LEAD AND ZINC RESOURCES IN UTAH

by

Allan H. James

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY
affiliated with
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University of Utah, Salt Lake City, Utah

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FOREWORD

This study on Utah's ability to sustain a viable lead-zinc industry was funded jointly by the Four Corners Regional Commission and the Utah Geological and Mineralogical Survey and contracted by the Utah Geological and Mineralogical Survey. Allan H. James, a graduate mining engineer from Stanford and Doctor of Science in geology from M.I.T., has had nearly 40 years field experience in seeking and developing lead-zinc, copper and precious metal deposits throughout North America.

The study, organized around the collection, analysis and evaluation of past production and potential resources of lead and zinc ores within Utah, focuses on the projection of potential production and on the effects of occurrence, costs and prices on resource reserves.

Data for the sections were obtained from published statistical reports of the U. S. Bureau of Mines and the Utah Mining Association, Utah Geological and Mineralogical Survey open-file material, published geologic descriptions, interviews with management, and from personal knowledge and evaluation.

The report serves three purposes: (1) As a source of factual data, it can aid those responsible for decisions on the government level. (2) It reminds those in charge of exploration programs that untapped lead and zinc resources remain in Utah. (3) For the interested layman, it provides an understanding of the complexities affecting the economics of mineral investigation.

The omission of any reference to the lead-zinc resource potential of a few well known mining districts, such as in the vicinity of Stockton, Alta or Big Cottonwood Canyon, is acknowledged. Time was paramount and the Utah Geological and Mineralogical Survey decided to limit the study. Through future publications, UGMS hopes to expand its analysis of lead-zinc resources.

W. P. Hewitt
Director, UGMS

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ILLUSTRATIONS

LEAD AND ZINC RESOURCES IN UTAH

by Allan H. James[1]

ABSTRACT

The average annual value of recoverable metals from Utah's lead-zinc mines during the decade 1960 to 1969 was $29 million.

During 1969, 1970 and 1971, nine U. S. lead and zinc reduction plants closed, including the lead smelter at Tooele, Utah, and the custom concentrator of UV Industries at Midvale, Utah. At the same time, five Utah lead-zinc mines closed leaving only the Mayflower and Burgin mines producing in 1972, with the Burgin mine expected to be the sole producer in 1973. Production dropped to $27,000,000 in 1972 and may drop to $12,000,000 or less in 1973. If recent metal price escalation continues, Utah mine output might be re-established at $30,000,000 or more per year plus the added value of metal price inflation.

The Utah mine closures, coming in the face of an expanding international demand for metals, resulted from increased production costs in relation to metal prices; discoveries of lead-zinc ores in Missouri and Tennessee, which may be mined at lower cost-per-ton than ores from Utah, Colorado and Idaho, were partly responsible for the low metal prices. Price increases of lead, zinc, gold, silver and cadmium occurring in Utah ores had been sufficient to pay most production cost increases, but not enough in all cases to attract long-range venture capital.

Only in rare, short-term situations has reduction in production resulted from a lack of a continuing ore supply. Geological formations, as yet untested but considered favorable for discovery of lead and zinc ores, are known in all recently producing districts.

The closure of the custom mill at Midvale forced the Ophir and the Deer Trail mines, which accounted for 6 percent of the state's lead-zinc mine production, to cease operations until a concentrator becomes available and a market for concentrates is developed.

During the 1960 to 1969 decade, 93.5 percent of the value of Utah's lead-zinc mines came from three districts: Park City, U. S.-Lark-Carr Fork and Tintic; 6 percent came from the Ophir and Marysvale districts and the remaining 0.5 percent from intermittent producers scattered through eight Utah counties–Juab, Beaver, Iron, Millard, Box Elder, Sanpete, Sevier and Morgan.

Financing and constructing a lead and zinc reduction facility within Utah's borders is not likely in the next few years. A concentrator (mill) within Utah, however, is necessary to reduce prohibitive freight costs resulting from interstate shipment of raw ores.

During the next several years, adverse economics may result in a nonproductive period with recoverable metals averaging $6 million per year or less.

An improved economic outlook could prove Utah's known lead-zinc resources adequate to sustain more than $6 million of annual production. And, with adequate capital for exploration and facilities, production could reach $17 million a year.

With strong metal prices, adequate capital for long-range exploration and the establishment of efficient programs and plants, plus exploration luck, an annual production rate of $50 million might be anticipated; nearly half would be expended in Utah.

INTRODUCTION

Utah occupies a prominent position in North America's lead-zinc-silver smelting industry; in 1971 the following were in full operation:

1. A custom lead-zinc sulfide concentrating mill at Midvale, owned by UV Industries (formerly United States Smelting, Refining and Mining Co.), capable of handling some 1,200 tons-per-day of ore;

2. An 800 ton-per-day captive lead-zinc mill at the Tintic Division of Kennecott;

3. A 400 ton-per-day captive mill at the Mayflower mine, operated by Hecla Mining Co., and

4. A custom lead smelter at Tooele, owned by the International Smelting and Refining Co., a subsidiary of the Anaconda Co., for reducing lead sulfide concentrates to lead metal and recovering byproduct zinc through fuming.

In November 1971, because of "rising costs and drop in smelter feed" (Durham and Eyring, 1972), the Anaconda Co. announced the closing of its Tooele lead and zinc plant, effective December 31, 1971.

With the closing of the smelter, UV Industries lost its market for lead concentrates and announced the immediate closing of its custom lead-zinc mill at

[1] Consulting mining geologist, Salt Lake City, Utah.

Table 1. Comparison of the gross value of lead-zinc ores in Utah (before and after the closure of the Tooele Smelter).

	Tons of ore	Market value of recoverable metals (dollars)
Average per year (1960-1969)	713,000	$29,000,000
1972 (all 12 months; only Hecla and Burgin mines operating)	316,000[1]	28,000,000[1]
1973 (Burgin alone)	150,000[1]	13,000,000[1]

[1] Author's estimate by projection.

Midvale and its U. S. and Lark mine. The Arundel Mining Co. and McFarland and Hullinger, forced by the loss of the Midvale market for milling ore, closed their mines at Marysvale and Ophir. Only Hecla Mining Co.'s Mayflower mine at Park City and Kennecott Copper Corp.'s Burgin mine at Eureka, each with its own concentrating mill and previously established outlets for concentrates, continued to operate (table 1).

The blow hit Utah's lead-zinc industry at a time when conservative estimates of future consumption and demand rates indicated the United States would be forced to import lead and zinc (figure 1) and when the cumulative free world production of lead and zinc required to meet assumed consumption or demand rates varies from 2 to 6 times the known ore reserves available to meet this demand (table 2).

Neither present reserves of base metals nor known lead-zinc exploration programs appear adequate to meet future world consumption. The demand projections may be challenged, but according to Park (1968), an international authority on mineral economics, "... it seems reasonable to expect an ever-increasing demand in lead and zinc regardless of major changes or substitutions that will come in the use of those metals."

This report substantiates the probable presence of a commercial lead and zinc resource in Utah. The question is whether or not large private industries believe the search for and production of the ores is worthy of large capital investments. Technical staffs of the raw materials industries, with available data on cost and technology, must critically evaluate the risk.

COMPARISON OF UTAH'S LEAD-ZINC PRODUCTION AND ECONOMICS TO OTHER STATES

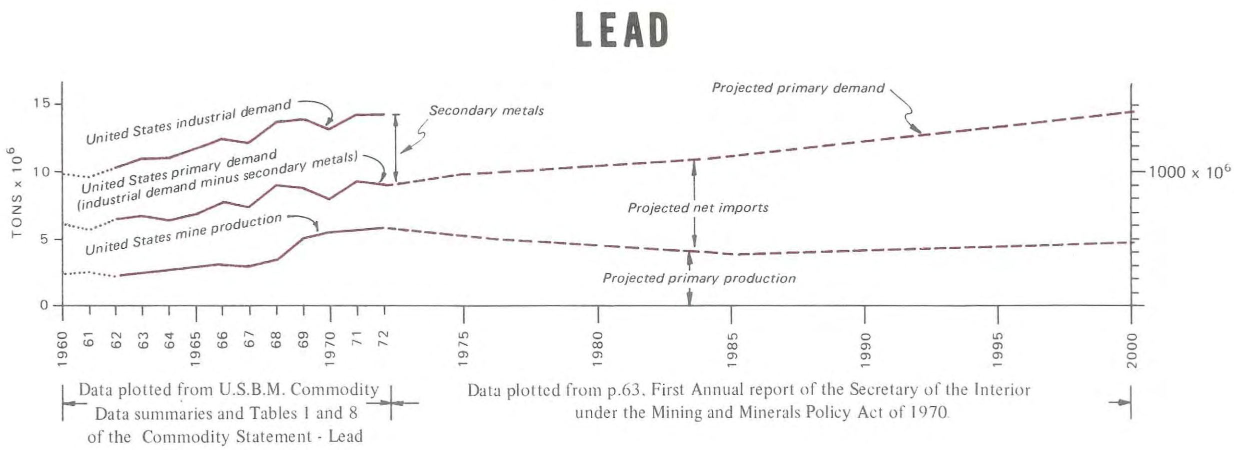
In 1968, the United States produced 15 percent of the free world's lead and 13 percent of its zinc. Ninety-three percent of the lead came from only four states and 62 percent of the zinc came from five states (table 3). The southeast Missouri lead belt contributed

Table 2. Comparison of projected world production rates to known available lead-zinc resources (modified from Chandler, 1970, p. 11 and 12, and U. S. Bureau of Mines).

Total World Resource Estimated to Exist in 1963 (USBM):
Lead 48.8 (141)[1] million tons, metal
Zinc 84.5 (259)[1] million tons, metal

	MILLIONS OF SHORT TONS			
	At 1963 rate of production	At 1963 per capita consumption	At post war growth rate	At 2 percent per capita production growth (approximate)
	World projected annual production in the year 2000			
Lead	2.7	5.2	5.7	11.0
Zinc	3.7	7.2	8.4	15.1
	Cumulative production for period 1963-2000			
Lead	97.0	142.2	151.2	280.0
Zinc	133.0	196.2	235.8	400.0
	Number of times cumulative production will exceed resource by year 2000[2]			
Lead	2.0 *(0.7)*	3.0 *(1.0)*	3.0 *(1.0)*	6.0 *(2.0)*
Zinc	1.6 *(0.5)*	2.3 *(.75)*	2.8 *(.9)*	4.7 *(1.5)*

[1] USGS estimates (Prof. Paper 820, 1973, p. 325 and 707) are shown in parentheses; they are about triple the USBM's estimates of 1963.
[2] Cumulative production divided by USGS estimated reserves (Prof. Paper 820, 1973, p. 325 and 707) are shown in italics in parentheses.



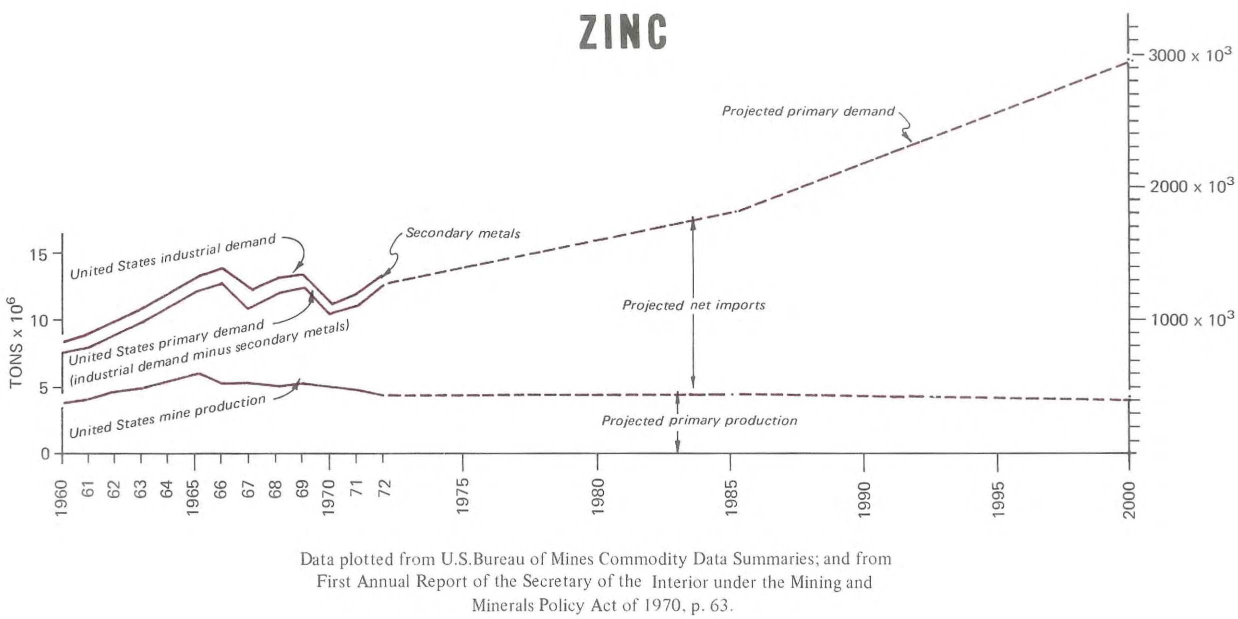


Figure 1. Past and future production of lead and zinc (from U. S. Bureau of Mines).

53 percent of the lead and Tennessee contributed 23 percent of the zinc. These two states, together with foreign production, dominated the lead-zinc market in the U. S. Utah ranked third in lead production and fifth in zinc (table 3; Chandler, 1970, p. 31).

Utah and other Cordilleran mines will operate as long as they can produce metals at a cost less than the price set by large eastern mines. Missouri lead mines and Tennessee zinc mines have many similar production characteristics; because descriptions of Missouri mines are available, data from Missouri will be used generally for economic comparisons in this report. The lead-zinc ore deposits of Colorado and Idaho are somewhat similar to Utah ore deposits in geological complexity, moderate size and high-metal content and relevant data from recent attractive developments in these states also have been included.

Missouri

The average metal content of Utah lead-zinc ore for the decade 1960 to 1969, compared to the average grade from sources in Missouri, Colorado and Idaho, is shown in table 4.

The high labor productivity of Missouri mines—circa 14 tons-per-man shift (tables 5 and 6)—is the result of the flat-lying locally continuous strata of the Missouri lead deposits, which can be mined with large underground equipment. The comparatively low productivity of Utah mines—circa 2 tons-per-man

Table 3. U. S. lead and zinc production by state, 1968 (in thousands of short tons; from Chandler, 1970).

	State	Rank	Tons	Percent of total	Cumulative percent of total
Lead					
	Missouri	1	210.8	60	60
	Idaho	2	49.7	14	74
	Utah	**3**	**47.3**	**13**	**87**
	Colorado	4	20.0	6	93
	California	5	4.0	1	94
	Virginia	6	3.5	1	95
	Arizona	7	1.9	–	95
	Montana	8	1.9	–	96
	Others	–	14.8	–	–
Zinc					
	Tennessee	1	120.4	23	23
	New York	2	65.0	12	35
	Idaho	3	55.5	11	46
	Colorado	4	50.0	9	55
	Utah	**5**	**35.6**	**7**	**62**
	Pennsylvania	6	30.8	6	68
	Wisconsin	7	26.4	5	73
	New Jersey	8	26.1	5	78
	Others	–	116.6	–	–

shift–is largely due to the restricted size, irregularity and adverse rock conditions (water, heat and pressure) encountered in recently worked Utah deposits. Although many large ore shoots have been encountered in Utah–Park City, Tintic, and U. S. and Lark–none has had the combination of economic dimensions and strong, safe wall rock found in most Missouri mines.

Whereas the lead content of Utah ores has been only slightly greater than the content of Missouri ores (individual deposits may be much higher), zinc in Utah is ten times the grade of Missouri ore; silver and gold are present in appreciable amounts in Utah ores, but are not present in Missouri ores. Thus, Utah ores, more costly to mine, return more dollars per ton (see following sections). Consequently, during the past decade, Utah mines have maintained a reasonable cost-price ratio because of the presence of high-grade ores, in spite of inherent high production costs. Increasing metal prices also have aided Utah mines (figures 2 and 3, page 6).

Colorado and Idaho

Utah, with Colorado and Idaho, which generally must meet similar mechanization difficulties inherent in the shape and distribution of their lead-zinc deposits, produced 34 percent of the United States' lead metal and 27 percent of its zinc in 1968. Although they do not exert a great influence on market price, their elimination from the lead-zinc industry because of adverse ore production factors does not seem probable in the coming years of predicted metal shortages.

Industrial optimism characterizes announced investments in new or recently expanded mining projects at Leadville and Telluride, Colorado. The projects are:

1. A new Leadville, Colorado, unit of American Smelting and Refining Co. (ASARCO) and Newmont Corp. The reserves available are about 2.5 million tons–12 percent in combined lead and zinc and 2 ounces per ton of silver; thus, the gross value of metals is less than Utah ores. An old mining district is being reopened, and with the aid of load-haul-dump equipment in the stopes, sand fill, centralized hoisting and a

Table 4. Comparison of average metal content (grade) of lead and zinc ores, Utah, Missouri and Colorado.

	Ounces/ton		Percent			
	Gold	Silver	Copper	Lead	Zinc	
Utah						
1960-1969 State average[1]	.06	4.0	.04	6.4	5.0	Largely cut and sand
Park City (1875 to 1970)	.08	15.3	.37	8.2	4.5	or waste fills and open
Tintic (1960-1969)	.003	11.9	–	15.8	9.4	stopes. Includes
Lark-U. S.-Carr Fork (1960-1969)	.02	3.33	.04	7.7	5.4	some dump recovery.
Missouri[2]						
U.S.B.M. 1969	–	–	–	4.51	0.52	Room and pillar
Magmont mine	–	–	0.15	6.8	0.5	mechanized.
Colorado[3]	2.0			Pb plus Zn = 12%		Cut and sand fill stopes.
AS&R, Newmont Leadville unit						
Idarado[4] Newmont Corp.	0.06	2.63	0.99	2.41	4.14	Several old mines revived.

[1]Includes low-grade dump ores.
[2]From U. S. Bureau of Mines data.
[3]Eng. and Min. Jour., 1972.
[4]Stevens and Granger, 1970.

Table 5. Comparison of Utah and Missouri lead-zinc mines.

Year	Tons ore[1]	Metal value[1+2]	Dollars per ton	Employ-ment	Payroll[3+4]	Tons per man shift	Payroll dollars per ton[3+4]	Payroll dollars in percent of metal value[4]
UTAH LEAD MINES								
1960	784,789	$23,529,000	$29.98	981	$5,449,442	3.20	$ 6.94	23.0
1961	702,357	21,504,000	30.61	932	5,225,320	3.01	7.43	24.2
1962	805,509	19,415,000	24.10	1,021	5,922,000	3.16	7.89	30.5
1963	745,262	24,828,000	33.31	1,120	6,479,636	2.66	8.69	26.1
1964	685,139	25,262,000	36.87	1,176	7,038,754	2.33	10.27	27.9
1965	718,785	26,650,000	37.07	1,130	7,319,088	2.54	10.18	27.5
1966	805,065	40,789,000	50.66	1,338	8,924,367	2.41	11.08	21.9
1967	624,865	43,805,000	70.10	1,059	7,220,701	2.36	11.55	16.5
1968	628,253	31,811,000	50.63	1,092	7,670,846	3.30	12.21	24.1
1969	629,132	32,733,000	52.03	1,226	9,226,708	2.05	14.67	28.2
MISSOURI LEAD MINES								
1960	5,897,000		$ 4.70			8.8		60[5]
1961	5,242,000		4.32			9.2		56[5]
1962	2,911,000		4.70			8.1		63[5]
1963	3,253,000		5.96			7.4		55[5]
1964	4,965,000		6.72			12.0		30[5]
1965	5,279,000		8.55			12.5		24[5]
1966	5,387,000		8.20			12.5		25[5]
1967	5,563,000		8.58			14.0		21[5]
1968	6,353,000		10.20			14.0		21[5]
1969	7,873,000		16.90			15.5		11[6]

[1] From U. S. Bureau of Mines.
[2] Value of gold, silver, copper, lead and zinc recovered.
[3] From Utah State Labor Board.
[4] Post-milling personnel not included.
[5] Adjusted for smelter payroll and regional wage differences by estimate factors. These numbers are good for comparison with Utah but are not precise.
[6] Apparently new mines coming into production were well mechanized and high in lead grade.

compact, modern mine plant, an efficient and profitable operation is expected.

2. The Idarado, Telluride, Colorado, plant of the Newmont Corp., a consolidation of several adjoining old mines. It mills 1,700 tons per day of crude ore; the reported mill head grade is: gold, 0.06 ounces; silver, 2.63 ounces; copper, 0.99 percent; lead, 2.41 percent and zinc, 4.14 percent.

Table 6. The Magmont mine–an example of Missouri mine productivity factors (from Schwand, 1970).

	Tons per man shift
A. Stoping productivity (muck, drill, blast, and roof control)	80
B. Overall mining productivity (equals stope productivity (A) plus transportation, pumping, hoisting, maintenance, etc.)	20
C. Overall milling productivity	78
D. Overhead (office, supervision, etc.)	100
Resulting:	
Stoping, mining, milling, overhead	14
Details:	
Equipment	Transloaders
Capacity	4,200 tons/day (about 6.8 percent lead)
Ore reserves	About 60,000 tons of lead per year, minimum of 15 years of reserves
Capital	$18.5 million in mine and mill

The ores from both projects are lower in metal content than average Utah ores (table 4) and they are concentrated at mine head flotation mills; concentrates are shipped out of Colorado for reduction and refining.

ECONOMIC GEOLOGY

Types of Deposits

Lead-zinc deposits are divided into economically significant groups as follows:

1. Mississippi Valley type: mainly lead in Missouri and zinc in Tennessee.

2. Cordilleran group: lead and zinc with silver, gold and copper. Occurs in Utah, Colorado, Idaho, Washington, Montana and New Mexico.

3. Other occurrences. Those at Jerome, Arizona; Franklin Furnace, New Jersey; and Balmat, New York, for example, are geologically old deposits greatly

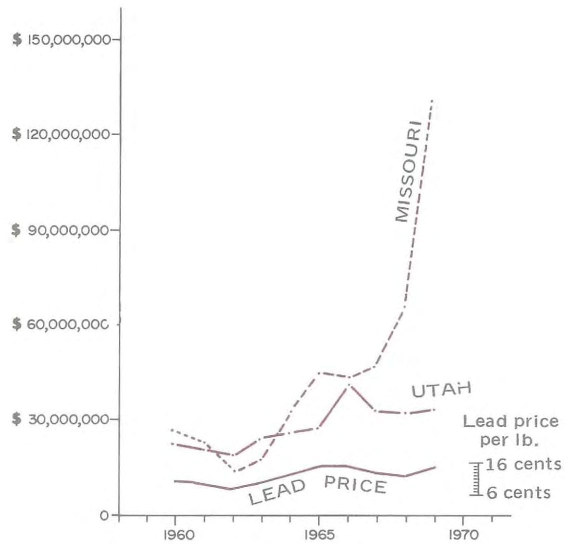


Figure 2. Comparison of dollar value of lead-zinc ores, Utah and Missouri.

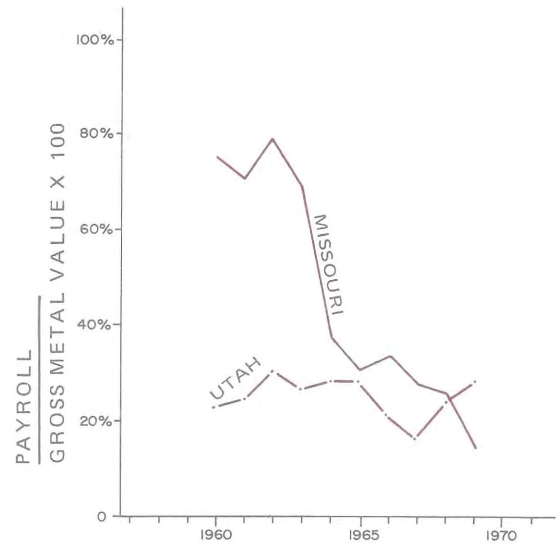


Figure 3. Mine and mill payroll dollars as percent of gross metal value.

metamorphosed. They have little affect on the lead-zinc economics of Utah and will not be described.

Missouri Deposits

The Missouri lead ore deposits occur in extensive flat-lying deposits bounded within flat-lying sedimentary beds (limestones, dolomites, conglomerates, cross beddings, masses of algal reef, subaqueous talus slopes, conglomerates, faults and fractures, rock collapse, slide and solution structures). Lead occurs in disseminated grains and streaks in limestone or dolomite. The ores, in erratically mineralized masses fifty to several hundred feet wide, ten to hundreds of feet thick, and in runs 2 or 3 miles long, are more like flattened fingers than a continuous tabular mass.

These long "runs" of flat-lying, thick Missouri ore, however, lend themselves to large-scale planning and development. They are largely sulfides of lead with a small percentage of zinc in sulfide form; both metals can be concentrated in large flotation mills with resulting lead concentrates smelted in large new facilities. The small volume of zinc concentrate generated is shipped out of the state for reduction.

The flat-lying nature of the deposits also exposes the ore runs to systematic diamond drill exploration from the surface; reserves of 20 million tons and more per mine have been outlined.

Mass lead production from the mines has kept the price of the metal relatively stable for the past two decades.

Cordilleran Group

The ore deposits of the Cordilleran group occur in igneous and sedimentary rocks and are related spatially to centers of igneous activity. Often the centers contain large porphyry copper deposits, e.g., Bingham, Utah; Chino, New Mexico; Bisbee, Arizona; and Morenci, Arizona; or they are intrusive complexes associated with no known copper mine, as at Park City and Tintic, Utah.

In the Cordilleran region mining districts, especially those displaying complex igneous intrusions, the sedimentary and igneous rocks often are folded extensively, faulted and crushed. In Utah, many of the deposits contain 5,000 to 100,000 tons of ore in a single vein or replacement. A few fissures, such as the Ontario and Mayflower at Park City, the Lark bedding fissure at Bingham, the replacements of the Silver King mine in Park City and the Tintic Standard massive replacement in East Tintic, contained several million tons of ore each.

Utah Deposits

Utah lead-zinc ore bodies exploited in the past have been complex in outline. The vertical range of mineralization in any one body is often several times the horizontal range and mining openings are seldom systematic, horizontally or vertically.

Most Utah lead-zinc ore deposits have been discovered by examining favorable surface outcrops. Although diamond drilling from the surface has revealed deep extensions and repetitions of ore, shafts and levels opened in or close to ore have been necessary to measure and identify the ore reserve and to determine the extent and grade of the deposit.

The unpredictable character of Utah lead-zinc deposits contrasts with Kennecott's Utah Copper mine where great areal extent plus continuity of mineralization makes possible thorough advance appraisal from the surface.

RELATIONSHIP OF COST TO VARIOUS FACTORS

Mining Methods

Lead-zinc is mined by several mining methods in Utah: (1) in open stopes where the surrounding rock is supported only by ore pillars or roof bolts, (2) by supported ground methods, each mining cut followed by sand or rock fill, or (3) by square setting or related methods which rely on heavy timber or cement for much of the support.

The economic influence of deposit size and character on Utah and Missouri ores is extreme. In none of the Utah mines are the size, continuity, inclination or strength of rock formations such that presently available large mechanized equipment can be used underground. Modernization and mechanization in Utah have been confined to the introduction of sand fill, jack-leg and jumbo drills and mechanized loading. Large rubber-tired jumbos, giraffes and load-haul-dump equipment used in Missouri do not fit into Utah ore deposits, although scaled-down models are used where space permits. In Missouri the new shafts are centralized in the ore bodies and large mills are built at the shaft head.

Utah mines have been enlarged by extending underground workings of older mines, making haulage ways long and tortuous; shafts have deteriorated and are in locations appropriate for ore reserves of 40 years ago. Complete redesign of mine and surface plant, new concepts of production scheduling and restructuring of investment and profit speculations may be necessary to overcome difficult conditions in the lead-zinc mines of Utah.

Labor Productivity

The payroll for mining and milling lead-zinc ores (smelting not included) in Utah was obtained from Utah Department of Employment Security reports (table 5); ore tonnage is from U. S. Bureau of Mines reports. The figures combined give gross dollars-per-ton of ore, tons-per-man shift of ore and payroll dollars as a percent of gross dollars. The increase of recoverable value per ton of Utah ore from approximately $30 in 1960 to $52 in 1969 is the result of an increase (1) in the price of metals and (2) in the metal content per ton (some low-grade ore reclaimed from mine dumps diluted production in the early 1960's).

In Utah, gross dollars have been increased through management's selection of increased ore grade (notably in Tintic, Utah County). But higher than average grade ores are limited in most deposits and may be exhausted quickly. High grading, therefore, only temporarily solves the problem of maintaining a profitable balance between value and costs.

A decrease in labor productivity, however, has offset the increase in value-per-ton of Utah ores. In 1960, production averaged 3 tons-per-man shift in lead-zinc mines and mills. It declined to 2 tons-per-man shift in 1969. Payroll dollars per dollar gross give an economic feasibility factor which ranges between 22 percent and 30 percent, which shows that from 1960 to 1969, the steady decline in labor productivity was erratically compensated for by an increase in ore grade and in metal prices (table 5). The payroll figures show only mining and milling statistics; smelting and refining statistics are not readily available for Utah ores.

Wage rates and the price of metals are not under the control of the Utah operator. For the entire industry, the price of metals should increase, less increases in industrial productivity, to compensate for the increase in wage rates to maintain a healthy lead-zinc industry.

Market Price

Figure 4 shows the average annual prices (adjusted for inflation) of metal plotted against annual tons production of lead in the Pacific Northwest and the United States. U. S. Bureau of Mines interpretations indicate a correlation between a good producing year and an improved metal price (adjusted for inflation). In a portion of the curve, an increase from 14 to 20 cents per pound in metal price coincides with an increase of 88,000 to 117,000 tons of lead produced per year in the Pacific Northwest states–price increased 43 percent, production 33 percent. Metal prices for the United States, 1954 to 1971, are given in table 7.

Figure 5 shows the relationship between mine production of lead in Utah and deflated market price. Production increases in the years 1966, 1967 and 1968 appear to correlate with metal price, but investigation shows the increases to be the result of Tintic production; production timing at Tintic was related to an exploration, development and production schedule set

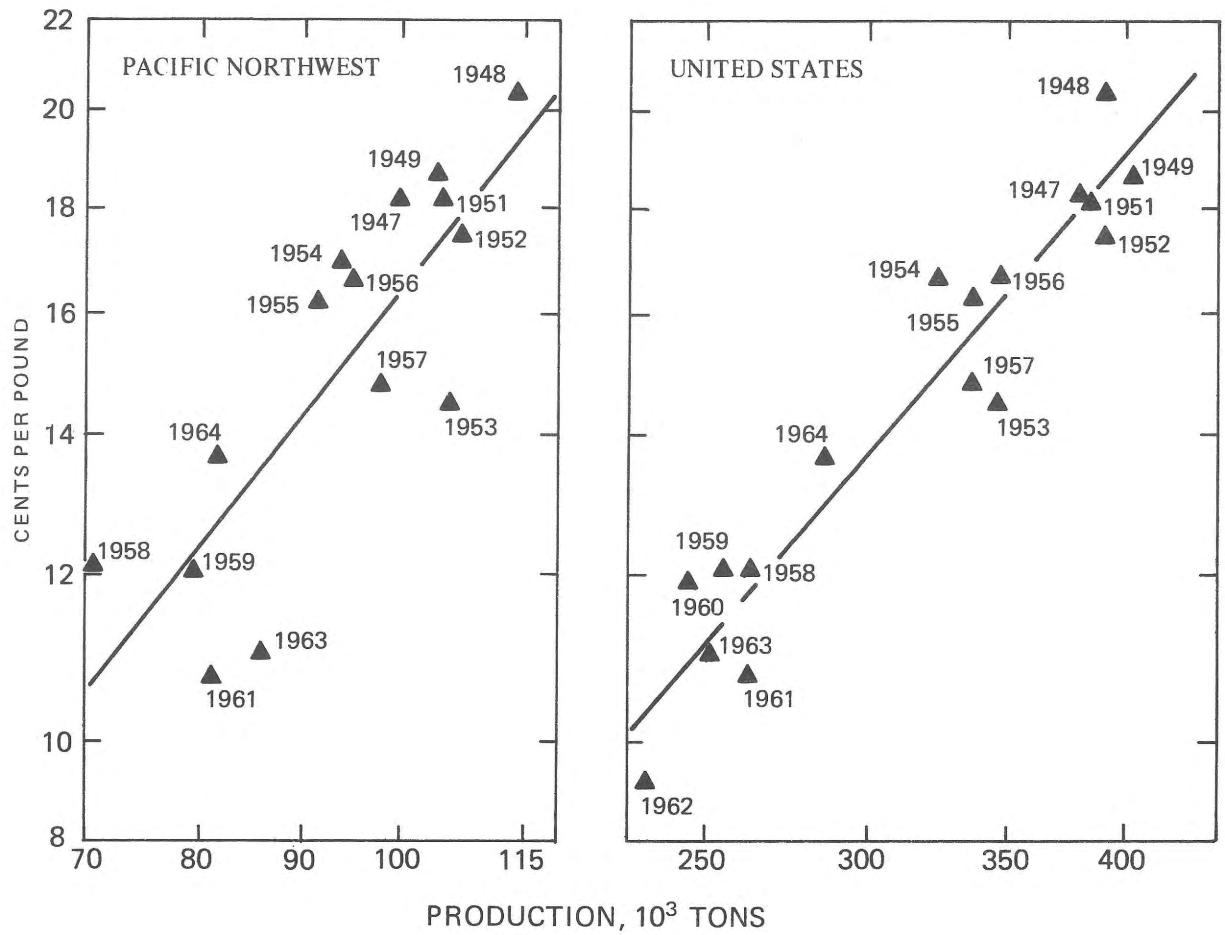


Figure 4. Relationship between mine production of lead and deflated market price, Pacific Northwest and the United States, 1947 to 1964 (from Knostman, 1967, p. 33).

Table 7. U. S. metal prices, 1954 to 1971.

	Dollars per ounce		Cents per pound			Dollars per pound
	Gold	Silver New York	Copper U. S.	Lead St. Louis	Zinc E. St. Louis	Cadmium
1954 to 1958 average				14.39	11.64	
1959				12.21	11.46	
1960	35.00	0.905	32.1	11.95	12.95	1.52
1961		.924	30.0	10.87	11.55	1.68
1962		1.085	30.8	9.63	11.63	1.72
1963		1.279	30.8	11.14	12.01	2.26
1964		1.293	32.6	13.62	13.57	3.00
1965		1.293	45.3	16.00	14.50	2.58
1966		1.293	36.6	15.12	14.50	2.42
1967	35.00	1.550	38.6	14.00	13.85	2.64
1968	39.26	2.144	42.2	13.21	13.50	2.65
1969	41.51	1.790	47.9	14.93	14.65	3.27
1970	35.65	1.76	57.7	15.62	15.32	

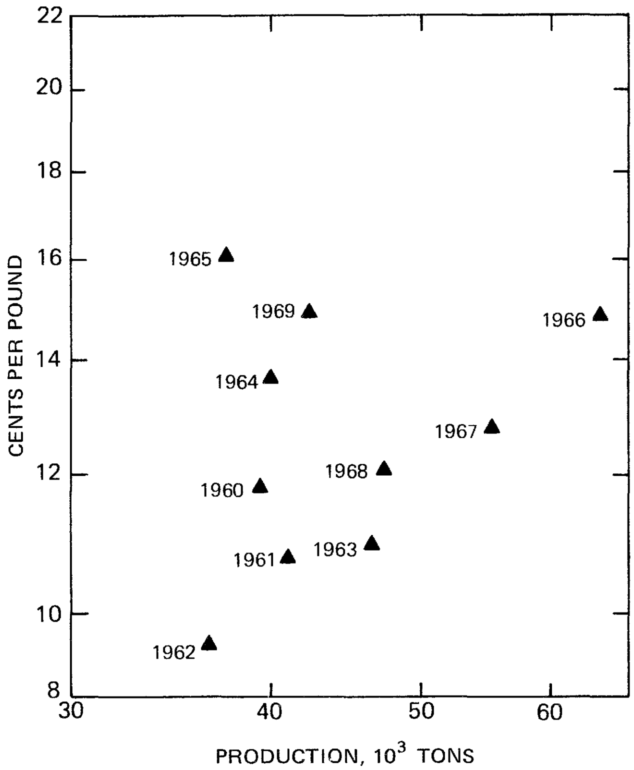


Figure 5. Relationship between mine production of lead and deflated market price, Utah, 1960 to 1969.

up 5 to 10 years earlier, not to the recent annual price of metals. A correlation between high metal price and initiation of exploration, and between initiation of exploration and date of production increase would be more informative; the delay in the effect of metal prices on production could then be measured.

In mines of the Missouri type, with many years of well-developed ore in reserves, the response to an increase in metal price with an increase in production may be achieved rapidly by expanding work force and equipment.

Reserves

Figure 6 shows tons of lead and zinc that can be produced from U. S. reserves at various price levels of metal. Prepared by the U. S. Bureau of Mines in 1966, the chart is based on information submitted largely by eastern mines in response to a questionnaire. The nature of mineral distribution in Cordilleran ores minimizes expansion of lead-zinc reserves as metal prices increase. The extensive assay information necessary to prepare curves for Utah is not available outside of mining company records.

SMELTER OUTLETS

Closures

Closing the Tooele smelter, which was the immediate cause of the closing of the Midvale flotation mill and of the U. S. and Lark, Ophir and Deer Trail mines, placed a financial burden on mine operators and on the people of Utah and raised the question: *Are a mill and smelter necessary to a viable industry or can Utah mines operate competitively while shipping ore to out-of-state mills or milling locally and shipping concentrates to out-of-state reduction works?*

Closing the Tooele smelter, the American Smelting and Refining Co.'s (ASARCO) lead smelter at Selby and seven zinc reduction works in the U. S. (tables 8 and 9) eliminated the open market for Utah zinc and lead concentrates (figure 7). The remaining reduction works, mostly in central and eastern states, were either oversupplied as a result of the shutdown or ill equipped to take complex western concentrates. While there remains a theoretical excess of lead smelting capacity in the United States (table 8), the principal facilities, the new and rebuilt lead smelters at Glover, Boss and Herculaneum, Missouri, are designed to smelt simple Missouri concentrates, and are not able or willing to take multimetal ores from Utah.

A numerical comparison of excess zinc capacity in 1968 with capacity shutdown in 1969-1972 indicates a shortage of zinc reduction capacity in the United States. While this shortage is real, some zinc reduction plants are experiencing difficulty finding zinc concentrates suitable to their process and location.

The availability of reduction capacity, however, should be self correcting. Smelting experts (personal communication) believe that as lead-zinc economics improve, out-of-state reduction capacity will expand to meet any steady and dependable supplies of concentrates. Competitive segments of the present international metals reduction industry will provide capital and build expanded facilities at sites with water access to insure a large and diversified national and international supply of raw materials (tables 10 to 12). But, if lead and zinc production from Cordilleran ores and similar complex ores from other countries continues on a depressed course, suitable reduction capacity may not be made available. Under such depressed circumstances, western resources will not be explored, developed and made dependably available.

New Plants

Utah lead production during the decade 1960 to 1969 averaged 45,000 tons per year, zinc 35,000 tons,

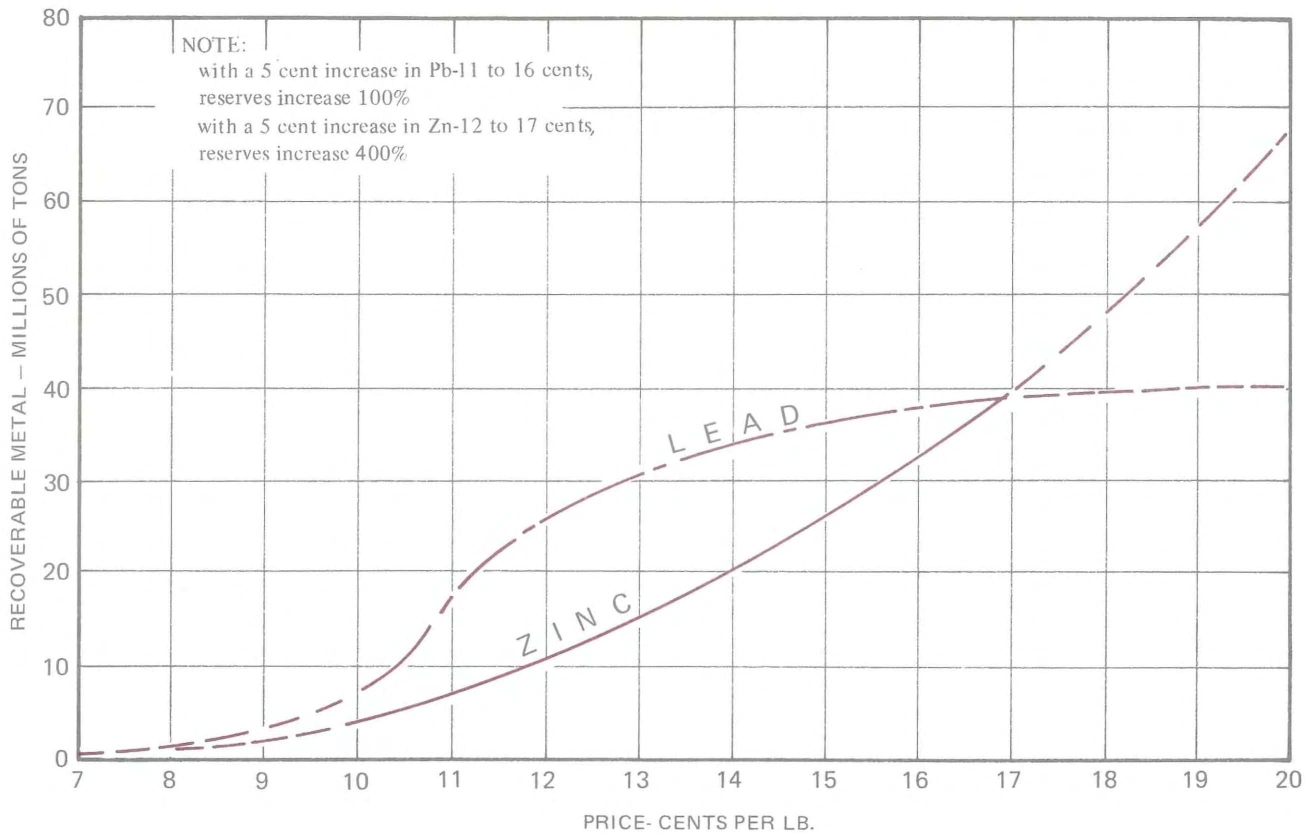


Figure 6. Lead and zinc reserves that could be produced from United States sources at various price levels (Everett and Bennett, 1967).

and the annual production average varied greatly from year to year, variations which don't encourage construction of a lead-zinc reduction complex in Utah. To be economic and competitive today, a metallurgical complex should be larger than that which could be continuously and dependably supported by Utah's mines alone, and to insure a dependable high use of its capacity, it must have cheap water access to worldwide concentrate sources.

Trends in size and type of new plants are shown in tables 10 to 12, condensed from Hatch, Hendrick and Sies (1970). The Imperial Smelting process combines lead and zinc reduction in one blast furnace-type of smelter. The Tooele, Utah, lead smelter (now closed) of International Smelting and Refining, much older than the others, is included for comparison.

Treatment Costs

Post-mine charges—sometimes in total called treatment costs—for Cordilleran lead-zinc ores commonly amount to more than half the gross metal value of the ore. A United Park City mines proxy statement June 12, 1970, indicates that the difference between average net settlement at the Midvale (custom) mill head and the gross metal value of the ore was 53 percent of the gross value for each year, 1967, 1968 and 1969 (tables 13 and 14). That is, more than 53 percent of the gross value of the ore was absorbed by post-mining costs of milling, concentrate freight, smelting or electrolytic reduction, refining, metal freight, sales costs, overhead and treatment profits (if any), and by metal losses.

Less than half of Utah's lead-zinc ores were smelted at the Tooele smelter even before it closed, because the plant was not sufficiently modern and efficient to compete with out-of-state plants. If all treatment is performed outside of Utah, the state clearly loses half the metal value equivalent in wages, supplies, services and metallurgical profits.

COST COMPARISON DATA

Cost comparison data are difficult to obtain and complicated treatment schedules for complex ores make cost generalizations hazardous. Each case must be studied independently. The following factors, costs and economic indicators, therefore, are presented as

Table 8. U. S. lead smelters and refineries closed in 1969, 1970 and 1971 (U. S. Bureau of Mines, personal communication).

Company	Location	Type	Date	Tons annual capacity
Closed				
Asarco	Selby, Calif.	Also zinc-firing plant	1969 or 1970	72,000
International Smelting	Tooele, Utah	Also zinc-firing plant	1971	40,000
USSR	Chicago Refinery based in Tooele, Utah	Lead	1970	
Total closed				112,000
Surviving (all are conventional lead smelters)				
American Smelting Ref.	East Helena, Mont.	Zinc fuming		97,975
American Smelting	El Paso, Texas	Zinc fuming		97,975
and Refining	Glover, Mo.			81,650
Bunker Hill	Bunker Hill, Idaho	Zinc fuming		113,065
Missouri Lead Operating Co.	Boss, Mo.			90,720
St. Joseph Lead Co.	Herculaneum, Mo.			204,115
Total surviving				685,500
Capacity of all U. S. lead smelters[1]			1968	810,000
Actual production of all U. S. lead smelters			1968	435,000
Unused capacity			1968	375,000
Smelter capacity shut-down[2]			1969-72	112,000

[1] According to Hatch, Hendrick and Sies, 1970.
[2] According to Rosenbaum, 1972.

Table 9. U. S. zinc reduction works, 1969 to 1972 (U. S. Bureau of Mines, personal communication).

Company	Location	Type	Date	Tons annual capacity
Zinc Reduction Works Closed				
Anaconda Co.	Anaconda, Mont.	Electrolytic	1969	90,000
Eagle-Picker Ind.	Henryetta, Okl.	Horiz. retort	1969	55,000
American Zinc Co.	Dumas, Texas	Horiz. retort	1971	58,000
American Zinc Co.	East St. Louis, Ill.	Electrolytic	1971	84,000
Matthiesson & Helgler Zinc Co.	Meadowbrook, W. Va.	Vert. retort	1971	48,000
New Jersey Zinc	Depue, Ill.	Vert. retort	1971	70,000
Anaconda Co.	Great Falls, Mont.	Electrolytic	1972	163,000
Total closed				568,000
Zinc Reduction Works Surviving (Vulnerable)				
American and Refining Co.	Amarillo, Tex.	Horiz. retort	Will close 4th quarter 1973	53,000
American Metal Climax, Inc.	Blackwell, Okl.	Horiz. retort	Will close 4th quarter 1973	90,000
National Zinc	Bartlesville, Okl.	Horiz. retort	Will close 4th quarter 1973	63,000
Subtotal, vulnerable				206,000
(Not vulnerable)				
Asarco	Corpus Christi, Tex.	Electrolytic		108,000
Bunker Hill Co.	Kellogg, Idaho	Electrolytic		107,000
New Jersey Zinc	Palmerton, Penn.	Vert. retort		118,000
St. Joseph Lead Co.	Monaca, Penn.	Electro-thermal		225,000
Amax[1]	East St. Louis, Ill.	Electrolytic	1973	83,000
Subtotal, not vulnerable				641,000
U. S. zinc production has been running at about				1,000,000
with concentrate imports of about				250,000
with domestic concentrates of about				750,000

[1] Sold by American Zinc Co. to Amax, which plans to reopen in 1973.

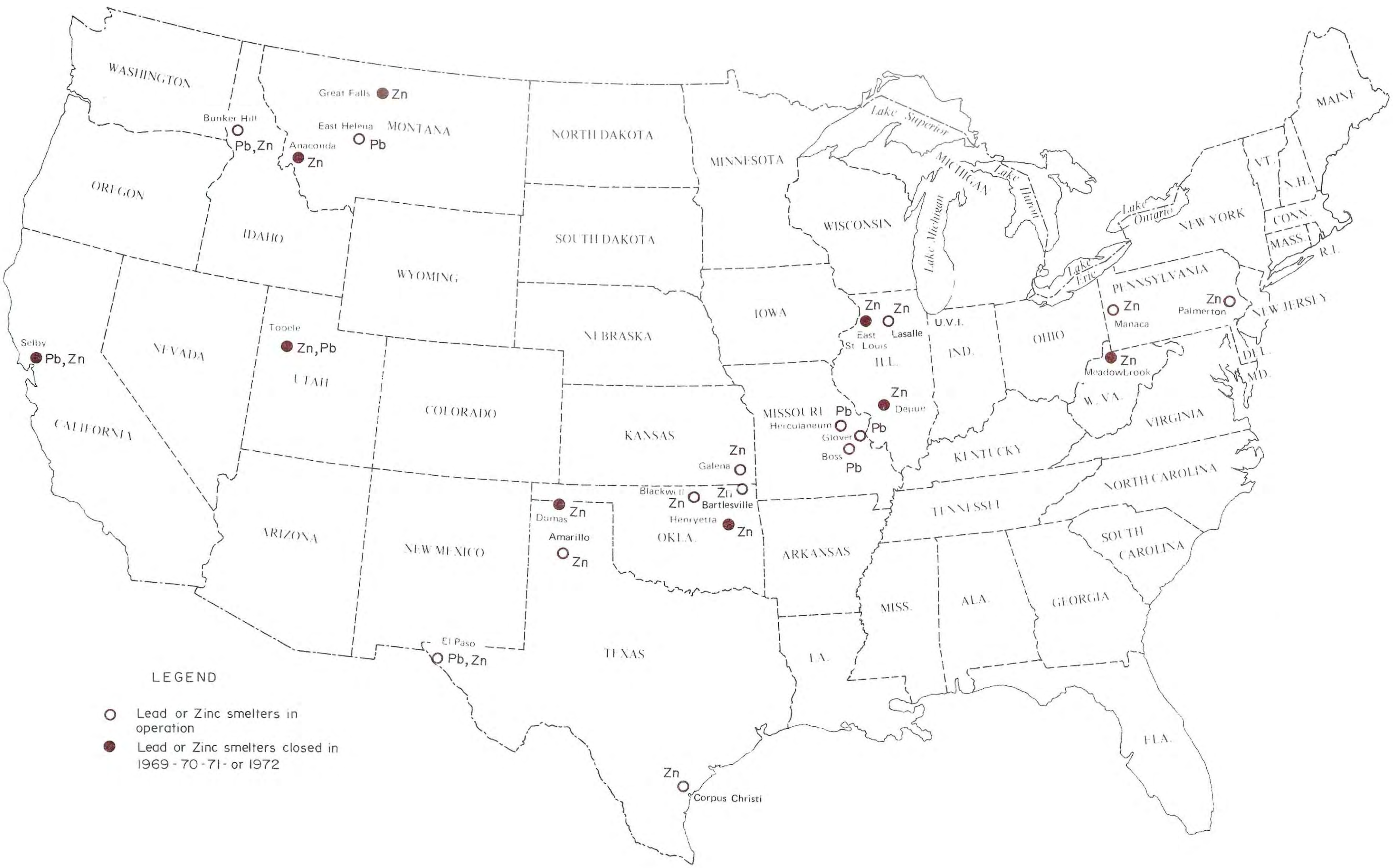


Figure 7. Lead and zinc reduction works in the United States.

Table 10. Lead smelters placed in operation after 1959 (Tooele Smelter listed for comparison; modified from Hatch, Hendrick and Sies, 1970).

	Plant	Year first operated	Type of plant	Tons lead–1968 Annual capacity	Tons lead–1968 Actual production
Zambia Broken Hill	Kabwe, Zambia	1962	I.S.P.	33,000	25,000
East Coast Smelting	Belledune, N. B.	1966	I.S.P.	33,000	15,000
A. S. & R.	Glover, Mo.	1968	C.	82,000	–
Missouri Lead Operating Co.	Boss, Mo.	1968	C.	91,000	–
Cia. Minera, Los Angeles	Ocampo, Mex.	1967	C.	2,000	1,200
Minera Metal Met.	Muzquiz, Mex.	1962	C.	2,000	2,000
Mitsubishi-Cominco	Naoshima, Japan	1966	C.	36,000	30,000
Sumiko, I.S.P.	Hyogo, Japan	1966	I.S.P.	24,000	18,000
Korea Mining	Chang, Korea	1964	C.	6,000	4,000
Berzelius	Duisburg, Germany	1965	I.S.P.	36,000	33,000
Imperial Smelting Corp.	Swansea, U. K.	1960	I.S.P.	25,000	20,000
Imperial Smelting Corp.	Avenmouth, U. K.	1967	I.S.P.	50,000	–
Sulphide Corp.	Cockle Creek, Australia	1961	I.S.P.	23,000	19,000
In addition:					
In Utah, now closed International Smelting and Refining Co.	Tooele, Utah	1912	C.	60,000	33,000'

C. = Conventional lead blast furnace. I.S.P. = Imperial Smelting Process.
Note: 34 lead plants older than 1960 are listed in Hatch, Hendrick and Sies, 1970.

Table 11. Zinc plants placed in operation after 1959 (modified from Hatch, Hendrick and Sies, 1970).

	Plant	Year first operated	Type of plant	Tons zinc–1968 Annual capacity	Tons zinc–1968 Actual production
Zambia Broken Hill	Kabwe, Zambia	1962	I.S.P.	33,000	30,000
Canadian Electrolytic	Valley Field, P. Q.	1963	Electrolytic	130,000	101,000
East Coast Smelting and Chemical, Ltd.	Belledune, N. B.	1966	I.S.P. plus reflux columns	63,000	23,000
Companhia Merc. Industrial-Brazil	Itaguai, Rio	1965	Electrothermic	7,200	
Zincamex	Saltillo, Mex.	1964	Horizontal retort	30,000	25,000
Cominco-Binanai	India	1967	Electrolytic	20,000	10,000
Hindustan Zinc	Debari, India	1968	Electrolytic	18,000	–
Sumiko-I.S.P.	Hyogo, Japan	1966	I.S.P.	48,000	43,000
Tong Shin Chem.	Seoul, Korea	1965	Electrolytic	3,000	2,000
Penarroya	Moyelles, France	1962	I.S.P.	100,000	48,000
Berzelius	Duisburg, Germany	1965	I.S.P.	80,000	69,000
Ruhr-Zink	Dattelim	1968	Electrolytic	135,000	–
Montevocchio	Montepone, Italy	1967	Electrolytic	30,000	12,000
Espanola de Zinc	Cartagena, Spain	1960	Electrolytic	30,000	22,000
Asturienne	Aviles	1960	Electrolytic	60,000	54,000
Imperial Smelting Corp.	Swansea, U. K.	1960	I.S.P.	50,000	49,000
Imperial Smelting Corp.	Avenmouth, U. K.	1967	I.S.P.	90,000	50,000
Sulphide Corp.	Cockle Creek, Australia	1961	I.S.P.	56,000	49,000

I.S.P. = Imperial Smelting Process.
Note: 53 zinc plants older than 1960 are listed in Hatch, Hendrick and Sies, 1970.

Table 12. Number of lead and zinc plants first producing before and after 1960 (modified from Hatch, Hendrick and Sies, 1970).

	Number of plants		
	Produced before 1960	Produced after 1960	
Lead plants			
U. S.	6	2	
Other countries	28	11	
World total	34 +	13	= 47
Zinc plants			
U. S.	14	0	
Other countries	39	14	
World total	53 +	14	= 67

Included in the list are eight Imperial Smelting Process furnaces. All were put in production after 1959.

abbreviated generalizations, not as firm accurate figures, which in many circumstances will be subject to large deviations. They are intended to aid the reader in understanding the miners' economic problem in a rough quantitative form. Accurate and up-to-date appraisals for a specific situation can only be made by organizations which continually receive the costs and results of on-going mining and metallurgical processing.

Hypothetical Break-Even Model

Costs and concentration ratios of lead-zinc mines and treatment plants vary greatly depending on type of ore and many economic factors. The assumed costs and value tabulation (table 15) is a hypothetical break-even model to permit the reader to visualize and weigh the general effects of mill and smelter location and the relationships and effects of mining, milling, concentrating, freight and reduction, refining, sales, overhead, metal losses and metallurgical profits on future mine profit and loss.

Table 13. Value, run-of-mine ore and post-mining charges, United Park City Mines Co.

	Assay X Metal price		
	1967	1968	1969
Lead	$19.00	$16.60	$16.70
Zinc	27.40	25.10	24.50
Copper	.96	1.05	1.44
Gold	.77	.94	.83
Silver	6.70	8.23	7.30
Gross total metal dollars in run-of-mine ore	$54.83	$51.92	$50.77
Average net settlement per ton dry ore[1]	$25.85	$24.24	$23.77
Cost plus metal losses	$28.98	$27.67	$27.00
Post-mining charges plus metal losses as percent of gross value of run-of-mine ore	53%	53%	53%

[1] Average settlement (amount paid for ore by International Smelting and Refining Co. at Midvale Mill head).

In the model the ore is milled in an in-state custom mill, and lead and zinc concentrates are shipped to out-of-state reduction works. The effects of different facility locations in the hypothetical model are given below:

Location 1. *Ore shipped to out-of-state custom mills.* Ore freight would increase to nearly $16.00 (table 16), less $3.00, an adverse balance of $13.00 per ton. This probably would eliminate any profits hoped to be gained by other economies.

Location 2. *Local custom mill, out-of-state smelters, reduction plants and refineries for lead and zinc* (used in the hypothetical model).

Location 3. *Captive mill built at the mine to serve a continuous steady stream of mine ore.* This

Table 14. Tons produced, grade and average price of ores, United Park City Mines Co.[1]

		Ounces per ton		Percent			Per ton		Average price[2]		
	Dry ore pro-						Average	Average net	Per pound		Per ounce
Year	duced (tons)	Gold	Silver	Lead	Zinc	Copper	mine cost	settlement	Lead	Zinc	Silver
1969	96,511	.020	4.10	5.61	8.44	.150	$23.39[3]	$23.77	$14.90	$14.60	$1.79
1968	84,345	.024	3.84	6.30	9.30	.125	16.37	24.24	13.21	13.50	2.14
1967	60,223	.022	4.32	6.79	9.88	.124	17.77	25.85	14.00	13.84	1.55
1966	82,610	.022	4.32	6.64	9.43	.128	22.26	25.95	15.12	14.50	1.29
1965	69,972	.020	3.88	6.19	9.26	.141	20.32	23.89	16.00	14.50	1.29

[1] These tabulated costs include all charges, except those for depreciation and administration, which latter charges, in the aggregate, insofar as they relate to these operations, amounted to $1.11 per ton of ore produced in 1969; $1.12 in 1968; $1.42 in 1967; $0.96 in 1966 and $1.39 in 1965. Also excluded is amortization of the useable and completed portion of the Ontario No. 6 shaft which has been charged at a rate of $1.00 per dry ton ore produced since January 1, 1968.

[2] Average metal prices represent the average of quoted (by Engineering and Mining Journal–Metals Week) market prices per pound of the metals in effect at the time of production of the metals.

[3] The increased 1969 mine cost per ton was largely due to hoisting cable failure and excessive water drainage through the main haulage level.

Table 15. A hypothetical break-even model of an imaginary Utah lead-zinc mine.

Ore milled at Utah Customs Mill–
Concentration ratio 8:1
Lead concentrate shipped to out-of-state lead smelter and refinery
Zinc concentrate shipped to out-of-state zinc reduction works

	Ore (per ton)	Recoverable metal value per ton of mine ore
Mining costs (per ton; range between \$4 and \$60 per ton)	\$24.00	
Railroad freight (mine to mill)	3.00	
Custom milling charges (mill costs might vary between \$1.50 and \$12.00 per ton)	8.00	
Concentrate (8 to 1) freight \$16.00/ton concentrate (to lead and to zinc works)	2.00	
Treatment: smelting, refining, metal freight, sales, overhead (lead works and zinc works; this cost is difficult to determine; proprietary information)	6.00	
Total costs per ton ore	\$43.00	
Assumed gross recoverable value in ore		\$43.00

would eliminate freight to mill (\$3.00) and replace the custom charge of \$8.00 by a milling charge of \$3.00 or \$4.00 per ton; it includes amortization of mill. In many cases, this would produce cheap sand fill for the mine, a minor cost reduction. Concentrates would be reduced within or outside of Utah as described in locations 4 and 5.

Location 4. *Concentrates reduced within Utah.* Savings in concentrate freight would be about \$2 per ton of ore in the hypothetical case and savings would be reduced by increased costs of metal freight, and economics of local smelting. Metal freight costs are shown for several hypothetical situations in Appendix III.

Location 5. *Reduction facilities at sites with water access.* Access to dependable worldwide supplies of concentrates and to world markets enhances this location. Smelting professionals believe that the advantage of water access outweighs other considerations. The disposal of byproduct sulfur, which must be removed in the future to meet environmental requirements, is also an important consideration.

Location 6. *Treatment at existing Cordilleran reduction facilities–East Helena, El Paso, Bunker Hill.* Lack of capacity, environmental problems, and erratic local supplies of raw materials restrict the capacity available for Utah concentrates. As noted in location 5, future expansion of capacity may be restricted to sites with access to world supplies.

Cost Objectives

To improve profit in the hypothetical model (1) increase the grade of ore, (2) reduce mining costs, (3) eliminate ore freight and custom mill charges, and (4) by negotiation, reduce treatment charges.

Increase Ore Grade. One way to increase profit which is under some management control is to increase the grade of the ore by selective mining. The \$43.00 per ton used in the break-even model is approximately the Utah average for 1960 to 1969. Increases in ore grade, plus some increases in price, have given Utah ores a higher gross during the last several years:

1969 average	Gross recoverable
Utah	\$52.00
Salt Lake County (Lark-U. S.)	50.00
Wasatch County (Park City)	60.00
Utah County (Tintic)	58.00
Gross used in model	\$42.00

Generally the production of ores cannot be maintained indefinitely at a higher than average grade. Mining only the highest grades leaves low economic grade materials for the future, thereby reducing the future life or profit of the mine.

Reduce Mining Costs. In modern industry, the reduction in workload negotiated by labor must be

Table 16. Savings in ore freight (ores and concentrates) from Tintic district to several mills and reduction plants.

Origin		Value of ore or concentrate	Freight charge per ton	Calculated cost per ton of ore at 8 to 1 ratio	Cost per ton, direct shipment of ore	Saving in freight cost[1]
Midvale, Utah	ore	\$ 30.00	\$ 1.73	–	\$ 1.73	–
	ore	50.00	2.00	–	2.00	–
El Paso, Texas	concentrate		17.36	\$2.17	17.36	–
Bunker Hill, Idaho	ore	50.00	15.16	–	15.16	13.26
	concentrate	200.00	19.08	2.38	–	12.78

[1] Saved by shipping concentrate, not ore.

met by improved industrial management and mechanization. Centralized mining, hoisting, milling and sand filling, as suggested by Park Ventures management as a possibility for its mines in the Park City district, is an example of proposed cost improvement.

Large equipment in Utah lead and zinc mines is limited and capital to explore and develop deposits and to build modern, centralized mine plants has not been attracted by operations with an inherent high degree of risk. Custom milling charges are always high. The mill must be designed to handle many kinds of ore from different mines and is necessarily a complex sampling and milling arrangement.

The Leadville Project of ASARCO and Newmont recently brought into production is a Cordilleran type deposit. It is highly mechanized and employs sand fill for wall support. With a 12 percent combined lead-zinc head, it is reported to carry a little silver and apparently runs less than Utah's average of $43.00 gross per ton. Value of Leadville Project ore is estimated as follows:

12 percent,[1] all zinc and lead at $.15	$36.00[2]
2 ounces silver[1]	3.00[2]
Total	$39.00 gross value of mine ore[2]
Subtracting estimated metallurgical losses, this becomes	$32.00/ton gross value of recoverable metal[2]

[1]Engineering and Mining Journal, 1972.
[2]Author's estimate.

Eliminate Ore Freight and Custom Mill Charges. The Idarado mine head mill (a Newmont subsidiary) treats 1,700 tons per day of a complex lead-zinc ore of Cordilleran type (similar to some Utah ores). Table 17 gives the per ton costs of this milling operation.

The cost—$1.69 per ton—is $6.31 less than the custom mill charge assumed in table 15. The cost advantages of a constant and uniform feed of all-sulfide ore in a modern plant are obvious.

Reduce Treatment Costs. Reduction of treatment costs, the total cost to reduce and refine lead and zinc, depends on the efficiency, size, modernity of design and location with regard to dependable concentrate supply of the smelting, leaching, electrolytic and refining plants or complex. Treatment charge also varies greatly depending on the type and complexity of the ore or concentrate.

Conclusions

Metallurgical losses have been researched within the industry and are difficult to reduce substantially.

Table 17. Mill operating costs, 1969, Idarado Mining Co., Colorado (Stevens and Granger, 1970).

Mill operating costs	
Crushing	$0.21
Fine grind	0.49
Flotation	0.58
Thicken and filter	0.08
Concentrate loading	0.03
Tailings disposal	0.03
Gravity concentration	0.02
Mill electrical	0.02
Mill supervision	0.09
Total direct	1.55
Indirect and overhead	0.14
Total	$1.69
Total operating personnel	15
Total tons milled per day	1,700
Tons milled per man shift	113

Concentrate freight is usually noncritical and difficult to reduce; it may be replaced, usually by metal freight, a lesser cost, only by building a local reduction plant.

The imaginary Utah mine apparently would be served best, under hypothetical conditions, by a mine-head mill shipping concentrates to an out-of-state lead smelting complex and an out-of-state zinc treatment complex. For high-level production in Utah, two classes of flotation mills will be required: (1) captive mills designed to handle ore from specific mines, and (2) a custom mill, centrally located and capable of handling batch ores from several small enterprises.

PRODUCTION STATISTICS

County

The U. S. Bureau of Mines annually compiles statistical data on a county basis. Geologic exploration and production projects usually are studied at the mining district or mining company level. In this section of this report, production is tabulated by county and in following sections by (1) large mining districts, (2) moderate producing districts and (3) potential lead-zinc mining districts.

Production from the large districts is readily studied on the county level (figure 8). For example:

1. The *Park City district* production is the total from Summit and Wasatch counties, which are dominated by the United Park City Mines Co. (Park Ventures) in Summit County and Hecla Mining Co., Wasatch County.

2. The lead-zinc mine production from the *Lark-U. S.-Carr Fork lead-zinc mining district* approximates the total lead-zinc mine production of Salt Lake

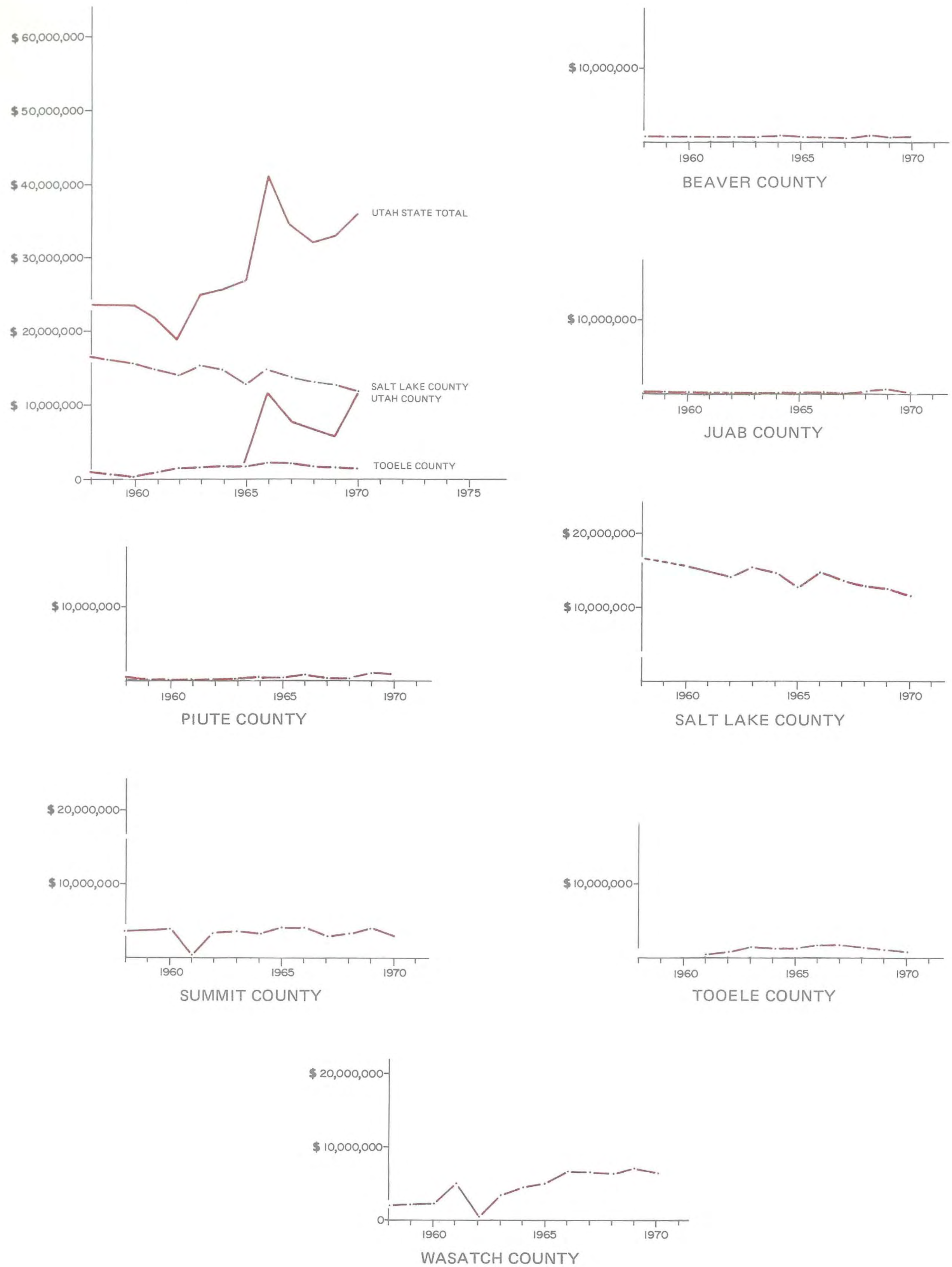


Figure 8. Production statistics by county, 1960 to 1970 (market value of recoverable metals).

County. Several other small districts in Salt Lake County are included in the U. S. Bureau of Mines statistics and in the following totals, but their statistical impact is nil and the magnitude of the Lark-U. S.-Carr Fork operation during the past decade is readily apparent.

3. The *Tintic district* lies in Utah and Juab counties. In the past Tintic mines often were divided into two districts: the Main Tintic in Juab County, most recently the site of Chief Consolidated and Bullion-Beck operations, and the East Tintic in Utah County, dominated by Kennecott's Burgin mine. In this report, East Tintic and Main Tintic are called areas and the two combined are called the Tintic district.

4. Tooele County production is substantially the production from the *Ophir district* (Ophir Hill mine, F. McFarland and S. Hullinger, operators), and

5. Piute County production is substantially from the *Marysvale district*, with Arundel Mining Co.'s operation (the Deer Trail mine) the dominant producer.

Some county statistics obscure district figures by inclusion of totals from neighboring major producers:

(1) Cottonwood-American Fork district in Salt Lake County is dominated by UV Industries and Kennecott. The dollar value of Kennecott's copper production is subtracted from county production, but UV production continues to mask smaller operations in the area. (2) Small operations in Tooele County are masked by production from Ophir, and (3) Some copper mine production is incorporated in Beaver County statistics. When available, it is subtracted from county totals. (4) Statistics from Summit and Juab counties are complicated by production from the reworking of old dumps.

In this report, county production statistics are assembled to 1970 and adjusted to separate gold, silver and copper metals produced in lead-zinc mines from those metals produced in Kennecott's Utah Copper mine and other copper mines; thus, an economic analysis of lead-zinc mine production is not slanted by the immense total of byproducts from Kennecott's Utah Copper mine and not masked by the effects of copper, gold and silver from the copper mines of Beaver, San Juan and Washington counties. Metals derived by leaching, thereby not potential contributors to a lead or zinc reduction plant, also were subtracted from the tables.

The decade 1961 to 1969 was chosen as a base to compare decade averages and trends for each county and counties with no recorded production are not listed (table 18). The following counties show production potential backed by significant recent production: Summit and Wasatch (Park City mining district), Utah (East Tintic area of the Tintic district), and Salt Lake counties (Lark-U. S.-Carr Fork district). They account for 93.5 percent of the state's production for the decade.

Tooele (Ophir district) and Piute (Marysvale district) counties display small, but strong and consistent production, totalling 6 percent. Mining in the other counties had little impact on the lead-zinc economy of Utah during the decade 1960 to 1969, totalling 0.5 percent of the state's production during the decade.

District

Heylmun (1964) lists a total of 70 lead-zinc districts in Utah (figure 9). West Mountain (Lark-U. S.-Carr Fork), Park City and Tintic were large, important producers during the past decade (table 19); Ophir and Marysvale are of moderate size, but strong, consistent and important producers.

Park City district (Summit and Wasatch counties): Ontario mine operated by Park Ventures (formerly United Park City mines), Mayflower mine operated by Hecla Mining Co. (formerly New Park Mining Co.).

Tintic district (Utah County): Principally Burgin mine of Kennecott Copper Corp., also extensive holdings by Anaconda Co.

Lark-U. S.-Carr Fork district (Salt Lake County): The Bingham area outside of and excluding Kennecott's Utah Copper mine. The recently producing mine, the U. S. and Lark, is owned by UV Industries (formerly U. S. Smelting, Refining and Mining Co.). Remaining pertinent area is owned by Anaconda and Kennecott. For many decades, the U.S. and Lark mine was the major producer of lead-zinc in Utah.

Ophir district (Tooele County): Ophir mine, F. McFarland and S. Hullinger, operating lessees from UV Industries.

Marysvale district (Piute County): Deer Trail mine, Arundel Mining Co., lessees from Deer Trail Mining Co.

The remaining 65 districts listed by Heylmun record occurrences of lead and/or zinc, often with gold and silver. Some have an important history of production and, in some, significant tonnages of lead and zinc "resources" are reported to exist today, unmined.

Table 18. Production totals by county.

Year	Tons ore	Ounces		Pounds			Value of recoverable metals	Dollars per ton
		Gold	Silver	Copper	Lead	Zinc		
				UTAH PRODUCTION TOTALS				
1960	741,830	16,245	2,159,220	5,108,500	78,794,700	70,943,300	$22,368,304	–
1961	897,407	19,142	2,364,371	4,890,700	81,788,000	74,478,000	21,163,172	–
1962	805,449	12,959	2,212,755	5,309,600	76,398,000	65,622,500	19,411,070	–
1963	744,925	31,274	2,599,215	4,008,200	90,056,000	72,358,000	24,819,049	–
1964	685,592	44,360	2,431,216	4,516,900	80,498,000	62,856,000	25,069,401	–
1965	718,785	53,205	2,610,102	4,367,900	75,400,000	55,494,000	26,647,798	–
1966	805,065	73,530	4,709,754	5,337,500	128,248,000	74,645,900	40,789,245	–
1967	623,309	74,999	3,110,933	4,715,000	107,626,000	68,502,000	33,805,777	–
1968	623,151	58,797	2,862,715	4,926,700	90,410,000	66,306,000	31,792,806	–
1969	629,087	61,597	2,934,122	5,035,000	82,604,000	69,804,000	32,723,307	–
10 year total	7,074,600	446,108	27,994,403	48,216,000	891,882,700	681,009,700	$278,589,929	
Yearly average (rounded)	700,000	.06	4.	0.4 percent	6.25 percent	5 percent	$28,000,000	$40.00
				BEAVER COUNTY				
1960	3,385	58	4,637	39,200	46,000	218,700	$ 52,404	–
1961	8,024	154	12,075	108,200	24,200	469,600	105,510	–
1962	11,808	131	10,545	165,600	4,400	182,200	88,389	–
1963	156	5	3,167	2,000	25,600	9,500	58,669	–
1964	266	14	1,656	800	49,600	14,300	11,335	–
1965	986	35	6,319	8,700	155,800	55,000	44,810	–
1966	442	16	4,136	1,700	49,100	30,900	18,062	–
1967	177	3	1,907	200	33,500	6,800	8,659	–
1968	165	17	4,306	600	53,700	19,200	37,217	–
1969	108	4	834	100	24,400	13,900	7,370	–
Total 1960-69	25,517	420	49,582	327,100	466,000	1,019,200	$432,425	–
				BOX ELDER COUNTY				
1961	203	1	513	–	21,000	46,600	$8,033	–
1962	–	–	–	–	–	–	–	–
1963	42	2	699	100	21,600	1,800	3,535	–
Total 1960-69	245	3	1,214	100	42,600	48,400	$ 11,568	–

Table 18. (continued)

Year	Tons ore	Ounces		Pounds			Value of recoverable metals	Dollars per ton
		Gold	Silver	Copper	Lead	Zinc		
				IRON COUNTY				
1965	424	2	2,748	600	0	0	$ 3,835	–
1966	13,714	77	118,414	18,100	60,000	0	171,420	–
Total 1960-69	14,138	79	121,162	18,700	60,000	0	$175,255	–
				JUAB COUNTY[1]				
1960	6,422	150	10,024	11,700	483,900	215,900	$102,545	–
1961	414	11	5,321	10,500	85,600	30,100	20,732	–
1962	–	–	–	–	–	–	–	–
1963	71	8	1,281	2,800	300	–	2,813	–
1964	34,826	306	18,749	24,000	–	–	–	–
1965	15,280	83	5,772	6,800	3,800	11,800	15,091	–
1966	1,713	437	26,557	5,100	110,900	–	68,241	–
1967	15,485	480	29,771	27,300	–	–	73,381	–
1968	22,892	667	49,650	41,200	16,800	4,500	152,734	–
1969	25,824	961	87,924	56,800	586,700	1,300	311,912	–
Total 1960-69	122,927	3,103	235,049	186,200	1,288,000	263,600	$747,449	–
Average	12,300	.025	1.92	.07 percent	5.2 percent	1.0 percent		$6.08
				MILLARD COUNTY				
1960	25	2	23	300	500	8,100	$ 1,291	–
1961	184	–	50	–	800	85,100	9,914	–
1962	94	–	44	–	–	26,300	3,072	–
1963	5	–	46	–	3,700	400	505	–
1964	21	3	428	1,100	4,400	4,300	2,178	–
1965	48	–	67	–	1,700	15,700	2,644	–
1966	2	–	2	–	400	600	150	–
1967	–	–	–	–	–	–	–	–
1968	–	–	–	–	–	–	–	–
1969	–	–	–	–	–	–	–	
Total 1960-69	379	–	660	–	11,500	140,500	$19,754	–
				MORGAN COUNTY				
1969	40	–	102	–	7,700	600	$1,071	–

[1]Erratic low values due to reclamation of low-grade mine dumps.

Table 18. (continued)

Year	Tons ore	Ounces		Pounds			Value of recoverable metals	Dollars per ton
		Gold	Silver	Copper	Lead	Zinc		
				PIUTE COUNTY				
1960	376	62	3,871	8,800	15,000	66,700	$ 18,875	–
1961	2,197	407	16,322	12,600	122,300	477,600	100,636	–
1962	1,209	72	9,065	5,200	97,800	113,800	36,041	–
1963	–	–	–	–	–	–	–	–
1964	6,987	545	33,764	10,100	557,900	1,009,400	137,278	–
1965	9,066	1,190	47,617	6,700	763,100	1,658,700	466,805	–
1966	10,428	886	58,067	21,100	945,500	2,045,900	553,289	–
1967	4,193	522	36,032	12,200	573,400	1,000,300	297,532	–
1968	4,836	287	57,932	29,700	600,700	997,800	362,005	–
1969	10,619	637	159,304	86,400	1,708,900	2,811,700	1,017,821	
10 year total	49,911	4,608	421,974	192,800	5,384,600	10,181,900	$2,990,282	–
10 year average	5,000	460	42,200	19,300	538,000	1,020,000	299,000	$60.00
		0.092 oz/T	8.5 oz/T	0.2 percent	5 percent	10.1 percent		–
1970	10,150	362	165,676	–	1,863,500	2,890,800	1,040,057	–
1971	9,873	–	–	–	–	–	448,839	–
				SALT LAKE COUNTY				
1960	496,788	8,829	1,173,099	4,109,300	57,951,400	47,235,200	$15,563,469	–
1961	451,630	9,709	1,316,960	3,546,800	60,562,500	51,085,400	14,632,000	–
1962	515,302	9,010	1,205,128	4,065,200	58,887,700	48,847,200	13,916,000	–
1963	345,848	9,769	1,290,888	2,352,300	61,238,500	43,008,200	15,276,875	–
1964	327,460	9,059	1,200,431	2,441,500	53,625,500	36,829,000	14,698,713	–
1965	248,279	6,422	959,155	2,242,700	43,210,100	26,645,100	12,889,834	–
1966	298,017	8,221	1,114,811	2,551,600	51,550,300	31,160,700	14,962,228	–
1967	281,675	7,527	1,046,624	2,363,200	50,699,400	27,487,100	13,711,920	–
1968	253,116	6,741	988,380	2,403,100	46,707,200	24,533,200	12,906,962	–
1969	246,213	5,506	892,399	2,215,500	39,272,600	25,200,400	12,433,230	–
Total 1960-69	3,464,328	80,793	11,187,875	28,291,200	583,705,200	362,031,500	$140,991,231	–
Average 1960-69	346,000	.024	3.33	.04 percent	7.7 percent	5.4 percent		$41.91
1970	201,223	5,187	804,917	1,709,400	37,228,400	21,421,800	11,696,082	–
				SANPETE COUNTY				
1965	135	–	44	–	6,100	18,100	$3,651	–
1966	54	–	16	–	2,200	8,600	1,601	–

Table 18. (continued)

Year	Tons ore	Ounces		Pounds			Value of recoverable metals	Dollars per ton
		Gold	Silver	Copper	Lead	Zinc		
Total 1960-69	189	–	60	–	8,300	26,700	5,252	–
				SEVIER COUNTY				
1968	42	–	17	–	500	8,200	$1,209	–
1969	16	7	593	–	–	200	1,382	–
Total 1960-69	58	7	610	–	500	8,400	$2,591	–
				SUMMIT COUNTY[1]				
1960	180,070	2,254	751,330	400,100	11,433,200	15,165,800	$4,181,387	$23.22
1961	79,586	868	198,812	187,400	963,700	1,198,000	507,431	6.31
1962	226,013	2,363	689,532	454,400	10,791,900	13,566,000	3,523,000	15.58
1963	258,672	2,735	727,003	345,100	11,210,900	13,754,600	3,924,496	15.17
1964	171,753	1,620	466,685	259,100	10,337,600	11,608,300	3,677,546	21.40
1965	272,709	2,586	611,397	396,600	10,286,400	13,155,500	4,546,824	16.67
1966	204,095	2,024	504,765	313,900	11,173,700	13,245,100	4,446,484	21.80
1967	88,917	1,234	310,449	173,900	8,319,500	9,875,300	3,122,629	35.12
1968	122,322	1,807	337,603	202,000	9,561,200	10,973,800	3,624,186	29.62
1969	98,908	1,093	389,614	247,400	10,120,900	13,682,600	4,365,807	44.13
Total 1960-69	1,703,045	18,584	4,987,190	2,979,900	94,199,000	116,225,000	$35,920,537	–
Average 1960-69	170,000	.01	2.93	.087 percent	2.7 percent	3.4 percent	3,600,000	$21.00
1970	69,767	718	318,991	169,100	6,577,800	8,775,000	3,060,207	–
Average 1970	–	.01 oz/T	4.6 oz.	0.1 percent	4.7	6.3 percent	–	$43.00
				TOOELE COUNTY				
1960	2,101	10	5,496	14,900	135,200	176,200	$ 48,655	–
1961	15,525	101	111,094	237,900	2,422,700	1,705,000	623,223	–
1962	31,252	145	225,463	518,400	4,858,900	3,549,900	1,264,626	–
1963	32,339	145	245,943	491,500	5,174,100	3,849,400	1,472,531	–
1964	27,770	120	220,826	433,100	4,600,800	3,255,800	1,476,413	–
1965	28,297	130	198,037	353,400	4,404,300	3,305,400	1,555,375	–
1966	39,613	163	271,123	538,200	6,132,700	4,363,300	2,110,570	–
1967	38,395	154	235,999	356,100	6,881,600	4,355,300	2,073,639	–
1968	32,218	167	168,255	261,500	5,197,800	3,430,600	1,626,689	–
1969	27,777	123	162,352	280,200	4,269,600	3,179,900	1,529,237	–
Total 1960-69	275,287	1,258	1,844,588	3,485,200	44,077,700	31,170,800	$13,780,958	–

[1] Erratic low values due to reclamation of low-grade mine dumps.

Table 18. (continued)

Year	Tons ore	Ounces		Pounds			Value of recoverable metals	Dollars per ton
		Gold	Silver	Copper	Lead	Zinc		
Average 1960-69	–	.0046	6.7	0.63 percent	8.0 percent	5.6 percent		$50.00
1970	19,637	127	134,466	265,600	2,780,400	1,935,900	1,126,818	–
				UTAH COUNTY				
1960	–	–	–	–	–	–	–	–
1961	4,717	117	4,737	5,400	8,100	2,100	$ 11,170	–
1962	–	–	–	–	–	–	–	–
1963	8,274	72	82,427	11,500	3,170,900	492,300	510,567	–
1964	7,132	40	43,160	6,100	1,700,800	526,500	353,603	–
1965	29,514	43	342,368	4,300	7,055,200	2,931,300	1,974,290	–
1966	104,487	111	1,937,980	39,300	45,684,600	14,474,200	11,527,894	–
1967	63,120	80	893,137	51,400	29,771,100	16,148,900	7,810,256	–
1968	65,203	41	693,648	28,200	18,910,500	19,280,800	6,603,182	–
1969	99,330	735	542,944	58,200	14,465,300	17,780,000	5,781,771	–
Total 1960-69	381,777	1,239	4,540,401	204,400	120,766,500	71,648,100	$34,572,733	–
Average 1960-69	–	.0032	11.9	0.0 percent	15.8 percent	9.4 percent		$90.50
1970	165,220	2,312	1,291,482	19,400	31,869,000	27,889,000	11,632,245	
				WASATCH COUNTY				
1960	52,623	3,429	161,776	312,800	8,710,300	7,850,100	$2,398,607	–
1961	134,927	7,774	698,016	628,800	17,576,200	19,375,100	5,144,523	–
1962	19,771	1,238	72,234	89,100	1,755,800	2,334,900	579,195	–
1963	99,518	18,538	302,872	799,900	9,210,200	11,232,600	3,569,058	–
1964	109,377	32,653	441,767	1,323,000	9,622,400	9,606,200	4,712,335	–
1965	114,047	42,714	436,578	1,348,100	9,513,500	7,697,400	5,144,639	–
1966	132,500	61,595	663,883	1,849,500	12,538,600	9,316,600	6,929,306	–
1967	131,347	64,988	553,699	1,713,500	11,347,500	9,628,300	6,707,761	–
1968	122,357	59,028	543,600	1,927,300	9,361,600	7,051,900	6,478,622	–
1969	120,292	52,531	698,149	2,069,800	12,215,600	7,128,000	7,274,777	–
Total 1960-69	1,036,759	344,488	4,572,574	12,061,800	101,851,700	91,221,000	$48,938,823	
Average 1960-69 (rounded)	100,000	.33	4.41	.60 percent	4.9 percent	4.4 percent		$47.00
1970	117,752	50,819	561,212	2,104,500	10,423,400	6,453,100	6,673,986	–

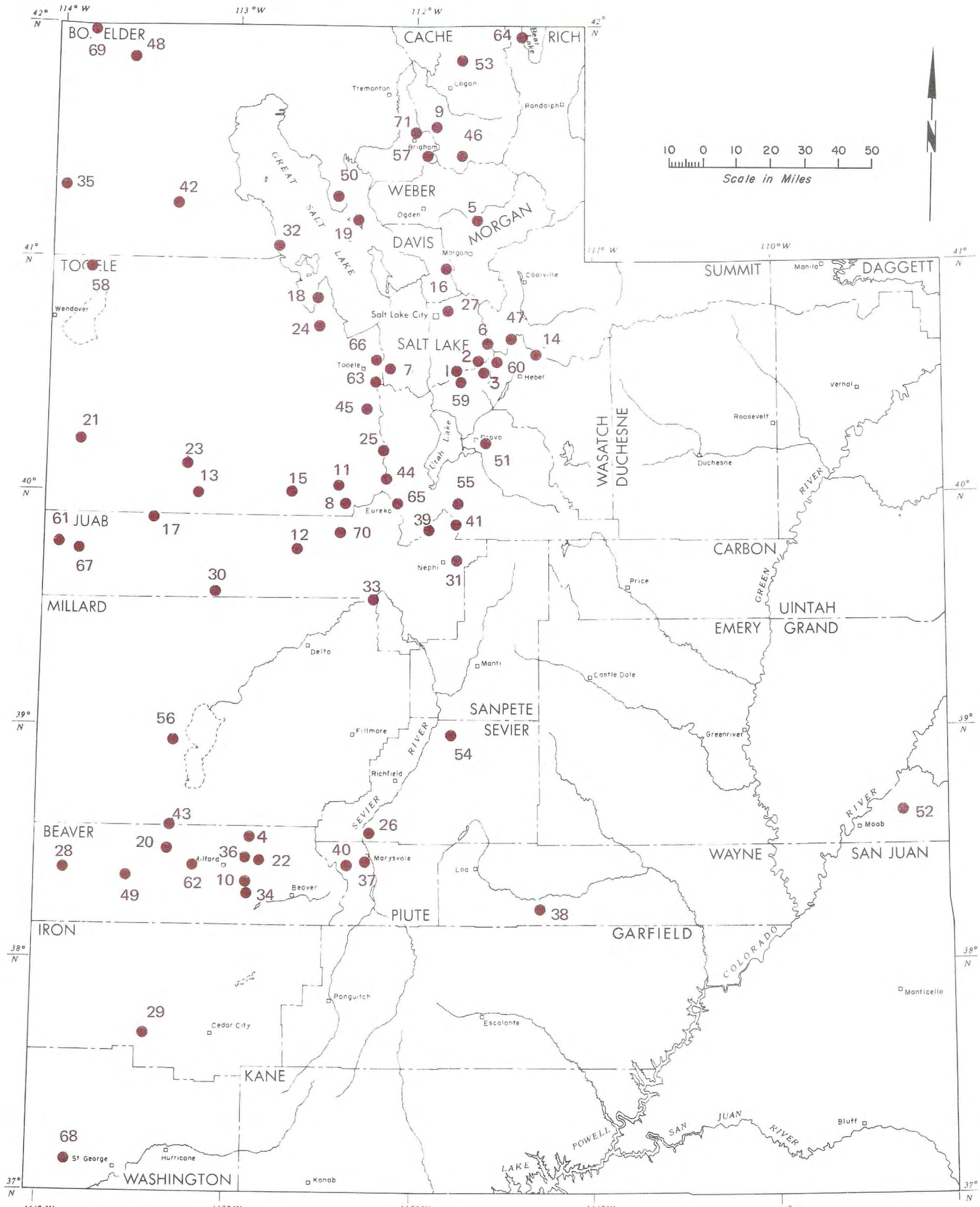


Figure 9. Utah lead-zinc mining districts (modified from Heylmun, 1964; explanation on page 25).

Mining District[1]	County	Mineral
1. Alpine	Utah	Pb
2. Alta	Salt Lake	Pb, Ag, Zn, Cu, Mo, Au, W, As, Bi, Sb, Mn, Ba, Fe
3. American Fork	Utah	Pb, Ag, Zn, Cu, Au, Ba, Mo
4. Antelope	Beaver	Pb, Ba
5. Argenta	Morgan	Pb, Ba, Fe
6. Big Cottonwood	Summit	Pb, Ag, Zn, Cu, Au, Mo, Mg, Ba
7. Bingham (West Mountain)—Large	Salt Lake	Cu, Au, Pb, Ag, Zn, Mo, Hg, As, Bi, Sb, Se, Te, Ba
8. Blue Bell	Tooele	Pb, Ag, Au, F, Be, Ba
9. Box Elder (Incl. Dry Lake)	Cache	Cu, Au, Pb, Sb
10. Bradshaw	Beaver	Au, Ag, W, Pb, Cu
11. Columbia	Tooele	Pb, Ag, Cu, Zn, F
12. Desert Mountains	Juab	Cu, Pb
13. Dugway	Tooele	Pb, Ag, Zn, Cu, F, Ba
14. Elkhorn	Wasatch	Pb, Ag, Au
15. Erickson (Black Crook)	Tooele	Pb, Ag, Zn, Au, Mn, F
16. Farmington	Davis	Cu, Au, Pb, W
17. Fish Springs	Juab	Pb, Ag, Au, Cu, Zn
18. Free Coinage	Tooele	Au, Pb, Hg
19. Fremont Island	Weber	Cu, Au, Pb, Ag
20. Frisco (San Francisco)	Beaver	Au, Cu, Pb, Ba, Se, Sb, Ag, Zn, Mo, W, Th, As
21. Gold Hill (Clifton)	Tooele	Au, Cu, Pb, Ag, Mo, W, As, Bi, Ba, Sb
22. Granite	Beaver	Be, Cu, Mo, Th, W, Pb, Bi, Ba
23. Granite Mountain	Tooele	Pb, Ag, Zn
24. Grantsville (Third Term)	Tooele	Pb, Cu
25. Greeley	Tooele	Pb, Cu
26. Henry	Sevier	Au, Ag, Pb, Fe
27. Hot Springs (Adams)	Salt Lake	Pb, Ag, Fe
28. Indian Peak	Beaver	Pb, Ag, F
29. Iron Springs	Iron	Fe, Pb, Cu, Ba
30. Joy (Detroit, Drum)	Juab	Au, Ag, Cu, Mn, Bi, Pb
31. Juab (Nephi)	Juab	Pb
32. Lakeside	Box Elder	Pb, Ag
33. Leamington	Millard	Cu, Pb, Ag
34. Lincoln	Beaver	Cu, Au, Pb, Ag, Zn, Bi, W, F
35. Lucin	Box Elder	Cu, Pb, Ag, Mo, Fe
36. McGarry	Beaver	Fe, Ba, Pb, Cu
37. Marysvale (Ohio)—Moderate	Piute	Cu, Pb, Ag, Hg, Mo, U, Se, Te, Alunite, Halloysite
38. Miners Mountain	Wayne	Cu, Pb
39. Mona	Juab	Pb
40. Mt. Baldy	Piute	Au, Pb, Ag, Hg, Zn, Cu, Mn, Te
41. Mt. Nebo (Timmons)	Juab	Au, Pb, Cu, Ba
42. Newfoundland	Box Elder	Pb, Ag, Cu, W, Bi
43. Newhouse (Preuss)	Beaver	Cu, Pb, Ag, Zn, Sb, Mo, W, Ba
44. North Tintic	Utah	Pb, Ag, Zn, Halloysite
45. Ophir—Moderate	Tooele	Cu, Au, Pb, Ag, Zn, Mn, W, Ba
46. Paradise (La Plata)	Cache	Pb, Ag, Zn, Au
47. Park City (Incl. Uinta)—Large	Summit	Pb, Ag, Zn, Cu, Au, As, Bi, Sb, Fe, Ba
48. Park Valley (Dove Creek)	Box Elder	Au, Cu, Pb
49. Pine Grove (Wah Wah)	Beaver	Pb, Ag, F, Fe
50. Promontory	Box Elder	Cu, Pb, Zn
51. Provo	Utah	Pb, Ag, Au, Fe
52. Richardson	Grand	Cu, Pb, U
53. Richmond	Cache	Pb
54. Salina Creek	Sevier	Cu, Pb, Zn, Sr
55. Santaquin	Utah	Pb, Ag, Zn, Cu
56. Saw Back	Millard	Cu, Pb, Mo
57. Sierra Madre	Box Elder	Cu, Au, Pb, Ag, Zn, Mo, Fe
58. Silver Islet	Tooele	Cu, Pb, Ag, Ba
59. Silver Lake	Utah	Pb, Ag
60. Snake Creek (White Pine, Howland)	Wasatch	Pb, Ag, Zn, Au
61. Spring Creek	Juab	Au, Pb
62. Star	Beaver	Cu, Pb, Ag, Zn, Au, Mo, As, F, W, Bi, Sb, Mn
63. Stockton (Rush Valley)	Tooele	Cu, Au, Pb, Ag, Zn
64. Swan Creek	Rich	Cu, Pb, Ba
65. Tintic (Eureka)—Large	Juab	Pb, Ag, Au, Zn, Cu, Mn, As, Bi, Sb, Fe, Ba, Halloysite
66. Tooele	Tooele	Pb, Cu
67. Trout Creek (Johnson Peak)	Juab	Pb, Zn, Cu, Be, W
68. Tutsagubet (Beaver Dam)	Washington	Cu, Pb, Ag, As, W
69. Vipont (Ashbrook)	Box Elder	Au, Ag, Pb, Zn, Mn, W
70. West Tintic	Juab	Cu, Pb, Ag, Zn, Mo, W
71. Willard	Box Elder	Cu, Fe, Pb, Sb

[1] Districts not designated large or moderate are potential.

Figure 9. (continued)

Table 19. Gross metal value of major districts, 1960 to 1970.

Year	Park City — Wasatch County, Largely Hecla	Park City — Summit County, Largely United Park City	Tintic — Utah County, Largely Kennecott	Lark-U. S.-Carr Fork — Salt Lake County, Largely UV Industries
1960	$ 2,398,000	$ 4,181,000	–	$ 15,563,000
1961	5,144,000	507,000	$ 11,000	14,632,000
1962	579,000	3,523,000	–	13,916,000
1963	3,569,000	3,924,000	510,000	15,276,000
1964	4,712,000	3,677,000	353,000	14,698,000
1965	5,144,000	4,546,000	1,974,000	12,890,000
1966	6,929,000	4,446,000	11,527,000	14,962,000
1967	6,707,000	3,122,000	7,810,000	13,711,000
1968	6,478,000	3,624,000	6,603,000	12,906,000
1969	7,274,000	4,365,000	5,781,000	12,433,000
Total for decade	$48,934,000	$35,915,000	$35,090,000	$140,990,000
Yearly average–decade	$ 4,893,000	$ 3,591,000	$ 3,509,000	$ 14,099,000
Yearly average–rounded	$ 5,000,000	$ 3,500,000	$ 3,500,000	$ 14,000,000

In most, no measurable resource is reported. Most remain idle because probability of profitable operation has not been demonstrated sufficiently by owners or producers.

Park City District, Summit and Wasatch Counties

Location

Park City district ore deposits extend across the Summit-Wasatch County line, with most of the historic mines, the Silver King, Daly, Daly West, Judge, Park City Consolidated and Ontario to the west and north in Summit County, with the Park Utah and Mayflower mines to the east and south in Wasatch County. Of these, only the Ontario and Mayflower, operated by Park City Ventures and Hecla Mining Co., respectively, are in operating condition at this time, either producing ore (Mayflower) or aggressively exploring and developing ore (Ontario).

Production

The Park City district has produced more than one-half billion dollars ($535 million) in metals during the past hundred years and paid more than $90 million in dividends (Wilson, 1959; re-calculated to 1970). Tonnages and grades of ore produced from 1875 through 1970 are shown on table 20.

Geology

Ore at Park City occurs within 2 miles and generally north of a complex group of acidic igneous rocks intruded irregularly into a north-trending anticline of Paleozoic sandstones, shales, limestones and quartzites. Slicing both sediments and intrusives is a series of east-northeast trending faults that are intensely mineralized throughout a zone 4 miles long, 1.7 miles wide and in excess of 2,000 feet deep (figures 10 and 11).

Ore occurs in intrusives and sediments, but with differing metal content:

Type of Host	Ounces/ton Gold	Ounces/ton Silver	Percent Lead	Percent Zinc	Percent Copper
Igneous intrusives (Mayflower vein complex)	0.334	5.68	5.33	5.77	0.72
Sedimentary rocks	9.03-0.13	5.8-58.2	1.2-14.1	3.3-12.1	0.02-0.49

Veins in the intrusives, important only in the Mayflower area, yielded 11 percent of the district's tonnage. In the sediments, production has come from veins and replacements; replacement deposits, principally mantos, yielded 70 percent of the district's 16,408,345 tons of recorded production.

Mineralization has replaced numerous horizons within the Thaynes (Triassic), Park City (Pennsylvanian-Permian) and Humbug (Mississippian) formations. The Park City, principally from the Jenney Horizon near the base of the formation, has been the district's largest single productive formation.

Where associated with fault zones, replacement ores adhere to an east-northeast trend. But a series of north-trending mantos in the Jenney Horizon, unassociated with major fault zones and up to 10,000 feet long, yielded 3,420,000 tons that averaged (Barnes and Simos, p. 1122):

Ounces/ton Gold	Ounces/ton Silver	Percent Lead	Percent Zinc	Percent Copper
0.024	18.45	13.52	10.68	0.495

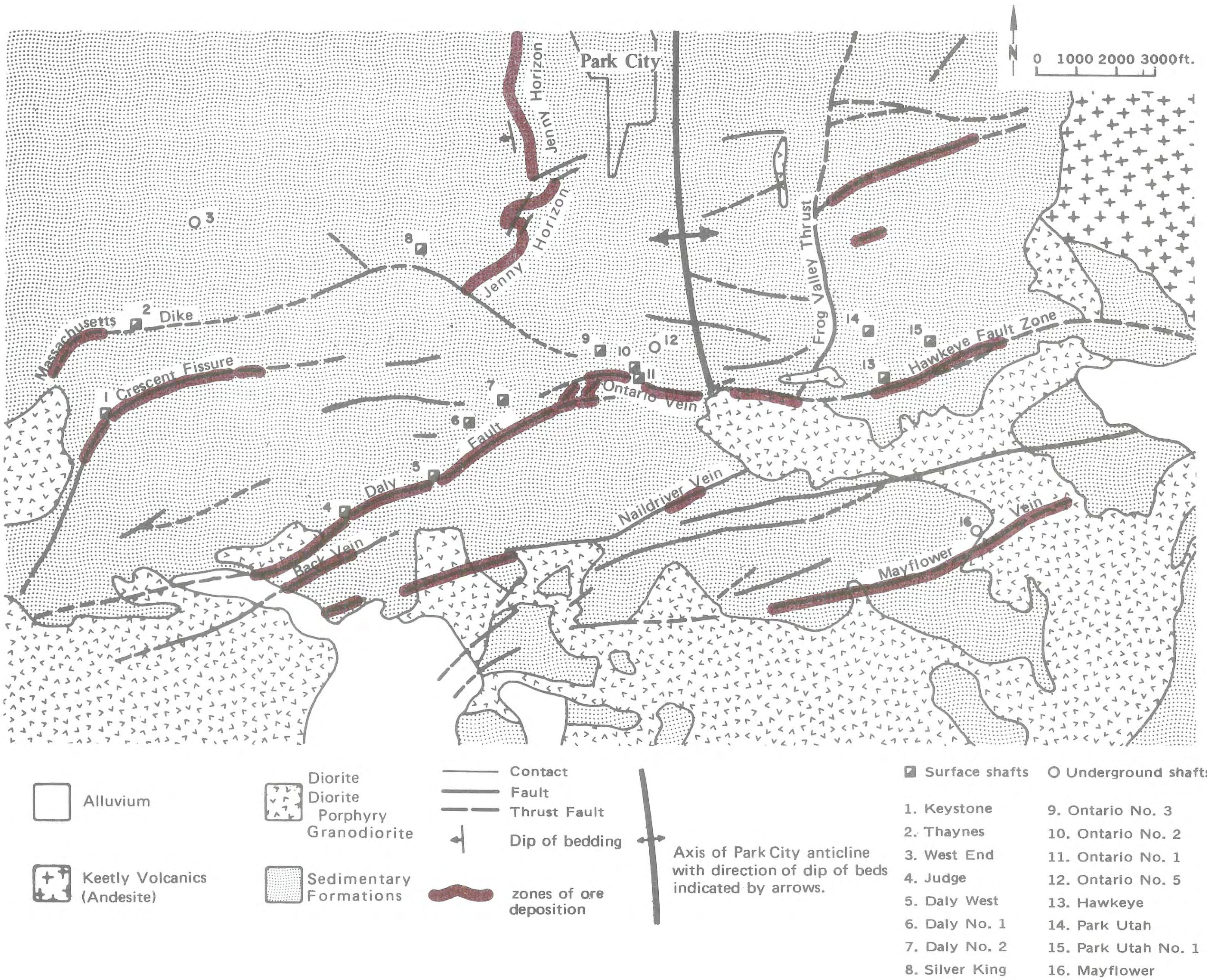
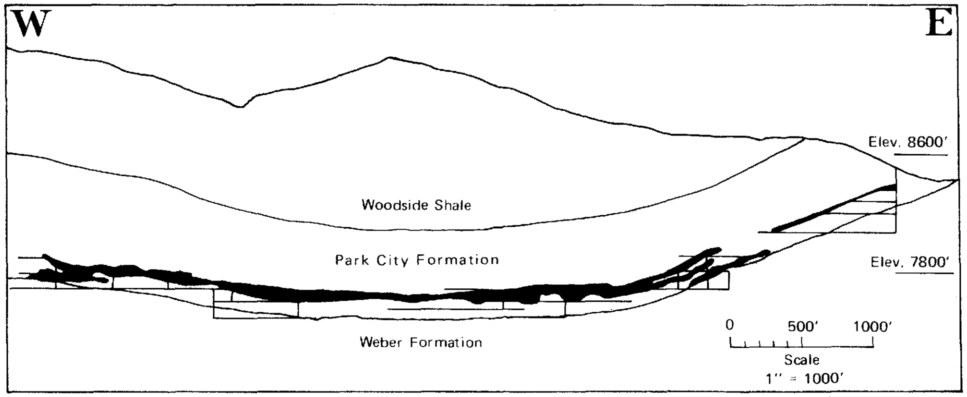
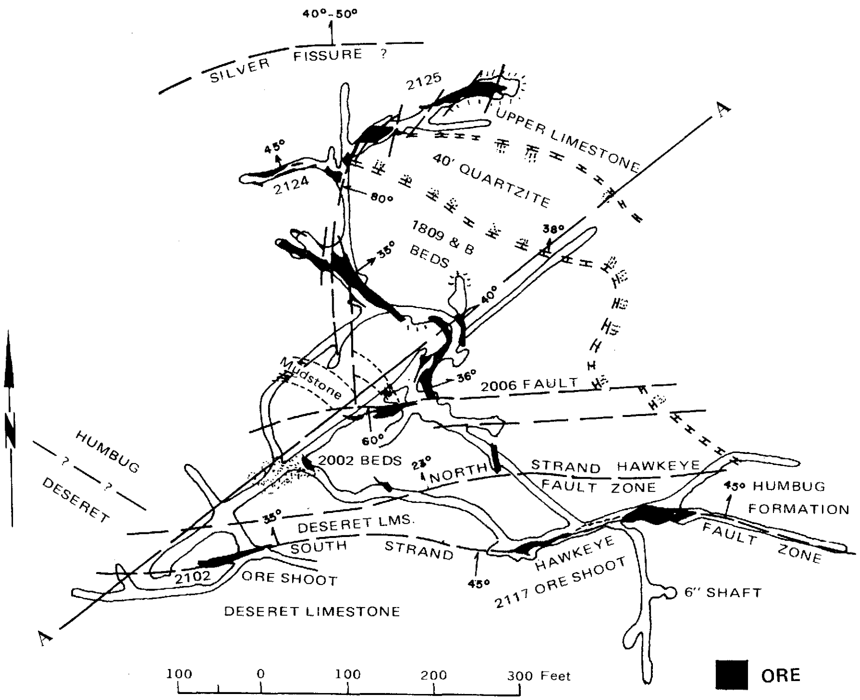


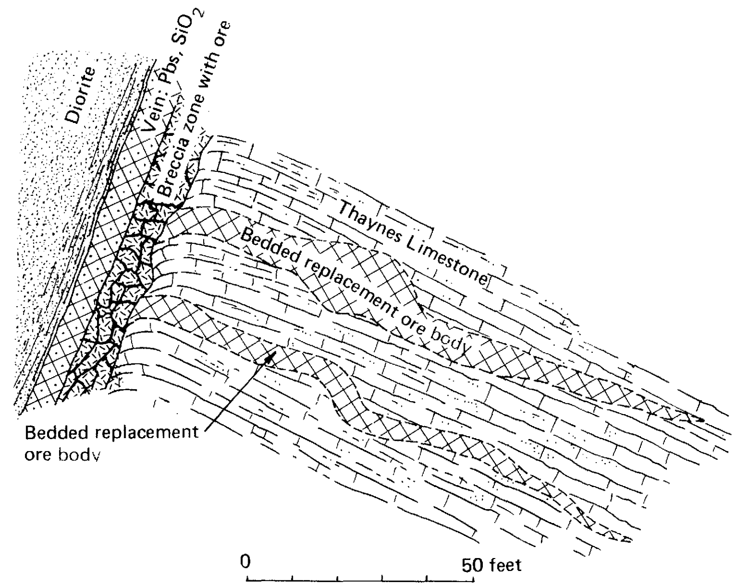
Figure 10. Generalized geologic map, Park City district (modified from Barnes and Simos, 1968).



Section through Jenney Horizon, Park City Formation, replacement ore bodies, facing north (modified from Barnes and Simos, 1968).



Plan view of scattered, irregular ore shoots mined in one area of the Ontario mine, 2,100 level (from Erickson and others, 1968).



Veins and bedded replacement ore bodies in the Thaynes Limestone (from Boutwell, 1912).

Figure 11. Sketches illustrative of conditions in the Park City district.

Table 20. Total production, Park City district, 1875 to 1970 (courtesy Hecla management).

Mine Average grade	Years	Tons	Gold Total Ounces Ounces/ton	Silver Total Ounces Ounces/ton	Lead Total Pounds Percent	Zinc Total Pounds Percent	Copper Total Pounds Percent
Ontario	1875-1970	2,761,613	52,237	58,046,724	227,935,149	301,345,882	5,455,468
Average grade			0.020	21.02	4.13	5.46	0.098
Silver King	1882-1967	4,698,609	200,224	86,126,781	1,334,765,435	331,859,041	45,801,007
Average grade			0.042	18.33	14.20	3.53	0.487
Daly	1899-1950	554,088	18,717	12,734,946	11,166,664	10,877,183	371,628
Average grade			0.035	22.90	1.00	0.98	0.003
Daly West & Judge	1899-1968	4,265,346	79,051	51,264,287	744,384,966	401,616,365	31,831,461
Average grade			0.018	12.02	8.73	4.71	0.373
Park Utah	1920-1951	1,238,778	168,264	21,690,467	104,032,694	136,311,084	6,003,021
Average grade			0.136	17.51	4.20	1.33	0.242
Park City Cons.	1929-1942	532,155	30,598	8,764,593	20,966,691	32,993,610	Unknown
Average grade			0.057	16.47	1.97	3.10	?
Mayflower	1873-1970	2,357,756	788,464	13,395,318	251,539,887	269,703,709	34,115,786
Average grade			0.334	5.68	5.33	5.77	0.72
Total		16,408,345	1,337,555	252,023,116	2,694,791,486	1,484,706,874	123,578,371
Average grade			.0815	15.36	8.21	4.52	.377

In the deep Humbug Formation (figure 12) replacement ores yielded more than 1 million tons averaging (Barnes and Simos, p. 1125):

Ounces/ton			Percent	
Gold	Silver	Lead	Zinc	Copper
0.025	5.80	6.40	8.67	0.14

Humbug Formation Ores. The Humbug Formation has been explored extensively only in the Ontario mine area where, in the crest of the Park City anticline, the formation becomes accessible to exploration. For almost 20 years, ores have been mined along both flanks of the anticlinal structure. Park City Ventures has concentrated its exploration campaigns in this area.

In addition to the Ontario ores, Humbug mineralization has been encountered in other parts of the district. Geologically the Humbug Formation has many of the same physical characteristics as the Park City Formation. It is highly receptive to replacement-type mineralization and has yielded abundantly in the Ontario area. As deeper parts of the district become accessible, the Humbug should be a prime target for exploration and development.

Blind Manto-type Ore Zones in the Park City Formation. On the west flank of the anticline in the northwest part of the district, a series of long, north-trending mantos have occurred in the basal part of the Park City Formation. Following the strike of the bedding, the ore runs parallel one another and, as the flank of the anticline gains depth, each succeeding ore run to the west occurs at an increasingly greater depth.

If additional ore runs exist, and no evidence suggests they don't, they should contain high-grade ores, but locating them is beyond the capability of surface prospecting.

Early Exploration

Early mine discoveries made on outcrops were followed to depth and laterally by shafts and levels. New discoveries were made from the underground openings, but because of the great expense of shaft sinking, tunnelling and diamond drilling, explorations at depth have been confined to ores near accessible shafts and levels or near the alignment of shafts sunk and levels driven to explore already partly known reserves.

Future Exploration

Although bonanza ores were mined close to the surface and deep Humbug ores averaged lower metal content, the disappearance of economic minerals at depth has not been demonstrated. If deep ores are prospected, access must be provided and modern haulage and drainage nets will become imperative as deep mineralization is developed.

In addition to deep exploration in the Ontario mine area currently underway, three areas of the Park City district merit future exploration for production: (1) the Mayflower area in igneous intrusions and associated sedimentary rocks; (2) deep Humbug ores, and (3) blind manto-type ore zones in the Park City Formation.

Exploration–Mayflower Mine

Table 21 shows production history of the Mayflower mine; regarding future exploration and production of the Mayflower area, Hecla management made the following statement (personal communication, August 22, 1972):

> Exploration results on 2,600 level, 2,800 level and 3,000 level were disappointing. As a result, in late 1970 all development was curtailed. The operators then proceeded to extract blocked out ore but carried out no compensatory exploration and development. By the end of 1972 it is anticipated that blocked out ore will be gone.

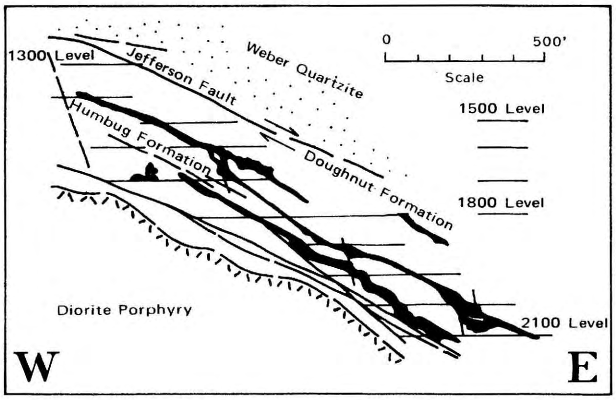


Figure 12. Section through Humbug Formation; replacement ore bodies facing northeast flank of Park City anticline (modified from Barnes and Simos, 1968).

Therefore, without a very costly development program at depth, ore to resume production at a later date cannot be developed.

The areas now indicated for exploration, however, outside and below the 2,600, 2,800 and 3,000 blocks, lie below water level and in an environment known to reach 140° F. Exploration of the untested areas, development and production would be costly. Further, the possibility of *nondiscovery* or discovery of an uneconomical grade of mineral is great.

The Park City district and this area are noted for erratically high-grade ore bodies, discovered during extensive exploration, which paid handsomely even under expensive operating conditions and an adverse metal market. Undeveloped target areas within geologically favorable projections, therefore, may contain resources of a grade higher than that encountered at 2,600, 2,800 and 3,000 feet.

Therefore, resumption of exploration from Mayflower mine levels is not anticipated unless improved gold, silver, lead and zinc prices combine with an improved outlook for production economics to indicate a probable financial return from the exploration and development investment at a rate (profit) commensurate with the exploration risks involved.

In December 1972 the Hecla Mining Co. terminated all operations in the Mayflower mine, removed pumps and salvageable equipment, and the mine was permitted to fill with water.

A Hypothetical Mayflower Exploration Target

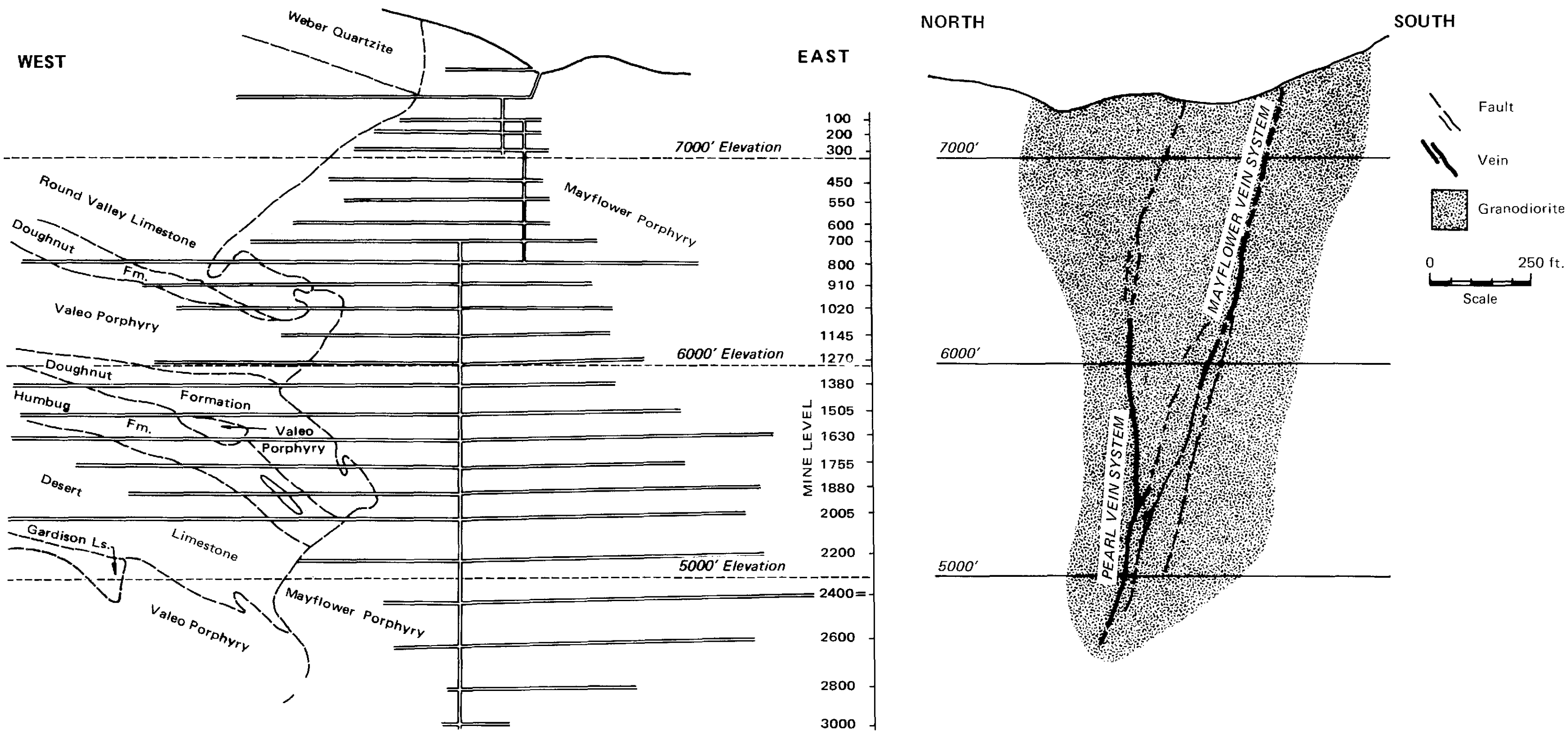
The Mayflower vein as described by Quinlan and Simos (1968, p. 50; figure 13) "... is commonly braided and in detail quite complex. . .(It) generally defines the footwall of the Mayflower ore zone. . .(where) ore has been found. . .from near the surface to the 2,005 level. . .The principal ore shoot was up to 1,400 feet long and averaged about 6 feet wide." A hypothetical ore shoot with the same dimensions and a density of 12.5 cubic feet per ton would contain 1.7 million tons of ore and could supply a 400 ton-per-day flotation plant (the size of the present Mayflower mill) for about 12 years.

The Mayflower mine was developed erratically over 100 years by some twenty-four levels spaced vertically at 100 and 200 feet, not all of them productive. The hypothetical lode might be developed today by twelve levels at 200 feet, or one level per year, if all mill feed came from the one hypothetical shoot. A small budget likely could not maintain the speed of shaft sinking and station and level development necessary for this rate of extraction. An average of one level every two or more years is more realistic. With such programming several ore shoots, some of them small, must be under exploration and development at all times.

Present mechanization at a scale fitting the hypothetical shoot's dimensions, averaging "6 feet thick, braided and in detail quite complex," is limited to jack leg drilling, rock bolting and sand fill, small slusher or small rubber-tired load-haul-dump equipment. The shoot would not be amenable to large open stopes and extensive unsupported areas needed for a high degree of mechanization and high volume production.

Table 21. Production history, Mayflower mine, September 1961 to 1970 (courtesy Hecla management).

	1961 from Sept.	1962	1963	1964	1965	1966	1967	1968	1969	1970	Total through 1970
Tons mined (milled)	658	2,838									3,496
		9,246	92,223	97,605	113,188	126,333	127,182	122,357	117,452	115,762	921,348
Average grade											
Au–ounces per ton	0.303	0.146	0.230	0.365	0.415	0.539	0.572	0.533	0.502	0.480	0.461
Ag–ounces per ton	6.68	2.90	3.23	4.49	4.27	5.57	4.66	4.85	6.25	5.18	4.85
Pb–percent	8.66	3.83	4.80	4.40	4.33	4.86	4.45	3.96	5.17	4.52	4.55
Zn–percent	7.70	5.64	6.39	4.75	3.90	3.75	4.00	3.22	3.13	2.85	3.94
Cu–percent	0.96	0.39	0.50	0.76	0.75	0.84	0.86	0.88	0.99	0.99	0.83
Contents											
Au–ounces	199	1,537	18,443	32,514	42,704	61,517	64,936	59,028	52,500	50,798	384,176
Ag–ounces	4,392	31,555	269,230	395,368	432,921	639,192	535,131	543,600	686,972	552,031	4,090,392
Pb–tons	57	450	4,279	4,185	4,781	6,007	5,536	4,753	6,055	5,140	41,243
Zn–tons	51	608	5,445	4,413	4,164	4,507	4,871	3,799	3,567	3,197	34,622
Cu–tons	6	38	424	700	731	930	979	1,005	1,077	1,104	6,994



A. Looking north.

B. Looking east.

Figure 13. Generalized sections through the Mayflower and Pearl veins, Park City district.

Exploration—Ontario Mine (Park Ventures)

From 1965 to 1970, the United Park City Mines Co.'s Ontario mine shipped an average of 300 tons of ore per day to the Midvale mill of United States Smelting, Refining and Mining Co. In 1971, the operating management, Park Ventures, anticipating that sufficient ore would be developed to justify a new efficient mining and milling plant, decided to stop shipping and to concentrate on exploration and development of manto ores in the deep Humbug Formation. By the summer of 1972 they had accomplished partial development of one-third of the target tonnage and were aggressively pursuing the opening of geologically promising areas, in which application of district development experience suggests possible additional reserve.

If their target of 3 million tons becomes reasonably assured by partial development, Ontario mine's management hopes to re-fit and modernize a centrally located vertical shaft and associated level stations, construct a 1,000 ton-per-day flotation plant at the shaft head, mine and mill the ore, and send a portion of the tails back down the shaft as sand fill for the stopes. An operation at this scale of production proved efficient at Idarado and Leadville mines, Colorado.

Outlook

Summit County production during 1960 to 1969 included the milling of several old mine dumps which diluted and reduced the average grade to the $21-gross-recoverable value that is reported in the county production statistics section: 170,000 tons a year of $21 a ton gross recoverable metal content and total recoverable metal value of $3.5 million a year.

A medium rate of future production from Summit County is projected in this report at a metal value of $50.00 per ton gross recoverable and at 150,000 tons a year. This would produce a recoverable gross metal value of $7.5 million per year.

Should Park City Ventures' long-range target of a 1,000 tons-per-day plant be achieved, projections made for this report indicate that Summit County gross production might exceed $15 million metal value per year (300,000 tons per year x $50.00 per ton) if existing plans are successful, metal prices are good and a reasonably priced labor supply remains available. The Colorado operations at Idarado and Leadville support this hope. But, if metal prices fall, production may cease.

Speculative resources and reserves for the next 10 productive years at Park City are estimated by (1) management, based on recent mine developments, and (2) projecting past annual production totals for Summit plus Wasatch counties:

	Tons
(1) Management's estimates:	
–partly developed, partly measured	900,000
–resources to be derived by exploration of areas determined as favorable targets and accessible to proposed exploration projects	2,100,000
Total	3,000,000
(2) Projecting past annual production totals:	
–1960 to 1969 decade average (including some dumps)	270,000 tons/year
–over a 10-year productive period equals	2,700,000 tons

Lead-zinc resources within the grade range[1] experienced in recent years in the Park City district exist; they are identified by mine exposures and are speculatively predicted by favorable geological projections. The resources can be completely identified and their content classified as ore, if estimated future lead-zinc mine economics are sufficiently attractive to warrant the investment of considerable risk capital in exploration, development and facilities, with its return deferred some years, and if reasonable luck is experienced in exploration.

Tintic District, Utah and Juab Counties

The following descriptions of the Tintic mining district are extracted from Morris (1968), Shepard, Morris and Cook (1968) and Don Rausch, manager, and Paul Mogensen, geologist, Tintic Division, Kennecott Copper Corp. (personal communications). Most of the production data was derived from published or unpublished reports of the U. S. Bureau of Mines.

Location

The Tintic district lies in Utah County to the east and Juab County to the west. It is divided into the Main Tintic (Juab County) and East Tintic (Utah County) areas.

The Main Tintic area has not produced underground ores since 1965, but includes such major old mines as the Gemini, Mammoth, Chief, Plutus, Godiva, Iron Blossom and Bullion-Beck. The East Tintic area includes the Burgin mine (Kennecott), Eureka Lily, Eureka Standard, North Lily and Tintic Standard. The Burgin (Kennecott Copper Corp.) is the only mine producing (tables 22 to 26).

[1] "Range" refers to grades reported in tables 13, 20 and 21. It does not refer to the range in statistical tables for Summit County (table 18) as these grades are very low due to dilution of mine ore by material recovered from old dumps.

Table 22. Production from Main and East Tintic areas (Tintic district; U. S. Bureau of Mines, published and unpublished reports).

	Ore (tons)	Gross dollars	Dollars per ton
Main Tintic, Juab County			
1869-1965[1]	13,500,000	$315,000,000	$23.30
1965-1970	66,000	606,000	9.20
East Tintic, Utah County			
1909-1966[1]	3,600,000	120,000,000	33.30
1967-1970	497,000	43,355,000	88.00
Total production Tintic district 1969-1970	17,663,000	$478,961,000	$27.10
Production 1970 Utah County (all Burgin mine, K. C. C.)	165,000	$ 11,632,000	$70.50
Average year 1960-1969, East Tintic only	38,000	$ 3,450,000	$90.00

[1] From Morris, 1968.

Main Tintic Area

Ore was discovered in the Main Tintic area in 1869; production peaked from 1911 to 1920, averaging 336,000 tons of ore per year. It gradually declined until 1965 when mine production ceased (table 25, page 39). Production reported by the U. S. Bureau of Mines since 1965 apparently came from the reworking of old dumps.

According to Morris (1968, p. 1045):

Production has come from about six square miles, extending south from Eureka through the declining or abandoned towns of Mammoth, Silver City and Diamond [figure 14].

The . . . deposits of the (Main) Tintic district include both fissure and replacement veins as well as the extensive replacement ore bodies. Together, these ore deposits form persistent linear zones (or ore runs) that extend north-northeasterly across the Silver City (igneous) stock and adjacent rocks and northerly through the sedimentary rocks . . . In the carbonate rocks . . . five ore runs (mantos) are recognized . . . (1) the Gemini [figure 15]. . . (2) the Mammoth-Chief zone . . . (3) the Plutus zone . . . (4) the Godiva zone and . . . (5) the Iron Blossom zone . . .

. . . The veins in these zones generally are aligned with the replacement ore deposits of the East Tintic . . . but are separated from them by an unexplored area covered by volcanic and hypabyssal rocks.

Ore Deposits. Morris (1968, p. 1055) further reports:

More than 90 percent of the ore produced [from the Main Tintic area] has come from ore bodies in folded and faulted carbonate rocks of Paleozoic age. These replacement ore bodies range in size from insignificant stringers and small kernels to great columnar, linear and bulbous masses, some containing several hundred thousand tons of ore. Several of the columnar and linear ore bodies in the trough of the Tintic syncline resemble the chimney and manto replacement ore deposits of north central Mexico . . .

Table 23. Estimate of minable amount of lead ore in the Tintic area (Mogensen, 1972).

Area	Tons (millions) of mineralized rock Percent lead 5-10	10-15	Above 15
East Tintic district	7.64	2.30	1.00
Main Tintic district	2.50	1.75	.50
Southwest Tintic district	.07	.02	.01
Total tons	10.21	4.07	1.51

The most productive of the replacement ore bodies are the great columnar masses or chimneys, locally termed "pipes," that were mined in the Mammoth Chief (averaging $50.00 net smelter return for 3.5 million tons), Gemini, Centennial Eureka, Gold Chain and other mines.

The largest of these pipes is the Apex ore body in the Mammoth mine . . . plunging steeply from the surface to the 2,400-foot level where it merges with the Gold Chain fissure. It is roughly elliptical in plan, averaging about 200 feet in breadth and 30 to 100 feet in width . . .

The largest manto-like replacement body in the Main Tintic area follows a nearly horizontal segment of the axis of the Tintic syncline northward for nearly a mile through the Iron Blossom No. 3, Sioux, Colorado and Beck mines . . . In the Colorado mine, this great horizontal pipe of ore ranges from 20 to 60 feet wide and averages 20 feet in height (Morris, 1968, p. 1055).

East Tintic Area (figure 16)

Between their discovery in 1909 and 1966, the mines of the East Tintic area produced 3.6 million tons of ore valued at $120 million (table 22). The grade of ore from several of the largest historic mines may be compared to the grade of ore produced in the Burgin mine, Utah County, the only mine now producing in the area.

Ore Deposits. The ore deposits were of two types:

(1) Massive replacement bodies of the Tintic Standard mine, North Lily (figure 17) and Burgin mines that are rich in silver, lead, zinc and manganese, and

(2) Fissure ores of the Eureka Standard, Eureka Lily and Apex Standard mines that are valuable for their gold, copper and silver content.

Most of the ore has occurred in the lower part of the stratigraphic section, primarily in the Tintic Quartzite and limy members of the Ophir Formation.

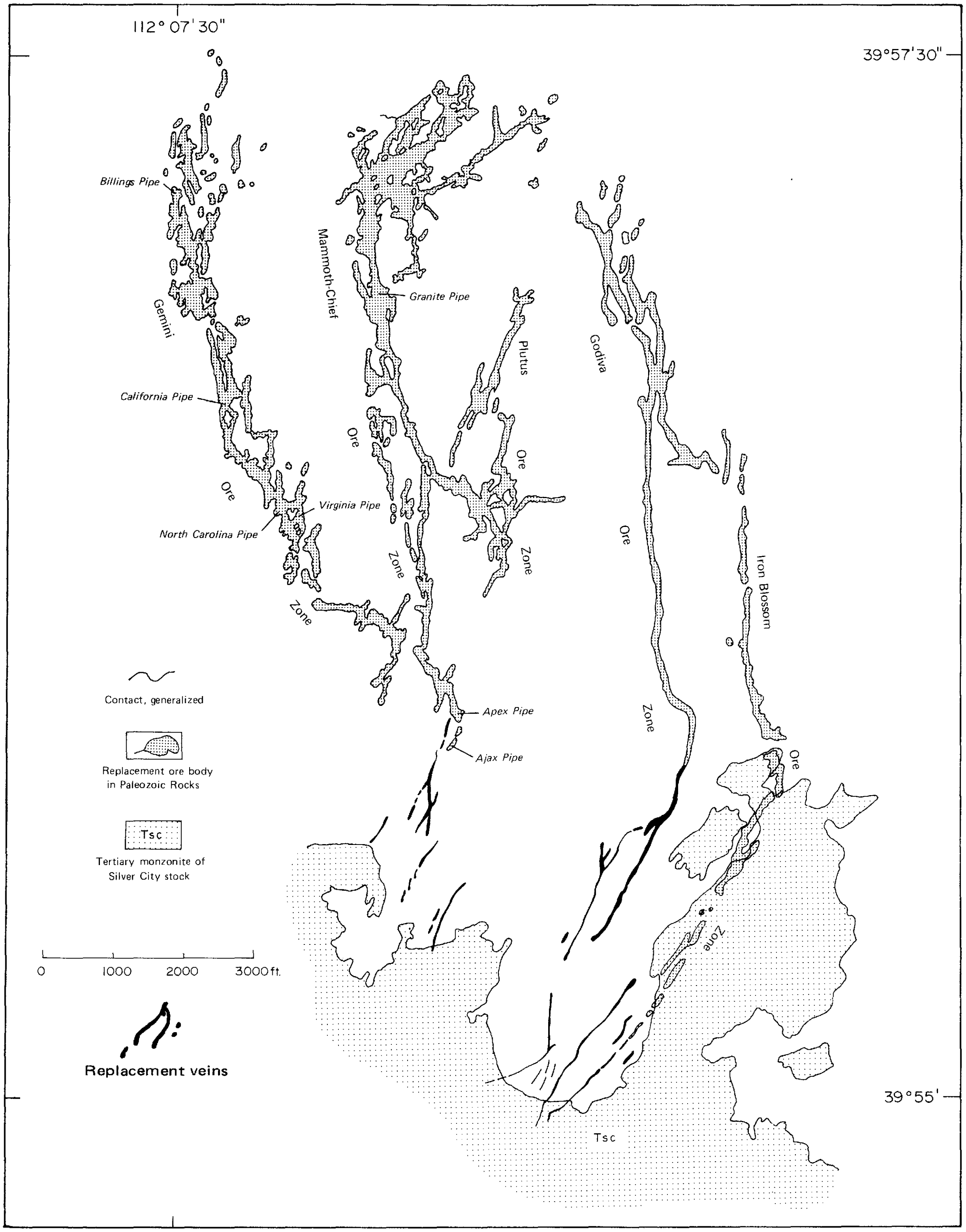


Figure 14. Ore bodies, Main Tintic area (from Morris, 1968).

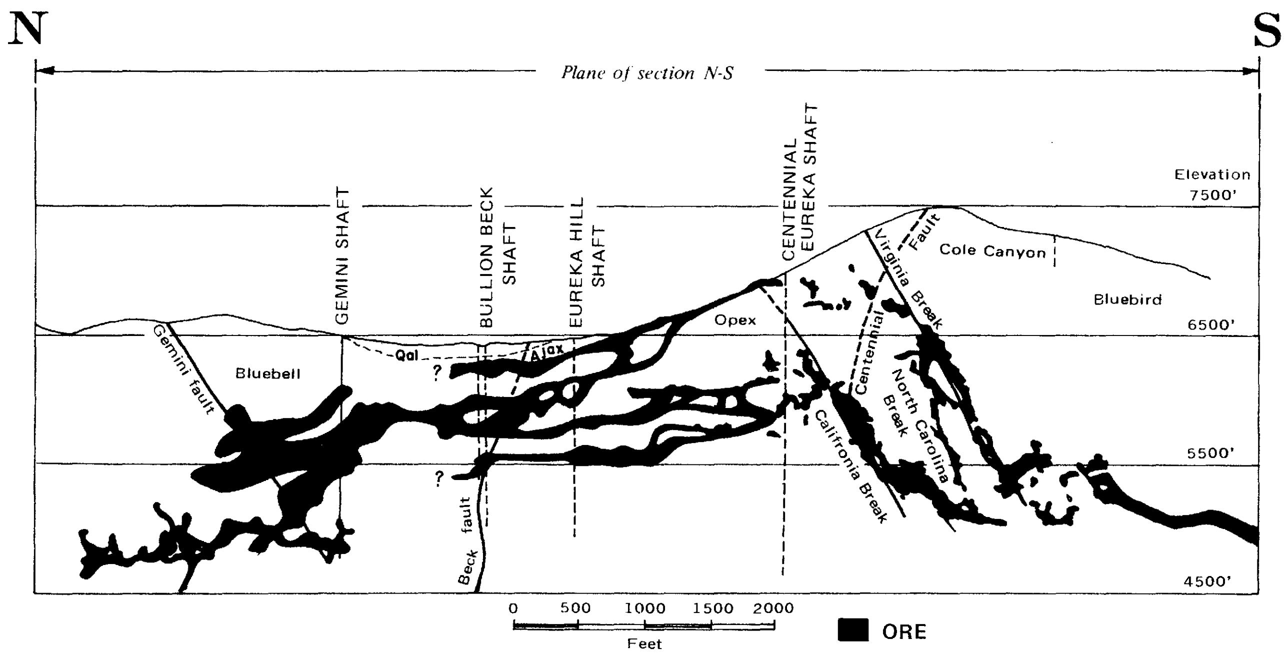


Figure 15. Generalized section of the Gemini ore zone (from Cook, 1957).

Recognition in the last 25 years of the East Tintic thrust fault (figure 16) has revealed mineralized fault areas much younger than the Ophir in the foot wall of the thrust. Mining geologist Paul Billingsley studied the deposits in the 1920's and he was impressed by the extraordinary complexity of their geology.

In the overall picture, some geologists consider the structural features to be more important than specific host rocks in the localization of ore at East Tintic. In suitable structural environments, it seems probable that ore will be found in many formations that have not been deemed favorable to ore deposition in the district (Shepard, Morris and Cook, 1968).

Because barren Tertiary volcanic rocks cover a large part of the area, the geological complexity can be seen and studied only in mine workings or drill holes.

Outlook

Shepard (Shepard, Morris and Cook, 1968), former chief geologist at Burgin, said, "The present development of the Burgin mine (Kennecott, in the East Tintic area, Utah County) would seem to assure the continued productivity of the district for at least a decade."

Since 1965 the Burgin has been the only substantial producer in the Tintic district (East Tintic and Main Tintic areas). The 1960 to 1969 average for the district was 38,000 tons of ore per year. Only following the start of the Burgin milling operation in 1965 was substantial production reported. Significant annual totals are estimated as follows:

	Tons of ore
1969	100,000
1970	170,000
1971	150,000

The *Salt Lake Tribune*, Nov. 27 and 29, 1972, reports that Anaconda is consolidating subsidiary companies in the Tintic area for "...ownership and operating purposes and for operating efficiency... Exploration is being carried out on eight unitized properties in the Tintic mining district."

Anaconda has not reported ore developed in the area, but apparently management hopes to fund an exploration program and to eventually establish a producing mine.

No estimates of long range tonnages in the Tintic district are available nor are such estimates possible. A recent speculative estimate (table 23) by Paul Mogensen, Burgin chief geologist, suggests that the total amount of remaining mineralized rock (lead-zinc ore) bearing more than 10 percent lead might be:

	Tons
East Tintic	3,300,000
Main Tintic	2,250,000

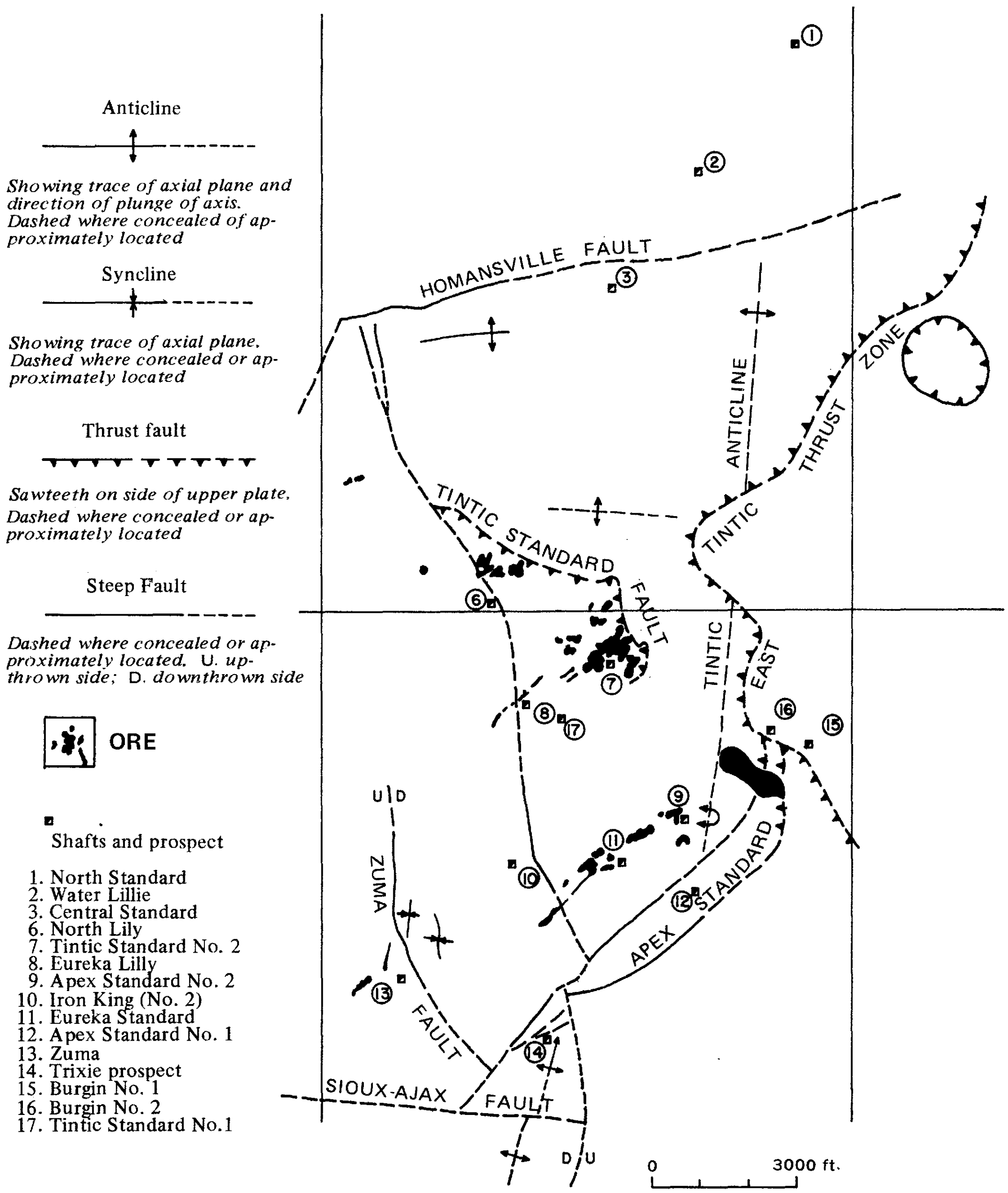


Figure 16. Map of the East Tintic area (modified from Shepard, Morris and Cook, 1968).

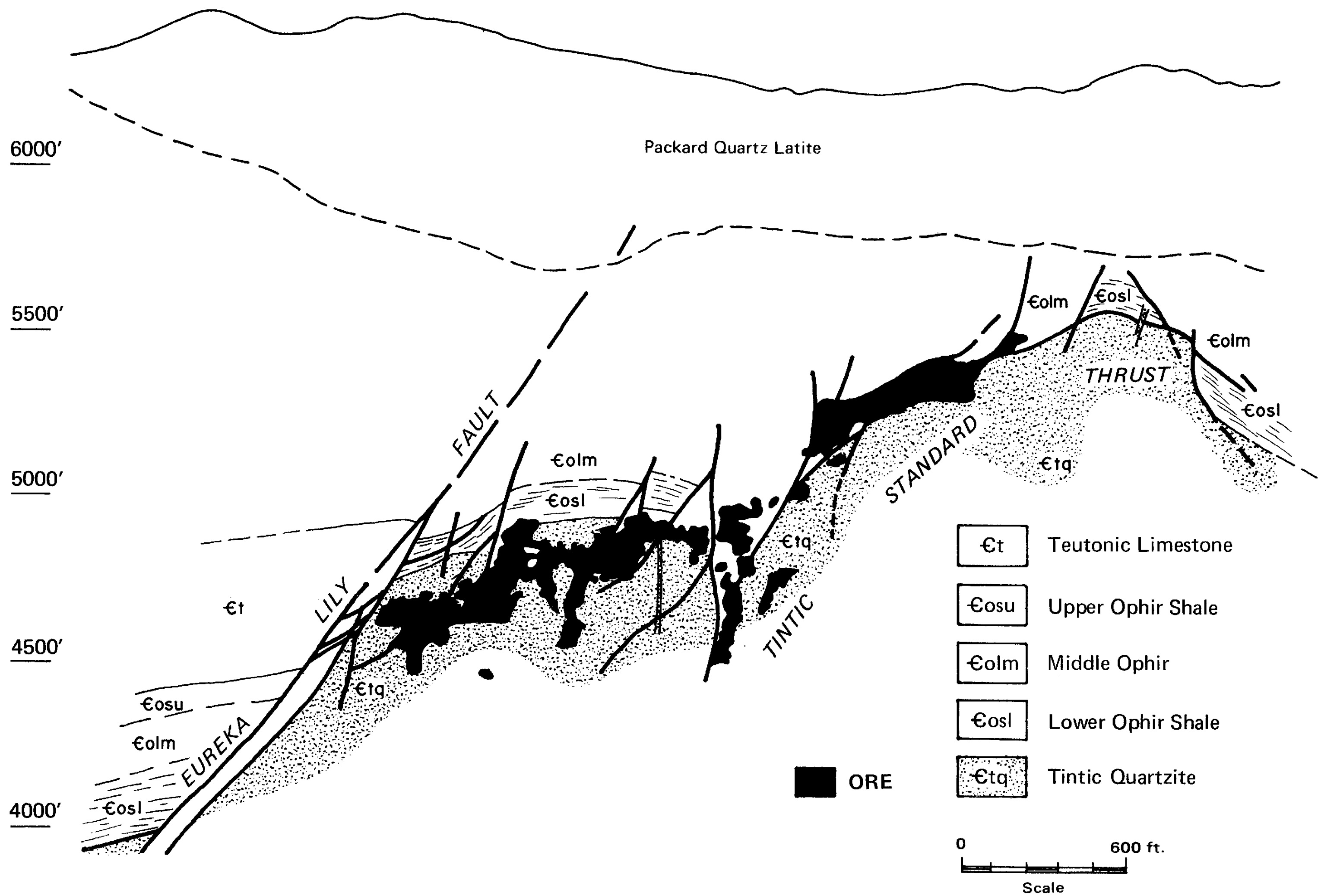


Figure 17. North Lily fissure zone looking northwest (from Shepard, Morris and Cook, 1968).

Table 24. Distribution of Main and East Tintic mining areas production from various rock units (from Cook, 1957).

Age	Unit	Thickness (feet)	Approximate gross production (dollars)
Middle of Upper Eocene	Silver City Monzonite		
	Swansea Quartz Monzonite		12,000,000
Middle Eocene	Laguna Latite Series		
	Packard Rhyolite Series		
Mississippian	Humbug	650	
	Deseret	875	46,500,000
	Madison upper member	500	
	Madison lower member	250	
Mississippian-Devonian	Pinon Peak	160	43,000,000
Devonian	Victoria	350	
Devonian-Silurian	Bluebell	500	110,000,000
Ordovician	Fish Haven	280	10,000,000
	Opohonga	875	9,000,000
Upper Cambrian	Ajax	640	60,500,000
	Opex	500	7,500,000
	Cole Canyon	600	7,000,000
	Blue Bird	180	
Middle Cambrian	Herkimer	375	10,000,000
	Dagmar	90	
	Teutonic	390	
Middle-Lower Cambrian	Ophir	440	84,500,000
Lower Cambrian	Tintic	3,000	25,000,000
Total gross production			$425,000,000

The figures would be revised as more data become available. Mogensen further speculates that with good economic support, 2 million tons might be available in the next 10 years. A more generous speculatve approach might add to the available tonnage for the entire district.

Lark-U. S.-Carr Fork District, Salt Lake County

History

Salt Lake County, excluding Kennecott's Utah Copper mine, averaged $14 million per year gross value of gold, silver, copper, lead and zinc during the decade 1960 to 1969.[1] The production was derived largely from lead-zinc fissures and replacement bodies in Pennsylvanian and Permian limestones, quartzites and sandstones and from fissures in all varieties of rocks found within a cylindrical zone or annulus encircling the Utah Copper mine (perhaps more prismatic than cylindrical in shape) about 4 miles in outer diameter, roughly 1 mile in inner diameter, and known by mining to be more than 4,000 feet deep (figures 18, 19 and 20).

[1] No appreciable lead and zinc were produced from Kennecott's Bingham Canyon operations in Salt Lake County during this decade; production of gold, silver and copper from Kennecott's Bingham properties is deleted from *all* tables and calculations in this report.

Table 25. Production of ore and metals from Main Tintic mining district, 1869 to 1965 (Morris, 1968).

Period	Short tons Ore	Fine ounces Gold	Fine ounces Silver	Pounds Copper	Pounds Lead	Pounds Zinc
1869-1880	3,666,671 (1869-1910)	36,149	1,605,545	3,179,628	10,353,378	–
1881-1890		61,786	11,692,031	9,692,031	54,318,428	–
1891-1900		332,518	31,366,185	21,441,370	187,524,539	–
1901-1910		731,312	31,856,168	76,565,474	279,893,533	–
1911-1920	3,358,073	496,927	54,227,364	71,086,437	289,143,135	16,914,973
1921-1930	2,674,335	218,712	45,621,103	23,994,912	300,264,767	12,927,818
1931-1940	1,099,913	187,375	8,176,028	8,535,664	20,261,646	2,774,092
1941-1950	1,761,943	64,177	8,689,849	4,838,969	86,444,873	67,339,058
1951-1960	825,605	21,019	4,131,117	1,415,653	58,398,642	38,046,531
1961-1965	50,599	408	31,794	44,300	101,600	42,531
Totals	13,437,139	2,150,383	197,397,184	220,794,438	1,286,704,541	138,045,003

[1] Statistics derived by subtracting the production from mines in East Tintic district from data presented in the following reports:
(1) U. S. Geol. Survey Prof. Paper 107;
(2) U. S. Geol. Survey Mineral Resources of the United States 1917-1923;
(3) U. S. Bureau of Mines Mineral Resources of the United States 1924-1931 and U. S. Bureau of Mines Minerals Yearbooks, 1932-1965;
(4) Utah Geological Society Guidebook to the Geology of Utah, no. 12; and
(5) Private sources.

The original discovery of base metals in the district was lead-silver ore in 1863. Since that time, the district has produced 4.5 billion pounds of lead and more than 2 billion pounds of zinc from fissures and bedded replacements from this cylindrical zone (table 27). Average lead production in earlier and later years is remarkably similar, despite numerous interruptions in the operation of the mines; the long-range uniformity of production, therefore, is significant. Zinc was not recovered in the early days and cannot be compared.

Exploration

Past exploration for lead and zinc has been from within about three-fourths of the cylinder. Of the remaining (north) quarter, little information is public because of the copper mining operations of Kennecott and Anaconda. Only superficial attention is believed to have been given to lead and zinc development within this sector. Further the copper mining companies are believed to have no plans to examine the area for lead and zinc because the loss to copper exploitation would be greater than the profits from successful deep lead-zinc explorations.

Only a small part of the cylindrical zone of lead-zinc occurrence has been prospected below about 2,000 feet above sea level, and no part has been prospected below the middle Pennsylvanian in the strati-

Table 26. Mine production, East Tintic area, 1909 to 1966.

Mine	Interval	Tons	Ounces Gold	Ounces Silver	Pounds Copper	Pounds Lead	Pounds Zinc
Apex Standard[1]	1928-1937	13,728	1,373	188,074	109,824	741,312	–
Burgin[2]	1955-1966	150,600	22	2,137,400	–	52,551,700	19,699,800
Eureka Lily	1909-1952	227,610	53,254	1,227,754	3,747,328	21,750,597	18,950
Eureka Standard	1928-1952	362,375	242,903	3,430,277	2,715,748	11,209,798	3,496,852
Iron King[1]	–	14,000	1,400	19,601	28,000	–	–
North Lily Group[3] (Includes: North Lily, Baltimore, Tintic Bullion, Eureka Bullion, Hannibal, Provo, and other properties operated through North Lily shaft)	1927-1949	375,000	148,000	3,554,000	2,482,000	101,682,000	4,270,000
Tintic Standard (Includes ore from Harold mill dump 1943-1952)	1913-1952	2,469,722	90,005	52,239,832	18,502,917	554,689,732	954,748
20th Century	1943-1947	1,419	40	7,320	59,716	1,338	–
Zuma[1]	1928-1944	2,208	442	3,754	8,832	343,608	–
Totals		3,616,662	537,439	62,808,012	27,654,365	742,970,085	28,440,350

[1] Data modified from Cook, 1957, pl. 3.
[2] This report. Burgin mill started in 1965.
[3] Data modified from Kildale, M. B., *in* Cook, 1957, p. 105.
All other data from U. S. Bureau of Mines.

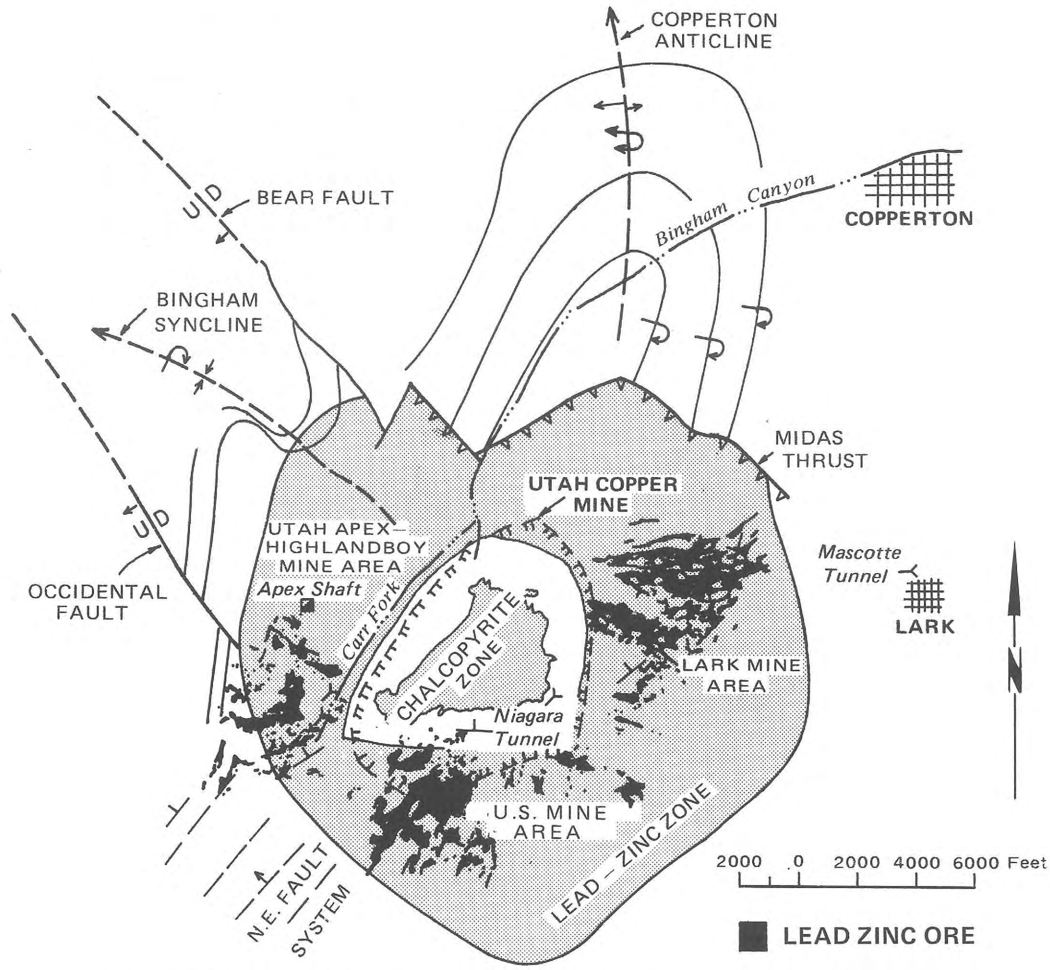


Figure 18. Lark-U. S.-Carr Fork mining district and Utah Copper mine (from James, Smith and Bray, 1961, and Rubright and Hart, 1968).

graphic column. (Regional geology indicates favorable limestone beds at intervals through 10,000 feet of strata below the Pennsylvanian before the "Pre-Cambrian" basement rocks, often presumed barren, are encountered.) This deep area in which lead-zinc deposits may be found in the future is complexly folded and faulted, and many geologists with experience in the Bingham district believe that lead-zinc will not be located at these great depths. They cite present mines wherein significant lead-zinc mineralization terminates at about 2,000 feet sea level elevation. Until cost-price ratios of deep, expensive

Table 27. Production from the Lark-U. S.-Carr Fork district.

		Ounces		Pounds			Recoverable metals, dollars
	Tons	Gold	Silver	Copper	Lead	Zinc	
1863-1964	43,947,000	2,377,000	136,125,000	816,498,000	4,180,000	1,709,091,000	$777,138,000
1965-1972	1,701,000	45,000	6,609,000	15,194,000	305,000,000	177,000,000	89,904,000
	45,648,000	2,422,000	142,734,000	831,692,000	4,485,279,000	1,886,091,000	$867,042,000
Annual average							
1863-1964					44,000,000		
1965-1972					43,000,000		

[1] Includes replacement lode copper from Highland Boy mine, Utah Apex mine, etc.
[2] Value in the year of production.
[3] Rubright and Hart, 1968.
[4] Author's total from unpublished records and personal communications from USBM, R. Rubright and W. Smith.

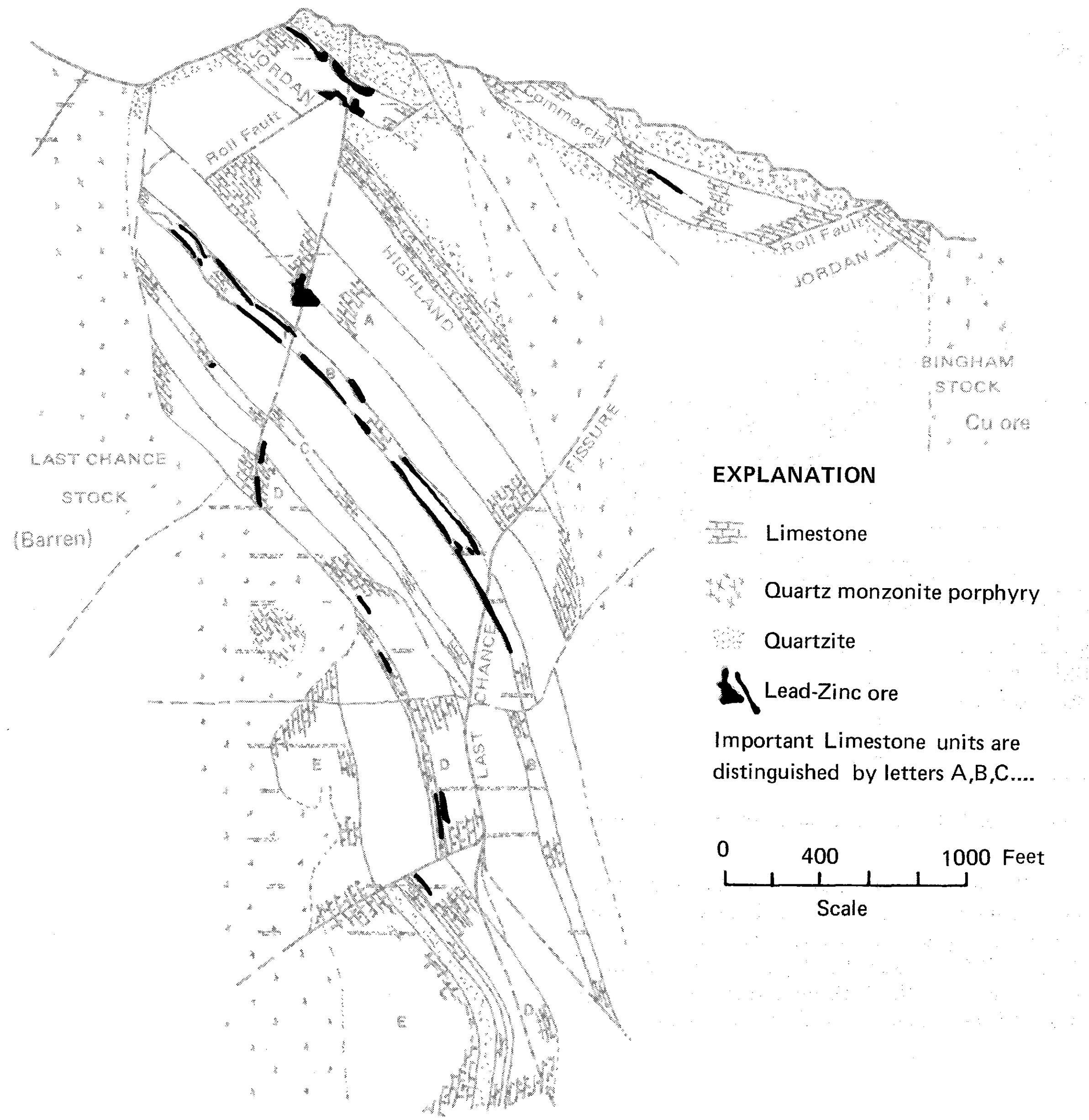


Figure 19. Vertical north-south section of the U. S. mine (from Rubright and Hart, 1968).

exploration improve or until sufficiently attractive lead-zinc showings are intercepted during exploration for copper, the question of ore at great depth will remain untested and open to discussion.

U. S. and Lark Mine

Clockwise around the cylindrical lead-zinc zone from west of the town of Lark, the most important mines are: Lark, U. S. (figure 19), Armstrong (figure 20), Highland Boy and Utah-Apex. During the last decade mainly the Lark mine (now called the U. S. and Lark mine) contributed significant production. With the closing of the U. S. and Lark mine in November 1971, lead-zinc production ceased.

Production. In Lark, more than 1 million tons of lead-zinc ore have been mined from eight named cross cutting fissures and a small production from a few unnamed ones; replacement ore production totalled 513,000 tons (Rubright and Hart, 1968, p. 900 and 904). Production of about 336,000 tons per year during the recent years, however, suggests that the 1.5 million tons are only a fraction of the total from this complex geological system.

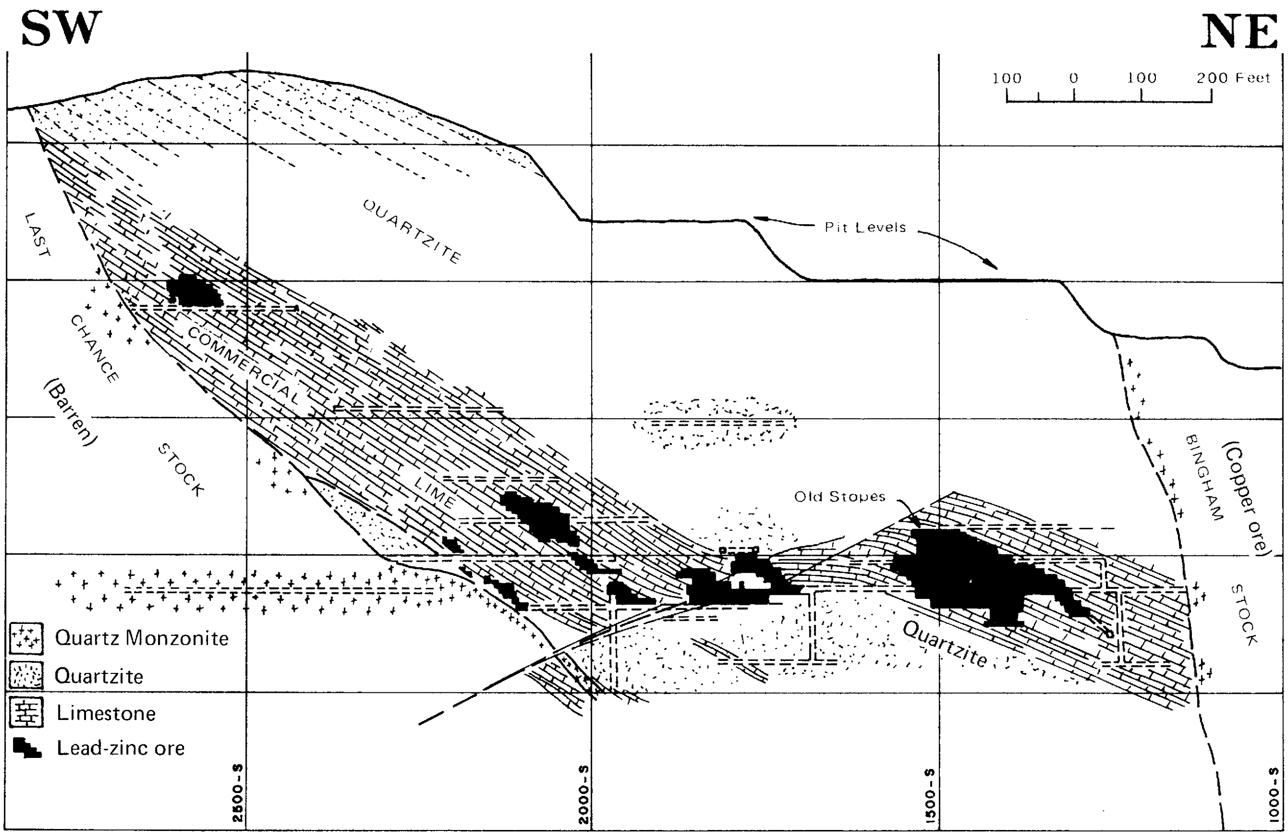


Figure 20. Section through the Armstrong mine between the Highland Boy and U. S. mines (from James, Smith and Bray, 1961).

Reported Ore Grades. Table 28 shows grades of ore remaining in the U. S. and Lark mine, and, for comparison, grades of district production during the 1960 to 1969 decade. The higher metal content of the ore remaining in the Lark mine represents ore in place, measured and calculated before grade reduction caused by dilution during mining.

Outlook

UV Industries (personal communication, 1972) reports the following tonnages remain in place in the mine (derived from engineering measurements):

U. S. and Lark mine

Tons in place	Between 500,000 and 600,000
Gross value of metals	About $70.00 per ton in place (1972 metal prices)

Resource tonnages from the other mines in the Lark-U. S.-Carr Fork district have not been reported at time of this writing.

The U. S. and Lark mine is now shut down, the pumps are removed and the lower levels are flooded.

Because the cost of labor in Utah during the last decade has increased and productivity has decreased in relation to price of metals (table 5), and because the U. S. and Lark mine workings, constructed over many decades of operation, are old, the U. S. and Lark mine apparently will not be reactivated until the economic outlook is sufficiently improved to warrant complete restructuring of lead-zinc-silver-gold mining in the district.

Ophir District, Tooele County

To ship run-of-mine ore to an out-of-state custom mill is uneconomical, so when the Midvale custom mill closed, the market for Ophir ores disappeared.

F. McFarland of McFarland and Hullinger, the former operators, said the present problem is the lack of a mill facility. He believes that smelter capacity can be found outside of Utah and reduction economically arranged if concentrates can be produced. Although expired, the McFarland and Hullinger lease with UV Industries apparently is open for resumption or renegotiation.

Table 28. Reported grades of ore, U. S. and Lark mine, and Salt Lake County.

	Ounces		Percent			
	Gold	Silver	Copper	Lead	Zinc	Gross value
Decade 1960-1969, all Salt Lake County[1]	0.024	3.33	.04	7.7	5.4	$42.00/ton when mined
Lark and U. S. mine–in place[2]		4.00		10.00	8.00	$70.00/ton 1972 price

[1] Grade of Salt Lake County during 1960-1969 is substantially the production grade from Lark, corrected for metal losses.
[2] Personal communication, R. Rubright–grade of ore in place at time of closing.

Production

The Ophir mine has produced 30,000 tons per year for 20 years and, during that time, there has never been a full year's reserve blocked out. At present (1972), 25,000 tons of ore are developed and blocked out, awaiting a solution to the milling problem.

The continuity or habit of repetition of ore zones has been well demonstrated during past production. The future with regards to "ore," says McFarland, is equally promising. He also stated that six more possible ore targets of excellent possibilities have been outlined by R. Rubright, geologist, but they cannot be tested until the mine can sell the product.

Geology

The Ophir district has produced lead-zinc-copper-silver ores since the 1870's. Operations have ceased several times because the ore was believed exhausted, but new and deeper discoveries revived activities. Since 1911 the mine was worked through a tunnel extending north from near the bottom of Ophir Canyon, just below the old Ophir townsite. Ore has been stoped below the tunnel to at least the 1,700-foot level of an inclined shaft.

Essentially all the ore has come from the Cambrian Ophir Formation which is exposed in the core of the Ophir anticline. Several 8- to 40-foot limestone beds have been the main producers and, in these, the ore often is localized in numerous thinner beds.

Estimated Resource

Based on the developed reserve of 25,000 tons of ore and the discovery ratio maintained during the past 20 years–one ton of ore developed for each ton produced–the speculative resource estimate calculated for this report is as follows:

Category II. Reported reserves plus operators' projections–partly discovered–based on past ore habit and operating experience:

27,000 tons per year x 10 years = 270,000 tons.

Marysvale District, Piute County

Production

Piute County lead-zinc mines produced an annual average value of $300,000 in recoverable metals during the decade 1960 to 1969. Recoverable content was:

	Per ton
Gold	0.09 ounces
Silver	8.5 ounces
Copper	2 percent
Lead	5 percent
Zinc	10.1 percent
Average recoverable value	$60.00

Deer Trail Mine

All significant production in Piute County came from the Deer Trail mine, Marysvale area, owned by Deer Trail Mining Co. and operated by Arundel Mining Co. The ore zone has been mined as an almost continuous ore shoot since its discovery in 1878. The upper part of the shoot also is known as the Salisbury mine.

When the Midvale custom mill closed in November 1971, the Deer Trail mine lost the market for its lead-zinc ore and the operation was shut down, leaving 16,000 tons of developed ore blocked out and ready for extraction in the mining faces.

Resumption of production depends on a new outlet for the mine ores–perhaps a custom mill to serve Utah and adjoining areas or a small captive minehead mill, shipping concentrates to out-of-state reduction plants.

A summary of the Deer Trail mine's production follows:

	Tons ore
1878 to 1954, Deer Trail and Salisbury mines	165,000
1954 to 1971, Deer Trail mine	72,000
Total	237,000

Since 1969, production has increased sharply as compared to the decade average:

	Tons per year
1969	10,618
1970	10,150
1971	9,873
1960-1969 (average)	5,000

Geology. According to Butler and others (1920), the ore of the Deer Trail mine is "a blanket deposit that has replaced the limestone immediately above the quartzite. The replacement appears to be associated with east-west fissures. The general dip of the formation is 10° to 15°."

According to Q. F. Treseder, manager and vice-president of Arundel Mining Co. (personal communication), the Deer Trail ore manto (or blanket) has produced throughout more than 4,000 feet of "ore run" replacement in the limestone (Toroweap), at or near the contact with the underlying sandstone (Coconino?). For the last 1,300 feet of length, the shoot has consistently averaged 53 tons of ore for each foot mined. A similar overall average was achieved for the entire 4,000 feet, although detailed shoot records are not available.

No geologic evidence in the mine indicates that the continuity of the ore shoot is about to terminate.[1]

Estimated Resources. The speculative production of the Deer Trail mine is based on three assumptions:

1. That exploration and development of the ore shoot with exploration for extensions and repetitions of ore in adjacent horizons should permit *continuous production at 1969 to 1971 rates for many years,* once a market for the ore is re-established. If the recent production rate of 10,000 tons per year is extended for the next ten productive years, from ore body habit and production experience, 100,000 tons of ore resource could be inferred. The management is awaiting funds to explore and test this favorable projection.

2. If ore habit experienced of 53 tons per foot and total production record of 237,000 tons of ore were extended by one third, a speculative projected resource of 237,000 x 1/3 ≅ 80,000 tons of developed plus projected resource would be indicated.

3. If tests of favorable areas are financed and are successful, 80,000 tons of ore might be made available. No geological obstruction to this projection has been uncovered.

The following tonnage, therefore, is assumed, based on management's exploration hopes, projection of past experience in ore shoot continuity and the speculative opinion of mine geologists:

	Tons
Developed ore	16,000
Additional speculative ore supported by operators' or geologists' projection	64,000
Total reported resource, plus operators' projection, partly discovered	80,000

Potential Lead-Zinc Mining Districts

Potential Resources

From 1960 to 1969, none of the sixty-five potential lead-zinc mining districts (page 18 and figure 9) demonstrated strength in production.

Juab County, with a record of $750,000 in metals produced largely from old dumps during the 1960 to 1969 decade, should be considered, for planning purposes, a part of the Main Tintic area. Beaver County, with 430,000 tons in lead-zinc-silver production (Creole, Harrington Hickory, Horn Silver, Lincoln, Smokey Joe mines and the Wah Wah Vedco development) has speculative potential, but not in a projectable quantity.

It is outside the scope of this report to determine the resources in the sixty-five potential lead-zinc districts. *Ore Deposits of Utah,* by Butler and others (1920), is the most comprehensive listing and description of Utah metallic ore deposits available. An up-to-date, thorough geologic and economic analysis of each, however, should be made. Presently such information is being prepared by the Utah Geological and Mineralogical Survey in the form of county or district studies. The studies entail regional geologic mapping and study of all mineral deposits–metals, nonmetals, hydrocarbons, uranium, etc. The following areas are now being investigated:

Marysvale area–geology and metallic and nonmetallic resources, by E. Callaghan, UGMS; scheduled publication 1973.

Deer Trail mine–geology by Q. F. Treseder, vice-president, Arundel Mining Co.; scheduled publication 1973.

[1] A detailed description of the geology of the mine is in preparation for the Utah Geological and Mineralogical Survey by Q. F. Treseder, vice-president, Arundel Mining Co.; Eugene Callaghan, consultant, Utah Geological and Mineralogical Survey, is preparing a detailed description of the geology of the Marysvale area. Both publications should be available in 1973.

Beaver County (especially Star Range)–geology and ore deposits, by J. A. Whelan, UGMS; progress reports are available and publication is anticipated in 1973 or 1974.

Box Elder County–mineral potential and geologic maps, by H. H. Doelling, UGMS; progress reports are available and publication is anticipated in 1973 or 1974.

Garfield County–mineral potential and geologic maps, by H. H. Doelling, UGMS; progress reports are available and publication is anticipated in 1974.

Oxidized Lead and Zinc Resources

The economics of oxidized zinc resources differ from sulfide zinc and lead economics and are grouped separately in this report.

With few exceptions, lead and zinc are mined today as lead or zinc sulfide. The ore minerals are galena or sphalerite, respectively. Within a few hundred feet of the earth's surface, however, sulfides may be attacked by oxygenated groundwaters which convert sulfides to lead carbonates, lead silicates, lead sulfates and zinc carbonates, zinc silicates, etc. Because of their origin, they are called "oxide ores," although chemically they are seldom oxides.

Lead carbonates are concentrated readily and economically smelted and are a commercial source of lead ore. Where found, they have been extracted and no significant reserves of these ores remain exposed in Utah mines. Because the formations are near the surface, discovery of lead carbonate resources at depth is not anticipated. Therefore, no lead carbonate ores are included in current Utah resources.

Zinc carbonate resources are not readily concentrated. Their treatment as unconcentrated ores is expensive and, except in rare ores containing well above 25 percent zinc, is uneconomical. Therefore, oxidized zinc ores, when encountered, generally are left in the walls of the mine. In this report, the remaining oxide ores (actually zinc carbonates) are considered a resource, but are not included in any future production projections because no economic method of treatment is known (Joe Rosenbaum, U. S. Bureau of Mines, 1972, personal communication).

The oxidized zinc resources of Utah are described in detail by Heyl (1963). His bulletin is the result of several seasons of field study. The resources cited by him are condensed in table 29.

MAJOR RESOURCE CATEGORIES

Estimated lead-zinc resources are divided into four categories based on degree of speculation or differing source of information. The totals derived from the four approaches are summarized in table 30.

Approach I. *Reported Reserve.* The measurement by mine operators of identified resource. It is based on mine and drill exposures plus short geological projections. The reserves are known to company operators and are located on company maps.

Approach II. *Reported Reserves plus Operators' Projections.* To Approach I is added target tonnages or expectations from planned and proposed development identified on company maps.

Approach III. *Reported and Projected Reserves plus Geologists' Speculative Estimate.* Attractive areas not yet tested or only partly tested by exploration, but identified within broad generalized areas on company maps. Approach III is the sum of Approach II and the geologists' projections.

Approach IV. *Past Production Projections.* The amount of resource that could sustain a production rate derived by production experience in the past, but modified by anticipation of noncontinuous conditions, such as new geological or ecological problems or radical changes in metal economics–the economic changes introduced by the development of large new lead mines in Missouri, for example, or the attack on SO_2 emissions from reduction plants.

OUTLOOK FOR UTAH'S LEAD-ZINC INDUSTRY

Present Crisis

The immediate crisis in the Utah lead-zinc-silver industry was triggered by the closures of the Midvale mill of UV Industries and the Tooele smelter. The present nonproductive years in Utah's lead-zinc industry could end and become normal productive years only as the production cost-price ratio of metals improves and local milling facilities become available and, for other than small amounts, reduction capacity is made available (figures 21 and 22). Eventually industrial reduction capacity will be available to handle any continuous, small or large production at efficient seaboard works, when and if a dependable supply can be demonstrated.

Table 29. Oxidized zinc resources of Utah (modified from Heyl, 1963).

County District	Recorded Production of Oxidized Ores (tons)	Oxidized Zinc Ore Resources
Box Elder County		
Lucin	300 to 400 tons of zinc metal	Substantial reserves of oxidized zinc ores, some 30 percent zinc, and zinc-bearing material . . . Much remaining in stopes and dumps, most 5 percent–20 percent zinc, some 30 percent (Butler, 1920, p. 448-494).
Promontory	14,000 tons of oxidized zinc and zinc-lead ores	Some thin veins, estimated 5-8 percent lead, 5-10 percent zinc.
Cache County		
Paradise	17 tons of zinc-carbonate ore	The district shows promise for small, high-grade oxide and sulfide deposits.
Morgan County		
Argenta	"Small shipments"	Iron-rich oxidized zinc-lead bearing material is common in upper working, and could be commercial if iron-rich ores were desired.
Salt Lake County		
Big Cottonwood	Several mines have produced 2,000 to 5,000 tons of oxidized ores.	Several of the mines in the district contain partly developed reserves of oxidized zinc ores . . . very probably other deposits could be found without great difficulty.
Little Cottonwood (and American Fork)	Production of oxidized ores has been very small.	
Summit County		
Park City (incl. Wasatch County)	"Oxidized ores . . . have not been shipped for zinc content."	"Commercial quantities of oxidized zinc ores exist." "These ores have not been recognized heretofore."
Tooele County		
Dugway	Small shipments	Most of the known ore deposits are apparently small.
Free Coinage	55 tons of ore	Ores are reported to be still present in minable quantities.
East Tintic (Utah County)		"Available reports suggest strongly that all the known deposits of oxidized zinc ores in the principal mines . . . have been mined out."
Tintic (Juab County)		From 1912 to 1953, the mines of the Tintic and East Tintic district produced 31,000 tons of oxide lead zinc ores, with a value of recoverable zinc of $1,706,000. ". . . Opinion is that known oxidized zinc ore . . . is largely mined out." "A known reserve in the hanging wall of the lower Mammoth Mine . . . is estimated to contain 100,000 tons of 12% zinc." (Heyl, 1963, p. B19)
West Tintic: Juab (Scotia Mine)		"Some minable reserves are reported . . . the geology is good for the discovery of new oxidized complex zinc-bearing ore bodies."
Utah County		
American Fork	Production of oxide ores apparently very small	Past production has been small. Low grade lead-zinc-silver ores remain in several mines.

Table 29. (continued)

County District	Recorded Production of Oxidized Ores (tons)	Oxidized Zinc Ore Resources
Columbia	Shipments of 122 tons	Reported to contain some reserves.
Lakeside	30,000 tons of ore of all grades	In 1920 the owners reported 100,000 tons of lead-silver ore blocked out. (Apparently Heyl believes this remains in the mine.)
Gold Hill		Only small tonnages are known in the district.
Rush Valley		Small tonnages remain in the old caved stopes.
Dry Canyon-Ophir	6,500 tons	Large quantities of low grade might be recovered from old dumps. Some old lead-zinc stopes are reported to have rich oxidized casings.
North Tintic	The largest (past) producer of oxidized zinc ores in Utah. 41,000 tons	The mines of the North Tintic district have long been Utah's largest source of oxidized lead and zinc ores. (Zinc produced from oxide, 1906 to 1953, was valued at $1,354,000.) Many thousands of tons remain on the dumps and in the mines. "Careful prospecting . . . would be worthwhile."
Juab County		
Fish Springs		"The mines and dumps . . . contain recoverable tonnages of silver-rich oxidized zinc-lead ores . . . If a market develops, this district may produce large quantities of such ores."
Spring Creek		"Reports indicate that potentially valuable deposits . . . exist . . ."
Mt. Nebo		From 1911 to 1953, the zinc produced from all lead-zinc ores totalled $75,000. "Most . . . worked out."
Beaver County		
Granite	700 tons	"Ores containing (oxide) zinc are reported to occur in some quantity."
Beaver Lake		Sizeable oxidized zinc deposits are reported in the district.
Star	7,000 tons	Zinc, from oxide ores, recovered from 1907 to 1953, was valued at $1,436,000. "The district is one of the more promising in Utah as a potential source of high-grade oxidized zinc and lead-zinc ores." Cedar-Talisman Co. estimated that ". . . mine and dump 40,000 to 50,000 tons of blocked-out ore that averaged 8 percent lead, 14 percent zinc, and 7 ounces of silver per ton."
San Francisco	Very little oxide produced	"The San Francisco District contains some of the largest deposits of oxidized zinc minerals in Utah. If a commercial milling process can be perfected to concentrate these low-grade deposits . . . the district is potentially a major source of ores." (Heyl, 1963, p. B93, p. B20)
Pine Grove		At the Wah-Wah Mine, the company reports (1946) that the USBM exposed by drilling 38,000 tons of oxide zinc ore, 8,000 tons of sulfide zinc-lead ore, and 20,000 tons of oxidized silver-lead ore. "Most of these reserves are still unmined." At present the Wah-Wah Vedco Mining Co. is active here."

Table 30. Estimated speculative resource for Utah derived by four different approaches.

The resource available is termed speculative because an unknown portion may not exist or an unknown portion could not be discovered and developed in time to serve the production paths. Further, if it does exist, it might not be of the predicted grade, or cost-price economics might be adverse.

On the other hand, the resource might be many times greater and richer than estimated.

	Resource estimates (limited to material now identified, projected or under speculative consideration)			Ore (tons) needed for next 10 productive years			
	Reported reserve (identified) I	Reported reserve plus operators' projection, partly discovered II	Reported reserve plus operators' projection plus geologically inferred partly discovered III	Low rate IV	Med. rate IV	High rate IV	Additional resources
Park City							
Ontario	900,000	3,000,000[1]	3,000,000[1]				Other exploration possibilities exist.
Mayflower	0	0	0				Exploration possibilities exist.
Tintic							
East Tintic	No report	3,300,000[2+3]	10,900,000[3+4]				
Main Tintic	None available	2,250,000[2]	4,700,000[2]				
Lark-U. S.-Carr Fork							
Lark-U. S.	600,000[5]	600,000[5]	600,000[5]				Identified resource not expected to be accessible.
Carr Fork							Speculations exist as to resource in Carr Fork and Bingham Canyon area, but estimates are not available and may not have been prepared.
Ophir	25,000	270,000	270,000				
Marysvale	16,000	80,000	80,000				
Total—Producing mines	1,541,000	9,500,000	19,030,000	3,000,000	4,700,000	8,500,000	
Resource to be discovered and developed before and during next 10 productive years	Unknown	Unknown	Unknown				

[1] Operators' target.
[2] Above 10 percent lead.
[3] Burgin facility nearby.
[4] Above 5 percent lead. No facility available or planned to handle ore from this area.
[5] Not available in next 10 productive years, no projections and no geologically inferred ore.

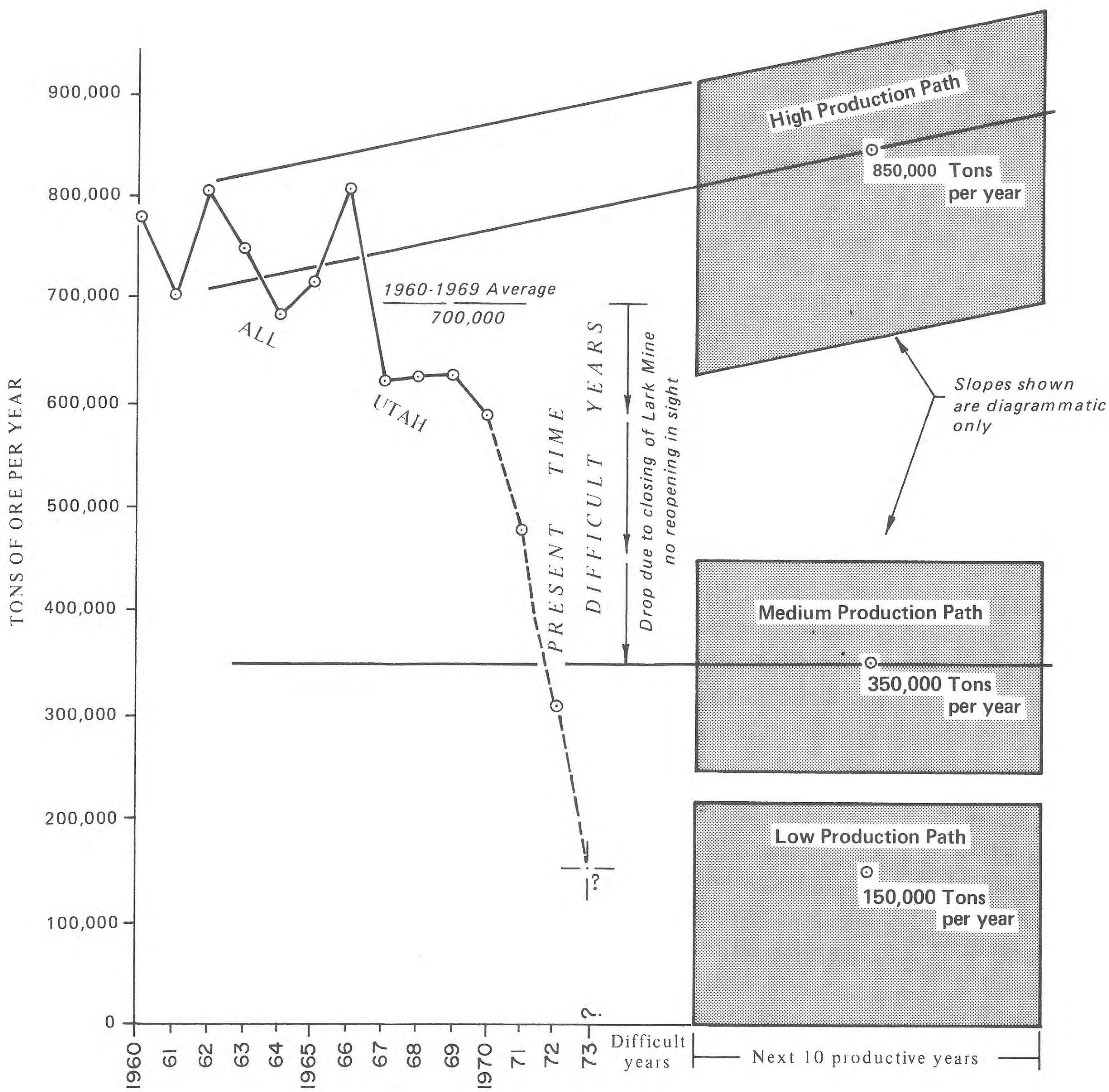


Figure 21. Utah lead-zinc past production and future paths, next 10 productive years.

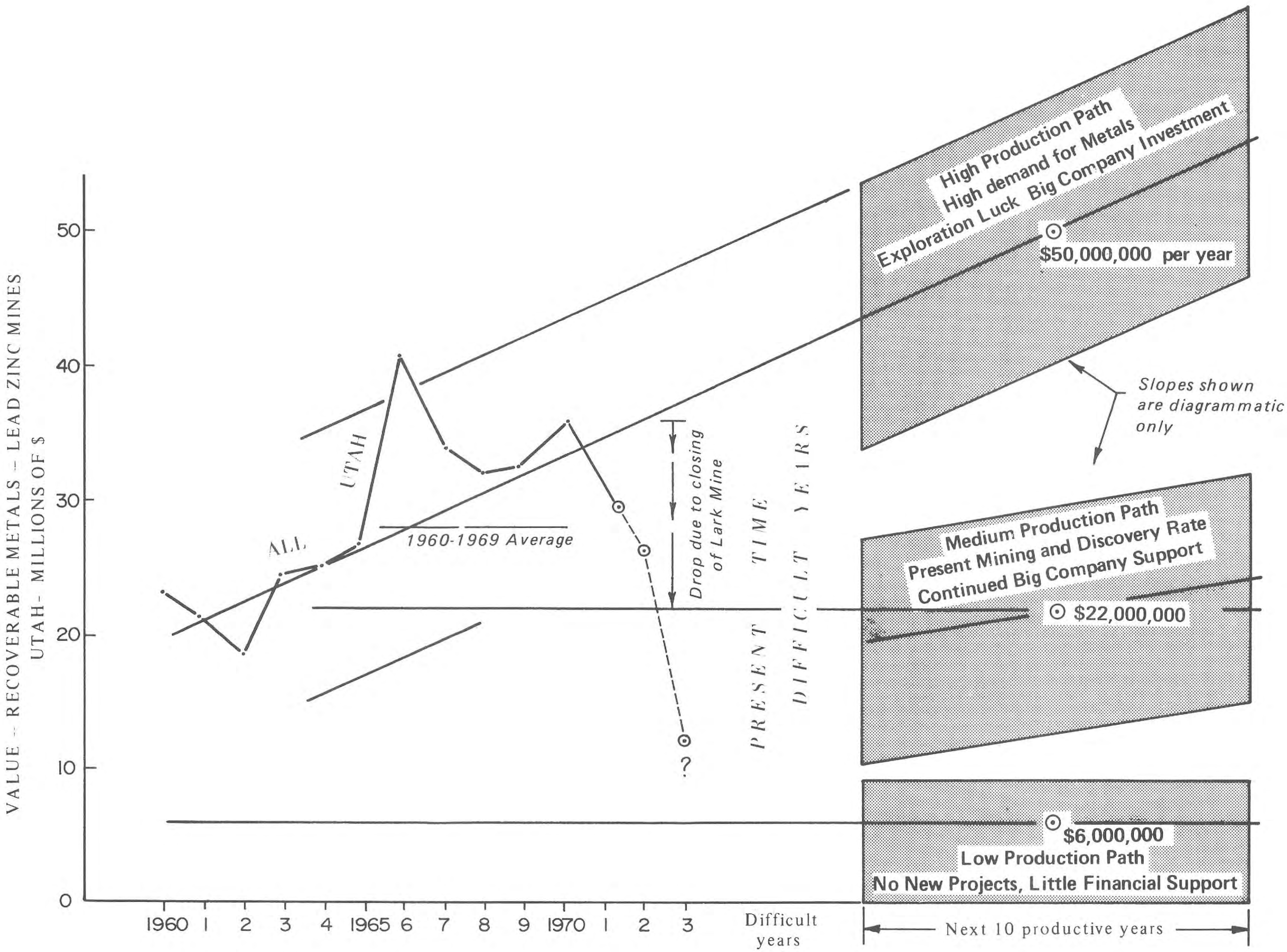


Figure 22. Value of recoverable metals, Utah–future paths next 10 productive years.

Future Production Possibilities

A target production schedule, hopefully to be achieved in the major mining districts of Utah, and the years of production remaining in the speculative reserve are shown in table 31. Past trends of lead-zinc mine production, projected as future possibilities, are summarized in tables 32 and 33.

The following analysis defines three courses the Utah lead-zinc industry may take as milling and reduction capacities become available. Each course would result from certain geological, technological, industrial and economic factors.

High Production Path

Lead-zinc economics are considered good business; profits are predicted. Metal prices and technology keep up with cost inflation. New risk capital is made available. Big companies participate in exploration and development and continue to support first-class geological and mining programs on regional and local levels. Lead-zinc-silver are a minor, but integral target in copper search programs. New industrial concepts promote mechanization of mines. Mills are built as needed. Concentrates probably are shipped out of Utah to seaboard works.

Medium Production Path

Production and discovery rates of the 1960 to 1969 decade are resumed by large companies. Better than "break even" metal economics continue. Some risk capital made available. Aggressive exploration within known districts is maintained. Increased labor prices must be met by higher metal prices and, with difficulty, by technological improvement. New mine plant concepts, mining and milling facilities are necessary. Smelting facilities are available out of state. Larger companies continue to support their operations with first-class geological and engineering personnel and to supply risk capital needed to implement the described restructuring. Production is maintained from one large mine only (e.g., Burgin mine) plus one or more medium producers (e.g., Ophir and/or Deer Trail).

Low Production Path

Two or more large producers terminate their operation and the production gap is not filled by new developments. Continued rise in costs not compensated by metal price increases. Insufficient mine development, resulting in little or no exploration outside the mines and only short-range, low-cost exploration within the open mines. Concentrates must be smelted outside of Utah and ores would be milled mostly in existing mills (Mayflower and Burgin). Much mining would be lease or contract to extract ores now well exposed. *Marginal economics* is both the cause and result of low production.

The low or nonproductive years immediately ahead (figure 21) can be replaced by medium or high productive years only as the following situations permit: (1) Metal prices must increase to cover increased operating and capital costs; (2) The future outlook for lead and zinc must be sufficiently optimistic to attract risk capital and to support the establishment of one or more custom or captive concentrating facilities within the state.

The medium production path might be achieved if (1) the East Tintic area continued on its past tonnage level at a slightly inflated metal price, (2) either Summit County or the Main Tintic area ores are developed in areas not yet exposed but now being searched, and if facilities for mining and milling are then provided, and (3) medium size mines–Ophir, Deer Trail and perhaps others–are able to make local milling arrangements.

The highest rate of production will result if metal prices are inflated rapidly, general economics are good and exploration luck is experienced resulting in strong financial support for the big mines. A high rate of production may be expected from East Tintic and Summit County. Either Wasatch County or the Main Tintic area must be explored successfully and developed and the medium and small mines must operate under favorable conditions. The Lark-U. S.-Carr Fork district is not expected to be re-opened in the forecast period.

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

Present Investigations

Presently Utah Geological and Mineralogical Survey (UGMS) is investigating the following lead and zinc resources:

Table 31. Speculative possibilities of future production.

	Average production tons/year 1960-1969	Reported reserve or resource	Years of production remaining	Measured plus inferred resources (partly discovered, partly developed)				Undiscovered or undeveloped possibilities in distant future
				Measured plus projection	Years at past rate	Suggested rate (tons/year)	Years at suggested rate	
Park City	270,000[1]							
Ontario		900,000	3	3,000,000[2]	30	270,000	11	Other exploration possibilities exist.
Mayflower		0	0	0	0	0		Two units for exploration not available.
Tintic								
East Tintic	100,000[3]	No report		2,000,000[4]	20	200,000	10	Reserves with more than 10 percent lead estimated at 3.3 million tons; from 5 to 10 percent, 11,000,000 tons.
Main Tintic	6,000[5]	No report		No report		No plans known		Exploration possibilities exist. Reserves with more than 10 percent lead estimated at 2.25 million tons; from 5 to 10 percent, 4.75 million tons.
U. S. and Lark mine	336,000	600,000	Reserve not accessible		Not accessible	0	0	Developed resource not expected to be accessible. Estimates of resources in the Carr Fork and Bingham Canyon area are not available.
Tooele County								
Ophir	27,000	25,000	1	270,000		27,000	10	
Piute County Deer Trail	5,000	16,000	3	80,000[4]	16	10,000	8	

[1] Table 18, Summit and Wasatch counties combined.
[2] Management anticipates this resource availability if exploration projects are carried out and are successful.
[3] Adjusted from start up of Burgin mill.
[4] Two million tons of the resource compiled by Mogensen might be developed during the next 10 productive years.
[5] Dump production subtracted.

Table 32. Trends in lead-zinc mine production, past and anticipated.

Year	Annual tons	Value of annual recoverable metals
Decade 1960-1969	700,000	$28,000,000
1970	584,000	35,000,000
1971	471,000	31,000,000
1972 (Burgin and Mayflower operating)	250,000	27,000,000
Projection:		
1973 (Burgin alone or with small amounts from Ophir or Deer Trail)	150,000[1]	13,000,000[1]

[1] Author's estimate or projection.

(1) County- and district-wide geological and mineral resource surveys in Piute, Beaver, Box Elder and Garfield counties. State geologists are developing background geology for all types of mineral deposits in these areas. The studies, which require several field seasons to complete, cover broader areas than a report on a single district or mine. From them will come more detailed studies of individual mines and districts.

(2) Compilation of production and operating statistics for all metal mines of Utah (based largely on U. S. Bureau of Mines statistics). Lead-zinc mine production values may be obscured as a result of combining the figures with previous metal statistics from copper mines and low-grade material from dumps.

Recommended Investigations

Recommended UGMS activities which might benefit the lead-zinc industry are:

(1) *Maintain production records* of districts and mines (subdivide counties, when permissible) using U. S. Bureau of Mines data plus data acquired directly from operating mining companies.

(2) *Maintain district plan maps,* based on annual inquiry, of major districts showing generalized location of explored, developed or to be developed areas.

(3) *Geologic aid to small mines.* The small mine with an annual gross income of a few hundred thousand dollars does not have sufficient margin to hire a permanent geological staff. The state could supply detailed mine mapping service to the small operators.

(4) Prepare a *rapid review of the sixty-five potential lead-zinc districts in Utah* (figure 9), utilizing

Table 33. Suggested possible future production paths, next 10 productive years.

	Annual	
	Tons	Recoverable metals (dollars)
High production path		
East Tintic	200,000	
Summit County	300,000	
Wasatch County	300,000	
or		
Main Tintic		
Medium size districts	50,000	
	850,000	$50,000,000
Medium production path		
East Tintic	150,000	
Main Tintic		
and/or		
Summit County	150,000	
Medium size districts	50,000	
	350,000	$22,000,000
Low production path	150,000	$ 6,000,000

quickly obtainable information on location, history, availability of publications, map coverage and apparent industrial and land status.

(5) Based on the findings in (4), *a systematic district by district study* could be planned. The magnitude of the study would vary with the importance of the district and with the information available, but might include:

a. Literature research for the districts which warrant attention;
b. Generalized local property identification;
c. Preparation or acquisition of topographic and generalized property maps at a scale which shows the mining district as a unit;
d. A summary of industrial history and production;
e. The location of mines and prospects on maps;
f. A summary of recent economic activities;
g. An estimation of speculative resources, and
h. Maintenance of a file to add data on new developments.

(6) If warranted, conduct *geologic mapping and study* or compilation at an appropriate scale.

The geological report should concentrate on the economic potential of the area and, when warranted, include generalized exploration target maps, estimates of resources and simple economic speculations for future possibilities by economic calculation, if possible, by projection of past operations and by analogy with on-going profitable operations. For most of the non-producing districts, the latest geological and engineering information is Butler and others (1920). Few adequate economic reports exist to orient and attract the interest of commercial exploration companies or local prospectors and land holders.

The proposed reports could contain a rough base map of the mining district and a permanent survey base, such as section corners or monuments, located on photogrammetric topography of the district, if such is publicly available.

Individual prospects, underground or surface sampling and drilling should be recorded if obtainable (similar to U. S. Bureau of Mines Information Circulars); prospect descriptions are no longer prepared by the USBM.

(7) *Lead-zinc concentration and reduction.* UGMS might review lead-zinc mining, milling, smelter or other reduction freight costs, and prepare an up-to-date generalized analysis of their impact on the industry and on typical mining situations. The figures are well known and available to industry, but for competitive reasons, are not made public. It is difficult, but not impossible, to obtain such information. The costs and losses due to reduction and freight of zinc material commonly absorb more than 60 percent of the gross value, which makes some of the lead and zinc mining problems more understandable.

(8) The state geologists could continue to *review the studies of other state geology departments* regarding gold, silver, copper, lead and zinc. For example, publications of the New Mexico State Survey, describing features common to many oxidized lead-zinc outcrops, the Arizona State Survey's information on economics of oxidized copper deposits, and similar information might be reviewed, summarized and recirculated to companies and persons interested in exploration in Utah. A short paper on the economics and future of oxidized zinc deposits would be valuable.

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APPENDIX I

Definitions (figure 23)

Ore. Material that is well located and identified on maps and that can be mined at a profit.

Resource. Combines *ore*-grade material and material not well identified, material of a lower grade, or material in an environment more difficult to identify and/or recover ore. A *resource* falls within a reasonable geologic or production statistic projection. It includes mineral bodies that are predicted, but not yet discovered. The limits of projection and prediction vary greatly depending on the nature of the problem and the outlook of the predictor. (Note the extreme difference between predictions of mining company engineers and U. S. Geological Survey geologists.) In this report an attempt was made to determine by inquiry the outlook of professional mining geologists, engineers and managers.

Reserve. Ore plus that part of the resource for which location, grade and mining factors have been identified, but which may be marginal or submarginal in calculated value.

Grade. Metal content of ores and concentrates or their dollar value; may be expressed in many ways, generally depending on the conditions surrounding the material described.

"In place" grade of mine ore: percent metal content or gross dollar value of ore as sampled in its natural position in the mine faces, drifts and stopes, etc.

Run-of-mine grade or *mill-head grade:* as sampled at mine discharge or entering the mill. This will be a composite of in-place grades modified by dilution with waste or low-grade rock because of mining procedures. Quantities are generally dry tons.

Recoverable-metals grade: the run-of-mine grade less an estimated metal loss in milling, reduction and refining. Records for county and state tabulations in this report are in terms of recoverable metals from information submitted by individual mine operators to the U. S. Bureau of Mines and statistics compiled from U. S. Geological Survey publications.

Gross value of recoverable metals: Average market value, during the year produced, of metals estimated to be recoverable by the available metallurgical facilities. The definitions were compiled from U. S. Bureau of Mines mineral yearbooks and related publications.

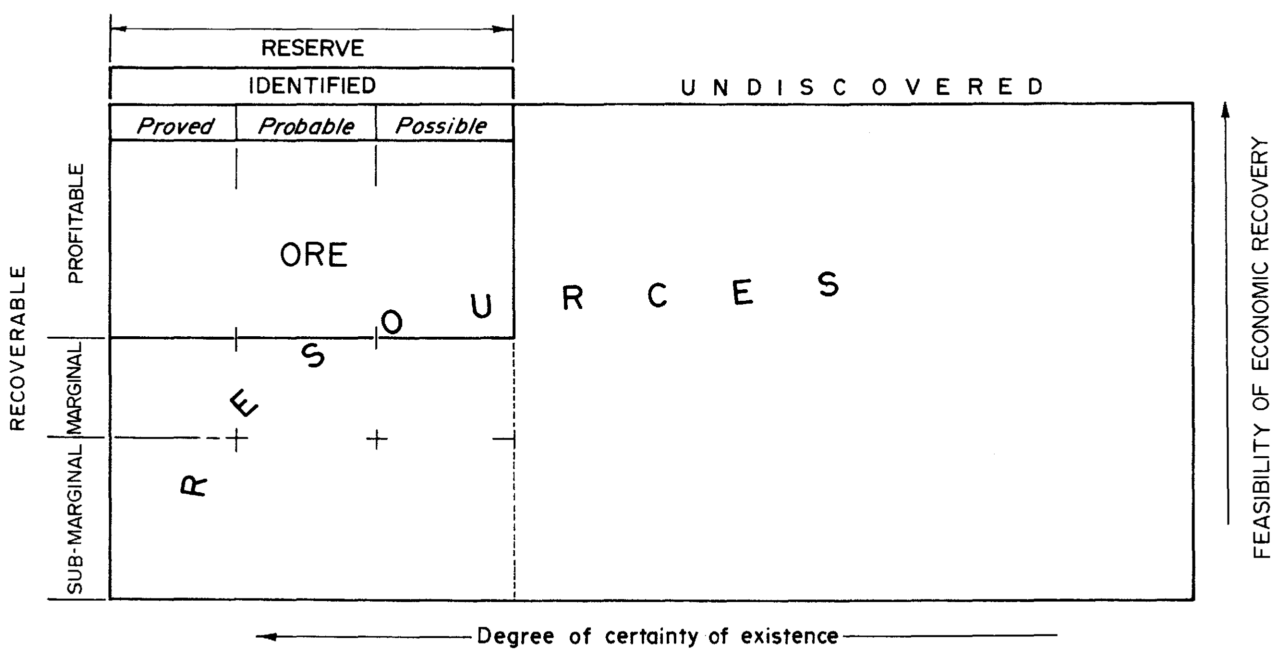
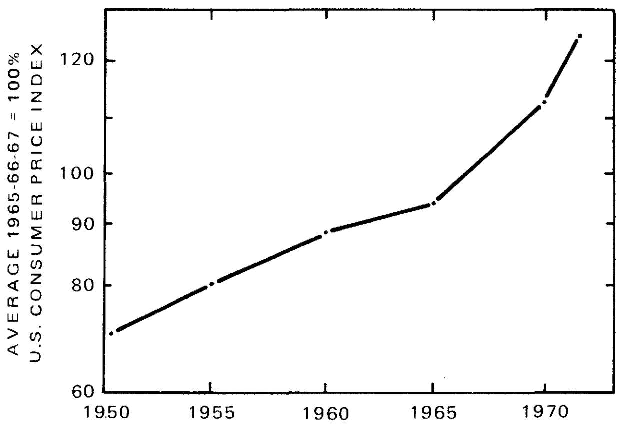


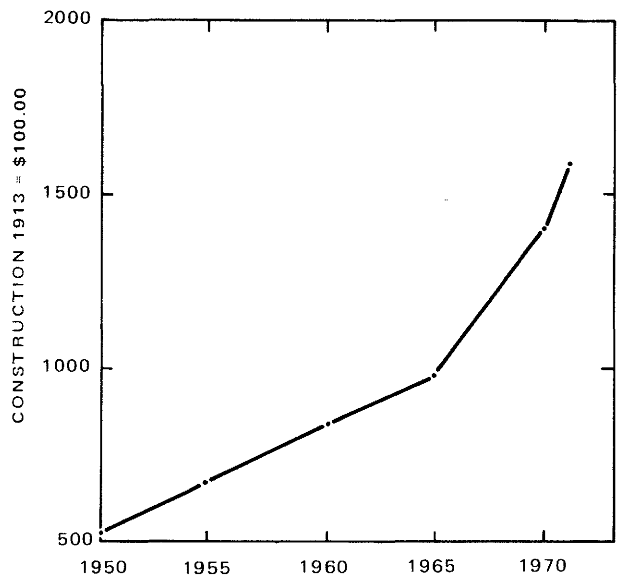
Figure 23. Classification of ore and mineral resources (modified from McKelvey, 1972).

APPENDIX II

Construction Cost Index and U. S. Consumer Price Index



U.S. Consumer Price Index



Engineering News-
Record Cost Index, Construction

APPENDIX III

Hypothetical Costs–Concentrate and Ingot Freight

Table 34 shows hypothetical freight savings of $.00 to $.019 per pound of metal achieved by smelting lead and zinc in Utah versus reduction in other areas. Neither Utah, nor the San Francisco Bay area have, at present, facilities for performing the reduction suggested. In Montana, St. Louis and Gulf areas, existing facilities are inadequate. Therefore new reduction complexes would have to be built, or old works expanded.

No attempt has been made to compare costs of reducing in Utah versus reducing in other areas.

Many freight rates, circa 1965, are listed in tables 41 and 42, Appendix IV.

Table 34. Difference in freight costs from Utah source to market (concentrates reduced in Utah versus concentrates reduced out of state).

Assumptions: 10 percent moisture. When dry 60 percent metal (wet concentrate 54 percent metal).

$$\text{Freight cost, metal in concentrate, cents/lb} = \frac{\text{concentrate freight rate per ton}}{.54 \times 2{,}000}$$

Location of reduction works		Market for metal							
		San Francisco Bay		St. Louis		Gulf area		New York	
		dollars/ton[1]	cents/lb[2]	dollars/ton[1]	cents/lb[2]	dollars/ton[1]	cents/lb[2]	dollars/ton[1]	cents/lb[2]
Utah	Ingot freight	24	1.2	32	1.6	52	2.6	46	2.3
San Francisco Bay	Concentrate freight	25	2.3						
	Freight saving if reduction is in Utah		1.1						
St. Louis	Concentrate freight			28	2.6				
	Freight saving if reduction is in Utah				1.0				
Gulf area	Concentrate freight			27	2.5	28	2.6		
	Ingot freight			20	1.0				
	Total metal freight				3.5				
	Freight saving if reduction is in Utah				1.9		.0		
Montana	Concentrate freight							16	1.5
	Ingot freight							38	1.9
	Total metal freight								3.4
	Freight saving if reduction is in Utah								1.1

[1] Freight cost = dollars per ton of concentrate or of ingot as indicated.
[2] Cents per lb of contained metal.
Prices used for concentrate and ingot freight have been generalized for this report from many 1973 sources. Real future rates will be subject to wide variation depending on precise specifications and competitive situations.

APPENDIX IV

Analyses of Costs in the Pacific Northwest

In 1966 and 1967, the U. S. Bureau of Mines analyzed lead-zinc costs in the Pacific Northwest. Although individual costs are outdated, the relationships and generalizations regarding mines, mills and smelters are still valid (tables 35 to 39).

Knostman (1967) discusses lead smelter costs:

An estimate of costs incident to lead smelting and refining (at Bunker Hill, Idaho) is given . . . [table 40]. It should be emphasized that no credit has been given for coproducts recovered.

Because of the age of domestic smelters, amortization costs probably would not be an important expense item; however, it is estimated that a new 60,000-ton-per-year lead smelter and refinery would cost approximately $10 million (date not specified). Capital cost would add more than 0.8 cents per pound to the cost of producing lead.

The construction of an electrolytic reduction plant requires a large capital investment. The electrolytic plant built at Anaconda, Montana, in 1916, cost approximately $45 per ton of annual capacity, but construction of a similar plant would now cost $300 or more per ton. The 70,000-ton-per-year electrolytic plant constructed since 1960 at Valleyfield, Quebec, is estimated to have cost about $20 million without roasting and sulfuric-acid-producing facilities. [Construction costs would be double today; Appendix II.] The additional cost of the facilities would probably be between $4 and $7 million. A $20-million investment amortized over 15 years at 6 percent interest would add 1.47 cents per pound to zinc production costs at a smelter with a 70,000-ton-per-year output. The estimated cost of $117.65 per ton of zinc produced would be lowered to $88.24 if the smelter were fully amortized.

He further (p. 36) comments on transportation costs.

Pacific Northwest slab zinc and refined lead consumption is small; therefore, these products are shipped to other markets located chiefly in Michigan, Illinois, Ohio, and California.

Carload freight rates for slab zinc from various smelter sites to market areas . . . [table 41] indicate the locational disadvantage of Pacific Northwest producers relative to those closer to market areas. For example, transportation costs from either Kellogg, Idaho, or Great Falls, Mont., to Detroit, Mich., are $14.62 per ton higher than from Blackwell, Okla.; $7.00 per ton higher than from Corpus Christi, Tex.; $11.82 per ton higher than from East St. Louis, Ill.; and $11.30 per ton higher than from Palmerton, Pa. Similar cost disadvantages exist for shipments to Chicago, Ill., and Youngstown, Ohio.

Refined lead from the Pacific Northwest also is at a competitive disadvantage created by higher transportation costs than from refineries at Herculaneum, Mo., and Omaha, Nebr. . . . [table 42] indicates that the St. Joseph Lead Co., the leading domestic lead producer, has an advantage over Bunker Hill of $15.91 per ton for lead shipments to Detroit, Mich., and $12.83 per ton to Chicago, Ill. Likewise, rates from the American Smelting and Refining Co. refinery at Omaha, Nebr., to Detroit and Chicago are lower than those from Kellogg. Rates to Los Angeles, Calif., from Kellogg are lower than from Herculaneum and Omaha, but considerably more than the $8.00-per-ton rate from the Selby, Calif., plant.

Table 43 shows the advantages of a smelter being near a mining district and of shipping concentrates instead of ore. Commodity freight rates established between an operating base metal mine and smelter and the smelter and marketing area are listed. The distances are similar and the difference should not have any appreciable effect. Prior trucking and handling costs to the loading point are not included. The cost of shipping slab zinc produced at an Idaho smelter, Bunker Hill area, to an eastern refinery and market and a 45.5 percent concentrate produced at the mine for a similar distance to an electrolytic plant was as follows:

	Cost per pound of contained zinc
Shipping the metal slab zinc 782 miles to refinery	$ .0059
Cost of shipping 45.5 percent concentrate 833 miles to electrolytic plant	.0145
Difference per pound	.0086
Thus shipping metal as concentrate results in an additional production cost, for 7 percent crude ore (140 pounds zinc per ton, 125 pounds recovered)	$1.08 per ton of crude ore

Utah ores are higher than 7 percent when lead and zinc are both considered. Therefore, with similar rail distances involved, the added cost per ton of crude ore to ship concentrate, not metal, to a central or Gulf coast reduction plant or market would be more than $1.08.

Lead-ore producers in Arizona, Kansas, Oklahoma, Wisconsin, Illinois, Colorado, Nevada and New Mexico must ship ore or lead concentrates to smelters in other states. Zinc-ore producing operators in Arizona, Colorado, Nevada, New Mexico, Missouri, Kansas, Wisconsin, Kentucky, New York, Tennessee, Virginia and Washington also must ship ore or zinc concentrates to smelting and refining plants in other states (U. S. Bureau of Mines data).

Table 35. Operating expenses and gross value per ton of ore produced at selected Pacific Northwest lead-zinc mines, 1958 to 1964[1] (modified from Knostman, 1967, p. 30).

Mine and year	Ore production, tons ore mined	Gross smelter receipts[2]	Mining cost	Haulage, milling and smelting costs[2]	Repairs and other expenses
Bunker Hill (largely cut and fill)					
1958	373,613	$26.94	$16.38	$ 8.77	$ 0.28
1959	470,303	27.21	15.35	9.03	.35
1960	176,462[3]	28.08	23.40	9.26	.50
1961[4]	510,584	26.49	15.21	9.21	.52
1962[4]	554,390	27.19	14.23	9.75	.34
1963[4]	472,345	31.33	16.83	10.63	.14
1964[4]	471,156	32.78	18.85	10.67	.49
Lucky Friday (largely cut and fill)					
1958	53,300	31.21	11.51	3.92	.96
1959	75,333	28.79	11.85	3.51	10.97
1960	127,354	37.08	12.95	2.05	2.06
1961	128,860	34.44	15.35	–	.20
1962	181,133	36.78	9.87	1.23	.12
1963	182,337	40.35	10.29	1.26	.07
1964[5]	182,704	45.74	10.54	1.22	–
Page (square set stopes)					
1958	117,411	30.42	20.69	10.71	.04
1959	111,405	31.85	20.73	11.57	–
1960	46,369[3]	52.09	28.06	17.11	–
1961	117,592	36.44	19.11	14.32	.22
1962	118,520	33.54	19.51	13.42	.41
1963	126,041	35.20	19.07	13.07	.01
1964	130,937	37.28	19.16	10.90	.04
Pend Oreille (extensive flat open stopes–mechanized mining)					
1958	607,695	3.89	1.90	1.14	.51
1959	619,779	4.30	2.03	1.14	.45
1960	727,759	3.27	1.91	1.05	.45
1961	742,934	4.52	1.89	1.15	.39
1962	619,946	3.87	2.04	1.20	.54
1963	651,922	4.14	2.05	1.18	.50
1964	697,113	5.05	2.19	1.05	.57
Star (cut and fill)					
1958	184,873	30.12	15.07	14.81	.18
1959	218,886	33.27	15.43	16.02	.03
1960	244,898	32.44	15.15	15.35	.02
1961	252,241	33.51	14.76	15.99	.07
1962	239,349	35.98	16.81	17.36	–
1963	253,513	36.06	16.61	16.54	–
1964	245,388	40.89	16.36	17.99	–

[1] Operating expenses shown do not include taxes, depreciation, depletion, royalties, donations and insurance (except compensation and Social Security).
[2] Smelting charges excluded for Lucky Friday and Pend Oreille mines and deducted gross smelter receipts.
[3] Production at Bunker Hill and Page mines reduced by a labor dispute.
[4] Includes data for Crescent mine.
[5] Reported costs adjusted to compare with accounting practice for prior years.

Table 36. Weighted average operating costs at the Page, Bunker Hill, Star and Pend Oreille mines, 1963 (Knostman, 1967, p. 31).

	Cost per ton of ore[1]	Cost per pound of recoverable lead-zinc
Extraction	$10.48	$0.0614
Freight and treatment	7.69	.0450
Other direct expenses	.26	.0016
Total	18.43	.1080
Estimated coproduct value	3.13	.0184
Final cost	15.30	.0896

[1] Based on data reported to the Shoshone County Assessor and in company annual reports to shareholder.

Table 37. Estimated costs of lead smelting and refining (Knostman, 1967, p. 36).

Cost item	Units per ton refined lead	Cost per unit	Cost per ton refined lead
Labor (hours)	11.0	$ 3.00	$33.00
Limestone (tons)	.85	2.40	2.04
Siliceous flux (tons)	.30	[1]	–
Coke (tons)	.45	23.00	10.35
Electricity (kilowatt-hours)	300	.0055	1.65
Natural gas (therms[2])	80	.04	3.20
Amortization of plant capital cost[3]	–	–	17.16
Maintenance, repair and supplies[4]	–	–	10.00
Insurance and taxes[5]	–	–	5.01
Total	–	–	$82.41[6]

[1] Siliceous material normally is obtained from siliceous ore, slag, or tailings.
[2] Btu content per therm estimated at 100,000.
[3] Based on a plant producing 60,000 tons per year costing $10 million and amortized for 15 years at 6 percent interest.
[4] Calculated at 6 percent annually of original capital cost.
[5] Calculated at 3 percent annually of original capital cost.
[6] Excludes credit for coproducts.

Table 38. Average value of products and principal operating expenses at lead-zinc mines,[1] 1958 and 1963 (Knostman, 1967, p. 32).

	1958			1963		
	Product value per ton	Principal expenses per ton[2]	Ratio of principal expenses to product value, percent	Product value per ton	Principal expenses per ton[2]	Ratio of principal expenses to product value, percent
United States	$ 7.21	$ 6.36	88.2	$ 7.78	$ 6.55	84.0
Northeast and north central states	[3]	[3]	[3]	7.98	5.14	64.0
Missouri	3.94	2.97	75.4	[3]	[3]	[3]
Tennessee[4]	[3]	[3]	[3]	3.27	2.32	70.0
Western states	[3]	[3]	[3]	15.32	11.65	76.0
Arizona	16.25	10.95	67.5	[3]	[3]	[3]
Idaho	20.20	16.23	80.3	23.44	18.69	80.0
Montana	32.62	29.00	88.9	[3]	[3]	[3]
Utah	39.52	30.83	78.0	44.32	35.54	[3]

[1] Not adjusted for interplant transfers.
[2] Includes wages, supplies, fuels and electricity.
[3] Not available.
[4] Based on U. S. Bureau of Mines tonnage data.

Table 39. Direct mine operating costs for various mining methods, period 1955 to 1959 (Everett and Bennett, 1967, p. 31).

Mining method	Amount mined per month, tons[1]	Direct mining costs per ton[2]			Labor, percent of total cost
		High	Low	Average[3]	
Square setting	439,330	$18.72	$6.22	$10.20	71.2
Cut and fill	585,300	14.73	3.07	6.69	56.7
Shrinkage	305,820	8.12	1.75	3.92	[4]
Room and pillar (trackless type)	733,220	2.41	1.16	2.00	43.7
Sublevel stoping	1,547,410	4.71	1.06	2.37	56.9
Sublevel caving	118,150	[4]	[4]	4.97	63.3
Block caving	1,803,150	2.25	1.15	1.41	54.2
Open pit[5]	5,198,060	1.15	.21	.32	36.4

[1] Total aggregate tonnage of ore mined each month except for open pits.
[2] Includes exploration and development, stoping, haulage, hoisting, pumping and general underground and surface costs.
[3] Weighted average on the basis of tons produced from each mine.
[4] Not available.
[5] Cost is per ton of "material" and is based on total tons of ore and waste handled.

Table 40. Estimated cost of producing slab zinc at electrolytic plants (Knostman, 1967, p. 35).

Cost item	Units per ton slab zinc	Cost per unit	Cost per ton slab zinc
Labor (hours)	13.0	$3.00	$ 39.00
Electricity (kilowatt-hours)	3,600	.0055	19.80
Natural gas	25	.04	1.00
Amortization of plant capital interest[1]	–	–	29.41
Supplies, maintenance and repair[2]	–	–	19.04
Insurance and taxes[3]	–	–	9.40
Total	–	–	$117.65[4]

[1] Based on a 70,000-ton-per-year plant costing $20 million.
[2] Calculated at 6 percent annually of the original capital cost.
[3] Calculated at 3 percent annually of the original capital cost.
[4] Excludes credit for coproducts.

Table 41. Railroad freight rates for carload shipments of slab zinc from selected smelter locations to major consuming areas (rate per ton[1]; modified from Knostman, 1967, p. 37).

From	Chicago, Illinois	Detroit, Michigan	Youngstown, Ohio	Los Angeles, California
Kellogg, Idaho	$19.02	$23.72	$22.97	$30.00
Great Falls (Black Eagle), Montana	19.02	23.72	22.97	20.20
Blackwell, Oklahoma	9.40	9.10	9.60	21.40
Corpus Christi, Texas	13.42	16.72	12.40	27.60
East St. Louis, Illinois	3.40	12.90	13.84	
Palmerton, Pennsylvania		11.30		

[1] The figures shown are for the largest minimum weight for which rates are available; rates effective in 1965.

Table 42. Railroad freight rates for carload shipments of refined lead from selected smelter locations to major consuming areas (rate per ton[1]; modified from Knostman, 1967, p. 37).

From	Chicago, Illinois	Detroit, Michigan	Los Angeles, California	Columbus, Ohio	New York, New York
Kellogg, Idaho	$21.03	$26.01	$24.80	$26.01	$26.97
Herculaneum, Missouri	8.20	10.10	51.80		
Omaha, Nebraska	6.90	15.40	47.00		
Selby, California			8.00		

[1] The figures shown are for the largest minimum weight for which rates are available; rates effective in 1965.

Table 43. Comparison between costs to transport zinc contained in ore or concentrate and slab zinc[1] (Everett and Bennett, 1967, p. 36.

Cost of transporting zinc contained in ore or concentrate[2]				Cost of transporting slab zinc in carload lots[3]		
Value of ore or concentrate (dollars per ton)	Rate, dollars per ton	Metal content, lbs. per ton[4]	Cost of transporting, dollars per ton-mile	Carload size, lbs.	Rate, cents per 100 lbs.	Cost of transporting, dollars per ton-mile
$ 0.00- 15.00	$ 9.56	1-136	$22.95 -0.169	60,000	58.5	$0.015
15.00- 27.50	10.06	136-250	.169-0.097	100,000	53.5	0.014
27.50- 50.00	10.52	250-455	.097-0.055	120,000	48.0	0.012
50.00- 60.00	11.20	455-545	.055-0.049			
60.00- 70.00	11.89	545-636	.049-0.045			
70.00- 80.00	12.56	636-727	.045-0.041			
80.00- 90.00	13.34	727-818	.041-0.039			
90.00-100.00	14.05	818-909	.039-0.037			

[1] Rates are not determined solely on basis of mileage; therefore, costs per ton-mile will vary slightly.
[2] Based on a shipping distance of 833 miles.
[3] Based on a shipping distance of 782 miles.
[4] Used 11 cents per pound to calculate the metal content.

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

103 Utah Geological Survey Building
University of Utah
Salt Lake City, Utah 84112

THE UTAH GEOLOGICAL AND MINERALOGICAL SURVEY since 1949 has been affiliated with the College of Mines and Mineral Industries at the University of Utah. It operates under a director with the advice and counsel of an Advisory Board appointed by the Institutional Council of the University of Utah from organizations and categories specified by law.

The survey is enjoined to cooperate with all existing agencies to the end that the geological and mineralogical resources of the state may be most advantageously investigated and publicized for the good of the state. The *Utah Code, Annotated, 1953 Replacement Volume 5, Chapter 36, 53-36-2,* describes the Survey's functions.

Official maps, bulletins, and circulars about Utah's resources are published. (Write to the Utah Geological and Mineralogical Survey for the latest list of publications available.)

THE LIBRARY OF SAMPLES FOR GEOLOGIC RESEARCH. A modern library for stratigraphic sections, drill cores, well cuttings, and miscellaneous samples of geologic significance has been established by the Survey at the University of Utah. It was initiated by the Utah Geological and Mineralogical Survey in cooperation with the Departments of Geology of the universities in the state, the Utah Geological Society, and the Intermountain Association of Petroleum Geologists. This library was made possible in 1951 by a grant from the University of Utah Research Fund and by the donation of collections from various oil companies operating in Utah.

The objective is to collect, catalog, and systematically file geologically significant specimens for library reference, comparison, and research, particularly cuttings from all important wells driven in Utah, and from strategic wells in adjacent states, the formations, faunas, and structures of which have a direct bearing on the possibility of finding oil, gas, salines or other economically or geologically significant deposits in this state. For catalogs, facilities, hours, and service fees, contact the office of the Utah Geological and Mineralogical Survey.

THE SURVEY'S BASIC PHILOSOPHY is that of the U. S. Geological Survey, i.e., our employees shall have no interest in Utah lands. For permanent employees this restriction is lifted after a 2-year absence; for consultants employed on special problems, there is a similar time period which can be modified only after publication of the data or after the data have been acted upon. For consultants, there are no restrictions beyond the field of the problem, except where they are working on a broad area of the state and, here, as for all employees, we rely on their inherent integrity.

DIRECTORS:
William P. Hewitt, 1961-
Arthur L. Crawford, 1949-1961