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jMemical refining study

of base a precious metal ore

in colorado

FOR

MINING INDUSTRIAL. DEVELOPMENT BOARD

STATE OF COLORADO

BY O.W. WALVOORD, INC.

To:

His Excellency, The Honorable John A. Love,
Governor of the State of Colorado;
and
Members of the Forty-Fifth General Assembly:

The Colorado Mining Industrial Development Board herewith transmits a comprehensive "Chemical Refining Study" by 0. W. Walvoord, Inc.

In submitting this Study of the most modern refining methods available, the Board does not approve or disapprove of the contents and recommendations contained therein but does hope and expect that the report will cause private industry and possibly federal agencies to use it as a basis for improving the marketing facilities of the ores and concentrates being produced and to be produced within the State of Colorado: and further to act as a medium for arousing the interest of the citizenry in the great mineral potential known to exist in the Centennial State.

Colorado Mining Industrial Development Board

Robert R. Williams, Jr., Chairman
Robert S. Palmer, Executive Director

204 State Office Building
1965

CHEMICAL REFINING STUDY

OF BASE & PRECIOUS METAL ORE IN COLORADO

Prepared For The

MINING INDUSTRIAL DEVELOPMENT BOARD

STATE OF COLORADO

June 1, 1965

By
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Denver, Colo.

CONSULTATION

CONSTRUCTION

301 Detroit Street
Denver, Colorado 80206
June 1, 1965

Mr. Robert R. Williams, Jr., Chairman
Mining Industrial Development Board
204 State Office Building
Denver, Colorado 80202

Subject: Chemical Refining Study
Final Report

Dear Mr. Williams:

The final report covering our study of the economic feasibility of Chemical Refining is respectfully submitted. This work was performed under terms of an agreement with The Mining Industrial Development Board dated January 6, 1965, Fund No. 2-3244-51.

The very encouraging results of this study should be of interest to all those who are concerned with the future of Colorado's mining industry. It is hoped that the realistic and promising findings will obtain the active support of our legislative and industrial leaders.

Yours very truly,

0. W. Walvoord, Inc.

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President

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1 SUMMARY & RECOMMENDATIONS

SUMMARY

In this study, an attempt has been made to objectively evaluate the economic feasibility of a Chemical Refinery processing base and precious metal ores of Colorado.

The results of the study indicate that a Chemical Refinery could be built and operated profitably. In fact, it is entirely feasible that several such units could be built and operated within the state.

For the conservative conditions assumed, a Chemical Refinery processing 125 tons per day of concentrate (eauivalent to 900 tons per day of ore) could produce a pre-tax return of 24^ on a plant investment of $5 1/2 million., and generate enough cash flow to pay-out in about five years. Additional money will be required for operating capital. At a feed rate of 125 TPD, this unit could operate profitably until the prices of lead and zinc dropped as low as 8.35 #Ab (assuming gold, silver, copper, and cadmium remained stable). If the prices assumed for the various metals should remain constant, the Chemical Refinery could operate with a profit on a feed rate as low as 75 tons of concentrate per 24 hour day.

The economic life of the Chemical Refinery was taken as 15 years. However, on the basis of currently published information, the measured and indicated reserves of Area 17 are sufficient to provide feed to the refinery for 30 years or more. This does not include any allowance for the many tons of ore now listed as resources, which would become available reserves because a method of processing them was now feasible. The impact of one or more of these plants on the economy of Colorado and the level of mining activity in the state can only be inferred. However, it seems reasonable to assume that it would provide a great stimulus. Many small mine operators could resume production since a facility would be available in which to treat their ore. The mill operators could improve their present profit picture as a result of savings they would realize from process changes and lower freight costs.

In addition, the Chemical Refinery would provide employment for 125 - 130 semi-skilled and skilled workers, and provide an annual payroll of nearly one million dollars.

1 SUMMARY & RECOMMENDATIONS (continued)

RECOMMENDATIONS

It should be recognized that due to limitations of time and money the present study could not undertake an exhaustive investigation of all facets of this problem. Consequently, there are several areas in which further study would appear to be desirable. The following recommendations are presented in the order in which they should be pursued.

1. A survey of mine owners and mill operators should be made to establish a firm picture of the amount of ore and concentrates that would be available to a Chemical Refinery. Data on ore reserves were taken from the records of various public agencies. This approach is reasonable and reliable, but fails to reveal the real availability of the ore. Contractural obligations and other commitments may actually preclude the use of this ore by the Chemical Refinery. Before any ore-treatment facility is constructed, the operating company should have an interest in or an assignment of enough ore reserves to insure the availability of an adequate supply of raw materials.

2« Some metallurgical and chemical test work should be undertaken on representative samples to verify and improve the process. It should be emphasized that the basic elements of the process have been proven in actual operating plants or have been successfully tested in many different laboratories.

3. A careful study should be made of all issued patents that relate to the various processes used in the Chemical Refinery. Most of these processes are based on fundamental principles of chemistry and are commonly available to use without restriction. However, some techniques of application or special features of equipment design have been patented, and may not be available without some form of licensing agreement.

4. The selection of the exact site of the first refinery unit should be made only after additional study. Information on available labor supply, housing, and community resources, etc. must all be gathered to provide a rational basis for the final decision.

5. The possibility of developing new markets for the products of the Chemical Refinery should be studied in greater detail. Consideration should be given to the fact that some products may be available in a quantity and at a price that would encourage the construction nearby of fabricating and manufacturing plants.

6. A final study of economic feasibility is suggested upon the completion of these various recommendations.

INTRODUCTION

At the February, 1964 meeting of the Colorado Mining Association a paper titled "Why Not A Chemical Smelter" was presented jointly by H. L. Hazen, E. A. Lang, and R. Kllerman.

This paper advanced the possibility of replacing the conventional pyro-smelter with a refining pirocess consisting of a combination of hydro-metallurgical and electrolytic operations.

At this same time, the concept of the Imperial Smelter and its adaptability to Colorado ores was being proposed and studied.

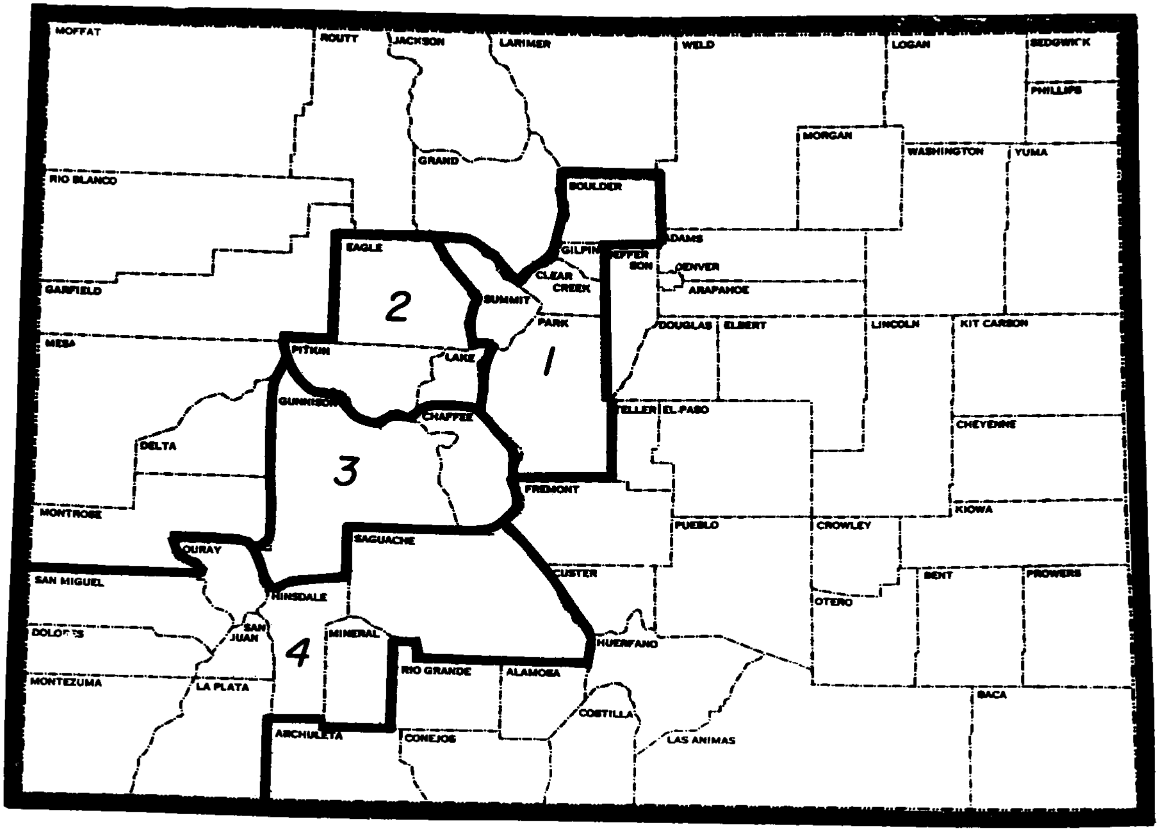
In a discussion with the Colorado Mining Industrial Development Board in September, 1964 0. W. Walvoord suggested a program to investigate the potential value of Chemical Refining.

The first phase of this program, an investigation of economic feasibility using the assumptions of the Imperial Smelter analysis was completed by 0. W. Walvoord, Inc., as a private study. The results were extremely encouraging, but some testing of the basic assumptions was still required.

The second phase of the program was then sponsored by the MIDB. The results of this study, presented in this report, include a careful analysis of the pertinent economic factors.

The purpose of this study was to investigate the availability of necessary raw materials required by a Chemical Refinery, develop a preliminary flowsheet, select a suitable site, estimate capital and operating costs, and determine the economic feasibility of the entire concept.

As a matter of convenience the U. S. Bureau of Mines' designation for the mining areas of Colorado was employed. The size and location of the principal areas is shown in the map on Drawing 1151-8, which follows this page.



PRINCIPAL MINING AREAS OF COLORADO

O. W. WALVOORD, INC.
CHEMICAL REFINING STUDY
MINING AREAS OF COLORADO
ACCORDING TO U.S. BUREAU OF MINES
1151-8

REVISIONS | REVISIONS | BILL OF MATERIALS | REFERENCE DRAWINGS

OBJECTIVE AND SCOPE

The principal objective of this study is to investigate the economic feasibility of a Chemical Refinery for treatment of Colorado metal lie ores.

Since the various processes employed in the Chemical Refinery are based on known and tested methods of chemical and metallurgical treatment it will be assumed that they can be applied successfully to the types of ores and concentrates presently being produced in Colorado. In a later study, the amenability of specific Colorado ores should be tested in the laboratory.

This study shall concern itself with delineation of a process or combination of processes for treating ores and concentrates. It shall investigate the potential profitability of such a refinery and establish a tentative location site. In addition, present and past ore production and the probable magnitude of resources and reserves shall be studied, to determine the prospective life span that such a refinery might expect.

This study shall not include an investigation of existing patents which might cover the various processes involved or the various aspects of product marketing. It is suggested that these subjects be studied at a later stage in the development of the Chemical Refinery concept, preferably after laboratory testing ha3 been completed and a definite flowsheet has been established.

DEVELOPING A CHEMICAL REFINERY

Metal in the ground has a relatively small value. As the raw ore is removed from the mine it acquires an increased value as a result of the work that has been performed. Each succeeding step in the sequence of treatment adds to the value of the metal, up to a limit — the current market price of the metal. Competition among producers forces the inefficient to become efficient, the low-grade miner to handle larger volumes, and the large volume producer to develop milling facilities; all of this so that they can reduce their costs of operation to the minimum.

One of the major expenses in the transformation of ore into metal is that of transportation. For this reason, the integrated producer will locate the mill as close to the mine as conditions will permit. Likewise, in the past, the smelter was usually located close to the centers of milling activity. Many factors have intervened in Colorado and as a consequence, base metal smelting facilities no longer exist in the state. This loss of smelting facilities has increased the distance that concentrates and ores must be transported for smelting and reduced substantially the profit potential of Colorado producers.

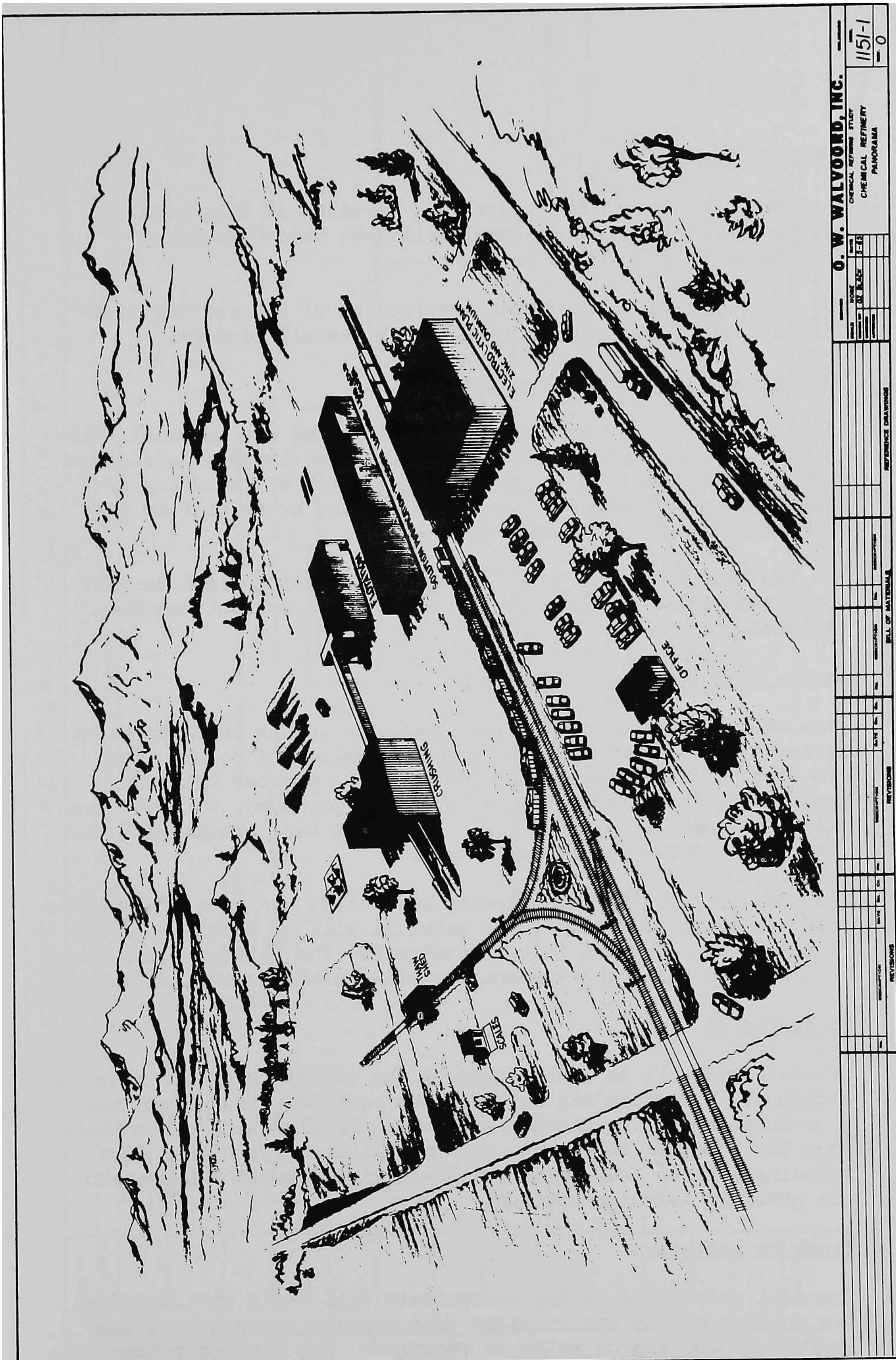
The small, independent miner is in an even more difficult position. Unless his ore is sufficiently high in grade to be shipped directly to the smelter, he is out of business, for there are no custom milling facilities to which he can deliver lower grade ore for upgrading or concentration.

The purposes of Colorado's mining industry would appear to be best served by a facility that could receive and process both metallic ore concentrates from the mills, and high-grade or low-grade ores from the mines. The Chemical Refinery appears to be such a processing facility. The Chemical Refinery includes facilities for such operations as, receiving and sampling, crushing, grinding, flotation, pressure leaching, solution purification and a zinc electrolytic plant.

See Section 5 for a simplified form of flowsheet, Drawing 1151-2, which shows the various sections of the Chemical Refinery and the unit operations performed in each.

Such a refinery could be housed readily in attractive modern structures and would resemble any up-to-date industrial plant. It would be clean, well maintained and could be located close to an established community without introducing any hazards or nuisance.

An artist's conception of such a refinery is shown in Drawing 1151-1, which follows this page.


ELECTROLYTIC PLANT
ZINC AND CADMIUM
FLOTATION
CRUSHING
OFFICE
SCALES
O. W. WALVOORD, INC.
CHEMICAL REFINING STUDY
CHEMICAL REFINERY
PANORAMA
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REFERENCE DRAWINGS
BILL OF MATERIALS
REVISIONS

PROCESS DESCRIPTION

A general outline of the operations involved in the Chemical Refinery are presented in Drawing 1151-2, Unit Operations Flowsheet, which follows on page 5-2.

The following detailed verbal description of the various operations is intended to elaborate on the overall picture.

Receiving. Sampling and Storage

Starting with the receiving station, incoming raw material will be weighed, marked with a lot number, and assigned to a storage area. Facilities will be provided to permit the handling of truck and rail shipments. Separate storage areas will be provided for ore and concentrates.

All raw material shall pass through the sampling plant so that a representative sample is obtained on which payment can then be based.

Ores - High Grade and Low Grade

Ores will be crushed to the required size in the crushing plant during a seven hour day shift and then delivered to the fine ore bins. If the supply of crushed ore is greater than the capacity of the storage bin, a bypass is provided, to route the excess material to a truck bin. From this bin, trucks will deliver the material to ground storage.

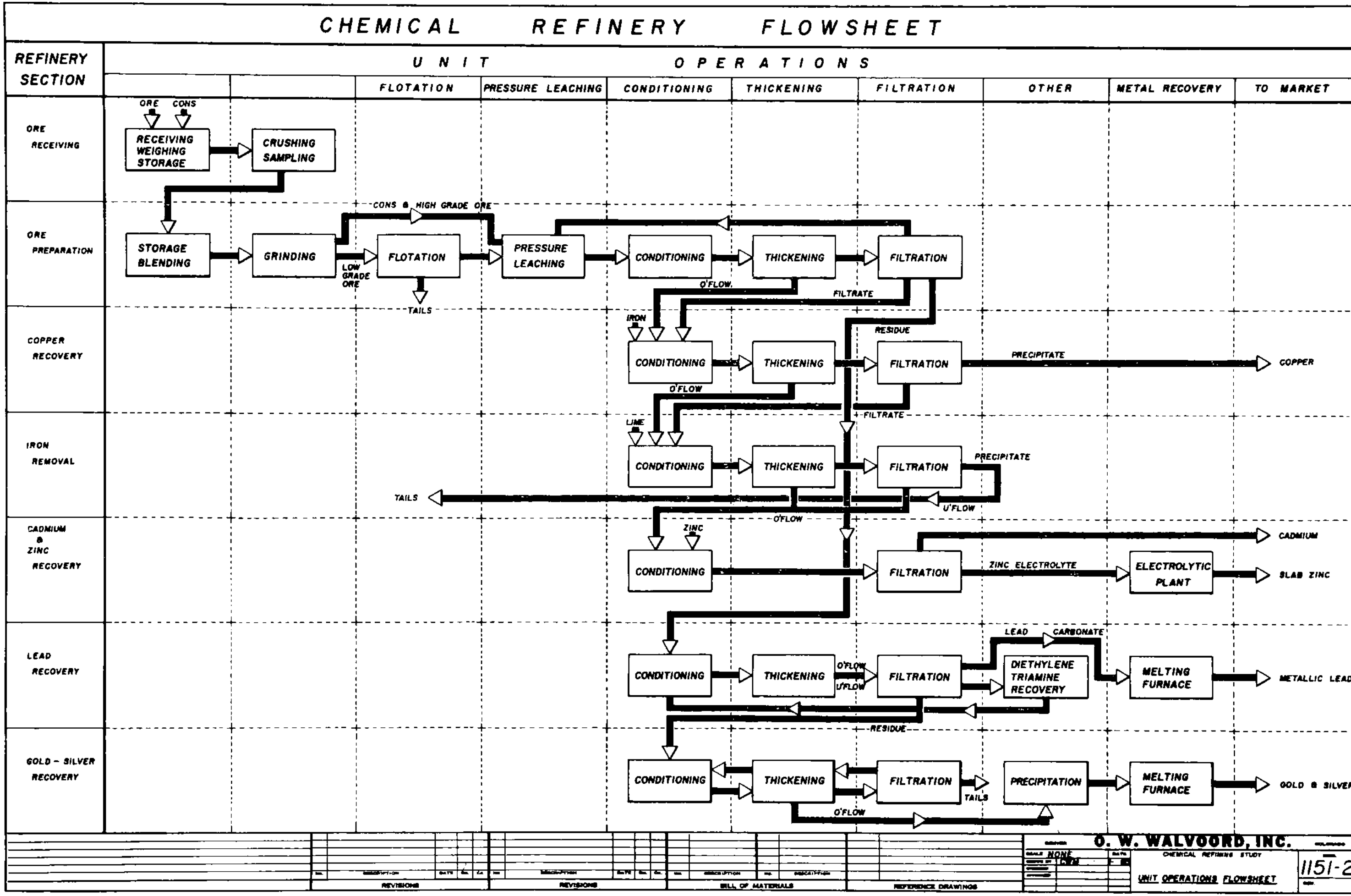
Fine ore is fed into the grinding circuit at the rate of 150 TPD. After grinding to 65 mesh, the material will be conditioned and "floated" to produce a bulk concentrate. The tailings will go to a tails pond while the concentrate will be thickened and filtered.

Concentrates

Concentrates will be transported by the conveyors of the crushing section to a storage bin ahead of the regrind mill. Purchased concentrates will be blended with the bulk flotation concentrate from the Chemical Refinery's custom mill and ground in a fine grinding mill to -200 mesh. This slurried product now goes to the pressure leaching section.

Pressure Leaching

Chemical processing of the concentrate will begin with blending the concentrate to the required pulp density using neutralized anolyte liquor and/or water as required. The blended concentrate


CHEMICAL REFINERY FLOWSHEET
REFINERY SECTION
UNIT OPERATIONS
FLOTATION
PRESSURE LEACHING
CONDITIONING
THICKENING
FILTRATION
OTHER
METAL RECOVERY
TO MARKET
ORE RECEIVING
ORE PREPARATION
COPPER RECOVERY
IRON REMOVAL
CADMIUM & ZINC RECOVERY
LEAD RECOVERY
GOLD - SILVER RECOVERY
ORE
CONS
RECEIVING WEIGHING STORAGE
CRUSHING SAMPLING
STORAGE BLENDING
GRINDING
LOW GRADE ORE
CONS & HIGH GRADE ORE
FLOTATION
TAILS
PRESSURE LEACHING
CONDITIONING
THICKENING
FILTRATION
O'FLOW
FILTRATE
RESIDUE
IRON
PRECIPITATE
COPPER
LIME
U'FLOW
ZINC
ZINC ELECTROLYTE
ELECTROLYTIC PLANT
CADMIUM
SLAB ZINC
LEAD CARBONATE
DIETHYLENE TRIAMINE RECOVERY
MELTING FURNACE
METALLIC LEAD
PRECIPITATION
GOLD & SILVER
O. W. WALVOORD, INC.
CHEMICAL REFINING STUDY
SCALE NONE
UNIT OPERATIONS FLOWSHEET
1151-2
REVISIONS
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REFERENCE DRAWINGS

PROCESS DESCRIPTION (continued)

is pumped continuously into the leaching autoclave where the metal sulfides are oxidized to sulfates, using high pressure air. The oxidation conditions are estimated to be in the order of 375 to 450° F and 650 to 750 psig. The residence time at these conditions is estimated to be 60 to 90 minutes. The oxidation of the metal sulfides to the sulfate can be described by the general reaction shown below where Me can be any of metals under consideration.

(1) MeS + 202 -»MeS0^

The chemistry of iron in the autoclave is more complex and the ultimate disposition of the iron is a function of the free sulfuric acid concentration. In this analysis, because of the low iron content reporting as FeS2, it was assumed that 90$ of the iron would report with the lead sulfate residue in the autoclave discharge as Fe20-j. The remaining iron would be present as ferrous and ferric sulfate. The chemistry of this phase is described by the series of equations below:

(2) 2FeS2 + 702 + 2H20 -* 2FeS04 + 2H2SO4

(3) 4FeS0^ + 02 + 2H2S0^ -+ Fe2 (SO^ + 2H20

(4) Fe2 (304)3 + 3H2 0 ->• 3H2S04 + Fe203

The slurry discharged from the autoclave is flashed to atmospheric pressure and conditioned with limestonu if required. The solution balance at this point is controlled by the addition of wash water or anolyte to the autoclave as make-up water. The conditioned pulp is thickened, filtered over drum filters and the lead residue (PbSO/^) containing the gold, silver, arsenic, and iron is washed and sent to the lead recovery section.

Copper Recovery

The thickener overflow and the filtrate from the above filtering step are combined and processed through copper recovery. The solution at this point contains the soluble sulfates of copper, zinc, and cadmium plus minor amounts of arsenic, antimony, and germanium. The arsenic is essentially all precipitated in the autoclave as a basic iron arsenate. The copper is precipitated from solution by deposition with iron as described by the following reaction:

(5) $CuSO_4 + Fe \rightarrow FeSO_4 + Cu$

The iron addition is controlled to insure the presence of a small amount of copper (about 0.5 gm/l) in the solution prior to purification in the zinc circuit.

The precipitated copper is collected by hydroclones and settling chambers. The washed copper is sold to the smelter and the overflow liquor is clarified, if necessary, and processed through iron removal.

Iron Removal

The first step in solution purification prior to electrolysis, aside from precipitation of the copper, is iron removal. Here, the soluble iron in the autoclave discharge plus the iron added to the circuit by the cementation of copper is removed by conventional techniques. This requires the oxidation of the ferrous iron to ferric with air and the subsequent hydrolysis of the ferric sulfate as hydrated iron oxide (ferric hydroxide). The chemistry here is as described in equations (3) and (4), differing only in that this step is carried out under atmospheric conditions. The pH of the solution is controlled by the addition of hydrated lime to favor the oxidation of the ferrous iron and the precipitation of the ferric hydroxide. Aeration of this solution is accomplished in flotation type cells. Residual amounts of arsenic plus the antimony and germanium are removed at this point and discarded with the iron residue.

Cadmium Recovery

The slurry from iron precipitation is thickened and filtered and the iron residue discarded after washing on a drum filter. The filtrate and thickener overflow which are now free of iron, but contain some copper, are combined and treated with zinc dust.

The zinc precipitates the residual copper plus any cadmium present which is then recovered by filtration. The cadmium is recovered from this residue by standard methods. Standard zinc electrolyte purification processes call for repeating the above, if required, after the addition of a small amount of copper as copper sulfate. Cobalt, if present, would be removed by the addition of nitroso-β-naphthol.

PROCESS DESCRIPTION (continued)

Zinc Recovery

The purified solution is next sent to the electrolytic section for the recovery of the zinc. The anolyte liquor containing about 125 gm/1 H2SOi is neutralized with limestone. The gypsum (CaS04»2H20) precipitated at this point is recovered by filtration and washed free of zinc sulfate. The filtrate containing about 50 gm/1 zinc is returned to the leaching section.

Lead Recovery

The chemical process for recovering the lead, based on the work of F. A. Forward and Associates, takes advantage of the solubility of certain lead amine sulfate complexes. Recovery of lead by this scheme requires leaching the washed lead sulfate residue with an amine to form the soluble complex. The pulp is thickened and finally filtered to separate the soluble lead amine sulfate solution from the iron oxide residue containing the gold and silver. The filtrate from this step and the clarified thickener overflow are combined and carbonated to precipitate a high-purity basic lead carbonate. The metallic lead is produced by reducing the carbonate in a small melting furnace. The amine solution, after carbonation, is regenerated with hydrated lime and returned to the dissolution step.

The chemistry of this phase of the operation is shown by the series of equations below:

Amine Leach:

Pb S04 + 2 EDA -• [Fb (EDA)2] SO^ &)

Pb 0 + EDA + EDAI2S0jif -• [Pb (EDA)2^| SO^ + H20 (2)

flnrhhnnA-M on •

2 Pb (EDA)2 S04 + 3 C02 + 5H20 ->

PbC03 • Pb (CH)2 + 2 EDAH2 CO3+ 2 EDAH2S04 (3)

Regeneration:

EDAH2S04 + Ca (CH)2 -> CaSO^ • 2H20 + EDA (4)

Reduction:

C + FbC03 • Pb(0H)2 800°C 2Pb + C02 + H20 (6)

PROCESS DESCRIPTION (continued)

Gold and Silver Recovery

The iron oxide residue remaining after the dissolution of the lead from autoclave discharge solids contains the gold and silver. It is proposed that these values be recovered in a conventional cyanide circuit. The cyanide pulp is washed in a series of three (3) counter-current thickeners and finally on a drum filter. The iron residue remaining is pumped to tailings, and gold and silver in the filtrate is precipitated with zinc dust and barren solution recycled in the conventional manner. The gold and silver precipitate is fluxed, melted, and cast into dore bullion bars.

CAPITAL COSTS OF A CHEMICAL REFINERY

The first step in the development of an economic feasibility study is the determination of the capital costs of the process under investigation. This step must, of course, be preceded by the establishing of a flowsheet, the selection of equipment and the preparation of approximate plant layout drawings.

The flowsheet, drawing U51-2, page 5-2, shows a proposed sequence of operations that should be suitable for Colorado ores and concentrates. From this preliminary flowsheet, a list of major equipment items was prepared. By pricing out this equipment and applying an experience factor, the total capital cost of the plant was obtained.

This estimate includes all direct costs (material, equipment and labor) and indirect costs (engineering, administration, insurance and taxes, contractor) for the complete refinery. Also, included are many auxiliary items, such as:

- Scales
- Scale House
- Thaw Shed
- Ore Receiving and Storage Pad
- Office
- Laboratory
- Lab Equipment
- Site Preparation
- Roads
- Sanitation System
- Water Supply
- Tails Pond
- Power
- Gas Lines

6 CAPITAL COST ESTIMATE - CHEMICAL REFINERY

Summary of Costs - By Sections

Section			Unit Costs	Total Costs
A	1	Receiving, Sampling and Plant Services	$ 145,000.	
	2	Flotation Mill	315,000.	
	3	Regrind Unit	133,500.	
				$ 593,500.
B	4	Leaching Section	1,337,477.	1,337,477.
C	5	Solution Purification	713,650.	713,650.
E	6	Zinc Electrolytic Flant	1,113,975.	
	7	Zinc Casting Riant	528,000.	
	8	Cadmium Recovery	145,785.	
				1,787,760.
F	9	Lead Recovery	736,060.	736,060.
G	10	Gold - Silver Recovery	200,336.	200,336.
		TOTALS	$ 5,368,783.	$ 5,368,783.

OPERATING COSTS OF A CHEMICAL REFINERY

Since the Chemical Refinery is composed of several different sections which perform separate and distinct operations, the operating costs have been prepared for each section.

This will permit the testing and evaluating of various alternative combinations for the final selection of the most efficient and most profitable combination.

The total annual operating expense of a Chemical Refinery is estimated to be:

7 A	Operating Costs	$ 2,881,776.
7 B	Cost of Feed	4,181,512.
7 C	Freight on Products	454,757.
	Total annual operating expense	$ 7,518,045.

For a more detailed summary of the above items, please see the following pages.

The operating costs above include payroll costs and fringe benefits for 122 workers directly employed by the Chemical Refinery.

ANNUAL OPERATING COSTS OF CHEMICAL REFINERY
Based on Feed Rate of 41,250 TPY Concentrates

Section of Refinery	Operating Cost
A Receiving, Sampling $ 388,318. Flotation Mill Regrind Unit	
B Leaching Section 426,043.	
C Solution Purification 401,419.	
E Zinc Electrolytic Plant 1,165,112. Zinc Casting Plant Cadmium Recovery Plant	
F Lead Recovery 359,398.	
G Gold - Silver Recovery 141,486.	
TOTAL ANNUAL COST	$ 2,881,776.

Note

Operating Costs include the following items:

1. Direct Costs, such as reagents, supplies, utilities, labor, etc.

2. Indirect Costs, such as payroll and plant overhead, etc.

3. Fixed Costs, such as depreciation, interest, property taxes, insurance. A 15 year period for depreciation and an interest rate of £>% have been assumed in calculating the above costs.

4. General expense, administration.

COST OF FEED TO CHEMICAL REFINERY

For a total annual concentrate feed rate of 41,250 tons, and assuming that 20# is obtained from the output of the custom Flotation Mill - costs would be as follows:

Feed	Ore	Concentrate	
Concentrate —		33,000 T @ $112.57 (a) =	$ 3,714,810.
Ore	57,750 T	8,250 T @ $ 56.57 (b) -	466,702,
Pay to Shippers —		41,250 T	$ 4,181,512.

Notes

(a) See page 7-4, for method of calculating unit price.

(b) This price is based on an assumed treatment charge of $8.00/ton of ore processed by flotation mill.

7 COST OF FEED TO CHEMICAL REFINERY (continued)

Note (a) - See page 7-3.

Weighted Assay of Typical Lead, Zinc and Copper Concentrates as Produced in Area 4 During 1963.

Metal	Weighted Assay	Weight Per Ton Concentrate	Unit Price of Metal */lb.(c)	Value of Metal Per Ton of Concentrate
Lead - Pb	22.97 %	459.4 #	13.47*Ab	% 61.88
Gold - Au	0.1596 oz	0.1596 oz	$ 34.9125/oz	5.57
Silver - Ag	13.230 oz	13.230 oz	$ 1.290/oz	17.06
Copper - Cu	4.85 %	97#	30.35*Ab	29.44
Zinc - Zn	33.16 %	663.2 #	I3.68$/Ib	90.72
	Total Value of Metal/Ton Concentrate			$ 204.6?
	Pay for concentrates at 55$ of value (d) - (For purposes of this study only)			%• 112.57

Notes

(c) For establishment of metal unit prices - see Section 9 - "Income From Products."

(d) Refer to Table titled "Estimated Gross Dollars Produced Annually by Mills in Area 4 of Colorado."

Note smelter payout averages 58.2# before freight and 51.8# after freight. The difference of 6.4$ represents truck and rail freight charges. For purposes of our study we have assumed that the shipper to the Chemical Refinery will save on rail freight - which is approximately equal to truck freight. To complete our study we have used 55$ of net smelter returns as the basis of paying for concentrates delivered to the Chemical Refinery.

For discussion of the Chemical Refinery's schedule of navment - See Section 13 - "Developing the Position of

Based on feed rate of 41,250 TPY concentrates.

	Products	Destination of Products	Freight Rate $/Ton	Annual Tonnage of Products	Freight To Market
1a	Lead	E. Chicago	$ 17.39	9,474.3 T	$ 164,758.
2a	Gold	Denver	83.00	0.226 T	19.
3a	Silver	Denver	83.00	18.67 T	1,550.
4	Copper	El Paso	24.35	1,999.8 T	48,695.
5a	Zinc	Chicago	17.39	13,678.5 T	237,869.
6a	Cadmium	Chicago	17.39	107.3 T	1,866.
	Total Freight Expense				$ 454,757.

Assumes 330 days of operation per year.
Note - 14.58 Troy ounces = 1 pound avoirdupois.

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PRODUCTS RECOVERED FROM THE CHEMICAL REFINERY

In this study, the feed to the Chemical Refinery was assumed to be concentrates having an assay comparable to the weighted assay of the present producers in Area 4.

The product recoveries, therefore, are a consequence of this initial assumption and are not to be regarded as being guaranteed rates of production for each metal.

The following table provides an over-all summary of production:

Mineral	Product Form	Annual Production
Lead	High Grade	9,474 Tons
Gold	Refined Metal (w/Silver)	6,600 oz.
Silver	Refined Metal (w/Gold)	544,500 oz.
Copper	Cement Copper	2,000 Tons
Zinc	Special High Grade	13,678 Tons
Cadmium	High Grade	107 Tons

Feed rate to Chemical Refinery is assumed to be 125 tons of concentrates for 330 days of operation. For convenience in preparing this report 100$ recovery of metal values was assumed. It is anticipated that actual recoveries will be in the order of 97 to 98$.

See Section 7 - Operating Costs, for details of weighted assay.

INCOME FROM PRODUCTS

Applying averaged metal prices to the estimated output of the Chemical Refinery, the following income is obtained.

Product	Averaged Metal Price (a)	Annual Income
la Lead	13.47#Ab	$ 2,552,220.
2a Gold	$ 34.9125/oz	230,340.
3a Silver	$ 1.290/oz	702,240.
4 Copper	25.394*Ab	1,015,410.
5a Zinc	13.68$/lb	3,742,200.
6a Cadmium	$ 2.60/lb	557,700.
Total Annual Income (b)		$ 8,800,110.

(a) See page 9-2 for method of determining averaged metal prices.

(b) Note that this is gross annual income from which all expenses must be met. A comparison of income and expenses will be discussed in detail in Section 11 - "Profitability of the Chemical Refinery."

INCOME FROM PRODUCTS

Determination of Averaged Metal Prices

The income to the Chemical Refinery will come from the sale of its finished products. These products were described in the preceding section. In this part of the study the probable selling price of each product will be established and the probable gross income from product sales determined.

Lead

The price of lead was taken as 13.47$Ab. based on a 15 year average (1950-1964) of E & MJ average annual metal prices. See graph of metal prices on page 9-3.

The price of gold was taken as $34.9l25/troy oz., based on payment schedule of U. S. Mint.

Silver

The price of silver was taken as $1.290/troy oz., based on latest quotations of Handy & Harman.

Copper

The price of copper was taken as 25.394$Ab» based on the following assumptions. Copper prices for the years 1959 through 1964 were averaged from E & MJ's report of average annual prices, to obtain a base price of 31.053$/lb. for domestic electrolytic copper. The price of cement copper was approximated by subtracting 4$Ab. from this base price. To obtain a realistic price for the copper product of the Chemical Refinery, the following additional adjustments were made:

To cover metallurgical losses: 30 lb./ton or 0.4057$Ab» was deducted.

To cover treatment charges, $25.00/ton or 1.250$Ab« was deducted.

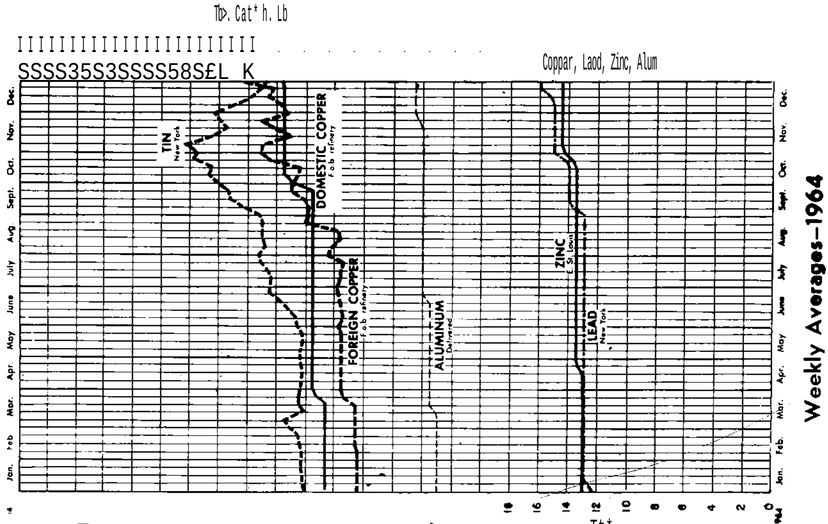
Zinc

The price of zinc was taken as 13.68$Ab», based on a 15 year average (1950-1964) of E & MJ average annual metal prices increased by 1£ to allow for a high purity product.

Cadmium

•ωl

The price of cadmium was taken as $2.60Ab«, based on April, 1964 quotations given in E & MJ.


Weekly Averages—1964
TIN
New York
DOMESTIC COPPER
F.o.b. refinery
FOREIGN COPPER
F.o.b. refinery
ALUMINUM
Delivered
ZINC
E. St. Louis
LEAD
New York
Dec.
Nov.
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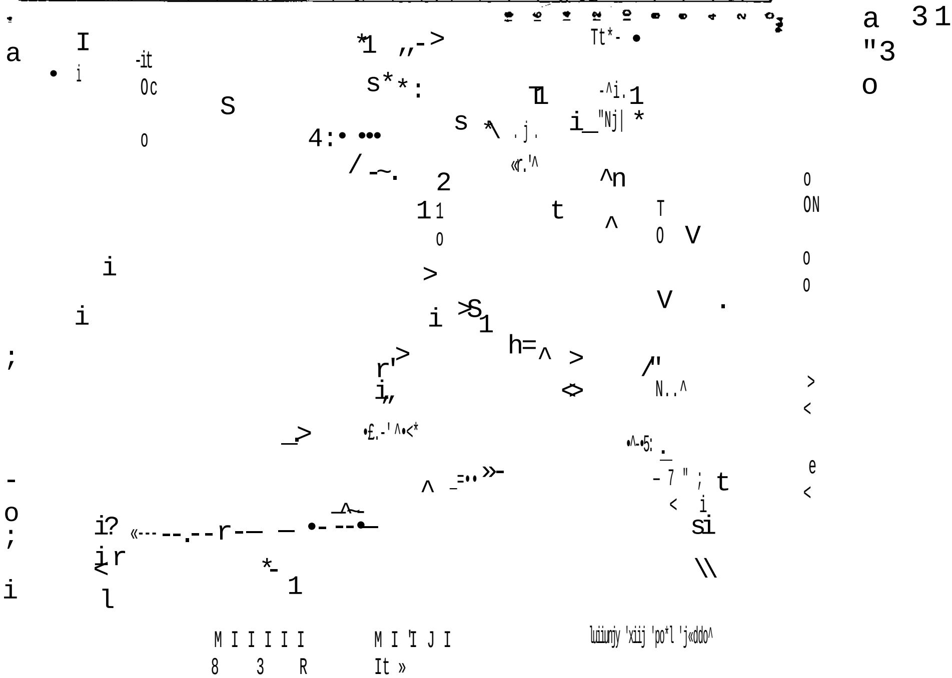

10 MARKET STATUS OF PRODUCTS

In this section, let us briefly review the latest market outlook for each of the products discussed previously. It is our intention here to consider some of the latest developments and evaluate their effect on the Chemical Refinery.

For a detailed study in depth, the reader is referred to pages 73 to 88 of "A Study of Non-Ferrous Metal Refining Opportunities in the Four Corner States" prepared by F. B. Turck & Company, Inc. and dated November, 1964.

Our data has been abstracted from the most recent issues of mining journals, such as Engineering & Mining Journal, Mining Engineering and others.

10 MARKET STATUS OF PRODUCTS (continued)

Lead

1964 was a year of substantial growth for the lead industry. Refined consumption exceeded refined production for the third year in succession - while both production and consumption attained record levels.

The future prospects for lead consumption appear good, with no developments to be seen in the immediate future which would alter the pattern.

The price of lead in New York rose 3£ per pound to l6# during the last half of 1964. This price remained firm during the first quarter of 1965. The primary cause of this strength is reported to be the long-running Mount Isa (Australia) strike, while heavy covering of shor* sales have magnified the firmness.

10 MARKET STATUS OF PRODUCTS (continued)

Gold & Silver

Gold

In 1964, U. S. mine production of gold dropped to 1.44 million troy ounces, with a value of $50.6 million. This represented a continuation of the World War II decline.

Silver

In 1964, the production of silver was 36.5 million troy ounces, (a 4$ gain over 1963 production), which gave a value of $47.2 million.

Approximately two thirds of domestic silver was obtained as a by product of base metal mines.

The average price of silver rose to $1,293 per troy ounce during 19o4. This gain of 1.4$ has been held through March, 1965.

10 MARKET STATUS OF PRODUCTS (continued)

Copper

Demand for copper remained strong throughout 1964, both at home and abroad. U. S. Mine production totaled a record 1.24 million ton3, a 3% increase over 1963 and 2$ above the previous peak of 1962.

After a three year period during which prices remained unchanged, the producers' price for domestic copper increased one cent a pound in mid-March, and two cents a pound in late September, raising the year end price to 34 cents a pound.

Demand is expected to continue high, but according to presently known plans, supply will also increase. By 1969, it is expected that Free World mine capacity will exceed projected demand by some 225,000 tons. New and expanded uses for copper will be required to reduce this over-supply and to maintain the stability of the copper market.

10 MARKET STATUS OF PRODUCTS (continued)

Zinc

Consumption of zinc in the U. S. and abroad made new highs in 1964. A release of 75,000 short tons of slab zinc was withdrawn from the U. S. National Stockpile to meet the demands of the market. It is estimated that during 1965, a withdrawal of 100,000 tons will be required to fill the gap between supply and demand.

Increased development of new mines and smelting facilities in the U. S. and abroad will help to alleviate some of the present short supply of zinc, but no projections relating estimated production to consumption are available.

The East St. Louis price of zinc rose to 14 1/2^/lb. in October, 1964, finally breaking away from the 11 1/2$ level at which it had remained for two and one-half years.

The trend of the market appears to be toward prices that are stable and realistic, which should contribute greatly to the future development of the industry.

10 MARKET STATUS OF PRODUCTS (continued)

Cadmium

The cadmium market appears to be entering a transitional phase from a state of short-supply to one of over—supply.

In September, 1963, the General Services Administration released one million pounds of cadmium from surplus National Stockpile stocks. By the end of that year, this release had been fully absorbed by the market.

In July, 1964, the GSA announced the release of five million pounds of cadmium from National Stockpile surplus at the rate of 600,000 pounds per quarter at a shelf price of $3.00 per pound in ton lots, $3.05 for less than ton lots FOB shipping point. Sales during the first quarter totaled only 23,400 pounds, while sales during the second quarter were believed to be nil.

Early in March, 1965, the price of cadmium fell 35$Ab. to $2.65. Future prospects in this weak market are not clear.

11 PROFITABILITY OF THE CHEMICAL REFINERY

In previous sections, approximate values for the capital and operating costs of the Chemical Refinery were developed, and the income to be realized from the sale of products was calculated.

From an analysis of these items of expense and income, the degree of profitability of this venture can be determined. In evaluating Chemical Refining*s economic potential, several different commonly used measures will be employed.

A summary of "Chemical Refining Economics" is given in drawing 1151-7, page 11-2. This data is presented in a flowsheet arrangement so that refinery sections and their capital and operating costs can be more readily correlated with their products and. estimated income. The tabulation in the lower left hand corner provides a convenient recapitulation of costs.

Return on Investment

The annual return on plant investment (before allowance for income taxes) is approximately 23.88$.

This rate of return is calculated as follows:

Total Income From Products	$ 8,800,110.
Total Operating Costs	7.518.045.
Gross Profit (Before Taxes)	$ 1,282,065.

$ Return - Gross Profit
Plant Investment

- $1.282.065.
5,368,783.

- 23.88$

Payback Period

The period for payback of plant investment (assuming a level rate of earnings) is 5.29 years, calculated as follows:

Annual Gross Income (Before Taxes)	$ 1,282,065.
Allowance For Income Taxes © 48$	615.391.
Net Profit	I666,674.
Depreciation	349.043.
Cash Flow	$ 1,015,717.

Pay Back Period ** Plant Investment
Cash Flow

= $5.368.783.
1,015,717.

= 5.29 -raATfi

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11 PROFITABILITY OF THE CHEMICAL REFINERY (continued)

It is unrealistic to assume that any plant will always find it possible to operate at rated capacity, or that the market value of its products will remain constant. For this reason, an effort was made to determine the break-even points for plant capacity and the prices of the two major products - lead and zinc.

Break-Even Point for Capacity - See Page 11-4.

The potential profits for various rates of refinery capacity were calculated and then plotted on the graph of drawing 1151-9, Profit vs Capacity.

The break-even point, at which income just balanced expenses, is 75 tons per dav of feed.

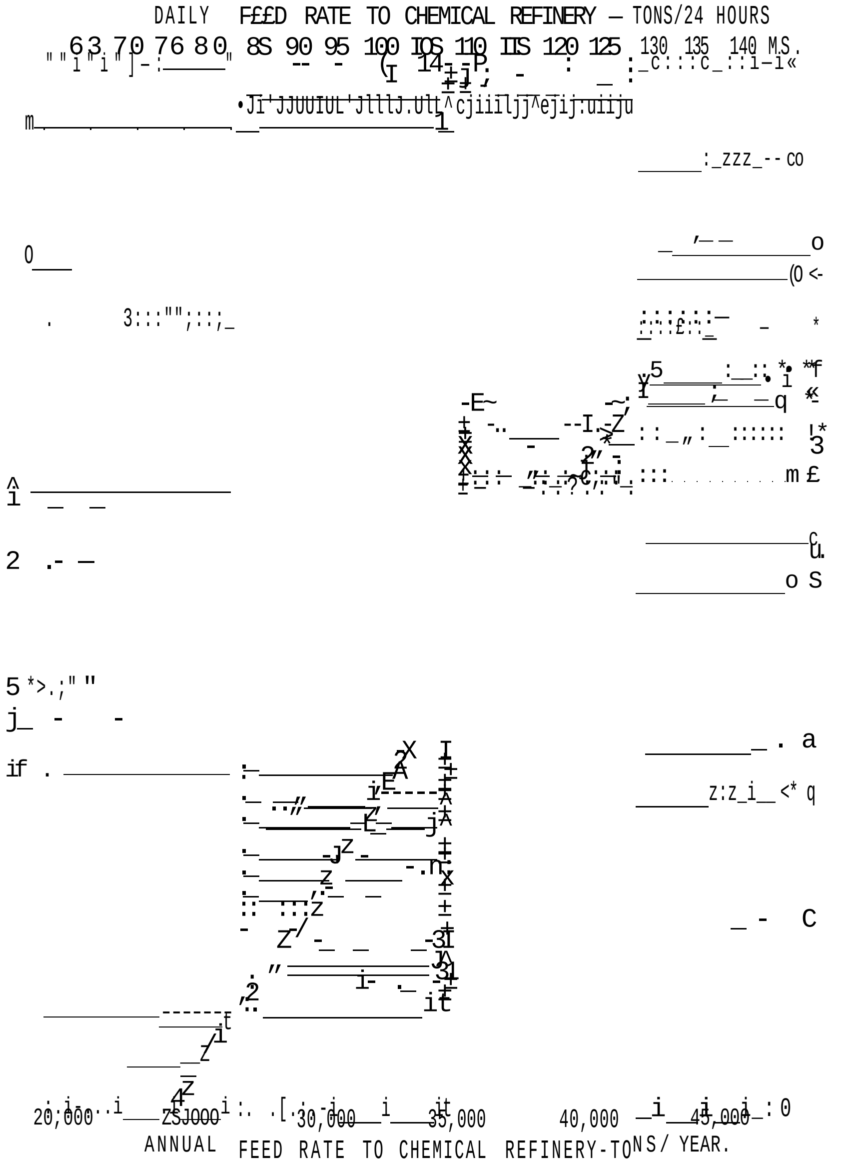
The potential profit for any other rate of operation can be read easily from this graph.

Break-Even Point for Various Prices of Lead & Zinc - See Page 11-5.

The potential profit was calculated for various combined prices of lead and zinc, and then plotted on the graph of drawing 1151-10, Profit vs Metal Price.

The break-even point is 8.35 & per pound for both lead and zinc.

The minimum price of 8.35£ may appear to be very low, but it should be remembered that this is possible only because there is considerable income available from the other products. This calculation, for convenience, assumes that the prices of gold, silver, copper, and cadmium will remain constant at the prices assumed for this study. This assumption has a stabilizing effect on the expected income from products, and allows the (combined) price for lead and zinc to fall considerably before producing a significant change in profits.


DAILY FEED RATE TO CHEMICAL REFINERY — TONS/24 HOURS
63 70 76 80 85 90 95 100 105 110 115 120 125 130 135 140 M.S.
20,000
25,000
30,000
35,000
40,000
45,000
ANNUAL FEED RATE TO CHEMICAL REFINERY-TONS/YEAR.

10 11 12 13 14 15

WEIGHTED AVERAGE PRICE OF LEAD S ZINC - Ctnf /

11 PROFITABILITY OF THE CHEMICAL REFINERY (Continued)

Capital For Initial Phases Of Operation

Some capital will be required to finance the operations of the Chemical Refinery until production has stabilized and income is received regularly. This initial requirement of additional capital is difficult to estimate accurately because of the many variables involved. However, as a conservative estimate, it would appear that two–and-one-half million dollars would cover start-up expenses, initial purchases of ore and concentrates, initial requirements of operating supplies and other materials, and provide a moderate reserve of cash for various unforeseen contingencies.

It is estimated that the Chemical Refinery will attain full production at rated capacity within the first six months and maintain a fairly uniform level of earnings thereafter.

This portion of the capital requirement for the initial phase of operation can be retired in about 5 years. In the calculation of the retirement of this special fund, no allowance has been made for additional monies that might be available from plant investment funds as a result of a depreciation period of less than 15 years, and "investment credits'* applied to income taxes.

SEr.RmTMtl THE SITE FOR THE CHEMICAL REFINERY

In selecting a site for the Chemical Refinery, it was decided to select first the mining area that met the following criteria.

1. A long-term record of substantial metallic ore production.

2. Total reserves and resources that could insure an adequate supply of raw material for the refinery.

3. Present ore production that comes from several sources, rather than a single large company.

After applying these criteria to the four areas with a record of base-metal production, it was decided that Area 4 was the most satisfactory. The magnitude of the metal production, reserves, and resources of Area 4 are graphically presented in Drawing 1151-3, page 14-2.

Within Area 4, our choice of a plant site was based on the following criteria:

1. Location on existing railroad to insure economical transport of products, to eliminate capital investment in any rail extension, and to permit the importation of ore, by rail, from other areas. See drawing 1151-6, page 12-2.

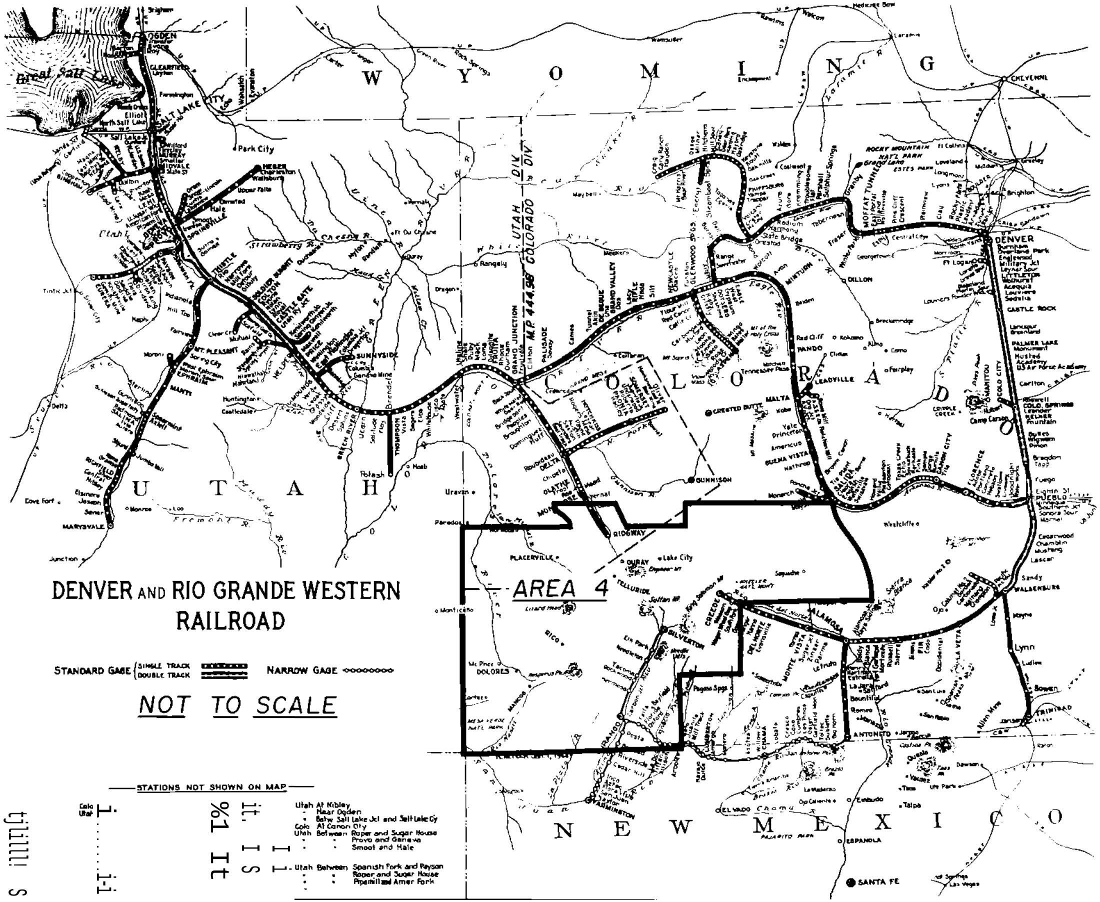
2. dose to present sources of raw materials, that is, within easy trucking distance of existing mills.

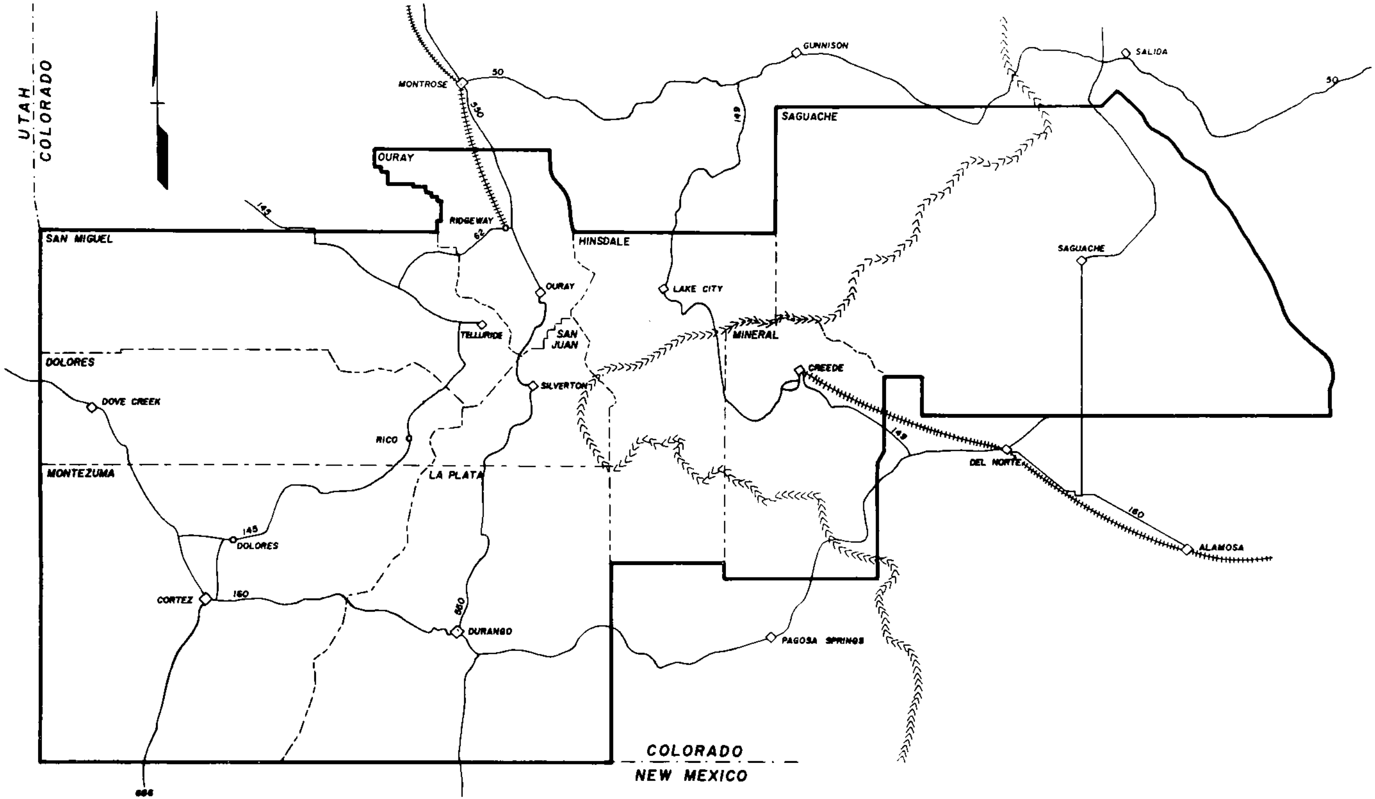
3. Close to potential sources of raw materials, that is, within easy trucking distance of mining districts that could be revitalized. See drawing 1151-5, page 12-3.

4. Close to city or town that could provide a labor force and satisfy their housing and recreational needs.

On the basis of these criteria, it was decided that the refinery site should be tentatively established along the trackage of the Denver & Rio Grande Western Railroad, in the Delta, Montrose, Ridgway area.

A final selection of site would have to be made after a more careful investigation of this area.


DENVER AND RIO GRANDE WESTERN RAILROAD
STANDARD GAGE (SINGLE TRACK / DOUBLE TRACK)
NARROW GAGE
NOT TO SCALE
AREA 4
WYOMING
UTAH
COLORADO
NEW MEXICO
UTAH DIV / COLORADO DIV
M.P. 444.96
DENVER
SALT LAKE CITY
OGDEN
GRAND JUNCTION
PUEBLO
ALAMOSA
DURANGO
SILVERTON
GUNNISON
LEADVILLE
SANTA FE
MOFFAT TUNNEL
STATIONS NOT SHOWN ON MAP
Utah At Kibley
Near Ogden
Betw. Salt Lake Jct and Salt Lake Cy
Colo At Canon City
Utah Between Roper and Sugar House
Provo and Geneva
Smoot and Hale
Utah Between Spanish Fork and Payson
Roper and Sugar House
Pipemill and Amer Fork



UTAH
COLORADO
MONTROSE
50
550
OURAY
RIDGEWAY
62
145
SAN MIGUEL
GUNNISON
149
SAGUACHE
SALIDA
50
HINSDALE
OURAY
LAKE CITY
SAGUACHE
TELLURIDE
SAN JUAN
MINERAL
DOLORES
CREEDE
SILVERTON
DOVE CREEK
RICO
149
DEL NORTE
MONTEZUMA
LA PLATA
160
ALAMOSA
145
DOLORES
CORTEZ
160
550
DURANGO
PAGOSA SPRINGS
COLORADO
NEW MEXICO
666

13 DEVELOPING THE POSITION OF THE SHIPPERS

As it has been conceived and developed in this study, the Chemical Refinery will receive and process three classes of raw materials.

a. Low grade ores
b. High grade ores
c. Concentrates

Each of these three classes will utilize different portions of the total facility. A simplified description of the various process requirements of different classes of raw materials is given in the table below.

PROCESS REQUIREMENT OF RAW MATERIALS

RAW MATERIAL BY CLASS	REFINERY SECTION						
	I I e o	°8 I O	1	&	3 •8 a) e		
Low Grade Ores	Yes	Yes	Yes	Yes	Yes	Yes	Yes
High Grade Ores	Yes	Yes	No	Yes	Yes	Yes	Yes
Concentrates	Yes	No	No	Yes	Yes	Yes	Yes

Within each section, there are other variables which will affect the operating cost of that section. These include considerations such as hardness of ore, reagent consumption, air requirements, etc.

In order to arrive at an equitable and reasonable buying schedule, it will be necessary to give consideration to all of these factors.

Whatever schedule is developed must cover the direct operating cost and provide a return of capital for each section.

13 DEVELOPING THE POSITION OF THE SHIPPERS (continued)

All of the shippers to a Chemical Refinery will gain from its operation and its stimulus to mining in general.

In addition each of the particular classes of shippers will enjoy certain specific advantages, as follows:

Low Grade Ore Shipper

1. Creates a market.
2. Resources become reserves.

High Grade Ore Shipper

1. Saving on rail freight.
2. Facilities for custom milling.
3. Bulk concentrate vs differential flotation.
4. Some resources become reserves.

Concentrate Shipper

1. Saving on rail freight.
2. Bulk concentrate vs differential flotation.
3. Some resources become reserves.

14 METAL PRODUCTION AND RESERVES AND RESOURCES

One of the reasons given for the selection of Area 4 as the location of the Chemical Refinery was the great magnitude of the Area's metal production and its reserves and resources. This choice was largely based on an acceptance of the observation made by Vanderwilt (in Mineral Resources of Colorado, page 21) that: "The production of metallie and non-metallic minerals is dependent on the same economic factors that influence industry. It is therefore logical that the past history of production over a long period is the safest guide to the future."

Refer to the Drawing 1151-3, page 14-2, in which the metal production, reserves and resources are compared. Note that the average annual metal production of Areas 1 and 3 are approximately equal, as are the values produced in 2 and 4. Note, however, that Areas 2 and 4 outproduced 1 and 3 by a ratio of 20 to 1. Note, also, that these quantities are not for a single year, but are -the average of the past eleven years.

Turning to metal reserves and resources, note again how closely Area 1 matches Area 3. Comparing Areas 2 and 4, we find that 4 outranks 2 by a ratio of nearly 2:1. The disparity between Area 4 and Area 1 or Area 3 is even more pronounced, being almost 8 to 1.

Another fact of real significance is that if ths Measured and Indicated portions of the reserves only (see chart - Reserves and Resources - Area IV) were available to a Chemical Refinery then 30 years of life would be assured. When one considers the possible additional supply in Inferred Reserves and along with Measure, Indicated and Inferred Resources then an even greater magnitude of production is possible.

These facts, plus the expanse of Area 4, the many producers in current operation and the potential lumber of mines that could be revitalized, and their past production (see drawing 1151-4), following, led to its selection as the first area within which a prototype of the Chemical Refinery should be operated. Additional Chemical Refineries can later be located in other major mining areas of Colorado.

In an effort to further evaluate the potential of Area 4, it was studied in greater detail. The result of this study is contained in the following county-by-county report.

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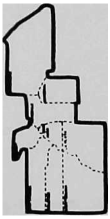

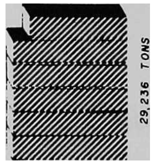

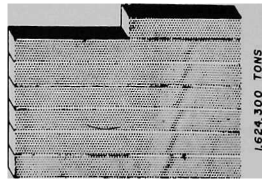

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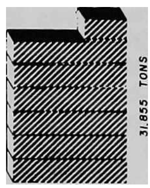

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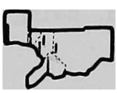

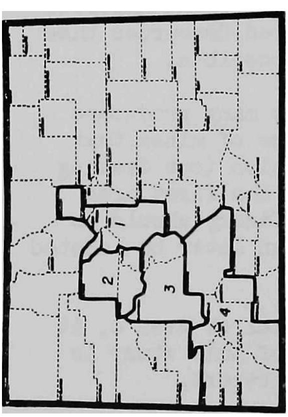

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1A METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

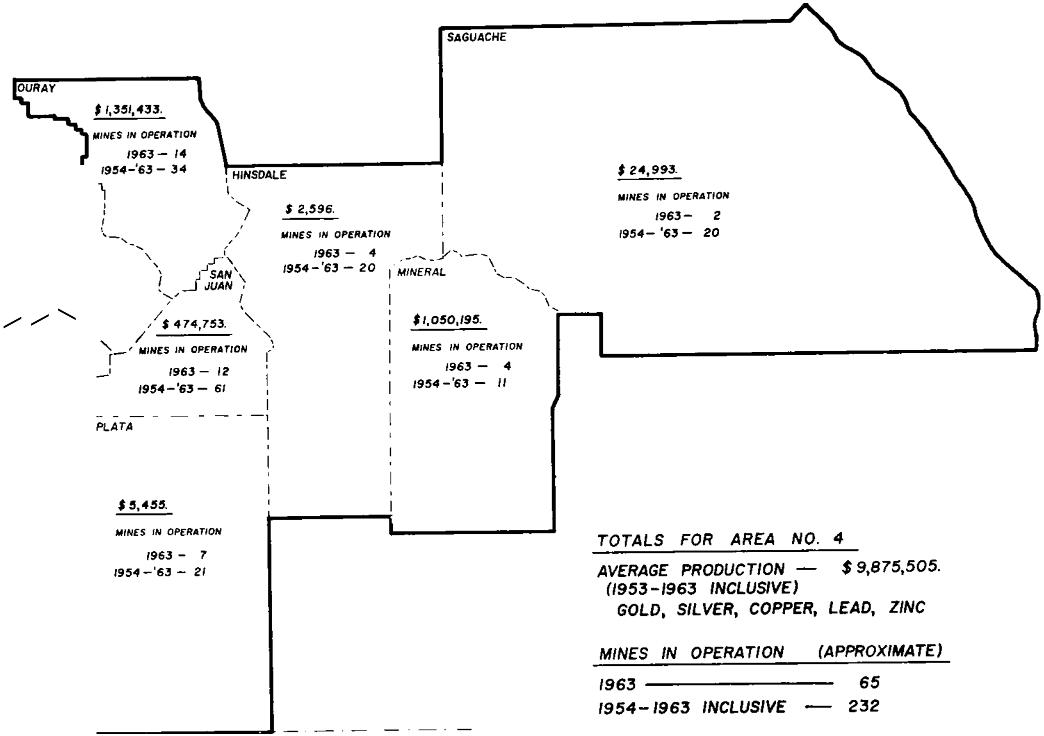
RESERVES AND RESOURCES - AREA IV

(Measured in Short Tons of Metal)

	Reserves	Resources	Total
Measured	300,700	11,900	312,600
Indicated	372,700	34,100	406,800
Inferred	842,200	62,700	904,900
Totals	1,515,600	108,700	1,624,300

Note: Above tonnage includes Copper, Lead, and Zinc only. The weights of gold and silver in troy ounces have not been included.

Above data provided by U. S. Bureau of Mines, February, 1965. See graphical presentation in Drawing 1151-3, page 14-2.



TOTALS FOR AREA NO. 4

AVERAGE PRODUCTION — $ 9,875,505.
(1953-1963 INCLUSIVE)
GOLD, SILVER, COPPER, LEAD, ZINC

MINES IN OPERATION (APPROXIMATE)

1963 — 65
1954-1963 INCLUSIVE — 232

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

DEFINITIONS OF TERMS

Reserves: (Mineral Ore Reserves) Material that can be mined, processed, and marketed at a profit under the economic and technologic conditions prevailing at the time of inquiry.

Resources: (Potential Ore Resources) Material that cannot be mined, processed and marketed at a profit under the economic and technologic conditions prevailing at the time of inquiry. Material that may become a mineral (ore) reserve with improved economic conditions or advancement in the mining and metallurgical methods.

In each of the broad categories above, three sub-classes have been established - measured, indicated, and inferred.

Measured: Ore for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes and for which the grade is computed from the results of detailed sampling. The sites for inspection, sampling and measurement are so closely spaced and the geologic character is so well defined that the size, shape, and mineral content are well established. The computed tonnage and grade are judged to be accurate within limits which are stated, and no such limit is judged to differ from the computed tonnage or grade by more than twenty percent.

Indicated: Ore for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement and sampling are too widely spaced or otherwise inappropriately spaced to outline the ore completely or to establish its grade throughout.

Inferred: Ore for which quantitative estimates are based largely on a broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. These estimates are based on an assumed continuity or repetition for which there is geologic evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred ore should include a statement of the special limits within which the inferred ore may lie.

The above definitions of terms are based on the current terminology employed by U. S. Bureau of Mines.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

County: Dolores
Dolores County lies at the western end of Area 4 (its western boundary being coterminous with the Colorado-Utah border.) The county seat is located in Dove Creek at the western end of the county. The mining activity of the county is centered in the two mining districts of Dunton and Rico.

The Dunton (Lone Cone) Mining District is on the West Dolores River, on State Highway 331 and lies 16 miles northwest of Rico. The altitude of the district is 9,000 to 10,500 feet. Dunton is located within Township 40N, Range 11W, New Mexico Principal Meridian.

The Rico (Pioneer) Mining District is in the valley of the Dolores River, on State Highway 145, 36 miles to Dolores to the southwest and 27 males to Telluride to the north. Altitude is 9,000 to 10,500 feet. Rico is located within Townships 39 and 40N, Ranges 10 and 11W, New Mexico Principal Meridian.

Ore Deposits: (Abstracted from "Mineral Resources of Colorado")
The mountains of the mining districts rise to an altitude of about 12,500 feet. The slopes are steep but not rugged, and below 11,000 feet they are covered by dense growths of aspen and spruce. The mountains are carved from a low structural dome which is roughly circular in shape and 12 to 15 miles across. Rocks ranging in age from pre-Cambrian to Jurassic were involved in the doming.

The main production of the district has come from the northeast, east and southeast sides of the central igneous core. A large part of the production of the district has came from blanket deposits in the lower part of the Hermosa formation on Newman Hill southeast of the town of Rico.

Properties:
The average annual production of metals as reported by the U. S. Bureau of Mines, for the period 1953-1963, was $618,125.

The value of this production is divided among the five principal metals as follows:

Gold	$	2,549.
Silver		51,836.
Copper		3,757.
Lead		281,477.
Zinc		278,506.

During the period 1954 - 1963, the Colorado Bureau of Mines reported that 14 properties had been in operation, of which 4 properties were in operation during 19o3.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Dolores County (continued)

Outlook: By Colorado Bureau of Mines

Ore reserves consisting of silver, lead, and zinc in the Rico and Dunton area and future production of these reserves depends upon favorable market demands and profitable marketing of these minerals. Important past production, under favorable conditions, is an indication of this county*s future production capabilities.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Hinsdale County

Location and Description

Hinsdale County is located between Mineral County (Creede) and San Juan (Silverton). The county seat is located in Lake City. The five mining districts of Hinsdale County are concentrated in the area southwest of Lake City between Lake Fork and its tributary, Henson Creek.

The Burrows Park District is in T 43 N, R 5 W, NMFM.

Carson District is located in T 42 N, R 5 W, NMFM, at the head of Wager Gulch.

Galena (Henson Creek) is in T 44 N, Ranges 4, 5 and 6 W, NMFM.

Lake Fork (Lake San Cristobal) is in T 43 N, R 4 W, NMPM.

Park (Sherman)

The altitude in these districts ranges from 8,600 to 12,000 feet.

Ore Deposits: (Abstracted from "Mineral Resources of Colorado")

The several districts have much in common as to geology and ore occurence. The districts are in the heart of the rugged San Juan Mountains with unsurpassed scenery. However, access is so difficult that prospecting and development are seriously handicapped. Future discoveries of ore comparable to the past are likely as soon as economic conditions are favorable. Zinc and lead production is a possibility if prices become stable at a reasonable level. The principal production has come from the Galena and Lake Districts.

Properties:

The average annual production of metals as reported by the U. S. Bureau of Mines, for the period 1953 - 1963 was $2,596.

The value of this production is divided among the five principal metals as follows:

Gold	$ 560.
Silver	1,505.
Copper	108.
Lead	378.
Zinc	45.

During the period 1954 - 1963, the Colorado Bureau of Mines reported that 20 properties had been in operation, of which 4 properties were in operation during 1963.

Outlook: By Colorado Bureau of Mines

High cost transportation of Hinsdale County ores as well as the lack of treatment facilities in this area has materially hindered metallic production. When these conditions are overcome, many properties in the Lake City and Lake San Cristobal area can become profitable producers.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

La Plata County

Location and Description

La Plata County lies at the south end of Area 4 (its southern boundary being coterminous with the Colorado-New Mexico border). The county seat is located in the county's largest city, Durango.

The principal mining districts are located as follows:

California (La Plata)	-	Townships 36 & 37 N, Ranges 10, 11 & 12 W, NMFM.
Cave Basin	-	Township 37 N, Range 6 W, NMFM.
Needle Mountains	-	Townships 38 & 39 N, Range 7 W, NMPM.

The altitude in these districts ranges from 8,000 to 12,000 feet.

Ore Deposits: (Abstracted from "Mineral Resources of Colorado")

The La Plata minlng district lies within the La Plata Mountains, a rugged mountain group between the main San Juan Mountains and the Colorado Plateau. The climate is rigorous, but the mountains are well-watered, and much of the area of 120 square miles that includes the mines is covered by moderately heavy vegetation. An excellent example of the complex laccolithic type of mountain group, the La Flata Mountains were carved from a domal uplift of sedimentary rocks that were invaded by numerous stocks, dikes and sills of igneous rock.

Ore was first discovered in 1873. By the end of 1937, nearly six million dollars worth of ore had been extracted. More than half this total came from two mines, The May Day and Idaho, and four others yielded a total of more then $1,000,000. Gold has always been the most valuable product of most of the mines, but over 2,000,000 ounces of silver and several hundred thousand pounds of iead and copper have also been recovered. The district ha3 been relatively dormant since 1938, particularly during the years of World War II, when gold mining was discouraged.

It is believed that new deposits will yet be found, and output in the future may well equal, if not exceed, that of the past.

Properties:

The average annual production of metals as reported by the U. S. Bureau of Mines, for the period 1953 - 1963 was $5,455.

The value of this production is divided among the five principal metals as follows:

Gold	$ 4,839.
Silver	467.
Copper	124.
Lead	23.
	2.

14 METAL PRODUCTION AND RESERVES MP RESOURCES (continued)

La Plata County (continued)

During the period 1954 - 1963, the Colorado Bureau of Mines reported that 21 properties had been in operation, of which 7 properties were in operation during 1963.

Outlook: By Colorado Bureau of Mines

Precious metal production along with some base metal production in La Flata County depends almost entirely on the price of gold and silver. When these factors allow profitable mining in the county, mineral production will return to early day proportions.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Mineral County

Location and Description

Mineral County is located in the southwest part of the state and is nearly centered on the New Mexico Principal Meridian. The south boundary line is approximately 30 miles north of the New Mexico border.

Creede, the only mining district in Mineral County, is located in Township 42 N, Ranges 1 E and 1 W, NMPM. The altitude of the district ranges from 9,000 to 11,000 feet.

Creede (the county seat) is at the end of State Highway 149, 41 miles northwest of Del Norte. Access to Creede and much of the surrounding area is not difficult, but as is common in a rugged mountainous country, individual mines and prospects may be hard to reach.

Ore Deposits: (Abstracted from "Mineral Resources of Colorado")

The ore deposits are silver - lead veins in extensive fault fissures in rhyolite and fractured zones of silver ore in shattered rhyolite. The veins carry sphalerite, argentiferous galena, gold, pyrite, and chalcopyrite in a gangue of quartz (amethystine) chlorite, barite, and fluorite. Secondary enrichment was important in places.

The production record illustrates the importance of the area. The persistence of veins with strong mineralization that produced medium to rich ore bodies are factors favorable for continued mining in the future.

Properties:

The average annual production of metals as reported by the U. S. Bureau of Mines, for the period 1953 - 1963, was $1,050,195.

The value of this production is divided among the five principal metals as follows:

Gold	$ 34,243.
Silver	197*438.
Copper	58,t414.
Lead	419,214.
Zinc	340,886.

During the period 1954 - 1963, the Colorado Bureau of Mines reported that 11 properties had been in operation, of which 4 properties were in operation during 1963.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Mineral County (continued)

Outlook: By Colorado Bureau of Mines

Mineral County, like other mineral areas in Colorado, has continued to produce base and precious metals despite inadequate mineral prices. Increased lead, zinc, copper, silver and gold production can be expected from this area when ore treatment facilities are available and favorable prices appear. Present prices would support production if the .small operator had access to a conveniently located ore purchase facility.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Montezuma County

Location and Description

Montezuma County is located in the southwestern corner of Area 4 and the State of Colorado.

There are only three mining districts, all located in the northeast corner of the County.

Bear Creek	- Township 38 N, Range 12 W, NMPM.
East Mancos River	- Township 36 N, Ranges 11 & 12 W, NMPM.
Stoner	- Township 39 N, Range 13 W, NMPM.

The altitude of these districts ranges from 7,200 to 9,500 feet. The county seat is located in Cortez, in the center of the county.

Ore Deposits: (Abstracted from "Mineral Resources of Colorado")

Montezuma County has yielded gold from small but relatively high-grade veins. Small amounts of placer gold are found in stream channels in the western approaches to the La Plata Mountains at the eastern boundary of the county. Placer production has been intermittent and small. The veins with one exception have been small but with sufficient high-grade gold specimens to attract the prospector. The exception referred to is the Red Arrow vein described in the East Mancos district, which was discovered about 1932. The Red Arrow received considerable publicity because of the high-grade native gold that it produced. The area in which the veins are found is in sedimentary formations, a large part of which is Mancos shale. Outcrops are few. Access to many areas is very difficult so that the discovery of the f^ma!! isolated rich veins is largely a matter of chance. It is more than likely that additional veins will be discovered from time to time in this area by the prospector who has the courage to devote the necessary time, which may require several seasons.

Properties:

The average annual production of metals as reported by the U. S. Bureau of Mines, for the period 1953 - 1963 was $765.

The value of this production is divided among the five principal metals as follows:

Gold	$ 636.
Silver	99.
Coppier	29.
Lead	1.
Zinc	0

During the period 1953 - 1963, the Colorado Bureau of Mines reported that 8 properties had been in operation, of which ;. ~w,Tv=iT«t-.T r.<? were in operation during 1963.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Montezuma County (continued)

Outlook: By Colorado Bureau of Mines

Precious metal production from the three mining districts in Montezuma County is contingent on increased prices for gold and silver. Transportation of shipping grade ore, except that of exceedingly high value, makes this area one of high cost production.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Ouray County

Location and Description

Ouray County, embraces an irregular area of land just south of the city of Montrose. The county is bisected by U. S. Highway 550 which connects with Durango to the south.

The four mlni ng districts of Ouray County are within a radius of 10 to 15 miles of Ouray in the southern part of the county, and the area as a whole has been referred to as the Ouray District. The several districts are characteristic localities; each is so isolated from the other by the extremely rugged topography as to justify the sub-division.

Red Mountain District in Township 43 N, Ranges 7 & 8 W, NMPM, is on U. S. 550, 12 miles south of Ouray and one mile north of Red Mountain Pass. Altitude ranges from 10,500 to 11,500 feet.

Ridgway District, in Township 45 N, Range 8 W, NMPM, is on U. S. 550, 13 miles north of Ouray and 23 miles southeast of Montrose. Altitude is 7,500 to 8,500 feet.

Sneffels District, in Township 43 N, Range 8 W, NMPM, is on State 36l. The District is 8 miles west - southwest of Ouray and 1,500 to 3,000 feet higher in altitude, with a well maintained road to the mine camp.

Uncompahgre District, in Township 44 N, Range 7 W, NMPM, is on the east side of the valley immediately north of Ouray. The mines are only a few miles off the main highway (U. 3. 550) but the grades are steep. Altitude ranges from 7,500 to 9,500 feet.

Ore Deposits: (Abstracted from "Mineral Resources of Colorado")

Red Mountain District - The main production of the district has come from the valley of Red Mountain Creek near the old town site of Red Mountain in Ouray County. The largest production came from chimney-like ore bodies in or near breccia pipes and other volcanic plugs.

The rocks are intruded by many plugs and pipes of porphyritic latite and rhyolite and of breccia which range from a few tens of feet to more than 2,000 feet across. Fracturing in and around these volcanic pipes is locally intense and many slightly mineralized fissures abound in the area. In places large bodies of rock are impregnated with finely divided pyrite and alteration products generally typical of ore-forming solutions. Much of the rock, particularly that forming the ridges east of the valley, •;«. v.iohi-0- altered throughout to an aggregate of clay minerals,

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Ouray County (continued)

diaspore, alunite, kaolin minerals and quartz. This weathers to a bright red color that has resulted in the popular name of the mountains. Despite the strong and widespread activity of hydrothermal solutions on the rocks only a comparatively few ore bodies have made an appreciably large production.

Ridgway District - Gold placering on the Uncompahgre River is credited to "near" Ridgway. No other record is available regarding the placer deposits.

Sneffels District - The Sneffels and Telluride (San Miguel County) districts cover about 30 square miles and comprise the northwest swarm of veins and dikes between the margin of the Silverton caldera northwest of Red Mountain Creek and the intrusive stocks of the Mt. Sneffels and Stony Mountain center. The mines are developed from portals in the volcanic rocks within the high glacial basins of several creeks tributary to the main valleys and are inter-connected by tunnels that penetrate the mountain divide between the two counties.

Structurally the veins of the area fall into three principal types though there also are some other local types. The vein swarm is characterized by curving fractures that converge at their northwest ends about the Mt. Sneffels intrusion and at their southeast ends they terminate against or interlace with the bounding faults and fractures of the Silverton caldera. In point of origin the oldest fissures are those occupied by dikes, and they generally follow curving courses. Soma dikes do not reach the surface. A number of important veins such as the Smuggler Union and the Argentine and Montana veins of the Tomboy group follow the walls of these dikes and form one of the main productive classes. Some of these veins in favorable places have yielded a good grade of ore down into the sedimentary strata beneath the volcanic rocks. Another set of vein fissures, somewhat later in origin have a more uniformly straight northwest course, at places cutting diagonally across or terminating against the curved fissures and dikes. These vein fissures commonly dip outward away from the center of the fissure swarm at lower angles of dip than the others; they are termed "flat veins," although their dips are not generally less than 50 degrees. They also tend to steepen upward and flatten somewhat in depth. The flat vein of the Smuggler Union, the Black Bear, the Humboldt, and possibly the Liberty Bell are representative veins belonging to this class. They are believed to have originated by tensions! rupture chiefly of the San Juan tuff,

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Ouray County (continued)

and consequently may not be expected to yield much ore below the base of this formation or of the Telluride conglomerate. A few veins follow the walls of dikes that are concentric to or which spiral outward from the volcanic center. They strike northerly or northeasterly across the other fissures and may be considered to form a third class, but other than the Camp Bird which is a fault fissure, the production from them has been small.

Uncompahgre District - The main part of the district and particularly the part containing the early Tertiary deposits covers about 15 square miles in the vicinity of the town of Ouray.

The commercial development of the mining district has been controlled to a very large extent by the physical features of Uncompahgre canyon, which cuts through the heart of the mineralized area. This canyon and its tributaries are carved •through the volcanic rocks deeply into the ore-bearing sedimentary formations, thus exposing the ores and their associated structural features which would otherwise have been effectively concealed. As the rocks through a vertical range of nearly 6,000 feet are thus exposed within an area only a few miles across, many structural features of San Juan geology spanning the period from the pre-Cambrian to late Tertiary are strikingly revealed. At the canyon bottom cross-cutting intrusive bodies and dikes penetrate the Carboniferous sedimentary rocks and 2,000 feet above spread out in laccoliths and sheets at the base of the Mancos shale. The mineralizing solutions rose beneath the laccolithic dome along the cross-cutting dikes or along fissures and then spread laterally along favorable open or porous sedimentary beds or along fissures where these cut rocks that were readily susceptible to fracturing.

The major gold production was yielded by pyritic deposits in the Dakota quartzite, the beds of which originally were sandstone and have been altered to quartzite for several miles about the center. These deposits, with or without tellurides of gold and silver, are in the form both of veins along dike walls and fissures and of replacement deposits and open channel fillings that follow certain zones along the bedding of the quartzite. The silver-lead production has come chiefly from veins and bedding deposits in rocks ranging from the base of the Dolores formation to the top of the Dakota quartzite.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Ouray County (continued)

Properties:

The average annual production of metals as reported by the U. S. Bureau of Mines, for the period 1953 - 1963 was $1,351,433.

The value of this production is divided among the five principal metals as follows:

Gold	$ 132,500.
Silver	133,991.
Copper	274,265.
Lead	354,931.
Zinc	455,746.

During the period 1954 - 1963, the Colorado Bureau of Mines reported that 34 properties had been in operation, of which 14 properties were in operation during 19o3.

Outlook: By Colorado Bureau of Mines

Ouray County's three major mineral districts are capable of producing large quantities of base as well as precious metals. Development and production of known reserves depends entirely on profitable disposition of these reserves which would be assisted by a local and convenient means of ore purchase and treatment-

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Saguache County

Location and Description

Saguache County lies at the extreme eastern border of Area 4. The county seat is located at the city of Saguache.

There are 7 mining districts in the county: Blake, Cochetopa Creek, Crestone, Crystal Hill, Embargo Creek, Kerber Creek (Bonanza), and Music.

Blake District - Township 45 N, Range U E, NMPM, with
Altitude 9,000-11,000 feet.
Cochetopa Creek - Township 48 N, Range 2 E, NMPM, with
Altitude 8,250 - 8,750 feet.
Crestone District - Township 43 N, Range 12 E, NMPM, with
Altitude 7,500 - 8,000 feet.
Crystal Hill - Township 42 N, Range 6 E, NMPM, with
Altitude 8,000 - 8,300 feet.
Embargo Creek - Township 41 N, Range 4 E, NMPM, with
Altitude 8,500 - 9,000 feet
Kerber Creek - Townships 46 & 47 N, Range 8 E, NMPM, with
Altitude 9,500 - 10,000 feet.
Music District - Township 41 N, Ranges 6 &. 7 W, NMPM, with
Altitude 9,300 - 13,000 feet.

Ore Deposits: (Abstracted from "Mineral Resources of Colorado")

Blake District - Scattered occurences of gold mineralizations.

Cochetopa Creek District - -^ail scattered veins in pre-Cambrian granite and schist, contain primarily gold.

Crestone District - Scattered occurences of gold mineralization in the band of pre-Cambrian rocks on the western side of the Sangre de Cristo Range.

Crystal Hill District - Is a local brecciated area, possibly in the form of a chimney or pipe with small quantities of free gold. Considerable development has been done but only a minor production is reported.

Embargo Creek District - It is reported that prospects show gold, with silver, lead and copper, presumably in veins. No production reported in recent years.

Kerber Creek (Bonanza) District - All of the known metallic ore deposits are veins formed either along fault fissures bounding the blocks or in subsidiary tension fissures formed in the walls of large faults. The extreme fracturing of the rocks in the district created conditions that were not favorable to the formation of long continuous veins, and many ore shoots end against

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

Saguache County (continued)

cross faults which may or may not be appreciably mineralized. Small production may be expected from the district for many years, and possibly other ore shoots as productive as the Rawley may be found eventually.

Music District - Similar to Crestone Area.

Properties:

The average annual production of metals as reported by the U. S. Bureau of Mines, for the period 1953 - 1963 was $24,993.

The value of this production is divided among the five principal metals as follows:

Gold	$ 652.
Silver	3,117.
Copper	2,169.
Lead	13,047.
Zinc	6,008.

During the period 1954 - 1963, the Colorado Bureau of Mines reported that 20 properties had been in operation, of which 2 properties were in operation during 1963.

Outlook: By Colorado Bureau of Mines

Saguache County's former heavy production from the Raleigh area and existing possible ore reserves makes this county a likely heavy producer of complex ores if and when mineral prices and ore outlets are a reality.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

San Juan County

Location and Description

San Juan County has the smallest land area of the counties in Area 4. It lies south of Ouray County and north of La Plata County and is bisected by U. S. highway 550. The county seat is located in the principal city, Silverton.

There are four mining districts in the county: Animas, Bear Creek, Eureka and Ice Lake Basin.

Animas District - is located in Township 41 N, Ranges 6 & 7 W, NMPM, and covers both sides of the Animas River valley immediately northeast of Silverton. Silverton on U. S. 550 is 52 miles north of Durango and 34 miles south of Ouray. Many of the mines and prospects may be 500 to 2,000 feet above the valley on steep slopes that are difficult to reach. The altitude is 9,300 to 13,000 feet.

Bear Creek District - is located in Township 40 N, Range 6 W, NMPM, on the continental divide at the head of Vallecity Creek. The area is in a very rugged part of the San Juan Mountains, 19 miles east of Silverton, mostly by trail and 50 miles west of Creede. The altitude is from 11,000 to 13,000 feet.

Eureka District - is located in Township 42 N, Ranges 6 & 7 W, NMPM, and joins the Animas District on the northeast. The town Eureka is on the Animas River 10 miles northeast of Silverton. The altitude is from 9,800 to 13,000 feet.

Ice Lake Basin District - is located in Township 41 N, Ranges 8 & 9 W, NMPM, in a very rugged mountainous area at the head of South Fork of Mineral Creek about 7 miles west of Silverton. A poor road follows South Fork to the ghost town of Bandora, but the trail from the valley up to Lake Basin is steep. Not only is access to the Basin difficult but the area itself is hard to prospect. Altitude is from 11,500 to 12,500 feet.

Ore Deposits: (Abstracted from "Mineral Resources of Colorado")

Animas District - The mineralized area south and southeast of Silverton is confined roughly to a belt several miles wide along the southern rim of the Silverton caldera. The most productive veins of this area are approximately radial

14 METAL PRODUCTION AND RESERVES AND R7.S0URCES (continued)

San Juan County (continued)

to the southern rim of the caldera or are in fractures that diverge from the radial veins. Another set of fractures trending more or less concentric to the caldera intersect the radial system at high angles. These are commonly filled with dike material and in places are mineralized.

The veins on Sultan Mountain, immediately to the southwest of Silverton, are within a large stock of quartz monzonite. The main product of these veins has been silver derived from galena and gray copper. The sulfide minerals occur in a gangue of quartz, siderite and barite. Hubnerite is also present in small quantities. Gold - bearing pyrite and chalcopyrite in quartz are locally found as bands within the lead-silver veins or in separate fractures. The veins of Sultan Mountain are similar in their mineralogy to the east-west system of veins in Ophir Valley a few miles to the northwest.

Bear Creek District - Narrow white quartz fissure veins with gold and silver telluride (probably petzite) and minor quantities of other sulfides occur in faulted, closely-folded pre-Cambrian schist, slate and quartzite. San Juan andesite tuffs and flows rest upon and partly cover a very irregular eroded surface of the pre-Cambrian rocks. The volcanic rocks have undergone very little noticeable change since their deposition.

Eureka District - The mines of the Cement Creek areas lie within the borders of the Silverton caldera in the Eureka District a few miles north and northwest of the town of Silverton. Two kinds of metalliferous deposits are found in this area; the first are true veins, the second are chimney deposits within volcanic pipes or within bodies of highly altered rocks. Some evidence is available to show gradations between the vein deposits and the more or less pocket-like masses of ore allied to volcanic pipes.

The vein deposits are represented by two more or less distinct mineralogic types. To the first type belong the quartz-pyrite-gold veins such as worked by the Gold King mine. These veins also commonly contain bunches of galena and other base metal sulfides. They are composed characteristically of white quartz with considerable pyrite. Locally free gold is visible in the quartz, but in much of the lower-grade ore it is not seen. Massive pyrite nearly free from quartz characterizes parts of some veins.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

San Juan County (continued)

Chimney deposits similar to those of the Red Mountain District are found in the area immediately northwest of Silverton on the ridge between Mineral and Cement Creeks known as Anvil Mountain. Typical of the deposits is the ore occurrence at the Zuni mine which formed a pipe-like mass 60 feet long and 15 feet wide at the surface consisting chiefly of massive anglesite (sulfate of lead). Un-oxidized guitermanite (lead-arsenic sulfide) and zunyite lay below the sulfate ore, and in depth enargite, pyrite, kaolin minerals, and a little barite were found. There was considerable silver in the enargite ore, and the pyritic ore carried a little gold. Other isolated and small ore bodies of this kind have been mined in this area, and probably many undiscovered ones remain in the large area of altered rocks on the mountain.

Ice Lake Basin District - No data available.

Properties:

The average annual production of metals as reported by the U. S. Bureau of Mines, for the period 1953 - 1963 was $474,753.

The value of this production is divided among the five principal metals as follows:

Gold	$ 35,843.
Silver	48,152.
Copper	48,071.
Lead	183,324.
Zinc	159,363.

During the period 1954 - 1963, the Colorado Bureau of Mines reported that 6l properties had been in operation, of which 12 properties were in operation during 1963.

Outlook: By Colorado Bureau of Mines

San Juan County mineral reserves have been known over a period of many years. Production capabilities from the many mines, some proven, some developed, are as large as any county in the State. Favorable marketing conditions capable of counteracting high transportation costs and reasonable mineral prices would again place this county among the first in production of base and precious metals.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

San Miguel County

Location and Description

San Miguel County is located at the northwestern corner of Area 4, its western boundary is coterminous with the Colorado-Utah border. The county seat is located at Telluride.

There are five mining districts in the county: KLondyke, Lower San Miguel, Mount Wilson, Ophir, Upper San Miguel.

KLondyke District - is located in Township 43 N, Range 16 W, NMPM, at the head of Gypsum Valley north of Cedar on State Highway l6l, and a few miles south of State Highway 80. The altitude is from 6,000 to 6,500 feet.

Lower San Miguel District - is located in Township 43 N, Ranges 10 & 11 W, NMPM, in the valley of the San Miguel River. The altitude is from 7,300 to 8,500 feet.

Mount Wilson District - is located in Township 42 N, Range 10 W, NMPM, on the slopes of Mount Wilson and Wilson Peak. The mineralized area lies between 12,000 and 13,000 feet of altitude - some 4,000 to 5,000 feet above the nearby town of Newmire. Access is difficult and mining costs high.

Ophir District - is located in Townships 41 & 42 N, Range 9 W, NMPM, on Howard Fork, a tributary of the San Miguel River. The district extends from Ames (on State Highway 145 - 9 miles southwest of Telluride) east for 6 miles to Iron Springs. The road along the valley is fairly good but the adjoining slopes are very steep and difficult for either prospecting or mining. The altitude is from 9,000 to 11,000 feet.

Upper San Miguel District - is located in Township 42 N, Ranges 8 & 9 W, NMPM, near Telluride, at the end of State Highway 108 in the valley of the San Miguel River. The mines are 2 to 6 miles east and southeast of Telluride and 1,000 to 3,000 feet above the valley. Access to the mines is difficult, but the higher costs are more than offset by the rich ore.

Ore Deposits: (Abstracted from"Mineral Resources of Colorado")

KLondyke District - The general area is best known for the vanadium that occurs in the Morrison formation. Copper minerals occur intermittently along faults that traverse the area, and native copper replacing limestone has been observed at several places. Relatively little prospecting has been done. In 1939 a trial shipment of 5 tons yielded 68 ounces of silver and 1,700 pounds of copper. No other production is recorded.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

San Miguel County (continued)

Lower San Miguel District - The Sawpit mineralization is found along an 8 foot bed of limestone. Chief values are silver and lead with gold. The ore is highly oxidized so that the original character of the mineralization is obscured, but the deposits are unlike those that characterize the Telluride District to the west.

Mount Wilson District - In this area the equivalent of the Telluride conglomerate is a series of sandstone and shale beds about 1,000 feet thick resting upon Cretaceous shales. The San Juan tuff and over-lying Silverton volcanic series are exposed on the higher grades. The main mass of the mountains, however, is composed of a large igneous stock which varies in composition from diorite to monzonite. All the mines of the area are within the stock or in the sedimentary rocks nearby.

The main vein systems strike west and southwest, and are slightly offset by thin barren veins striking north. The more productive veins are quartz-filled fissures containing pyrite, chalcopyrite and arsenopyrite with lesser amounts of galena, sphalerite, tetrahedrite, stibnite, and calcite. The pay streaks within the veins, though generally narrow, carry high values in gold. In veins in the fine-grained facies of the diorite, chalcopyrite and galena commonly indicate high values of gold, and in those in coarser—grained parts of the intrusion the gold is thought to be associated with arsenopyrite. In the eastern part of the area near Bilk Creek the veins contain considerable galena and sphalerite.

Difficulty of access to this very rugged group of mountains has done much to discourage mining on all but the most prominent veins. Except for the few large explorations in the vicinity of the Silver Pick Mine, the mineralized area still remains one of undetermined value.

Ophir District - The Ophir Mining District centers in Ophir Valley on the Howard Fork of the San Miguel River about 6 miles south of the town of Telluride.

The geology of Ophir Valley is similar to that of the valley at Telluride. Paleozoic and Mesozoic sedimentary rocks are exposed in the bottom of the main westward-draining valley and are successively overlain, on the higher slopes, by the Telluride conglomerate, San Juan tuff, and volcanic formations of the Silverton volcanic series. The thorough alteration precludes the close correlation of these rocks with their

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

San Miguel County (continued)

unmetamorphosed equivalents in the Telluride Valley, and formations of Triassic to Cretaceous age may also be included in the rocks beneath the Telluride conglomerate.

The main system of veins extends along the sides of the valley westward through the intrusions at the mouth of the valley and on toward the Mt. Wilson stock. In general, this system of overlapping veins trends westward, and the individual veins dip steeply into the north and south sides of the valley. The principal values of these veins are in gold, silver and lead. Pyrite, galena, sphalerite, chalcopyrite, and gray copper are the more common sulfide minerals. Hematite and magnetite are not uncommon. The gangue material of these veins is largely quartz with considerable amounts of calcite, manganiferous iron carbonate, and barite. Lesser amounts of fluorite and anhydrite have been noted in some veins. The vein matter forms a typical fissure filling with well defined walls although along strongly shattered parts of the fissures the vein fillings show braided or "linked" structure.

In addition to the prominent vein system just described, there is a complex network of fissures and altered zones high on the north side of Ophir Valley which trend north and northeast and differ considerably from the westerly system in structure and mineralogy. These veins are seams of quartz and pyrite carrying free gold and some silver. Gold values extend out into the altered and pyrite-impregnated country rock.

Upper San Miguel District - See Sneffels District, Ouray County.

Properties:

The average annual production of metals as reported by the U. S. Bureau of Mines, for the period 1953 - 1963 was $6,347,190.

The value of this production is divided among the five principal metals as follows:

Gold	$ 766,742.
Silver	544,619.
Copper	1,335,395.
Lead	1,677,517.
Zinc	2,012,917.

During the period 1954 - 1963, the Colorado Bureau of Mines reported that 43 properties had been in operation, of which 14 properties were in operation during 19&3.

14 METAL PRODUCTION AND RESERVES AND RESOURCES (continued)

San Miguel County (continued)

Outlook: By Colorado Bureau of Mines

Production of base and precious minerals in San Miguel County has remained high due to the efficient operations of the Idarado Mining Company, coupled with outstanding developed ore reserves. The potential production of this county can be estimated by the fact that only a small portion of known deposits are being worked. Convenient ore purchasing facilities would greatly stimulate further production.

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