ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/275275387

History and production of the West Mountain (Bingham) mining district, Utah

Conference Paper · January 1997

CITATIONS
6

READS
183

1 author:

Ken Krahulec
Utah Geological Survey

24 PUBLICATIONS 25 CITATIONS

SEE PROFILE

All content following this page was uploaded by Ken Krahulec on 21 April 2015.

The user has requested enhancement of the downloaded file.

History and Production of the West Mountain (Bingham) Mining District, Utah

KENNETH A. KRAHULEC

Kennecott Utah Copper Corporation, Bingham Canyon, Utah

Discovery (1848 to 1863)

Erastus Bingham and his two sons, Thomas and Sanford, began ranching in a wooded canyon in the Oquirrh Mountains in 1848. This was a year after the Latter-day Saint (LDS) pioneers entered the Great Salt Lake Valley, then a part of Mexico (Arrington and Hansen, 1963). They were probably the first Caucasians to recognize mineralized rock in the Oquirrh Mountains and brought their discovery to LDS President Brigham Young.[1] Young, however, wisely counseled the Saints to settle and farm Utah to provide the necessities of life and avoid the pursuit of precious metals:

> Instead of hunting gold let every man go to work at raising wheat, oats, barley, corn, and vegetables and fruit in abundance that there may be plenty in the land (Robertson and Harris, 1962).

Young did, however, encourage the utilitarian production of coal and iron from the Iron Springs area in southwestern Utah, near Cedar City, in 1851. The Mormon (LDS) pioneers also began a lead mine, discovered by Henry Rollins, and furnace for bullets near Minersville in 1858 (Salt Lake Mining Review, 9/15/1902). They also began producing salt from the Great Salt Lake as early as 1847 (Arrington, 1963). In 1864, Young persuaded a wagon train of pioneers headed for Idaho to set up their saw mill in Bingham Canyon (Boutwell, 1905). Logging flourished in the canyon for the next several years (Spendlove, 1937).

In 1848, gold was discovered at Sutter's Mill in California. The eager Forty-Niners rushed through Utah en route to California, but were too busy to notice the strong signs of mineralization in the imposing Wasatch and Oquirrh Mountains near Great Salt Lake City (Fig. 1). During the 1850s the California gold rush subsided, but the famous Comstock Lode silver mines were discovered in Nevada in 1858, as the prospectors migrated eastward in a wave across the Great Basin. On May 9, 1860, the Deseret News ran an article announcing the discovery of copper "in Cedar county, some ten or twelve miles from Camp Floyd" (probably Stockton), although they noted:

> in these days gold is the principal thing sought after, and a man who would engage in copper mining in an inland country like this, might, by some, be considered in a state of insanity (Hansen, 1963).

In October 1862, Colonel Patrick E. Connor and the Third California Infantry entered the Salt Lake Valley and erected Fort Douglas on the bench above Great Salt Lake City. They were stationed in Utah to guard the telegraph and offer protection from the Indians. They were also to watch over the Mormons, whom the Union was afraid were going to join the Confederacy. The infantry had little to actually keep them busy in Utah and were unhappy at not being more involved in the ongoing Civil War (Tullidge, 1881). Connor believed that he had a solution to the "Mormon question": he would encourage his soldiers, many of them veterans of the California Gold Rush, to prospect the mountains for precious metals (Neff, 1940). The publicity resulting from these discoveries would cause the immigration of many non-Mormons and thus dilute the LDS church's hold on Utah politics and culture. In 1863, Connor got what he needed: George Ogilvie rediscovered silver-rich lead ore while logging the large red pines near the head of Bingham Canyon (Boutwell, 1903). Copper had previously been noted in the canyon by John Lowder while logging:

> One day while he and his companions were returning to their camp, they saw what looked to them like copper in a creek bed. They got some out and the next morning decided to look for signs of copper ore which they found on the side of the mountain (Hansen, 1963).

Ogilvie and others reported their discovery to Colonel Connor, who organized a "picnic party" of officers and their wives to accompany Ogilvie to Bingham Canyon. Outcroppings of argentiferous lead ore were located in the upper reaches of the canyon in what became known as Galena Gulch. On September 17, 1863, the "Jordan" was the first claim staked in the present state of Utah by Ogilvie, Connor, and 23 other members of the party (Boutwell, 1903).[2] The claim was located on "extensive exposures of galena" (Boutwell, 1905). In December, the "West Mountain Quartz Mining District" was organized at Gardner's grist mill in present day West Jordan (Fig. 1), with Archibald Gardner named recorder (Spendlove, 1937). Several other important lode claim locations were recorded that fall and the following year, including the Galena in January followed by the Empire, Columbia, Kingston, and Vidette, the latter being the first claims staked on copper occurrences (Boutwell, 1905).

In the summer of 1864, the West Jordan Mining Company was incorporated under the laws of California

[1]Curiously, there are no known written reports of either Native American or Spanish exploitation of the Bingham Canyon mineralization.

[2]The Jordan claim is 5,200 feet long—200 feet for each of its 25 claimants and an additional 200 feet to Ogilvie for the discovery. Having been staked prior to the mining law of 1872, this is the longest claim ever patented.

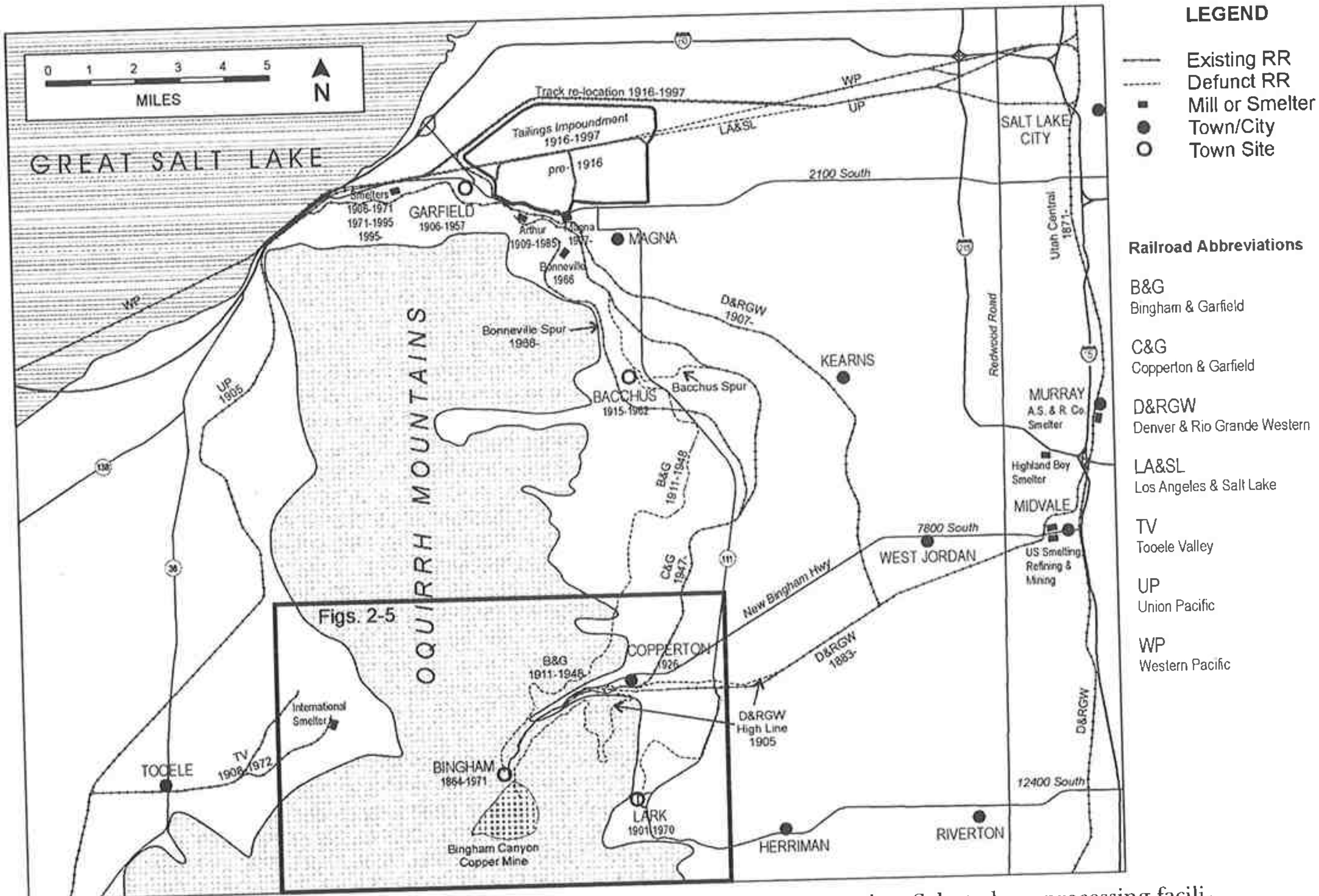

FIG. 1. Location map for the Bingham Canyon porphyry copper mine. Selected ore processing facilities and railroads are shown. The box containing Bingham in the south-center represents the area shown in Figures 2 through 5.

by General Connor and work was begun on a tunnel, the first in Utah (Murphy, 1872). The tunnel was run about 40 feet into The Hill, but the only supplies to reach the district came by ox team, and the freighting, supply, and development costs were too high for economic production (Raymond, 1873). In the end, the sheer remoteness of the district prevented effective development.

The year 1864 also saw Connor's soldiers discover mineral shows in the Little Cottonwood mining district of the Wasatch Mountains and the Rush Valley district on the west flank of the Oquirrhs. General Connor issued the statement:

> [There is] the strongest evidence that the mountains and canyons in the Territory of Utah abound in rich veins of gold, silver, copper, and other minerals, and for the purpose of opening up the country to a new, hardy, and industrious population deems it important that prospecting for minerals should not only be untrammeled but fostered by every proper means (Jones, 1890).

The California Volunteers were disbanded in 1865 to 1866 (Tullidge, 1881). The mining district's laws were revised to allow the soldier's claims to continue to be valid though they had left the territory. This revision was to hamper later development.

These early mineral locations were followed in quick succession by the Ophir mining district in 1865, the Park City and Tintic districts in 1869, and the Camp Floyd (Mercur) district in 1870, as prospectors spread throughout the Territory (Boutwell, 1933). By 1872, there were 44 mining districts in Utah (Murphy, 1872).

Early Development of Gold and Oxide Ores (1864 to 1871)

The miners from that period were mainly interested in gold and silver ores amenable to pan amalgamation and not to Utah's metallurgically complex lead ores (Wegg, 1915).

> [T]he treatment of ores by smelting was a task new to these Californians, and their experience in milling the gold ores of their State was of no service to them (Tullidge, 1881).

However, in early 1864 placer gold was discovered in lower Bingham Canyon by a party of Californians (Murphy, 1872). This being a much simpler extractive process than the hard rock silver and lead ores, gold became the first economically produced mineral in the West Mountain mining district. Over 50,000 ounces of coarse gold (85% gold with 14% silver) were produced by 1871 (Jones, 1890; Boutwell, 1905). The richest deposits occurred in deep canyon gravels up the main canyon over a distance of nearly five miles (Murphy, 1872). The placer miners generally extracted about a quarter ounce of gold per day per man (Raymond, 1870). Placer mining ultimately led to the extraction of nearly 100,000 ounces of gold, including the largest gold nugget (over seven ounces) ever found in Utah (Boutwell, 1905). However, by the early 1870s the placer mines were playing out (Boutwell, 1903).

Although the initial workings at Bingham were for silver, lead, and gold, it was recognized early that copper predominated (Raymond, 1870). The rugged terrain, with peaks reaching nearly 10,000 feet, and meager vegetation above the steep canyon bottoms, combined with the extensive exposures of copper and lead, were favorable for early mine development (Billings, 1948). The first shipment of base metals from the district was a wagon load of copper ore sent by the Walker brothers to Baltimore in 1868 (Bancroft, 1889). A second 10-ton shipment from the Kingston mine by the Woodhull brothers occurred in July 1869 (Hansen, 1963). This ore came from Soldiers tunnel, driven 220 feet in coarse-grained monzonite on the west side of Bingham Canyon about 150 feet above the canyon floor (Murphy, 1872), presently the center of the Bingham Canyon open pit. The tunnel intersected a sheeted vein structure two to five feet wide averaging 10 to 20 percent copper (Chase, 1907). However, important copper production from the West Mountain mining district had to wait 30 years (Rickard, 1919).

The late 1860s and early 1870s saw the discovery of very rich, easily worked silver chloride ores in the Little Cottonwood and Ophir districts, which distracted work from the larger, but lower grade, ore deposits at Bingham. These high-grade discoveries also attracted the attention of eastern and European capitalists (Tullidge, 1881). In 1870, the Woodhull brothers built a smelter below the mouth to Big Cottonwood Canyon and shipped the first bullion produced in Utah. It operated using one cupola blast furnace and one reverberatory furnace. By the end of 1871, a dozen smelters were in operation in Utah (Tullidge, 1881). Most of these smelters were small shaft furnaces treating oxidized ores using charcoal for fuel (Wegg, 1915). The ore was hauled to a smelter by 6- to 20-horse, dead-axle wagons carrying from six to eight tons each (Spendlove, 1937).

Bingham's first practical hard rock mine development began on the silver and lead carbonate lodes of Bristol & Daggett's Winnamuck and Spanish claims in 1870 (Murphy, 1872). The ores averaged over 50 oz/t silver and nearly 35 percent lead. They were reported to be "the only successful mine-owners in the district" (Raymond, 1873). Bingham's earliest smelter, a cupola and blast furnace erected by David E. Buell, and later sold to Utah Silver Mining Company—an English company, began operation using hand-sorted, silver-lead carbonate ores produced during the winter of 1870 to 1871 (Murphy, 1872). Raymond (1873) reported that in most of the early smelters: "half the lead is lost in the slag, or up the chimney" and went on to label the Utah Silver Mining Company operation "extraordinarily unprofitable." Later that same year, however, Bristol & Daggett's Winnamuck smelter's two Piltz furnaces were blown in and operated successfully until 1875 (Boutwell, 1905; Deseret Evening News, 12/20/1919).

In the early days each mine had its own little camp; however, the steep canyon eventually led "most miners to set up housekeeping in the floor of the canyon and gradually the town of Bingham Canyon developed as several camps merged together" (Carr and Edwards, 1989). Bingham Canyon was organized as a voting precinct of Salt Lake County in February 1871, but was not incorporated until 1904 (Spendlove, 1937). By 1874, Bingham had 53 mines and a population of 800 in the one-street string town crammed in the "narrow and tortuous canyon," but significant development still had to await the arrival of the railroad (Utah Mining Gazette, 1874).

Arrival of the Railroads (1871 to 1886)

The first transcontinental railroad was connected at Promontory in northern Utah in May 1869 with a spur completed from Ogden to Salt Lake City by the Utah Central Railroad in early 1870 and south to Sandy by the Utah Southern Railroad in the fall of 1871 (Fig. 1). This eased the shipping of supplies and equipment to Utah and also facilitated the shipment of concentrates and ores from the mines. The bulk of Utah's early exploration and development still concentrated on the rich, oxidized, surface ores of the Little Cottonwood, Ophir, and Stockton mining districts. The first profitable hard rock mine in Utah was the Emma silver mine near Alta (Raymond, 1872).[3] The arrival of the railroad also initiated a period of successful surface prospecting for oxidized base metal ores. As late as 1870, however, Bingham was still only Utah's sixth largest mining district with a meager six tons of production in July (Raymond, 1872).

In the late 1860s liberal Mormons William S. Godbe and Elias L.T. Harrison, publishers of Utah Magazine, established a pro-mining faction in Salt Lake City—the Godbeites. In their support for mining, they were joined by others including the Walker brothers from Alta and the

[3]After a few years of highly profitable production, the Emma mine was purchased by British capitalists. Following the purchase, the mine almost immediately ran out of ore. This set off a huge scandal and soured further mining investments in Utah for some time (Robertson, 1972).

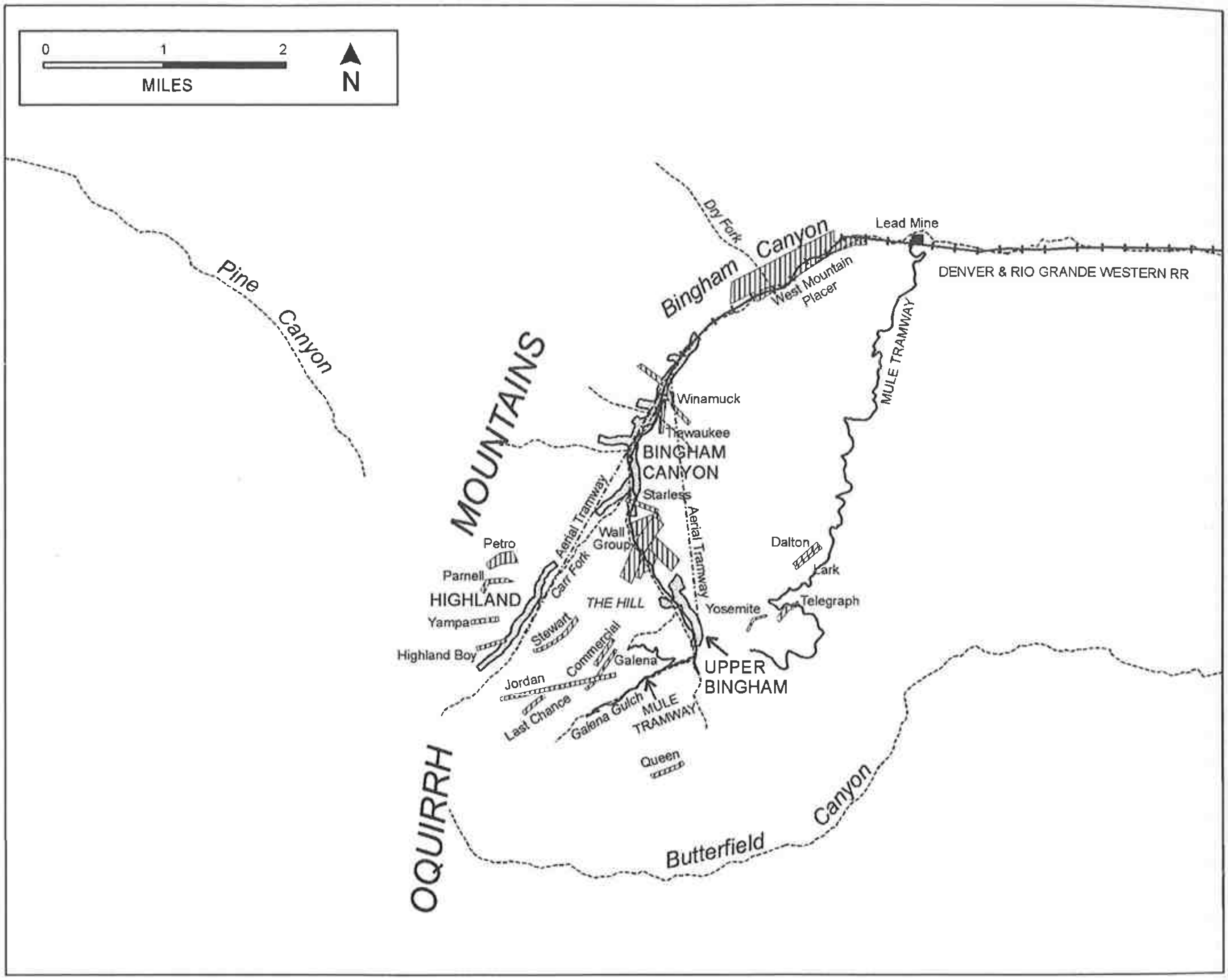

FIG. 2. The West Mountain mining district in the 1890s. This was the era of individual claims, when production was predominantly lead-silver-gold. Mule-drawn and aerial tramways serviced the mines.

Snyder family from Park City. As the mining industry produced boom towns in the Great Basin, it also produced mansions in Salt Lake City (Comp, 1975; Lester, 1979). By 1873, six of Utah's seven banks were owned by non-Mormons (Arrington, 1966).

As a result of the arrival of the railroad, additional claims were located and shallow development was performed on individual claims at Bingham. The Highland Boy claim was located in upper Carr Fork along with the Last Chance above the Jordan (Fig. 2) and the Lead Mine in lower Bingham Canyon (Boutwell, 1905). A second blast furnace for the treatment of supergene-enriched, silver-rich lead carbonate ores was also constructed at Bingham in 1871 (Murphy, 1872).

At this time, the mines were generally hand-operated, near-surface, selective operations mining high-grade oxidized ores using short drifts and shallow shafts which bottomed at the water table (Billings, 1952). Lighting was by tallow drip-candles whose flame was hampered by smoke and gas from the black powder blasts (Robertson, 1972). Transportation of ore was by tram and six-horse team wagons to the nearest railhead or smelter (Billings, 1952). The trams consisted of wooden ore cars on wooden rails with an iron capping (Spencer and Pett, 1953). They were powered by gravity from mine to railhead, and the empty cars were hauled back up to the mine by mules (Spencer and Pett, 1953). The steep grade and icy winter and spring conditions resulted in a few fatal accidents (Spencer and Pett, 1953).

In regard to living conditions, Papanikolas (1965) noted:

> The water was bad and the sanitation primitive; the only protection for the miners was the old-country prescription of whiskey.

There was no municipal sanitation department until 1905 which prompted one editor to refer to Bingham as "a sewer five-miles long" (Engineering and Mining Journal, 1912). However, the presence of "copper sulfate in the water not only killed all bacteria but eliminated offensive odors" (Spendlove, 1937).

By 1871, there were 18 smelters scattered across the central Utah Territory with a total capacity of 348 ton per day (Murphy, 1872). These small, inefficient smelters were later replaced by fewer, larger, more efficient blast furnaces—fueled by Utah coal—centralized in the Salt Lake Valley. This made Salt Lake City one of the first important, nonferrous smelting centers in the United States and allowed the mixing of Bingham's siliceous lead ores with the ferruginous lead ores of the Little Cottonwood mining district. In 1872, the Germania works in Murray became the first refinery in Utah and later added blast and reverberatory furnaces (Wegg, 1915). The capacity of the Germania was initially 50 ton per day (tpd) and it operated almost continuously until 1902, when its capacity was 500 tpd, but its function was replaced by the American Smelting & Refining Company lead smelter at the same site (ASARCO, 1996).

Bingham's Winnamuck, Jordan, Galena, and Spanish mines were some of the largest producers in Utah, and there were over 3,300 claims in the West Mountain mining district alone (Arrington, 1963). Then in November 1873, the Bingham Canyon and Camp Floyd narrow gauge railroad was completed from Sandy Station to the Jordan River and on to the Winnamuck smelter in Lower Bingham (Boutwell, 1905). Curiously, the railroad was laid with three rails as far as the Jordan River to handle either narrow or standard gauge traffic. The track continued on with only narrow gauge to Bingham (Fig. 1). The Bingham Canyon and Camp Floyd Railroad was purchased by the Rio Grande Western Railroad in 1883 and broad gauged in 1890 (Jones, 1890). A 5-mile, mule tramway (Fig. 2) was completed from the terminal at lower Bingham to the Jordan and Galena mines in 1874 (Spendlove, 1937).

By 1874, Bingham Canyon's easily smelted silver-rich, lead carbonate ores, which only extended to the groundwater table at depths of 30 to 50 feet, were largely exhausted in the principal mines as the underlying sulfide zone was encountered. The Winnamuck smelter shut down in 1875 (Boutwell, 1905). Without concentrating, the sulfide zones, which were zinc-rich, were poor smelting ore, and there was little water available in the canyon to run mills (Raymond, 1875). The first concentrator was built by A.H. Bemis in 1874 to treat low-grade lead ore (Spendlove, 1937). Additional stamp mills were constructed at the Jordan, Stewart, and Stewart No. 2 mines. The complex galena-sphalerite-chalcopyrite ores made good recovery and clean concentrates difficult to obtain. In addition, amalgamating or leaching plants were constructed in an attempt, generally financially unsuccessful, to extract gold from the oxidized ore (Boutwell, 1905). Concentrating plants were erected for the treatment of sulfide ores. From 1879 to 1894, the oxidized ores of the Stewart and Stewart No. 2 claims were worked with a 20-stamp mill capable of handling 50 tpd (Spencer and Pett, 1953).

The focus of early silver-rich, lead carbonate production in Bingham Canyon eventually shifted to Butterfield Canyon (Fig. 2), immediately to the south (Huntley, 1885; Boutwell, 1905). By the mid-1880s the Brooklyn, Yosemite, and Lead Mine had become Bingham's leading lead producers (Boutwell, 1905).

The collapse of the French copper syndicate undermined the price of copper in 1889 (Hansen, 1963). This was followed by the governments of the United States and India stopping the routine purchase of silver for coinage resulting in the Great Silver Crisis of 1893. Many of the early silver camps of the West collapsed with the price of silver. The value of the West Mountain mining district's production promptly fell by 20 percent (Butler et al., 1920). The financial panic of 1873 and the ensuing depression caused two Utah banks to fail (Arrington, 1966). Many of the out-of-work silver miners in the Bingham camp turned their attention back to the gold placers (Engineering and Mining Journal, 1893). By 1882, however, mining was again a major force in Utah's economy.

> The total values of [Utah's] imports was estimated at \$11,410,000 and of exports at \$11,525,000, ... the exports of metals alone amounting to \$9,000,000 (Bancroft, 1889).

Huntley, in 1885, noted that the water in Bingham Creek draining The Hill (Fig. 2) between Carr Fork and Copper Center Gulch contained copper in solution and native copper had been deposited in the organic-rich parts of the creek bed.

> Attention was first drawn to the peculiar properties of the water in the immediate locality by the late Dr. Hickman, who constructed some ordinary ground sluices and after filling them with scrap iron, turned the water of the creek through them. In from six to ten weeks time his iron would be converted into a mass of metallic copper, about 85 percent pure (Engineering and Mining Journal, 1897).

Boutwell (1905) described masses of iron-cemented gravels in the creek. Together, these conditions indicated the oxidation of a large copper sulfide system upstream. Huntley (1885) also noted that gold had been discovered in Barneys Canyon, a few miles north of Bingham in 1878, but the significance of this discovery would go unrecognized for another hundred years.

Initial Sulfide Ore Development (1887 to 1903)

With gold and silver production on the wane, but a strong demand for copper as a result of its utility in electrification, and an inability of the high-grade Michigan and Montana underground mines to supply the booming new demand, copper production in the West Mountain mining district finally came to the forefront. Bingham had become an important mining camp having been rebuilt after a destructive fire in November 1880 (Barrett, 1971).

The town of Bingham lay at the fork in the canyon with the villages of Upper Bingham near the head of the main drainage to the south and Highland up Carr Fork to the west (Fig. 2).

In July 1887, Enos Andrew Wall was riding up Bingham Canyon and noticed green discoloration of the rocks near springs coming out of both sides of the canyon, and the entire stream bed had been dyed green (Spendlove, 1937). Investigating the abandoned tunnels nearby, Wall found disseminated copper mineralization in monzonite, channel samples of which aggregated 70 feet of 2.4 percent copper. At the claim recorder's office he realized that some of the old claims to this ground had been dropped, including the Kingston, and were open to relocation (Spencer and Pett, 1953). Wall staked the open ground covering the exposures of copper-stained monzonite.

Wall was a successful inventor, mine developer, and a past-president of the upper house of the Idaho Territorial Legislature. He had invented, patented, and produced the Wall Roll Crusher for grinding mills (Barrett, 1971). Wall had also developed and sold the Queen of the Hills silver mine at Ophir, Brickyard gold mine at Mercur, and the Yampa mine in Carr Fork. Wall then turned his attention to this intriguing occurrence of disseminated copper in monzonite that he had found in several of the old tunnels. By 1887, he had assembled a 179-acre claim block (Wall Group, Fig. 2) in the heart of the district, including the old Soldiers Tunnel property, which consisted of small veins of high-grade copper ore in a mass of low-grade monzonite. By 1896, he had driven a total of about 3,250 feet of tunnels, drifts, and crosscuts in the mineralized monzonite (Rickard, 1919). However, selective mining of the veins had always

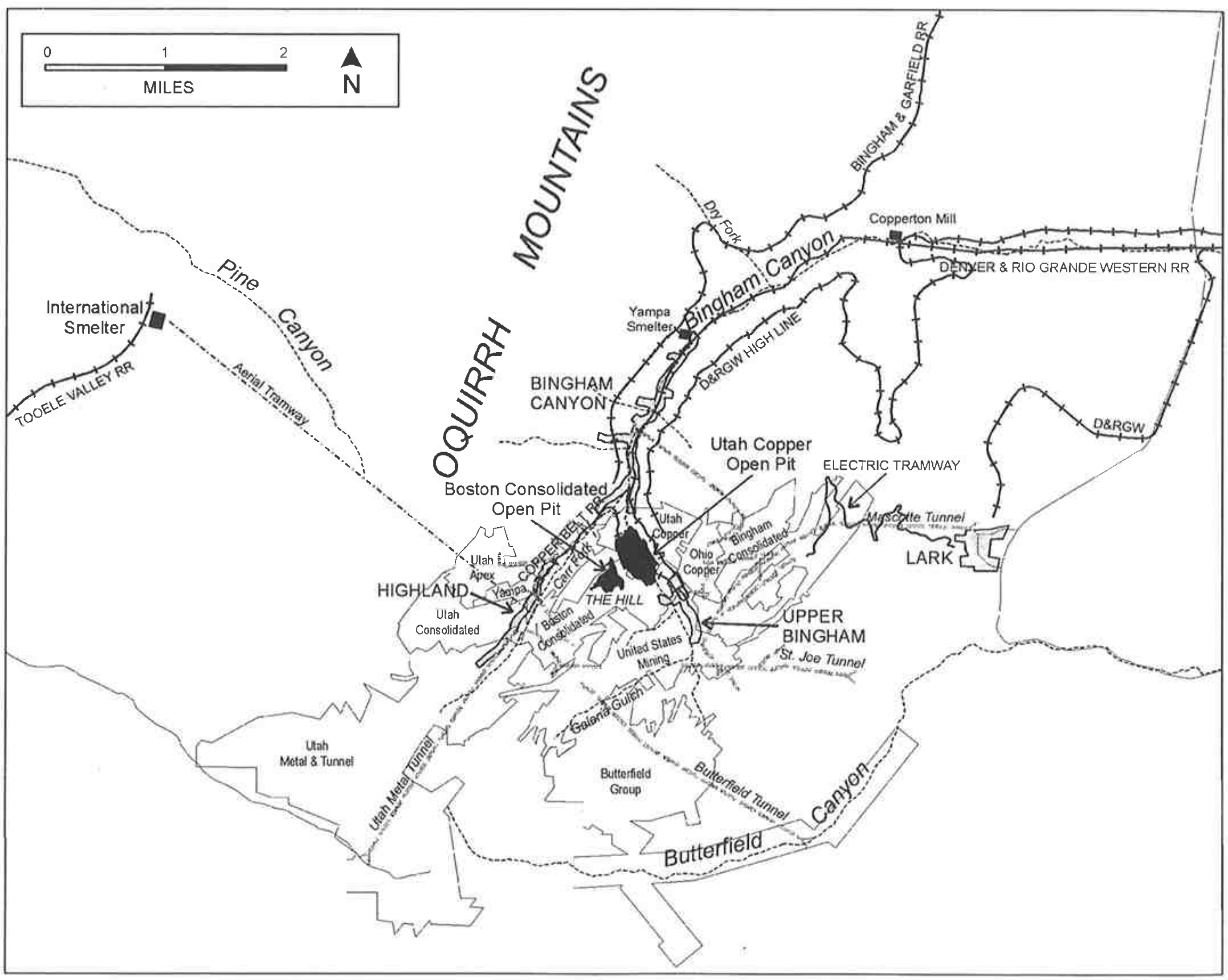

FIG. 3. The West Mountain mining district circa 1910. Individual claims have been consolidated into larger, more efficient operations. The two small open pit copper mines indicate the emergence of copper production. The peripheral lead-silver zone is being exploited by deep level drainage/haulage tunnels.

proved unprofitable and no one was interested in 2 percent copper ore, irrespective of the tonnage available (Billings, 1952). This mineralization became derisively known as "Wall-rock."

Prior to 1880, several small copper producers operated in the West Mountain mining district, including the Kingston, What Cheer, Hickman, Washington, and Murphy mines (Huntley, 1885). However, as late as the mid-1890s, Bingham's major mines were still dominantly silver-lead producers: Jordan, Galena, Brooklyn, Telegraph, York, Petro, and Yosemite (Wegg, 1915).

The Highland Boy mine

In the mid-1890s, Samuel Newhouse, a promotor, and Thomas Weir, a successful mine operator, formed a partnership to promote the sale of mining properties to English capitalists. Their first promotion, a gold mine in Sevier County, Utah, developed title problems after Newhouse had secured a $250,000 check to purchase the property. Embarrassed by the situation and reluctant to return the money, Newhouse and Weir cabled London to allow them to use the money to instead buy ten claims Weir had optioned in Carr Fork. These claims included the Highland Boy gold mine. Permission was granted and development work begun (Hanchett, 1937).

The resulting Utah Consolidated Gold Mines, Ltd. was formed in 1896, the year Utah became a state, as a successor to Sevier Gold Mines, Limited. Utah Consolidated attempted to recover the nearly 0.5 oz/t gold from the oxide zone on the property, but the gold recovery using a 100 tpd cyanidization mill was hindered by the abundance of copper—resulting in only 50 percent recovery with accompanying high cyanide consumption (Jones and Wilson, 1949; Hansen, 1963). Copper had been encountered in many of the old gold mines, but its occurrence was either concealed or avoided, because it interfered with the gold recovery (Boutwell, 1905). That Fall, while Newhouse was in Denver attempting to raise additional funds, Weir intersected high-grade copper ore 200 feet thick and 350 feet long in the Highland Boy mine (Atkinson et al., 1973). The ore averaged 12 percent copper, 2.8 oz/t silver, and over 0.2 oz/t gold (Hansen, 1963).

> The No. 1 shoot in this mine is not only the largest ore body yet opened in Bingham, but is one of the largest single bodies of copper-iron ore in the world that are known to have been deposited by replacement (Boutwell, 1905).

Their first copper sulfide ore was shipped in May 1897, and the era of important copper production at Bingham had begun (Hansen, 1963).

By May 1899, Bingham's first copper sulfide smelter, the Highland Boy smelter, was in operation in Murray. This 250 tpd reverberatory smelter was supplied by a 500 tpd concentrator constructed at the mine in 1901 and by a 12,700-foot aerial tram (Fig. 2) completed in 1897 (Stevens, 1907). Utah Consolidated became Utah's largest copper producer with over 11,000,000 lbs produced in 1902 (Stevens, 1903). The property was soon purchased for $12,000,000 by Utah Consolidated Mining Company, Limited, composed of H.H. Rogers, William Rockefeller, and associates, also known as the Standard Oil Syndicate (Salt Lake Mining Review, 4/15/1899). Newhouse received $3,000,000 from the sale. The operation was so successful that the smelting capacity was immediately doubled to 500 tpd and later doubled again to 1,000 tpd (Hansen, 1963). The copper matte carried 35 to 40 percent copper and the bullion ran 99.1 percent. The Highland Boy mine became one of the leading innovators in the camp using machine drills, electric fuses, and mule-powered ore cars (Boutwell, 1905).

By 1906, there were 40 mines producing copper in the West Mountain mining district and three large copper smelters in the Salt Lake Valley. The sulfurous emissions damaged nearby crops and livestock, which led to a court suit and an order that compelled all copper sulfide smelters to cease operations in the Salt Lake Valley by January 1907 (Arrington and Hansen, 1963).

Utah Consolidated instigated the construction of the International Smelting copper smelter on the west side of the range near Tooele in July 1910 (Fig. 3). Since several older smelters in Salt Lake Valley were being dismantled at this time, they provided an inexpensive source of building materials for the new $3,000,000 smelter (Comp, 1975). The 1,500 tpd smelter used reverberatory furnaces with off gases put through a large bag-house dust collector (Mining and Scientific Press, 3/9/1912). They also constructed the seven-mile-long Tooele Valley Railroad to hook up to the San Pedro, Los Angeles, and Salt Lake main line (Fig. 1). Fearful of smoke damage lawsuits, they took options on the nearby farms, did background environmental studies, set up a self-recording weather bureau, and built a 350-foot smokestack (Comp, 1975). Unfortunately, the Highland Boy mine soon ran out of its abundant copper ore, and the new smelter had to add a lead-silver ore blast furnace in 1911 to 1912 with electrostatic precipitators. Utah Consolidated added a 500 tpd copper concentrator to the site in 1922. The concentrator was purchased by International Smelting in 1924, converted to lead-zinc ores, and expanded to 1,000 tpd in 1925. The copper plant was finally closed in 1946. The remodeled smelter operated until 1971, and the entire complex was razed in 1972 (Steinbach, 1975?).

Around the turn of the century, several innovations eased the backbreaking work at the mines: large steam plants were built to supply compressed air for machine drilling and electricity generation. Also aerial tramways were constructed for ore haulage (Billings, 1948). The pumping of water was just becoming a problem, and the Winnamuck and West Mountain placer had installed powerful Cornish pumps (Boutwell, 1905). Access between Bingham and Salt Lake City was by a two-horse team stage line, which left Bingham at 7:00 am and arrived in Salt Lake at 10:30 (Spendlove, 1937). Even after the arrival of the railroad, stages still ran from the railhead in Lower Bingham to the various mining camps farther up the canyon (Spendlove, 1937).

The narrow, one street town of Bingham was booming, with 30 saloons, bordellos, and gambling joints open 24 hours a day (Robertson and Harris, 1962).

> There was a regular red-light district, but on paydays two-hundred fifty prostitutes came into town and men gave up their rooms to accommodate them during their stay (Papanikolas, 1965).

In addition to the hazards of fire, which were endemic to mining camps throughout the arid Western United States, Bingham's location in the bottom of a steep, narrow canyon also subjected it to flash floods, landslides, and snow avalanches (Robertson and Harris, 1962). However, the ability of the camp to weather adversity resulted in its nickname "Old Reliable" (Salt Lake Mining Review, 12/30/1900).

Property consolidation

The success of the Highland Boy mine led to copper replacing lead-silver as the dominant product of the West Mountain mining district. It also led to increased exploration and development work at other Bingham properties, which proved successful at the Jordan, Commercial, and Yampa claims (Billings, 1952). In 1899, several of the silver-lead mines around Galena Gulch were consolidated as the United States Mining Company (Billings, 1952). The Utah-Apex Mining Company consolidated the New York and Copperfield claim groups in upper Carr Fork below the Highland Boy, added the Dana and Petro groups of the Phoenix Mining Company, and developed a 250,000-ton reserve of 2.5 percent copper with fair gold and silver values (Stevens, 1907).

The Commercial and adjoining claims to the north were consolidated into the Bingham Gold & Copper Mining Company (Bingham Mines) in 1901 (Bingham Commercial Club, 1909). Their high sulfide ore ran 2.5 to 3 percent copper and 0.1 to 0.15 oz/t gold and was the perfect smelting complement to the more common siliceous copper ores of the district (Stevens, 1903). The Dalton & Lark and Brooklyn-Yosemite claim groups were added and the company was reorganized into the Bingham Consolidated Mining Company, controlling about 300 acres (Hansen, 1963). Bingham Consolidated also developed the 7,000-foot Mascotte drainage and haulage tunnel (Fig. 3) under the Dalton & Lark property with a portal at Lark and built a 500-tpd smelter at Bingham Junction (now Midvale, see Fig. 1). The smelter, with two blast furnaces designed for copper sulfide ores, was completed in January 1901. The smelter produced about 10,000,000 lbs of copper in the first year, initially from the Brooklyn mine. This production ranked as the third largest copper producer in the state behind the West Mountain mining district's[4] Utah Consolidated and United States Mining and Smelting Company (Stevens, 1903; Hansen, 1963). By 1907, the smelter had been expanded to 1,000 tpd (Stevens, 1907).

The Yampa Consolidated Company also followed this trend, bringing together the Yampa and seven adjoining claims. In late 1903, Yampa Consolidated built a 12,300-foot long aerial tramway to haul their self-fluxing copper sulfide ore from the Yampa mine down to their new 250-tpd Yampa reverberatory smelter in Bingham Canyon, just below the town of Bingham. The difficult ground conditions at the Yampa mine required square-set timbering, a method developed for the unstable ground in the Comstock silver mines, Nevada. The Yampa smelter was enlarged to 1,000 tpd by 1909, processing about 800 tons from the Yampa and the rest from custom work. However, the smelter was closed when Yampa Consolidated was taken over by International Smelting in August 1910 (Spendlove, 1937).

Similarly, Utah-Apex completed a 2,200-foot aerial tramway and 2,300-foot railway spur in 1906, and American Smelting & Refining Company erected a large, $1,000,000 lead smelter at Murray (Fig. 1) in 1901 (Billings, 1952). The American Smelting & Refining custom smelter operated with eight blast furnaces (ASARCO, 1996). Likewise, the Ohio Copper Company consolidated a 120-acre group of claims on the east side of Bingham Creek previously held by the Columbia Copper Mining Company (Boutwell, 1905).

While this property consolidation was going on, considerable development work was also in progress. The narrow canyons and steep mountains had been serious obstructions to building a railroad, but the Copper Belt Railroad (Fig. 3) was finally constructed from the end of the standard gauge railroad at lower Bingham to Galena Gulch over the old Jordan mule tramway right-of-way in 1901 and on to the upper reaches of Carr Fork in 1903. It was a steep, narrow-gauge track with sharp curves, utilizing short, powerful, gear-driven steam locomotives capable of hauling a few hundred tons (Spilsbury, 1905).

Extensive drainage and haulage tunnels were driven from the bottom of the major drainages during this period (e.g., 8,766-foot Butterfield tunnel, Fig. 3) (Boutwell, 1905). Soon tons of timber, blasting powder, machinery, fuel, and merchandise were being shipped into the camp while ore, concentrate, and metal were shipped out.

By this time, the less labor-intensive block caving method of mining had been introduced in Utah by Duncan McVichie, first across the range at Mercur, and then in Bingham Consolidated Mining & Smelting Company's Commercial mine at Bingham Canyon (Billings, 1948)[5]. Four long, aerial bucket tramways were operating from the Jordan-Galena, Highland Boy, Yampa, and Commercial mines to the Rio Grande Western depot three-quarters of a mile below Bingham for the transport of the ore to the concentrator or smelter

[4]By the turn of the century, the popular name for the West Mountain mining district had changed to the Bingham mining district.

[5]This may be the first application of the underground caving system to copper mining.

(Billings, 1952). On the east side of the district, the tramway from Lead Mine to Lark (Fig. 2) was replaced by the Dalton & Lark Railroad (Fig. 3), a branch of the Rio Grande Western, in 1902 (Carr and Edwards, 1989). Bingham Consolidated then constructed electric surface tramways (Fig. 3) from its Dalton & Lark and Fortuna operations down to loading bins at the Lark railhead (Billings, 1952).

Prelude to Disseminated Copper Mining

Most of Bingham Canyon's copper ore, like that from the Wall Group, was low grade which required property consolidation so that the mines could be developed economically on a large scale (Boutwell, 1905). The Wall Group was submitted to many of the important people in copper mining in the western United States, including Benjamin Guggenheim of American Smelting & Refining, Marcus Daly of Anaconda, and Senator W.A. Clark of United Verde, but all turned it down (Deseret Evening News, 1919). Finally in the mid-1890s, Joseph R. DeLamar, who had an interest across the Oquirrh Mountains at Mercur, sent Hartwig A. Cohen, his general manager, Daniel C. Jackling, metallurgist, and Robert C. Gemmell, mining engineer, to examine Wall's property submittal. DeLamar's Mercur gold mine had the largest gold mill in North America, the Golden Gate mill, which processed 1,000 tpd by cyanide extraction. Gemmell took 566 channel samples in the tunnels on the Wall Group, including the old Soldiers tunnel (Cohen, 1898). Jackling processed a 76-ton sample from the Mackintosh tunnel through the Little Giant Chief mill in Markham Gulch and recovered 59 percent of the copper. Cohen's report cited an indicated reserve of 15 million tons at 2.22 percent copper and 0.018 oz/t gold (Cohen, 1898). Cohen concluded, however, that the proposition was unprofitable, because the 50-foot-thick, partially leached capping "... cannot be removed, so as to make the profitable sulphide ore underlying it available for cheap quarrying" (Cohen, 1898).

A later review of the Jackling and Gemmell report by Victor M. Clement for DeLamar showed a proven reserve of 12 million tons averaging 1.98 percent copper, 0.15 oz/t silver, and 0.016 oz/t gold with an additional 25 million tons probable "by quarrying or by caving" methods (Clement, 1899). In a more complete test running 575 tons through the old Rogers five-stamp, 25-tpd mill Jackling calculated 75 percent recovery, a concentrating ratio of 16:1, and an ultimate profit of $2.83 per ton (Kennecott, 1939). The report concluded:

> For working the property, it is proposed to build a concentrating plant of 2,000 tons daily capacity, near the point of the mountain between Salt Lake City and Garfield Beach, where water is plentiful and railroad facilities good. This plant would be connected with the mine by 15 miles of standard gauge railroad. The ore would be worked by quarrying or open pit methods, the overlying deposits of waste and low-grade material being first stripped off the ore and hauled by railroad to the most convenient dumping ground. (quoted in Kennecott, 1939).

In the end, Clement was unable to secure a mutually acceptable agreement with the irascible Wall and left for new mining opportunities in Mexico taking Gemmell with him (Parsons, 1933). DeLamar eventually held options on the Wall Group on three separate occasions, but never actually owned more than a 25 percent interest in the property (Rickard, 1919).

In 1903, after leaving DeLamar's employ, Jackling went to Republic, Washington, and then became the general manager for United States Reduction and Refining Company's Canon City Bartlett zinc-pigment plant in Colorado. U.S. Reduction was controlled by Spencer Penrose and Charles MacNeill, who had made considerable money in the Cripple Creek mining district of Colorado (Kennecott, 1939). Jackling returned to Salt Lake City, and with the help of Cohen and a local banker and close friend of Wall's, W.S. McCornick, negotiated an option on the 195-acre Wall Group. Utah Copper Company was formed by Penrose (25%) and MacNeill (25%) along with Daniel C. Jackling (5%) and H.A. Cohen (5%) in 1903 and acquired an option to purchase 67.5 percent of the property (including half of DeLamar's 25%) for $545,000 (Parsons, 1933). MacNeill became president of the new enterprise with Spencer Penrose as secretary-treasurer and Jackling appointed as general manager (Fairbanks and Berkey, 1952).

A favorable review of the Utah Copper property by F.H. Minard and R.A.F. Penrose for Charles MacNeill and Spencer Penrose indicated a reserve of 9,000,000 tons of 1.6 percent copper. Minard's report observed that the enriched zone of 2 percent copper was over 100 feet thick, and lay between a 50-foot-thick leached cap which averaged less than 0.75 percent copper and an underlying primary zone with 1.1 percent copper (Minard, 1903, as quoted in Rickard, 1919). Drilling showed that the enriched zone contained covellite and chalcocite and was up to 150 feet thick (Rickard, 1919). The results were sufficiently encouraging for Utah Copper to exercise its option. The company was initially capitalized for $500,000 at $1 per share under the laws of Colorado and later recapitalized at $4,500,000 at $10 per share under the laws of New Jersey in 1904 (Stevens, 1911). In July 1904, Utah Copper purchased Wall's remaining 20 percent interest for $900,000 in company stock and $150,000 in bonds, as well as DeLamar's final 12.5 percent interest by paying $656,250 (Spencer and Pett, 1953).

After the sale of the Utah Consolidated's Highland Boy mine, Samuel Newhouse focused his efforts on securing additional copper-rich properties. Having found copper at the old Highland Boy gold mine, Newhouse apparently decided to try his luck at the old Stewart and Stewart No. 2 gold claims, which adjoined the Highland Boy on the south, and in all probability had also experienced copper metallurgical problems. Newhouse took his new property to the Boston Stock Exchange, a major brokerage for mining companies. When he attempted to start a company with his new claims, his Boston associates told him the 27-acre property was too small to raise a substantial stock play. In a stunning stroke of luck, Newhouse cabled associates in Utah to acquire all available ground between the Stewart claims and Wall's ground. This added over 300 acres, much of it covering barren-looking leached monzonite, plenty of ground for the promotion (Hanchett, 1937). In 1897, he brought these claims together as the Boston Consolidated Mining Company, organized under the laws of New York. The Stewart ore body showed copper oxides at the surface running from 3.5 percent copper and 0.1 oz/t gold with the underlying sulfides carrying 4 percent copper and 0.05 oz/t gold (Stevens, 1903). They also developed an estimated reserve of 200 to 350 million tons carrying 1.5 percent copper, 0.25 oz/t silver, and 0.003 oz/t gold disseminated in monzonite (Mining and Scientific Press, 4/17/1909). However, in the words of the prestigious Engineering and Mining Journal:

> It would be impossible to mine and treat ores carrying 2 per cent or less of copper at a profit under existing conditions in Utah. . . . On the company's own showing, therefore, the more ore it has of the kind it claims, the poorer it is (May 27, 1899).

By 1903, they had also blocked out a higher grade, high-sulfide skarn reserve of about 1,100,000 tons of 2.7 percent copper with 2 oz/t silver and 0.1 oz/t gold credits (Parsons, 1933). This ore carried a high percentage of pyrite and could not be concentrated by the gravity circuits of the time, so it was sold directly to the smelter (Bradford, 1910). Initial production from the high-sulfide skarn began in 1904 by square-set stoping and reached a peak of 1,000 tpd in 1907 (Stevens, 1907).

Porphyry Copper Development

This set the stage for Jackling's Utah Copper and Newhouse's adjoining Boston Consolidated to develop the first successful bulk-minable, disseminated, porphyry copper mines on the 1,500-foot Hill between Carr Fork and the main branch of Bingham Creek.[6] It was literally a mountain of ore. Boston Consolidated, with Louis S. Cates[7] as general superintendent, started development on an underground, high-sulfide skarn operation. The Boston Consolidated had a 2,100-foot long, double track, balance-skip, gravity-operated, inclined tram for haulage from the operations near the top of The Hill to the Carr Fork railhead of the Copper Belt Railway (Stevens, 1908). Boston Consolidated began production from their underground high-sulfide skarn in October 1903, shipping 500 tons of ore grading over 5 percent copper the first month. This high-grade copper sulfide production was used to help supply the funds for Boston Consolidated's later porphyry development work (Spencer and Pett, 1953). The experimental, five-stamp, 100-tpd, Dewey gravity mill was constructed on the Boston Consolidated ground in 1905 (Boutwell, 1905; Engineering and Mining Journal, 1905).

Development of the Utah Copper underground mine began in November 1903, and Jackling constructed an experimental 300-tpd, steam-powered, gravimetric concentrator at Copperton (Fig. 3), which began operation in July 1904, using disseminated ore (Utah Copper Company 3rd Annual Report, 1908). All of the ore on the Utah Copper claims was produced by underground stoping derived from two haulage tunnels driven into the mountain sides as near as possible to the canyon bottom. The first tunnel driven west into The Hill and the second tunnel driven east were known respectively as the Main and Quinn tunnels (Janney, 1905). The Quinn, an old prospect tunnel, was soon replaced by the East tunnel.

In the prophetic words of Boutwell (1905):

> An experiment which may exert much influence upon the future of this district is the mining and concentration on a large scale of the mineralized monzonite at Upper Bingham. Low values in gold and copper are here disseminated through a great laccolithic stock. The Utah Copper Company has secured an extensive acreage (including the Wall group) in that vicinity, and has erected a concentration mill of 500 tons daily capacity in main Bingham Canyon . . . The holdings of other companies, notably the Boston Consolidated, embrace large bodies of this mineralized monzonite, and the work of Utah Copper Company may inaugurate an important new phase of copper mining in Bingham.

The Utah Copper underground operation used top slicing and sub-level stoping from the large loading tunnels on either side of the canyon. Later the underground caving acted as insurance against the shovels in the open-pit operation being unable to supply the mills (Spencer and Pett, 1953). Frank G. Janney, the Utah Copper mine manager and another past DeLamar Mercur mine employee, reported in July 1905 in regard to the underground development work:

> In no instance ... was it found necessary to waste any material whatever from the mine during the past year, everything encountered in our development having been of a profitable grade.

Incredibly, despite the initial development cost, experimental nature of the mill, and the interest due on the bonds, Utah Copper had a positive net income of $142,488 its first year of operation (Utah Copper Company 1st Annual Report, 1905).

The underground production from the east side of the canyon supplied the initial feed for the Copperton mill, but was stopped in November 1909, when the caving stopes threatened the railroad (Spencer and Pett, 1953). Underground production continued on the west side of

[6]In addition to Newhouse's Cactus mine in southern Utah, the Arizona Copper Company, Ltd.'s mine at Clifton-Metcalf, Arizona may also lay claim to low-grade copper production as early as 1901 (Colquhoun, 1970). Neither of these operations, however, proved as successful over the long-term as Bingham Canyon's open pit copper mine.

[7]Cates later became general manager at Utah Copper and went on to become president and chairman of the board of the rival Phelps Dodge Corporation where he is credited with the development of the Morenci open pit copper mine.

the canyon until September 1912, and on the Boston Consolidated property until March 1914 (Weed, 1917). The experimental Copperton mill was gradually modified and enlarged to 1,000 tpd, in part using secondhand machinery from Colorado, before finally closing in August 1910 (Rickard, 1919).

Because of Bingham's low-grade ore and large capital requirements, willing investors were still difficult to find (Hammond, 1961). General Electric was in need of a steady supply of copper and studied the property, but ultimately rejected it when one of the directors remarked that he did "not believe the damn numbers" (Rickard, 1919). At this time, Guggenheim Exploration Company enters the picture through the efforts of John Hays Hammond, who had earlier tried to acquire the Wall property (Hammond, 1935). As Hammond (1935) proposed to Dan Guggenheim:

> There was needed, I said, someone with imagination enough to see beyond the great initial outlay and to grasp the eventual success of large scale operation.

The remarkable trio of Henry Krumb, Seeley W. Mudd, and A. Chester Beatty (all of whom went on to great fame and fortune) did an extraordinarily thorough review of the property at a cost of more than $150,000. The Guggenheim's then purchased $500,000 in Utah Copper stock and $3,000,000 in convertible bonds providing the capital for expansion, and installed Hammond as managing director and Daniel, Murry, and Solomon Guggenheim as directors (Parsons, 1933). MacNeill remained as president and Daniel Jackling as general manager. In 1906, Gemmell returned from Mexico following the death of Clement, and Jackling appointed him general superintendent. Frank Janney became manager of mills for Utah Copper (Rickard, 1919). The Guggenheims were also the largest shareholders in the American Smelting & Refining Company, which agreed to build a copper smelter at Garfield and received a 20-year contract to smelt the concentrates from Bingham Canyon (Parsons, 1933)[8].

By 1905, Boston Consolidated, using the profits from its underground copper-gold-silver sulfide operation, also had an experimental Copperton mill. The test work at the mills showed satisfactory results for both Boston Consolidated and Utah Copper ore (Davey and Morris, 1991). In early 1906, Jackling and Gemmell visited the Mesabi iron range in Minnesota, where steam shovel and rail haulage operations were first developed in 1892. They returned with J.D. Shilling, who became mine superintendent (Parsons, 1933). Steam shovel stripping operations began in June 1906 at Boston Consolidated and in August 1906 at Utah Copper (Fig. 3; Smith, 1975). However, due to a thinner leached cap, Utah Copper began shipping open-pit ore in June 1907 and Boston Consolidated in January 1908 (Boston Consolidated Mining Company Annual Report, 1908). To move the large volume of material, the narrow gauge Copper Belt Railroad was replaced by the standard gauge High Line (Fig. 3) with a low-grade cutoff from Welby (West Jordan) to the mill sites at Garfield from 1905 to 1907 (Salt Lake Mining Review, 10/31/1911).

Utah Copper, after issuing new bonds for $3,000,000 in 1906, $1,500,000 in 1907, and $1,500,000 again in 1908, built the largest (6,000 tpd) electric gravity concentrator in the world for about $3,100,000. The mill site was near Garfield at the north end of the Oquirrh Mountains, 15 miles from the mine (Fig. 1). The site was near the Great Salt Lake, where water and room for the large volume of tailings were readily available. The name Magna was chosen by Jackling for the mill from the Latin for "great." Utah Copper also began construction of a $900,000, 13,000-h.p. steam power plant 2,000 feet from the mill (Mines and Methods, 12/1909). Construction of the Magna mill began in September 1906 and operation started in June 1907 (Gemmell, 1919). The plant was divided into four sections: coarse crushing, fine crushing, concentrating, and dewatering. Similarly, Boston Consolidated built the 3,000-tpd Arthur mill for $1,500,000 nearby, beginning in July, 1906, but not being completed until July, 1909 (Kennecott, 1939). The two concentrating plants were very similar in design except that Magna used Chilean mills for fine grinding, whereas Arthur used 312 fifteen-hundred-lb stamps. The nature of the fine-grained, disseminated chalcopyrite ore necessitated fine grinding which resulted in considerable sliming and only moderate recovery from the gravity circuits (Stevens, 1907).

Guggenheim's American Smelting & Refining Company built the Garfield 2,250-tpd custom copper smelter there, which was completed in August 1906 at an estimated cost of $6,000,000. Prior to this, the Utah Copper ores went to the Bingham Consolidated smelter in Bingham Junction (Parsons, 1933). Since no permanent housing existed at Garfield, construction crews lived out of tents at the site. The smelter consisted of two reverberatory furnaces, two blast furnaces, six acid-lined converters, and eight roasters. The reverbatories were 19 feet wide by 112 feet long and were heated by hand-fired coal grates (Beyer, 1964). The coal and coke used in the furnaces were derived from Utah Fuel Company mines. The capacity of the Garfield smelter was increased to 2,700 tpd in 1908, and became fully operational in 1910 (Arrington and Hansen, 1963). The fuel was changed to oil in 1911, powdered coal in 1915, and natural gas in 1930 (Beyer, 1964). The fine concentrate derived from flotation cells was incompatible with the blast furnaces which ceased operation in 1922 (Beyer, 1964).

The Garfield Improvement Company, formed by American Smelting & Refining (60%), Boston Consolidated (20%), and Utah Copper (20%), purchased

[8]The American Smelting & Refining Company was formed in 1899 as a consolidation of numerous silver-lead smelting companies and was controlled by the Rockefeller syndicate. Although the Guggenheim smelters were not initially part of the American Smelting trust, they joined later, taking a controlling interest.

some suitable ground and constructed the company town of Garfield in 1906 (Utah Copper 2nd Annual Report, 1906). The name came from the old Garfield Beach Resort built in 1881 on the shore of the Great Salt Lake. The resort had been connected to Salt Lake City by a narrow gauge railroad and was popular until the turn of the century. A total of over 100 three-, four-, and five-room houses were built along with hotels, businesses, railroad depots, and an employees' clubhouse (Carr and Edwards, 1989).

The significance of these combined developments were reported by Stevens (1907) in The Copper Handbook:

> At no point on the globe are there developments of greater importance, or that are likely to have a more profound and far-reaching effect upon the future of the copper industry. It is not beyond the bounds of possibility that the Utah Copper Co. is the pioneer in solving the question of the world's future copper supply ... The mining work of the Utah Copper Co. is an evolution, yet it may prove to be the beginning of a revolution also ... the mine must be regarded as a step in advance of anything heretofore accomplished in mining ... and the success of the company, which is not open to question, opens a new and vast field of possibilities in the mining world.

Utah Copper began the distribution of dividends in October 1908 (Stevens, 1919).

Although Enos Wall was made vice president and a director of the new company, he was never satisfied with the Utah Copper operation. He objected to the use of Chilean mills in the Magna plant, and he also condemned the use of steam shovels in the mountainous terrain (Stevens, 1907). Wall may also have been jealous of the young Jackling when he, not Wall, had been asked to become manager of Utah Copper. The problem was exacerbated because Jackling ignored his advice (Rickard, 1919).

In any case, Wall resigned as director of Utah Copper in 1907, sold all his Utah Copper stock, and used the money to purchase Boston Consolidated stock and several surrounding claim blocks. Wall acquired additional ground up Carr Fork adjoining the Boston Consolidated to the north, including the Starless Mine and the Alamo, Gould, and Maxwell claim groups totalling about 260 acres (Bingham Commercial Club, 1909). The Starless had produced some 8.5 to 10.5 percent copper ore with some silver and gold from veins in the mid-1890s (Stevens, 1911).

TABLE 1. Milling Costs per Ton (US$)

	Magna	Arthur
General mill	0.0509	0.0466
Coarse crushing	0.0490	0.0404
Fine crushing	0.1355	0.1696
Concentrating	0.1205	0.0667
General expense	0.1559	0.1942
Maintenance	0.0110	0.0064
Total	0.5228	0.5243
Percent Recovery	67.4%	63.7%

For a decade after the sale of his Utah Copper stock, Wall wrote a long series of anonymous, bitter articles ridiculing the Utah Copper mine, mill, and Daniel Jackling in Wall's personally published Mines and Methods magazine. The magazine carried complete reprints of the Utah Copper quarterly reports with commentary, oversize fold-out photos of the operation, as well as full coverage of the numerous Enos A. Wall vs. Utah Copper and Daniel Jackling lawsuits. A typical quote from the introduction to an article concerning the closure of the Copperton mill follows:

> **"UTOPIAN ORE DRESSING METHODS"**
>
> ONE OF THE UTAH COPPER COMPANY'S MILLS GOING TO THE SCRAP-HEAP
>
> As promised in our last issue we undertake to review as briefly as possible the extraordinary and chequered experience of the managerial department of the Utah Copper Company in its futile and costly efforts to install a successful system of ore dressing, without having first learned at least something of the rudiments of established practice, or sought the advice and aid of those who were familiar therewith. (Mines and Methods, 7/1910)

Mines and Methods ceased publication with Wall's death in 1920 (James, 1978). An enlightening insight into Wall's destructive perfectionism may be gleaned from the following story:

Wall "is said to have viewed in silence a statue of a miner that he had ordered for his Salt Lake home. Finally, he took up a hammer and proceeded to alter the miner's pick, which he felt was held incorrectly, and before he was through the statue was a total wreck" (Barrett, 1971).

At that time, Jackling and his wife Jeane lived near Wall in a mansion at 731 East South Temple. He also, however, supported two notorious ladies "of easy virtue," one in Salt Lake City and one at Bingham (Goodman, 1997). In 1915, his wife, who was rumored to have "drunk in excess," died and Jackling moved into a suite at the Saint Francis Hotel in San Francisco, California, where he remarried a socialite (Lester, 1979).

Merger of Utah Copper and Boston Consolidated

Consolidation of the two parallel and adjoining Utah Copper and Boston Consolidated properties was inevitable. The Boston Consolidated had never been as successful as Utah Copper, in part because their porphyry development on top of The Hill was hampered by thicker (approximately 100 feet) leached cap with a more irregular oxide-sulfide boundary requiring more stripping and a slightly lower initial ore grade of about 1.5 percent compared to Utah Copper's initial 2 percent grade. These difficulties were exacerbated by low copper demand and, in part, by the financial panic in the fall of 1907, which forced delays in the completion of their mill and the personal financial endorsements by its directors: Samuel Newhouse and Frank Schirmer. These difficulties were exemplified in 1909 when Boston Consolidated produced less than 17 million lbs of copper compared to Utah Copper's nearly 60 million lbs (Bradford, 1910). Boston Consolidated had never paid a dividend, while Utah Copper had paid dividends annually since 1905.

Utah Copper, on the other hand, was limited in its mining by the adjoining Boston Consolidated ground up The Hill. In 1910, Utah Copper was recapitalized to \$25,000,000 and merged with Newhouse's Boston Consolidated for 310,000 Utah Copper shares valued at \$18,832,500 (Spencer and Pett, 1953), a price which was reportedly a good buy for Utah Copper (Parsons, 1933). The deal was arranged by Samuel Untermyer, the lawyer for both sides (!), who was paid a \$775,000 fee (Robertson and Harris, 1962). At the same time, Utah Copper purchased Shawmut Consolidated's 100 acres, the Payroll group of 175 acres, and outlying fractional claims totaling another 11 acres bringing their total to 665 acres of mineral claims in the West Mountain mining district (Stevens, 1912).

At the same time, Utah Copper also attempted to purchase the Nevada Consolidated at Ely, Nevada, another of the Guggenheim porphyry copper deposits. However, the takeover was opposed by the President of Nevada Consolidated and slightly less than half of the stock was turned in (Mines and Methods, 1910). This left the Guggenheim Exploration Company with a significant interest in the new Utah Copper Company.

Samuel Newhouse was a flamboyant entrepreneur. He constructed the twin Newhouse and Boston Buildings, as well as the lavish Newhouse Hotel and over two dozen other buildings in downtown Salt Lake City. In addition, he donated the land for construction of the Commercial Club (chamber of commerce) and Salt Lake Stock Exchange. He initiated a second copper mining project at the Cactus copper mine in southwestern Utah; interestingly, this was the first open-pit copper deposit in the world to use steam shovels, opening in early 1906 (Mines and Methods, 8/1910). Unfortunately, as Stevens (1908) notes:

> Apparently there has been much manipulation of this stock [Newhouse Mines and Smelters] in the New York and Boston markets, and many misleading statements have been put out regarding production, costs and net earnings.

In any case, after building the town of Newhouse, a 1,000-ton mill, power plant, railroad, and long drainage/haulage tunnel, the Cactus project failed.

Newhouse was married to a beautiful young woman, Ida, who lived mostly in London, where Samuel did much of his financing. "She soon caught the eye of the philandering [King] Edward, and between the years 1904 and 1910 Ida was a frequent guest at the Edwardian court" (Lester, 1979).

A series of financial setbacks, combined with Newhouse's personal extravagance, ultimately brought down his financial empire (Rudd, 1978). He later ruefully observed that when he had agreed to the Utah Copper and Boston Consolidated merger he had sold "Aladdin's Lamp" (Hanchett, 1937).

The early days of the newly combined Utah Copper Company saw an escalation in the size and proliferation in the number of pieces of equipment. Utah Copper's Copperton mill was dismantled in August 1910 and the usable equipment was sent to the Arthur mill for its remodeling. A careful comparison (Wegg, 1915) of the two mills for 1910, prompted by Wall's complaints, showed a slight edge to Utah Copper's Magna Plant (Table 1).

The shift from coal-fired to electric equipment was forestalled by the cheap supplies of coal available from mines in Carbon County, Utah (Rickard, 1919). The period June 1907 until March 1914 witnessed the change from combined open-pit and underground operation to complete open-pit production, by which time Utah Copper had approximately 85 miles of underground workings (Utah Copper Company 10th Annual Report, 1914).

Utah Copper was also forced, by very poor service from the Rio Grande Western Railroad, to build its own line to handle its growing production and in September 1911, completed the 22-mile long, standard gauge Bingham & Garfield Railroad (Fig. 3) for \$5,000,000, connecting the mine to the mill (Stevens, 1915). This railroad was shorter, straighter, had an even grade of 2 to 2.5 percent, and employed four tunnels totaling 4,795 linear feet and several graceful, steel-tower and girder-type viaducts across steep canyons as much as 190 feet deep (Stevens, 1912). The new railway connected to the Denver & Rio Grande Western at both Bingham and Garfield with a branch line to American Smelting & Refining's Garfield smelter (Gemmell, 1919). The Bingham & Garfield also constructed a 554-foot, double-track, incline railway, because the line passed over 200 feet above the station at the town of Bingham (Bingham & Garfield, 1939). The Bingham & Garfield operated four passenger trains a day between Bingham, Garfield, and on to Salt Lake City over the Union Pacific tracks into the 1920s (Kennecott, 1956). Improvements and enlargements were also instituted at the two mills with the Arthur mill increased from 3,000 to 8,000 tpd and the Magna mill enlarged from 6,000 to 10,000 tpd (Parsons, 1933).

By 1912 Utah Copper had:

> the largest developed ore body in the world, its proven tonnage exceeding that of the Rio Tinto, its nearest copper competitor, and even exceeding the proven tonnage of the greatest of the enormous iron mines of the Mesabi range, and exceeding the developed tonnage of gold ore of all of the combined mines of the Witwatersrand. Not only has the Utah Copper Co. the largest body of developed ore of any mine, but it also is, at present, the greatest ore producer, measured by tonnage, of any mine of any metal (Stevens, 1912).

In the fall of 1912, a strike was called against all of the companies operating in the West Mountain mining district by the Western Federation of Miners. Nearly 5,000 workers went on strike for a 25 percent raise and an end to the padrone system, patrons who worked as labor agents to recruit new workers (Spendlove, 1937). The problems with the padrone were centered on a Greek labor agent, Leonidas Skliris. The workers claimed Skliris was an extortionist who demanded tribute from the workers for getting them jobs. Thousands of men went on strike against the companies. The companies responded with hundreds of guards and strikebreakers, and a month later slowly returned to production without the strikers. Violence broke out and a total of ten men, on both sides, were shot, two fatally. The companies refused to negotiate with the union, but in the end the workers received a 12.5 percent raise and Skliris resigned (Papanikolas, 1965). Work at Utah Copper was disrupted between September 18 and October 9, but it took five months for the companies to return to normal operation (Bailey, 1988).

The Hercules Powder Company was looking for a site in the western United States to take advantage of their expanding explosives business with mining companies (Dyer and Sicilia, 1990). Hercules had been formed by the United States courts in 1911 to 1912 from the breakup of the Du Pont powder trust under the Sherman Antitrust Act. In 1913, Hercules opened a sales office in Salt Lake City and acquired 2,300 acres along the Bingham & Garfield Railroad south of Magna to construct a dynamite plant (Dyer and Sicilia, 1990). Named Bacchus, after a corporate vice-president, the 12,000,000-lb per year plant began operation in March 1915 and included a company village. The village encompassed a general store, barber shop, school, and 42 houses (Carr, 1990). Dynamite production at the Bacchus Works continued nearly without interruption for almost 50 years in parallel with the fortunes of the Bingham Canyon mine, until Utah Copper's conversion to ANFO (ammonium nitrate) in 1961 led to Hercules' closure of their dynamite line in 1962 (Dyer and Sicilia, 1990).

Ohio Copper Company

A third company which attempted early development of disseminated copper ore at Bingham Canyon was the Ohio Copper Company (Fig. 3), incorporated in 1903 under the laws of Maine. Early production came from high-grade copper fissures in quartzite. About 1906, F. Augustus Heinze acquired control of the Ohio Copper Company, which he reorganized in 1907, when he also purchased the Mascotte tunnel from Bingham Consolidated (Billings, 1948). Like Boston Consolidated, Ohio Copper and Heinze were damaged by the financial panic of 1907. Heinze was infamous for his apex litigation and underground wars with Anaconda at Butte, Montana, but no such battles occurred at Bingham. However, as Stevens (1911) reported on Ohio Copper:

> The stock has suffered, marketwise, through its domination by Mr. Heinze, whose devious methods of management have wrecked various other companies.

Heinze put Duncan McVichie in charge of the operation where McVichie introduced the finger-raise system of block-caving (Billings, 1948). They also constructed a 4,000-tpd concentrator near the mouth of the Mascotte tunnel at Lark which commenced operation in 1909 (Stevens, 1908). Ohio Copper had lower grade ores (about 13.5 million tons of 1.64 percent copper, largely developed in quartzite, a poor host rock) than the neighboring Utah Copper. It is noteworthy, however, that the quartzite-hosted ore made a better concentrate than the monzonite, being free of clays and the sulfide minerals were not as fine-grained, thus requiring less crushing, causing less sliming, and resulting in a higher recovery rate (Ohio Copper Company Annual Report, 1909). Ohio Copper was reorganized into the Ohio Copper Company of Utah about 1917 (Ohio Copper Company Annual Report, 1917). In August 1918, fire destroyed the Ohio Copper mill at Lark, which was rebuilt in 1919. However, the postwar recession closed the plant from 1919 to the fall of 1922 (Ohio Copper Company Annual Report, 1923).

These difficulties brought with it innovation, and in 1923 Ohio Copper began using low-cost, in situ, leaching methods to produce copper from broken ore:

> The method of operation, consisting of leaching in place and precipitation, in use at our property, which so far as we know is the first successful operation of its kind, is attracting wide interest in the industry (Ohio Copper Company Annual Report, 1923).

In situ leaching proved mildly successful, producing over 44 million lbs of copper before Ohio Copper closed down again in March 1931, due to declining production and low copper prices (Utah Copper Company Annual Report, 1931). By 1937, Ohio Copper was in default on its bonds and taxes and sold all of its surface rights at Bingham to Utah Copper for $600,000 which alleviated the company's indebtedness (Ohio Copper Company Annual Report, 1937).

Although Ohio Copper managed some production during World War II, mainly through the leaching of its old tailings which averaged 0.4 percent copper, the end was in sight. In 1948, the Lark mill buildings were sold and, in 1950, the old Ohio Copper property was purchased by the United States Smelting, Refining and Mining Company (Billings, 1952).

Non-Porphyry Ores

Production of lead, silver, gold, and zinc ores in the West Mountain mining district was continuous from 1874 to 1971 (Butler et al., 1920). However, the number of operating lead-zinc-silver companies at Bingham decreased from 22 in 1909 to 12 in 1930, nine in 1942, three in 1950, one in 1970, and none today (Smith, 1975).

The court action of 1907, regarding smelter fumes, forced the closure of the Bingham Consolidated smelter and led Utah Consolidated to move their copper smelter from Murray to Tooele on the west side of the range (Smith, 1975). The financial panic of 1907 in conjunction with the loss of its smelter bankrupted Bingham

Consolidated in late 1907, and it was reorganized as Bingham Mines Company in 1908 (Stevens, 1908). In 1913, they connected their Yosemite shaft with Ohio Copper's deep level Mascotte tunnel (Engineering and Mining Journal, 4/19/1913).

The International Smelting & Refining Company Inc. built the Tooele smelter works. This smelter was connected to the Highland Boy mine by a 21,100-foot long areal tramway surmounting the crest of the Oquirrh Mountains (Spendlove, 1937). The tram carried 1,200-lb ore buckets, spaced 200 feet apart at a rate of 600 feet per minute (Steinbach, 1975?). International Smelting & Refining Company was acquired by Anaconda in 1914 (Elton and Saskett, 1929).

On June 22, 1913, The Utah Metal and Tunnel Company completed an 11,494-foot tunnel (Fig. 3) from Middle Canyon on the west side of the range to their property in Carr Fork (Wegg, 1915). Utah Copper leased the water rights on the west side and brought a potable water pipeline through this tunnel to Upper Bingham and Carr Fork (Spencer and Pett, 1953). In 1914, Utah Metal absorbed the adjacent Bingham-New Haven Copper & Gold Mining Company, a small producer (Hansen, 1963).

Likewise, the Butterfield claim block, on the south end of the district, had two long drainage/haulage tunnels: the 2,750-foot Queen tunnel and the 8,766-foot Butterfield tunnel (Boutwell, 1905). Initially consolidated by the Butterfield Mining Company, the property was later taken over by the Combined Metals Reduction Company (CMR). CMR controlled the bulk of the Rush Valley mining district on the west side of the Oquirrh Mountains near Stockton, where they owned the Bauer lead-zinc concentrator (Craig, 1953).

The various properties in Carr Fork Canyon, to the west of the open-pit copper mine, were consolidated into three companies: Utah Consolidated Mining Company, Utah-Apex Mining Company, and Utah Metal and Tunnel Company (Atkinson et al., 1973). The Utah-Apex ores averaged about 2 percent copper with a $6 to $8 per ton gold and silver credit with some high-grade lead-silver ores, and were very similar to Utah Consolidated's ores which ran 2.36 percent copper, 1.0 oz/t silver, and 0.064 oz/t gold (Stevens, 1910).

A major lawsuit over the apex rights of a large replacement body of copper-lead-zinc ore between Utah Consolidated and Utah-Apex, in 1919, brought out all the famous mining geologists of that time: Waldemar Lindgren, Reno Sales, C.K. Leith, R.N. Hunt, H.V. Winchell, and A.C. Lawson. This led to a series of articles on the West Mountain mining district's geology in the 1920s, (e.g., Lindgren, 1924). The court's decision favored Utah-Apex, which forced Utah Consolidated to borrow funds from International Smelting. The intertwined property position eventually led to the consolidation of Utah-Apex and Utah Consolidated into the National Tunnel and Mines Company in 1937 (James, 1978). Utah Metal and Tunnel, New Bingham Mary Mining Company, Boston Apex Mining, and the Bingham Development Companies were acquired by the new National Tunnel and Mines (Atkinson et al., 1973).

National Tunnel and Mines drove the 5-mile-long Elton haulage tunnel (Fig. 4) from near the Tooele smelter to the Utah-Delaware ground and then connected to the Rood shaft in 1941 to service this block of copper ores (Dunlavy, 1986). The production subsidies and manpower shortages during World War II led National Tunnel to abandon exploration. With few reserves, the mine closed at the war's end due to lower metal prices. The company eventually failed in 1947. Anaconda Copper Company, who already owned the International Smelter and 50 percent of the National Tunnel stock, secured a stronger position in the West Mountain mining district with their purchase of the remaining part of the bankrupt National Tunnel Company in 1948 for $500,000 (Bailey, 1988).

United States Companies

As the porphyry copper ores of the West Mountain mining district were dominated by Utah Copper's production, so the surrounding base metal lodes were ruled by the United States Mining Company. The United States Mining Company was founded in 1899, and reorganized in 1901 under the laws of Maine. Albert F. Holden interested eastern capitalists in the possibilities of consolidation of the fractured property picture and reorganized the company into the United States Smelting Company in 1902 and the United States Smelting, Refining & Mining Company (USSR&MC) in 1906 with Holden as managing director (Mixter, 1948).

The USSR&MC's Bingham property started with three claim blocks: the Jordan and Galena, Spanish, and Telegraph groups in upper Bingham Creek Canyon (Grant et al., 1948). In the early years, copper was the most important product followed by gold and silver; however, as mining progressed the lead-silver ores soon dominated production (Mixter, 1948). The early copper ore averaged 1.5 to 2 percent copper, 2 to 5 oz/t silver, and 0.05 to 0.1 oz/t gold (Stevens, 1903).

Copper sulfide production by USSR&MC, at both the Jordan mine at Bingham and the Centennial-Eureka mines in the Tintic district, resulted in the construction of a gravity concentration mill and copper smelter at Bingham Junction in 1902 for $700,000 (Stevens, 1903). The 850-tpd smelter used pyritic blast furnaces and converters (Struthers, 1902). Additional silver-lead furnaces were added to the smelter in 1905, the original 90-tpd capacity was increased to 150 tpd with later expansions to 200 tpd in 1910, and 300 tpd in 1915, although the copper section was discontinued in 1908 (Wallace and Johnson, 1948). Through a court settlement with the farmers in 1907, the smelter was allowed to continue operation on lead-zinc ores with the addition of a mammoth bag house to reduce particulates, an arsenic plant to collect and produce arsenious trioxide, and prescriptive sulfurous emission standards (Stevens, 1908). The first zinc, previ-

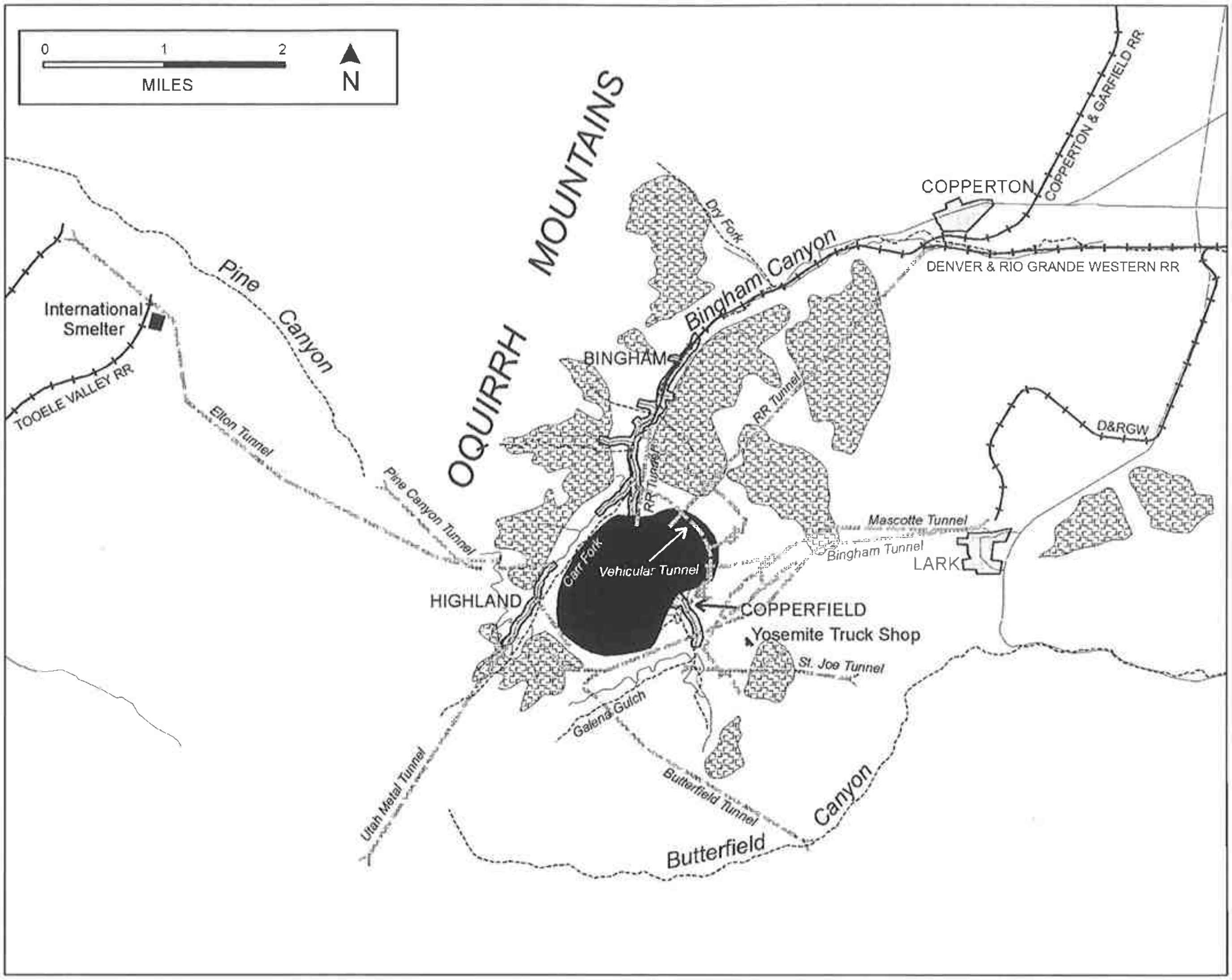

FIG. 4. The West Mountain mining district in the 1950s. Mineral production is dominated by copper-gold-molybdenum-silver. Lead-zinc-silver production continues through activities based at Lark.

ously considered deleterious, was recovered in 1909 by electrostatic separators (Butler et al., 1920). In addition to the metal mines, concentrator, and smelter, the USSR&MC was vertically integrated with limestone quarries, flux mines, coal mines, and a coking plant (Stevens, 1908).

As the USSR&MC's mines grew, the Niagara haulage tunnel near Upper Bingham was enlarged and extended to the Jordan-Galena mines in 1914. The tunnel was equipped with 8-ton, compressed air locomotives. A new loading platform from the tunnel was constructed over the Bingham & Garfield Railroad (Billings, 1948). The Bingham Junction gravity mill was enlarged in 1915 (Mixter, 1948). The USSR&MC, after extensive experimentation, replaced the old gravity mill with the new technology of the time, a 750-tpd flotation mill. A zinc separator was added in 1926 (Billings, 1952). In 1935, a fourth unit was added to the mill, bringing the total capacity to 1,700 tpd (Mixter, 1948).

USSR&MC followed a program of aggressive property acquisition in the West Mountain mining district in 1929 to 1930, which included the purchase of the Bingham Mines Company's Marvel Group, Castro Group, Lenox, Bingham Orleans, Auburn, Silver Gauntlet, Atlantic, Tom Moore Group, and Midas Group (Billings, 1952). By the late 1940s, the cumulative length of USSR&MC's underground workings at Bingham totaled nearly 300 miles, and their original Jordan and Telegraph mines had been exhausted (Grant et al., 1948). The USSR&MC extended the old Mascotte tunnel to over 7,400 feet, dewatering the Dalton and Lark properties (Billings, 1952). In 1948, the continuing expansions of the Utah Copper open pit caused the removal of the USSR&MC's Niagara surface workings near Copperfield[9]. In return, Kennecott Copper Corporation funded the driving of the Bingham tunnel (Fig. 4) from Lark to the U.S. mine in Butterfield Canyon, as well as the construction of surface facilities at Lark to replace those at Copperfield.

The USSR&MC's West Mountain district mines continued to be their most consistent producer, with any lost production elsewhere replaced by increased production from the U.S. and Lark fissure and manto deposits (Mixter, 1948). A variety of stoping methods were employed to meet the diversity of deposit types and ground conditions, including: longwall, top-slice, vertical cut, shrinkage, square-set, lane and pillar, horizontal back slice and others (Grant et al., 1948). USSR&MC began another phase of property acquisition in 1951 with the addition of the Ohio Copper Company, United Bingham Copper Company, and Bingham Congor Copper Company properties (Billings, 1952).

A second strike was called by the International Mine, Mill and Smelter workers union against the underground mines in 1936. Approximately 600 miners went on strike for a 50 cents-per-day pay raise and an eight hour portal-to-portal shift. Picket lines were set up, but the strike was not broadly supported by the workers and failed after ten peaceful weeks (Spendlove, 1937).

American Smelting & Refining closed their Murray lead smelter due to lack of feed in 1949, leaving only the USSR&MC's lead smelter in Midvale and the International Smelter in Tooele. The lack of lead feed continued to be a problem into the 1950s at both of the remaining smelters, which were only working part-time. These problems led the USSR&MC to close their Midvale lead smelting facilities on June 1958. However, in an agreement with International Smelting, both company's ores, as well as other custom ores, were processed at the USSR&MC's Midvale concentrator and then shipped to the International Smelter at Tooele. This agreement allowed both the U.S. concentrator and the International smelter to operate more efficiently. The U.S. Smelting Lead Refinery, Inc., a wholly owned subsidiary of USSR&MC in East Chicago, Indiana, continued to process U.S. and Lark's lead from the International smelter. The zinc was sent to Anaconda's Great Falls, Montana, plant for refining (USSR&MC Annual Report, 1958).

By the early 1960s, the U.S. and Lark mines had about 338 miles of underground workings. As the mines became deeper, it became more difficult and costly to do exploration, development work, and mining (USSR&MC Annual Report, 1963). Cost and engineering studies were done continuously to increase efficiency. The USSR&MC's Ophir Hill mine on the west side of the Oquirrh Mountains was operated by lessees with its ore sent to Midvale.

[9]The village of Upper Bingham was renamed Copperfield about 1919 with the construction of the Copperfield Grade School (Jackson, 1984).

The U.S. and Lark mines closed permanently, along with their Midvale mill and the International smelter, in September 1971. Although the U.S. mine was virtually exhausted, the Lark was closed due to the lack of concentrating and smelting facilities (R. D. Rubright, pers. commun., 1995).

Kennecott Copper Corporation

Kennicott, Alaska

Guggenheim Exploration, with John Hays Hammond and later Pope Yeatman as general managers, was probably the most successful exploration group of all time. Their discoveries and acquisitions read like a litany of the most important copper deposits of the twentieth century: Braden (El Teniente), Chile (1904); Ely, Nevada (1904); Utah Copper (1905); Kennicott, Alaska (1906); Ray, Arizona (1907); Chino, New Mexico (1909); and Chuquicamata, Chile (1910—sold to Anaconda in 1922). Guggenheim Exploration's corporate strategy was to acquire prospects and then sell public shares in the individual properties to fund development. This resulted in each mine becoming a separate company (O'Connor, 1937).

The Kennicott mine near Valdez, Alaska, was an extraordinarily copper-rich massive sulfide deposit, almost pure chalcocite, assaying up to 80 percent copper and 20 oz/t silver and averaged 13 percent copper (Douglass, 1964). But it lay in a very remote area of south-eastern Alaska. The property was discovered by a pair of prospectors in 1900 who staked the Bonanza claim. They showed the property to Steven Birch who returned to New York and presented the project to Henry Havemeyer, his financial backer. Havemeyer supported the project, but lacked the financial wherewithal for the development capital in so remote a region. Birch then contacted the Guggenheims and the banking house of J.P. Morgan for financing (Kennecott, 1956). Guggenheim-Morgan formed the Alaska Syndicate in 1906 and acquired 40 percent interest in the Kennicott mine from Alaska Copper & Coal Company (O'Connor, 1937). They built the Copper River & Northwestern Railway Company in 1906 and purchased the remaining 60 percent of Kennecott Mines Company in 1909. The 196 mile railroad to the property cost $23,000,000 by the time it was completed in 1911 and ore shipments began (Douglass, 1964).

The property was named after the nearby Kennicott Glacier, which was in turn named after a government surveyor. The 'new' spelling occurred when a clerk misspelled "Kennicott" on the incorporation papers.

The Guggenheims chose to combine all of their individual copper companies under one holding company, and the vehicle they chose was Kennecott Copper, organized in 1915 with control of the Kennecott mine, Copper River Railroad, and 43 percent of the Alaska Steamship Company as its core assets. It appears that the Guggenheims might have chosen Kennecott Copper

TABLE 2. Ethnic Composition in 1919

"Americans"	600
Japanese and Koreans	416
Greeks	406
Italians	151
Armenians	72
Albanians	55
Fifteen other nationalities	100
Total	1800

because they were afraid that they would never recoup their railroad expenditures and the initial mine development was not promising. They need not have worried, Kennecott Copper began producing copper for under five cents a pound (Douglass, 1964). In a stock swap between Kennecott Copper and Utah Copper in 1915, Kennecott Copper assumed a 25 percent interest in Utah Copper and in a related transaction acquired 96 percent of the Braden Copper Company in Chile. Kennecott Copper had profits of nearly $16,000,000 in 1917 which allowed it to purchase an additional 12.5 percent of Utah Copper, and over the next six years, acquired an additional 40 percent interest (O'Connor, 1937). In 1936, Utah Copper Company became a wholly owned subsidiary of Kennecott Copper Corporation and in 1947, was absorbed as an operating division (Spencer and Pett, 1953). The Kennecott Alaska mines were abandoned in November 1938 (Douglass, 1964).

Bingham Canyon Development

In the early years of operation, the Bingham Canyon open-pit copper mine consisted of large benches cut across the side of The Hill like an enormous terraced hillside. As late as 1930, the mine resembled a gigantic amphitheater cut out of a mountain with a face over 1,500 feet high and 3,600 feet wide at the base (Rickard, 1919). It was not until the 1940s that the mine actually became recognizably "bowl-shaped."

Utah Copper was a multi-ethnic operation with Rickard (1919) reporting the mine employed 1,800 (Table 2). The various nationalities were segregated into separate work crews with an English-speaking foreman of that nationality (Rickard, 1919). The foreign-born workers also had their own stores, churches, and saloons. Another 1,600 workers were employed at Garfield (Stevens, 1915). Mine operators used the national pride of the work crews to enhance production by encouraging competition between the various shifts (Robie, 1948). A company-run union was installed in 1919 "to advise and consult with the management" (O'Conner, 1937).

During the period 1910 to 1919, nearly 100 exploratory churn drill holes tested the porphyry copper ore body at depth. Nine of the holes were over 1,000 feet deep. Results included 1,620 feet of 1.36 percent copper in drill hole #90 (Spencer and Pett, 1953).

In 1916, Utah Copper moved the main line tracks of the Los Angeles & Salt Lake Railway (Union Pacific) and Western Pacific Railroad in order to double the size of the tailings impoundment to 5,100 acres (Fig. 1). The expansion cost about $1,000,000 (Salt Lake Tribune, 11/9/1941).

Utah Copper responded to World War I with a record copper production of approximately 200,000,000 lbs/year and record profits. During 1916, an innovative 2,000-tpd, 12-vat leaching plant was constructed at Garfield. The plant used Bingham copper oxide ores and sulfuric acid, recovered at the Garfield smelter, to produce copper (Weed, 1921). The sulfuric acid was recovered from sulfur dioxide gas by the Chamber process and had an output of 40 tons of 77 percent sulfuric acid a day. The acid was produced by Garfield Chemical & Manufacturing Corporation, a 50:50 joint venture between American Smelting & Refining and Utah Copper (Beyer, 1964). From October 1917 to December 1920, the plant processed 627,209 tons of oxidized capping averaging 0.78 percent copper, and with a 63 percent recovery, produced over 6,000,000 lbs of copper (Anderson, 1930).

A postwar recession, large stocks of copper on hand, and a government-held one billion lb copper surplus caused intermittent closures and finally led to the shut down of the Magna concentrator in 1919, followed by the mine and Arthur concentrator in April 1921. The Utah Consolidated, Utah-Apex, Bingham Mines, Ohio Copper, and Utah Metal and Tunnel also closed or dramatically reduced production (Deseret Evening News, 12/20/1919). This was a calamity for both the companies and the associated mining communities. The Bingham & Garfield railway discontinued passenger trains, but did add a passenger coach to its freight train (Bingham & Garfield, 1939).

During the shut down, the mills were enlarged to 40,000 tpd and converted from gravity separation to froth flotation, despite Utah Copper reporting a loss of over a million dollars in 1921 (Utah Copper Company 17th Annual Report, 1921).[10] The remodeling allowed for a rotation of employees through the construction project. Mining and milling resumed on a limited scale in April 1922, but the Magna concentrator remained closed until November 1922 (Utah Copper Company 18th Annual Report, 1922). The new flotation design by Frank Janney and his two sons increased the grade of the concentrate from 18 to over 20 percent copper and dramatically increased copper recoveries from about 61 to 81 percent (Parsons, 1956).

[10]Flotation was initially introduced in the concentration of porphyry copper ores in 1912 by the Inspiration Copper Company of Globe, Arizona (Colquhoun, 1970).

In 1920, R.A.F. Penrose replaced John Hays Hammond on the board of directors and, in 1926, Jackling replaced MacNeill as President (Weed, 1927). The 1920s saw the conversion from rail-mounted steam shovels to crawler track electric shovels in 1924 to 1926, and electric trains began work in the pit in 1928 (Parsons, 1933). Another significant change during this period was the conversion of the mill's flotation cells from acid to alkaline circuits (Kennecott, 1939).

Fire destroyed 20 buildings in the town of Bingham in 1919 and killed two firemen in a major blaze in 1924 (Jennings, 1946). In February 1926, a large snowslide virtually destroyed the village of Highland, killing 39. Another snowslide occurred in Highland in 1939 (Dunn, 1973).

Utah Copper began the construction of the company town of Copperton (Fig. 4) at the mouth of Bingham Canyon in 1926, "equipped with waterworks, sewage system and electric lights" (Spencer and Pett, 1953). Naturally, all of the fixtures in the homes were made of copper, including piping and roofing (Spendlove, 1937). The homes were rented to selected employees for a nominal sum (Vranes, 1957). Trees and shrubs were provided free to residents, and the company built a central park and playground (Christiansen, 1996). Copperton was to eventually replace the Anglo town of Bingham, the Greek and Japanese community of Copperfield, the Finnish village of Carr Fork, and the Slavic and Italian village of Highland, all farther up the narrow, constricted canyon (Bailey, 1988). The county highway from Salt Lake City was paved in 1927 (Spendlove, 1937). Copperton was initially eighteen units with expansion by an additional twenty-five units in 1926, 1929, and 1930 (Crump, 1978). A grade school was added in 1927, and a high school in 1931 (Kennecott, 1956). Construction ceased during the Depression, but resumed with 11 houses in 1937 and an additional 39 in 1940 to 1941. Six duplexes were added in each 1949 and 1950. By the end of 1950 there were a total of 231 dwellings in Copperton (Crump, 1978). Kennecott Utah Copper sold the homes to the residents in 1956, "most of them at a lower price than what Utah Copper had built them for" (Crump, 1978).

Utah Copper purchased peripheral claim groups, as they became available, mostly for surface rights, and often leasing the mineral rights to United States Smelting, Refining and Mining Company. In 1926, it acquired the 110-acre Starless Group from the Wall estate, which contained some disseminated copper ore. This brought Utah Copper land ownership in the West Mountain mining district to nearly 1,000 acres (Utah Copper Company 22nd Annual Report, 1926). In 1925, Utah Copper's Bingham & Garfield Railroad bought out the Denver & Rio Grande Western's High Line and Copper Belt rights-of-way (Strack, 1994).

Utah Copper's early vat copper leaching at Magna eventually led to experimental leaching of the estimated 40 million tons of oxidized leached cap dumps at Bingham, running 0.3 to 1 percent copper, in the early 1920s. In 1928, a successful launder precipitation plant was constructed in Bingham Canyon (Engineering and Mining Journal, 1928). The Cuprum precipitation plant treated, on average, 1 million gallons per day, carrying 20 lbs copper per 1,000 gallons, recovering 97.5 percent, and producing a precipitate of 87 percent copper. During 1929, 4,420,460 lbs of copper were recovered from precipitates.

In 1923, the Chino Copper Company of New Mexico merged with the Ray Consolidated Copper Company of Arizona. This was followed in 1926 by Ray merging with the Nevada Consolidated Copper Company, partially owned by Utah Copper. In 1933, Kennecott Copper purchased the remainder of Nevada Consolidated, acquiring the Ray and Chino porphyry copper operations in the process (Kennecott, 1974).

In 1929, Kennecott Copper acquired the Chase Brass & Copper Company, a fabricator of copper and brass rods, tubes, and rolled products. This expansion into downstream industries continued in 1935 with the acquisition of American Electrical Works, a wire and cable business (Kennecott, 1974).

In the late 1920s Utah Copper began first aid and safety training. This paid immediate benefits, with a 50 percent reduction in lost-time accidents in 1930. The Magna plant went through approximately one million man-hours in 1933 and 1934 without a lost time injury (Kennecott, 1956).

Great Depression

The Great Depression of the 1930s saw a decrease in world demand for copper, a parallel cutback in Bingham Canyon's production, and the accompanying decline in the fortunes of the people and businesses of Bingham and Magna. All of the mines in the district, except the U.S. mine, cut back to skeleton crews or closed. The Arthur mill was closed from January 1930 to September 1936. To make matters worse, in 1936 a cloudburst in Markham Gulch destroyed 20 homes in Bingham and the town of Highland was nearly destroyed by fire causing several hundred thousand dollars in damages (Bailey, 1988).

Again, Kennecott Copper took advantage of the plant closure to modernize the concentrators, replacing the old flotation cells with step-down-type Fagergren flotation machines. To provide jobs for the workers, Kennecott Copper employed twice as many men as needed at half time (Kennecott, 1956). By 1931, the mills had a capacity of 24,000 tpd at Magna and 16,000 tpd at Arthur (Weed, 1931). These improvements were followed by the addition of a molybdenite circuit using the Dextrin process at both plants in 1936 and construction of the Central rail yard in 1937 (Arrington and Hansen, 1963).

American Smelting & Refining's Garfield copper smelter built a new 408-foot stack in 1935 (Burt, 1935). Continued demand for by-product sulfuric acid from the smelter prompted Garfield Chemical & Manufacturing Corporation to replace the old Chamber equipment with a contact plant capable of producing 100 tpd of 100 percent sulfuric acid in 1937. Increased industrial usage of sulfuric acid in oil refining, sugar refining, and fertilizer production resulted in the addition of a 150-tpd plant in 1945. A third 250-tpd acid plant was added to the smelter in 1950, a fourth in 1952, and a fifth in 1956 (Beyer, 1964).

In 1937, Kennecott Copper purchased the surface rights to the old Ohio Copper Company ground on the east side of the mine for $600,000 to allow pit expansion up the east side of Bingham Canyon. This also required the construction of a 7,000-foot, one-way, vehicular tunnel (Fig. 4) between the towns of Bingham and Copperfield near the head of the Bingham Creek Canyon. The tunnel was completed in February 1939 (Kennecott, 1956).

World War II and the Post-War Expansion

After a two-month complete shutdown in mid-1938, production began to increase in response to demand caused by the outbreak of World War II in 1939. By 1942, the requirement for copper was such that the use of copper was essentially restricted to military needs (Kennecott Copper Corporation Annual Report, 1942). At the request of the federal government, Kennecott Copper built an eight-million-dollar, 100,000-kilowatt electric generating plant at Magna in 1941 to 1944 to facilitate copper production during the war (Kennecott, 1956). The Central Power Station also fit into the corporate strategy of vertical integration (Cononelos, 1994). The power plant was expanded in 1947 and again in 1959 to 175 megawatts (Davey and Morris, 1991).

Kennecott Copper Corporation responded to World War II by producing one-third of the copper used by the Allies with the Bingham Canyon mine reaching a peak production of 620,000,000 lbs of copper in 1943 (Davey and Morris, 1991). This level of production was reached despite the severe manpower shortage at the mine, mills, and smelter due to the war effort. By 1945, 67 percent of Bingham Canyon's copper production came from the less labor-intensive dump leach program (Kennecott, 1956).

At the War's end:

> The law prohibiting the employment of women in the mines, mills, and smelters, which was set aside for the duration of the war, again became operative by a special act of the Utah State Legislature (Kennecott, 1956).

Daniel Jackling left the company in 1942, the last of the major players from the formation of the company to retire. With his departure, labor unions became a major factor in production in the postwar years (Arrington and Hansen, 1963). Strikes resulted in a regular disruption of Bingham Canyon's production averaging 29 days per year over the period 1946 to 1980. Major work stoppages of over 150 days each occurred in 1946, 1959, and 1967 (Davey and Morris, 1991).

The Copperton & Garfield railroad (Fig. 4) was constructed in 1947 to replace the old Bingham & Garfield, which was scrapped in 1948 (Parsons, 1956). The new line included the Copperton Assembly Yards and a 4,650-foot long tunnel into the bottom of the pit. The tunnel was at an elevation of 6,040 feet above sea level and came out in the Canyon at the site of the old Yampa smelter (Parsons, 1957). The new line shortened haulage from 22 to 16 miles, reduced grades from 2.5 to 1.35 percent, and used broader curves. Electric locomotives replaced the old steam locomotives for ore haulage between the mine and mills in 1948. In 1949, a second tunnel, 7,000 feet long, was driven 200 feet lower at 5,840-foot elevation (Parsons, 1957). The continued deepening of the pit led to the excavation of yet a third 18,000-foot long ore haulage tunnel at the 5,490-foot level in 1961 at a cost of $12,000,000. This tunnel came out near Copperton (Fig. 4). The size of the ore cars increased from the original 60-ton capacity to 80-ton cars by 1930, and 100-ton in 1960 (Cononelos, 1994). The year 1947 also saw the construction of the Dry Fork train maintenance shops at the mine.

Continuing to follow the strategy of vertical integration, in 1950, Kennecott Copper completed the construction of a nearly $17,000,000 electrolytic copper refinery next to American Smelting & Refining's Garfield smelter. The refinery produced gold, silver, platinum, palladium, and selenium, in addition to copper, with production beginning in 1951 (Parsons, 1956). A $2,300,000 expansion of the Arthur flotation section was completed in 1952.

In January 1959, Kennecott Copper purchased the Garfield smelter from American Smelting & Refining for $20,000,000 (Salt Lake Tribune, 5/1/1958). In conjunction with the purchase of the Okonite Company, a manufacturer of cable in 1958, this completed an integration from mining, through milling, concentrating, smelting, refining and production of consumer products (Kennecott, 1961).

The Korean War of the early 1950s was followed by a broad economic expansion in the mid- to late-1950s, which led to record profits for Kennecott Copper. During 1952 to 1953 the old Fagergren flotation cells were replaced with new, larger, trough-type flotation cells at both mills. This was accompanied by the modernization of the mills' electrical systems (Kennecott, 1956). In 1955, five new seven- and eight-yard shovels, four more 125-ton locomotives, and two additional mobile drills were added at Bingham (Kennecott, 1956).

During the 1950s and 60s, the continuing expansion of the pit necessitated the removal of the historic mining towns of Highland and Copperfield in 1958, then Bingham in 1971 (Fig. 4). The towns had been built well up Bingham Canyon and had been periodically subjected to fires (1880, 1895, 1919, 1924, 1927, 1932), avalanches (1926 and 1939), and flash flooding (Spendlove, 1937; Dunn, 1973). People moved either to the planned residential community of Copperton or into the Salt Lake Valley (Spendlove, 1937; Bailey, 1988). These early mining towns followed in the footsteps of Bacchus, which was sold off in 1954, Garfield, which was abandoned in 1957, and Lark, which met its demise in 1977 (Kennecott, 1974; S. Richardson, pers. commun., 1997).

In a $100,000,000 expansion, the mills were enlarged to 80,000 tpd and then, with the addition of the 28,000-

tpd Bonneville crushing and grinding plant, to 108,000 tpd in 1966 (Davey and Morris, 1991). The new Bonneville mill required nine miles of new rail. These improvements also included a new molybdenite roasting plant and rhenium recovery facilities (Kennecott, 1974). Bonneville installed a new rail car dumper system, and the smelter built three large, green-feed reverberatory furnaces, and a 500-tpd acid plant was constructed at the Garfield smelter. In 1962, Kennecott Copper purchased 7,400 acres southeast of the pit from the USSR&MC for $14,000,000 (Salt Lake Tribune, 9/22/62). In addition, the haulage of waste rock from the upper half of the mine (above the 6190 level) was shifted from rail to more versatile diesel electric truck haulage in 1963. In addition to the 79 new haul trucks (65 to 110 tons), larger blast hole drill rigs and electric shovels were added at the mine (Cononelos, 1994). By 1965, a new $4,000,000 copper precipitation plant was constructed near Copperton.

Closures, Divestitures, and Acquisition

The beginnings of the environmental movement in the late 1960s brought the Clean Air Act of 1970. Kennecott Copper constructed a new $300,000,000 smelter to comply with these new regulations. It incorporated Noranda continuous smelting furnace, a new sulfuric acid plant, and a 1,215-foot smoke stack completed in 1976 (Davey and Morris, 1991). The new acid plant captured 94 percent of the contained sulfur. The Clean Air Act also forced the closure of lead-zinc smelters throughout the United States and the subsequent conclusion to nearly a century of continuous lead-silver production in the West Mountain mining district.

The 1970s also brought a reappraisal of Bingham Canyon's deep copper-gold skarn potential. This resulted in Anaconda's decision to develop the Carr Fork copper skarn, on the down-dip projection of the old Highland Boy-Apex mines, which had closed in 1947. By 1974 Anaconda had tested the deposit with 17 deep surface holes from their property on the northwest flank of the open pit copper mine. After five years of development, the Carr Fork mine began production in August 1979. The mine only operated for slightly over two years, however, before high operating costs, dilution, shaft problems, and low copper prices forced its closure (Cameron and Garmoe, 1987).

Similarly, Kennecott Copper re-examined the North Ore Shoot copper-gold skarn to the northeast of the pit. The deposit was discovered in 1957 and initially delineated by 24 surface holes drilled over the next 15 years (Harrison and Reid, 1997). A 20-foot diameter shaft was completed to a depth of 3,089 feet in 1983. The deposit was further explored by 12,300 feet of drifting, three test stopes, and 72,848 feet of drilling in 124 underground holes (Reid and Ballantyne, 1990). The North Ore Shoot has yet to begin production, and both the Carr Fork and the North Ore Shoot mines are now flooded.

Kennecott Copper acquired all of the USSR&MC's remaining Bingham properties in 1977. The year 1979 witnessed the switch from electric to diesel locomotives for the long haulage runs to the mills. The lack of significant modernization and cost reductions at Bingham and Ray in the 1970s, in conjunction with the nationalization of Kennecott Copper's Braden copper mine in Chile in July 1971, and the closure of the Ruth, Nevada, porphyry copper mine in 1978, were all difficult events leading into the 1980s.

In 1968, Kennecott Copper purchased the Peabody Coal Company for $622,000,000, but the purchase was challenged under Federal antitrust laws. Finally in 1977, the Federal Trade Commission forced the sale of Peabody following nine years of costly litigation. Kennecott Copper used the proceeds from the sale of Peabody to purchase the Carborundum Company for $571,000,000. This ultimately resulted in a hostile takeover attempt of Kennecott Copper led by the Curtiss-Wright Corporation in 1978 (Cononelos, 1994).

These corporate, legal, and financial difficulties, combined with the large capital expenditure required to meet new environmental laws and the lack of cost cutting and process modernization in the 1970s, would lead to serious problems in the 1980s. In May 1980, Kennecott Copper Corporation changed its name to Kennecott Corporation (Salt Lake Tribune, 5/7/1980). Kennecott Corporation was acquired by the Standard Oil Company through a merger transaction in 1981 after the Curtiss-Wright takeover attempt failed.

The early 1980s were a difficult time for copper producers: costs were up and prices were down. The once great Anaconda Copper Company ran into severe financial difficulties and merged with ARCO. Kennecott Corporation purchased the Carr Fork property from ARCO in September 1985 (Babcock, 1991). In 1982, Kennecott Corporation's Chino and Ray copper operations were closed, and the Tintic division was sold in 1983. The Chino operation was sold to Phelps Dodge and Ray was purchased by ASARCO in 1986 (Jay Hammitt, pers. commun., 1996).

Kennecott Corporation initiated cost-cutting programs, but it was unable to keep up with the falling prices, which reached historic lows in constant dollar terms, from 1984 to 1986 as copper prices fell from $1.40 to $0.60 per lb. The old Arthur mill was closed and Bingham's production was reduced by two-thirds in 1984 (Davey and Morris, 1991). In 1985, after four consecutive years of losses, the Bingham mine was shut down. The Arthur plant was demolished and the land reclaimed. The remaining 30,000-tpd Bonneville grinding plant and a modernized Magna flotation plant were combined to become the North Concentrator (Kennecott, 1994).

This forced a serious re-examination of labor practices and a more cooperative agreement had to be reached with the unions. The new agreement, combined with the previously implemented cost reduction programs, a decrease in the labor force from 7,000 to 2,000, and a dramatic reduction in stripping ratios as a result of slope stability studies, reduced production costs in 1987 to half of those in 1980 (Davey and Morris, 1991). In September 1986, Bingham resumed mining. In June 1987, the smelter came back on line.

In 1989, some of the assets of British Petroleum (the parent of Standard Oil Company), including the Bingham Canyon mine, were purchased by RTZ Corporation PLC (Skillings, 1992). The Bingham Canyon operations were acquired by Kennecott Utah Copper Corporation, an indirect subsidiary of RTZ. In 1997, RTZ changed its name to Rio Tinto plc. (Engineering and Mining Journal, 5/1997).

Capital Investment and Modernization

The late 1980s saw improved conditions in the West Mountain mining district. Bingham Canyon was declared a National Historic Landmark in 1972 and the town of Copperton was listed as a National Register Historic District in 1986. Kennecott Corporation purchased ground north of Copperton for $20 million in 1982 and initiated engineering modernization studies for an additional $23 million in 1983 (Cononelos, 1994). Also in 1983, the entire mine, both ore and waste, was converted from rail to truck haulage within the pit.

Low copper and high gold prices in the early 1980s led Kennecott Corporation to diversify into gold exploration. In 1985, Kennecott's exploration division rediscovered gold in Barneys Canyon, a few miles north of Bingham, after a century of inactivity. The Barneys Canyon sediment-hosted gold deposit discovery was followed by the nearby Melco deposit (Fig. 5) in 1986 and several smaller satellite deposits in the following years (Gibson and Hammitt, 1991). Production began in 1989 and has continued without interruption to the present (Babcock, 1991).

The late 1980s and early 1990s have been a period of unprecedented capital improvements totalling over $2 billion. A $350,000,000 modernization completed in 1988 included: an in-pit gyratory crusher, a 5-mile-long, 240,000-tpd ore conveyor system through the existing

TABLE 3. West Mountain Mining District Past Production and Present Resources

	Short Tons	Cu	Au	Ag	Pb	Zn
Placer Gold Deposits [1]			72,568 ounces			
	Short Tons		Au			
Sediment-Hosted Gold Deposits [2]	22,400,000		0.072			
	Short Tons	Cu	Au	Ag	Pb	Zn
Base Metal Replacement Deposits [3]	32,815,864	0.38%	0.041	3.65	6.8%	2.8%
	Short Tons	Cu	Au	Ag	MoS_2	
Copper-Gold Skarn—Production [4]	14,802,836	2.14%	0.075	1.58		
Copper-Gold Skarn—Resources [5]	382,777,000	1.85%	0.021	0.35	0.025%	
	Short Tons	Cu	Au	Ag	MoS_2	
Porphyry Copper—Production [6]	2,109,738,466	0.80%	0.014	0.10	0.050%	
Porphyry Copper—Reserves [7]	995,387,104	0.59%	0.010	0.08	0.027%	
Porphyry Copper Deposit—Total	3,105,125,570	0.73%	0.013	0.09	0.043%	

[1] Total recovered ounces of placer gold from 1864 to 1919 (Butler et al., 1920).

[2] Total resources including past production and present reserves (W.L. Gunter, pers. commun., 1995; Gunter and Austin, 1997). Gold head grades are in ounces per ton.

[3] Recovered grades from 1863 to 1964 calculated from Rubright and Hart (1968) and production from 1965 to 1972 from James (1974). Gold and silver values are in ounces per ton.

[4] Recovered grades from 1897 to 1908 calculated from Butler et al. (1920), grades from 1909 to 1946 from Hunt and Peacock (1950), and estimated production from 1979 to 1981 from Cameron and Garmoe (1987).

[5] Head grades from Harrison and Reid (1997). Gold and silver values are in ouces per ton.

[6] Head grades from past production, includes the Boston Consolidated. Gold and silver values are in ounces per ton.

[7] Reserves from RTZ-CRA annual report (1996).

5490 rail tunnel, and a new 77,000-tpd concentrator. The new Copperton Concentrator (Fig. 5) incorporated three 34 × 15-foot, semi-autogenous (SAG) grinding mills, six 18 × 28-foot ball mills, and 97 flotation cells (Kennecott, 1994). Also added were a 48-inch tailings pipeline, 6-inch concentrate slurry pipeline, pressure filtration plant, and a water return pipeline (Walenga, 1988). A new $10,000,000 peripheral discharge system was installed at the Magna tailings pond to improve fugitive dust control.

This was followed by a $227,000,000 mill expansion program, completed in 1992, to increase Bingham Canyon's production by 35,000 tpd. This expansion included a 36 × 17-foot diameter SAG ball mill, two 20 × 30-foot ball mills, 21 flotation cells, and three tailings thickeners in the Copperton concentrator. It also led to expanding the coarse ore stockpile capacity to 483,000 tons and adding a molybdenite recovery plant (Davey and Morris, 1991). This expansion brought the capacity of the Copperton Concentrator to 112,000 tpd and total Bingham Canyon copper production to a record 671,000,000 lbs of copper in 1994.

In 1992, Kennecott Utah Copper Corporation initiated construction on a new $700,000,000 Outokumpu flash converting smelter, double-contact acid plant, cogeneration power plant, and a $180,000,000 refinery. The new smelter has an expected capacity of 620,000,000 lbs of copper per year. Modification after start-up programs to improve the sub-design performance are still in progress. This smelter was designed to be the cleanest in the world (Salt Lake Tribune, 6/13/1997).

In addition to the new smelter, Kennecott Utah Copper has initiated an ongoing environmental cleanup campaign. This program, costing $230,000,000 through

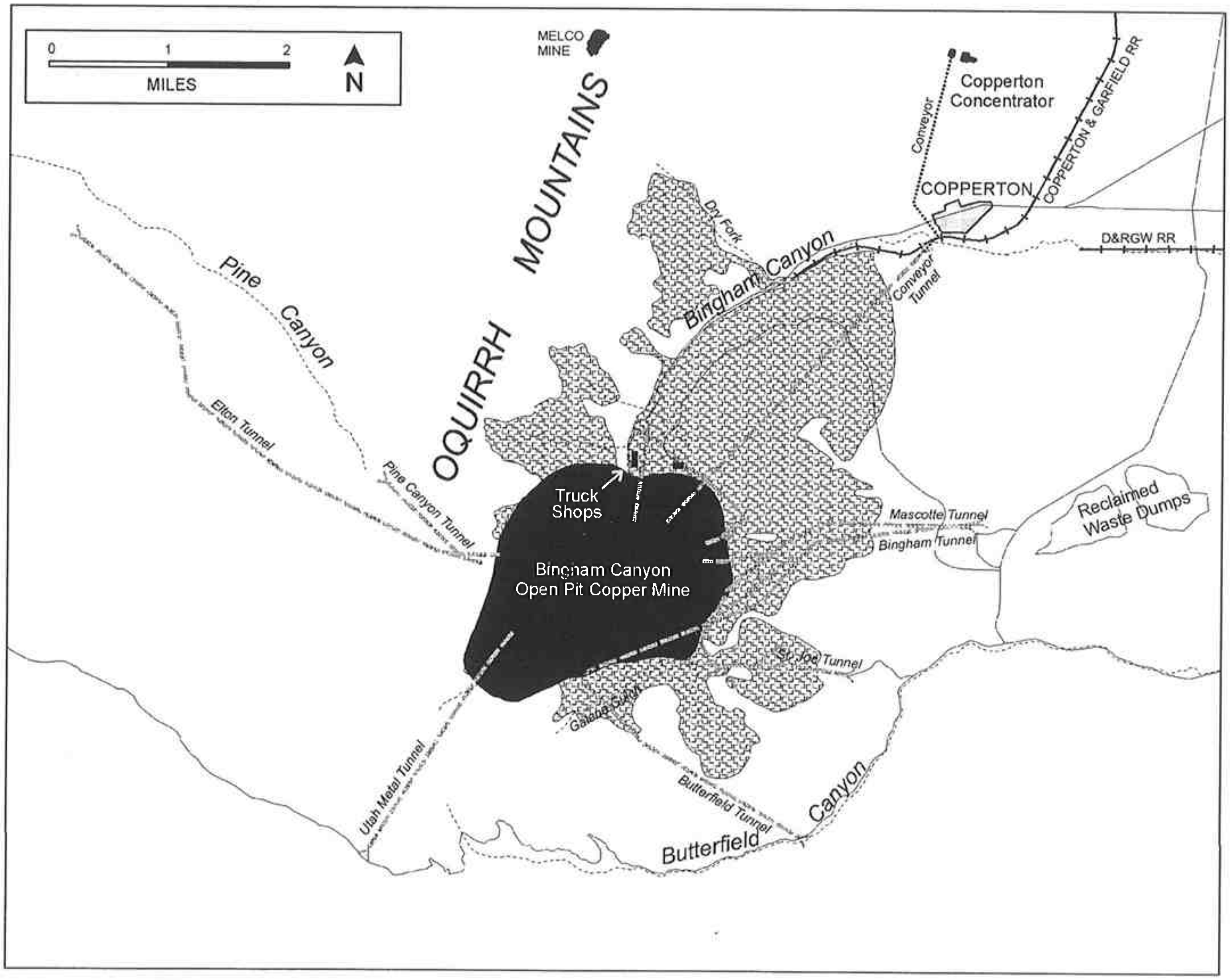

FIG. 5. The West Mountain mining district at the present time (1997). The expanding Kennecott Utah Copper mine is the primary operation. All lead-zinc-silver production has ceased and reclamation is well underway. Gold is being produced at the Melco sediment-hosted gold mine.

TABLE 4. West Mountain District Total Metal Production

Copper pounds	Gold ounces	Molybdenite pounds	Silver ounces	Lead pounds	Zinc pounds
59,474,295,474	51,533,416	2,694,723,594	565,269,212	4,605,917,099	1,965,102,748

These numbers include the total past metal production and present reserves from all of the geological environments listed in Table 3 as well as precipitate copper.

TABLE 5. Recent annual production (average of 1992-1996)

Short tons ore per year	Copper pounds	Gold ounces	Molybdenite pounds	Silver ounces	Precipitate Cu pounds	Stripping ratio
56,622,000	652,750,000	540,000	31,000,000	4,440,000	14,000,000	0.8

1996, involved reclamation at 18 different sites near the mine, smelter, and tailings pond. The cleanup included the relocation of over 25 million tons of historic lead-silver mine dumps and mill tailings, particularly near Bingham Creek, Lark, and Butterfield Canyon (Fig. 5). A total of 5,500 acres were reclaimed and revegetated for wildlife (Kennecott, 1996).

The year 1995 saw the initiation of a four-year, $460 million expansion of the Magna tailings impoundment to the north. This will greatly increase the storage capacity and increase the impoundment area from 5,100 to 9,100 acres.

Production

Historic Production and Present Reserves

Bingham Canyon has a distinguished history as the first successful, large-scale, open-pit copper mine in the world. However, the Bingham Canyon porphyry copper deposit and the West Mountain mining district also have an extraordinary record of metal production. Table 3 gives the West Mountain district's total historic metal production from gold placers, lead-zinc-silver lodes, copper-gold skarns, and sediment-hosted gold deposits. It is worthy of note that in terms of porphyry copper systems, Bingham ranks as one the largest producers in the world in each of these associated deposit types.

Even more striking is the Bingham Canyon porphyry copper deposit's record of polymetallic production and remaining reserves. The accompanying graphs of annual grades, tonnages, and production statistics chronicle the history of the mine (Fig. 6A and 6B). Most notable is the general increase in the tons mined, copper recovery, and associated increase in metal production. This trend is only partially offset by a downward drift in head grades as production costs and cutoff grades are lowered.

Table 4 summarizes Bingham Canyon's total metal content, including past production and present reserves, for all environments in the West Mountain mining district. The final total reveals a remarkable signature among ore deposits of the world.

Current Production

Bingham Canyon's present annual production marks it as an exceptional deposit in terms of copper, gold, molybdenum, and silver (Table 5). Not recorded here is its associated production of significant volumes of sulfuric acid and precipitate copper; the latter has totaled approximately 2.2 billion lbs over the life of the district. In total product sales, Bingham Canyon's production is valued at approximately $1 billion annually.

Acknowledgments

I am indebted to many people for their guidance and assistance in the construction of this history. I would like to thank Geoff Ballantyne for encouraging me to take up the project. I owe particular gratitude to Steve Richardson, Claudia Arabasz, Louis Cononelos, John Files, Brian Vinton, Tracy Bowman, Don Strack, John Guilbert, Jay Hammitt, Tracy Smith, Dan Bryant, Cindy Price, Marjorie LeFevre, and Betty Smith for assistance in locating all the research materials. I also appreciate the work of Steve Richardson, Jay Hammitt, Julia Reid, Geoff Ballantyne, Brian Vinton, Phil Fikkan, and Dick Rubright in making suggestions to improve early drafts of the paper. The final editing by David A. John, Bill Gunter, Larry James, Steve Richardson, Marcelle Shoop, and Phil Fikkan significantly improved this paper.

I relied on William Stockdale for generating the annual grade and production figures. Patient computer drafting of

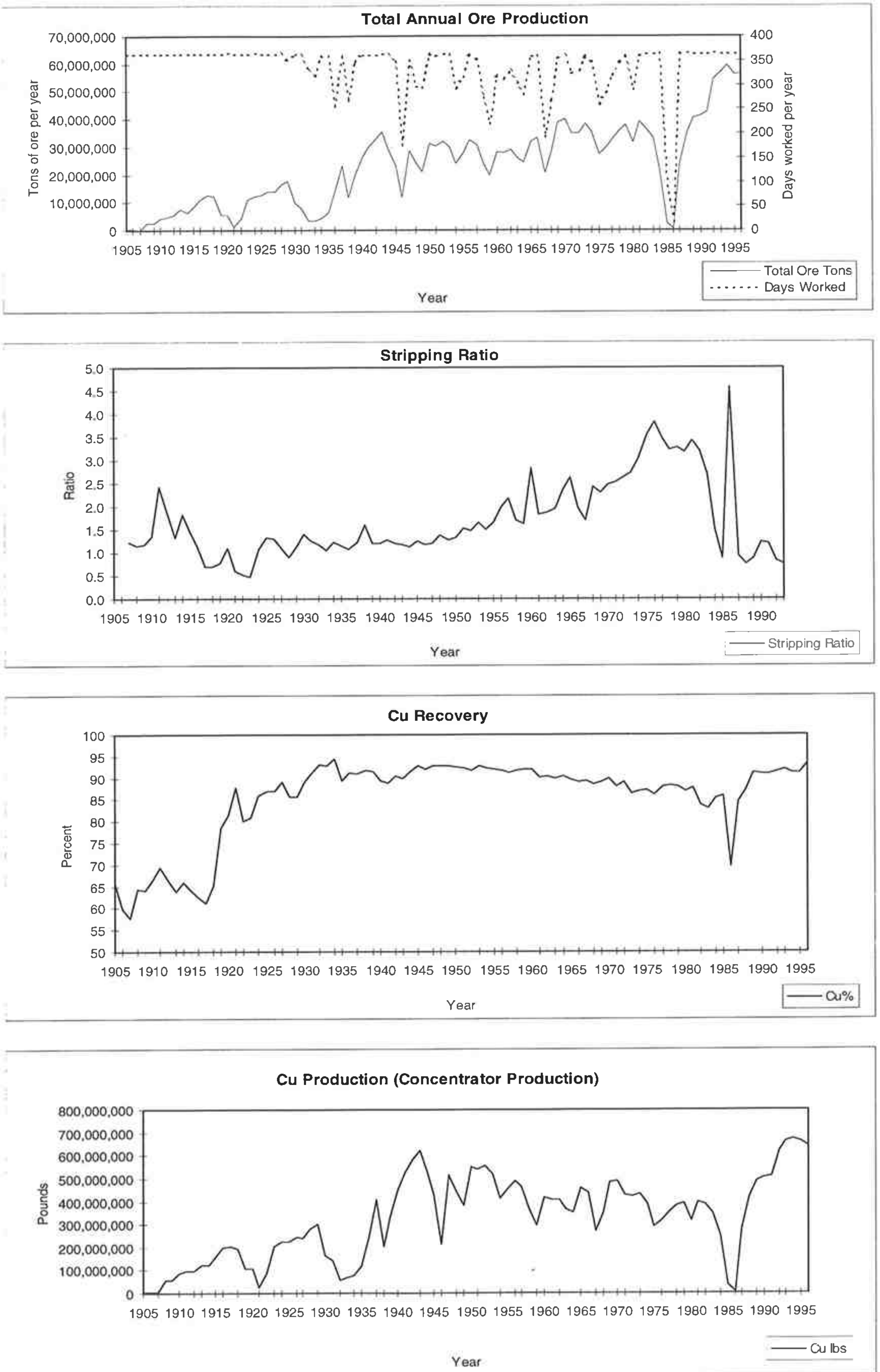

FIG. 6A. Annual Kennecott Utah Copper production statistics

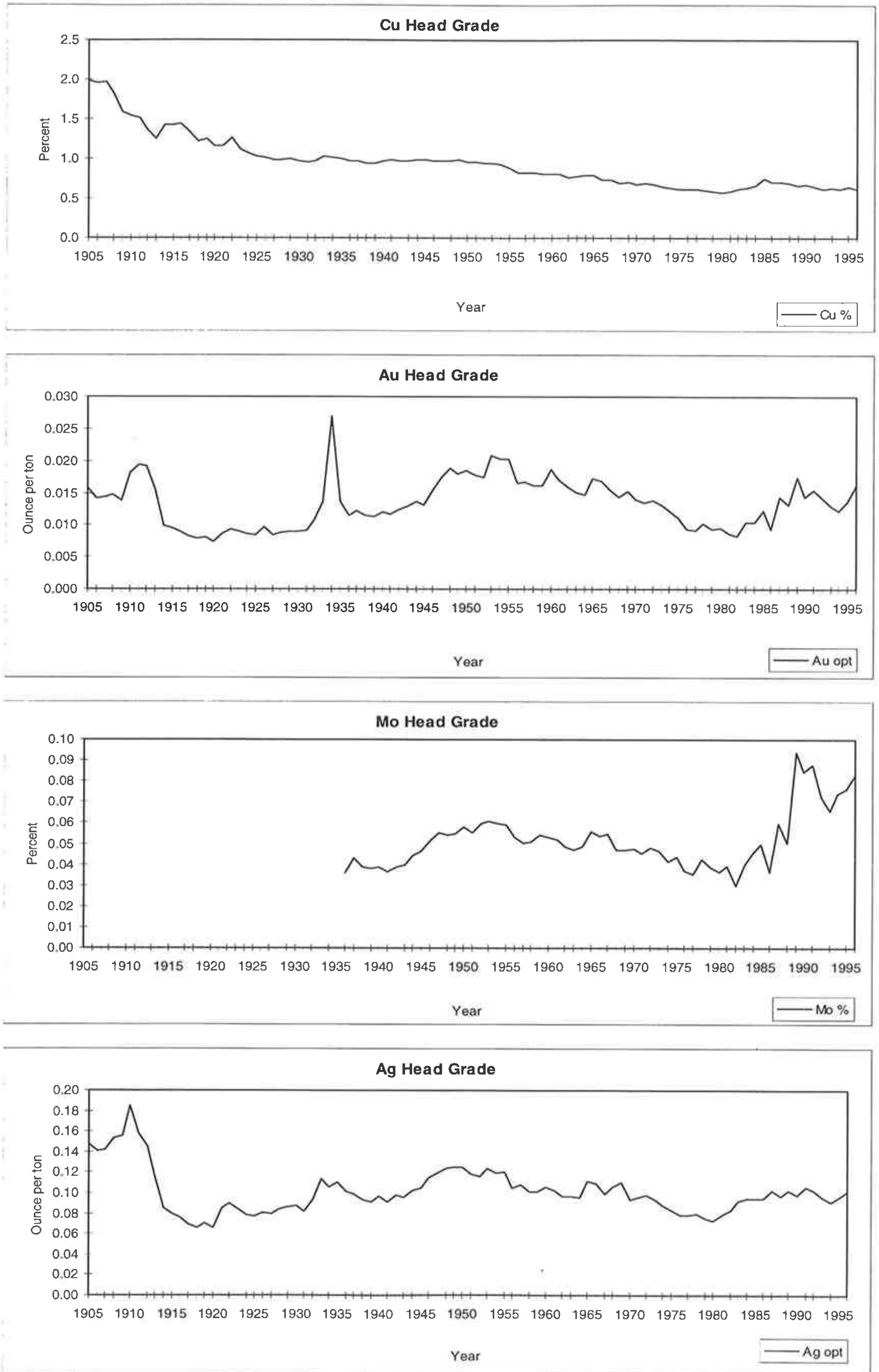

FIG. 6B. Annual Kennecott Utah Copper head grades

the maps was provided by Richard Warnick. This work was supported by Kennecott Utah Copper Corporation.

I would also like to acknowledge my predecessors in chronicling the history of mining at Bingham, from whom I have drawn heavily. This list includes significant works by John Murphy (1872), John Boutwell (1903 and 1905), David Wegg (1915), T.A. Rickard (1919), A.B. Parsons (1933 and 1956), Beatrice Spendlove-Bates (1937), William Spencer and Fern Pett (1953), Gary Hansen (1963), Leonard Arrington and Gary Hansen (1963), and Larry James (1978).

References

Anderson, L.W., 1930, History of the concentrating mills of the Utah Copper Company: Unpublished Utah Copper Company Metallurgical Department report, p. 18–26.

Arrington, L.J., 1963, Abundance from the Earth: The beginnings of commercial mining in Utah: Utah Historical Quarterly, XXXI, p. 192–219.

—— 1966, Great Basin kingdom: An economic history of the Latter-day Saints 1830–1900: Lincoln, University of Nebraska Press, 534 p.

Arrington, L.J., and Hansen, G.B., 1963, "The richest hole on earth"—A history of the Bingham copper mine: Utah State University Press, Monograph Series, v. XI, no. 1, 103 p.

ASARCO, 1996, anonymous unpublished ASARCO Incorporated notes, 5 p.

Atkinson, W.W, Britt, T.L., Einaudi, M.T., and Garmoe, W.J., 1973, Report on geology of Anaconda's Carr Fork property, Bingham mining district, Salt Lake and Tooele Counties, Utah: The Anaconda Company, unpublished report, 71 p.

Babcock, R.S., 1991, An introduction to the geology of the Bingham mining district: Guidebook to the geology and ore deposits of the Bingham Mining District and the Northern Oquirrh Mountains, Utah: Unpublished Kennecott Exploration Company report, 5 p.

Bailey, L.R., 1988, Old reliable—A history of Bingham Canyon, Utah: Tucson, Arizona, Westernlore Press, 186 p.

Bancroft, H.H., 1889, History of Utah: San Francisco, The History Company Publishers, 808 p.

Barrett, G.W., 1971, Enos Andrew Wall—mine superintendent and inventor: Idaho Yesterdays, v. 15, no. 1, p. 24–31.

Beyer, J.H., 1964, History of Utah Copper Division smelter: unpublished Kennecott Copper Corporation report, 7 p.

Billings, T.P., 1948, Mining in Utah during the past 45 years: American Institute of Mining Engineers meeting October 14, 9 p.

—— 1952, History of the Bingham district: unpublished manuscript, 115 p.

Bingham & Garfield, 1939, Descriptive history of Utah Copper Company and Bingham & Garfield Railway Company: unpublished Kennecott Copper Company report, 13 p.

Bingham Commercial Club, 1909, Bingham: The greatest copper tonnage camp in the world: Salt Lake City, Utah Tribune-Reporter Printing Company, 126 p.

Boston Consolidated Mining Company, 1908, Corporate Annual Report.

Boutwell, J.M., 1903, Ore deposits of Bingham, Utah: U.S. Geological Survey, Bulletin 213, p. 105–122.

—— 1905, Economic geology of the Bingham mining district, Utah: United States Geological Survey, Professional Paper 38, 413 p.

—— 1933, Economic geology: The Salt Lake Region, *in* Boutwell, J.M., ed., International Geological Congress, XVI Session, United States, Guidebook 17, 149 p.

BP America, 1987, Corporate Annual Report.

Bradford, R.H., 1910, Utah's mines, mills, and smelters in 1909: Mining and Scientific Press, p. 76–77.

Burt, C.C., 1935, A new stack for the Salt Lake Valley: Engineering and Mining Journal, p. 227–228.

Butler, B.S., Loughlin, G.F., Heikes, V.C., and Others, 1920, The ore deposits of Utah: U.S. Geological Survey, Professional Paper 111, 672 p.

Cameron, D.E., and Garmoe, W.J., 1987, Geology of skarn and high-grade gold in the Carr Fork mine, Utah: Economic Geology, v. 82, p. 1319–1333.

Carr, S.L., 1972, Utah ghost towns: Salt Lake City, Western Epics, p. 20–46.

Carr, S.L., and Edwards, R.W., 1989, Utah ghost rails: Salt Lake City, Western Epics, 209 p.

Chase, E.E., 1907, Report on Utah Copper Company's property, Bingham, Utah: unpublished letter to D.C. Jackling dated February 25, 7 p.

Christiansen, W., 1996, The company town: Copper Pipeline—A quarterly newsletter for Kennecott Utah Copper employees, retirees and their families, Spring, p. 9.

Clement, V.M., 1899, Unpublished letter to J.R. DeLamar, dated May 9, 3 p.

Cohen, H.A., 1898, Report on Wall's copper property: Unpublished letter to J.R. DeLamar, dated June 1, 4 p.

Colquhoun, J., 1970, The story of the birth of the porphyry coppers: London, William Clowes and Sons, Ltd., 31 p.

Comp, T.A., 1975, The Tooele copper and lead smelter: The Journal of the Society for Industrial Archeology, v. 1, no. 1, p. 29–46.

Cononelos, L.J., 1994, A brief history of change and leadership challenges at Kennecott: unpublished Kennecott Copper Corporation report, 12 p.

Craig, S.E., 1953, Utah Operations—Combined Metals Reduction Company: Mining, smelting, and railroading in Tooele County, 1986, Tooele County Historical Society, 138 p.

Crump, S., 1978, Copperton: Salt Lake City, Publishers Press, 311 p.

Davey, R.K., and Morris, D.B., 1991, The evolution of Utah Copper: Guidebook to the geology and ore deposits of the Bingham Mining District and the Northern Oquirrh Mountains, Utah, unpublished Kennecott Exploration Company report, 11 p.

Deseret Evening News, 1919, History of Bingham—one of failure and success: Salt Lake City, Weekly Newspaper, December 20, p. 25–30.

Douglass, W.C., 1964, A history of the Kennecott mines, Kennecott, Alaska: unpublished report, 13 p.

Dunlavy, F.C., 1986, The Carr Fork project: Mining, smelting, and railroading in Tooele County, 1986: Tooele County Historical Society, 138 p.

Dunn, M., 1973, Bingham Canyon, Salt Lake City, Publishers Press, 152 p.

Dyer, D., and Sicilia, D.B., 1990, Labors of a modern Hercules: Boston, Harvard Business School Press, 528 p.

Elton, J.O., and Saskett, B.L., 1929, Smelting lead at Tooele: Engineering and Mining Journal, p. 313–316.

Engineering and Mining Journal, 1893–1997, Weekly and monthly magazine.

Fairbanks, H.R., and Berkey, C.P., 1952, Life and letters of R.A.F. Penrose, Jr.: New York, Geological Society of America, 765 p.

Gemmell, R.C., 1919, Some engineering features in connection with the Utah Copper Company's operations: Mining and Scientific Press, v. 119, p. 440–446.

Gibson, T.R., and Hammitt, J.W., 1991, Discovery of the Barneys Canyon and Melco gold deposits, Salt Lake County, Utah: Guidebook to the geology and ore deposits of the Bingham Mining District and the Northern Oquirrh Mountains, Utah: unpublished Kennecott Exploration Company report, 21 p.

Goodman, J., 1996, Commercial Club enjoys a revival: Salt Lake Tribune, September 22, p. D5.

—— 1997, Refined home is fit for a copper king: Salt Lake Tribune, May 18, p. D2.

Grant, B.E., Ehrhorn, J.M., and DuBois, M.M., 1948, Practice at the company's Utah metal mines: Mining and Metallurgy, p. 535–541.

Gunter, W.L., and Austin, G.W., 1996, The Geology of gold deposits in the Barneys Canyon Project Area, Salt Lake County, Utah, *in* Green, S.M., and Struhsacker, E., eds., Geology and ore deposits of the American Cordillera, Great Basin porphyry deposits: Geological Society of Nevada Field Trip Compendium, 1995, Reno/Sparks, Nevada, p. 43–58.

Hammond, E.D., 1961, History of mining in the Bingham district, Utah, *in* Cook, D.R. ed., Geology of the Bingham mining district and northern Oquirrh Mountains: Utah Geological Society Guidebook, no. 16, p. 120–129.

Hammond, J.H., 1935, The autobiography of John Hays Hammond: New York, Farrar & Rinehart, Inc., two vol., p. 500–525.

Hanchett, L., 1937, The old sheriff and other true tales: New York, Margent Press, p. 119–140.

Hansen, G.B., 1963, Industry of destiny: copper in Utah: Utah Historical Quarterly, v. XXXI, p. 262–279.

Harrison, E.D., and Reid, J.E., 1997, Copper-gold skarn deposits of the Bingham Mining District, Utah: Society of Economic Geologists Guidebook 29, p. 219–236.

Hunt, R.N., and Peacock, H.G., 1950, Lead and lead-zinc of the Bingham district, Utah, Lead-Zinc Symposium, p. 81–85.

Huntley, D.B., 1885, The mining industries of Utah, *in* Emmons, S.F., and Becker, G.F., eds., Statistics and Technology of the Precious Metals; Tenth U.S. Census—1880, v. 13, p. 405–422.

Jackson, A.B., 1984, Copperfield: Salt Lake City, Publishers Press, p. 98.

James, A.H., 1973, Lead and zinc resources in Utah, Utah Geological and Mineralogical Survey, Special Studies 44, 66 p.

James, L.P., 1978, The Bingham copper deposits, Utah, as an exploration target: History and pre-excavation geology: Economic Geology, v. 73, p. 1218–1227.

Janney, F.G., 1905, General manager's report covering mining & milling operations of the Utah Copper Company for the year ending June 30, 1905: unpublished Utah Copper Company report, 10 p.

Jennings, D., 1946, Jinx Town, U.S.A.: Coronet Magazine, September, p. 41–44.

Jones, M.E., 1890, Utah: Internal commerce of the United States, United States Treasury Department, p. 856–954.

Jones, R.L., and Wilson S.R., 1949, Diamond drilling at the Boston Consolidated copper mine, Salt Lake County, Utah: U.S. Bureau of Mines, Report of Investigations 4579, p. 2–3.

Kennecott, 1939, History of milling from date of inception to present time: Anonymous unpublished Kennecott Utah Copper Company Department of Mills report, 40 p.

—— 1954, Chronological history of important events in mining: Anonymous unpublished Kennecott Copper Corporation report, p. 8.

—— 1956, Historical Index—Utah Copper Division operations: Anonymous unpublished Kennecott Copper Corporation manuscript, 201 p.

—— 1961, All About Kennecott: The story of Kennecott Copper Corporation: Anonymous Kennecott Copper Corporation pamphlet, 27 p.

—— 1974, Kennecott chronology: Anonymous unpublished Kennecott Copper Corporation report, 18 p.

—— 1994, Kennecott Utah Copper Concentrator: Anonymous Kennecott Utah Copper Corporation informational brochure, 16 p.

—— 1996, Kennecott Utah Copper's environmental cleanup program: Anonymous unpublished Kennecott Copper Corporation report, 51 p.

Kennecott Copper Corporation, 1942, Corporate Annual Report.

Lester, M.D., 1979 Brigham Street: Salt Lake City, Utah State Historical Society, 260 p.

Lindgren, W., 1924, Contact metamorphism at Bingham, Utah: Bulletin of the Geological Society of America, v. 35, p. 507–534.

Mines and Methods, 1909–1910, Rice, C.T., ed. and publisher, Salt Lake City, Utah.

Mining and Scientific Press, 1909–1912, weekly magazine.

Mixter, G., 1948, Organization and growth of the United States Smelting, Refining and Mining Company: Mining and Metallurgy, p. 528–531.

Murphy, J.R., 1872, The mineral resources of the Territory of Utah with mining statistics and maps: Salt Lake City, James Dwyer, 104 p.

Neff, A.L., 1940, History of Utah 1847 to 1869, *in* Creer, L.H., ed., Salt Lake City, The Deseret News Press, p. 628–644.

O'Connor, H., 1937, The Guggenheims: The making of an American dynasty: New York, Coviei Friede, Inc., 496 p.

Ohio Copper Company, 1909–1937, Corporate Annual Reports.

Papanikolas, H.Z., 1965, Life and labor among the immigrants of Bingham Canyon: Utah Historical Quarterly, v. 33, no. 4, p. 289–315.

Parsons, A.B., 1933, The porphyry coppers: New York, American Institute of Mining Engineers, 581 p.

—— 1956, The porphyry coppers in 1956: New York, American Institute of Mining Engineers, 270 p.

Raymond, R.W., 1870–1875, Statistics of mines and mining in the states and territories west of the Rocky Mountains: Washington, Government Printing Office, published annually.

Reid, J.E., and Ballantyne, G.H., 1990, Exploration targets in the vicinity of the North Ore Shoot deposit at Bingham Canyon, Utah: unpublished Kennecott Copper Corporation report, 45 p.

Rickard, T.A., 1919, The Utah Copper enterprise: San Francisco, The Mining and Scientific Press, 107 p.

Robertson, F.C., and Harris, B.K., 1962, Boom towns of the Great Basin: Denver, Sage Books, 331 p.

Robertson, R.W., 1972, This is Alta: Alta, Utah, Alta Historical Society, 80 p.

Robie, E.H., 1948, The drift of things: Early days of mining around Salt Lake: Mining and Metallurgy, p. 584–585.

Rubright, R.D., and Hart, O.J., 1968, Non-porphyry ores of the Bingham district, Utah, *in* Ridge, J.D., ed., Ore deposits in the United States 1933–1967, New York, AIME, p. 886–907.

Rudd, H., 1978, Samuel Newhouse: Utah mining magnate and land developer: Western States Jewish Historical Quarterly, p. 291–307.

Salt Lake Mining Review, 1899–1911, weekly magazine, predecessor to Skillings' Mining Review.

Salt Lake Tribune, 1941–1997, Salt Lake City, Utah, Daily Newspaper.

Salt Lake Tribune, 1958–1980, Salt Lake City, daily newspaper.

Skillings, D.N., 1992, Kennecott now operating fourth grinding line at Copperton concentrator: Skillings' Mining Review, v. 81, no. 16, p. 4–7.

Smith, W.H., 1975, A short history of the Bingham mining district: Bray, R.E., and Wilson, J.C., eds., Society of Economic Geologists and Kennecott Copper Corporation, Bingham Canyon, Utah, p. 3–15.

Spencer, W., and Pett, L.F., 1953, History of Utah Copper: unpublished Kennecott Copper Corporation report, 57 p.

Spendlove, B., 1937, History of Bingham Canyon, Utah: Unpublished Master's Thesis, Salt Lake City, University of Utah, retyped copy, 113 p.

Spilsbury, E., 1905, Report on the mines and concentrating plant of the Utah Copper Company: Unpublished report, 13 p.

Steinbach, E.W., 1975?, The Tooele smelter: Unpublished report, University of Utah, Clark Wilson papers, 6 p.

Stevens, H.J., ed., 1903–1915, The copper handbook: Houghton, Michigan, published annually by The Stevens Copper Handbook Company.

Strack, D., 1994, Railroads and mining in Bingham Canyon, Utah: unpublished private notes, 39 p.

Struthers, J., 1902, The mineral industry, its statistics, technology and trade in the United States and other countries to the end of 1901: New York and London, The Engineering and Mining Journal Inc., p. 1895–1896.

Tullidge, General Connor, 1881, The founder of Camp Douglas: Tullidge's Quarterly Magazine, p. 177–198.

United States Smelting, Refining and Mining Company, 1958–1963, Corporate Annual Reports.

Utah Copper Company, 1905–1930, Corporate Annual Reports.

Utah Mining Gazette, 1874, The mineral resources of Utah, with commercial and other statistics for 1873: Salt Lake City, Utah Mining Gazette Steam Book and Job Press, 100 p.

Vranes, J., 1957, History of mining in Bingham: Unpublished undergraduate seminar paper, Utah State Agricultural College, 23 p.

Walenga, K., 1988, Updated plant makes Bingham low-cost producer: Rocky Mountain Pay Dirt, p. 4A–11A.

Wallace, R., and Johnson, H.L., 1948, Technical developments leading up to the present Midvale plant: Mining and Metallurgy, p. 542–543.

Weed, W.H.. (ed.), 1917–1931, The mines handbook: Tuckahoe, New York, published biannually by The Mines Handbook Co.

Wegg, D.S., Jr., 1915, Bingham mining district, Utah: Unpublished Master's thesis, Salt Lake City, University of Utah, 224 p.

View publication stats