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EVALUATION OF DOMESTIC RESERVES AND POTENTIAL SOURCES OF ORES CONTAINING COPPER, LEAD, ZINC, AND ASSOCIATED METALS

By F. D. Everett and H. J. Bennett

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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* * * * * * * * * * * information circular 8325

UNITED STATES DEPARTMENT OF THE INTERIOR
Stewart L. Udall, Secretary

BUREAU OF MINES
Walter R. Hibbard, Jr., Director

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need approximately 45 percent more copper in 1970 and 110 percent more by 1980 than was consumed in 1960; similar projections for lead indicate increases of 20 percent by 1970 and 45 percent by 1980; zinc projections are 40 percent more by 1970 and 90 percent by 1980. Much of the production of gold and silver is a coproduct of base metals recovery and the projected need for the precious metals exceeds all the United States can produce. Some problems of the industry are mentioned. A graphic evaluation of the economic availability of the reserve and potential sources is shown.

INTRODUCTION

A nationwide investigation, completed in 1964, was made to establish quantities and sources of reserves and potential sources of ores of copper, lead, and zinc and their coproduct and byproduct metals. These quantities were classified according to metals in the ore reserve or potential resource; the quantities were further cataloged as to mining method. Past and 1963 production is reported along with projections of future consumption.

The investigations were made to establish realistic ore reserve and potential resource estimates for copper, lead, zinc, silver, and related metals. The results indicated the adequacy of the resources as related to consumption and the probable trend of future development.

The economic status of the nonferrous base metal industries is dependent upon complicated factors having both domestic and international implications. The terms of the availability for the resources are necessary factors to be used in planning such national policies as tariffs and import quotas, materials for international barter, trade agreements, domestic subsidies, depletion allowances, stockpile allotments, emergency requirements and price controls, procurement, and regional economic planning.

Some of the problems affecting the development and exploitation of the potential resources are noted with the view of providing data for guidance of policy, industrial planning, and technologic improvement. Potential resources could become commercial raw materials if solutions could be found to many of the problems.

The investigations were conducted by personnel of the Bureau of Mines Mineral resource offices. (See appendix.) Mining engineers obtained the reserve and potential resource data from many sources but mainly by contacting mining company officials. Because many companies demanded that reserve information is confidential, company names are not mentioned. Published and unpublished reports, State and Federal Government records, or estimates of the engineers were used when information could not be obtained by personal contacts. In all cases the data were appraised and final estimates adjusted according to the best knowledge available.

Investigative work was completed in 1964. Data from the eight Mineral Resource Areas of the Bureau of Mines were compiled in the national estimate in January and February of 1965. In addition to estimates of reserves and potential resources, engineers of the various areas supplied production data

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by

F. D. Everett[1] and H. J. Bennett[2]

ABSTRACT

This report summarizes the results of a nationwide investigation completed in 1964 to determine the nonferrous base metal ore reserves and potential sources of ore and to evaluate criteria for their ultimate exploitation. Engineers of the Bureau of Mines contacted mining company officials, reviewed reports and Government records, and where necessary made personal appraisals in arriving at the results. The estimates are presented by metals in ores in geographic regions and include some of the problems affecting the reserves and potential sources.

The recoverable metal in the measured ore category and in the total ore reserves was estimated as follows:

Metal	Metal; 1,000 tons	
	Measured reserves	Total measured, indicated, and inferred reserves
Copper............	21,990	74,700
Lead..............	570	30,600
Zinc..............	2,680	21,980

At the 1963 rate of domestic mine production these total reserves would be adequate to provide copper for 62 years, lead for 121 years, and zinc for 42 years. Data also are given for gold, silver, and other coproducts.

Reserve estimates greatly exceed those of previous investigations; some prior estimates of copper reserves are included for comparison (table 23). Projections of requirements for base metals indicated the United States will

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[2]Mining engineer, Area V Mineral Resource Office, Bureau of Mines, Denver, Colo.

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shown in copper until just before 1900 when production began from deposits at Bingham Canyon. The change in 1905 from underground methods to surface mining of the large disseminated deposit in the district stimulated development of other "prophyry" type deposits that have yielded the greatest production of copper in the United States.

The mines of the United States supplied 60 percent of the world primary copper production during World War I and U.S.-controlled mines in other parts of the Western Hemisphere supplied an additional 20 percent. Companies were able to supply all domestic requirements from mines in the United States until 1939 when increased defense needs necessitated importing copper. Since then domestic consumption has depended partly on imports except for the brief period 1960-62, when the United States was a net exporter of copper.

The progressive development of the domestic copper industry is illustrated in figure 1, which shows trends of production, apparent primary consumption, and price. Production data by States is given in table 1.

Six States accounted for 98 percent of the total 1963 mine production of copper: Arizona, 54 percent; Utah, 17 percent; New Mexico, 7 percent; Nevada, 7 percent; Montana, 7 percent; and Michigan, 6 percent.

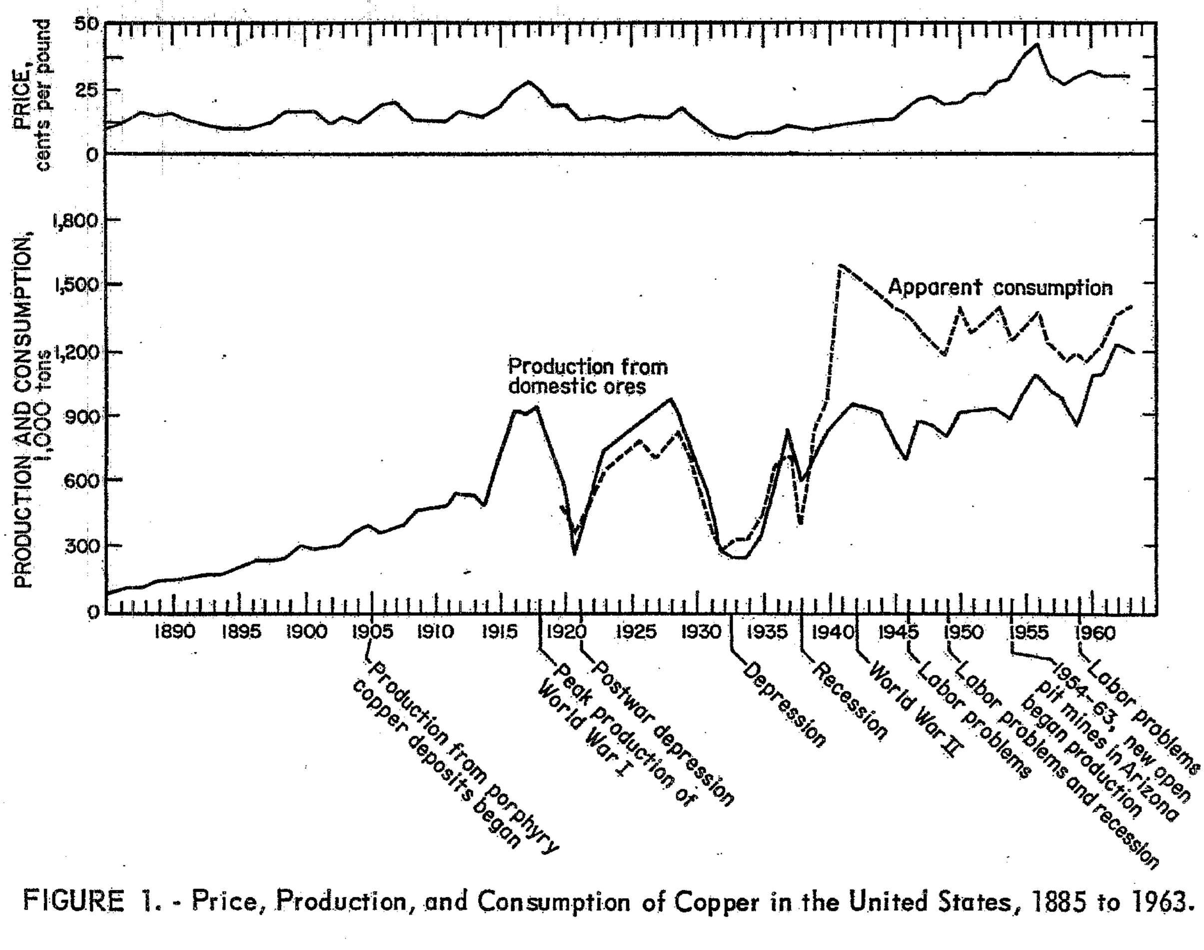

FIGURE 1. - Price, Production, and Consumption of Copper in the United States, 1885 to 1963.

and evaluated problems of the industry. Consumption projections were provided by the Minerals Division of the Washington Office.

The status of nonferrous base metal reserves and potential resources is continually changing. Technologic improvement and expanded development have resulted in increasing reserves in Montana, Nevada, and New Mexico. These expanded reserves and new sources of ore, mostly in Arizona, Michigan, Missouri, Tennessee, and Utah, are in part responsible for a large difference between the present estimate of reserves and that of the President's Materials Policy Commission of 1952.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the many company officials, consulting engineers, and geologists who gave information on mineral deposits. Mineral specialists of State organizations also cooperated by furnishing information and offering constructive evaluations.

Bureau of Mines personnel who directly contributed to the work include the following: Area I, S. A. Gustavson and R. W. Metcalf; Area II, J. R. Boyle; Area III, R. C. Briggs; Area IV, F. F. Netzeband; Area V, W. E. Young (deceased), S. R. Wilson, and W. E. Burleson; Area VI, A. R. Kinkel; Area VII, G. A. Kingston, R. W. Knostman, and S. W. Zoldak; and Area VIII, R. S. Warfield, K. Malone, and R. L. Thorne. W. H. Kerns coordinated the work prior to May 1964. Robert W. Geehan, Area Director of Area V, directed the investigation.

HISTORY AND PRODUCTION

Copper

Copper was being fashioned into jewelry and crude farm and defensive implements by the Indians of North America prior to settlement by white men; the first copper was produced by colonists at Simsburgy, Conn., in 1709 (8).[3] After the rich ore deposits of the Upper Peninsula of Michigan was discovered and exploited in the early 1850's several thousand tons of copper were produced yearly. By 1880 the copper industry was firmly established in the United States with the Calumet and Hecla Mining Co. producing half the domestic output from ore deposits in Michigan which contained as much as 400 pounds of copper per ton.

Following the development of rich gold placers in Montana in the 1860's and of silver deposits in the 1870's, large copper deposits were found at Butte, Mont.

The copper industry of Arizona also began in the 1860-80 period when oxidized silver-copper ores were developed by Phelps Dodge & Co. Production of small quantities of copper in Utah began about 1870 but little interest was

[3] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

discoveries and ultimately to development of the major central and western lead-mining districts such as the Tri-State district of Missouri, Kansas, and Oklahoma; Bingham Canyon, Park City, and Tintic districts of Utah; Leadville district of Colorado; and Coeur d'Alene district of Idaho.

Lead was only an incidental metal in most of the early organized western districts, being associated in ores valued for their gold and silver content. The precious metals, although now usually secondary in value, are important coproducts in lead production.

Following World War I ores containing easily recovered lead-metal were nearing depletion, and smelter penalties for zinc content often offset payments for the lead and silver values in complex ores. At that time selective flotation concentration was developed which enabled the separating of lead and zinc in complex ores, and deposits formerly considered unworkable were able to yield profitable production.

Domestic mine production of recoverable lead reached a peak of 684,000 tons in 1925 and 1926, and subsequently declined with the most recent peak of 496,000 tons in 1942. Secondary production has steadily increased since the

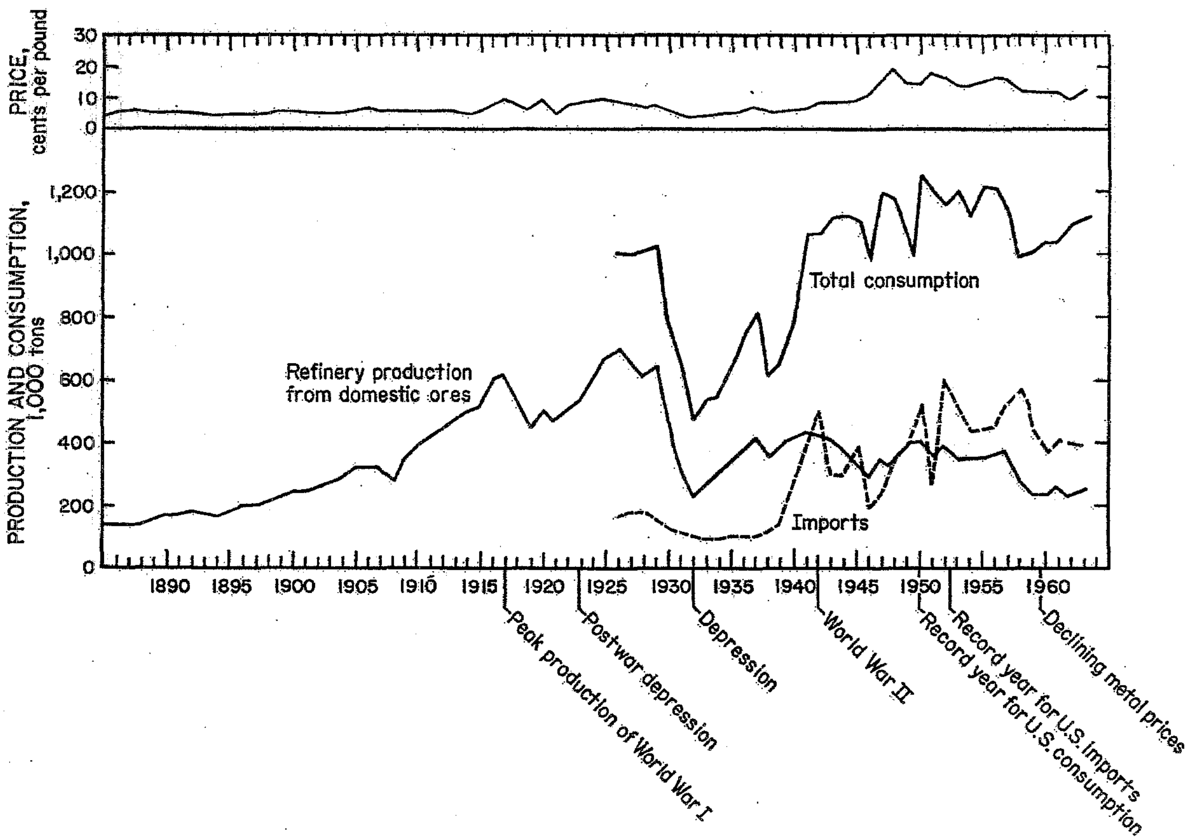

FIGURE 2. - Price, Production, Imports and Consumption of Lead in the United States, 1885 to 1963.

TABLE 1. - Copper production and ranking by States

State	Production			
	Total recoverable metal (short tons)	Ranking	Total 1963 (short tons)	Ranking
Alabama	64	26	-	-
Alaska	686,084	7	-	-
Arizona	19,087,663	1	660,977	1
California	640,848	8	916	11
Colorado	311,875	10	4,169	9
Georgia	1,117	21	-	-
Idaho	183,247	11	4,172	8
Maine[1]	586	22	-	-
Maryland[1]	311	23	-	-
Michigan	5,625,000	4	75,262	6
Missouri	54,434	15	1,816	10
Montana	7,858,000	3	79,762	5
Nevada	2,893,000	5	81,738	4
New Hampshire[1]	137	24	-	-
New Mexico	2,505,560	6	83,037	3
North Carolina	67,609	14	([2])	-
Oregon	12,500	18	([2])	-
Pennsylvania[1]	128,357	13	-	-
South Carolina	10	27	-	-
South Dakota	108	25	1	-
Tennessee	547,095	9	13,717	7
Texas	1,400	19	-	-
Utah	8,813,172	2	203,095	2
Vermont[1]	44,292	16	-	-
Virginia[1]	1,181	20	-	-
Washington	121,855	12	([2])	-
Wyoming	16,336	17	-	-

[1] Data not available prior to 1907.
[2] Less than 70 tons. Data concealed to avoid disclosing individual company data.

Lead

Records indicate that lead mining within the present boundaries of the United States started in Virginia in 1621. In 1659 surface outcrops of lead ores were discovered in the Upper Mississippi Valley district in Wisconsin and northern Illinois with mining starting in 1690. Surface mining began in southeast Missouri about 1700. In 1867 deposits at depths over 100 feet below the surface were exploited by the St. Joseph Lead Co.; this enterprise expanded to become the most productive lead-mining enterprise in the world. In 1963, southeastern Missouri was the leading lead-producing district of the United States and is one of the three leading districts of the world (9).

Completion of the first railroad across the United States in 1869 marked the beginning of significant expansion of the mining industry. Vast unexplored regions were opened to prospecting which resulted in many mineral

About 1850 the New Jersey Zinc Co. developed zinc mineral deposits and began producing ore at the Sterling Hill mine in New Jersey; later, other properties in the Eastern States had zinc ore production. The first commercial production of the smelted zinc was by the Lehigh Zinc Co. of South Bethlehem, Pa., in 1858.

Between 1860 and 1870 several important developments influenced the production of zinc. At LaSalle, Ill., zinc ores from the Upper Mississippi Valley district were successfully smelted in 1860. The first domestic galvanizing was done in 1864, and zinc ore from Missouri was first mined near Joplin in 1872.

Three outstanding technological advances contributed to the development of the domestic industry between 1900 and 1930. The first commercial use of the electrolytic deposition of zinc metal was made in 1914. Two years later the economic applicability of this method was proven by The Anaconda Company at Great Falls, Mont., where cheap electric power was available. A selective flotation which allowed economic use of large reserves of complex ore that previously had been unworkable because of high treatment costs was developed. Also, the reduction of zinc ores and concentrates by continuous distillation in vertical retorts is a significant technical improvement in the reduction of zinc ores and concentrates.

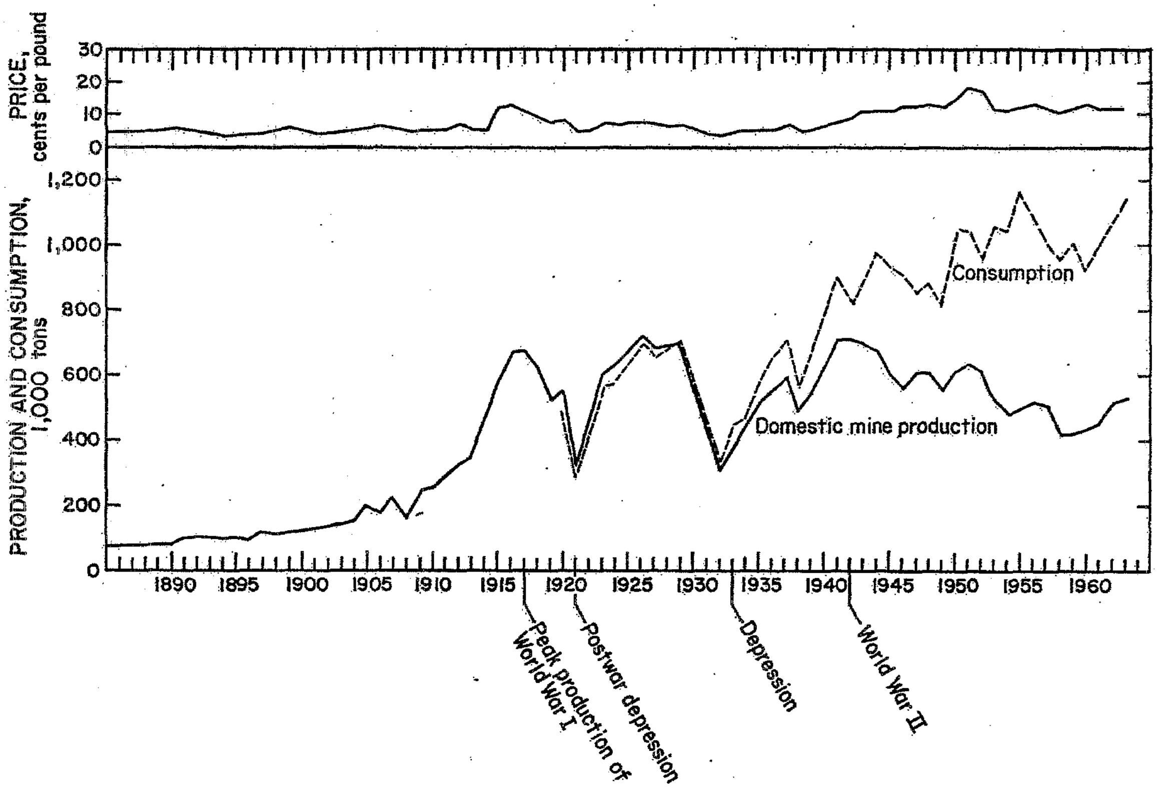

FIGURE 3. - Price, Production, and Consumption of Zinc in the United States, 1885 to 1963.

first recorded production in 1907 and imports abruptly increased in 1940. During 1963, domestic mine production comprised 22 percent of domestic supply; imports, 34 percent; and secondary lead, 44 percent. Lead production, consumption (including secondary as well as primary lead), imports, and price trends are shown in figure 2. Table 2 contains data for comparing by States the past and 1963 production.

TABLE 2. - Lead production and ranking by States

State	Production			
	Total recoverable metal (short tons)	Ranking	Total 1963 (short tons)	Ranking
Alaska	25,000	19	-	-
Arizona	627,559	8	5,815	5
Arkansas	29,333	17	-	-
California	264,699	13	823	17
Colorado	2,816,407	4	19,918	4
Idaho	7,171,859	2	75,759	2
Illinois	486,515	9	2,901	10
Iowa	600	24	-	-
Kansas	645,164	7	1,027	13
Kentucky	5,484	20	831	16
Maine[1]	-	-	-	-
Missouri	10,332,858	1	79,844	1
Montana	928,000	6	5,000	7
Nevada	393,547	11	1,126	11
New Hampshire[1]	132	26	-	-
New Mexico	337,430	12	1,014	14
New York[1]	48,108	16	1,009	15
North Carolina	1,044	22	62	18
Oklahoma	1,291,570	5	3,192	9
Oregon	830	23	-	-
South Dakota	504	25	-	-
Tennessee	27,143	18	-	-
Texas	5,450	21	-	-
Utah	5,194,650	3	48,028	3
Vermont[1]	-	-	-	-
Virginia[1]	142,354	15	3,500	8
Washington	227,014	14	5,374	6
Wisconsin	430,000	10	1,116	12

[1] Data not available for production prior to 1907.

Four States accounted for 87 percent of the total 1963 lead production: Missouri had 31.6 percent; Idaho, 30.0 percent; Utah, 17.6 percent; and Colorado, 8.0 percent.

Zinc

Zinc minerals in quantity were found originally in association with the lead ore mined. In the early period of lead mining, zinc was considered a nuisance metal and, where possible, generally was avoided (7).

Placer gold, discovered in California in 1848, precipitated the famous gold rush of 1849. By 1853 the United States was the leading gold producer of the world, a position it maintained for 50 years. Gold was discovered in Alaska in 1869, and important production has come from several districts (14, p. 7). The major gold-producing properties in the United States in 1964 were the Homestake mine (discovered in 1879) at Lead, S. Dak., and the Bingham Copper mine at Bingham, Utah (Kennecott Copper Co.). The Carlin property of the Carlin Mining Company (Newmont Mining Co.), Carlin, Nev., became operative in May 1965 and was scheduled to attain a production of 200,000 ounces per year. Thus Homestake and Carlin were the only major properties mined only for gold in 1965. Virtually all production from the Cripple Creek, Colo., ore deposit (discovered in 1891), ceased in December 1961. In 1963, 36 percent of the domestically mined gold was recovered as a coproduct in the treatment of base metal ores.

Figure 4 presents a graphical history of domestic gold production by showing trends, price, and source. Table 4 contains data for comparing by States past and the 1963 production.

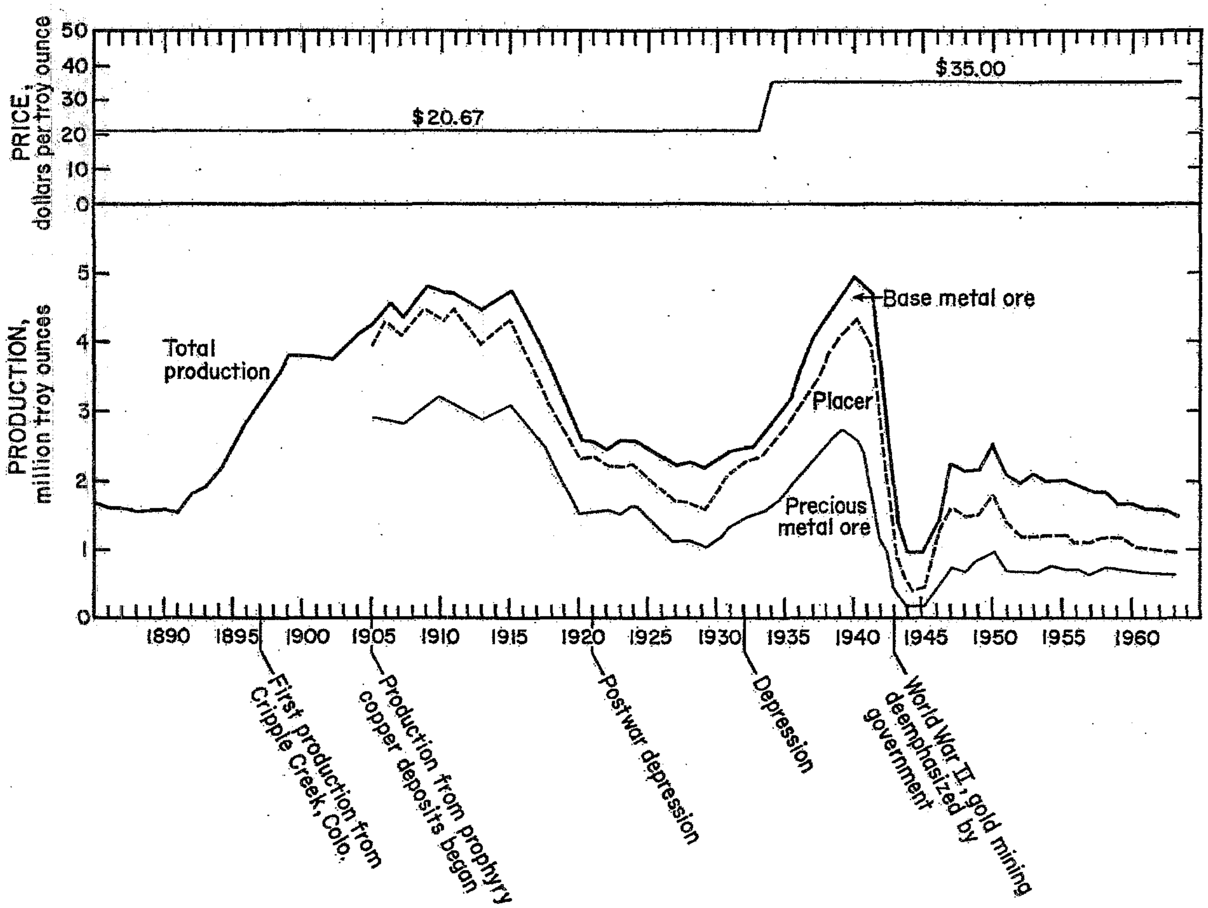

FIGURE 4. - Price, Production, and Source of Gold in the United States, 1885 to 1963.

Domestic mine production of zinc was sufficient to supply demand until about 1939 when domestic demand began to rely upon imported zinc.

Zinc production, consumption (primary slab zinc plus zinc contained in pigments made directly from ore), and price trends are shown in figure 3. Table 3 contains data by States for comparing past and the 1963 production. Seven States accounted for 68 percent of the total 1963 mine production: Tennessee, 18 percent, Idaho, 12 percent; New York, 10 percent; Colorado, 9 percent; Utah, 7 percent; Montana, 6 percent; and New Jersey, 6 percent.

TABLE 3. - Zinc production and ranking by States

State	Production			
	Total recoverable metal (short tons)	Ranking	Total 1963 (short tons)	Ranking
Arizona	938,592	13	25,419	9
Arkansas	1,928	22	-	-
California	150,676	18	101	20
Colorado	2,058,963	7	48,109	4
Idaho	2,400,930	6	63,267	2
Illinois	376,081	17	20,337	12
Iowa	130,000	19	-	-
Kansas	2,863,253	4	3,508	16
Kentucky	37,825	21	1,461	17
Maine[1]	-	-	-	-
Missouri	3,697,403	3	321	19
Montana	2,742,000	5	32,941	6
Nevada	483,925	15	571	18
New Hampshire[1]	-	-	-	-
New Jersey[1]	3,988,323	2	32,738	7
New Mexico	1,267,187	11	12,938	15
New York[1]	1,418,221	10	53,495	3
North Carolina	13	26	13	21
Oklahoma	5,159,079	1	13,245	14
Oregon	176	25	3	22
Pennsylvania[1]	117,401	20	27,389	8
South Dakota	265	24	-	-
Tennessee	1,692,861	8	95,847	1
Texas	850	23	-	-
Utah	1,621,189	9	36,179	5
Vermont[1]	-	-	-	-
Virginia[1]	710,905	14	23,988	10
Washington	483,682	16	22,270	11
Wisconsin	1,155,000	12	15,114	13

[1] Data not available for production prior to 1907.

Gold

Historical records indicate that gold was reported by the early explorers in the southwestern area and the eastern Appalachian area of the United States in the latter part of the 16th century and the early part of the 17th century.

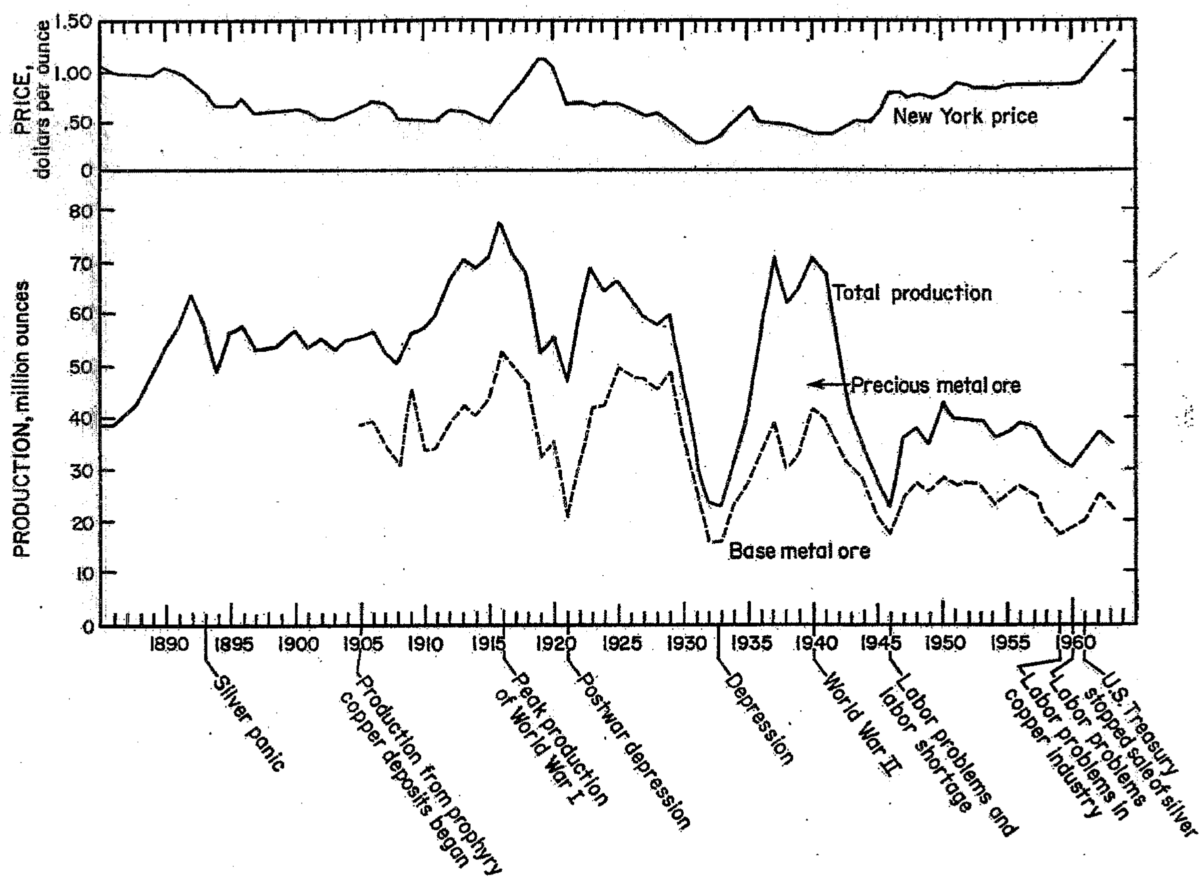

FIGURE 5. - Price, Production, and Source of Silver in the United States, 1885 to 1963.

TABLE 5. - Silver production and ranking by States

State	Production			
	Total recoverable metal (1,000 ounces)	Ranking	Total 1963 (1,000 ounces)	Ranking
Alabama..............	6	25	-	-
Alaska...............	[1]20,300	10	-	-
Arizona..............	375,260	5	5,373	2
California...........	119,307	7	157	10
Colorado.............	772,861	3	2,307	5
Georgia..............	17	24	-	-
Idaho................	769,274	4	16,711	1
Illinois.............	158	21	-	-
Kentucky.............	5	26	2	16
Maine[2].............	-	-	-	-
Michigan.............	12,196	12	339	7
Missouri.............	8,459	14	132	11
Montana..............	841,699	1	4,242	4

See footnotes at end of table.

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TABLE 4. - Gold production and ranking by States

State	Production			
	Total recoverable metal (1,000 ounces)	Ranking	Total 1963 (1,000 ounces)	Ranking
Alabama...............	50	17	-	-
Alaska................	[1]29,800	4	100	4
Arizona...............	13,017	8	140	3
California............	105,995	1	87	6
Colorado..............	40,697	2	34	7
Georgia...............	871	14	-	-
Idaho.................	8,312	9	5	10
Maine[2]..............	-	-	-	-
Montana...............	17,701	5	19	8
Nevada................	15,329	7	99	5
New Hampshire[2]........	-	-	-	-
New Mexico............	2,251	12	8	9
North Carolina........	1,174	13	([3])	-
Oregon................	5,794	10	2	11
Pennsylvania[2].........	52	16	([4])	-
South Carolina........	319	15	-	-
South Dakota..........	29,963	3	577	1
Tennessee.............	24	18	([3])	-
Texas.................	4	20	-	-
Utah..................	17,051	6	286	2
Vermont[2]............	2	21	-	-
Virginia[2]............	12	19	-	-
Washington............	[5]2,844	11	99	5

[1]Approximate.
[2]Data not available for production prior to 1907.
[3]Less than 150 ounces.
[4]Included with Washington.
[5]Production for 1957-63 not included.

Silver

Rich deposits of silver ore were discovered and exploited in the Western United States in the 1860's. These discoveries included the Comstock Lode, Reese River, and Eureka deposits, Nevada; Tintic and Park City deposits, Utah; Leadville deposits, Colorado; and many others. Production from the Coeur d'Alene district, Idaho, started in the mid-1880's (8). In 1963 this remained the only major area in which ores were mined chiefly for their silver content. In 1963, 67 percent of the domestically mined silver was recovered as a coproduct in the treatment of base metal ores.

The historical trends of the domestic silver-producing industry are shown graphically by production, price, and source in figure 5.

Table 5 contains data for comparing past production and 1963 production.

Inferred ore: 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. Mineral bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Specific estimates of inferred ore usually include a statement of the special limits within which the inferred ore may occur.

Potential (submarginal) resources: Material that may become a mineral (ore) reserve with improved economic conditions or by advancements in the technology of mining and metallurgy enabling more economical production methods. The definition of Blondell and Lasky (5) is appropriate and can be stated:

> Potential resources equals marginal plus submarginal plus latent resources. (No latent resources are included in the estimates made for this report.)

Classification of Ores

Definitions of ores as pertain to reserves and potential resources in this report were taken from classifications published in the 1954 Bureau of Mines Minerals Yearbook (4). Details of the classifications follow:

> Copper ores include direct smelting ores containing 2.5 percent or more recoverable copper, and ores and tailings concentrated or leached chiefly for their copper content. Ores leached in place or ores for which tonnage cannot be calculated are excluded; slags smelted for their copper content are included.

> Lead ores include direct smelting ores containing 5 percent or more recoverable lead, irrespective of the precious metal content, and ores, tailings or slags that are concentrated chiefly for their lead content.

> Zinc ores include ores and tailings that are concentrated chiefly for their zinc content, irrespective of the precious metal content. Virtually no zinc ore is smelted directly except for cold slags, which when fumed are classified as smelting ore and may contain as little as 5 percent recoverable zinc.

Ores of Base Metals

Copper

Copper ores are classified as ores containing native copper and sulfide and oxidized minerals. The principal oxide mineral of copper, cuprite (Cu_2O) is found at many deposits but is not as abundant as the oxidized minerals in the form of carbonates, sulfates, or silicates. These include (1) the carbonates, malachite and azurite; (2) the sulfates, brochantite, chalcanthite, and kronkite; and (3) the silicates, chrysocolla and dioptase (6).

TABLE 5. - Silver production and ranking by States--Continued

State	Production: Total recoverable metal (1,000 ounces)	Ranking	Total 1963 (1,000 ounces)	Ranking
Nevada................	605,165	6	215	9
New Hampshire[2]........	-	-	-	-
New Mexico............	73,181	8	256	8
New York[2]............	1,100	17	20	15
North Carolina........	473	19	([3])	-
Oregon................	5,381	15	58	14
Pennsylvania[2].........	347	20	([4])	-
South Carolina........	40	23	-	-
South Dakota..........	11,875	13	117	12
Tennessee.............	4,079	16	108	13
Texas.................	33,300	9	-	-
Utah..................	823,249	2	4,791	3
Vermont[2].............	508	18	-	-
Virginia[2]............	90	22	-	-
Washington............	[5]16,391	11	374	6

[1]Approximate.
[2]Data not available for production prior to 1907.
[3]Concealed to avoid disclosing confidential information.
[4]Combined with Washington.
[5]Production for 1957-63 not included.

ORE RESERVES AND POTENTIAL RESOURCES OF BASE METALS

Definitions

Definitions of ore reserves and potential resources and the classifications used in this report follow:

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.

Measured ore: Ore for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drillholes 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 20 percent.

Indicated ore: 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 or otherwise inappropriately spaced to outline the ore completely or to establish its grade throughout.

Replacement occurrences include (1) massive deposits as at Bisbee, Ariz., Bingham and Tintic, Utah, and Ducktown, Tenn.; (2) lode deposits as at Superior and Bisbee, Ariz., and Butte, Mont.; and (3) disseminated porphyry deposits as at Bingham, Utah, Ely, Nev., Ajo, Miami,, Morenci, Ray, San Manuel, and others, Ariz., and Santa Rita, N. Mex.

Lead and Zinc

The important lead and zinc ores in the United States occur either as replacements or cavity- and fissure-filling deposits (3).

Replacement deposits commonly occur in sedimentary rocks as mineral replacement of limestone and dolomite. These deposits are lower in grade but larger in tonnage than the cavity- and fissure-filling deposits. Structurally, they are often flat lying or gently dipping deposits best exemplified in the southeast Missouri lead belts and the Tri-State zinc-lead district of Missouri, Kansas, and Oklahoma. Many other replacement deposits, such as the massive type, occur at Leadville, Colo., and at the West Mountain (Bingham) and Tintic districts in Utah, or in vein type as at Park City, Utah; Coeur d'Alene, Idaho; and Franklin, N. J.

Cavity- and fissure-filling deposits can be subdivided into (1) fissure veins as in the San Juan mining district, Colo., (2) breccia filling as at Jefferson City and Mascot, Tenn., and (3) pitches and flats as in the Upper Mississippi Valley of Illinois and Wisconsin.

Compilation of Reserves and Potential Resources

Ore reserves and potential resources are reported by quantity of material and by gross content of metals according to the applicable mining method and type of ore. No estimate is included of the low-grade oxidized or sulfide material surrounding minable portions of porphyry or disseminated copper deposits. Improvements in technology may allow these weakly mineralized materials to be a future source of metals.

Estimates of reserves and potential resources must be considered as continually changing according to economic and technologic influences. Base metal reserves and potential resource data for copper, lead, zinc, silver and associated gold in these deposits in the United States, as estimated in 1964, are contained in table 6. Tables 7 through 12 list the reserves and potential resources by geographic regions. Combinations of certain areas were necessary to avoid disclosing confidential company data. Tables 13 through 21 concern distribution of the reserves and potential resources by types of deposits. Figures 6 and 7 show general location and type of deposits containing the reserves and potential resources.

Where appropriate the quantities listed in tables were rounded; the measured and indicated quantities in both the reserve and potential resource classifications were rounded to contain a maximum of four significant figures, and the inferred quantities were rounded to contain a maximum of three significant figures.

Sulfide copper minerals include chalcopyrite and bornite (each containing iron as well as copper); enargite, containing arsenic; and tetrahedrite, containing antimony. Chalcocite, a secondary mineral, usually is a contituent of the richest sulfide ore.

Mixed sulfide and oxidized ores normally are processed by milling, smelting, and refining. Oxidized ores are usually treated by leaching and the copper is recovered from solution by electrolysis or chemical precipitation (16).

Lead and Zinc

Lead ores may be conveniently segregated as comprising oxidized and sulfide minerals. Some ores contain but one mineral of lead, such as cerussite or galena; however, minerals of lead, iron, zinc, and sometimes gold, silver, and copper are often associated together in complex deposits (9).

Galena (PbS) is the most common lead mineral; when pure it contains 86.6 percent lead. The oxide-type minerals, anglesite and cerussite, are usually found in the oxidized or near-surface zone of deposits.

The most important zinc mineral is sphalerite, and its oxidation products are the minerals smithsonite and hemimorphite. Zincite, willemite, and franklinite, zinc oxides and silicates, occur in a separate group of deposits. Ores of zinc often include minerals with lead, silver, gold, copper, iron, and other metals.

Complex lead, zinc, and copper ores usually are concentrated by means of selective flotation. The metals are recovered from the concentrates by conventional smelting and refining processes. High-grade oxidized ores are usually smelted directly but can be concentrated by gravity methods prior to smelting. Gravity concentration of lead-oxidized ores has yielded satisfactory recovery, but gravity concentration of zinc-oxidized ores has not been practical.

Mode of Occurrence of Base Metals

Copper

Most copper occurrences (3) are related genetically to hydrothermal solutions associated with igneous intrusions. Disseminated deposits of this type include cavity fillings and replacements with the majority of deposits classified as the replacement type.

The White Pine deposit in Michigan, which is in Precambrian shale, has geological advocates for both hydrothermal and sedimentary origin (17).

Cavity filling deposits are subdivided into the following types:
(1) Fissure veins as at Butte, Mont.; (2) breccia filling as at Bisbee, Ariz.; (3) cavity fillings as at Bisbee, Ariz.; and (4) vesicular fillings as in the Lake Superior district in Michigan.

TABLE 8. - Reserves and potential resources of copper, lead, zinc, silver, and the associated gold in deposits of Arkansas, Kansas, Missouri, Oklahoma, and Texas

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore.....tons..	(1)	424,700	689,200	(1)	(1)	193,000
Gold........ounces..		(2)	(2)			(2)
Silver........do....		17,720	20,000			2,390
Copper.......tons..		1,040	1,430			90
Lead...........do...		14,200	17,200			1,290
Zinc...........do...		2,040	3,270			720

[1] Some companies have measured or indicated ores but many of them preferred that the Bureau combine the measured with the indicated or the inferred classification for this published record.
[2] Small quantities are present.

TABLE 9. - Reserves and potential resources of copper, lead, zinc, silver, and the associated gold in deposits of Arizona, Colorado, New Mexico, South Dakota, Utah, and Wyoming

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore.....tons..	2,752,000	856,700	913,000	103,400	991,600	1,750,000
Gold.......ounces..	9,970	3,480	4,030	20	450	1,510
Silver........do....	183,300	110,000	211,300	1,510	11,090	119,000
Copper.......tons..	21,390	4,930	6,470	610	3,460	7,800
Lead...........do...	300	690	870	40	110	520
Zinc...........do...	970	1,090	1,690	80	290	820

TABLE 10. - Reserves and potential resources of copper, lead, zinc, silver, and the associated gold in deposits of California and Nevada

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore.....tons..	135,300	43,660	77,100	230	10,760	17,100
Gold.......ounces..	490	450	1,980	(1)	140	400
Silver........do....	2,870	24,380	88,000	100	15,010	27,300
Copper.......tons..	890	230	550	10	40	210
Lead...........do...	10	60	160	(1)	140	120
Zinc...........do...	10	140	170	10	230	480

[1] Small quantities may be present.

TABLE 6. - Reserves and potential resources of copper, lead, zinc, silver, and the associated gold in deposits of the United States[1]

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore...tons..	3,170,000	2,445,000	5,620,000	247,300	1,239,000	15,100,000
Gold......ounces..	10,830	4,590	6,700	70	1,650	6,530
Silver[2 3] ...do....	346,300	299,500	549,000	12,650	89,240	395,000
Copper......tons..	24,510	17,480	43,600	2,910	4,540	57,200
Lead.........do...	670	15,480	19,100	70	480	14,500
Zinc.........do...	3,570	11,500	13,600	200	3,560	58,300

[1]The totals of this table may not agree with totals from other tables owing to the rounding of numbers.
[2]Excludes silver in ores containing principally gold with tungsten.
[3]Copper metal produced in Michigan contains about 10 ounces of silver per ton; most of the silver is not recovered and is not included in the estimates.

TABLE 7. - Reserves and potential resources of copper, lead, zinc, silver, and the associated gold in deposits of the States east of the Mississippi River[1]

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore...tons..	55,070	816,000	3,470,000	140,700	64,070	10,300,000
Gold......ounces..	([2])	([2])	([2])	([2])	([2])	40
Silver[3] .....do....	1,110	34,720	5,050	9,220	720	36,000
Copper......tons..	160	8,660	30,500	2,280	80	45,000
Lead.........do...	20	90	50	([2])	30	80
Zinc.........do...	1,880	6,910	7,940	100	2,100	3,980

[1]States included in totals are Alabama, Georgia, Illinois, Indiana, Kentucky, Maine, Michigan, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Tennessee, Vermont, Virginia, Wisconsin.
[2]Small quantities reported.
[3]Copper metal produced in Michigan contains silver of which only small quantities are recovered. This silver is not included in the estimates.

TABLE 14. - Reserves and potential resources contained in lead deposits of the United States

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore.......tons..	510	421,500	680,000	1,010	1,180	157,000
Gold..........ounces..	([1])	50	10	([1])	10	320
Silver..........do....	10,750	29,980	21,100	250	1,050	15,170
Copper..........tons..	([1])	1,040	1,430	([1])	([1])	100
Lead.............do...	10	14,240	17,200	30	60	1,460
Zinc.............do...	([1])	1,900	3,000	([1])	([1])	170

[1] Small amounts may be present.

TABLE 15. - Reserves and potential resources contained in zinc deposits of the United States

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore.......tons..	32,330	116,900	229,000	6,350	55,720	120,000
Gold..........ounces..	([1])	([1])	([1])	([1])	30	30
Silver..........do....	100	120	300	([1])	100	580
Copper..........tons..	([1])	([1])	([1])	([1])	([1])	10
Lead.............do...	([1])	([1])	([1])	([1])	([1])	10
Zinc.............do...	1,330	5,430	7,320	140	2,110	3,690

[1] Small amounts may be present.

TABLE 16. - Reserves and potential resources contained in copper-zinc deposits of the United States

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore.......tons..	15,900	70,010	260	710	9,490	4,800
Gold..........ounces..	([1])	([1])	([1])	([1])	150	10
Silver..........do....	1,610	5,260	640	([1])	410	730
Copper..........tons..	230	820	10	10	60	50
Lead.............do...	([1])	([1])	([1])	([1])	([1])	([1])
Zinc.............do...	310	900	([1])	10	60	80

[1] Small amounts may be present.

TABLE 11. - Reserves and potential resources of copper, lead, zinc, silver, and the associated gold in deposits of Idaho, Montana, Oregon, and Washington

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore.....tons..	228,100	303,100	476,000	1,390	152,700	2,420,000
Gold........ounces..	380	670	700	40	970	460
Silver........do....	159,000	112,600	225,000	1,590	58,550	180,000
Copper........tons..	2,070	2,610	4,620	([1])	860	230
Lead...........do...	340	430	780	20	200	12,500
Zinc...........do...	710	1,320	560	10	910	52,300

[1] Small amounts are present.

TABLE 12. - Potential resources of copper, lead, zinc, silver, and the associated gold in deposits in Alaska

Crude ore and gross metal content, 1,000 units	Potential resources[1] (1964)		
	Measured	Indicated	Inferred
Crude ore............tons..	1,550	19,400	436,000
Gold...............ounces..	10	90	4,130
Silver...............do....	230	3,860	30,600
Copper...............tons..	10	100	3,840
Lead..................do...	([2])	10	10
Zinc..................do...	([2])	30	30

[1] All estimates were reported as potential resources.
[2] Small quantities may be present.

TABLE 13. - Reserves and potential resources contained in copper deposits of the United States

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore...tons..	3,084,000	1,747,000	4,640,000	236,900	1,127,000	12,300,000
Gold......ounces..	10,210	3,290	5,490	10	1,080	5,000
Silver[1].....do....	203,500	133,000	270,000	9,440	16,020	142,000
Copper......tons..	24,200	15,520	42,100	2,900	4,390	56,600
Lead.........do...	([2])	([2])	10	([2])	([2])	([2])
Zinc.........do...	80	([2])	10	([2])	([2])	30

[1] See footnote 3 in table 6.
[2] Small amounts may be present.

TABLE 20. - Reserves and potential resources contained in zinc-copper deposits of the United States

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore.......tons..	10	3,170	380	590	4,930	36,300
Gold...........ounces..	([1])	30	20	50	60	380
Silver..........do....	20	1,920	1,670	280	2,660	15,000
Copper..........tons..	([1])	60	10	10	50	330
Lead.............do...	([1])	([1])	([1])	([1])	10	70
Zinc.............do...	([1])	190	30	10	200	720

[1] Small amounts may be present.

TABLE 21. - Reserves and potential resources contained in zinc-lead deposits of the United States

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore......tons..	32,320	80,790	53,800	650	30,650	2,370,000
Gold.........ounces..	530	980	470	10	230	740
Silver.........do....	43,810	77,470	115,000	1,080	53,480	126,000
Copper.........tons..	60	40	60	([1])	30	90
Lead............do...	410	840	830	10	220	11,100
Zinc............do...	1,720	2,740	2,700	30	1,010	52,500

[1] Small amounts may be present.

Comments on Reserve Data

Copper

The measured, indicated, and inferred copper-ore reserves total approximately 75 million tons of recoverable copper metal (assuming recovery at 90 percent of gross content). The copper is in different ore types, but predominately copper, copper-zinc, and zinc-copper ores. A total of 74 million tons is in ores mined principally for copper (table 22). An additional 58 million tons of recoverable copper are estimated in the potential resources and may be recovered with future technologic and economic improvements. Estimated measured copper-ore reserves contain almost 22 million tons of recoverable metal.

Measured copper reserves are sufficient for production at the 1963 annual rate of 1,213,000 tons for 18 years. Measured, indicated, and inferred reserves might sustain that production for 62 years. In addition, the measured, indicated, and inferred potential resources, if proven to be minable might extend that production for 110 years at the 1963 rate. The ore reserves average 0.86 percent copper; potential resources average 0.47 percent copper.

TABLE 17. - Reserves and potential resources contained in lead-zinc deposits of the United States

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore.......tons..	2,720	4,200	14,400	1,060	8,700	97,700
Gold..........ounces..	70	130	320	([1])	100	60
Silver..........do....	11,200	34,800	81,000	1,590	14,000	93,700
Copper..........tons..	([1])	10	([1])	([1])	([1])	([1])
Lead............do...	160	360	920	20	160	1,850
Zinc............do...	120	350	530	10	180	1,140

[1] Small amounts may be present.

TABLE 18. - Reserves and potential resources contained in lead-silver deposits of the United States

Crude ore and gross metal content, 1,000 units	Reserves (1964)			Potential resources (1964)		
	Measured	Indicated	Inferred	Measured	Indicated	Inferred
Crude ore.......tons..	760	1,420	2,280		1,000	1,000
Gold..........ounces..	10	110	390		([1])	([1])
Silver..........do....	14,960	15,520	35,000		1,510	1,500
Copper..........tons..	([1])	([1])	10		([1])	([1])
Lead............do...	80	40	100		40	30
Zinc............do...	10	([1])	50		([1])	([1])

[1] Small amounts may be present.

TABLE 19. - Reserves contained in silver-lead deposits of the United States

Crude ore and gross metal content, 1,000 units	Reserves (1964)		
	Measured	Indicated	Inferred
Crude ore............tons..	1,410	50	700
Gold..............ounces..	10	([1])	([1])
Silver..............do....	60,470	1,370	24,500
Copper..............tons..	10	([1])	10
Lead................do...	([1])	([1])	([1])
Zinc................do...	([1])	([1])	([1])

[1] Small amounts may be present.

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TABLE 32. - Problems affecting potential resources of copper--Continued

Resources, 1,000 tons[1]	Copper, percent	Problems and remarks
		Area V[2]--Continued
900,000	0.40	Low-grade ore is a problem requiring an efficient low-cost operation or a higher price for copper. Ore body may be suitable for leaching-in-place type of operation; much of the ore too low grade for current surface mining methods.
200,000	.125	Do.
3,500,000	0.2-0.5	Ore containing less than 0.5 percent copper bordering known deposits. Research needed on methods of cheap extraction, possibly by leaching.
500,000	.50	Research needed for leaching copper-oxide-sulfide material in carbonate rocks.
24,000	.33	Research needed to develop copper-sulfide leaching methods for relatively small deposits.
800,000	.35	Large ore body of mixed oxide-sulfide material; leaching in place may be applicable.
		Area VI[2]
3,367	1.48	Lower costs needed for mining and developing steeply dipping, lenticular, pyritic ore shoots in bedded rocks.
		Area VII[2]
172,000	0.75	Operating costs are prohibitive; the deposits are in rugged terrain and are inaccessible during winter and spring seasons. Cost of ore transportation is high because of remoteness of deposits.
2,427	1.56	Copper occurs in an ore with cobalt and arsenic minerals. Mining costs are extremely high because of square set mining and hydraulic backfilling. Mineral processing costly because of cobalt and arsenic. Cobalt and arsenic recovery costs exceed current value.
		Area VIII[2]
450,000	0.90	General high-cost problems are due to location, mining, development, processing, transportation, and marketing.

[1]Resource in terms of material having a potential of becoming ore.
[2]States in area designations are shown in figure 6.

TABLE 33. - Problems affecting potential sources of lead and zinc

Resources, 1,000 tons[1]	Copper, percent	Lead, percent	Zinc, percent	Problems and remarks
				Areas I, II, and III[2]
1,300	1.23	-	2.27	Several small deposits with diversified ownership that cannot be worked on a scale large enough to yield a profit at current metal prices.
5,300	-	-	1.70	Zinc has been produced as a coproduct of fluorspar production. Fluorspar mines were not operated in 1964.

See footnotes at end of table.

TABLE 33. - Problems affecting potential sources of lead and zinc--Continued

Resources, 1,000 tons[1]	Copper, percent	Lead, percent	Zinc, percent	Problems and remarks
				Areas I, II, and III[2]--Continued
3,500	-	-	0.80	Zinc has been produced as a coproduct of fluorspar production. Fluorspar mines were not operated in 1964.
5,000	-	0.25	1.00	Lead and zinc production is dependent on fluorspar production which in 1964 was not profitable.
108,600	-	-	3.20	Problem is one of a stable price to enable long-range planning and development of efficient mining operations.
8,950	-	-	3.80	Problems involve mining steeply dipping deposits with lower costs.
				Area IV[2]
15,000	-	0.25	1.00	The problem is economics. Higher prices than exist in 1964 must be paid for metals.
166,000	-	.71	.20	Ore deposits are low grade and require improvements in either technology or economic factors.
11,722	-	.30	1.00	Grinding abrasive ore is a costly problem.
				Area V[2]
16,000	-	0.93	2.78	Problems involving unitization of several small deposits. Transportation and absence of milling and smelting plants are basis for relatively high costs.
349	-	-	10.00	Processing facilities are needed for zinc-oxide ore. Problems involve economics; need for increasing reserves and higher prices for zinc.
692	-	-	2.4	Production will depend upon the use of manganese products from rhodenite veins.
16,511	0.25	1.15	1.85	Operating costs must be lowered. High-cost items include mining, transportation, and smelting.
				Area VI[2]
4,489	0.50	0.50	2.68	Problems include relative inaccessibility and need to process mixed oxide-sulfide ores of several small deposits.
7,630	2.41	-	3.81	Do.
12,631	-	1.81	2.37	Transportation costs to smelter and markets are a limiting problem. Some of the ore is a mixed oxide-sulfide and cannot be economically concentrated. Deposits are relatively small and require high-cost operations. Excessive water pumping is a problem at some of the deposits.

See footnotes at end of table.

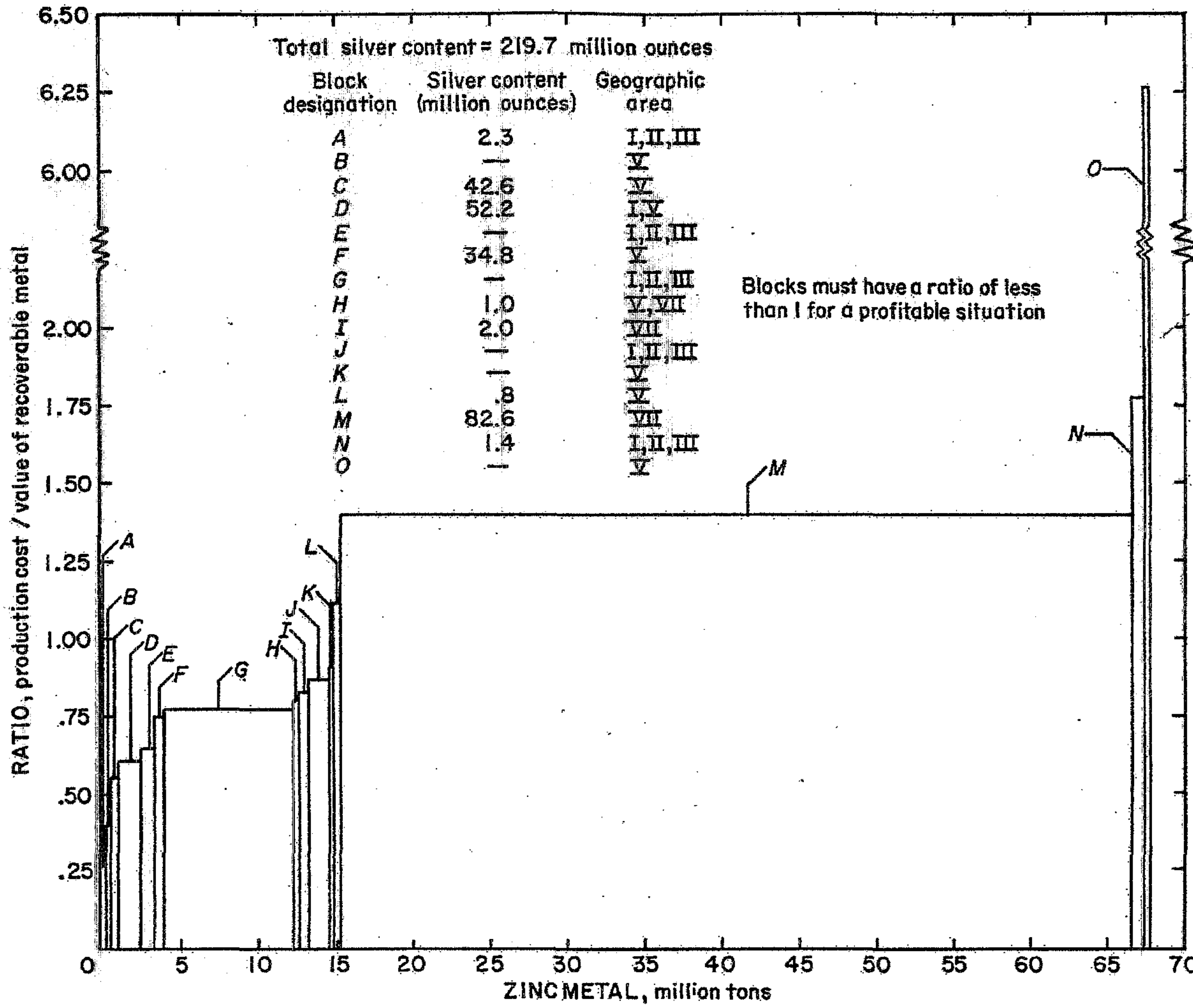

FIGURE 18. - Classification of Zinc Reserves and Potential Resources and the Associated Silver in Terms of the Ratio of the Appraised Production Costs to the Price of the Recoverable Metal.

(particularly lead) have had a less favorable competitive position. In general, the world's abundant supply of lead and zinc has contributed to lower domestic output of these metals and discouraged exploration and development of new reserves. The comparatively recent discoveries in Missouri, Tennessee, and Maine are the exceptions to this trend.

Imports

Accurate appraisal of domestic supply, imports, and expected demand is necessary for copper, lead, and zinc producers to regulate supply and stabilize prices.

Domestic lead-zinc production during World War II was inadequate and consumers became partially dependent on imports, principally from Australia, Canada, Mexico, Peru, Chile, and the Republic of the Congo. Since 1950, the world mine output of nonferrous base metals has increased while United States mine output has declined. The U.S. Government has been cognizant and appreciative of the ready supply of foreign minerals and the need for trade development with foreign countries; thus trade agreements have been made for nonferrous base metals, controlled by restrictive tariffs and import quotas. Although this has resulted in some restraint on domestic prices, benefits have been derived by consumers and by continued favorable internationsl relations. It is possible, in fact quite likely, that the United States will not be dependent on imports in the future, perhaps as soon as 1970.

In 1958, efforts to protect domestic producers included tariffs and import quotas for specific countries. Since 1958, most of those countries have been able to complete their quotas.

TABLE 32. - Problems affecting potential resources of copper

Resources, 1,000 tons[1]	Copper, percent	Problems and remarks
		Areas I, II, III, and IV[2]
3,506	1.98	Several small deposits that can support operations only with higher price for Cu.
1,785	.71	Lead 0.1 percent and zinc 0.64 percent. Small deposits with high-cost problems.
8,000,000	.40	Ore too low-grade to be presently competitive. Problems relate to underground mining steeply dipping veins at depths of more than 5,000 feet below the surface. Specific problems include ground support, control of rock bursts, ventilation, large-volume mining of irregularly distributed mineral, and materials handling. Backfilling may be necessary.
194,000	1.40	Research needed to establish economical, safe underground mining method to recover pillars in heavy ground. Other problems include materials handling, necessity for fine grinding, prevention of sliming. Research needed for leaching of concentrates.
134,491	1.70	Problems include ground support and materials handling. Mining research into applicability of longwall methods of mining.
87,200	.78	Do.
14,491	.78	Research needed for a method for mining steeply dipping replacement bodies in a large-volume operation.
		Area V[2]
100,000	0.60	Low-grade ore is a problem requiring an efficient low-cost operation or a higher price for copper. Ore body may be suitable for leaching-in-place type of operation; much of the ore too low grade for current surface mining methods.

See footnotes at end of table.

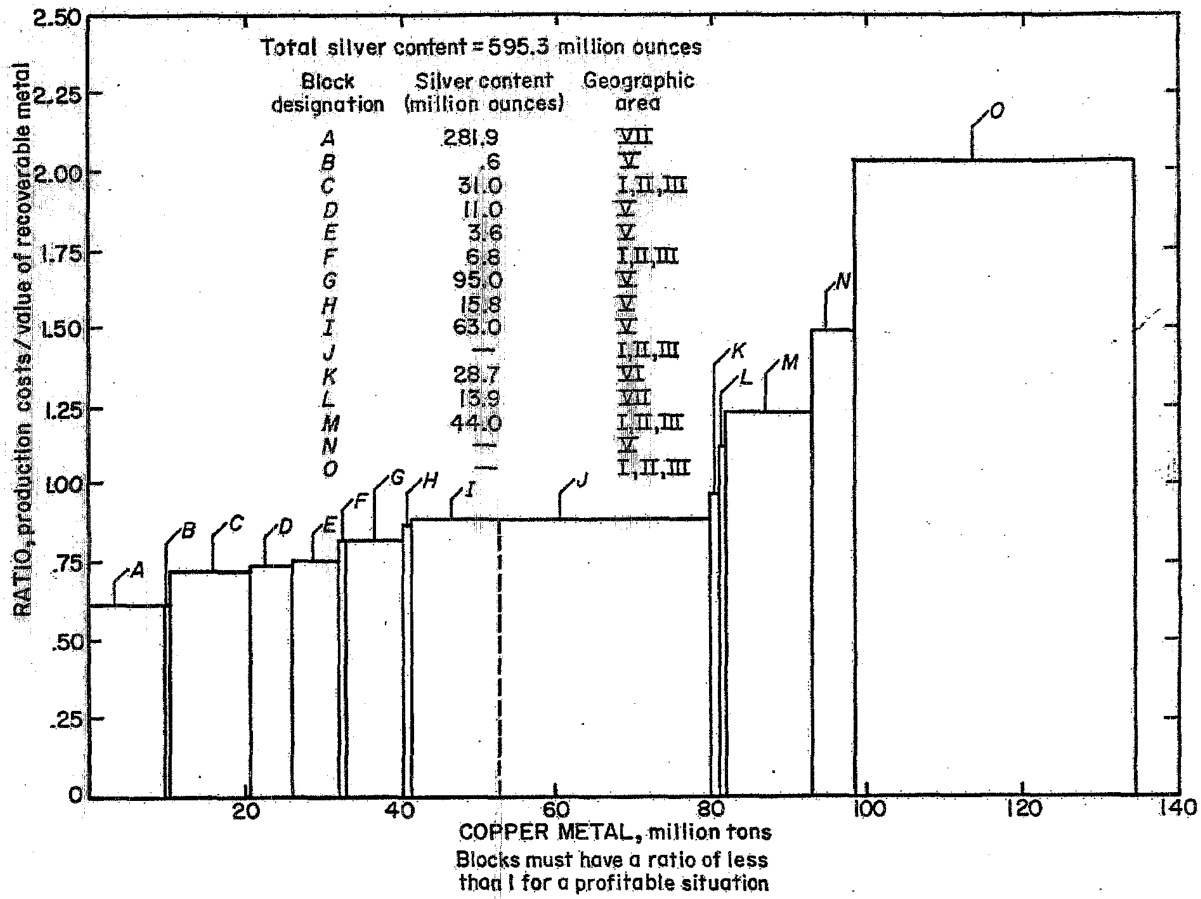

FIGURE 16. - Classification of Copper Reserves and Potential Resources and the Associated Silver in Terms of the Ratio of the Appraised Production Costs to the Price of the Recoverable Metal.

Figures 16-18 can be useful to indicate the quantity of metal that could be produced at a particular cost-value ratio. For example, in figure 16 a ratio of 1.0 would apply to the various blocks at the following cents per pound of copper: A--18, C--21, D--24, E--25, F and G--29, I--30, J--31, M--41, N--50, and O--71.

In figure 17, ores for blocks B, D, and E would have ratios of 1.0 if lead and zinc prices were 10, 13, and 18 cents per pound, respectively. In figure 18, ores in blocks G and J would have a ratio of 1.0 if lead and zinc prices each were 10 and 11 cents per pound, respectively (silver was assumed constant at $1.29 per ounce and copper was adjusted to lead or zinc equivalents).

PROBLEMS OF THE INDUSTRY

Problems of the base metal industry concern adequacy of reserves, economics, and need for technologic improvements. A resumé of some specific

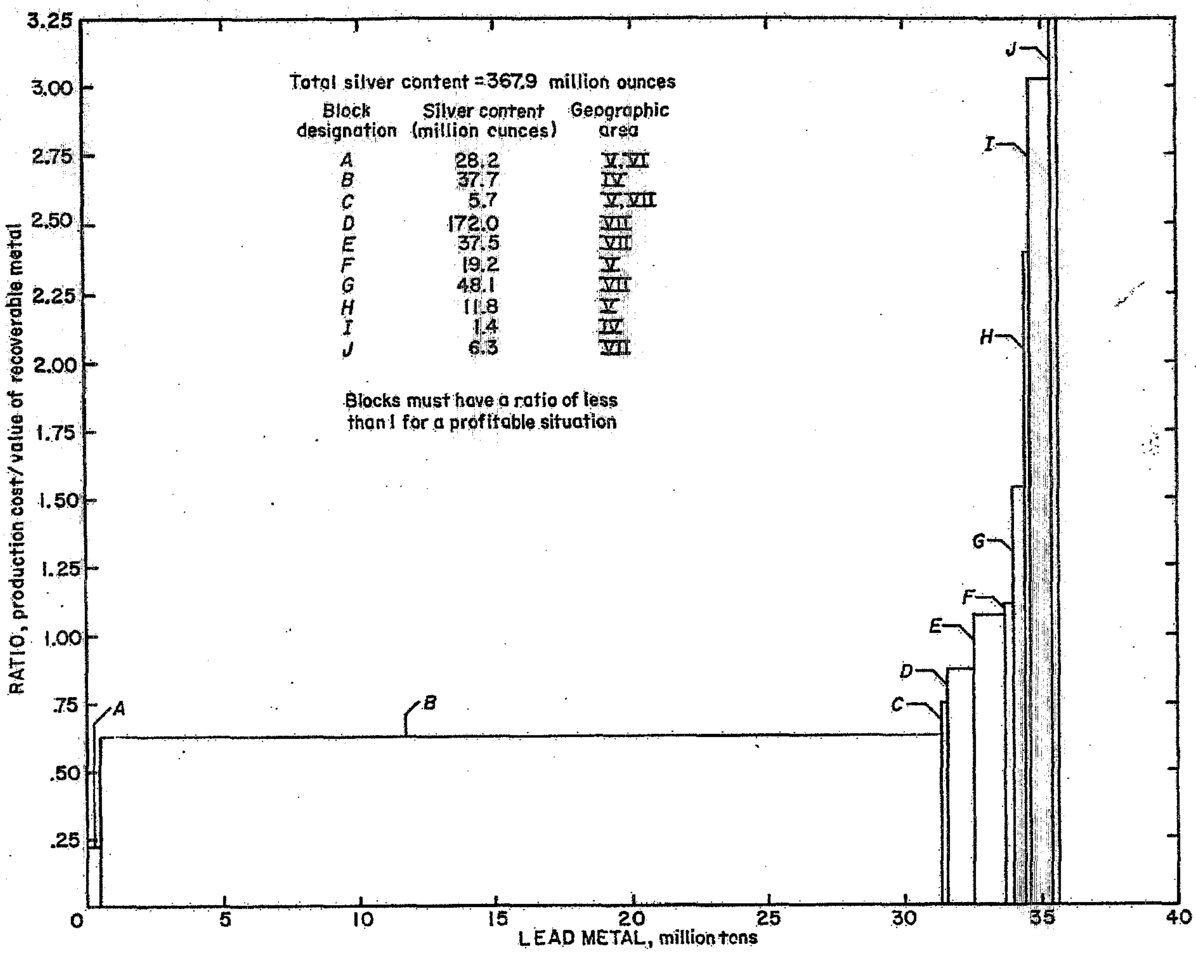

FIGURE 17. - Classification of Lead Reserves and Potential Resources and the Associated Silver in Terms of the Ratio of the Appraised Production Costs to the Price of the Recoverable Metal.

problems in relation to the ore reserves and potential resources is given in tables 32 and 33.

Price of Metals

Prior to World War II domestic producers supplied most of the metals required for consumption in the United States. Requirements during World War II were supplemented by large imports, and foreign producers have continued to supply large portions of our requirements. The abundance of world supply since World War II has resulted in unstable and relatively low metal prices, particularly for lead. Copper producers have been more successful in regulating the production according to demand partly because many of the domestic producers were also foreign producers, and this industry has benefited by a more stable price. The domestic copper industry also has been able to produce at competitive rates with foreign producers, whereas lead and zinc

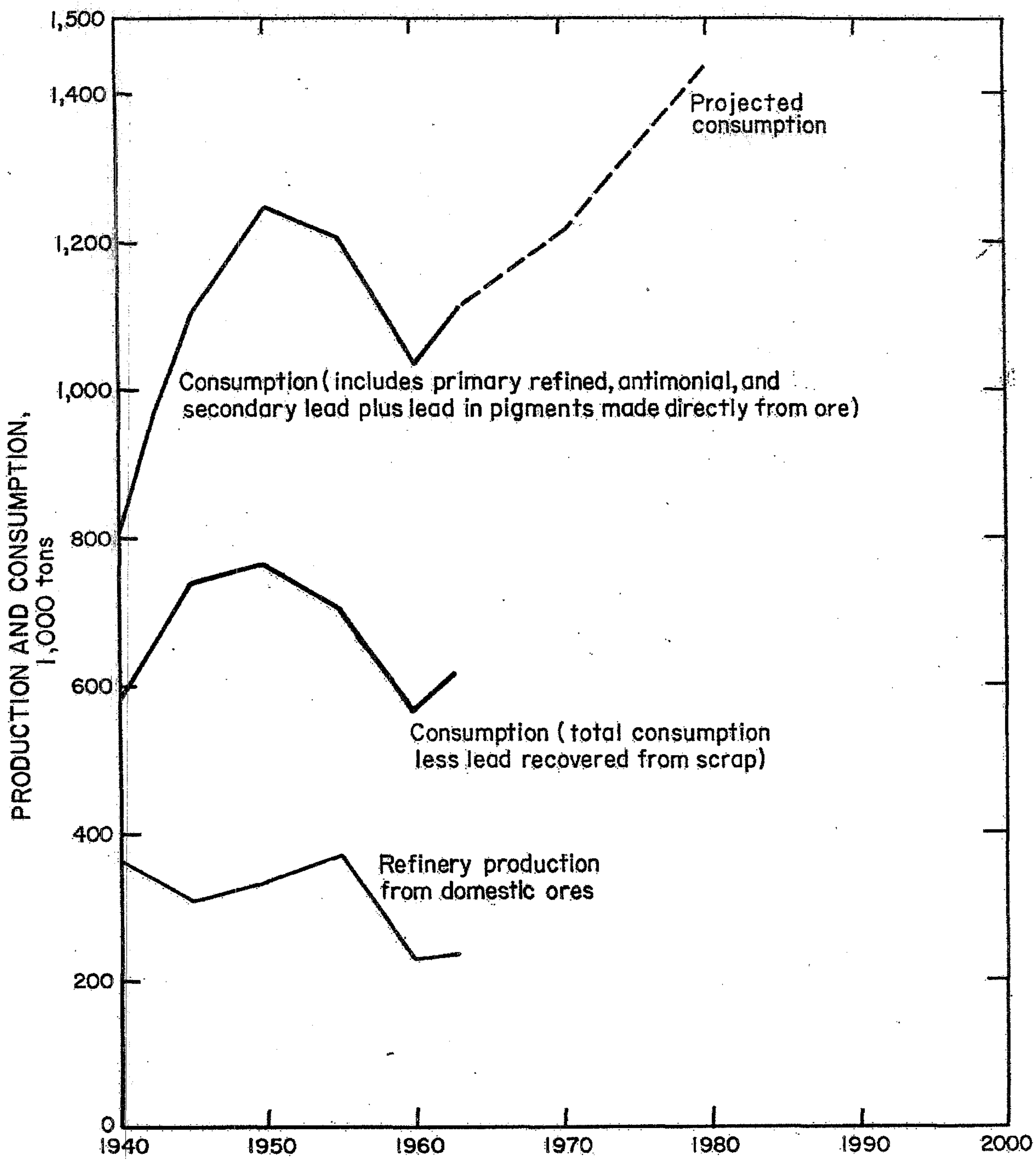

FIGURE 14. - Projection of Domestic Lead Consumption Through 1980. (The 1980 forecast was developed by the Division of Minerals.)

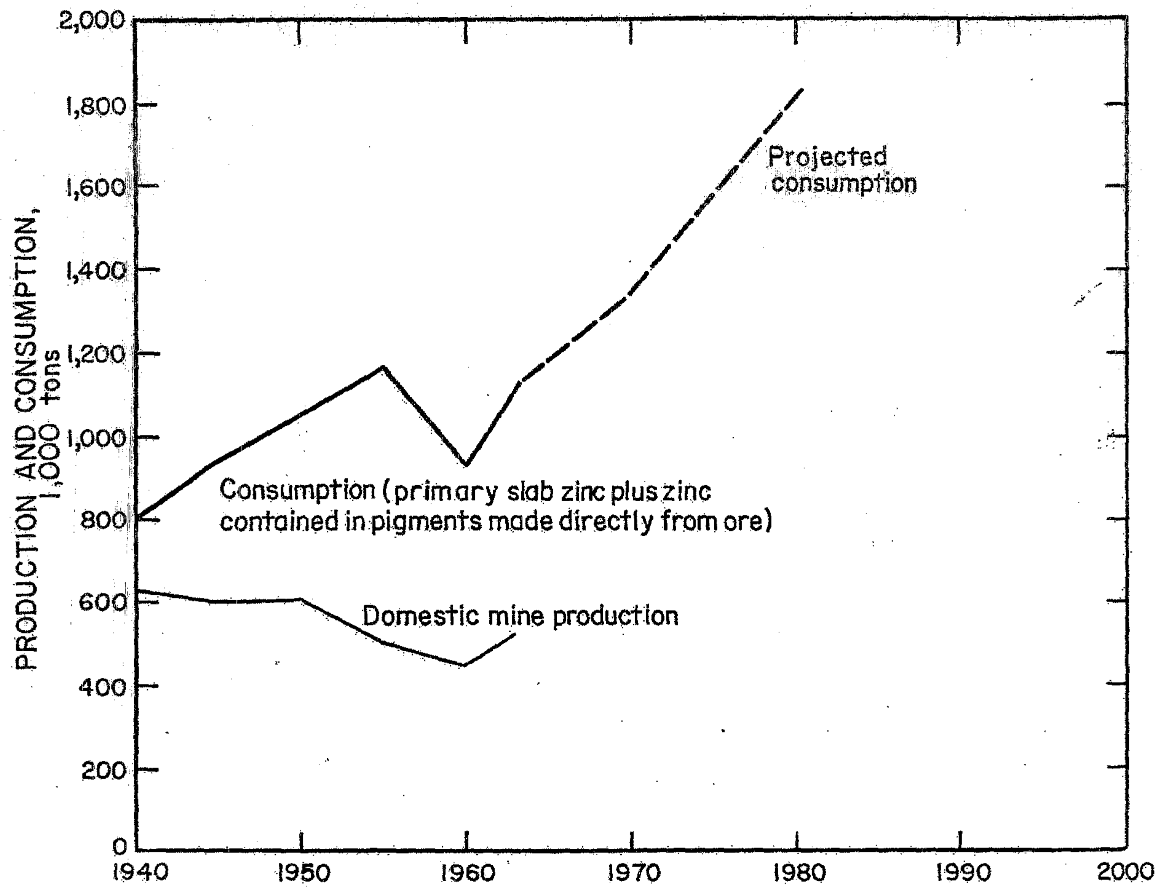

FIGURE 15. - Projection of Domestic Zinc Consumption Through 1980. (The 1980 forecast was developed by the Division of Minerals.)

companies for similar deposits and assuming applicable production methods (1, H-19 to H-22).

An average value of recoverable metals was calculated according to market prices and the recoverable metal in the reserves and potential resources.[4] For example, in figure 17 costs to produce lead were estimated at $6.50 per ton of ore in block B and the recoverable metal content was computed as $9.60 per ton. A ratio of costs divided by value is 0.68 or a favorable ratio for production. Ores in block A have a more favorable ratio than ores in block D. Detailed data on production costs cannot be given as much of it is confidential. Reserve and potential resource quantities shown in figures 16-18 do not equal the totals given in tables 6-12 because production data could not be established for some potential resources.

[4]Recovery was assumed as 90, 87, and 77 percent and metal values used were 33, 15, and 15 cents per pound of copper, lead, and zinc, respectively. Silver price used was $1.29 per ounce.

New York--All from zinc ores.

Oklahoma--All from zinc-lead ores.

Tennessee--Almost all from zinc ores.

Utah--Almost all from lead-zinc-silver ores.

Washington--All from zinc-lead ores.

Operations in Tennessee are particularly favorable with respect to reserves, potential resources and mining costs and are expected to provide the bulk of any increase in production. The State of Washington contains vast amounts of potential resources which await improved mining technology or higher zinc prices before any significant increase in zinc production can be expected.

ESTIMATED FUTURE CONSUMPTION

Projections of consumption for copper, lead, and zinc are shown in figures 13, 14, and 15. Increased demand can be expected for all metals in the future but only in the copper industry does production appear near adequate for supplying the immediate consumption needs. Consumption for copper, lead, and zinc was projected to 110 percent, 45 percent, and 90 percent greater in 1980 than for 1960.

Lead, zinc, and silver metal prices increased significantly in 1963 and 1964; with the incentive of higher prices many mines were reopened and companies increased exploration for new sources of ore. Supplies for lead and zinc will be partially dependent upon foreign sources until domestic production improves its competitive position. Domestic self-sufficiency for lead appears probable within the next 5 years; domestic self-sufficiency for zinc is highly questionable in the forseeable future.

Increased output of lead and zinc is expected from new developments in Missouri, Tennessee, and New York, where low-cost mining methods are used. Increased production of lead is expected in Missouri by 1965 with additional increases in the years following.

Domestic producers of copper from deposits in Arizona, Michigan, Montana, New Mexico, and Utah can be expected to supply most copper requirements of the United States.

Figures 16, 17, and 18 show the quantities of ore reserves and potential resources that might be produced according to the ratio of the cost of production to the value or revenues of recoverable metals (ratio $= \frac{\text{cost}}{\text{value}}$). Although the data on the figures were compiled from 1964 estimated costs and prices, comparative ratios should be applicable or easily adjusted to future changes in costs and metal prices. A ratio of 1.0 indicates production costs equals value of metals, a nonprofitable situation (13). A ratio of less than 1.0

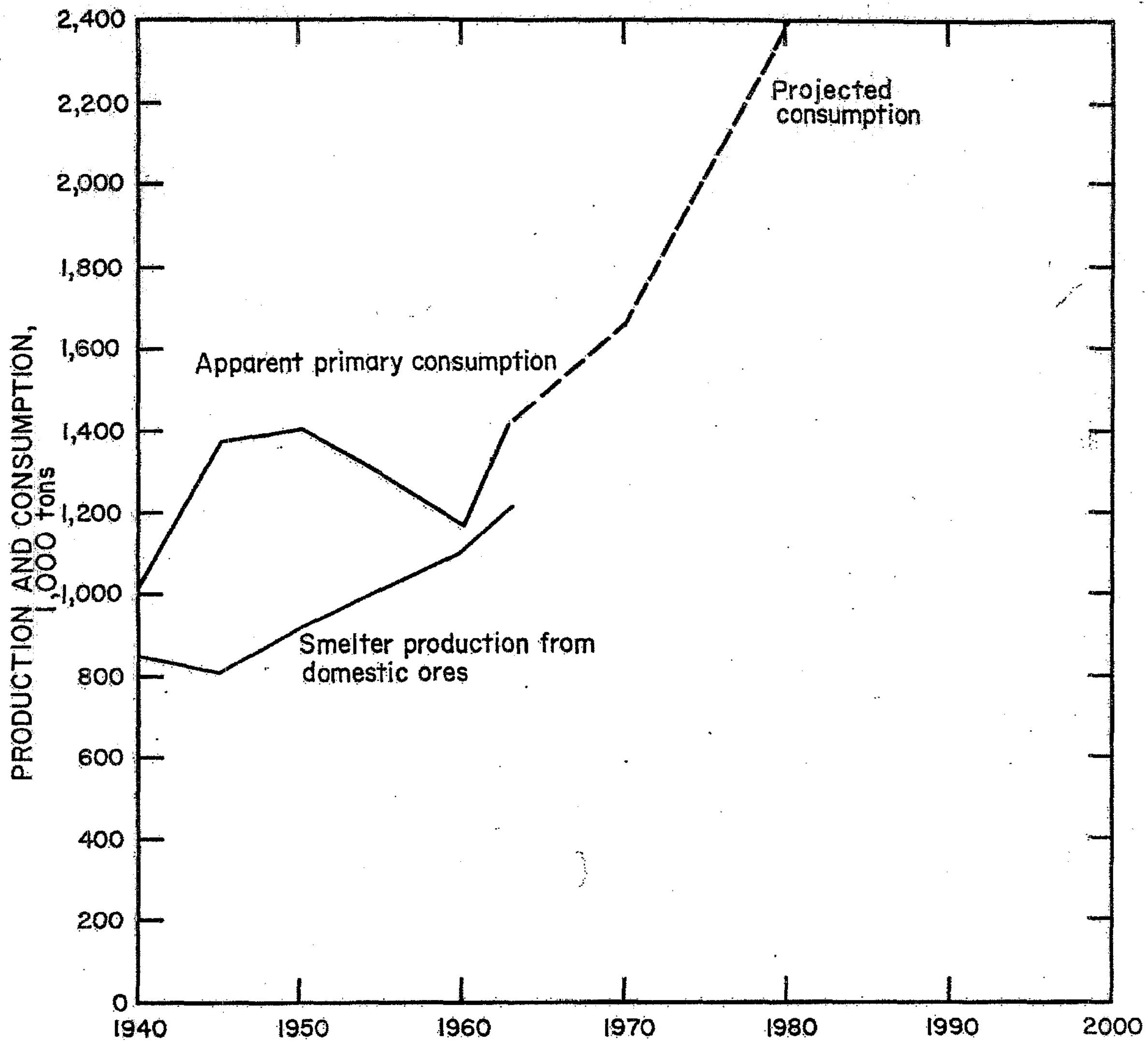

FIGURE 13. - Projection of Domestic Copper Consumption Through 1980. (The 1980 forecast was developed by the Division of Minerals.)

indicates a possible profitable production situation; the lower the ratio the more favorable the ore reserve is for profitable production. The costs of production will vary with changes in productivity resulting from a changing technology and organization as well as factor costs.

The data for the graphical illustrations were developed by grouping the reserves and potential resources by areas where similar costs of production could be determined. These costs of production were obtained (1) by estimating the mining, processing, and administrative costs (24), (2) by analyzing annual reports of companies where quantities produced and production costs were discernible, and (3) by actual reporting of the companies. Data for potential resources were estimated by using production costs of operating

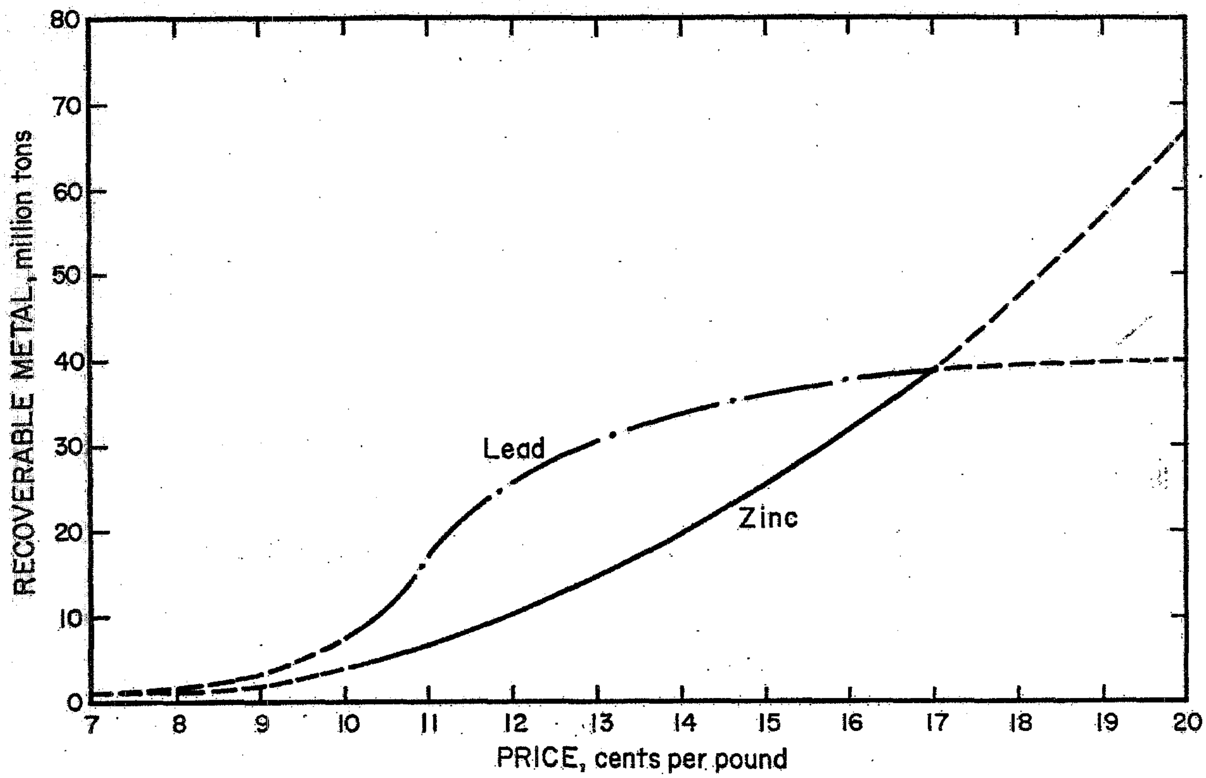

FIGURE 11. - Estimate of Lead and Zinc Metal That Could Be Produced From Reserves and Potential Resources for Various Price Levels.

Idaho, with a national ranking of second in production (1963), was not included in figure 12 because of the special effects of labor problems. Utah production generally increased while that of Colorado decreased. Ore production in Colorado, as in Arizona, Nevada, and New Mexico, must bear higher costs of transportation of ore and concentrates to smelting plants in other States.

Production in the period 1949-61 was predominantly from the following sources:

Colorado--Approximately 50 percent from zinc-lead ores and 50 percent from lead-zinc ores with silver as a principal coproduct.

Idaho--All from lead-zinc ores.

Kansas--All from zinc-lead ores.

Missouri--All from lead ores.

Montana--Almost all from complex ores.

New Mexico--Almost all from zinc-lead ores.

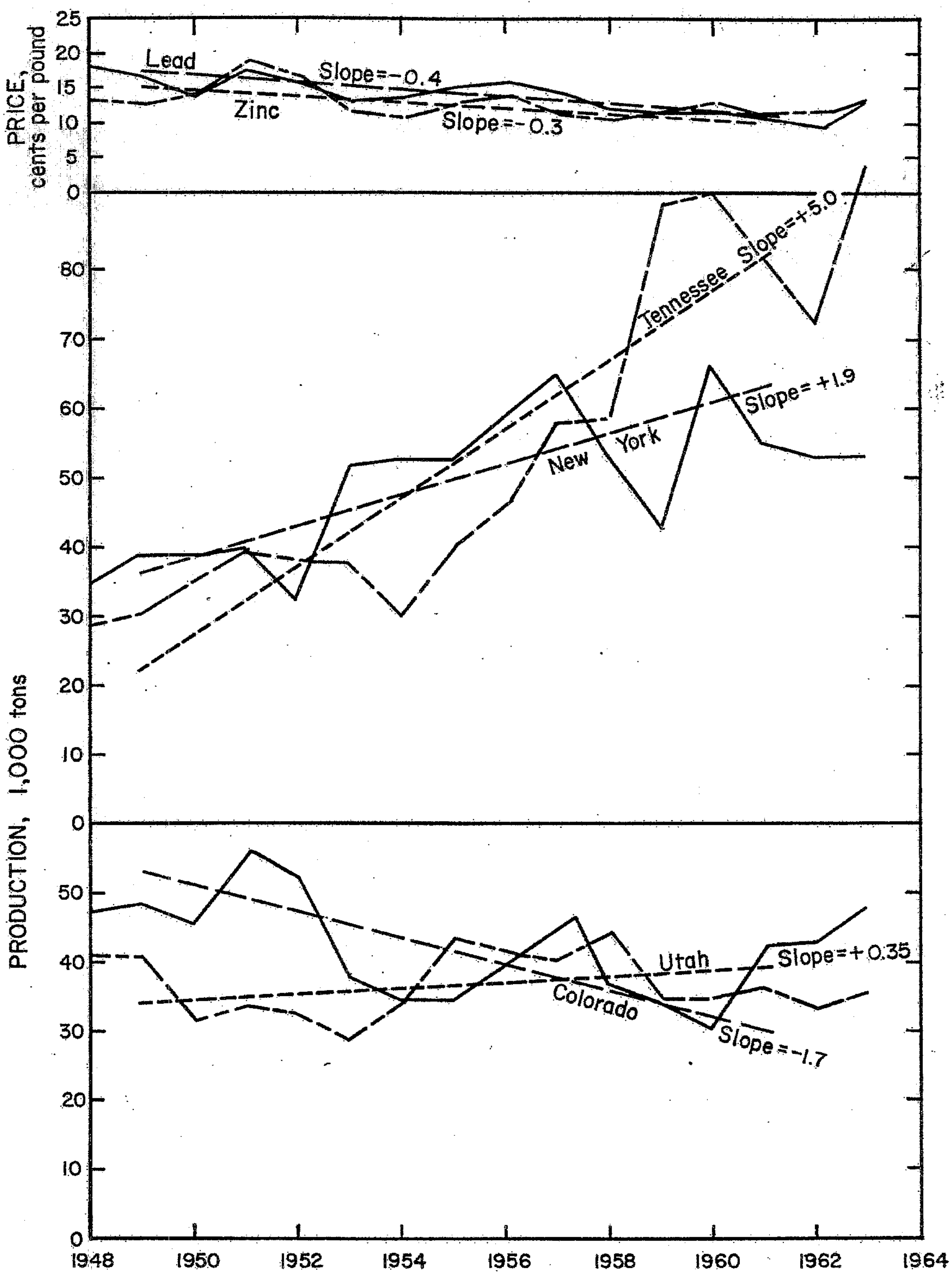

FIGURE 12. - General Price and Production Trends for Major Zinc-Producing States, 1948 to 1963.

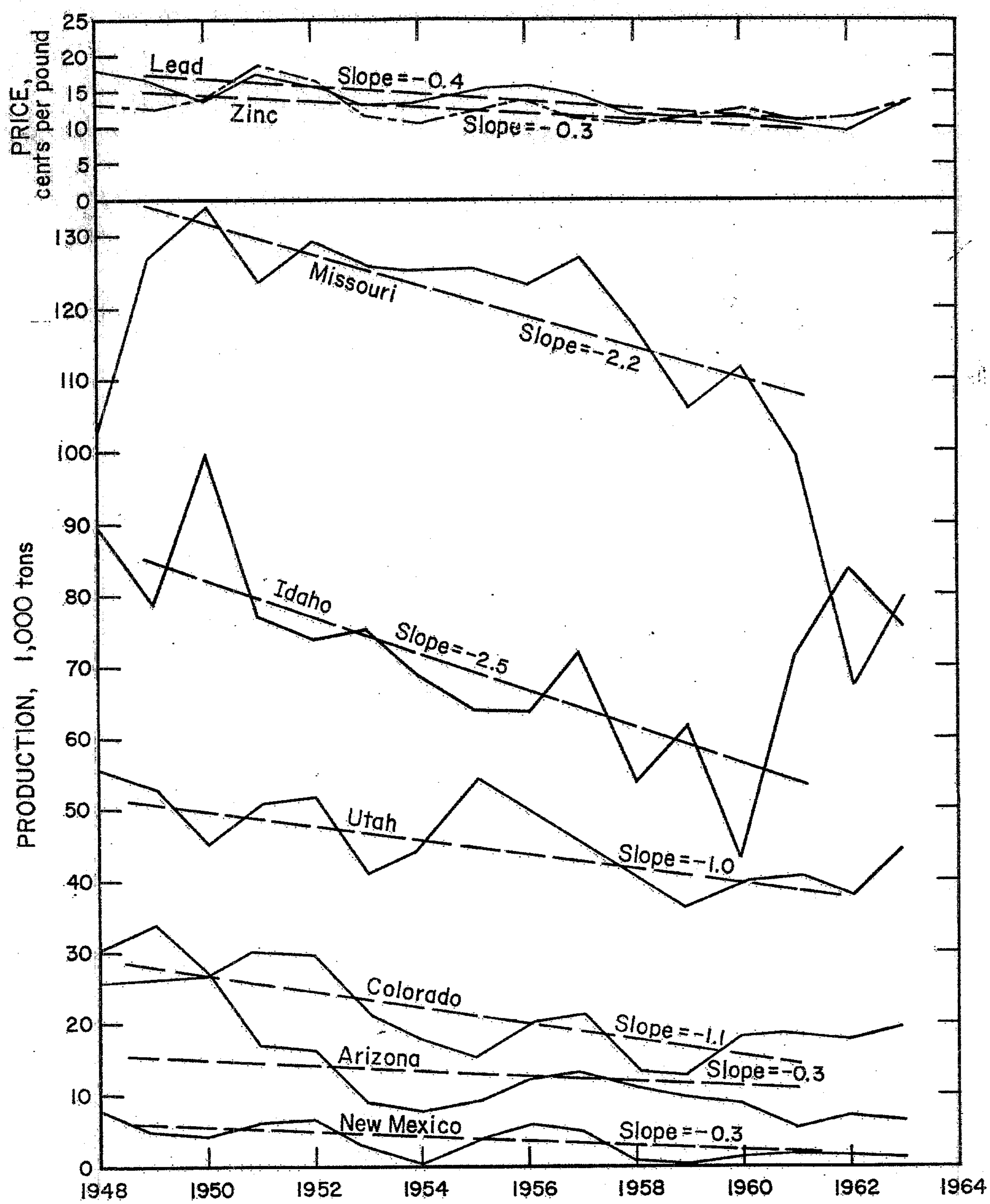

FIGURE 10. - General Price and Production Trends for Major Lead-Producing States, 1948 to 1963.

New Mexico--Almost all from zinc-lead ores with silver as a coproduct.

Kansas--All from zinc-lead ores.

Oklahoma--All from zinc-lead ores.

Utah--Almost all from lead-zinc ores with silver as a coproduct.

Washington--All from lead-zinc ores.

An analysis of past production leads to the assumption that at a price of 10 cents per pound for lead, most presently producing lead operations would become marginal and domestic production would decrease rapidly. Any profitable production below this price probably would depend upon values contributed by coproducts and byproducts.

Many lead-zinc deposits in the Rocky Mountain province contain 7 to 15 percent combined lead and zinc supplemented by appreciable amounts of silver, while the low-grade ores produced both in the Eastern and Central United States contained as low as 2 to 3 percent of either lead or zinc. The large low-grade deposits of Missouri can be expected to continue to provide the largest portion of domestic lead production. Announcements have been made that the St. Joe Lead Co. would increase lead smelting capacity by about 80,000 tons per year, and a new 100,000-ton lead smelter and refinery is planned by American Metals Climax, Inc. and Homestake Mining Co. for the new "lead belt" of Missouri; production was scheduled for late in 1967 or early 1968.

Production from Idaho fluctuated considerably in the past years, partially because of labor strikes in 1954 and 1959. In 1961 the State showed a remarkable increase in lead production. At this time the price of silver began increasing from $0.90 to the 1963 price of $1.29 per troy ounce.

In collecting base metal ore data, some producers indicated the various metal-price levels for probable production of their reserves and potential resources. These data were compiled and are shown in figure 11. The trends shown compare favorably with similar data prepared by the U.S. Tariff Commission (22).

Zinc

In contrast to lead, zinc production increased in some of the major producing States from 1949 to 1961, as shown in figure 12. Few labor strikes occurred in this period and production of zinc was not affected. Also during the period zinc had a relatively stable price which declined only 0.6 cent per pound compared with a 4.5-cent per pound drop in the price of lead. Exploration in Tennessee resulted in finding additional zinc ore reserves and in increasing the production. The zinc ore output in Tennessee and New York was not affected by the general decline in lead and zinc prices. The Tennessee deposits are being mined by room and random-pillar methods resulting in relatively large-volume, low-cost operations (7).

TABLE 30. - Location, mode of occurrence, metals, and mining methods for base metal deposits in the United States--Continued

Area[1] and State	Mode of ore occurrence	Metal contained in ores[2]			Mining method[4]	Major area or district
		Principal	Coproduct[3]	Byproduct		
Area IV--Continued:						
Kansas......	Bedded and breccia-filling replacement.	Zn,Pb	Cd,Ge,Ga, In	-	Random pillar...	Tri-State district.
Missouri....	Bedded disseminated replacement deposits.	Pb,Zn,Cu	Cd,Ge,Ga, In,Ni,Co, Ag	"Chats"	.....do.........	Southeast Missouri lead belt, Central district, portion of Tri-State district.
Oklahoma....	Bedded and breccia-filling replacement.	Pb,Zn,Cu	Cd,Ge,Ga, In	-	.....do.........	Portion of Tri-State district and central Oklahoma.
Texas.......	Fissure veins...........	Cu,Pb,Zn	Ni,V,Cr, Mo,Ag	-	-	Southwest Texas.
Area V:						
Arizona.....	Fissure vein, bedded replacement, and "porphyry".	Cu,Pb,Zn	Se,Te,Re, Pt,Au,Ag, Mo	-	Block caving; open pit; room and pillar; shrinkage; cut and fill.	Cochise, Gila, Greenlee, Mohave, Pima, Pinal, Santa Cruz, Yavapai Counties.
Colorado....	Fissure vein, bedded replacement.	Cu,Pb,Zn	Be,Cd,Te, Ag	-	Shrinkage; open stoping; square setting.	Clear Creek, Eagle, Lake, Summit, Dolores, Hinsdale, Mineral, Saguache, San Juan, Park, San Miguel Counties.
New Mexico..	"Porphyry," fissure vein, bedded replacement.	Cu,Pb,Zn	Au,Ag,Mo	-	Open pit; sublevel.	Grant, Socorro, Hidalgo Counties.
South Dakota	Fissure vein............	Pb,Zn	Ag	-	-	Custer, Lawrence, Pennington Counties.
Utah........	Fissure vein, bedded replacement, and "porphyry".	Cu,Pb,Zn	Au,Ag,Mo Sb,As,Bi, Cd,Se,Te, W,CaF_2	-	Open pit; cut and fill; open stoping; random pillar.	Bingham, Park City, Tintic, East Tintic districts.
Wyoming.....	Lode, fissure vein, bedded deposits.	Cu	Au,Ag	-	-	Albany, Carbon, Fremont, Laramie Counties.

TABLE 30. - Location, mode of occurrence, metals, and mining methods for base metal deposits in the United States

Area[1] and State	Mode of ore occurrence	Metal contained in ores[2]			Mining method[4]	Major area or district
		Principal	Coproduct[3]	Byproduct		
Area I:						
Maine........	Replacement veins and lenses.	Cu,Pb,Zn	Ag	-	Sublevel stoping	Hancock County.
New Jersey..	Replacement in veins....	Zn	-		Shrinkage; topslice.	Sussex and Warren Counties.
New York....	.........do..............	Zn	Pb,Au,Ag	-	Sublevel stoping	St. Lawrence County.
Pennsylvania	.........do..............	Zn	-	-	Open stoping....	Lehigh County.
Virginia....	.........do..............	Zn	Pb	Ls	Under hand open stoping.	Wythe and Smythe Counties.
Area II:						
Alabama.....	Massive sulfides, irregular lenses in chlorite schists.	Cu	-	Fe,S	-	Randolph and Clay Counties.
Georgia.....	Lenslike; massive; and disseminated veins.	Cu,Zn	-	Fe,S	-	Fannin, Haralson, Lumpkin, Paulding Counties.
Kentucky....	Fissure vein............	CaF_2	An,Pb,Ag, Ge	-	-	Western Kentucky fluorspar district.
North Carolina.	Fissure veins in schist and gneiss.	Cu	Au,Ag	S	Sublevel stoping	Ashe, Granville, Haywood, Macon, Madison, Person, Swain Counties.
Tennessee...	Disseminated; continuous veins.	Cu,Zn	Pb,Cd,Au, Ag	Fe,S,Ls	Random pillar; sublevel stoping.	Knox, Jefferson, Polk, Grainger, Hawkins, Hancock Counties.
Area III:						
Illinois....	Fissure veins and bedded replacement.	CaF_2,Pb, Zn	Cd,Ge,Ag, Pb,Zn	-	Shrinkage; random pillar.	Hardin, Jo Daviess, Pope Counties.
Michigan....	Lode and fissure; bedded disseminated.	Cu	As,Ti,Fe, Au,Ag	-	Open stoping; room and pillar.	Upper Michigan peninsula.
Wisconsin...	Pitches and flats; gash veins.	Zn	Cu,Ag,Au, Pb	Ls,S	Open stoping; random pillar.	Grant and Lafayette Counties.
Area IV:						
Arkansas....	Replacement in pods, pockets, lenses, and blanket veins.	Zn,Pb	-	-	Modified room and pillar.	Boone, Newton, Marion, Searcy Counties.

See footnotes at end of table.

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TABLE 31. - Comparison of cost of transporting zinc contained in ore or concentrate to cost of transporting slab zinc[1]

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[4]	Metal content, pounds per ton[5 6]	Cost of transporting, dollars per ton-mile	Carload size, pounds	Rate, cents per 100 pounds	Cost of transporting, dollar per ton-mile
0 - 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- .097	100,000	53.5	.014
27.50- 50.00	10.52	250-455	.097- .055	120,000	48.0	.012
50.00- 60.00	11.20	455-545	.055- .049			
60.00- 70.00	11.89	545-636	.049- .045			
70.00- 80.00	12.56	636-727	.045- .041			
80.00- 90.00	13.34	727-818	.041- .039			
90.00-100.00	14.05	818-909	.039- .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]Rates established for these commodities by the railroad for 80,000-pound carload lots.
[5]Based on 100 percent recovery.
[6]Used 11 cents per pound to calculate the metal content.

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.

BASE METAL PRODUCTION TRENDS

Copper

Copper production has increased in response to demand during the period 1948 to 1963 (fig. 9). All dominant copper-producing States except Utah showed an increasing trend (slope lines or linear trends were calculated by the least squares method, using production data of 1948 to 1963). In 1962 Kennecott Copper Corp. started an expansion program at its Utah operations, the largest copper-producing facilities in the United States, to increase the output by about 100,000 tons of copper per year by 1967. The increase in Arizona production has been due to expansion of existing operations and development and exploitation of several new porphyry deposits (Esperanza, Ithaca Peak, Mission, and San Manuel). Development of the White Pine property accounted for most of the increase in Michigan. Expansion of existing facilities accounted for the increased production in Montana.

Lead

Output of lead declined in most States since 1949. General price and production trends were calculated for the principal producing States and are shown in figure 10; the 1949-61 period was used because labor problems were a minimum factor. Lead production in this period mostly was from the following sources:

Arizona and Colorado--Predominantly lead-zinc ores with silver as a principal coproduct.

Idaho--Predominantly lead, lead-zinc, and lead-silver ores.

Missouri--Almost all from lead ores.

Area VI:						
California..	Fissure veins, replacement veins, lenticular bodies.	Cu,Pb,Zn	Co,Au,Ag, Cd	-	Open stoping....	Inyo, San Bernardino, Riverside, Shasta, Plumas, Madera, Fresno Counties.
Nevada......	"Porphyry," fissure vein, and bedded replacement.	Cu,Pb,Zn	Sb,As,Bi, Cd,Ni,Co, Au,Ag,Mn, Mo,Pt,Re, Se,Te	-	Open pit; open stoping.	Washoe, Elko, Clark, Humbolt, White Pine, Mineral, Pershing, Eureka, Lincoln, Lander Counties.
Area VII:						
Idaho.......	Steeply dipping tabular veins.	Pb,Zn	Sb,As,Bi, Cd,Co,Ni, Te,Au,Ag	-	Open stoping; sublevel stoping; shrinkage; cut and fill.	Shoshone, Blaine, Custer, Lemhi Counties.
Montana.....	Fissure filling, replacement.	Cu,Pb,Zn	Sb,As,Bi, Cd,Ag,Au Ge,In,Mn, Ni	-	Open pit; cut and fill; open stoping; block caving.	Cascade, Jefferson, Judith Basin, Park, Stillwater, Silver Bow, Granite, Lewis and Clark Counties.
Oregon......	Fissure veins, shear zones.	Cu,Pb,Zn	Au,Ag	-	Shrinkage.......	Baker, Lane, Josephine Counties.
Washington..	Fracture filling, breccia filling, and disseminated.	Cu,Pb,Zn	Au,Ag,Cd Mo,W	-	Open pit; open stoping; sublevel stoping.	Ferry, King, Pend Oreille, Stevens, Snohomish Counties.
Area VIII:						
Alaska......	Veins, bedded and massive disseminations.	Cu,Pb,Zn	Au,Ag	-	Open pit; open stoping; sublevel; shrinkage.	Southeast Alaska, Prince William Sound, Nizina district, White River Area, Iliamna-Lake Clark Area, Aleutian Islands, Nabesna Area, Northwestern Alaska, Seward Peninsula.

[1]States in area designations are shown in figure 6.
[2]Explanation of symbols:

Antimony--Sb	Cobalt--Co	Indium--In	Nickel--Ni	Tellurium--Te
Arsenic--As	Copper--Cu	Iron--Fe	Platinum--Pt	Titanium--Ti
Beryllium--Be	Fluorite--CaF_2	Lead--Pb	Rhenium--Re	Tungsten--W
Bismuth--Bi	Gallium--Ga	Limestone--Ls	Selenium--Se	Vanadium--V
Cadmium--Cd	Germanium--Ge	Manganese--Mn	Silver--Ag	Zinc--Zn
Chromium--Cr	Gold--Au	Molygdenum--Mo	Sulfur--S	

[3]Coproducts contained in the ore but not necessarily recovered.
[4]Mining method used, has been used, or could be used (depending on the status of the property).

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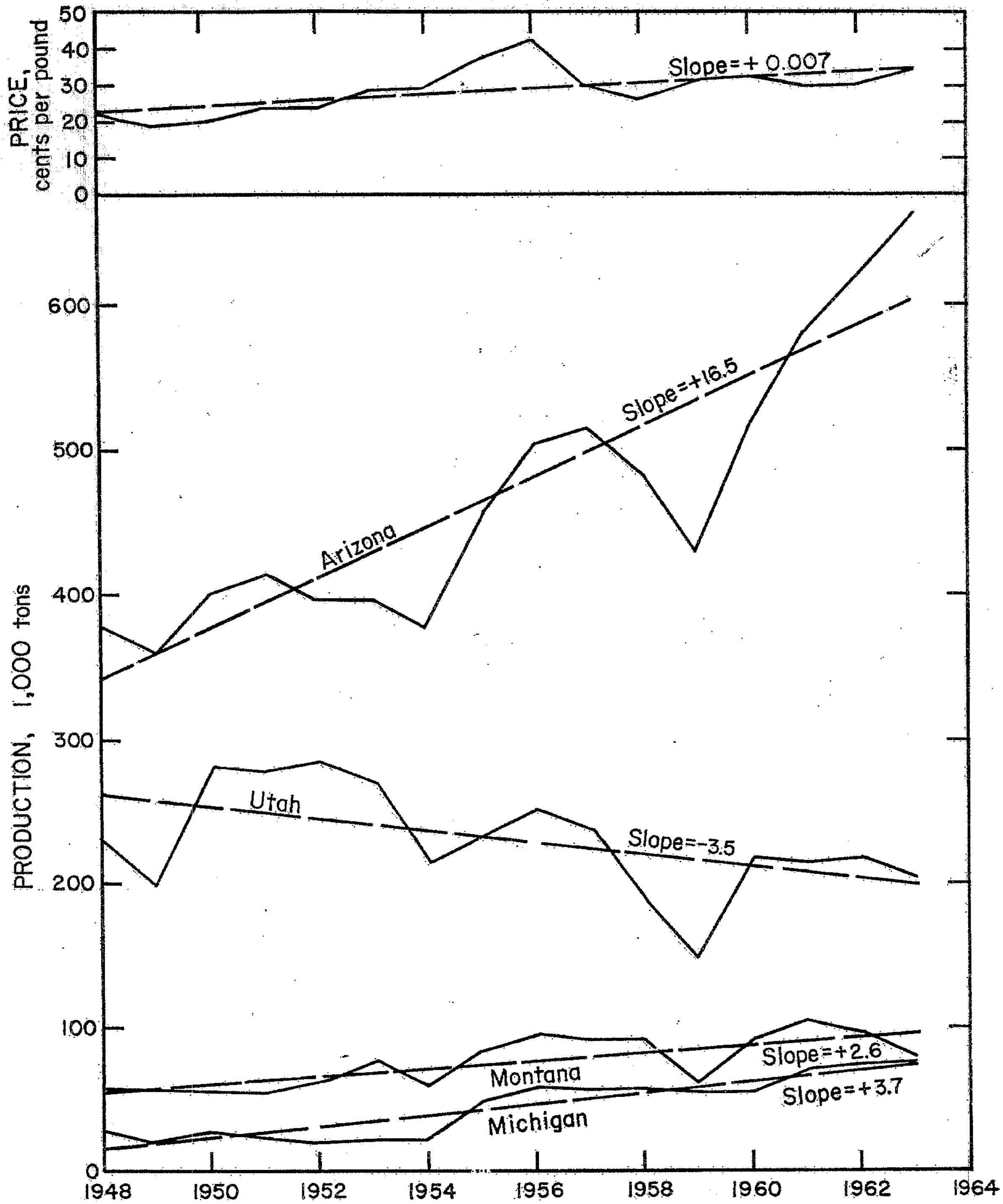

FIGURE 9. - General Price and Production Trends for Major Copper-Producing States, 1948 to 1963.

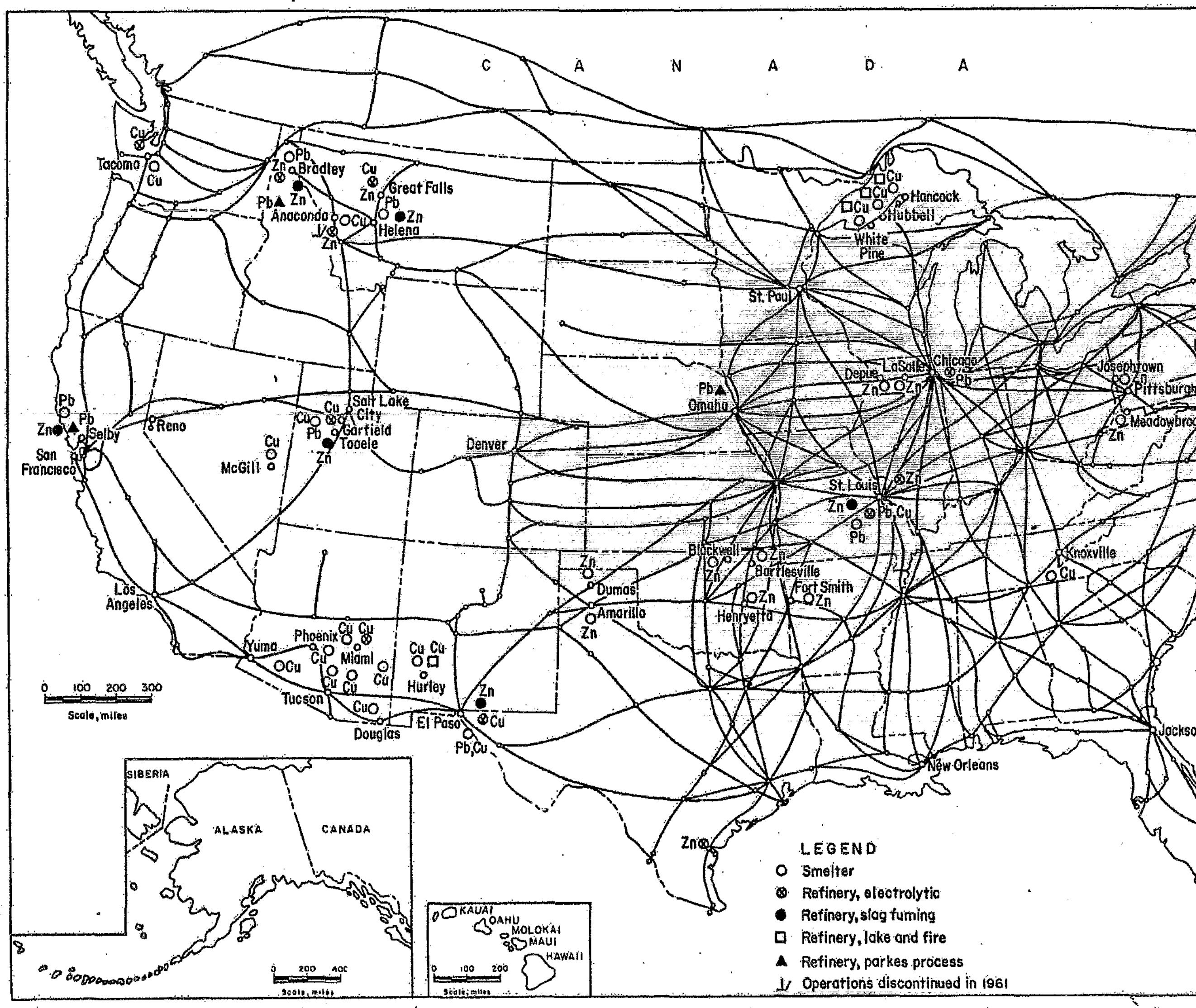

FIGURE 8. - Location of Base-Metal Smelting and Refining Plants With Respect to Mainline Railroad Servi

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Characteristics of the deposits which govern the mining methods include (1) the size and shape of the ore body, (2) the depth and type of overburden, (3) the attitude of the deposit, and (4) strength and physical nature of the surrounding rocks. Mining is done through underground openings or from the surface, depending upon the characteristics of the deposit. Some low-grade or waste-dump material contains metals that can be recovered by leaching methods.

Table 28 shows the range of costs by mining with different methods (11); table 29 presents the proportion of base metal reserves and potential resources that are or might be extracted from deposits by various mining methods.

TABLE 28. - Direct mine operating costs for various mining methods, period 1955-59[1]

Mining method	Amount mined per month, tons[2]	Direct mining costs per ton[3]			Labor, percent of total cost[4]
		High	Low	Average[4]	
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	([5])
Room and pillar (trackless type)	733,220	2.41	1.16	2.05	43.7
Sublevel stoping	1,547,410	4.71	1.06	2.37	56.9
Sublevel caving	118,150	([5])	([5])	4.97	63.3
Block caving	1,803,150	2.25	1.15	1.41	54.2
Open pit[6]	5,198,060	1.15	.21	.32	36.4

[1]Reference (11).
[2]Total aggregate tonnage of ore mined each month except for open pits (see footnote 6).
[3]Includes exploration and development, stoping, haulage, hoisting, pumping, and general underground and surface costs.
[4]Weighted average on the basis of tons produced from each mine.
[5]Not available.
[6]Cost is per ton of "material" and is based on total tons of ore and waste handled.

TABLE 29. - Estimated percent of base metal reserves and potential resources in the United States according to mining method

Mining method	Total reserves, percent	Total resources, percent
Open pit	38.6	9.3
Open stope	26.9	68.2
Shrinkage	.2	1.4
Random pillar	13.0	1.9
Room and pillar	8.1	8.2
Block caving	7.6	.5
Sublevel	.3	1.3
Square setting	.6	.3
Cut and fill	.2	.1
Miscellaneous[1]	4.5	8.8

[1]Includes properties for which information was not available and methods which do not apply to the categories listed.

Arsenic is recovered as a coproduct of smelting arsenic-bearing copper ores by The Anaconda Company at Anaconda, Mont., and American Smelting and Refining Company at Tacoma, Wash.

Indium is recovered by American Smelting and Refining Company at the copper refinery in Perth Amboy, N. J.

Rhenium concentrate is recovered entirely as a coproduct of molybdenite derived from southwestern porphyry copper ores.

Selenium and tellurium are recovered as a coproduct of the electrolytic refining of copper and lead.

Thallium is recovered from cadmium-containing flue dust.

Domestic antimony is recovered as a coproduct of silver-lead ore refining. Properties of the Sunshine Mining Co. and Hecla Mining Co. in Idaho are the principal sources of domestically produced antimony.

Sulfuric acid is manufactured from the sulfur-oxide gases during roasting of pyrite and other sulfide concentrates from base metal ores. Chats (chert tailings), dolomite, limestone, sandstone, and smelter slags are byproducts used as road metal, railroad ballast, soil conditioning, and specialized products in manufacturing. Iron sinter is recovered as a byproduct by Tennessee Copper Co., Polk County, Tenn., and is used in iron and steel plants.

ECONOMIC FACTORS INVOLVING RESERVES AND POTENTIAL RESOURCES

The economic exploitation of a mineral deposit is determined by the costs of producing and marketing salable products. Producing minerals involves locating, exploring, and developing deposits, mining and beneficiating the ore, and smelting and refining the metal. Marketing involves sales and distribution to consumers. These factors are considered in estimating costs of production and are used here in making comparisons of favorability of reserves and potential resources by States or geographic areas.

Costs of production can not be considered as static but are subject to change according to economic factors and improvements in production technology. Improvements in production technology have been greatest for mineral deposits conducive to low-cost, large-volume extractive methods. Generally, the small high-grade deposits have required high-cost mining methods having comparatively less possibility for improvement in production technology.

Mining Methods

Mineral deposits have physical characteristics that govern the methods of mining. Factors affecting costs include geologic environment for optimum extraction, safety, capital investment, and methods of production for the largest net return.

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TABLE 24. - Average annual and adjusted price of copper, lead, and zinc, 1945-64, cents per pound

Year	Average annual copper price[1]	Copper price, adjusted[2]	Average annual lead price[3]	Lead price, adjusted[2]	Average annual zinc price[4]	Zinc price, adjusted[2]
1945	11.8	21.0	6.5	11.5	8.3	14.7
1946	13.8	22.4	8.1	13.1	8.7	14.1
1947	21.0	27.9	14.7	19.5	10.5	13.9
1948	22.0	26.9	18.0	22.0	13.6	16.6
1949	19.2	24.0	15.4	19.3	12.1	15.1
1950	21.2	25.6	13.3	16.0	13.9	16.8
1951	24.2	26.4	17.5	19.1	18.0	19.7
1952	24.2	27.1	16.5	18.5	16.2	18.1
1953	28.8	32.0	13.5	15.0	10.9	12.1
1954	29.7	32.9	14.1	15.6	10.7	11.8
1955	37.5	40.6	15.1	16.3	12.3	13.3
1956	41.8	43.3	16.0	16.6	13.5	14.0
1957	29.6	29.8	14.7	14.8	11.4	11.5
1958	25.8	25.9	12.1	12.2	10.3	10.4
1959	31.2	30.8	12.2	12.0	11.5	11.4
1960	32.1	31.7	11.9	11.7	12.9	12.7
1961	29.9	29.7	10.9	10.8	11.5	11.4
1962	30.6	30.4	9.6	9.5	11.6	11.5
1963	30.6	30.4	11.1	11.0	12.0	11.9
1964	32.0	31.6	13.5	13.3	13.5	13.3

[1]Engineering and Mining Journal copper price, domestic refinery.
[2]Adjusted according to the wholesale price index, 1957-59 = 100. (All commodities except farm products and foods.)
[3]Engineering and Mining Journal lead price (New York).
[4]Engineering and Mining Journal zinc price (East St. Louis).

TABLE 25. - Estimated tonnage of recoverable lead in the United States by ore type

Type of ore deposit	Reserves		Resources	
	Metal content, 1,000 short tons[1]	Average ore grade, percent	Metal content, 1,000 short tons[1]	Average ore grade, percent
Lead..................	27,350	2.85	1,350	0.97
Lead-silver...........	190	4.93	60	3.50
Lead-zinc.............	1,250	6.75	1,770	1.89
Zinc-lead.............	1,810	1.25	9,860	.47
Total...........	30,600	-	13,040	-

[1]Assuming 87-percent recovery.

Maintenance of the small measured reserve base has been governed by geologic conditions and the high costs necessary to block out ores during irregular and low price fluctuations. At most of the properties included in the estimated reserves of this report indications of ore were sufficient to warrant development. Ore reserves in the measured and indicated categories should increase as production advances with little additional cost beyond the usual development and mining costs.

Discovery of the new "lead belt" in southeast Missouri has more than replenished the previously depleted lead reserves of the United States. The four States ranking highest in lead reserves are Missouri, Idaho, Colorado, and Utah; these States account for 91 percent of the total reserves.

Zinc

The measured, indicated, and inferred zinc reserves are estimated as containing 22 million tons of recoverable zinc metal (assuming 77-percent recovery). This metal occurs in the various ore types as indicated in table 26. An additional 48 million tons of recoverable zinc is included as potential resources; these resources may become reserves by economic changes or improved technology. Measured reserved contain an estimated 2.7 million tons of recoverable zinc, and measured potential resources contain 154,000 tons.

TABLE 26. - Estimated tonnage of recoverable zinc in the United States by ore type

Type of ore deposit	Reserves		Resources	
	Metal content, 1,000 short tons[1]	Average ore grade, percent	Metal content, 1,000 short tons[1]	Average ore grade, percent
Zinc..................	10,830	3.72	4,560	3.26
Lead-zinc.............	770	4.68	1,020	1.24
Copper-zinc...........	930	1.40	110	1.00
Zinc-copper...........	170	6.18	720	2.40
Zinc-lead.............	5,510	4.29	41,230	2.23
Lead..................	3,770	.44	130	.11
Total............	21,980	-	47,780	-

[1]Assuming 77-percent recovery.

Measured zinc reserves are sufficient for 5 years at the 1963 rate of production of 529,000 tons. Measured, indicated, and inferred reserves are sufficient to maintain this production rate for 42 years.

The major portion of the zinc reserves are contained in zinc and zinc-lead ores. The average grade of the zinc ore reserves is 3.7 percent and of the potential resources, 3.3 percent.

COPRODUCTS AND BYPRODUCTS

Most nonferrous base metal ores contain recoverable coproducts and byproducts. Many ores have small quantities of valuable minerals which are not produced because of lack of markets or the excessive cost of recovery.

Some of the more common coproducts in the ores are antimony, arsenic, cadmium, cobalt, copper, fluorspar, gallium, germanium, gold, indium, lead, manganese, molybdenum, nickel, rhenium, selenium, silver, tellurium, thallium,

TABLE 22. - Estimated tonnage of recoverable copper in the United States by ore type

Predominate metals in ore deposits	Reserves: Metal content, 1,000 short tons[1]	Reserves: Average grade, percent	Resources: Metal content, 1,000 short tons[1]	Resources: Average grade, percent
Copper	73,640	0.86	57,530	0.47
Copper-zinc	950	1.23	110	.80
Zinc-copper	60	1.97	350	.98
Total	74,700	-	57,990	-

[1]Assuming 90-percent recovery.

The States ranking highest in measured and indicated reserves are Arizona, Montana, Utah, New Mexico, and Michigan; Michigan outranks the other States in inferred reserves. These five States account for 92 percent of total copper-ore reserves.

Previous estimates (18) of copper reserves and the 1964 estimate are listed in table 23. This 1964 estimate of copper reserves greatly exceeds those of the past; this increase is the result of accelerated mineral development, improvement in mining and metallurgical technology, and greater effort in obtaining reliable data. Most of the production from newly discovered deposits is the result of development between 1950 and 1964 of large low-grade mines which will sustain large-volume operations. During this period the price per pound of copper, adjusted to a common level according to the wholesale price index (1957-59 base of 100), has increased about 6 cents per pound (table 24). New porphyry deposits brought into operation between 1950 and 1964 include Copper Cities, Esperanza, Ithaca Peak, Mission, San Manuel, and Silver Bell in Arizona, and Yerrington in Nevada. New bedded replacement or sedimentary type deposits brought into operation during this same period include the Christmas in Arizona, Bayard in New Mexico, and White Pine in Michigan.

Lead

The measured, indicated, and inferred lead reserves contain about 31 million tons (assuming an 87-percent recovery) in ores classified as lead, lead-silver, lead-zinc, and zinc-lead (table 25). In addition, approximately 13 million tons of lead are estimated in potential resources.

Measured lead-ore reserves (table 6) are sufficient for 2 years at the 1963 rate of production of 253,000 tons; however, measured reserves in Missouri are included in indicated and inferred categories. Measured, indicated, and inferred reserves are adequate for this rate of production for 121 years.

Ores with lead as the principal metal comprise the largest reserves and the average grade is 2.9 percent. The second most important source is in lead-zinc deposits with an average ore grade of 6.8 percent lead and 4.6 percent zinc. (The second largest quantity of lead is contained in the zinc-lead deposits, but the recovery of the lead is dependent upon mining the deposit for the zinc content.)

TABLE 23. - Previous estimates of copper reserves in the United States

Year	Reference	Recoverable copper,[2] 1,000 tons	Price, cents	"Life", years	Annual rate of production used to estimate "life", 1,000 tons
1931	(2, v. 131, p. 178)	At least 18,500	9	31	[2]600
1931	(19)	18,800	9	31	[2]600
1934	(2, v. 135, pp. 448-449)	18,900	10	32	[2]600
1935	(15)	16,000	10	22	[3]750
1935	(15)	23,500	12	32	[3]750
1936	(15)	23,700	12½	33	725
1944	(10)	20,000	[4]13	25	800
1945	(12)	29,200	[4]13	36	800
1950	(18, p. 34)	25,000	20	25	1,000
1960	(16, p. 45)	[5]32,500	32	30	1,100
1964		[6]77,000	32	63	1,213

[1]Recovery factor of 90 percent.
[2]1925-35 average rate of production.
[3]Predicted by estimators from trend. Actual 1935 production was about 400,000 tons.
[4]Premium price plan in effect.
[5]Measured and indicated ore reserves (no estimate was made for inferred reserves).
[6]Measured, indicated, and inferred reserves.

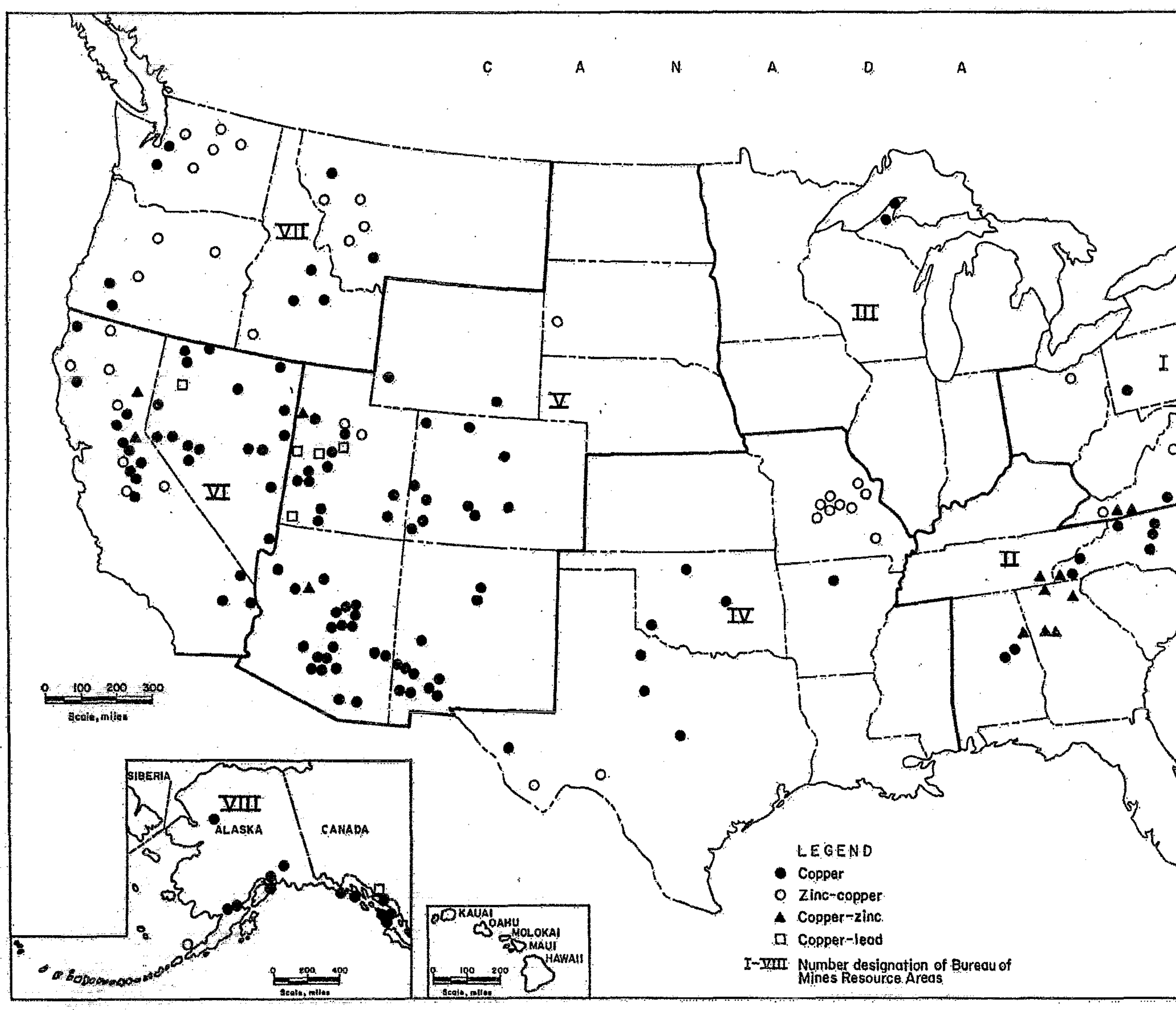

FIGURE 6. - Location of Areas Having Copper-Bearing Occurrences.

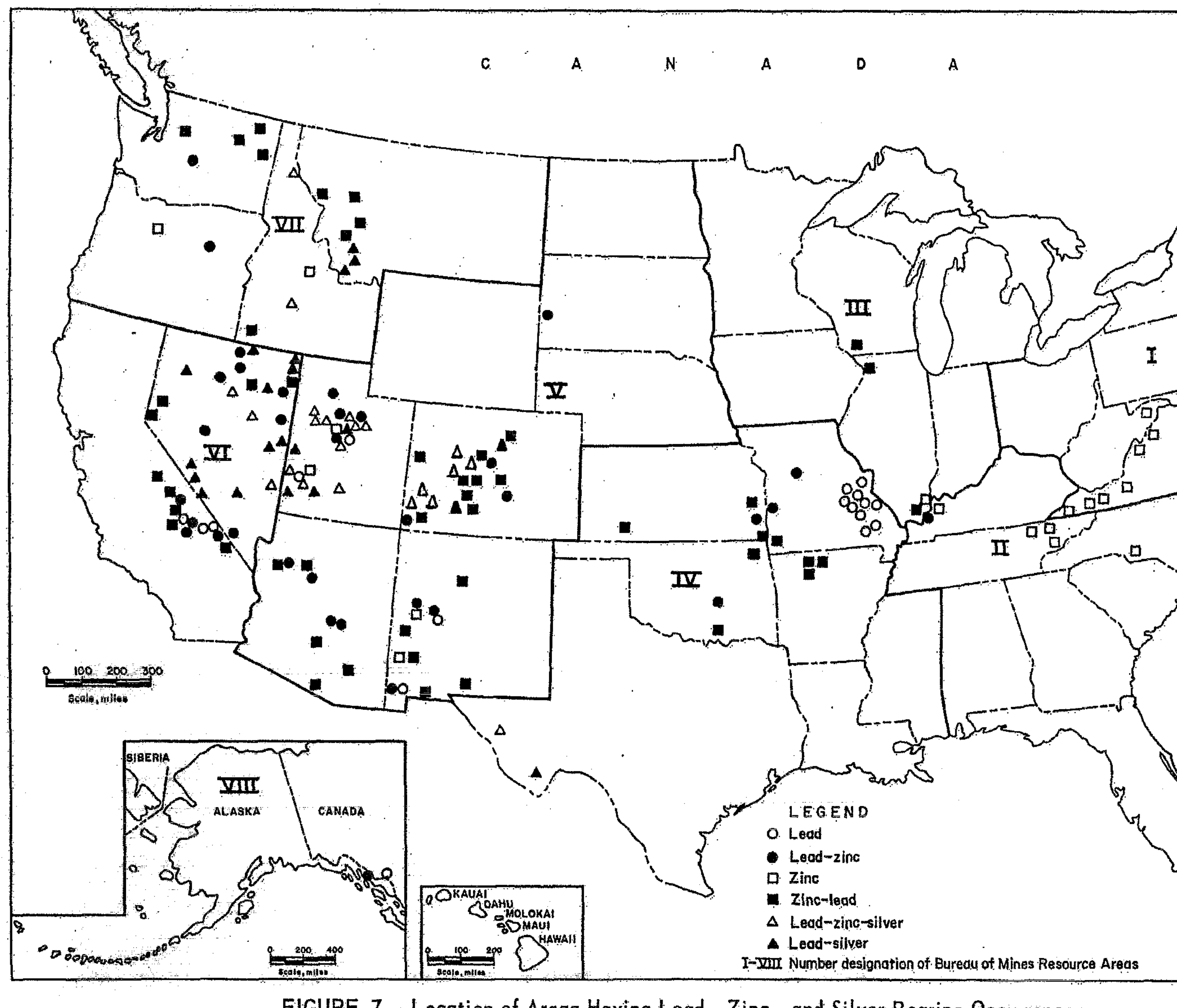

FIGURE 7. - Location of Areas Having Lead-, Zinc-, and Silver-Bearing Occurrences.

Financing

The mining industry is a business venture involving high monetary risks, especially in the exploration and development stages; therefore, adequate financing is usually difficult to obtain.

At some properties ore deposits are marginal according to the price of metals, and funds available are insufficient to sustain an operation until prices improve. Other properties require additional exploration or development to enable operators to plan for and achieve long-range benefits; some companies have been unable to obtain the necessary finances for this work. The inability of some companies to obtain financing has been attributed to the poor metal-producing outlook during specific periods. Many properties, particularly in the Western States, have not been operated because sufficient ore reserves or money were not available for efficient operating facilities.

Many individuals or companies who own or control promising mineral properties attach an excessive selling or leasing value to the property with the result that possible profitable operations are prevented or curtailed. Frequently this overevaluation prevents consolidation of properties in areas where such combining is necessary for the most economical development. Examples of the need for consolidation can be found in many of the older mining districts in the Western States. Some of the ore reserves and potential resources compiled in this report probably would be mined if agreements could be made among operators and property owners.

Exploration financial assistance was available for promising deposits of copper, lead, and zinc as well as other commodities through the Office of Mineral Exploration (OME) until June 30, 1962. At this time the financial assistance for copper, lead, and zinc was withdrawn. Development financial assistance has been given to some producers through the Small Business Administration (SBA).

Exploration

Exploration is being increasingly directed toward discovery of deeper and obscured deposits. Greater reliance is being placed on geophysical and geochemical detection methods. Research is needed for cheaper, more efficient exploratory drilling methods, for new interpretive indicators in drillhole logging, and for development of new techniques for use in evaluation of ore deposits. Many economic and technical problems are being attacked and resolved by private companies, State research departments, and Bureau of Mines, and the Geological Survey. Improvements in technology of exploration have been notable since 1950.

Mineralogy

The mineralogy of the lead and zinc deposits of the Eastern and Central United States is relatively simple when compared with that of the complex ores of the Western United States. Greater recovery can be achieved in processing ores of simple mineralogy resulting in a larger net return to the mining

TABLE 33. - Problems affecting potential sources of lead and zinc--Continued

Resources, 1,000 tons[1]	Copper, percent	Lead, percent	Zinc, percent	Problems and remarks
				Area VII[2]
75,000	-	1.49	0.52	Ore deposits are too low-grade for present high cost operations.
830	-	5.00	10.00	Problem involves economical separation of mineral associated with abrasive gangue rock.
20,000	-	3.40	3.20	Ground support is an operating and cost problem. Rock bursts are common as depth of mining increases. Inadequacy of labor is a problem, and in some areas custom milling facilities are needed.
12,000	-	-	.50	Mining, milling, and transportation costs exceed value of ore. Production depends on mining by low-cost underground methods for bedded replacement type of deposit.
1,500,000	-	.25	1.75	This tremendous resource is at depths exceeding 2,000 feet. Recovery is dependent upon finding some cheap mining method that is beyond current technology and economics.
2,000	-	3.50	4.00	Small, scattered mineralized deposits currently cannot be produced cheaply enough to compete with other sources. Deposits would require underground stoping methods involving deep deposits having allied operating problems.
				Area VIII[2]
500	-	1.50	1.50	High operating cost is the problem. High-cost items are due to location and accessibility; a beneficiation problem requires fine grinding of ore to minus 200 mesh to separate the lead and zinc minerals.

[1]Resource in terms of material having a potential of becoming ore.
[2]States in area designations are shown in figure 6.

Domestic Competition

The aspects of competition usually are not indicated at the ore-production stage but are evident at the marketing stage. Effects of domestic competition may be evident in the future on specific high cost production.

Lead and zinc deposits of the Western States contain relatively high-grade ore but are more costly to mine and process than the disseminated deposits in Missouri and Tennessee. Deposits discovered and developed since 1956 in Missouri and Tennessee probably will restrict production in the Western States by virtue of lower costs.

efficient, economical method of producing metal raw materials for use directly in manufacturing. Such plants varying in capacity to meet needs, could be planned to serve a particular area or State.

Marketing

Marketing problems are mainly associated with costs in transporting the metals to users. Most of the base metals are processed or fabricated into consumer items in the industrialized sector of the Eastern and Midwestern United States. Manufacturing markets in Illinois, Michigan, Ohio, Pennsylvania, and Indiana consumed about 62 percent of the slab zinc produced in 1963. Manufacturing plants in New Jersey, Illinois, California, and Indiana used about 46 percent of the copper and lead and other plants in the Eastern States accounted for the greatest portion of the remaining production.

Base metal producers are faced with strong competition from substitute materials. Aluminum is being used in place of copper in many electrical applications. Plastic materials are substituted for lead in cable coverings and latex materials and titanium dioxide are used in paints replacing markets formerly dominated by white lead-type paints. Ceramic and plastic coatings are replacing zinc in some metal covering uses. Substitute materials are a principal factor in restricting the price of copper, lead, and zinc.

Research and market development are needed to find new uses of base metals. Efficient substitution for the base metals is worthwhile but new uses for base metals is also desirable.

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[6] Area refers to Bureau of Mines mineral resource areas. (See fig. 6.)

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APPENDIX. - BUREAU OF MINES RESOURCE OFFICES CONTRIBUTING TO THIS REPORT

Bureau of Mines station	Location	States covered in resource activities
Area I.......	Pittsburgh, Pa. Area field office at College Park, Md.	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia.
Area II......	Knoxville, Tenn. Area field office at Tuscaloosa, Ala.	Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, Tennessee.
Area III.....	Minneapolis, Minn.	Illinois, Indiana, Iowa, Michigan, Minnesota, Wisconsin.
Area IV......	Bartlesville, Okla. Area field office at Dallas, Tex.	Arkansas, Kansas, Louisiana, Mississippi, Missouri, Oklahoma, Texas.
Area V.......	Denver, Colo. Area field offices at Tucson, Ariz., Socorro, N. Mex., Salt Lake City, Utah, and Laramie, Wyo.	Arizona, Colorado, Nebraska, North Dakota, South Dakota, New Mexico, Utah, Wyoming.
Area VI......	San Francisco, Calif. Area field office at Reno, Nev.	California and Nevada.
Area VII.....	Albany, Oreg. Area field office at Spokane, Wash.	Idaho, Montana, Oregon, Washington.
Area VIII....	Juneau, Alaska. Subarea office at Anchorage, Alaska.	Alaska.

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