior to roasting the ores were coarsely crushed to a uniform size for more efficient roasting. At this stage the ore was crushed as coarsely as possible to minimize costs and to minimize the production of fines that were often lost during handling. The fines produced during this stage could lead to a heavy loss in the assayed values of the ore as wind and rain tended to carry the particles away while in the yard. Fine materials also tended to cake during roasting which yielded an inconsistently oxidized product.

The principle aim in roasting lead-silver ores was to remove as much arsenic and sulfur as possible. During the process heat caused a reaction where the sulfide minerals combine with the oxygen in the air creating sulfur dioxide and oxidized ore minerals (e.g. $PbS + 3O = PbO + SO_2$) although small amounts of sulfur trioxide (SO_3) are often created but also act as oxidizing agent (ITC 1902:30-39). This reduced the amount of iron flux required to reduce the ores. Any ore containing at least 15 percent sulfur required roasting, and the presence of zinc also necessitated the process. However, ores that were exceptionally rich in silver (100 ounces per ton or greater) often skipped roasting due to the danger of losing large amounts of silver due to volatilization. Argentiferous galena ores were also rarely roasted as the galena contributed valuable lead to the smelting process (lead was highly susceptible to volatilization during roasting) and the galena ores were valued for their ability to raise the lead content of ores with a low lead content (dry ores) which increased their silver yield (Howe 1885:25; ITC 1909:30-2).

The method of roasting chosen at this stage was largely based on the particle size of the ore. Fine ores were sand sized or smaller including mill tailings, and coarse ores were anything larger than this. Although most ores arrived directly from the mines in early districts the initial milling to recover gold often left substantial values in the tailings. In Black Hawk the early amalgamation mills often recovered less than twenty percent of the gold content of the refractory ores they processed. The Boston and Colorado Smelter exploited the tailings from these early mills as a readily available source of gold, a pattern observed in other districts as well. Fine ores could only be effectively roasted using hand-rabbled reverberatory calcining furnaces, revolving cylinder furnaces, or automatic reverberatory calciners. Coarse ores could be roasted in any of these methods with the addition of heap and stall roasting methods.

Heap Roasting

Heap Roasting was the cheapest roasting method, and when properly managed produced a good product. It was often used at small and/or early works due to the initial capital investment needed to use other roasting types. Ore processed using this method tended to produce mattes with a higher concentration of precious metals than ores roasted by the stall method. Ores for this method were usually broken by jaw crusher, but hand crushing was sometimes used to reduce the production of fines. The main disadvantages of heap roasting were that it was time consuming and the exposure of the ore to the open air meant that rain and other forms of atmospheric moisture leached some of the oxidized components out of the ore, causing a loss in metal values (ITC 30-27-31; Howe 1885:16).

A typical roasting pile (Figure B- 4) was 40 feet long, 24 feet wide, and 6 feet high. This would hold approximately 240 tons of ore which would be burned for an average of 70 days before the process was complete. The removal of the roasted ore and the creation of a new heap added 10 days to the process. With multiple heaps undergoing roasting simultaneously this equated to the production of 3 tons of roasted ore daily requiring 35 roasting piles to provide sufficient roasted ore to support continuous operation of a 100-ton capacity furnace. A yard supporting this many heaps would occupy approximately 75,600 ft^2 (1.7 acres). Heap roasting could also be used to remove excess sulfur from matte produced in the smelting furnace, but the process was slow requiring two to three roasts to remove sufficient sulfur (Peters 1895:107, 137).

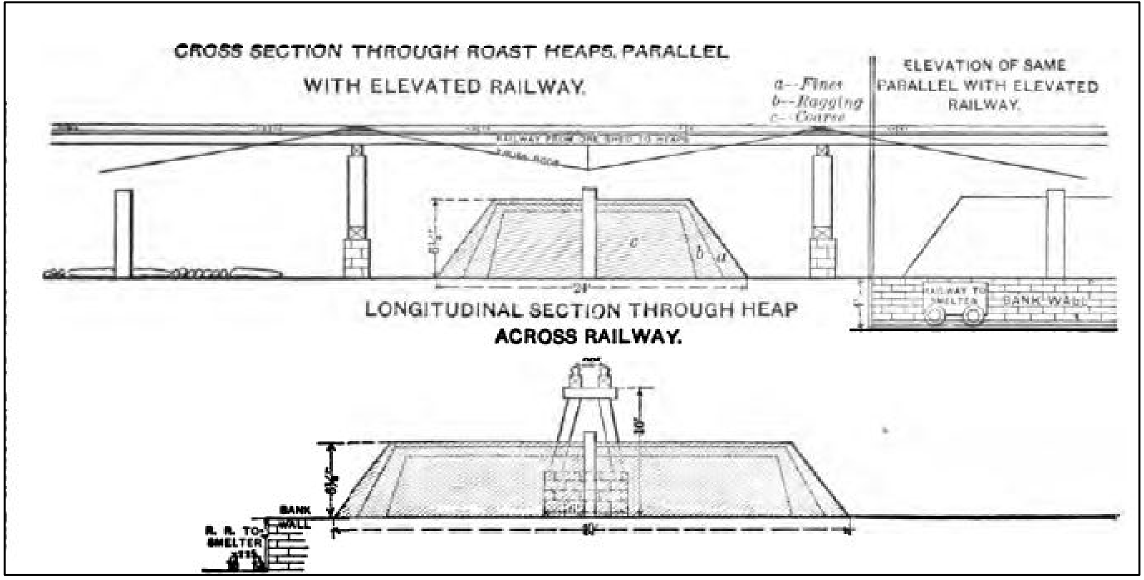


Figure B- 4. Heap Roasting Diagram. Illustration from Peters 1895:111.

Stall Roasting

A somewhat more sophisticated roasting method was stall roasting (Figure B- 5). The stalls were long structures consisting of a series of bays with an open side. The bays were generally built of common brick, masonry or slag blocks. They were usually open at the top, but some had arched roofs to protect the roasting ore from precipitation. The stalls were served by a common flue along their back walls that fed a single stack. A typical stall could hold a 20-ton charge which would be roasted over a period of 10 days giving a daily output of 2 tons per stall. A 100-ton capacity furnace required 56 stalls to remain in continuous operation. Usually a slight excess in roasting capacity was provided to allow for repairs and maintenance of the stalls without impacting furnace operations (ITC 1909:30-31 30–35; Peters 1895:139-149). Stall roasting was the preferred methods for

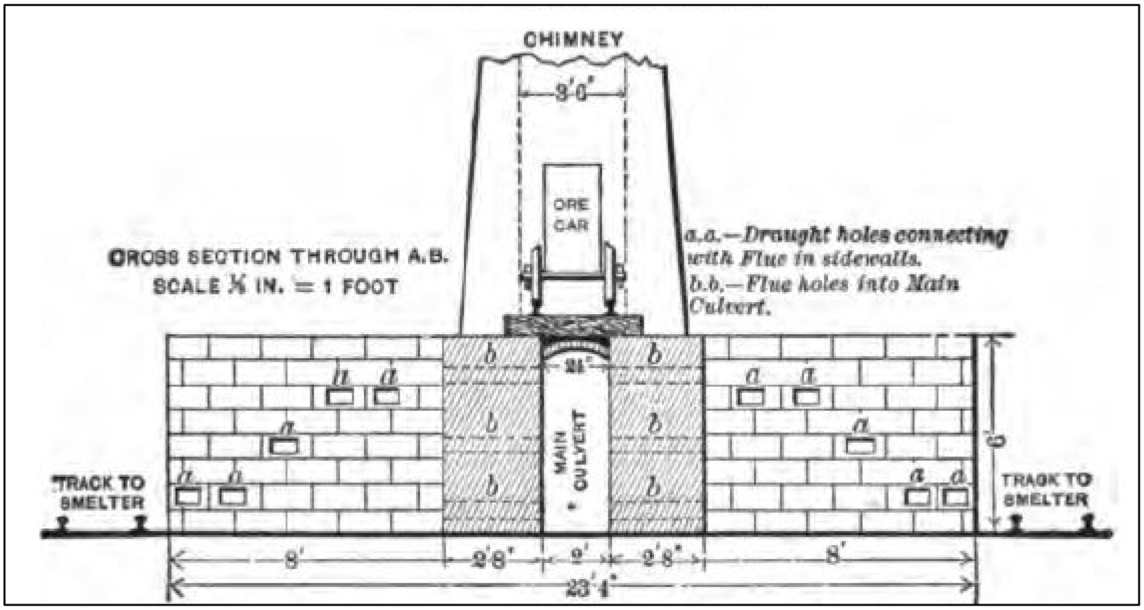


Figure B- 5. Roasting Stalls Cross Section. Illustration from Peters 1895:148.

companies that could afford to construct them as the process was cheaper and faster than heap roasting over the long run and produced a higher quality ore as the stalls served to protect the roasting ore from environmental conditions that limited losses. However, they required significantly greater labor and were often built only where fuel was expensive and labor was cheap (Howe 1885:18).

Stalls were the preferred method for roasting matte and *speise* (metallic arsenides) produced during furnace runs. These products contained high concentrations of precious metals and the threat of leaching had to be minimized. One stall could roast four to six tons of matte as a charge. The high sulfur content of the mattes required up to three roasts to reduce the sulfur to an acceptable level. For further processing the initial matte roasting normally took four days, with the two additional roasts of three days each (Schnabel 1898:113-115.).

Manual Reverberatory Furnaces

The reverberatory furnace (Figure B- 6) was the earliest form of calcining furnace. This was the only option for roasting fines in the earliest period and remained in use for many decades by firms that did not wish, or were unable, to invest in mechanized roasting technology. These furnaces were usually constructed of common brick with a roof shaped like a flattened arch and a firebox at one end and a flue at the other. The interior contained low brick bridge walls that combined with the arched roof caused the flame from the fireplace to "reverberate" along the top of the charge. The sides of the furnace were lined with multiple small openings with doors through which the workers could manipulate the charge (ITC 1909: 30-5 to 30-11). These furnaces were typically served by natural draught as using a forced draught caused a substantial loss in fine materials. This limited the size of the furnaces to 35 feet or less. While the width of the furnaces was limited to the area that workers could reach.

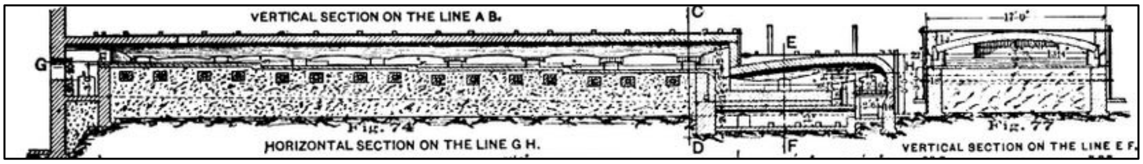


Figure B- 6. Reverberatory roasting furnace cross section. Illustration from HofmanHoffman 1893:163.

Typically, reverberatory roasters were divided into 16-foot-wide hearths. The number of hearths used depended on the amount of sulfur in the charge. The additional heat provided by the decomposition of sulfur in ore could increase the number of hearths that could be run as the additional heat allowed acceptable operating temperatures further from the firebox. A single hearth could process ore containing less than 10 percent sulfur while an increase of sulfur in the ore to 15 percent allowed for the addition of another unit. Similar step increases were possible to four hearths at 25 percent which was generally considered the maximum practical size. Although manual reverberatory roasting furnaces were highly labor intensive and ill-suited to the labor conditions of the western mining districts, it was recognized as producing the best quality ores for galena rich ores as it volatilized less of the lead and silver (Eissler 1891:57-58).

Revolving Cylinder Furnaces

The revolving cylinder furnaces were in common use in Colorado, with the early the Brückner Cylinder (Figure B- 7) introduced in Gilpin and Clear Creek counties in the 1860s. The most common size was 8 feet 6 inches in diameter and 18 feet 6 inches long. The interior of the iron furnace was lined with a layer of good quality common brick. Earlier models of the 1860s to 1880s had dedicated fireboxes to heat their charges. An innovation in the 1890s allowed the use of a movable fire box on a track that could serve multiple furnaces. The mobile fire box would heat a cylinder until the sulfur in the charge ignited, and then would be moved to light the next furnace in the series. Although the Brückner cylinder was the most common type, there were several other models in use. However, they all followed similar designs that were slightly inclined cylinders, rotated slowly by pinion gears. The interiors were brick lined and most had low brick ridges along their lengths to ensure the ore was lifted and turned during the rotation to ensure an even oxidation of the charge. The capacity of the furnaces varied depending on both the speed of rotation and the angle of the furnace (Peters 1895:194-197). The Brückner became the roasting furnace of choice in most Colorado works (Cone 1876:321).

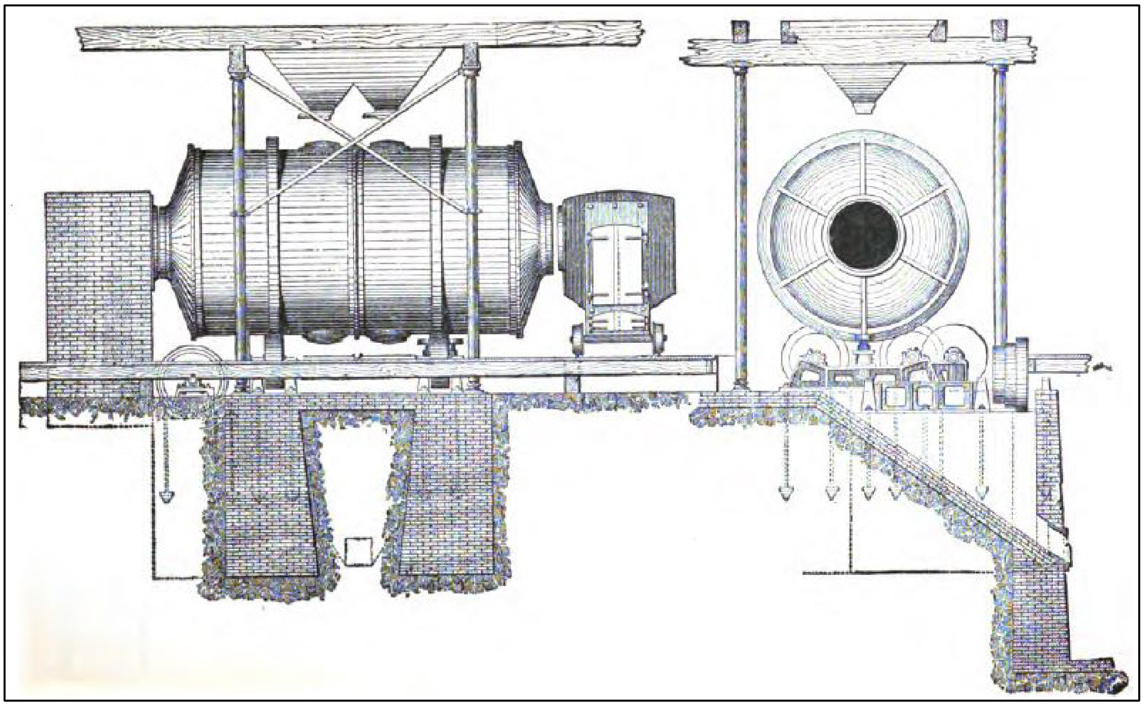


Figure B- 7. Bruckner Cylinder Furnace. Illustration from Peters 1895:197.

Automatic Reverberatory Furnaces

The last type of ore roasting furnace used in Colorado was the automatic reverberatory furnace. These were similar in concept to manually operated reverberatory furnaces, but with a mechanical apparatus to stir and move the charge. By the 1890s these had become the most common roasting furnaces in the large plants of the Front Range, and were used to roast lead-silver ores, pyritic gold ores, and matte. The two most common models used in Colorado were the Pearce turret furnace and the O'Hara furnace (Peters 1895:200).

The Pearce turret furnace (Figure B- 8) was used at several of the large smelters in Denver and Pueblo. These furnaces consisted of a long, narrow hearth of brick shaped as a partial circle. The gap in the circumference of the circle was used to load the ore in one end and unload the roasted ore from the other end. Two or three fireboxes were located along the circumference of the furnace. The charge was stirred and moved along by a series of air-cooled rabbles. The charge was stirred every 40 seconds and the total roasting time was six hours. One of the main advantages of the furnace was it produced very little flue dust. Furnaces of this type generally cost $5,000-6,000 (ITC 1909:30-13; Peters 1895:205).

The other O'Hara furnace was used at the Argo Smelter (Boston and Colorado) in Denver. The model used at Argo consisted of two long, vertically stacked hearths with the upper furnace feeding into the lower one. The ore was stirred and moved through the furnace by a series of chain-driven iron plows. The furnace had the disadvantage of having high maintenance costs as the chain drive and plows required frequent maintenance and replacement (Peters 1895:200).

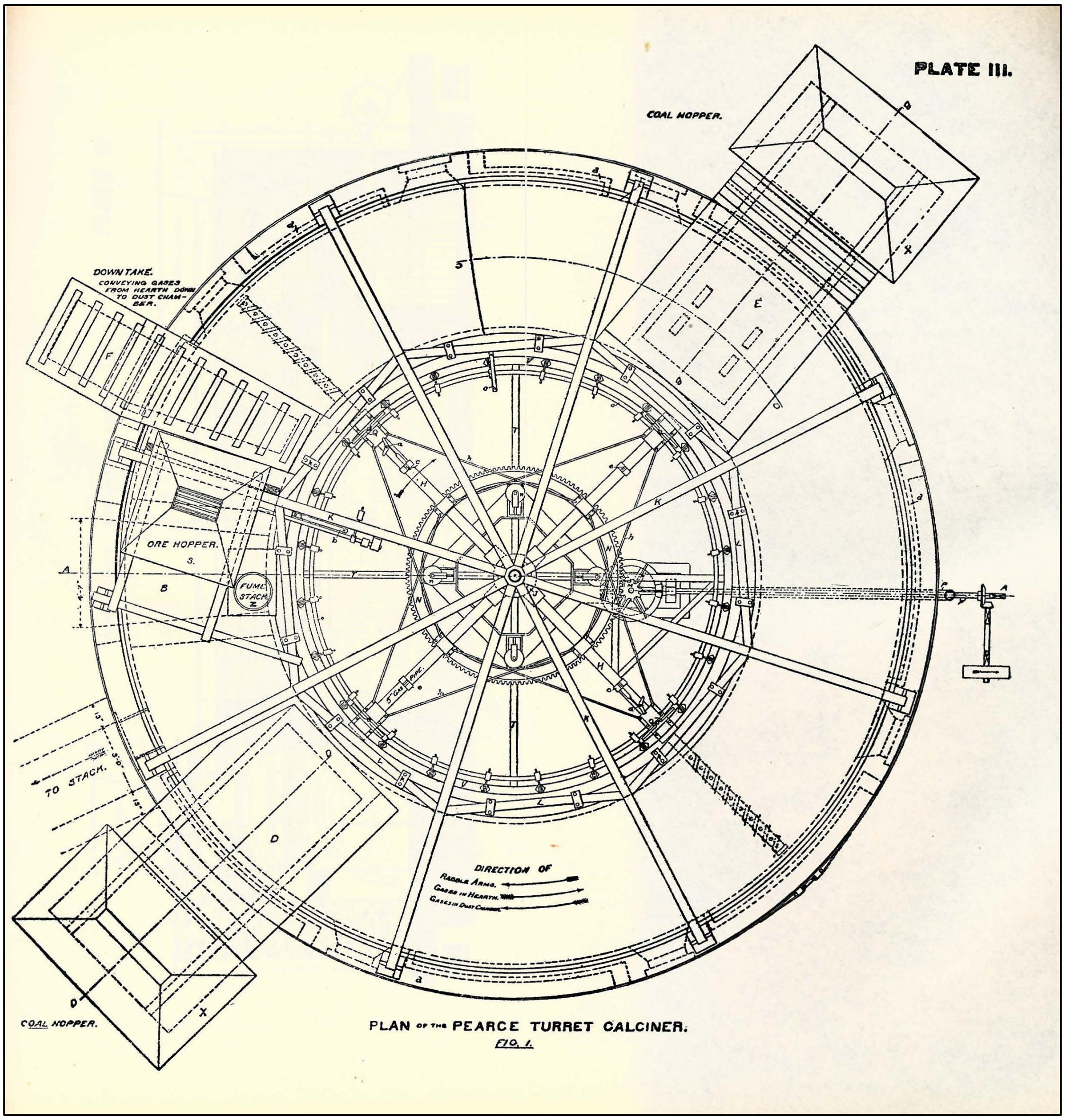


Figure B- 8. Pearce turret furnace. Illustration from Peters 1895 Plate III.

C Hall Valley Record

Although the available information is relatively sparse, the Hall Valley (Figure C-1) is one of the best documented small smelters of the period appearing in a series of articles in the *Engineering and Mining Journal.*

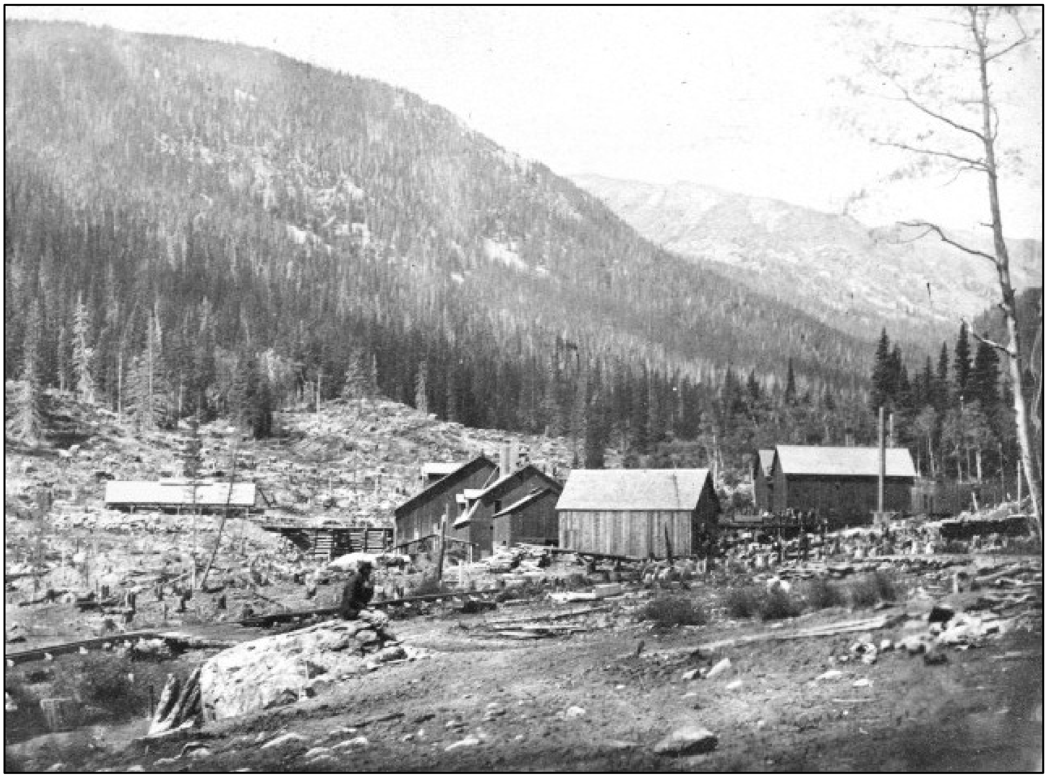


Figure C- 1. Hall Valley Smelter circa 1887, view up valley toward company mines Park County Archives photo number 3134.

The location of the smelter and nearby transportation routes is depicted on the 1883 GLO map of Township 6S Range 75W (Figure C- 2). These features include wagon roads connecting the works to the railroad to the east, the company mines and Webster Pass to the northwest, and Handcart Pass to the north. The company's wooden tramway to the mine is clearly shown paralleling the wagon road.

The physical layout of the plant is depicted on an 1887 GLO Plat (Figure C- 3) for the Whale Mill Site (the Whale was the largest mine in Hall Valley). Although the plat post-dates the abandonment of smelting at the plant, there appears to be little change to its layout at this point. All buildings on the plat appear on an 1887 photograph, but additional buildings appear to have been constructed between the creation of the plat and the taking of the photograph. Features in the photograph but not on the plat include a bridge or dam over the river, a long building on the south bank of the river that may be the roasting shed, and a frame building east of the original smelter building. The wooden tramway through the site is clearly visible, as is a large stone retaining wall that forms the edge of a large earthen platform at the right side of the photograph.

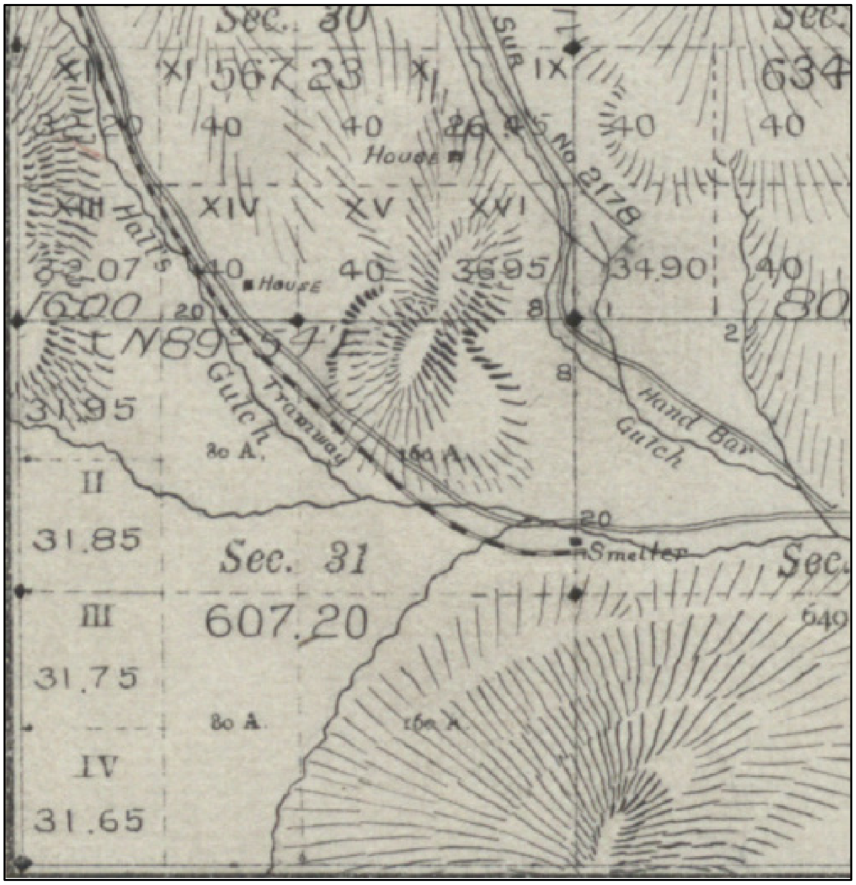


Figure C- 2. Portion of 1883 General Land Office plat of Township 6S Range 75 W showing Hall Valley Smelter and its associated tramway.

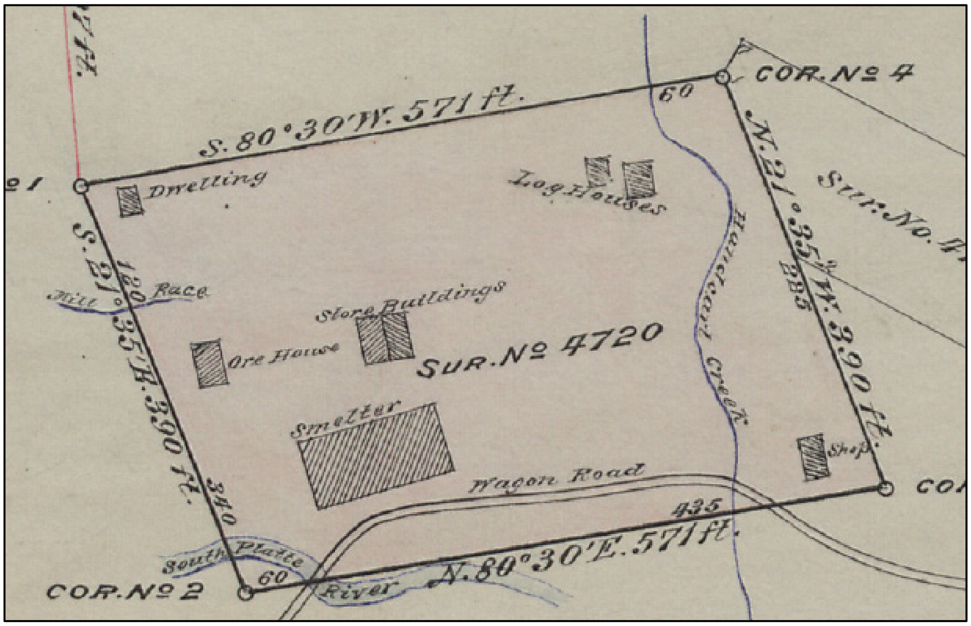


Figure C- 3. Portion of General Land Office Plat for Whale Mill Site (Hall Valley Smelter) May 10, 1887.

A later (1903) plat for a mill on the smelter site shows the boundaries of the 1887 survey (Figure C- 4). None of the original buildings are still present by this point. The new mill building is in the approximate location of a large earthen platform at the site.

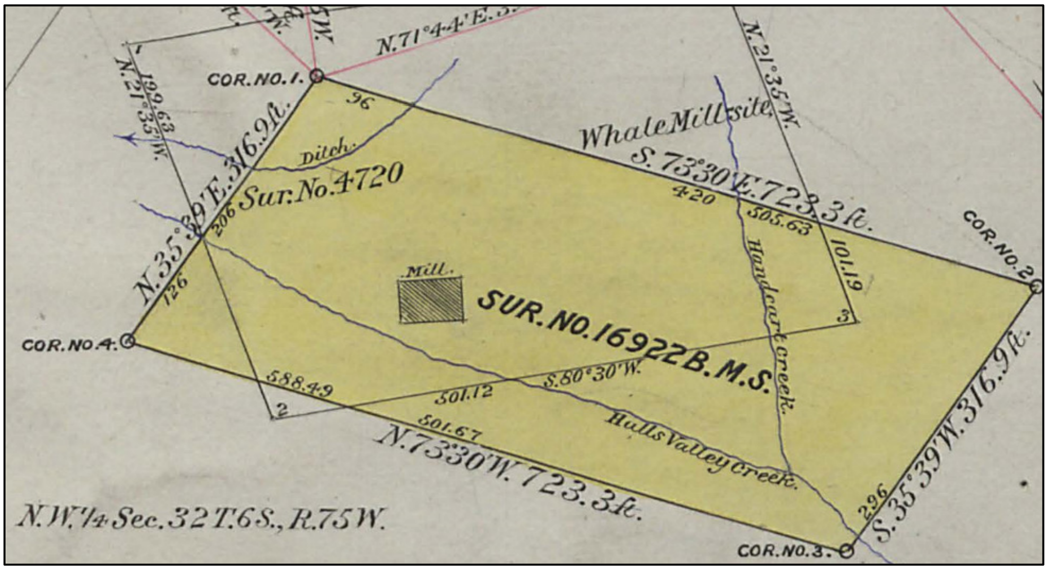


Figure C- 4. Portion of General Land Office Plat for Swordfish Lode and Cyvert Mill-site December 31, 1903.

The Hall Valley Smelter was originally recorded by archaeologist Robert Rosenberg in 1977. Like other smelters recorded during the 1970s and early 1980s the site description is brief, stating only that “The smelter is in ruins. Stone foundations are visible as well as scattered artifacts, lumber and slag pile from treated ore.” No site map was included in the form, and the only photograph shows a large amount of collapsed timber from the mill building. The timber pile has since been removed. Permission to re-record the site was granted by Julie Bell, U.S. Forest Service archaeologist for Pike-San Isabel National Forest in the fall of 2018 but limited to surface recording only. Due to high visitation rates associated with the Hall Valley Campground immediately east of the site no effort was made to clear vegetation or pine duff from the features to avoid drawing attention to them. Parts of the smelter location are used as informal camp sites and the general lack of artifacts indicate intensive artifact collection has occurred.

The October 2018 recording identified fifteen features at the site (Figure C- 5). These consist of a mill race (Feature 1), five foundations (Features 2, 4, 6, 9, and 11), the current Forest Service Road (Feature 3), a large depression (Feature 5), an artifact concentration (Feature 7), a privy pit (Feature 8), a large platform (Feature 10), the slag pile (Feature 12), a large unidentified piece of machinery in the river (Feature 11), a wagon road (Feature 14), and a large mound of burnt fire brick (Feature 15).

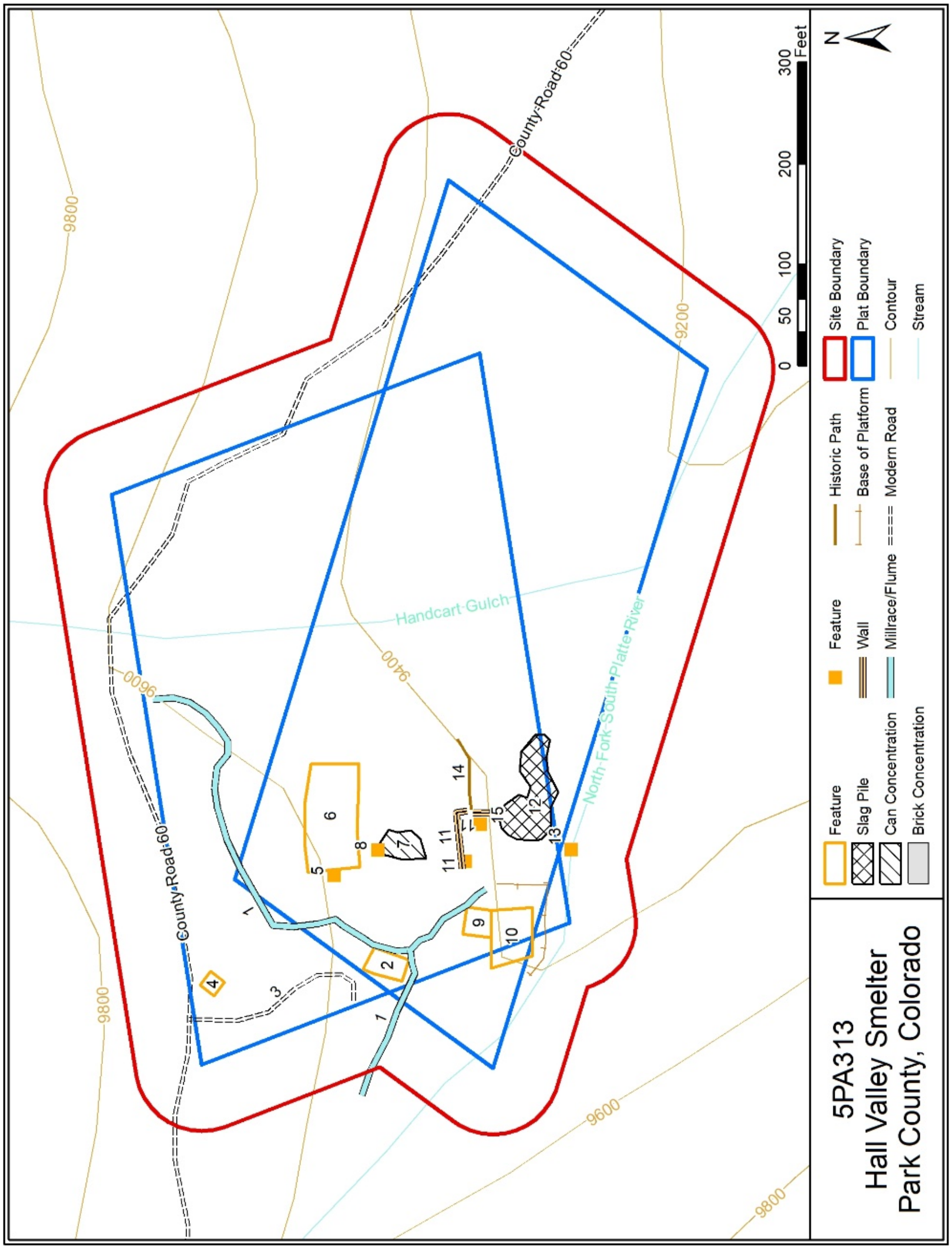


Figure C- 5. Site Map of Hall Valley Smelter.

Feature 1 – The mill race (Figure C- 6) for the waterpower installation follows a gentle gradient along the north edge of the site. Erosion has destroyed part of the mill race at its west end and its original diversion from the South Platte River is unclear. The race flowed along the south and east walls of the ore house before turning north and then east to empty into Handcart Gulch. Construction of the modern Forest Service road crosses the area where the race entered Handcart Creek destroying the last 5 to 10 meters of the feature. For most of its course the mill race is 2 to 3 feet deep.

Figure C- 6. Hall Valley, Feature 1, mill race, view northeast.

Feature 2 is the foundation for the ore house (Figure C- 7). The feature is 40 feet long, 20 feet wide, and the ground surface within the feature slopes 15 feet vertically from the top toward the smelter. The foundation is at the highest point of the site at the transition between a relatively level meadow to a moderate slope down to the South Platte River. The masonry foundation walls are easily traced except on the west side where a modern campsite has destroyed or obscured the feature. Many of the rocks in the foundation wall do not occur on site and appear to have been transported from the company mines at the head of the valley. Along its north side the foundation wall is partially buried, and its south wall has partially collapsed. The mill race (Feature 1) followed the east edge of the feature.

Figure C- 7. Hall Valley, Feature 2, east wall of ore house foundation view south.

Due to disturbance from the campsite and access road, no evidence of the tramway was found near the feature. No artifacts were directly associated with the feature. Within the campsite a few pieces of quartz and barite rich ore material were observed.

Feature 3 is the modern Forest Service road that connects US 285 to the east with Webster pass at the head of Hall Valley. A spur of the road diverts south along the west edge of the site to the cleared campsite bordering Feature 2. Although the road is a relatively new alignment to the east of the site, to the west it appears to closely follow the route of the wagon road and tramway to the mines.

Feature 4 (Figure C- 8) is the dry-laid stone foundation of a dwelling depicted on the 1887 GLO plat of the mill site. The feature was built on a moderate slope and is approximately 17 feet square. Most of the south foundation wall has partially collapsed. The interior of the foundation was filled with earth to make a level pad for the structure. The feature is immediately off the modern road (Feature 3) and the northern foundation wall has been either destroyed or covered by the road berm. No artifacts were directly associated with the feature.

Figure C- 8. Hall Valley, Feature 4, south wall of structure.

Feature 5 is a large depression (Figure C- 9) 5-feet deep and 20-feet in diameter. The original purpose of the feature is unknown but large pieces (10 to 15 cm) of charcoal were observed near Feature 6 that borders the depression on the east.

Figure C- 9. Hall Valley, Feature 5 Unidentified pit to the west of storage structure view north.

Feature 6 (Figure C- 10) is a poorly defined platform excavated into the slightly sloping hillside. A dry-laid stone foundation wall extends along the downhill edge of the platform. The western part of the platform is in the location of the storage buildings depicted on the 1887 plat and photograph. Thick deposits of pine duff and dead vegetation made mapping the feature difficult, but the area of the storage structures has three shallowly excavated bays. The westernmost bay contained large pieces of charcoal similar to those found in Feature 5. The middle bay contained a light scatter of coke ranging in size from 5 to 15 cm. The eastern bay did not contain any artifacts or materials. If the storage buildings contained the materials for making furnace charges the last bay likely held flux. The smelter used fluxes including bog iron, scrap iron, limestone, fluorspar, silica rich slag, and low-grade matte, the last two procured from the Boston and

Colorado smelter at Alma (Jernegan 1877:50). Excavation of the feature may identify the materials stored here. The remaining length of the foundation wall continues to the east defining the edge of the large earthen platform seen on the 1887 photograph. This was most likely used as a yard for mixing charges that were then carted to the furnace.

Figure C- 10. Hall Valley, Feature 6. Storage structure view southwest.

Feature 7 is a poorly defined depression between the storage buildings and the smelter building that contains a concentration of historical artifacts. The artifacts consist of hundreds of hole-in-cap cans, sardine cans, one paint can, barrel hoops, large rectangular cans (possibly fuel cans), fragments of cast iron, and two pieces of flashing for chimney pipe.

Feature 8 is 3-foot diameter, 2-foott deep depression that is likely a privy. The walls of the feature are still close to vertical and the waste rock from the excavation is on the downhill side of the feature. The interior is filled with a thick deposit of pine duff and woody debris.

Feature 9 is a dry-laid "L" shaped stone retaining wall (Figure C- 11) that appears to mark the northwest corner of the smelter building. The west edge of the feature has been reused to support a structure that was built on a large earthen platform (Feature 10).

Figure C- 11. Hall Valley, Feature 9 collapsed stone wall/foundation, view southwest.

Feature 10 is a large earthen platform (Figure C- 12) between the ore house and the smelter building. The feature is unique in containing a large amount of yellowish sediment derived from sulfide rich minerals. The structure built on the mound appears to have been substantial and the stubs of two 20-inch by 12-inch timbers and a vertical cast iron pipe still rise from the platform. Along the northwest side of the platform there is an anomalous concentration of burnt and unburnt common brick and sheet metal. The platform is likely the location of the ore crushing machinery and the pipe may have been part of the water supply for the jig tables used in sorting the ore. If this is the case the building was likely reused in the later concentration works accounting for the large amount of structural materials observed (a large amount of timber was seen on the side of the platform in the 1977 site photograph). Crushed materials from here could have been easily transported downslope to Feature 6 for making charges. The top of the feature has a well-used fire pit and evidence of recent camping was observed.

Figure C- 12. Hall Valley, Feature 10 upper platform. Showing surviving timber along edge and modern firepit in foreground. Dark area in middle of center is slag pile (Feature 12) View east.

Feature 11 is a well-built dry-laid stone retaining wall (Figure C- 13) that appears to have marked the transition from the upper level of the smelter building to the furnace floor. The retaining wall is 56 feet long with a remaining height of 5 to 6 feet. On the upper (north) side of the wall the area was leveled (Figure C- 14). The floor area at the base of the wall has a light scatter of common and fire brick on its surface (Figure C- 15). Three square stone blocks (Figure C- 16) appear to have served as foundation piers for columns that supported a second level. One circular wrought iron ring 46-inches in diameter is five feet from the retaining wall. A series of cast iron flanges are bolted to the ring, each 6 six inches long and 4 inches wide. Although other iron rings like this one were not discovered, two small mounds of fire brick and other debris are evenly spaced with the ring along the retaining wall indicating the location of the three blast furnaces described in historic accounts. There were few artifacts directly associated with the feature, although part of the blast pipes and a short section of wrought iron smoke stack were observed at the sides of the feature (Figure C- 17-Figure C- 19)

Figure C- 13. Hall Valley, Feature 11, view showing lower wall of smelter from edge of South Platte River view north.

Figure C- 14. Hall Valley, Feature 11 view of platform atop smelter foundation wall view west.

Figure C- 15. Hall Valley, Feature 11 view of interior smelter wall with scattered common and fire brick in foreground.

Figure C- 16. Hall Valley, Feature 11 square stone base. One of three possible supports for lightweight roof structure.

Figure C- 17. Hall Valley, Feature 11, partially buried furnace base along smelter wall showing attached flange.

Figure C- 18. Hall Valley, Feature 11, part of blast pipe.

Figure C- 19. Hall Valley, Feature 11, part of wrought iron stack in northeast corner of foundation.

Feature 12 is the slag pile (Figure C- 20). The surface of the pile has been leveled as a working surface and is at the same elevation as the furnace floor. The pile has been truncated by stream meandering of the South Platte River exposing a profile consisting of approximately 1 foot of finely crushed slag and burnt earth overlying a 3 to 4-foot-deep deposit of glassy slag. The amount of slag seems low but according to the historical records the smelter was only run successfully for a few short campaigns. A large slag pile is not visible in the 1887 photograph of the plant and this may represent the entirety of the slag from the plant. Small holes and piles of slag indicate artifact hunting at the site is ongoing.

Figure C- 20. Hall Valley, Feature 12 slag pile looking east. Edge of pile has been truncated by erosion from North Fork of the South Platte River.

Feature 13 is a large piece of unidentified piece of equipment in the active channel of the South Platte River (Figure C- 21). The artifact is a large cylindrical wrought iron shell 72-inches in diameter, and 87-inches long. The cylinder consists of several sections that were bolted together. A cast iron flange, 6-inch wide and 6-inches tall, has been bolted around one end cylinder. Additional wrought iron plates lie partially under the cylinder in the bed of the creek. The artifact may be a portion of the water jacket to one of the furnaces.

Feature 14 is a short length of wagon road that originates at the east edge of Feature 12 and heads east. The road is approximately 12 feet wide and can be traced for only a short distance before it disappears into the surrounding forest. This appears to be a section of the road depicted on the 1883 GLO plat of the mill site.

Figure C- 21. Feature 13, part of water jacket (?) within South Platte River.

Feature 15 is an anomalous pile of burnt fire brick east of the smelter building on the south side of the wagon road.

The 2018 revisit identified the foundations of three of the six structures depicted on the 1883 GLO plat for the site. The outlying log houses and the shop shown on the map were not relocated. A georectified version of the plat map shows that the structures are within an area currently occupied by the meandering channel of the stream emanating from handcart Gulch. No foundations or other evidence of the structures was identified. Scattered concentrations of common brick and 1880s era artifacts were observed in this eastern portion of the site, but subsurface testing would be required to determine if they are associated with activity areas onsite. No evidence of the bridge or dam was observed. No piers or abutments associated with the bridge crossing the river were observed.