NONFERROUS METALS MILLING PLANTS IN UTAH

by

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ABSTRACT

The production of base and precious metals typically requires the milling, or concentration, of ores. Approximately 100 such mills of various sizes have operated in Utah. Significant mill tailings remain at perhaps a third of these sites. The largest are located in Salt Lake, Tooele, Utah, Summit, Wasatch and Beaver counties. Some Utah tailings have been considered resources for exploitation -- or sources of environmental concern.

The grinding and chemical processes that yielded Utah tailings varied greatly. Mills ranged in size from small, some-

times experimental plants that proliferated along canyonsides in old districts to the huge, recently-modernized Kennecott complex that has served the Bingham district since 1908. Processes included gravity concentration (mainly prior to 1920), amalgamation (used largely before 1890) roast-leach processes, cyanide leaching and flotation. The last has been the most important process in Utah. It was used on a large scale at relatively few sites. Cyanide leaching and flotation remain important to Utah's economy. Each yields different tailings, due to differences in fineness of grind and aqueous chemistry. A few mills involved substantial investment in novel processes, some of which had no identifiable relationship to accepted facts of chemistry and physics.

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INTRODUCTION

Utah's economy grew rapidly after settlement from small -scale farming to a substantial industrial and financial empire. Major metallic resources developed near Salt Lake City were a significant cause of this growth. Deposits of copper, silver, lead, gold, zinc and other metals were discovered and opened during the 1860s. A few districts and deposits proved to be unusually rich or large. Capital to develop them came first from overseas, then from American financial centers. Utah became a major producer of nonferrous metals. Milling of ores eventually became an essential step in production of metals in Utah.

Some definitions are in order. Milling, or concentration, of ores uses physical or chemical processes to yield a product rich in the desired metals. The waste material (generally in the form of sand) remaining after a mill has removed most of the sought-after metallic constituents, is called tailings. (The waste rock produced from metal mines, and typically placed on waste dumps near the entries to open pit or underground workings, is not generally called tailings.) After milling, the conversion of the recovered metallic product to useful metals can be completed. This is called smelting. The waste product of smelting is typically a molten glass, known as slag.

This open-file report makes a rudimentary list of mill sites in Utah and a general classification of the tailings types left behind. The historical origins of the tailings, i.e. the processes used, are considered. The individual plants and the geological sources of feed, are also briefly discussed. The result is a general catalog based on available literature and personal observation of mill sites. These sites are presently of interest as:

1) Places where environmental testing and clean-up may benefit from information on past activities. It is believed an assortment of agencies has already identified the major problem sites. However, improved data on what historically was done at these sites can lead to improved prediction of present day tailings character and potential aqueous geochemistry of reaction with surficial processes. Many years of effort by plant metallurgists and economic geologists concerned with metal extraction are already recorded in the literature. It is hoped this data can augment and improve costly sampling and environmental procedures. (i.e. The raw materials that fed the plants were well characterized and analyzed).

2) A significant quantity of valuable metals remains in tailings in Utah. In many localities elsewhere, and to a limited extent in Utah, improved processing and changing economics have

turned tailings into economically recoverable resources.

3) A few sites may deserve historical study (e.g. Utah Architect, 1974 cited in James, 1984) or even preservation. The whole history of the metallurgical industry, so vital to the economy of Utah, is a fertile subject for historians.

History of mineral processing in Utah

In the western United States, major mining districts and necessary metallurgical technology developed together. As geologists, financiers and engineers outlined new reserves, new technology developed to more efficiently exploit them. Utah became noted as a center of milling and smelting pioneering. The first experimental mills appeared soon after lodes containing partially oxidized complex base and precious metal ores were discovered at Bingham Canyon in 1863.

Mills were once much more numerous in Utah, especially in the Salt Lake and Tooele valleys, than they are today. They included many large plants for milling (and smelting or reduction) of lead, silver, zinc and other metals. Some of these plants are listed in Table I. From the 1920s to the 1940s this complex was at times noted as the largest in the world. It survived the Great Depression, partially by emphasizing gold production. Some of its plants specialized in "custom" processing of ores from diverse mines of varied ownership. Other plants remained largely "captive" operations, fed by their own mines. Many of the smaller mines that fed both captive and custom plants were heavily depleted by the end of the Second World War. Parts of the complex became economically and environmentally obsolete from the 1950s to the 1970s. They were closed or not replaced. New mines, fewer environmental problems and lower labor costs elsewhere made many Utah underground mining operations too costly. The closing of mills and smelters followed.

The rise in the price of gold and silver after 1979 led to a few new substantial operations and discoveries, particularly in old districts. Interest in old mill sites tailings as metal resources was accompanied by concern over their possible toxicity. Federally-funded studies were made of some areas, resulting in considerable publicity.

Utah's uranium and vanadium milling plants are not discussed in this paper. Neither are the extensive iron ore processing and smelting complex of Iron and Utah Counties, nor the unique hydrometallurgical plant in Millard county for extracting beryllium from Utah bertrandite ores. Another unique plant, the recently-erected gallium and germanium plant of St. George Mining Co/Hecla Mining Co. in Washington County is mentioned only because of its byproduct base metal production. The extensive nonmetallic mineral industry of the state, including salts, dolomite, limestone, evaporites, clays, as well as plants for extracting various solid hydrocarbons and bitumens from rock are not discussed.

A compilation was made of metal milling operations, past and present, in Utah. Table 1 lists most of the many milling operations that produced noteworthy economic results. Also listed are a few mills which scarcely treated any ores or produced any quantities of tailings. These experimental plants are mainly of historical interest.

Table 2 lists some of the processes that were used in Utah milling plants. The history of process development, and its application to specific Utah ore bodies, are documented mainly by references in the text. Ritcey (1989) Somasundaran (1989) and others provide detail on current processes with respect to tailings management. Accounts are also presented of a few plants that used highly experimental to probably imaginary processes. A description of the latter is presented by Carpenter (1941).

Figure 1 shows the locations of most of the substantial-sized plants discussed in the text and in table 1.

CONCENTRATORS AND LEACHING PLANTS IN UTAH

I. The major Bingham District metallurgical complex

The Kennecott or Utah Copper milling plants (Fig. 1), part of one of the largest copper facilities in the world, are much larger in scale than any of the others in Utah. The concentrators and tailings storage on the northeast flank of the Oquirrh range were originally built in the 1900s (Parsons, 1933) and have grown and changed processes considerably in the ensuing years. A brief history is given in Rickard (1919) and U.S. Bureau of Mines (1927). The present (1990) Bingham milling facilities include four treatment plants west of Salt Lake City. The newly-constructed grinding and flotation plant at Copperton employs the largest semi-autogenous grinding mills and flotation cells used anywhere in the world (Mining Engineering, November 1988). The copper, gold, silver and molybdenum produced and the tax dollars paid by these operations completely overshadow the other smaller, sometimes short-lived milling operations detailed here. The tonnage treated by the Utah Copper Milling plants has no comparison to the majority of the small plants in other counties. This compilation does not present information on this major operation in proportion to its size and economic significance.

Some of the other plants, including those serving the non-porphyry mines of the Bingham district, were also significant in size and history. The largest and most recent of these plants, shown in Fig. 1 as solid circles, have the largest tailings repositories. These includes the idle United States Smelting, Refining and Mining Company lead-zinc mill at Midvale, and multiple tailings areas in Tooele county.

II. Other major milling plants of Utah

East of the Wasatch Range, the Mayflower mill northeast of Heber, and plants that served various silver-base metal mines in the Park City district, had varied histories. The Park City milling plants were mainly located in the mountains to the west. Tailings ponds related to these operations (fig. 1) in some instance contain material from several operations. These ponds are believed to contain more than 1 million tons per site. Relatively large operations, and resultant tailings repositories, are also present in Utah and Washington counties. Other equally large quantities of tailings were once discharged on the eastern side of the Bingham district and in the valley west of the Cactus mine in the San Francisco Mountains of Beaver County. Some of these tailings, deposited long ago, have blended into the local environment. The Atlas mill near Moab is noted because it reportedly floated minor quantities of copper sulfides, but primarily it processed uranium-vanadium ores.

III. Small plants

At least 85 sites of once-productive nonferrous and precious metals milling plants were identified in Utah. This does not include specialized plants for various rare metals, such as tungsten, beryllium, uranium, vanadium. Nor does it include sampling plants, placer recovery apparatus or small jigging plants erected downstream from old gravity mills.

The smaller milling plants of Utah have diverse histories, which began in the 1870s. A few are identified as examples on Fig. 1 and in photographs of old sites. Many more are known. Small, experimental mills appeared almost at the same time as the first smelters. The principle of gravity concentration, by which heavy metal-bearing particles (e.g. galena, PbS) are separated from less dense waste rock, was well known long before the 19th century. Devices like the gold pan and sluice box were common in the early camps. Easily-fabricated machines like the Harz-type mineral jig were tested on many ores. Promotors of new and sometimes secret technology were at times nearly as common as promotors of new mineral prospects. R. W. Raymond (1874) noted an abundance of "process peddlers" passing through the west like a plague of locusts in the mid 1870s selling new devices to new mine owners. Even today, new technology suffers from blurred distinctions between profit potential and saleability to the uninitiated.

As small mines developed at more isolated locations, small smelting plants were built hoping to reduce transportation costs. Jesse Knight erected a smelter in Tintic in 1908, (Salt Lake Min. Rev. Jul 15, 1908). For years, into the early decades of the 20th century, the most isolated mines, faced with impossibly high transportation costs, tried smelting on site. The Dixie Apex copper mine, Tutsagubet district south of St. George. (Salt Lake Min. Rev, July 15, 1902) A small smelter was also erected in

Ogden in 1906 (Salt Lake Min. Rev. Sept 30 1906, Oct. 30, Dec. 30th, and May 30, 1908). Pyrometallurgical smelting plants are energy intensive and do not easily achieve economy at a small scale. The small plants closed due to combinations of technological failure, lack of ore and exhaustion of capital. The large smelters clustered around the Bingham district survived. Mills were erected to upgrade ores, hence cutting smelting costs.

MAJOR METALLURGICAL PROCESSES AT UTAH MILLS

Table 2 lists processes commonly used in Utah mills. Mercury amalgamation, utilizing the affinity of metallic mercury for gold and silver, was the first process used extensively. Experimentation with combined gravity and/or roasting processes with amalgamation met with failure in several districts. The early Bingham gold placers (James, 1987), and sandstone-hosted mines at Silver Reef (site of several major milling plants in Utah territory: Rolker, 1881; Rothwell, 1880) successfully treated ores by a modification of amalgamation. The basic amalgamation process was readily usable at such isolated localities as Park Valley (Fig. 1; Doelling, 1980) and near Gold Hill in the Deep Creek mountains (Fig. 1), western Tooele Co.

The complex oxidized base and precious metal ores of the state were also amenable to new, hydrometallurgical processes. The chloridization process for silver led to construction of several large mills. Silver Reef (fig. 1; James and Newman, 1986) and Ophir (Butler and others, 1920) were sites of early extraction plants in Utah territory. At Park City the Marsac mill and refinery also tried these processes (Rothwell, 1880 Stetefeldt 1894). Similar processes were tried at Tintic, at first without success. Some districts had rich but mineralogically complex oxide ores near the surface, amenable mainly to smelting. Others were rich in zinc, closely intergrown with pyrite and lead, silver and copper sulfides. Technology for the latter kind of ores began to develop late in the 19th century.

The development of the cyanide leaching process (Elsele, 1988) concurrent with rise in relative value of gold in the 1890s led to several new Utah mills during that era. Cyanidation dissolves specific metals with an organic compound. They are then re-precipitated in metallic form. A large cyanide mill at Mercur proved a success once Daniel C. Jackling and George H. Dern devised roasting processes to destroy carbon and sulfides associated with the gold (Allen, 1910). A cyanide plant to treat sulfide-bearing gold ores from the Highland Boy mine at Bingham proved a failure. (Rickard, 1919; Parsons 1933).

The history of milling process development in Utah shows a hiatus around 1900, as smelting plants and technology improved. James (1990) and several earlier technical articles discuss the history of subsequent milling developments in Utah.
To upgrade base metal ores to smelter feed required mills. After 1900, evolution led to the standard: the gravity concentrator.

The United States Smelting, Refining and Mining Co. built a substantial gravity concentrator, commencing around 1906, to upgrade Bingham ore so that the various components of it could feed different smelters. This seemed to be the pioneering step that others followed. The USSRM Midvale mill was erected on the site of several older smelting (and perhaps milling) plants. It was in the center of the Salt Lake valley, accessible to railroad lines and visible to all. (c.f.Mining Engineering, October 1990, p.1155).

At the same time, a much larger and bolder technological experiment was underway. Daniel C. Jackling's Utah Copper mine began with an experimental 5,000 tons per day plant at Copperton, in lower Bingham Canyon. Such a large mill was scarcely imaginable to the mining world, but soon a much larger gravity concentrator was built at Magna. The Boston Consolidated Copper Co., owner of the other half of the Bingham porphyry copper deposit, commenced building the huge Arthur mill nearby.

All of these plants depended on wet shaking tables and belt vanners (Table 2), devices that processed at most a few tons per hour each. An enormous floor space, hence huge multistory buildings were required (e.g. Figs 6 thru 9).

Gravity concentrators also served the Bingham non-porphyry ores (e.g. Smith. 1973) as well as the Park City (Fig. 9), Alta, American Fork, Stockton (Fig. 6, etc.) and other districts. The

Ohio Copper mill at Lark ground 5,000 tons per day (Butler et al, 1920, p. 342). A few of the plants are shown in Figs. 1, and 3-10. Small plants to reconcentrate values lost into tailings were erected downstream from some of these plants. Additional technology, such as electrostatic separation of zinc minerals (Ralston, 1961) once used at Midvale, supplemented gravity. The flotation process, gradually introduced into many of these plants, simplified milling and had a major impact on the recovery and economics of some of these districts, especially Bingham. Taggart (1944) and others have noted the world-wide effect of the flotation process on metal production. Flotation mills used much less floor space and equipment per ton of ore processed. High technology companies of the times, building flotation cells and vacuum filters, clustered near Salt Lake City and Denver.

One prominent Salt Lake City metallurgist, Charles Butters, had first tried an early flotation process using large quantities of fatty oil at the Mammoth mine in the Tintic district. The Boston Consolidated company made a Butters installation (Stander, 1916) but new, foreign-owned froth flotation technology using aeration and small quantities of organic reagents proved far superior. The technical and courtroom battles that followed involved huge sums for operations like Utah Copper, as implied by Fig.2. Large royalties were at stake (e.g. Rickard, 1916; Barker, 1928). In addition to the porphyry copper mines, world class zinc deposits, such as those at Broken Hill, New South Wales, especially benefited from the new processes.

Flotation brought a significant improvement in recovery. The most important device introduced along with flotation was the large scale grinding or tumbling mill. The most important variant, the ball mill for fine grinding, made possible large scale flotation separations as well as leach treatment. Ball mills also required large amounts of electrical energy and generated large volumes of fine-grained tailings.

Early flotation cells used low pressure compressed air (e.g. Fig. 4) to generate the bubbles which raised sulfide particles to the surface of water. Later cells used huge mechanical agitators to create the air bubbles for the froth.

Flotation technology also changed the economics of smaller mines distant from electric power and water supplies, especially after heavy trucks and a road network developed. In Utah, three major custom mills served such mines in distant parts of the west. All grew near existing installations, at Bauer (below the Stockton district) and the International smelter in Tooele county and at Midvale (Figs. 3- 10, etc). All were situated on railroad lines near the Bingham district. Evans (1928) and the Tooele County Historical Society (1986) describe the Bauer (Combined Metals Reduction Co.) plant. Page (1926) and McKenna (1928) describe the International (Anaconda Company) plants. Lemke (1926) Pallanch (1928) and Nackowski (1964) describe the Midvale (United States Smelting, Refining and Mining Co.) flotation mill. Periodic reports by the U. S. Bureau of Mines (e.g.

1927) and the U.S. Geological Survey (e.g. 1922) also provide details.

The oxide ores of the Tintic district did not respond well to flotation. The ores had to be shipped to a smelter. The high shipping costs and an ongoing battle with railroads over rates led to a new series of experimental mills for pyritic silicate ores (James, 1984). The Knight Christensen mill (table 1, Juab county) was an early prototype. A lower cost, less mechanical version followed. The largest of these were the Tintic Standard or Harold ??? (Parsons, 1925; Allen, 1926) and the Tintic Milling Company or Knight (Higgins, 1916) identified on Fig. 1. These used the Holt-Dern chloridization roasting process, which was also tried elsewhere (Holt, 1915; Allen, 1939), to recover both base metals and silver. Tailings left by the process typically have been smelted later or leached for their gold content.

Reappearance of gold mining, and a decline in base metal demand, occurred in the 1930s. The cyanide process, all but extinct in Utah for two decades, reappeared. New small mills, including significant renewed efforts in the Mercur district, developed. At Mercur, the placing of coarse, crushed ore on an asphalt pad and treating with dilute cyanide solution was attempted (J. Bean, written commun., 1970). Heap leaching, a low-cost alternative to fine grinding and flotation or leaching in tanks, has since become a very important process in gold production. The typically lower recoveries and longer leach times are balanced by the elimination of fine grinding and facilities to contain wet, slimy tailings. An example of recent heap leaching is the Drum mine of Western States Minerals in southernmost Millard county. This alternative to conventional milling has been used elsewhere in Tooele, Juab, Washington and Salt Lake counties. It is presently very important in Nevada.

The 1940s through 1960s saw expansion of base metal production and mill capacity. Some tailings were partially retreated, as at Lark (Fig. 1; Milliken and Kittle, 1939). Custom plants expanded, then gradually vanished as small mines closed. Better flotation reagents, including sulfidation processes for oxidized ores and improved selectivity, spurred the opening of a few new smaller mills, e.g. the Burgin lead-zinc plant at Tintic (Fig. 1; Morris, 1979) and the Mayflower gold-base metals mill southeast of Park City (Quinlan and Simos, 1968). The Calera mill (Figs. 1, 16) treated copper-cobalt ore from Idaho using hydrometallurgy.

Utah's three major custom mills -- United States, International and Combined Metals (Bauer) -- handled a great variety of ores. Page (1926) discussed the feed sources of the International mill. Old records indicate that the Bauer custom mill feed came from very diverse sources. In 1944, the Combined Metals company's four Utah and Idaho mines, plus leasers within them, produced 52 percent of the Bauer mill feed. The remainder came from fifteen operations, including the major Chief Consolidated mine in the Tintic district. This company had failed to make the right choices in its purchase of milling technology during its years of good profits. When the depression stopped base metal mining, the company had sold its volatilization and flotation plant equipment. War and postwar demands for metal reopened its mines, but the Chief company was forced to depend on custom mills (J. Quigley, personal communication).

SMALL "EXPERIMENTAL" MILLS

A variety of unsuccessful schemes, ranging from honest attempts to develop new technology to fraudulent money-raising to religious faith in untried processes, also led to the building of mills in Utah. The archetypal mill failure that brought this whole spectrum together at one site near Payson is described by Pierce (1972). The Relief Mine, believed by its backers to contain rich but highly refractory un-assayable gold ore, was equipped with an architecturally-stunning concrete mill building. Pierce (p.70-74) described the evolution of the mill and process:

> One day in 1932, in the depth of the depression, the Great Powers guiding the mine directed Bishop Koyle to build a large ore refining mill near the portal of the long tunnel. The assignment seemed so great and his supporting stockholders so hard run because of the depression, that he hardly believed such a task could be accomplished. In fact, he did not dare reveal his intentions to anyone until the work was pretty well underway and the workmen demanded an explanation of what it was they were supposed to be doing: Why this type of excavation where little, if any, dynamite was permitted? Just what was going on here, anyway? And with great reluctance, the Bishop finally admitted they were going to build an ore refining mill.
>
> Although the job looked impossible under existing

conditions, money came in almost miraculously, and a beautifully designed, re-enforced concrete refining mill was built according to the inspiration given the Bishop as the work progressed and each new section was developed. And always he was one jump ahead of Alexander Pope, the architect who was employed to design it. The same improvements the architect was planning were already being constructed before he could produce or tell about them.

"The mill," declared Bishop Koyle, "will someday contain a new process that will revolutionize the milling and refining industry. Some inventors from east of here will come with a process, and our company will be the first to have it. It would be far more simple and more efficient than all other processes now in use, and would give far higher values from the ore processed..."

The Chemical Process

High hopes were again raised in the hearts of the stockholders in 1937, when (a stockholder) introduced three strangers from Colorado who had what they claimed was a new and revolutionary process for extracting metals from ores by the use of chemicals. A special demonstration to prove their claims was arranged at the mine by the inventor, John Harper, and his two associates, Gus Englehardt and Jake Brakhage.

Although the process demonstrated unusual merit, it is alleged that in order to make a greater impression on company officials and the stockholders a certain amount of selenium was planted in these chemicals while processing a half ton of ore that was brought from the upper workings on the mountain.

The chemicals used seemed to have the remarkable quality of dissolving just about everything except wood, rubber and silica. After the load was precipitated, the solution actually could be re-activated and used over again simply by adding certain chemicals.

Having thoroughly demonstrated this amazing process to the complete satisfaction and knowledge of the mine's chemist, the inventor convinced Bishop Koyle and the directors of the need to set up a large scale process in the mill, which seemed to be designed perfectly for this process, and there the values in the present ore could be processed on a commercial scale.

Using only makeshift equipment with the first half ton of ore, they produced some 12 pounds of selenium and 32 pounds of iron hydroxide, while other values were left still unrecovered. The selenium and iron hydroxide were shipped to the Harrison Co. of Chicago, and a check for $103.03 was promptly returned in payment for the two metals. It was the first actual money ever received for a shipment form the Dream Mine. The check was dated Sept. 7, 1937, the 43rd anniversary of the day when the first claims were staked out on this mountain.

While the new process was being established, a wave of new hope and encouragement swept over the stockholders. A great mass meeting was called, which filled the Spanish Fork high school auditorium to overflowing. A three-car train out of Salt Lake City pulled up at the high school to unload ... passengers, while others came from far and near by automobile and on foot to hear the good news.

Upon hearing the startling claims made by the inventor, and the high praise given him and his process by various ones of importance in the Koyle Mining Company, the stockholders then scraped the bottom of their depression-worn pockets to raise money ... for a large-scale installation of this revolutionary process that would fit so nicely into their beautiful mill, a mill that so far had been nothing more than an idle monument to their faith. Here was the key that would unlock the values.

A series of graduated crushers, a pulverizer, a line of wooden tanks with rubberized electric agitators, a special rubberized rotary filter, precipitation tanks, pumps, and other equipment went into the development of a large scale process. The stockholders' hopes soared.

The inventor promised to remain and solve...the many problems, and reap his reward in stock and from production returns; but the progress was slow, very, very slow, and the ore was of such poor quality that...John Harper and his associates became disgruntled and decided to abandon this project and seek quicker results elsewhere...

All that remained in the mill now was the abandoned equipment and a few crocks of half processed ore, mostly lime or calcium, and but little desire on the part of anyone to try to complete this process until there was some worthwhile ore to justify it..."

While most Utah mills were more thoroughly grounded in proven technology, a number of them (table 1) sat idle after construction for lack of ore.

OVERVIEW

Most Utah ores varied considerably in mineral content. The mineral content varied among the multiple mines that fed small mills and it even varied substantially within individual deposits. The metals sought by the recovery processes at major Utah plants ranged from minor (a few percent) to trace constituents (as in most gold ores) of mill feed. Thus the mill feed remains largely preserved, in comminuted form, in the tailings.

While plant metallurgists know well what enters the tailings pond, natural processes rapidly modify the discharged material (e.g. James, 1990). Prediction of aqueous processes is becoming possible through simulation of geochemistry (e.g. Davis et. al., 1989, 1990). Principles of sedimentation also apply. But tracing tailings back to a given source, based on mineralogy and trace element content (e.g. Rose, 1967) is not yet a proven technique.

The development and installation of metallurgical processes in Utah progressed by evolution and revolution -- not always in a planned manner. Economics dictated changes in existing plants, rather than more costly rebuilding at other sites. Utah precious metals production depended more on pyrometallurgy -- including both smelting and roasting -- than did adjacent Nevada. Fewer small mills were erected than in adjacent Colorado.

Today, custom milling of metalliferous ores is not practiced at a significant scale in Utah. In past decades, tens to hundreds of mines of the 20 to 100 tons/day size yielded mill feed in the state. Study of tailings from present-day operations is simpler: fewer, larger mines feed mills. But as the grade of available resources inevitably decreases, the tonnage milled will likely increase. The Kennecott complex below Bingham, exemplifying this, has recently completed yet another significant tonnage throughput expansion.

CONCLUSIONS

Utah will continue as a major producer of metallic resources. Its desert valleys, with relatively low potential for agriculture, recreation and real estate development, will likely serve as tailings repositories in the future. As in the case of the Vitro Corp.'s uranium tailings that were moved from the Salt Lake Valley to Tooele County during the 1980s, the desert valleys may also become repositories for mineral waste initially deposited elsewhere.

The study of the origins and mineralogical interactions of mill tailings, based on information already available from past operations, can aid in characterization of this environmentally and economically important material. A discussion by James, (1990) emphasizes this concept. As tonnage milled increases, the study of the interaction of tailings mineralogy and the local environment will become even more important.

Base metals were percentage wise somewhat less important than in adjacent Arizona; gold was more important than in adjacent Idaho. But one district dominated Utah's production, and now more than previously continues to do so. The Bingham district was closely associated with most of the important developments. It was also by far the largest industrial contributor of tax revenues.

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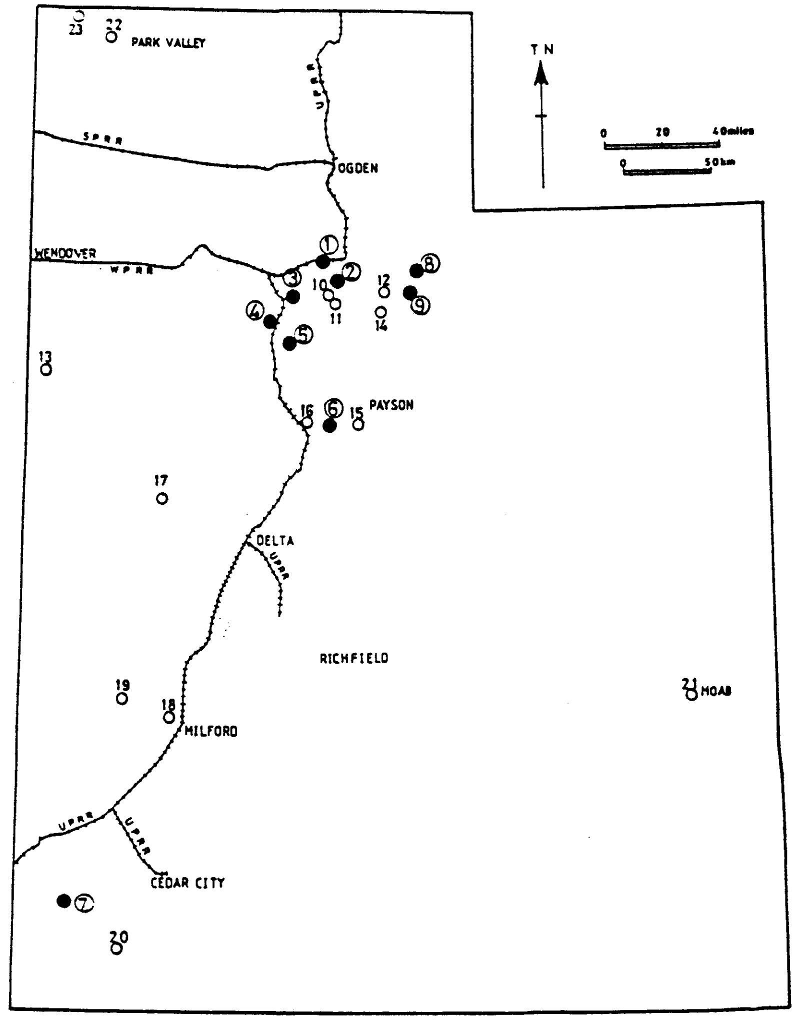


Figure 1 Map showing location of 23 mill and tailings accumulation sites in Utah, discussed in the text. The dark (filled) circles include the largest present and former mills in the state, each believed to have produced more than 1 million tons of tailings from nonferrous metal ores. Less than one third ofthe sites of former Utah mills are shown. Smaller mill sites were selected only as examples.

List of Mills and Millsites Shown

1. Kennecott flotation mills near Magna
2. United States mill
3. International mills (site) and Carr Fork millsite
4. Bauer (Combined Metals) mill site
5. Mercur mill sites and mill
6. Burgin mill
7. Escalante mine and mill
8. East Park City tailings sites
9. Mayflower mine and mill site
10. Bingham Canyon - site of various mills e.g. Winamuck and Utah Apex plants cited in Table 1.
11. Ohio Copper mill sites at Lark
12. Columbus Consolidated mill site, Alta
13. Cane Springs mill sites near Gold Hill
14. Pacific mill site, American Fork Canyon
15. Tintic Standard (Harold) mill site, east of Goshen
16. Silver City (Tintic Milling Co) chloridization mill site
17. Drum (Western States) heap leach site
18. Rocky District mill sites, west of Milford
19. Cactus (Newhouse or Southern Utah) mill site
20. Silver Reef mill sites, west of Leeds
21. Atlas Minerals mill near Moab
22. Century - Susannah mill site
23. Vipont mine and millsites

Other sites shown in illustrations:

Calera mill site West of 1

West Dip mill site West of 5

NOTE:
Locations are approximate. No representation is made that this list is completely accurate. Data herein should be used by readers with caution, and should be checked before reproduction or publication.

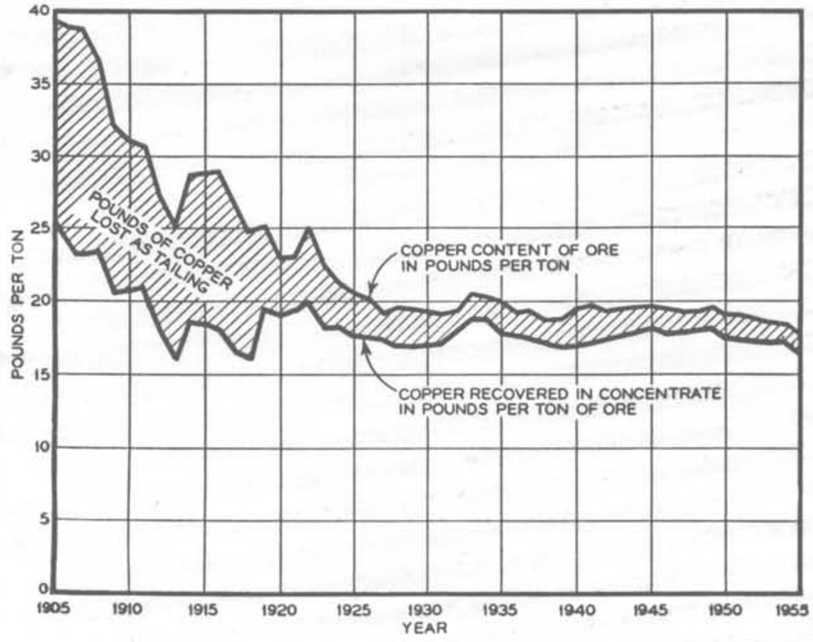


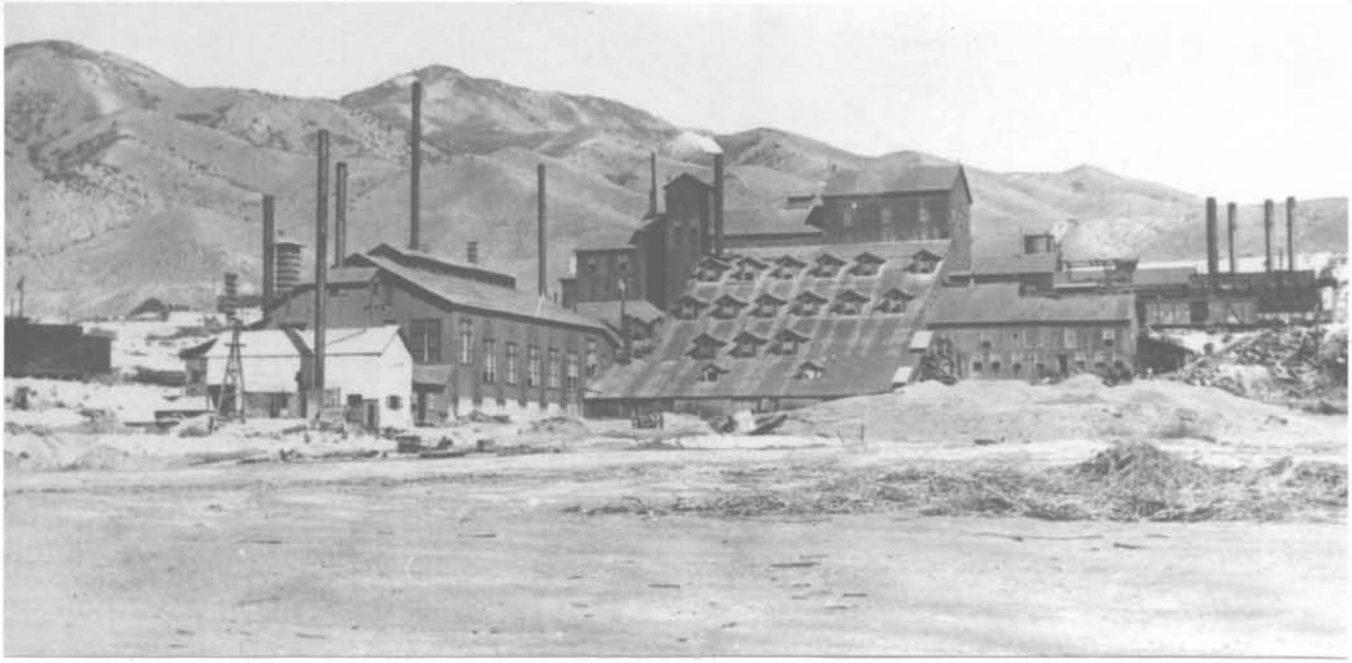
Fig 2. Graphic presentation of copper recovery at the mills of Utah Copper (Kennecott), from the start of production in 1905 through 1955. The substantial decrease in loss to tailings between 1918 and the late 1920s was due to the introduction of the flotation process.
From Parsons, (1956), p. 42.

photographs:

Fig. 3. One of two mills at the former Tooele smelting plant, International, Tooele County. Ore from distant mines arrived by railroad, while ore from Bingham arrived by an aerial tramway extending over the Oquirrh range. Plant was dismantled in 1976; one conveyor gallery was incorporated in building Trolley Square, Salt Lake City.
Photo by L. P. James 1972.

4. Part of Tooele smelting plant (mainly the copper smelter; plant office to left). Some of the heavy equipment was brought from Anaconda's former Washoe Copper Co. plant at Anaconda, Montana, probably via an earlier smelting installation west of Murray.
Photo by L.P.James, 1972

5. "Ambassador Club" at Tooele plant, where an employee could escape the hot, dirty environment that characterized many areas of the International mills and smelting facilities.
L.P.James photo, 1972



6. Bauer mill Tooele County, 1920s looking eastward into foothills of Oquirrh range. Original Honerine gravity concentrator and steam power plant were built to serve mines of the Stockton district (see next figure).
From Engineering and Mining Journal

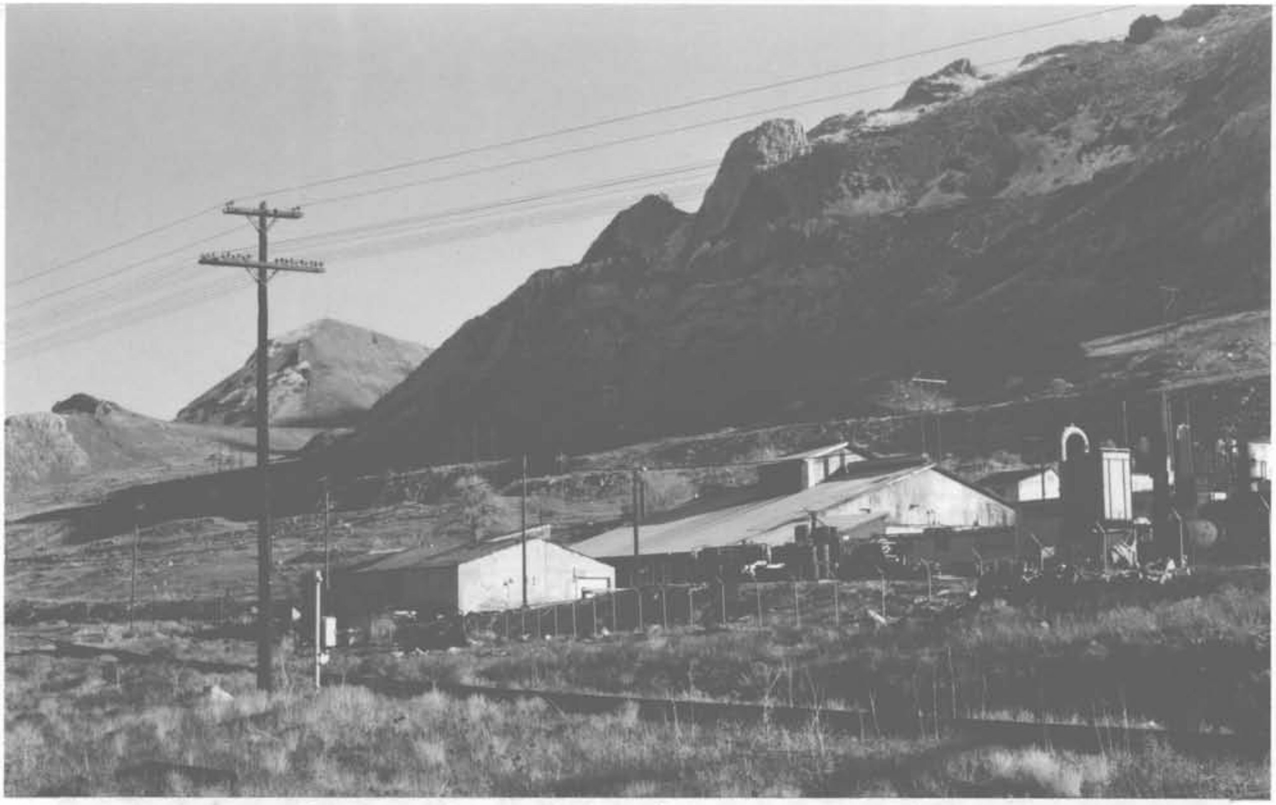
7. Bauer mill (left), Honerine drainage adit, Combined Metals Reduction Co's warehouses, resin refinery and town of Bauer (right), looking west from Union Pacific railroad tracks, 1950s. Tailings were discharged into ponds on flat to left. See also fig. 13.
courtesy I.C.Droubay, Combined Metals Reduction Co.

8. An early view of the Bauer mill, looking south toward Stockton Bar, and trackage of Union Pacific Railroad Mill was first known as the Bullion Coalition gravity concentrator, built for the Honerine mine in the Stockton district. This was accessed by a long drainage tunnel east of the mill. It was purchased in the 1920s by Combined Metals Reduction Co., partially to treat ores brought by railroad from Pioche, Nevada. Later it was converted to flotation.
Courtesy Sam Craig, Atlas Minerals

9. Newly-constructed cyanide mill at West Dip gold mine, Tooele County, 1937. Area is now on U.S.Government military reservation.
Courtesy L. K. Requa.

10. United States (U V Industries or Sharon Steel) mill and tailings near Midvale, Salt Lake County, 1982. Railroad (center) brought non-porphyry ores from Bingham district for processsing by selective flotation. The mill also treated custom ores from other districts.

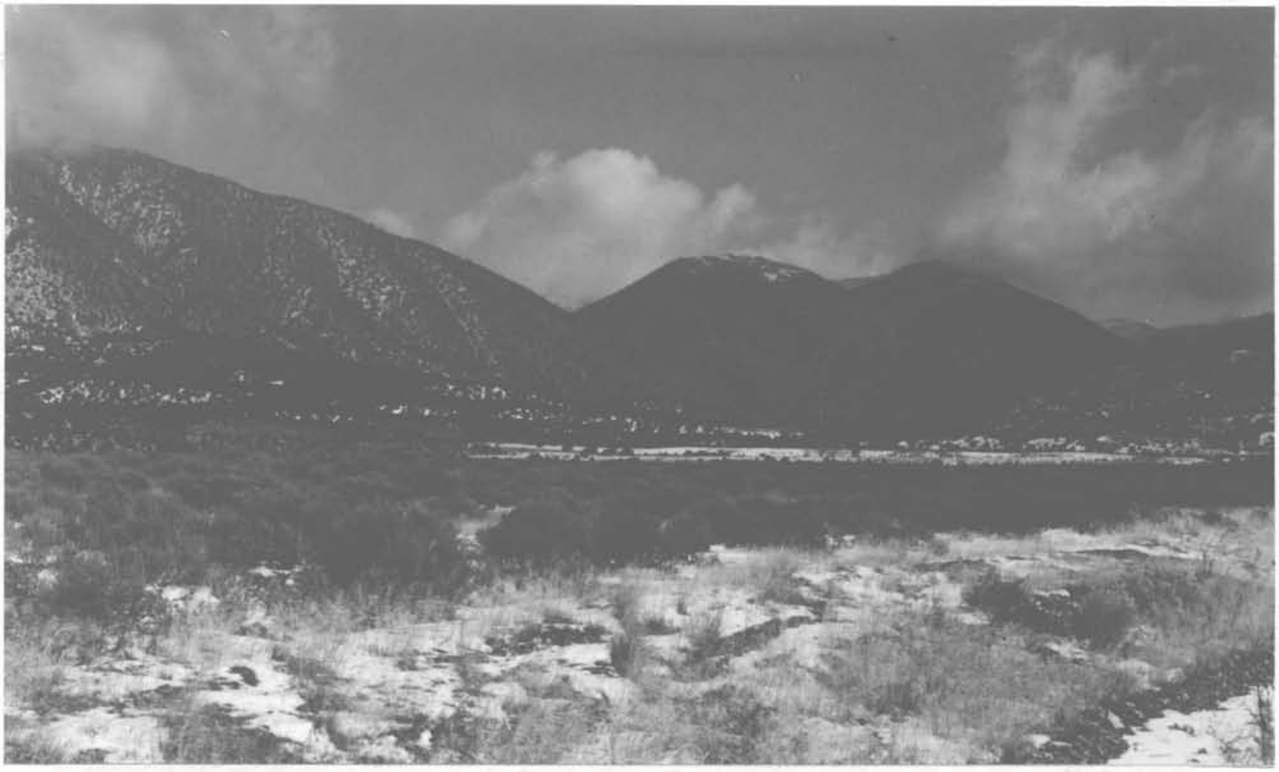
11 and 12. Closer views of main flotation building, United States mill, Midvale. Plant is briefly described by Nackowski, 1964. The heavy concrete construction of this and other plants of the era suggests the faith company personnel and investors had in the future of Utah's base metals industry.



13. Remains of Calera cobalt mill west of Garfield, Oquirrh Range, south of railroad line. This somewhat experimental mill treated ore from Idaho. It was probably first erected by Howe Sound Mining Co., and subsequently operated by others. View south, 1987.

14. Some of the extensive Kennecott copper tailings, shadowed by the frame of an old conveyor gallery, near Magna, Salt Lake County, 1987, prior to reopening of operation. Parts of the Magna and Arthur plants have since been closed permanently.

15 and 16. Parts of the Kennecott copper milling complex near Magna, Salt Lake County, 1987, prior to recent modernization.



17. Tailings site north of the mouth of Ophir Canyon, Tooele County. A small plant retreated old gravity tailings from the Ophir Hill mine area during the 1920s-1930s era, providing some additional lead concentrate feed for the International smelter. Taggart (1956 printing), p. 2:189-190 gives a brief description of the 275 ton per day flotation plant.

18. A small 1980s heap leach site for precious metals recovery near St. John, below the mouth of Ophir Canyon, Tooele County, and the surrounding vastness of Rush Valley. The somewhat-experimental leach plant operated only briefly, treating dump rock from some distant mines (Gee and Benson, 1987). A number of such plants, based on low capital cost and contractors' excavation and hauling, were constructed in the Great Basin following the rise in gold prices of 1979-80.

Table 1 Nonferrous Metal Mills and Mill Sites of Utah Tabulated by County

Mining District	Mill Name or Names	Location of Mill or Site	Mines Served	Yrs. built	tons /dy (max.)	Yr. Closed	Plant on site?	Process used	Tailings at site?	References and Notes
BEAVER COUNTY										
San Francisco	Horn Silver	Ghost town of Frisco	Horn Silver	1900s et seq	50	1920s	No	Gravity (etc)	Minor	Butler, B.S., Geology of San Francisco Mts., U S Geol. Survey Prof. paper 80 1907;photo in James, 1986; U.S. Bureau of Mines 1927. (refs to Peck Mill, etc) U. S. Geol. Survey, Min. Res. of the U.S., 1900s-
Frisco	Cactus Newhouse South Utah M&S	Ghost town of Newhouse, W. side of S.F. Mountains	Cactus	1900s	800	1900s	No	Gravity	Yes	1920s Butler, Ibid; Salt Lake Mining Review, 1902-1905 (feature, Nov. '15, 1905 p. 504). Also called Utah Leasing Co. in later days? (this group retreated tailings, per Salt Lake Min.Rev., Jul 15, 1916) First mill at mouth of copper gulch, No.2, much larger, on flats below,
Rocky	Essex Cu, Shield Devel. Co., Prosper M. Co.?	West of Milford	OK, Bwana, etc. Also Horn Silver	1940s?		1974?	Yes	Acid Leach etc.	Yes	Whelan, J., Geology of Rocky District, Utah Geol. & Min. Sur. Bull; Whelan et. al., 1973, Guidebook to Rocky Dist., Utah Geol. Assoc. also shows photos of cactus mills
Beaver carbonate				1900s?		1900s?	No	Jigs?		
Milford	Milford Stamp	Milford town	Old Hickory	1873			No	Gravity/Amalg.?		Huntley, D.B., 1085, Precious metals in US., 10th Census vol.13. p471-475
BOXELDER COUNTY										
Park Valley	Century Susanna	Below mines in foothills of Raft River Mts.	Century Susannah	ca. 1899	50	1918?	No	Amalgamation Gravity	Minor	Salt Lake Min. Rev., Sept. 30, 1902; Doelling, Utah Geol. Min.-Sur.1980 U.S. Bu. Mines IC 6027 1927
	Ashbrook	Below Vipont mine, South of Burley area, Idaho	Vipont etc.	1915	225	1923?	No	Gravity Flotation?		Doelling, Ibid p. 152,; Butler and others, 1920; Economic Geology, 1920. Bu. Mines IC 6027
			Same	1970s	?	1980s	Yes	Cyanidation /heap leach		
GARFIELD COUNTY										
Imperial	Bromide	Below old mine Mt. Ellen area of Henry Mtns.	Bromide	1903	20	1920s?	?	Amalgamation	Minor	Salt Lake Mining Review, 1902-1917; U.S. Bu. Mines, 1927 Hunt, C.B., U.S.Geol. Survey Prof. Paper 228; Butler, 1920 p. 629 Minor attempt to leach tailings begun in 1980s.
Imperial	Rico Wolverton	Mt. Pennell Straight Creek	Unknown	1922	3	?	No	Amalgamation		U.S. Bu. Mines 1927 Hand-crafted arrastra powered by water wheel remained at site ca. 1959 Appearance suggested mill processed only minor tonnage.
IRON COUNTY										
Stateline	Johnny	At mine site	Johnny	1890s	50?		ruins?	Amalg.-Gravity	Minor	Butler and others , 1920, p. 564 Perry, L.A., Stateline District, in Utah Geology (UT.Geol.Min.Surv)
	Big Fourteen	Ditto	Big 14	1912 ?			?	Ditto	?	Butler, Ibid. Mill moved from Johnny mine in 1914.
	Ophir	Near mine site	Ophir	1901	150		ruins	Russell Lixiviation Cyanidation		Work in area also conducted by Kinetic Minerals, 1984, consisting of test cyanide heap leaching of old tailings.
Gold Springs	Jennie	Ditto	Jennie	1900s			ruins	Amalgamation Cyanidation		Butler, Ibid p. 565 Perry, L.A., Gold Springs Dist., in Utah Geology (Ut. Geo.& Min.Sv)
Escalante	Escalante	Adjacent to mine	Escalante	1981	6000	1988		Cyanidation	Yes	Harlin, T.T., 1982, Introduction & geology of Escalante silver mine, Ranchers Exploration and Development Corp., presentation/preprint, Northwest Mining Assoc.; Hogan, K.D., Fitch, D.C., Scheffel, R.E., and Welch, M.R., 1982, Escalante mine nears first year of full operation: Mining Engineering, p. 1323-1328; Annl. Repts., Hecla Mng. Co.
JUAB COUNTY										
Tintic District	Mammoth	South of Diamond, at Copperopolis? Spring (Roseville)	Mammoth	1873	22.5	1874?	No	Antique	No(?)	Huntley, D.B., 1885, Mining Industries of Utah: 10th Census, US, v.13 Raymond, R.W., 1877 p.395; Eng. and Min. Jour., v. 52, Oct.3, 1891;
		8 Miles S. of Mammoth; Vicinity		1876		1882		27 stamps, amalg.		Stander, 1916. Furnaces were used in or replaced earliest mills.
				1891		1890s		15 stamps, lixiviation		Tower, G.W. jr. and Smith G.O, Folio accompanying U.S.G.S. 19th Annual Report, Part 3, 1899, shows sites of mills near Mammoth.
				1893	180 ?			60 stamps, pan amalgamation.		Development of custom smelters proved more efficient than mills for Mammoth and other Tintic oxide-sulfide ores.
	Miller Custom mill, near Diamond, S. of Silver City			1873		1879?	-	Stamps,roasting, et	No	Raymond, Ibid.; Later Mammoth mills were at Robinson, below Mammoth
	Homansville custom mill			1872	25	1873				V.C. Heikes in Butler et. al., 1920 p. 403-405.
	Wyoming M&M Co	Homansville, NE of Eureka (Utah Co.?)		1872		1887?		stamps, pan amalg. chloridizing roast using first Stetefeldt furnace in Utah		First successful mill on Tintic ores. Eng. and Min. Jour, v. 52, Oct 3 1891. Later operated by Tintic Mining & Milling Co.
	- Knight - Christensen	East of Silver City, nr. Dragon		1913		1915	Yes	Christensen roast-Lixiviation		Metallurgical and Chem. Engrg., 1914. Plant burned April 6, 1915.
	Tintic Milling	NE of Silver City	Swansea, other Knight company mines	1915		1920s?		Holt-Dern and Christensen roasting, lixiviation, similar to Standard Reduction (Utah Co.)	Yes	Described by Higgins (1916) and Heikes (Ibid, p. 406)
	North Lily	Same	Tailings	1987?				Cyanide heap lch.		Plant erected to retreat Holt-Dern tailings, mainly for Au recovery.
	Utah Mineral Concentrating Co.		Various	1914		1916		Isbell concentrators		Plant near Eureka described by Heikes (Ibid). Site and process not identified. Evidently east of Eureka, near Chief Cons. mine?
	Eureka Hill	West of Eureka	Eureka Hill	1890s	250	?		100 stamps, amalgamation.		Cited by Heikes, ibid.
	Bullion Beck	West of Eureka	Bullion Beck	1890s	200	?		Gravity?		Also from Heikes, Ibid. See also map in Tower and Smith (Ibid).
	Sioux or Farrell	Robinson	Sioux-Ajax?	1890s	60	?		20 stamps		Also Heikes, Ibid.
	Chief Cons.	E.bdry Eureka Townsite	Chief Consol.	1924-5	250	1930s	No	Gravity, Flotation volitization		Nieman and Wigton, A.I.M.E. Trans. 1925; U.S. Bu. Mines Inf. Circ. 6027 1927, p. 3
Trout Creek	Oro del Rey	W of Callao	Oro del Rey	1983?		1986?	Yes?	Cyanide heap lch.	Yes?	Built by E. Payne kibbe interests to serve nearby mine operation; prob. 3000 to 4000 tons treated
Fish Springs	Joseph	Below Utah mine dumps	Utah,Galena	1920s	150		no	gravity	minor?	U.S. Bu. Mines Inf. Circ. 6027
KANE COUNTY										
none identified										

Mining District	Mill Name or Names	Location of Mill or Site	Mines Served	Yrs. built	tons /dy	Yr. Closed	Plant on	Process used	Tailings at site?	References and Notes
MILLARD COUNTY										
Drum	Western States	So. Little Drum Mts.	Drum gold pit	1983?				heap lch. cyanide	yes	James, 1987
Amasay ?? Notch Peak	Amasa Placer	Amasay Valley, So. House Range		1950s?	small			gravity	minor	Minerals Yearbook
PIUTE COUNTY (Note: Some mill/power plant facilities extended north into Sevier Co.)										
Ohio	Wedge	West - NW of Marysvale, Wedge		1930s?	Small			Unknown		
	Bully Boy & Webster	same in Pine Canyon	B. B. & W.	1913 1922	50	burned		Unknown Gravity		Butler et. al., 1920, page 556-557 According to I.C.6027, 1886 mill rebuilt 1922.
(Ohio,Cont.)	Dalton	Bullion Canyon	Dalton					Unknown		Butler et. al. p. 556
Mt. Baldy	Deertrail	Bullion Canyon, W. of Mv	Deertrail	Early 1880s			no	Unknown		
		6 miles SW of Marysvale		1917	50			Gravity + cyanide		U.S.Bu. Mines I.C. 6027, 1927
Gold Mountain	Sevier Con.	nr. Clear Creek	Sevier Consol	1902	150			Cyanide		U.S. B.M. IC 6027: operated only 1 year after construction Salt Lake Mining Review (Warren, 1972)
	Annie Laurie	Below Annie Laurie Mine, South of Sevier		1900s Rebuilt 1930s, 1980s				Cyanide	yes	Ibid;'Eugene Callaghan, Ut. Geol. & Min. Survey
				1970s				Flotation	Minor	Operated only on a test basis
SALT LAKE COUNTY										
Bingham (West Mtn.)	Ohio Copper	Lark, below Mascotte Tunnel	Ohio	1907?	5000	1920s?	yes	Gravity	yes	Butler et al, 1920 p. 342; etc. Plant may not have reached capacity; third section completed May 1913, per Salt Lake Min. Rev. (numerous 1905-late 1920s;feature Mar 30,1909) Also Mines & Methods,3/1910.
				1924		1920s?	no	In-situ leach	no	Ibid; I.C. 6027 U.S. Bu. Mines; W. H. Smith, Pers. Communic. 1965. Launders inside Mascotte tunnel precipitated copper on iron; failure reportedly occurred due to iron oxide sealing of leach column.
				1939		1940s		Flotation	yes	Retreatment plant, gravity tails:F. Milliken & P. Kittle,AIME Trans.
	Dalton & Lark	Above Lark townsite?	Dalton & Lark	1870s?		1896	burned	gravity?	?	Salt Lake Min. Review, Nov. 15, 1900. Probably small.
	Copperton	Below mouth of Bingham Canyon	Utah Copper	1987	very large		yes	Flotation		Tailings by pipeline to Magna-Arthur area to north; Part of Kennecott expansion described in many trade journals. Summary in Mining Engrg., Nov. 1988 p.1017-1020 includes history. Plant includes largest autogenous mills in world, 9ktph crushers.
	Highland Boy	Carr Fork? Bingham	Highland Boy	ca 1910		soon	No	Cyanide	?	Butler et al, 1920, p. 342; Rickard, 1919; Bailey, 1988
	Utah Apex	Adj. Parvenue Adit, Carr Fk.	Apex	1910	350	1924	no	gravity	Tails pond in lower Bingham Creek?	Mill rebuilt 1924 as flotation mill (U.S. Bu. Mines, 1927). Photo in James, 1978.
	Midvale, U. S.	West Midvale, S.L. Valley	Numerous	1906	500	1972	yes	flotation gravity electrostatic sep.	yes	Large custom mill used mainly by owner, U.S. Smelting, Refining and Mining Co., on Bingham Pb-Zn ores. Nackowski (1964), James (1990) and A.James, 1973, summarize.See refs. Also called Sharon Steel mill site. Described by Taggart, 1956 printing, p.2-189-190, and USBM IC 6492.
	Winamuck	Portal of mine adit	Winamuck	1900s	small	?	No	gravity	?	Small plant, shown in photograph in James (1990)
	Lead Mine	Lower Bingham	?		small					Probably near Lead Mine station, lower Bingham Canyon.
	Redwing	Ditto, Markham Gulch	Red Wing	1900s	small?		?	gravity		S. L. Min, Review, various issues. Probably short-lived, treated Pb ore
	New England	' 3 mi from Bingham Canyon P.O.	New England	1925	Small?		No	gravity	?	U.S.Bu Mines Inf. Circ. 6027 p.5. "2 Harz jigs, electric power" General area buried beneath Kennecott dumps.
	Revere	Bingham Canyon	Revere							Salt Lake Mining Review, brief mentions.
	Rogers	Upper Bingham Canyon Site excavated by copper pit	Utah Copper, etc.		small		No	gravity	no	Remains preserved at Kennecott pit overlook? Noted as historic site where D. Jackling tested Utah porphyry ores. See Parsons 1933,Rickard 1919. A small plant, idle when Jackling leased it.
	Starless	Site excavated by copper pit	Starless	1908?	small		No	" (?)	"	Utilized equipment designed by owner, Col. E.A. Wall. Mines and Methods 1910 describes location.
	Utah Leasing Co.	Upper Bingham (?)	Telegraph	1910	50	?	no			
	Stamp mills	Unknown - ("several were built"-Butler et al, p.341)					no	Amalgamation	?	Butler et al (ibid) state that in 1915 era several small mills still operated in the Bingham district.
	Barneys Canyon	North of Bingham Canyon E. front of Oquirrh Rge	Barneys, Melco	1989	-		Yes	Heap Leach	Yes	Gold leach serving two open pit mines in Barneys Canyon area of Bingham district, built by BP-Kennecott, operated by Kennecott. Mentioned in trade journals.
Smelter	Magna	15 Mi N of Bingham, at Magna, adj. Great Salt Lake	Utah Copper	1905	Very Large		yes	Gravity later Flotation	yes	Well described in Parsons 1933, 1956, and many trade journals. Also Bu.Mines Inf.Circ.6027. Utah's most successful and long-lived mill Also Taggart, (1956 printing) p.2-42-43
	Arthur	Same, to west	Same	1906	same	1990?	yes	same	yes	Built for Boston Cons. co, who held half of Utah Copper ore body. Gradually modified and upgraded, processed Kennecott ore. Descr. Salt Lake Min. Rev. Dec.30.1906, Nov.15,1908
	Calera	West of Garfield Smelter along D&RGW Railroad	Blackbird, Salmon Idaho	1950s?		1960s	yes	leaching,	yes?	Small, somewhat experimental plant built to treat Co-Cu ores, probably used on some other ores from other mines.
Big Cottonwood	Wasatch Utah	Gold City, Little Willow area		1916	50	1917	no	Cyanidatio?		Described in James; 1990; Utah Geol & Min. Sur. Bull 114,1979. Short lived, processed few tons.
	Alta Tunnel & Transportation Co.		Silver Fork	1920s	50	1930s	no	Gravity	?	Small; described in James, 1979 and 1981.

Mining District	Mill Name or Names	Location of Mill or Site	Mines Served	Yrs. built	tons /dy	Yr. Closed	Plant on	Process used	Tailings at site?	References and Notes
Little Cottonwood	Columbus	Lower Alta	Columbus	1905	150	1912	no	Gravity	yes?	Noted in U.S.G.S. Prof. Papers 111 and 201. Small gravity plants downstream retreated some tails. Site near Gold Miners Dtr. Lodge.
	Continental-Alta Mill	Tanners Flat	Michigan--Utah Group	1904	100	1907?	no	Gravity	?	Short-lived plant, experimental. Run by Water power. Brief descriptions in Salt Lake Mining Rev., USGS PP201
	Jacobs	Snowbird Area	Custom Mill	1920s	?	1920s	no	Flotation	?	Small plant mentioned in Salt Lake Min.Rev., Jacobs Engineering Co. built plant. Short lived, almost no record of activity or production.
	Emma	Bay City Tunnel	Emma, etc.	1920s ?	?		no	Gravity	?	Small, speculative plant, operated little. Other small gravity jig plants run by leasers in Emma mine area, 1930s etc
SAN JUAN COUNTY										
Lisbon Valley	Big Indian	Sandstone copper mine area	Big Indian	1916	300 ?	?		Roast-Acid Leach	?	Various later plants also. Described Bu. Mines (Ibid) as steam powered probably experimental plant. Other processes tried later. Refs given by G.N. Breit etal, Econ. Geology v.85 1990, p891 (geology, ores only)
	Micro Copper	Nearby	Micro Cu	1970s ?		1970s ?		Acid Leach?		Various ventures, including Cleveland-Cliffs Corp., tried to apply new technology to sandstone-hosted Cu. Refs. in trade journals.
Unknown	Unknown	LaSal Mtns.? (Miners' Basin?)	Dream, etc.	1913?	Small	?	No	Gravity/Am	?	Butler et al, 1920 p. 619; U.S. Geol. Surv. Min. Res. of U.S., 1922, p. 421 note small, unsuccessful plant existed.
SEVIER (See Piute)										
Summit Park City	(See Also Wasatch County)									Note review of history of process evol. from amalgamation to flotation at various plants, in Butler et al, 1920, p.287-289, partly based on earlier descriptions by J.M.Boutwell, U.S.G.S. Prof.paper 77. Also Min. Res. U.S.
	Silver King	Woodside Gl., SW of t	Sil.King Coalition	1900s	500	1950s	yes	Gravity, Flotation	yes	Evolution, and a mill fire, led to state-of-art concrete flotation plant, described by M. Dailey, U.S.Bu.Mines. Tails piped to valley.
	Daly Judge	Head of Empire Canyon,	ditto Anchor, etc?	1900s	500	?	No	Gravity		Large short-lived plant, one of several in canyon. Refer to J. M. Boutwell, USGS Professional Paper. Tailings retreated by jigs.
	Daly West	Ditto	Daly West		400					History very similar to above. Mine ore treated 1970s at Ontario mill
	Park Utah (Judge)	Empire Canyon, Pk. City	Judge/Park-Utah	1901 et. seq	150?	1940s?	No	Flotation (etc.)	Yes	Described U.S.Bu.Mines IC 6027. Burned (?) along with tramway, 1950s Tails piped to Silver Creek valley NE of Park City.
	Crescent/CC	Thaynes Canyon, W. of to	Crescent	1880s	small	?	No	gravity et?		Evolution described by Butler et al, and IC 6027, cited above.
	Comstock	Comstock Mine, same are	Comstock, California				yes	Ditto		May be same plant as Keystone. See Mineral.Soc. Utah Park City bull publ. in 1950s for photograph and brief commentary.
	Judge Electrolytic	Deer Valley?	Judge	1920s?		1920s	No	Leach Zn, electrowin	?	Experimental plant; foundations appeared identifiable 1960s. Described in Salt Lake Mining Review as Judge Electrolytic Smelter.
	Moore	Silver Creek, NE of Pk.City		1903	150?	1920s	No	Gravity, Flot., Etc.	Yes	Partially used to retreat tails of other mills for Zn. Discussed by Butler et al, 1920, p291, and G.A. Stott, B.S. thesis, Univ. Utah, 1916. Identical copy of one unit, Silver King Mill per Butler, Ibid.
	Kearns Keith	Walker & Webster Gulch, SE Pk.City?		?	150?					
	Ontario	Ontario Canyon, So. of Park City		1900s 1960s	1000	1920s 1980s	No	Gravity et Flotation	yes	Evol.of leach, roast, gravity plants descr. by Butler et al; ibid James 1990; see refs. 1960s Anaconda plant operated intermittently.
	Marsac	Mouth of Ontario Canyon		1880s	var.	1920s	No	Gravity, roast, lch.		See refs. cited above; Various processes tried on various ores
	Union	Empire Gulch		1889	100	?	No	Gravity	?	Butler et al, 1920 provides some detail
	Mines Operating Co.	Ontario Canyon	Tails?	1909?	?	?	No	Holt-Dern	?	Roast-chloride leach, described in article by T.Holt; see Refs.
TOOELE COUNTY										
Camp Floyd	Barrick Mercur Golden Gate	Mercur canyon minesite	former Con. Mercur, etc.	1890s			Yes	CIP Cyanide formerly roast-Cn	Yes	First mills built were chloridization, in 1880s (refs in Gilluly, 1932, Spurr, 1895, U.S. Geol. Survey Prof. Paper 173 and Annl.Rpt. 16 pt.2) failed. Cyanidation was success by 1900s on large scale - see James, 19 1990. See also Utah County. In 1930s Snyder interests built new mill to treat ores and tails. Getty Mining built present mill, 1?30s. Pressure oxidation plant started 1988 (Mining Engineering Feb. 1990 p. 169).
	Geyser Marion	North side Mercur Canyon	G.Marion	1900s 1930s	?	1930s	No	Cyanide		1930s mill known as Franklin Lease. See Ref. cited above.
	West Dip	NW extreme, Mercur mining area.	West Dip	1900s 1937	x00	1940s	No	Cyanide	Yes?	First plant built 1900s, closed soon. In 1930s, new mill built by Requa and Associates; cf photos in James, 1987, p.444
	Sunshine	South end of Mercur area	Boston Sunshine			1910				Descr. in Salt Lake Min.Rev. Jan. 30, 1902 p. 11; Jun.15. 1910. etc.
	Sacramento	Southwest of Con. Mercur	Sacramento	1900s		1914?	No	roast/cyanide	No?	Described in Salt Lake Min.Rev. August 15, 1913 p12 et seq
	Overland	Same, Overland area	Overland	1900s		1900s?	No	Cyanide	?	See above reference. Small, unsuccessful operation
Pine Canyon	Carr Fork	NE of Tooele Smelter site (see below)	Carr Fork	1970s	9500	1980s	No	Flotation	Yes	New mill erected by Anaconda Co. to serve new underground mine, stoping in Bingham district. Described in trade journals. Dismantled and moved as a unit after a few years operation. Tailings and site reclaimed, 1980s.

Mining District	Mill Name or Names	Location of Mill or Site	Mines Served	Yrs. built	tons /dy	Yr. Closed	Plant on	Process used	Tailings at site?	References and Notes
International Townsite	IS&R	SE of smelter site, ENE of Tooele		1921	1000	1940s	No	Flotation	Yes	Two mills, one for oxide, Pb,one for sulfides, were interdependent. Both were custom plants serving Anaconda subsidiary's smelter. McKenna (1928)and U.S.B.M.I.C. 6027 describe. Dismantled 1976; reclamation of tailings area carried out. Bingham was major ore source.
Rush Valley	Bauer (CMR)	S. of Bauer townsite, nr. Stockton Bar, So'most end of Tooele Valley	Honerine, Calumet Also custom mill	1903	1000	1954	No	Gravity Flotation	Yes	Gravity concentrator erected by Bullion Coalition Mines Co. was rebuilt 1924 by Combined Metals Reduction Co. Treated custom ores from Nevada etc.Expanded and modified; see Gilluly, U.S.G.S. ibid; James 1990. Dismantled 1976.
Ophir	Ophir Hill	Ophir Canyon, mouth of Ophir Hill mine lower adit Moved and rebuilt 1930s nr. mouth of Dry retreated tailings 1940s	Ophir Hill etc.	ca. 1900	200 275	1930s	No	Gravity flotation		See U.S. Bu. Mines. Moved and rebuilt 1930s nr. mouth of Dry Canyon to north. See Taggart, (1956 printing) p.2-194-195.
	Pioneer	Lion Hill, south of Ophir	Zella	1871		1880s		roast, amalgamate 20 stamps	?	Used a furnace, etc. Moved to Butte, Montana later, by Walker Bros. of Salt Lake. Descr. by D.B.Huntley, 10th Census US, V. 13,p. 477, 1885
	Various small	South of Ophir and in Ophir (East) Canyon	Chloride Point etc. etc.	1870s		1870s		Arrastres, Amalgamation etc	?	Various small water powered mills, some with smelters. See Huntley,Ibid
	St. John Heap Leach	St. John Station area below Ophir		1984		1987	Yes	Cyanide	Yes	Ore was dumps hauled from other districts. Process was small scale. Gee and Benson (1987) note corporate ownership.
Erickson	Imperial	Death Canyon, ca. 45 Mi. N. of Delta in Simpson Mountains.	Imperial Lead	1924	40	1920s	No	Gravity	?	Small plant operated for short time, 1924-25. Described in U.S.B.M. Inf. Circ. 6027 p. 10.
Clifton	Cane Springs Woodman	West of Gold Hill townsite,S. of Wendover		1890s	200		Yes	Gravity Amalgamation	Yes	First erected for precious metals, using 5 Crawford grinding mills. Modified 1950s for tungsten. Pieces removed to Victoria Nv. 1985-86. Some data in U.S. Geol. Survey Prof. Paper by T.B.Nolan
Delle	Lakeside Monarch	Near old Pb Mine		1920s?						Small experimental plant may have been built.
UTAH COUNTY American Fork										
	Fissures-X	Below adit, on Dutchman Flat	Dutchman	1917	50?	1918	No	Gravity	?	Erected by Fissures Exploration Co.; moved 1 year later to Pacific Mine farther up canyon. Noted in U.S.Geol. Survey Prof. Paper 201.
	Pacific	Portal, lower Adit	Blue Rock or Pacific		150?	1930s?	No	Grav., Flotation	Yes	See above; descr. briefly in Salt Lake Min. Rev. Minor retreatment of old tails by Jigs, floration, smelting?
	Belorphan	Lower portal, Yankee mine' Mary Ellen Gulch	Yankee	1920s	50?	1920s	No	Gravity	?	See above, also U.S.Bu. Mines. Plant destroyed by snowslide?
Utah Valley (Orem) Area										
	Utah Consolidated, United minerals Int'l	No.of Geneva Steel works	South Hecla	1978	150?	1984?	?	Flotation,etc.	?	Built to serve South Hecla mine, Alta, and as custom mill. Apparently treated little ore.
Northeast of Payson										
	Relief or Dream'	Adj. lowest adit	Relief	1930s	?	?	Yes	See Text	?	As described in text, process and mill feed were developed partly based on religious beliefs. The substantial buildings are impressive.
East Tintic										
	Burgin	At Burgin No.2 Shaft. Silver Pass Creek, W. of Goshen	Burgin	1965?	800?		Yes	Flotation	Yes	Built by Kennecott Copper Corp. to treat partly oxidized Ag-Pb-Zn ores discovered 1950s-1960s. Operated regularly 1970s, intermittently 1980s. Designed to float cerussite.
	Harold	Mountainside E. of Goshen	Tintic Standard	1920	200	1920s	Ruins	Chlorid'-ization	No	Used Holt Dern process, described by Allen (see refs; also I.C. 6027). Colorful concrete tanks described as architectural heritage by Utah Architect (ref. in James, 1984). Tailings later shipped to smelter.
		Knightsville Area, E. of Eur.	Godiva, Uncle sam	1905		?		Dietz and keedy pat'd dry process		Heikes, Ibid; see also under Juab County, Homansville. Water piped 2 miles from Homansville.
Mercur-Camp Floyd	Manning	Upper reaches of Manning Canyon, SE of Mercur (see Tooele Co.)	Con. Mercur and tailings	1900s 1930s		1930s	No	Cyanidation Roasting	Yes?	Manning site was on Salt Lake & Mercur Railroad. Briefly described in J. Gilluly, 1932, U.S. Geol. Sur. Prof. Paper 173 Salt Lake Min Rev. Ap. 15 1906 descr. Holderman mill. Last mill built by Snyder interests in 1930s to treat tails.
WASATCH										
Blue Ledge (Park City)										
	Mayflower	Below portal of New Park mine adit, E. Flank, Wasatch Range at mouth of Big Dutch Pete Hollow	New Park	1962	400	1972	No	Flotation	Yes	Built by Hecla Mining Co., and treated ca. 1 million tons Au-Pb-Cu-Zn-Ag ore from structures below Mayflower tunnel level. See J. Quinlan and J. Simos, in Erickson et al, Eds.,Guidebook - Park City District; Utah Geol. Soc. 1968, p. 40-57.
	Glenallen	Glencoe Canyon, East side of Wasatch Range, Star of Utah adit?	Glencoe	1924	100	1930s?	no	Gravity	?	Described in U.S.B.M. Inf. Cir 6027. Previous experimental plant described by U.S. Geol. Survey. Apparently operated briefly.
WASHINGTON										
Harrisburg	Christy Stormont Others	Below and north of mines of Silver Reef area	Six mills served mines	1880s	1000?	'1890s	No	Pan Amalgamation	Yes	Large silver operation, described by James and Newman 1984; P.D.Proctor Utah Geol. & Min. Sur. Bull; see refs. Later retreatment, shipment of some tailings. History of this old, isolated camp is limited.
	Western Gold & Uranium Company	Between mines and Silver Reef Townsite	Silver Reef	1950s	200?	1950s?	Yes	Flotation	Yes	Built to accompany deep exploration at northeast end of district. See refs. Richard V. Weiman, pers. commun., 1984.
	?	Flat SE of new townsite	Christy and other tailings	1980s				Cyanide heap leach	Yes	Initial test heap behind Wells Fargo bank building; production commenced 1980s using conventional heap technology at new site.
Bull Valley	Hamburg	Goldstrike District	Hamburg	1900s	small		No	Amalgamation	?	One-stamp mill, described in trade journals.
	Tenneco	Same		1987?			Yes	Heap leach Cn		Currently extracting gold from ore discovered in 1970s-1980s. Described in trade journals, Utah Mining Association notes.
Tutsagubet	St. George Mining Co.	Below Apex Mine	Apex	1970s -1980s				Leach, etc.		Built to extract Ga and Ge from oxidized copper-zinc ore by Musto Expl. Co. closed, 1986, then purchased and closed by Hecla Mining Co. Described in trade journals. Closed for modification, 1990.

Table 2 Milling Processes Historically Used In Utah (Sources of Tailings)

Recovery Process	Basic Technology Used In Utah	Major Equipment Used in Utah Plants	Examples in Utah	Character of Tailings
I. Physical Separation of Metallic Product				
Gravity	Coarse grinding: separation in water based on difference in specific gravity	Jig; Concentrating table (Wilfley) etc. belt vanner (Pre-1920) sluice box or riffle (Au only)	Arthur. Magna pre-1920s. Cactus. Beaver County	Relatively coarse sand predominates
Amalgamation	Coarse grinding; agitated/contact with metallic mercury. Steam and inorganic chemicals sometimes added in silver mills	Pan or barrel amalgamator (grinding device)	Park Valley district 1900s: Silver Reef. Washington county,1880s	Relatively coarse sand is typical
Electrostatic Separation	Behaviour near electric charge distinguishes sphalerite from gangue	Huff precipitator	United States mill. Midvale. 1920s	Byproduct of gravity or flotation concentration
Flotation	Fine grinding Addition of minor chemicals to modify pH and surface properties. Metallic particles cling to organic froth and rise to surface of agitated water	Ball mill and flotation cells Filters	Magna (Kennecott) After 1922 Ontario mill (Park City Ventures) 1970s: Burgin mill. Tintic district	Relatively fine. (Typ. greater percentage of -400 mesh slimes)
Variations: Selective Flotation	Separate metallic sulfides based on properties	Multiple banks of cells	Kennecott: Mo recovery United States mill, 1960s. Bauer mill	
II. Hydrometallurgical Separation of Metallic Product				
Cyanide (or other organic) Leach	Grind: adjust pH. dissolve metals in sodium or potassium cyanide. separate solution from pulp; Precipitate native metal. Recycle leach solution	Leaching system/tanks and material handling system. filters. carbon or zinc precipitation system	Barrick Mercur (Getty Minerals) mill. Tooele Co.	Coarse to very fine-(as required for extraction)
Variation	Leach on pad, coarse crushing only		Drum mine. Detroit district-Millard Co. 1980s	Heap leach process tails typically coarse. include lesser percentage of slimes from grinding
Variation	Destroy sulfides by roasting (or today. by pressure autoclaving)	Roasting plant	Cons Mercur mill 1900 - 1912	Contain cinders. Fe oxides
Inorganic Leach	Adjust pH. dissolve metallic minerals. Natural bacteria may aid some processes. Precipitate by reaction with ferrous or base metal scrap or in electrolytic cell	Leaching system/ Tanks, precipitation	Cliffs Copper (Lisbon Valley): Rocky Range Copper West of Milford 1970s	Iron oxide precipitates from leach solution
Variation	Destroy sulfides by roasting with powdered coal, salt	Roasting plant. leaching vats or tanks	Holt-Dern process. e.g. at Standard and Silver City. Tintic district 1920s	Fe-Oxide bearing cinders