

Historical Perspective of the Mineral Production of Idaho, with Comments on the Hailey 1°×2° Quadrangle, Idaho

By Walter J. Bawiec *and* Lawrence L. Dee

U.S. Geological Survey Bulletin 2064-T

*Prepared in cooperation with the Idaho Geological Survey,
Idaho State University, and the University of Idaho*

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

This publication is only available online at:
<http://geology.cr.usgs.gov/pub/bulletins/b2064-t/>

Version 1.0 2001

Any use of trade, product, or firm names in this publication
is for descriptive purposes only and
does not imply endorsement by the U.S. Government

Published in the Central Region, Denver, Colorado
Manuscript approved for publication April 27, 2001
Graphics by Alice and Joe Springfield
Photocomposition by Gayle M. Dumonceaux

Contents

Abstract	1
Introduction	1
Brief Mining History of Idaho	1
Mineral Production of Idaho, 1905–1972	3
Unit Regional Value of the United States.....	3
Description of Production Data.....	3
Mineral Production of Idaho, 1905–1972.....	3
Distribution of Mineral Production in Idaho, 1902–1951.....	7
Description of Production Data.....	7
Distribution of Idaho Production by County.....	9
Historical Development of Selected Mining Districts and Areas in the Area of the Hailey Quadrangle.....	14
Atlanta Mining Area.....	14
Rocky Bar Mining Area.....	16
Boise Basin Mining Area.....	18
Quartzburg District.....	19
Featherville District.....	19
Neal District.....	19
Little Wood River (Muldoon) District.....	19
Little Smokey and Rosetta Districts.....	19
Willow Creek District.....	19
Wood River (Mineral Hill District) Mining Area.....	20
Warm Springs District.....	20
References	20

Figures

1. Map showing mining districts and areas described in report.....	2
2. Diagram showing unit regional value of mineral resources by State in the United States.....	5
3-7. Diagrams showing unit regional value for the States of the United States for:	
3. Construction materials.....	5
4. Fuels.....	7
5. Metals.....	7
6. Nonmetals.....	8
7. Precious metals.....	8
8. Map showing value of mineral industries products in the United States by State, 1905–1972.....	9
9. Maps showing Idaho county boundaries and mine locations having reported production of gold, silver, copper, lead, and zinc, 1902–1951.....	10
10. Graphs showing relative production by selected commodity for each county in Idaho with reported production, 1902–1951.....	12

11-16. Spatial histograms, produced by county in Idaho, of:	
11. Tonnage	13
12. Lode gold.....	14
13. Silver.....	15
14. Copper.....	16
15. Lead	17
16. Zinc	18

Tables

1. Mineral resources produced in the United States, by State, 1905–1972.....	4
2. Standard commodities in each of the mineal resource sectors.....	6
3. Relative production in Idaho, by county, of tonnage, gold, silver, copper, lead, and zinc.....	11

Metric Conversion Factors

Multiply	By	To obtain
Miles	1.609	Kilometers
Feet	0.3048	Meters
Inches	2.54	Centimeters
Tons	1.016	Metric tons
Short tons	0.907	Metric tons
Troy ounces	31.103	Grams
Ounces	28.35	Grams

Historical Perspective of the Mineral Production of Idaho, with Comments on the Hailey 1°×2° Quadrangle, Idaho

By Walter J. Bawiec and Lawrence L. Dee

Abstract

Idaho has a long and diverse history of minerals exploration and production. A comprehensive look at this history, combined with documentation of the distribution and magnitude of past and present mineral production, can lead to a better understanding of the mineral endowment and potential resources.

The total mineral production of Idaho (1905–1972), when examined as unit regional values and compared to the rest of the United States, shows that Idaho has produced above the median value of other States for both metals and precious materials, near the median value for nonmetals, and below the median value for construction materials and fuels. An examination of selected commodities within Idaho, by county, for a fifty-year period (1902–1951) shows the dominance of Shoshone County in total production within the State for silver, copper, lead, and zinc.

Introduction

Idaho has a long and diverse history of minerals exploration and production that is related to westward expansion and development of the western United States. Exploration for metals and precious materials acted as a lure for new inhabitants. The mining and development of these metals and precious materials, along with nonmetals and construction materials, contributed to establishment of permanent settlements and has thus long been an integral part of the economy of Idaho. Continued development and advancement in this sector of the Idaho economy is dependent, however, on understanding the diversity, distribution, and magnitude of the State's mineral endowment. One approach to understanding the mineral endowment is the development and use of mineral inventories. Mineral inventories provide baseline information from which regional metallogenic studies can be extrapolated. Also, they are a requirement for mineral commodity and related regional geologic studies, which are necessary in planning future mineral exploration and production (Gabert, 1978).

The purpose of this investigation is to examine the diversity and distribution of known mineral production in Idaho and to use this knowledge to gain insight into potential new mineral resources and to enhance our understanding of the remaining mineral resources. Although much of the information presented

herein is generally known or intuitive to economic geologists familiar with Idaho, this report offers a comprehensive look at mineral production in the State and perhaps a new perspective toward utilizing this type of information.

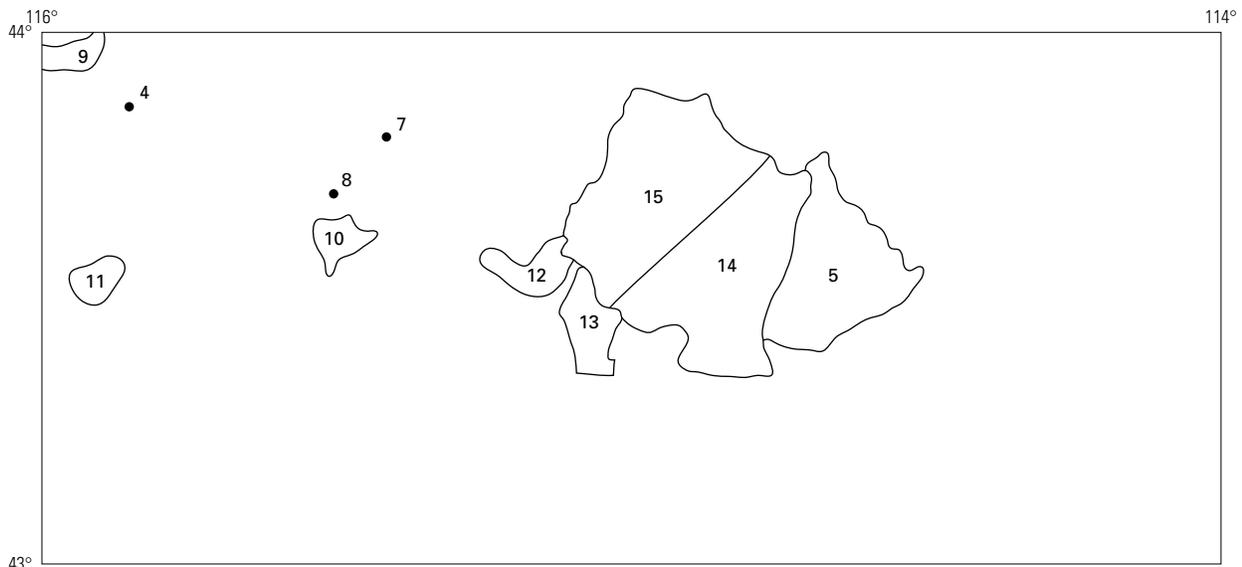
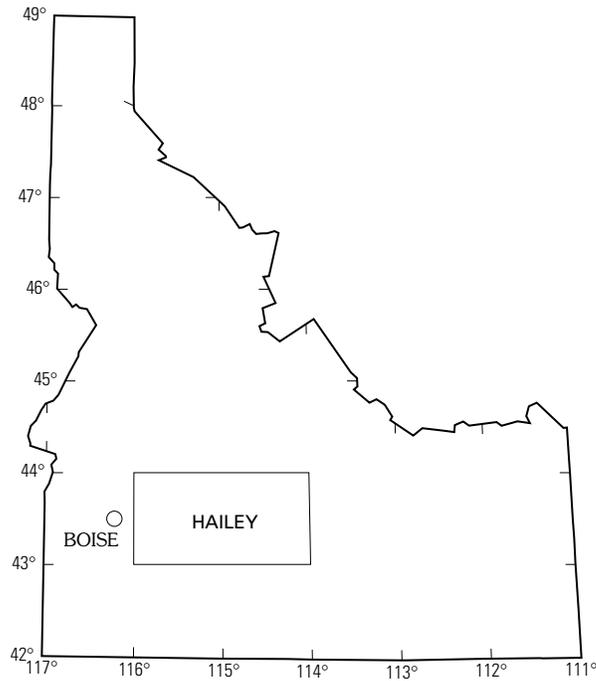
Brief Mining History of Idaho

The first white men known to have set foot in what is now Idaho were members of the Lewis and Clark Expedition in 1805 (Ruppel and Lopez, 1988). They were followed by mountain men and fur traders, after whom came the missionaries and westward-bound immigrants in search of new lands. The mountain men, trappers, and immigrants can be credited with the opening of the West, but it was the miners and those with affiliated occupations who established the first permanent settlements. Of equal importance to establishing permanent towns was the impetus that development of the mineral industry provided for establishment of railroads and markets for local agricultural and forest products (Wells, 1976).

In 1848, gold was discovered in California, and prospectors and miners from around the world rushed to the Pacific coast. When the easily extracted gold of the California gold placers began to dwindle, prospectors moved into other areas of the West searching for new sources. Nevada, Colorado, and British Columbia showed promise as mining regions in 1858–1859, and Idaho soon followed (V.O. Goodwin and J.A. Hussey, U.S. Forest Service and National Park Service, written commun., 1965).

It is not clear when and where metals were first discovered in Idaho, but the presence of placer gold in the Boise Basin (fig. 1) was known to a Hudson Bay Company trapper as early as 1844 (Wells, 1983). Other discoveries were reported, but Indian hostility delayed the investigation of the discoveries.

In 1860, the discovery of gold on the North Fork of the Clearwater River, now Clearwater County, Idaho, marked the beginning of Idaho's mineral industry. The man credited with the 1860 discovery was Captain E.D. Pierce, a California prospector who also had been a trader with the Nez Perce Indians. Although a treaty forbade Captain Pierce from prospecting the Clearwater River country, he disguised a prospecting expedition as an Indian trading venture and went gold hunting with the leader of the Nez Perce band. They were successful and found



- | | |
|---|---|
| 1 Pierce City mining district | 9 Quartzburg mining district |
| 2 Florence mining district | 10 Featherville mining district |
| 3 Warren mining district | 11 Neal mining district |
| 4 Boise Basin mining district | 12 Little Smokey and Rosetta mining districts |
| 5 Little Wood River (Muldoon) mining district | 13 Willow Creek mining district |
| 6 Coeur d'Alene mining district | 14 Wood River (Mineral Hill district) mining area |
| 7 Atlanta mining area | 15 Warm Springs mining district |
| 8 Rocky Bar mining area | |

Figure 1. Map showing mining districts and areas described in report. Boundaries of mining districts are from Ross (1936).

gold. Within the year, the town of Pierce was established, the Pierce City mining district was organized, and the rush to the Idaho Territory was underway (Koschmann and Bergendahl, 1968). The population of this part of the then Washington territory grew to such an extent that a new territory was carved out. This new territory eventually became the State of Idaho in 1890.

2 Historical Perspective of the Mineral Production of Idaho, Hailey 1°x2° Quadrangle, Idaho

By July 1861, 5,000 miners were prospecting in the new mining district. In spite of Indian hostility, prospecting rapidly spread south with the establishment of the mining camps of Florence and Warren. In the fall of 1862, placer gold was discovered in the Boise Basin, in the northwest corner of the Hailey 1°x2° quadrangle, northeast of the present city of Boise. The

Boise Basin immediately drew a large number of miners to the area. Prospectors swarmed through the hills, and more discoveries soon followed. The classic situation of the placer leading to vein outcrops was evident in the Boise Basin, and soon a number of hard-rock mines began operation. As the miners fanned out from the Boise Basin, they established other lode and placer districts.

Silver and base-metal mining came into greater prominence in the Idaho Territory with the development of lead mines in the Wood River area in about 1883 and the establishment of the Bunker Hill mine in the Coeur d'Alene area in 1885. Development of these areas led to the establishment of a multitude of mining districts in the State from which precious- and base-metal riches were extracted.

Mineral Production of Idaho, 1905–1972

The mineral production of the United States has been documented at a national scale by the U.S. Geological Survey (1880 to 1923 and 1996 to present) and the U.S. Bureau of Mines (1924 to 1995) as well as at the regional level by many Federal and State agencies. This information has been invaluable in studies related to the mineral resources of the United States. The combination of mineral production information, inventories, and regional geologic data assists in assessment of mineral potential and in delineating permissible terranes for specific deposit types. The application of mineral resource assessment methodology aids in projecting the possible existence and amount of undiscovered resources. An example of how mineral production data or inventories can be used as a measure of mineral resource endowment for an area is demonstrated in an application of the unit regional value concept as developed by Griffiths (1978).

Unit Regional Value of the United States

Unit regional value is defined as the cumulative deflated value of mineral production summed over time and divided by the total area under consideration. If unit regional values are calculated for many regions, such as for States, frequency distributions can be constructed. Different regions can then be ranked using the mean and standard deviation intervals as calibration levels. For all fifty of the United States, the logarithm of the unit regional value is normally distributed (Griffiths, 1978). This lognormal distribution of unit regional value for the United States has been used by geoscientists as a reference background for estimating the resource potential of undeveloped areas (Griffiths and Singer, 1971). For our purposes, we use this distribution to evaluate how Idaho has performed in producing commodities as compared to the remaining States.

When evaluating the mineral resource potential of an area, it has been found that no area is completely deficient of resources (value) and that no area has as yet been completely depleted. Features pertinent to resource estimates include the inherent characteristics of the region and the amount produced.

The inherent characteristics, or geologic processes, that affect a region determine whether any resource is present and how much resource is present. The amount produced from a region is somewhere between these upper and lower bounds and depends on acquired socioeconomic conditions. Reasons for which areas might under produce include socioeconomic factors such as inhospitable climate, lack of social or transportation infrastructure to facilitate the development of commodities, or lack of commitment by the administrators of areas to foster and encourage development. Reasons for an area to substantially overproduce include availability to consumer markets and a commitment to develop available resources.

Description of Production Data

The value of mineral resources is presented in this study as the total value of all mineral resources produced and subdivided by type into construction materials, fuels (energy resources), metals, nonmetals, and precious materials. Data used in this report to examine Idaho's production history are from 1905 to 1972 and represent aggregate figures reported in annual reports on the mineral resources of the United States by the U.S. Geological Survey for 1905–1923 and by the U.S. Bureau of Mines for 1924–1972. The reported values in current U.S. dollars were deflated, using the wholesale price index, to the index year 1967=100 and then prorated against the unit area of the State as deflated dollars per square kilometer. In this way, the value of production is not linked to inflation, and the values of more recently produced commodities are not inflated relative to those on earlier produced commodities.

It has long been recognized, however, that no data set documenting mineral production for large areas can ever include all material that has been removed. Reasons for this include the lack of recorded production figures for earlier mines, nonreporting by producers during historical times, errors in recording or reporting, and the necessity to keep proprietary data confidential. Even so, patterns can be recognized from the production data and trends or relationships inferred.

Mineral Production of Idaho, 1905–1972

A comparison of the unit regional values (log 1967\$ per square kilometer) of total mineral production for the United States (1905–1972) is given in table 1 and is graphically represented in figure 2 (Griffiths, 1978). The three States having the highest unit regional values are Pennsylvania, West Virginia, and Louisiana, respectively, primarily due to the production of coal in Pennsylvania and West Virginia, and the production of petroleum in Louisiana. Idaho, which has an area of 216,413 km² and a U.S. 1967 dollar cumulative value of \$5,043,425,237, has a unit regional value of 23,305 1967\$/km² or log 1967\$/km² of 4.3674 (table 1), less than that for the entire 50 States (54,954 1967\$/km²) (fig. 2).

The total mineral production for each of the 50 States can be subdivided by commodity into five mineral resource sectors: construction materials, fuels, metals, nonmetals, and precious

Table 1. Mineral resources produced in the United States, by State, 1905-1972.

[Dollar amounts have been deflected to the year 1967+100. See text for details. Compiled from Griffiths (1978)]

State	Area (km ²)	U.S. 1967 \$ Cumulative value	Unit regional value (\$ km ²)	Log unit regional value (log \$ km ²)
1. Alabama	133,667	11,364,654,696	35,022	4.9295
2. Alaska	1,518,807	4,159,712,439	2,739	3.4376
3. Arizona	295,024	20,226,896,247	68,560	4.8361
4. Arkansas	137,539	6,846,569,453	49,779	4.6970
5. California	411,015	69,588,956,609	169,310	5.2287
6. Colorado	270,000	13,661,542,680	50,598	4.7041
7. Connecticut	12,973	846,566,521	65,256	4.8146
8. Delaware	5,328	78,242,951	14,685	4.1669
9. Florida	151,670	6,041,796,133	39,835	4.6003
10. Georgia	152,489	3,856,850,945	25,293	4.4030
11. Hawaii	16,706	413,949,055	24,778	4.3941
12. Idaho	216,413	5,043,425,237	23,305	4.3674
13. Illinois	146,076	32,977,377,150	225,755	5.3536
14. Indiana	93,994	11,981,576,088	127,471	5.1054
15. Iowa	145,791	4,911,801,443	33,691	4.5275
16. Kansas	213,064	22,188,913,319	104,142	5.0176
17. Kentucky	104,623	26,656,799,509	254,789	5.4062
18. Louisiana	125,675	68,638,059,322	546,155	5.7373
19. Maine	86,027	795,879,843	9,251	3.9662
20. Maryland	27,394	2,919,086,001	106,559	5.0276
21. Massachusetts	21,386	1,682,779,875	78,686	4.8959
22. Michigan	150,779	21,162,013,569	140,351	5.1472
23. Minnesota	217,736	21,260,811,657	97,645	4.9896
24. Mississippi	123,584	5,087,395,097	41,165	4.6145
25. Missouri	180,487	10,950,507,277	60,672	4.7830
26. Montana	381,087	11,529,312,200	30,254	4.4808
27. Nebraska	200,147	2,054,957,876	10,267	4.0115
28. Nevada	286,299	5,412,366,685	18,904	4.2766
29. New Hampshire	24,097	326,037,480	13,530	4.1313
30. New Jersey	20,295	5,827,132,180	287,121	5.4581
31. New Mexico	315,155	19,525,019,399	61,962	4.7921
32. New York	128,402	13,071,024,164	101,798	5.0077
33. North Carolina	136,198	2,221,100,079	16,308	4.2124
34. North Dakota	183,022	1,840,790,854	10,058	4.0025
35. Ohio	106,765	27,559,379,943	258,131	5.4118
36. Oklahoma	181,090	43,439,516,951	239,878	5.3800
37. Oregon	251,181	1,883,975,995	7,500	3.8751
38. Pennsylvania	117,412	95,124,749,805	810,179	5.9086
39. Rhode Island	3,144	159,769,983	50,817	4.7060
40. South Carolina	80,432	1,136,734,422	14,133	4.1502
41. South Dakota	199,552	2,335,996,684	11,706	4.0684
42. Tennessee	109,412	7,185,553,577	65,674	4.8174
43. Texas	692,408	153,136,548,471	221,165	5.3447
44. Utah	219,932	16,723,514,007	76,039	4.8810
45. Vermont	24,887	1,540,295,865	61,892	4.7916
46. Virginia	105,716	9,620,203,531	91,000	4.9590
47. Washington	176,617	3,749,907,531	21,232	4.3240
48. West Virginia	62,629	49,442,930,947	789,457	5.8973
49. Wisconsin	145,439	3,330,256,338	22,898	4.3598
50. Wyoming	253,597	14,412,498,324	56,832	4.7546

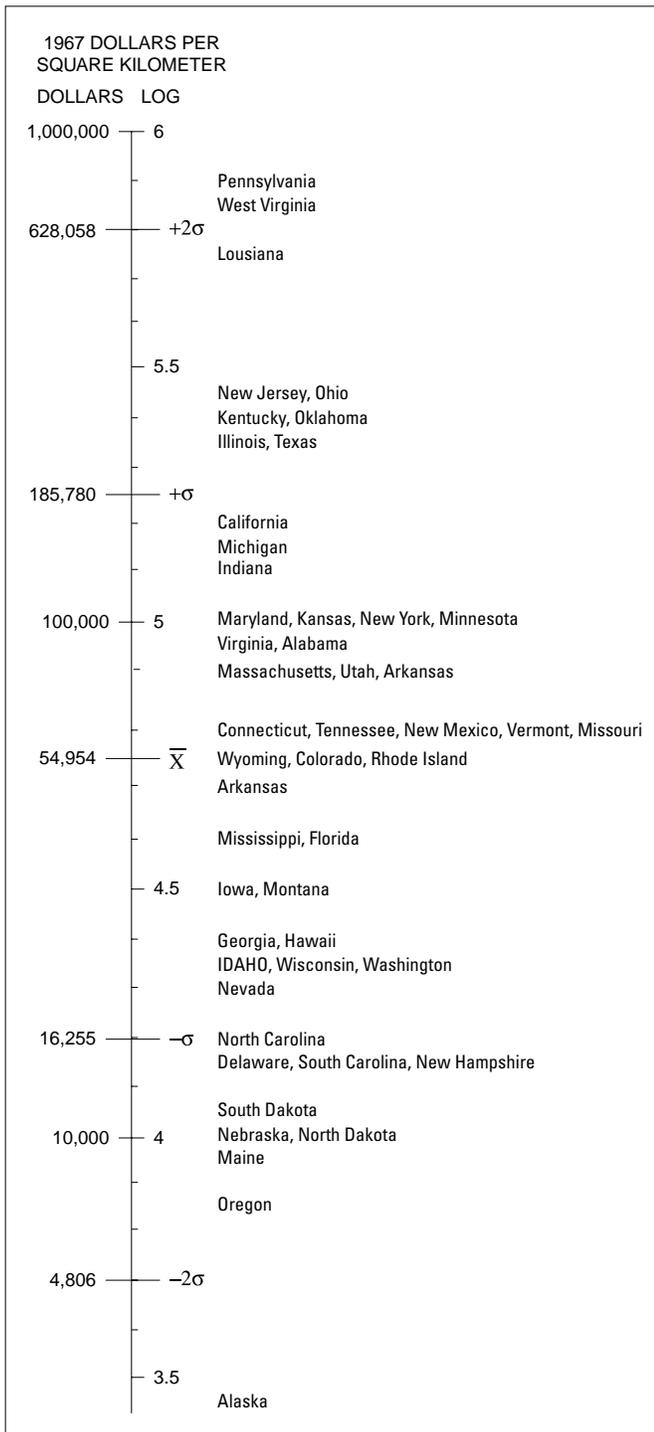


Figure 2. Diagram showing unit regional value of mineral resources by State in the United States (1905–1972, deflated U.S. dollar, 1967=100). \bar{X} , is mean value; values for first and second standard deviations are also shown.

materials. Each of these resource sectors, in turn, consists of the contributing commodities as shown in table 2. For the illustrations showing unit regional values (figs. 3–7), if a State does not have reported production of a commodity in that resource sector, the State is not shown in the figure.

The States having the highest unit regional values for construction materials (fig. 3) are the same States that contain and (or) are proximal to the largest urban areas. It is no coincidence

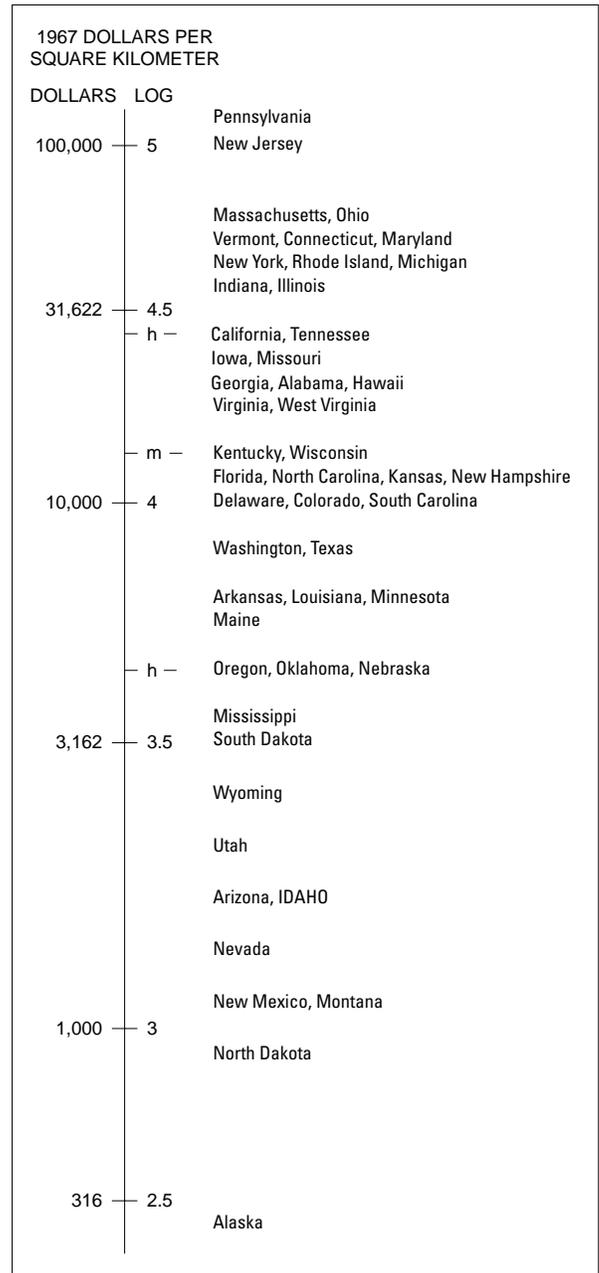


Figure 3. Unit regional value (log 1967 dollars/ km²) for construction materials for the States of the United States (1905–1972). m, medium; h, upper and lower quartiles. Modified from Walsh (1979).

that the least populated States have the lowest unit regional values in construction materials. Although construction materials make some contribution to the mineral economy of Idaho, Idaho ranks low in unit regional values as compared to other States.

The high unit regional values for fuels in the United States (fig. 4) are dominated by petroleum- and coal-producing states. West Virginia, Pennsylvania, and Louisiana are the highest ranked States for fuel unit regional values, and it is for this reason that they rank high in total mineral production. Idaho ranks only ahead of Vermont and New Hampshire for fuel production from producing States.

Table 2. Standard commodities in each of the mineral resources sectors.

Construction Materials	
Asbestos	Mica
Cement	Sand and gravel
Clays (construction)	Stone
Diatomite	Vermiculite
Gypsum	
Fuels	
Anthracite coal	Natural gasoline
Asphalt	Oil shale
Bituminous coal	Peat
Lignite	Petroleum
Liquid propane gas	Uranium
Natural gas	
Metals	
Aluminum	Manganese
Antimony	Mercury
Arsenic	Molybdenum
Beryllium	Nickel
Bismuth	Rare Earths
Cadmium	Tantalum
Chrome	Thorium
Cobalt	Tin
Copper	Titanium
Iron ore	Tungsten
Lead	Vanadium
Lithium	Zinc
Magnetite	Zirconium
Nonmetals	
Aluminum silicates	Magnesite
Barites	Mineral paints
Borates	Nitrates
Bromine	Phosphates
Carbon dioxide	Potassium salts
Clays (nonmetal)	Pyrites
Corundum	Salt
Feldspar	Sand (nonmetal)
Fluorspar	Soda
Garnet	Sulfur
Gemstones	Talc
Graphite	Abrasives
Lime and limestone	Calcareous marls
Precious Materials	
Diamonds	Platinum
Gold	Silver

The unit regional values for metals in the United States are shown in figure 5. The top producing States of Minnesota and Michigan can attribute their metallic wealth to iron ore, and Arizona's position is due to its copper production. Idaho ranks above the median due to its production of copper, lead, and zinc.

Nonmetal unit regional values are represented in figure 6. Idaho is very near the median of this lognormal distribution because it produced the expected value per unit area as compared to the other States. Nonmetallic commodities produced in Idaho include phosphate, clays, and garnet.

Unit regional values for precious materials of the United States are shown in figure 7. Idaho ranks very near the top of production of precious materials because of its production of large amounts of silver and gold.

In summary, a visual representation of the total unit regional value of mineral production by State (table 1) is shown as thousands of dollars per square mile in figure 8 (Griffiths, 1978). Of interest are the three States (Pennsylvania, West Virginia, and Louisiana) having the highest value per unit area, whose positions are due primarily to their production of the

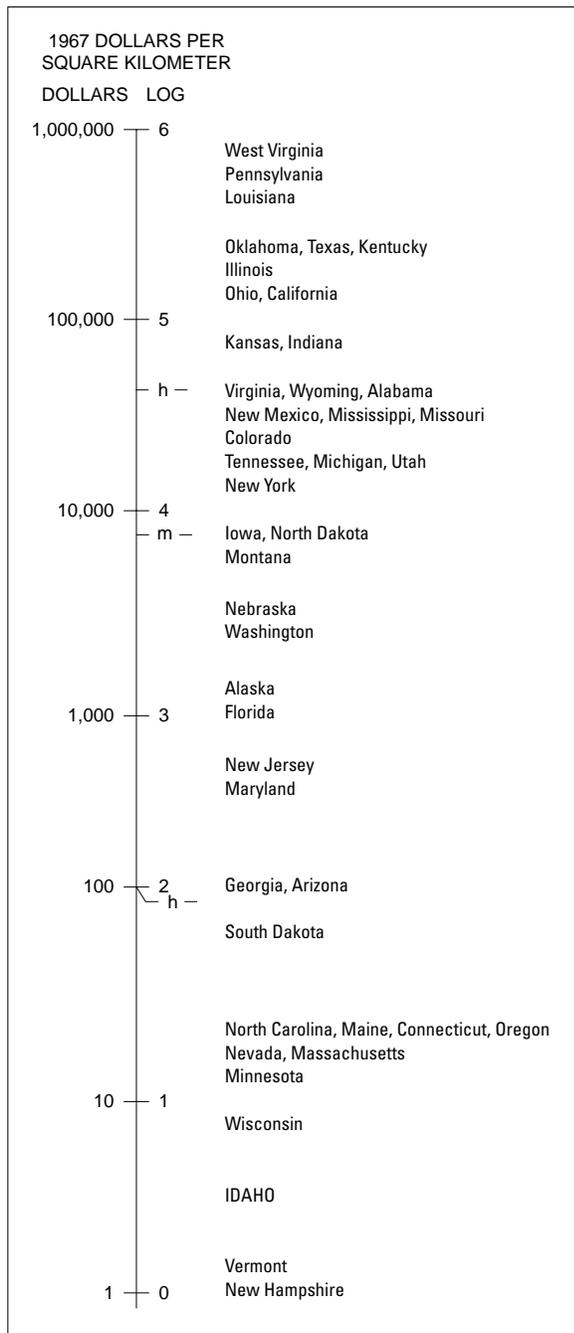


Figure 4. Unit regional value (log 1967 dollars/ km²) for fuels for the States of the United States (1905–1972). m, medium; h, upper and lower quartiles. Modified from Walsh (1979).

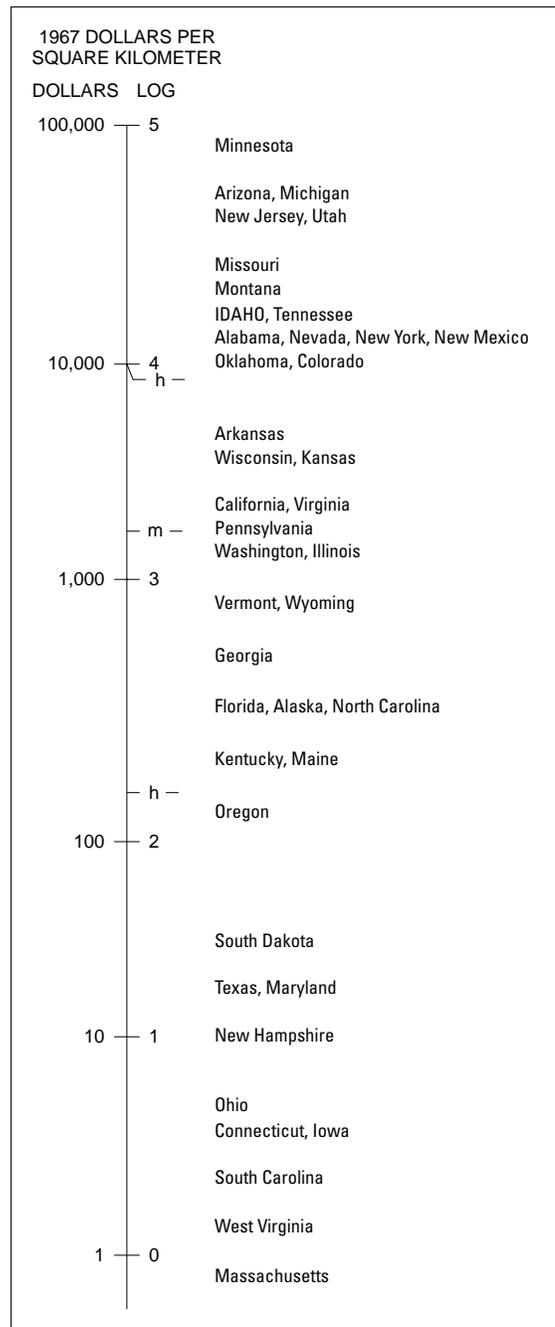


Figure 5. Unit regional value (log 1967 dollars/ km²) for metals for the States of the United States (1905–1972). m, medium; h, upper and lower quartiles. Modified from Walsh (1979).

fossil fuels coal and petroleum. The State having the fourth highest unit regional value is New Jersey; its position is due in part to its proximity to a large metropolitan area and the production of needed construction materials. From the tables and figures presented here, it can be seen that Idaho is below the mean unit regional value for total State production in the United States; it has produced above the median unit regional values for metals and precious materials, close to the median unit regional value for nonmetals; and below the median unit regional value for construction materials and fuels.

Distribution of Mineral Production in Idaho, 1902–1951

Description of Production Data

In the previous section, mineral production values for each State for the years 1905 to 1972 were aggregated, analyzed, and compared. In this section, we examine mineral production only in the State of Idaho, as reported to the Federal Government by

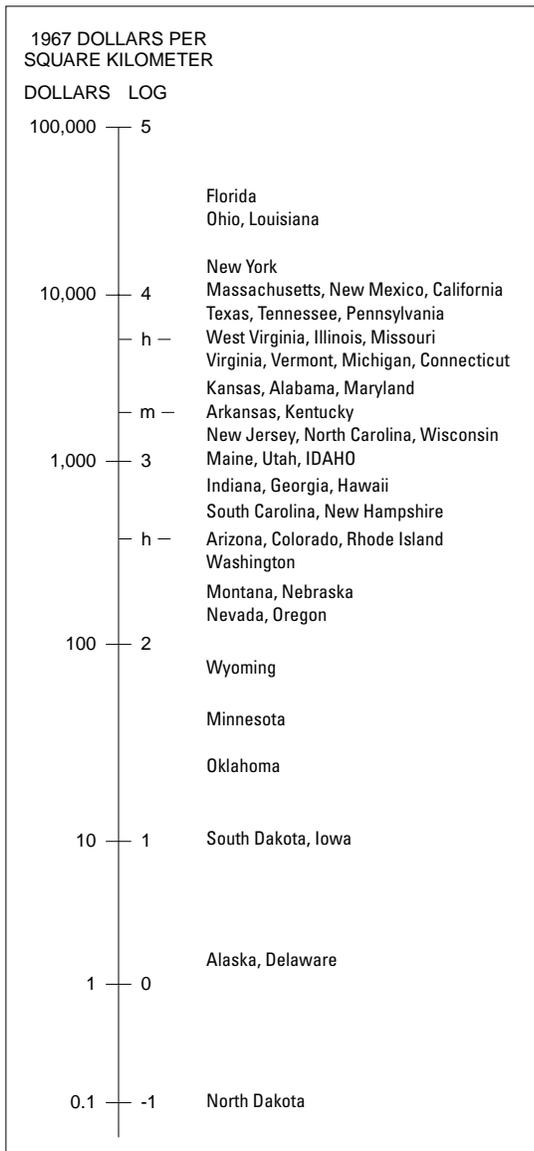


Figure 6. Unit regional value (log 1967 dollars/ km^2) for nonmetals for the States of the United States (1905–1972). m, medium; h, upper and lower quartiles. Modified from Walsh (1979).

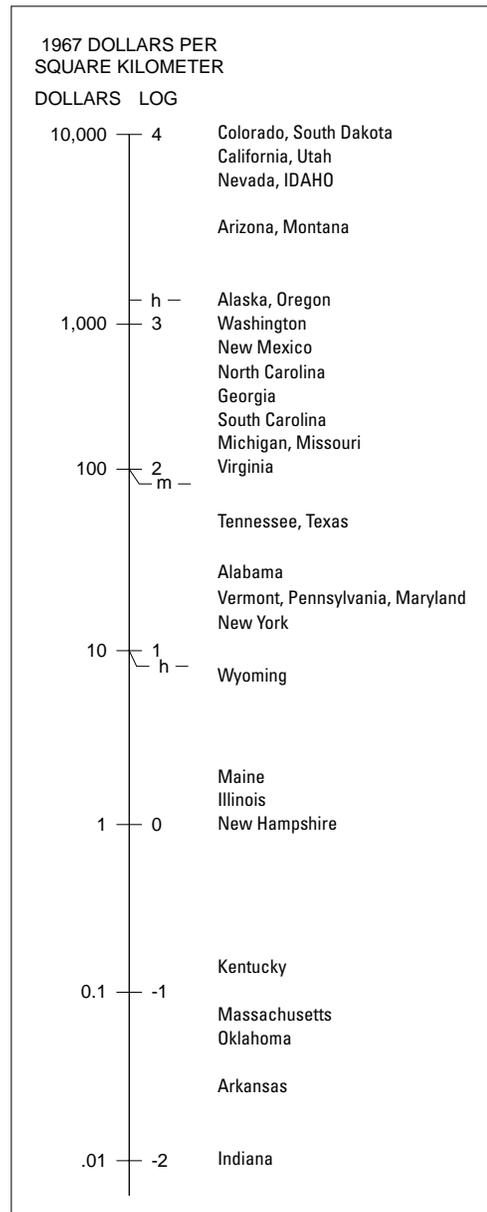


Figure 7. Unit regional value (log 1967 dollars/ km^2) for precious metals for the States of the United States (1905–1972). m, medium; h, upper and lower quartiles. Modified from Walsh (1979).

individual mine operators, for a 50-year period 1902–1951. This data set is more restricted than that used in the previous section because only five commodities are considered: gold and silver from the precious materials resource sector and copper, lead, and zinc from the metals resource sector. Information compiled for these commodities includes tonnage of ore mined, amount (ounces) of gold and silver produced, and amount (pounds) of copper, lead, and zinc produced. To minimize the confusion that could easily arise when attempting to document mines of small, questionable, and (or) undocumented production, only statistics from mines that reported production of 500 or more short tons (454,000 kg) of ore for a given year were included. Also, with respect to gold all reported production was from lode gold veins; no placer production was included.

For the 50-year production interval (1902–1951) used to examine the mineral production in Idaho, a file with almost 2,600 records was constructed. Each record consists of county, mining district, mine name, year of production, tonnage of ore, gold (ounces), silver (ounces), copper (pounds), lead (pounds), and zinc (pounds). Those records that reflect multiple years of production for the same mine were aggregated into cumulative reported production for that mine. This aggregation resulted in approximately 450 mines having reported production of either gold, silver, copper, lead, or zinc or some combination of these commodities. Location data of latitude and longitude were then assigned to these mines using the U.S. Geological Survey Mineral Resource Data System (MRDS), the U.S. Bureau of Mines Minerals Industry Location System (MILS), and the Idaho



Figure 8. Map showing value of mineral industries products in the United States, by State, 1905–1972 (thousands of dollars per square kilometer).

Bureau of Mines and Geology Mines and Prospects Map series. The number of individual mines for which production is reported and a location could be determined is approximately 367, as shown in figure 9.

Distribution of Idaho Production by County

To evaluate the spatial distribution of production in the State of Idaho, reported production data were aggregated by individual county. The totals of Idaho production, by county, were determined by aggregating production from all mines within individual counties and summing reported tonnage, gold, silver, copper, lead, and zinc values. Plots or geographic areal histograms of these commodities, in which the height of each

county reflects its relative contribution to production of the total State, were computed. A limitation to this data set is reflected in the way it was collected. Only mines that reported production of 500 tons (545,000 kg) per year or more were considered. If production data from a mine for a given year(s) were not reported, no assumptions for missing data were put into the analysis. These total cumulative production figures of each county for each commodity were not divided by the size of the county (that is, normalized to square area), as was done in unit regional unit applications. It must also be noted that because of the dominance of some individual operators in a county, and the desire for this information to remain proprietary, amounts of county production remain in relative terms, and no absolute and real production figures are released.

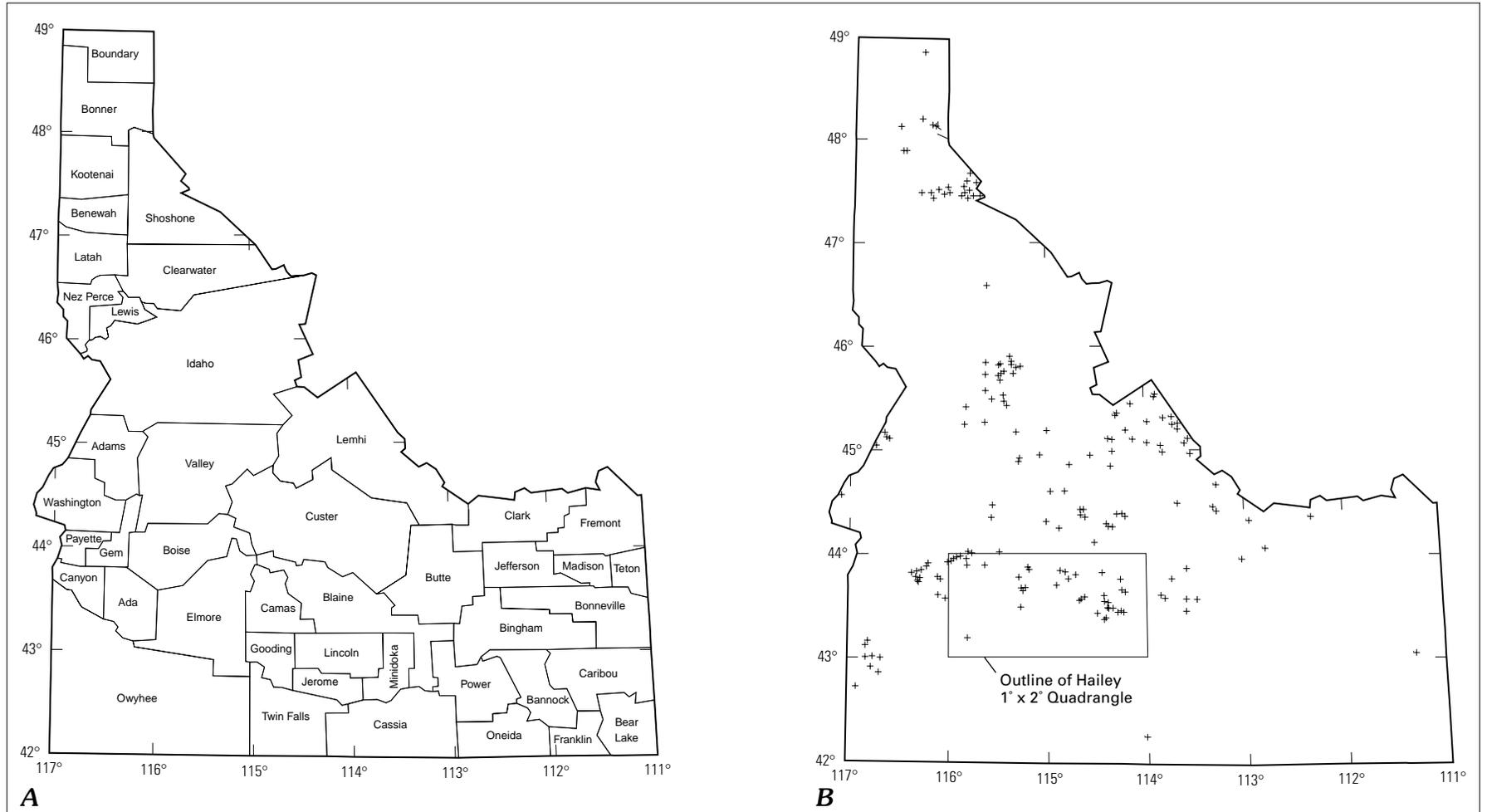


Figure 9. Maps showing *A*, Idaho county boundaries and *B*, mine locations having reported production of gold, silver, copper, lead, and zinc, 1902–1951 (+).

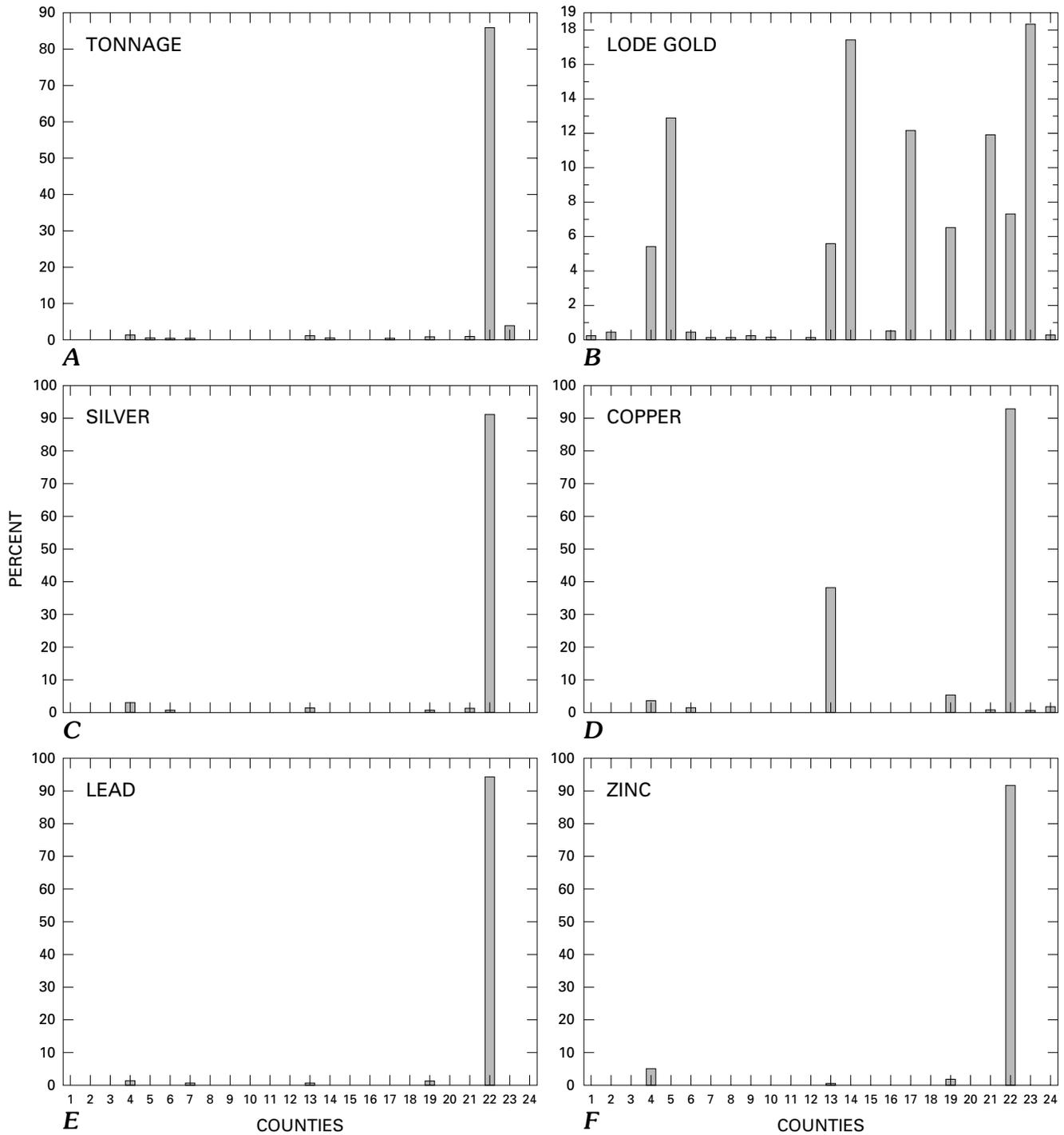
Table 3. Relative production, from highest to lowest in Idaho, by county, tonnage, gold, silver, copper, lead, and zinc.

TONNAGE	GOLD	SILVER
Shoshone	Valley	Shoshone
Valley	Elmore	Blaine
Blaine	Boise	Owyhee
Custer	Idaho	Custer
Lemhi	Owyhee	Lemhi
Elmore	Shoshone	Bonner
Owyhee	Lemhi	Valley
Idaho	Custer	Boundary
Boise	Blaine	Elmore
Boundary	Bonner	Washington
Bonner	Gem	Boise
Butte	Adams	Idaho
Fremont	Washington	Butte
Gem	Camas	Fremont
Washington	Ada	Gem
Camas	Cassia	Camas
Ada	Boundary	Kootenai
Adams	Clearwater	Adams
Clearwater	Butte	Ada
Cassia	Nez Perce	Clark
Bingham	Bingham	Nez Perce
Nez Perce	Fremont	Clearwater
Kootenai	Clark	Cassia
Clark	Kootenai	Bingham
COPPER	LEAD	ZINC
Shoshone	Shoshone	Shoshone
Custer	Blaine	Blaine
Lemhi	Lemhi	Lemhi
Blaine	Custer	Custer
Washington	Boundary	Owyhee
Bonner	Bonner	Valley
Owyhee	Fremont	Butte
Valley	Butte	Boundary
Fremont	Valley	Bonner
Boundary	Boise	Adams
Idaho	Owyhee	Gem
Boise	Clark	Fremont
Butte	Gem	Bingham
Elmore	Kootenai	Ada
Camas	Camas	Nez Perce
Gem	Idaho	Boise
Adams	Washington	Clark
Clark	Elmore	Idaho
Ada	Adams	Cassia
Nez Perce	Bingham	Elmore
Bingham	Cassia	Kootenai
Clearwater	Nez Perce	Clearwater
Cassia	Clearwater	Camas
Kootenai	Ada	Washington

Production from Shoshone County dwarfs production from other counties in all categories except lode gold (fig. 10). Because of this disproportionate amount of production from Shoshone County, contributions from other counties are muted and difficult to see. For this reason, county proportions of State production for each of the commodities in figures 11–16 are presented in two formats, the true scale, and a normalized scale. To observe the spatial distribution of production and possible

patterns at a vertical scale that enhances the variation among these other counties, the value of the highest producing county (Shoshone County in every case except for lode gold) was set to the value of the second highest producing country for that variable (table 3). This procedure results in amplification of the remaining counties.

Idaho's cumulative ore tonnage produced by county from 1902 to 1951 shows the dominance of Shoshone County (fig.



COUNTY					
1	Ada	9	Camas	17	Idaho
2	Adams	10	Cassia	18	Kootenai
3	Bingham	11	Clark	19	Lemhi
4	Blaine	12	Clearwater	20	Nez Perce
5	Boise	13	Custer	21	Owyhee
6	Bonner	14	Elmore	22	Shoshone
7	Boundary	15	Fremont	23	Valley
8	Butte	16	Gem	24	Washington

Figure 10. Graphs showing relative production by selected commodity for each county in Idaho with reported production, 1902–1951. *A*, percent of tonnage by county; *B*, percent of lode gold by county; *C*, percent of silver by county; *D*, percent of copper by county; *E*, percent of lead by county; and *F*, percent of zinc by county.

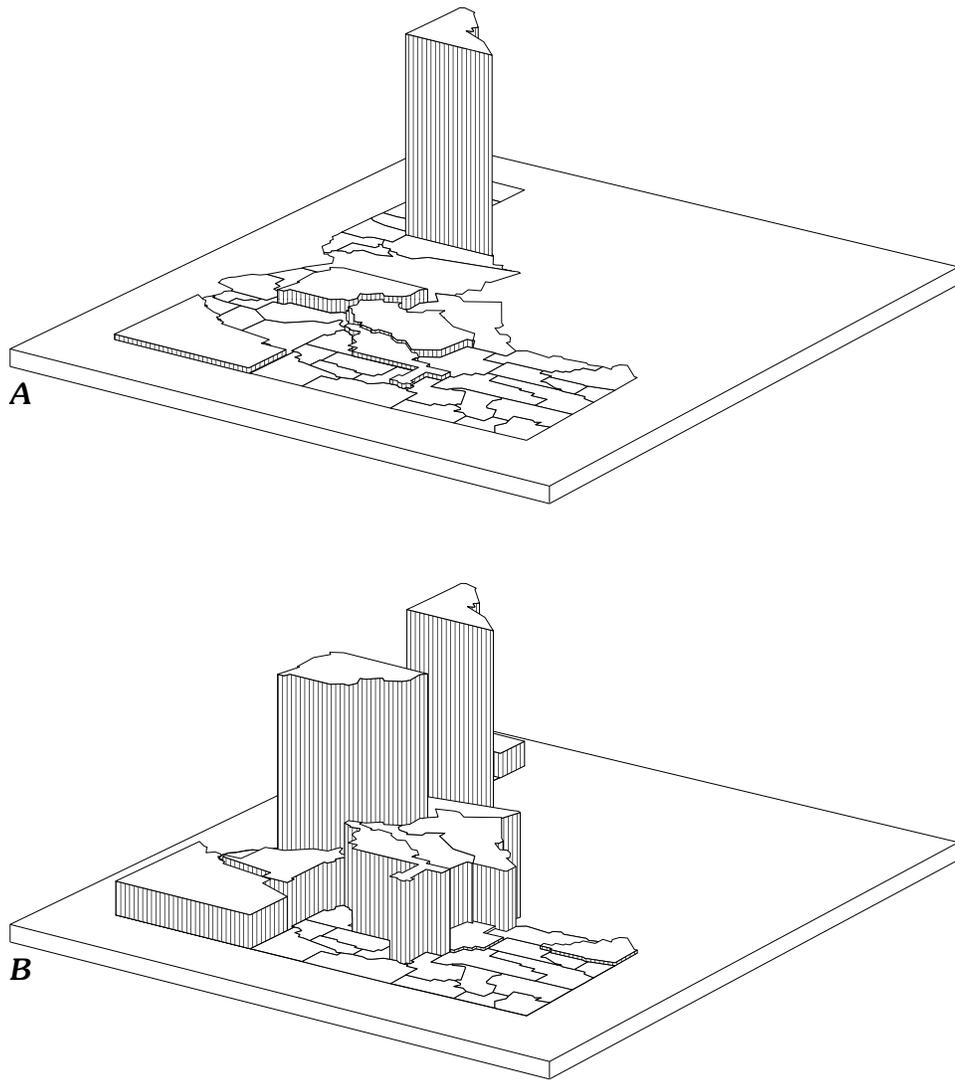


Figure 11. Spatial histograms showing *A*, percent of tonnage by county in Idaho and *B*, normalized county tonnage described in text.

11), a pattern that will persist for all commodities discussed here except lode gold. If Shoshone County’s cumulative production is set to the value of the county having second highest ore tonnage, Valley County (table 3), enhanced variability in the counties can be observed (fig. 11). The relative order, from highest to lowest, of ore tonnage mined within each county related to amounts of gold, silver, copper, lead, and zinc produced is shown in table 3.

The distribution of gold production from lode deposits by county in Idaho from 1902 to 1951 is shown in figures 10 and 12. In contrast to the metallic commodities mined, gold is more evenly distributed among counties and, the normalized county gold production does not significantly differ. Lode gold production is dominantly from the central part of the State.

Silver production in Idaho has been dominantly from Shoshone County (fig. 13). If the production from Shoshone County is reset to the amount of production from the much smaller second-leading silver-producing county in the state, Blaine County, the distribution of silver production from other counties is more apparent (fig. 13). Owyhee, Custer, and Lemhi Counties have also contributed to silver production, along with those other counties shown in figure 10.

Copper production in Idaho has been dominated by two counties, Shoshone and Custer, as shown in figure 14. Even when normalized, other counties have contributed little to production.

Lead production has been dominated by Shoshone County (fig. 15). If normalized, Blaine, Lemhi, and Custer Counties also are contributors.

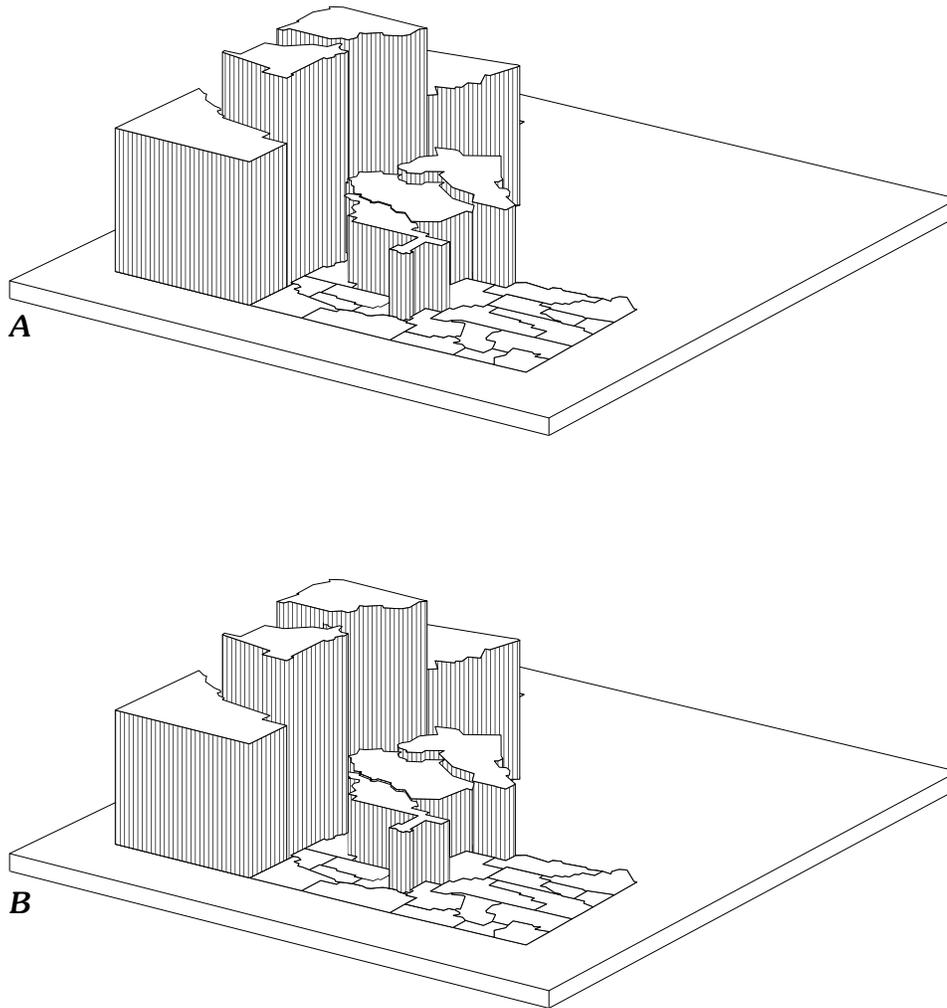


Figure 12. Spatial histograms showing *A*, lode gold produced by county in Idaho and *B*, normalized county tonnage described in text.

As with most of the other commodities, zinc production has been mainly from Shoshone County (fig. 16). When normalized, Blaine and Lemhi are significant producers, along with those counties listed in table 3.

Historical Development of Selected Mining Districts and Areas in the Area of the Hailey Quadrangle

Many mining districts and areas, new and old, active and inactive, are in and around the Hailey $1^{\circ}\times 2^{\circ}$ quadrangle and the western part of the Idaho Falls $1^{\circ}\times 2^{\circ}$ quadrangle. These mining districts are discussed in greater detail in other chapters in this bulletin. In this section we introduce some of the important mining districts of the area, their locations, and a brief history indicating their significance and contribution to mining in Idaho. Much of the historical material in this section was extracted from Merle W. Wells' (1983) "Gold camps and silver cities." All districts and mining areas mentioned here are shown on figure 1.

Atlanta Mining Area

The Atlanta mining area is in rugged, mountainous country about 70 mi (112 km) northeast of Boise (fig. 1). It was founded by prospectors who discovered placer deposits on the Middle Fork of the Boise River. Additional placer discoveries, along the Yuba River south of Atlanta, drew attention to the area, and in 1864 two prospectors traced gold in Quartz Gulch to a gold-silver lode. The Buffalo mine was the result of this discovery.

The initial development of the Buffalo mine was made at about the time a mistaken report reached Idaho that Confederate General J.B. Hood had soundly defeated General W.T. Sherman during the battle of Atlanta. In a burst of patriotic enthusiasm, the southern sympathizers in the area named the new deposit at the head of Quartz Gulch the "Atlanta lode" (Wells, 1983).

The Atlanta lode, which is 40–120 ft (12–37 m) wide, can be traced for about 2 mi (3.2 km). As with many of the early lode discoveries, rich ores at the surface made the lode appear to be far better than it actually was. Newspapers contained exaggerated reports of the size and tenor of the lode, and prospectors swarmed to the discovery locality. Claims were established

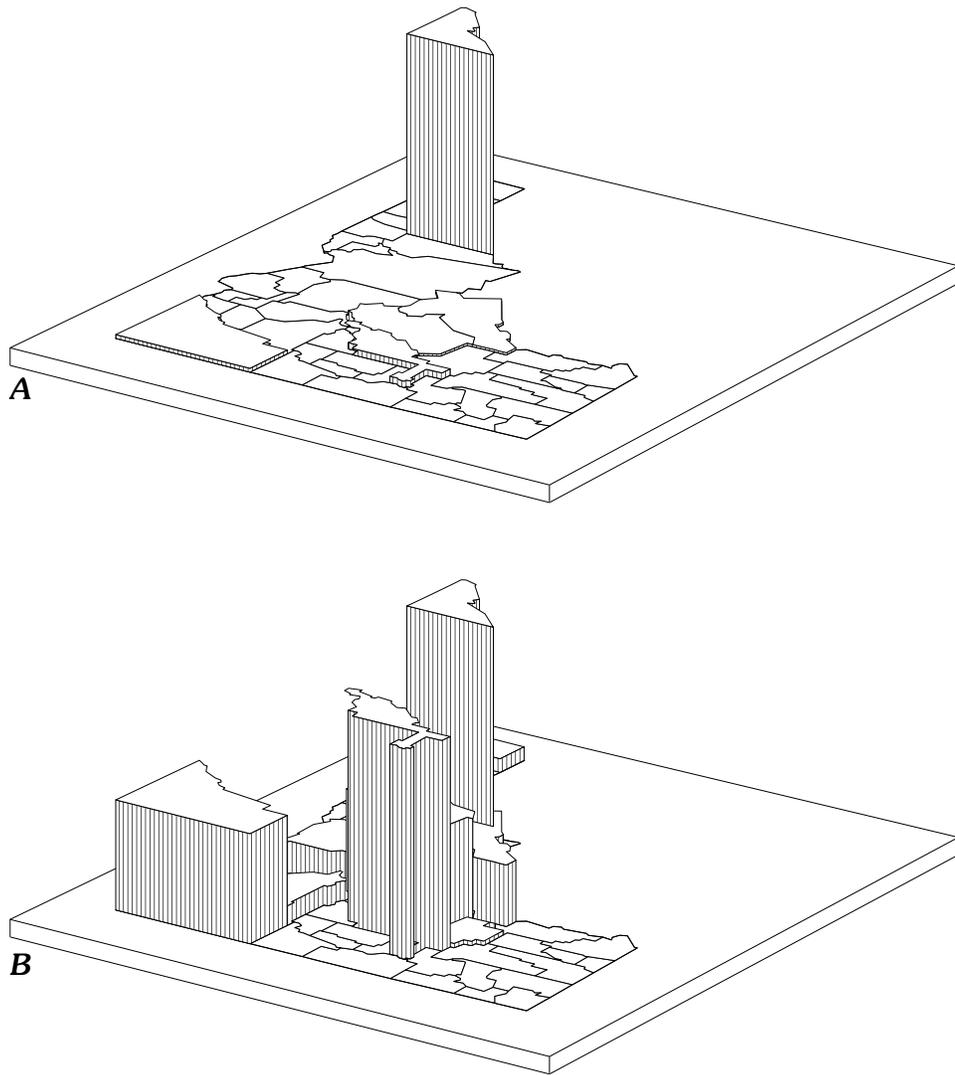


Figure 13. Spatial histograms showing *A*, silver produced by county in Idaho, and *B*, county tonnage described in text.

along the entire trace of the lode and on nearby veins, but the miners had to wait for capital investment to develop the mines and mills.

Atlanta's isolation proved, however, to be a barrier to development. High-grade ore was processed in primitive arastras constructed by the miners. An idea borrowed from the Mexicans via the early Spanish, arastras were circular rock-lined basins in which the ore was ground. Drag stones crushed the ore, and a horse, mule, or water power acted as the motive power. They were, unfortunately, painfully slow and inefficient, but they worked. In 1867 the first stamp mill, hauled in by mules over the Bald Mountain trail, started operation. Primitive and poorly equipped, it is estimated that more than 75 percent of the values were lost in this early milling operation; however, discoveries of new high-grade lodes served to keep excitement high. Some of the mines that opened during this period of exploration include the Monarch, Tahoma, Buffalo, and Last Chance.

In 1870, British interests wishing to recover their losses in the original Atlanta developments sent a mining engineer to look

over the situation. High-grade ore samples convinced him that the Monarch mine looked better than anything he had seen at the Comstock lode in Nevada; however, in spite of the existence of high-grade ores, the Atlanta mines continued their up-and-down cycles due to the limited extent of the ore.

Expanded capital investment finally brought improved transportation and advanced mining and milling technology, the keys to profitable, large-scale production on the Atlanta lode.

For several years, mainly from 1878 to 1884, Atlanta showed considerable activity. Unfortunately for the operators, the cost of roasting and processing the Atlanta ore was so great that only the high-grade ores of the lode could be mined. Several noted mining engineers were called in to examine the ore, but, despite their efforts, a satisfactory method of milling the large bodies of lower grade rock could not be found.

About 1908, new amalgamation, concentration, and cyanidation plants were installed, and the mines were back in business. Again, the lower grade ores were the problem because they could not be processed at a profit. By 1912, the mines were again shut down.

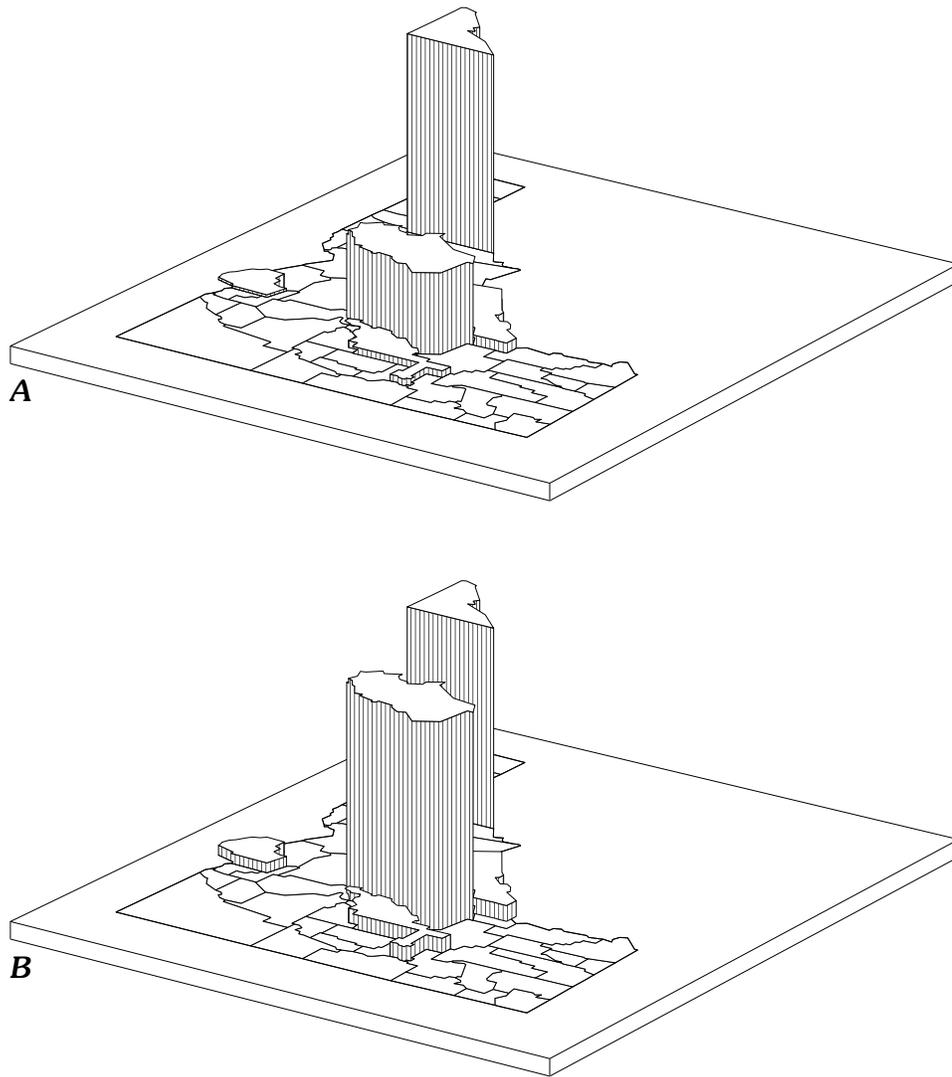


Figure 14. Spatial histograms showing *A*, copper produced by county in Idaho and *B*, normalized county tonnage described in text.

In the 1900's, the district went through a number of up-and-down cycles as deeper development encountered new orebodies. In 1929, the St. Joseph Lead Company acquired the Monarch and adjoining properties. Installing a modern amalgamation-flotation concentrator in 1931 proved that the value of the metals could be recovered from the refractory ore. From this point until 1936, the Atlanta mining area was the leader in Idaho gold production. Deeper exploration of the Atlanta lode continued, but the results were disappointing. This exploration indicated that commercial ores of that time were confined to relatively shallow shoots extending only 400–800 ft (122–244 m) below the surface. Extensive exploration in the 1980's revealed large reserves of low-grade gold ore in the Atlanta lode, and, in 1990, plans were being developed to mine these reserves by open-pit methods (Kiilsgaard, and Bacon, in press).

Rocky Bar Mining Area

Similar to most other early mining camps, the Rocky Bar mining area began as a placer camp. By the fall of 1863, 35 companies, averaging one to five miners each, were making \$12–\$15 per man per day placering. At the census of 1863, the South Boise area (Rocky Bar and Atlanta) had a population of 560, second only to that of the Boise Basin.

Prospecting eventually discovered lodes in the Rocky Bar area, including later producers such as the Elmore, the Confederate Star, the Ophir on Elk Creek, and the Boneparte on Cayuse Creek.

Extravagant promotion of the newly discovered gold and silver lodes began early. H.T.P. Comstock, of the celebrated Comstock Lode, came to Rocky Bar where he advertised

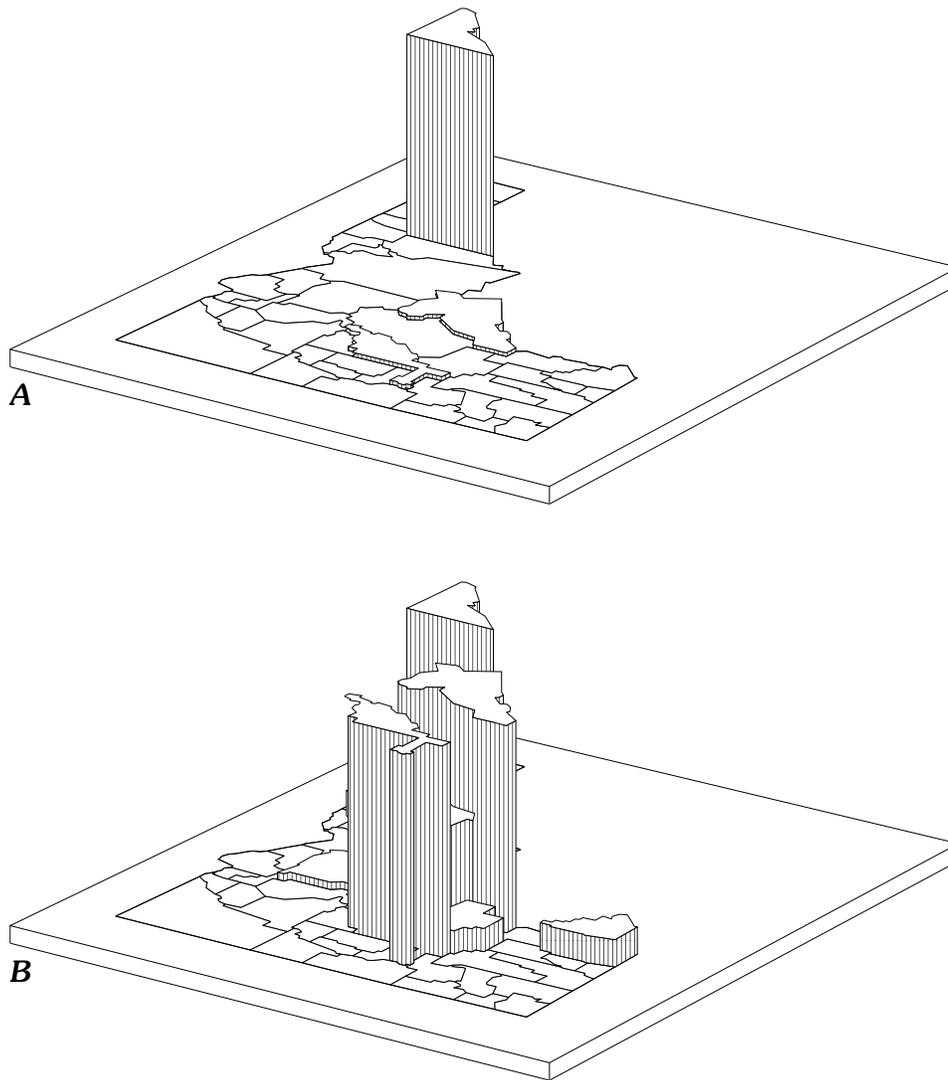


Figure 15. Spatial histograms showing *A*, lead produced by county in Idaho and *B*, normalized county tonnage described in text.

another Comstock Lode. Promotion of the hard-rock mines and the introduction of working capital allowed the miners to develop underground workings and construct arastras to crush the ore.

The existence of similar mines in the Atlanta area and the difficulty in transporting equipment and supplies retarded development of the Rocky Bar mines. While an improved toll road was being built to alleviate this problem, arastras were used to process the ore; by the summer of 1864, the number of arastras had grown from 10 to 80 (Wells, 1983).

In 1865, milling with the more efficient stamp mills began on a large scale, but new stamp mills were not the complete answer to the production problem; high labor and transportation costs prevented the operators from milling other than high-grade ore. In addition, orebodies close to the surface were quickly exhausted, new orebodies were discovered but were too low in grade to pay expenses, and although some veins were continuous, the orebodies within them were not.

As production from Rocky Bar mines continued to languish, the coming of the Union Pacific and Central Pacific Railroads, though distant from the Rocky Bar mines, improved transportation considerably.

Beginning in 1870, production increased in the Rocky Bar area. The Bonaparte, Vishnu, Idaho, Eureka, and Wide West mines were all active. Once more, the climate in Idaho was favorable for extensive mining with discoveries on the upper Salmon and the adjacent Wood River brought new luster to the territory's reputation for rich mineral production. The new boom in the Rocky Bar mines began around 1884 when English and New York investors began buying the larger properties. Convinced that a large-capacity mill would solve all of the problems, a group of English investors brought in a fifty-stamp mill. Large-scale operations brought down the costs of both extracting and milling, and, by 1887, mines were making a profit.

The bust came in March 1889, when rich ore at the Elmore mine was exhausted. Shafts were sunk and exploration

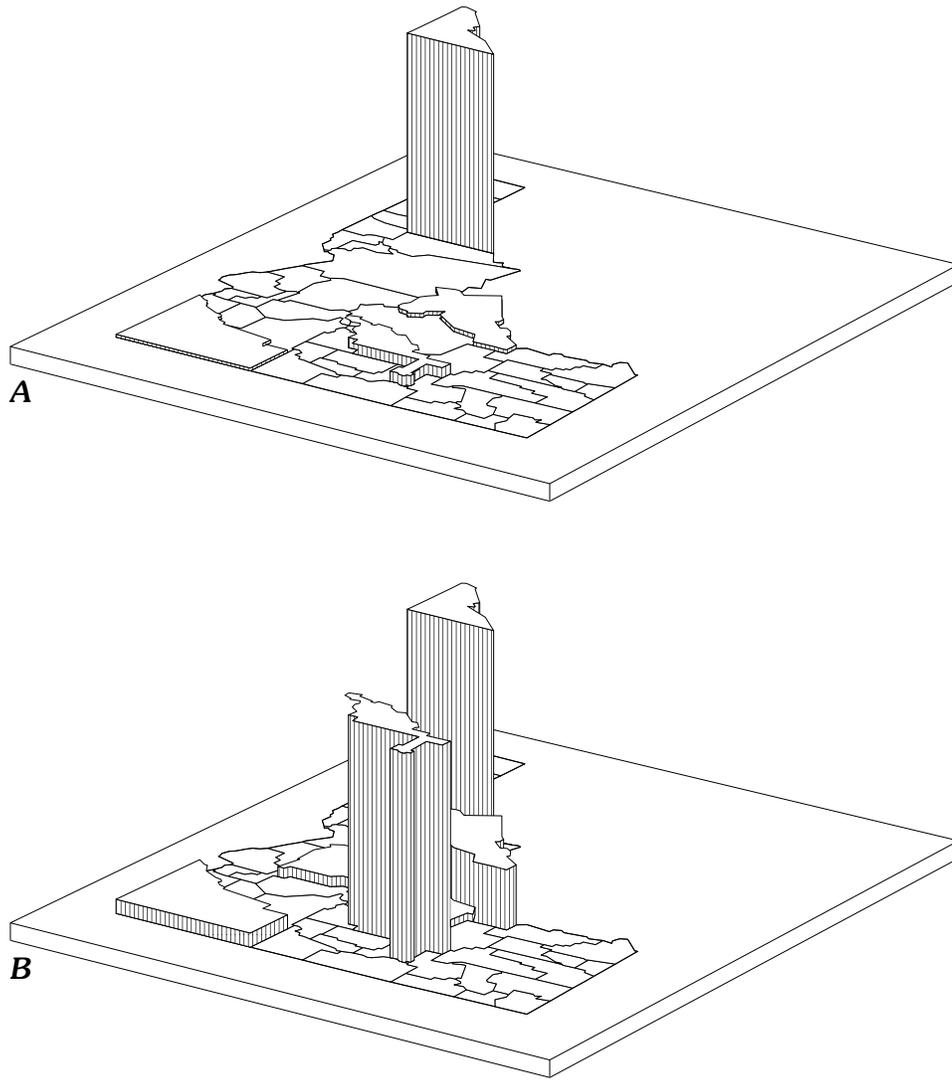


Figure 16. Spatial histograms showing *A*, zinc produced by county in Idaho and *B*, normalized county tonnage described in text.

operations continued for three years before company operators realized that the rich ores of the Rocky Bar area did not extend to depth. In 1892, fire swept through Rocky Bar destroying much of the town.

Boise Basin Mining Area

The Boise Basin mining area contains about 200 mi² (518 km²), and is located generally to the north and east of Boise (fig. 1). Discovery of the Boise Basin gold fields is credited to Moses Splawn and a friendly Indian, who told him where he had seen yellow metal in streams. Splawn gathered a party of men and in 1862 located what turned out to be one of the richest placer areas in the country. The local and regional newspapers soon spread the word, and, by 1863, an estimated 20,000

men had arrived in the basin, and the towns of Pioneerville, Centerville, Placerville, and Idaho City were established. The major town, Idaho City, soon surpassed Portland, Ore. in population to become the largest community in the Pacific Northwest (Ballard, 1922).

The first mining was done by hand methods in the gold-bearing gravels of the creek bottoms. There, most miners could anticipate making \$8–\$20 a day and a few claims returned \$100–\$200 per day. Water shortages plagued many of the placers, but those miners with enough energy to pack the gold to water could recover \$50 a day using rockers during the short mining season (Wells, 1976). Some placers could be worked only during early spring months, using melt water from snow.

Placer mining was generally not a difficult operation. At first, it requires only relatively simple recovery devices and hard work. Lode mines, on the other hand, generally required a large

capital investment to employ miners and purchase supplies and equipment. In addition, large amounts of money had to be invested in a milling and amalgamating plant in remote, commonly almost inaccessible mountain wilderness.

Thousands of miners continued working the placers until the richer stream gravels were exhausted. In 1864, hydraulic mining, introduced from the California gold fields, started above the town of Placerville. The high gravels of the area were perfect for hydraulic mining because they were situated above the creek beds and generally on sloping hillsides so the tailings could be discharged into the creeks. Eighty miles (129 km) of ditches were dug in time for the 1863 placer season near Idaho City, which provided water for large production from the beginning of the operation (Metzger, 1938).

Unable to effectively mine the larger creeks in the district, the miners eventually turned to the bucket line dredge. The first dredge in the district, built near Placerville on Wolf Creek about 1898, was a failure. Soon after, two dredges were built on Grimes Creek, in the vicinity of Centerville. These were successful and operated intermittently for about 7 years, shutting down only in the winter.

Intermittent placer production from the Boise Basin, mostly by dredging, continued until 1954. Production followed the same general pattern as that of other western placer-mining districts. The greatest annual output was during the years that followed the first discoveries of rich, virgin placers when hand methods were used. The total production from the Boise Basin has been estimated at about 2,819,000 ounces of gold (Kiilgaard and Bacon, in press).

Quartzburg District

Early placer miners generally gave little thought to the lode deposits in the hills surrounding the placers. An exception was the development of the Quartzburg mining district, which is within the Boise Basin mining area. The main vein in this district, later known as the Gold Hill vein, was discovered in 1864 by placer miners who worked their way to the rich quartz vein and located claims. News of the rich float and high-grade outcrops brought attention to the northwestern part of the Boise Basin, and additional mines were located and stamp mills built. With amalgamation as the principal recovery process, milling losses were high, but, even so, most of the mines were profitable.

Unlike the boom and bust cycles of many of the gold mines in the Idaho mining districts, the Gold Hill mine was worked almost continuously until 1938. Other important producers in the Quartzburg district were the Mountain Chief, Belshazzar, and Mayflower mines.

Featherville District

The Featherville mining district is on the South Fork of the Boise River near the community of Featherville. Placer gold production from the district began in 1922, when a bucketline dredge was installed to mine gravels along the Boise River.

Working until 1927, the dredge operations produced a total of 32,777 ounces (929 kg) of gold.

Neal District

The Neal mining district is located along the ridge south of the south fork of the Boise River, about 15 mi (24 km) southeast of Boise. It covers an area of about 10 mi² (26 km²), and the most productive veins are at the headwaters of Blacks and Wood Creeks. The Homestake and Hidden Treasure mines, discovered in 1889, have been the principal producers.

Little Wood River (Muldoon) District

The Little Wood River mining district is in Garfield Canyon and the canyon of Muldoon Creek in the Pioneer Mountains of eastern Blaine County. Little is known about the early mining history of the district. The Muldoon mine, discovered in 1881, was the only mine with any significant production, although the Mutual mine was actively exploited for a few years. The surface showings of the mineralized rocks were promising, bringing a large number of miners into the area to work at the Muldoon mine and other properties. By late 1882, there were two 40-ton (36,000 kg) smelters and a concentrator handling the ore.

In the early 1900's, ambitious attempts were made to restart the mines but with little success. A major problem was the 26 mile (42 km) long wagon haul between Muldoon and the closest smelter. In all the mine produced ore valued at about \$200,000, most of which came from silver in the lead ores (Anderson and Wagner, 1946).

Little Smokey and Rosetta Districts

Both the Little Smokey and Rosetta mining districts were discovered during the boom in lode mining in the early 1880's. Mines in these districts flourished for awhile, but by 1900 they were almost entirely abandoned. Ore milling problems apparently contributed to their demise; although prior to closing, the mines ran up a respectable record of production for a relatively small district. The gross value of shipments to the Ketchum smelter is listed at about \$1.2 million, half of which came from one mine, the Carrie Leonard. The ore consisted of mostly lead and zinc with very little gold (Ross, 1956).

Willow Creek District

The only recorded production from the Willow Creek mining district received by the Ketchum smelter is from the Gertie Riddle and Buttercup mines, which may have been one and the same mine. The Princess Blue Ribbon mine was developed during the mining boom of the 1880's and reopened for unknown periods in 1915 and the 1930's. It was reopened in 1986 as an open-pit mine supplying silver ore and some gold to a modern vat leach mill. The operator, Precious Metals Technology,

moved its mining operation to the old Camas mine in the Hailey gold belt within four years.

Wood River (Mineral Hill District) Mining Area

The Wood River mining area is in the drainage of the Big Wood River, extending from around Ketchum to the edge of the Snake River Plain south of Bellevue.

The first discovery in the region, a vein containing galena, was made in 1864 by W.P. Callahan while on his way from the Boise Basin to Montana. Problems with the Bannock Indians, as well as a greater interest in gold, slowed development of the area until 1878, but by 1880 hundreds of claims were located, and several towns had sprung up along the Big Wood River. Development of the area progressed rapidly, and by 1883 ore was being processed in four smelting plants where daily output was 50 tons (45,000 kg) of bullion. Between 20 and 30 mines operated successfully during this period, and prosperity reigned until 1887.

Around 1887, the known ore shoots began to be exhausted at a much more rapid rate than discoveries and silver prices dropped precipitously. The decline in production continued until the period from 1911 to 1921, when it increased as unknown or underdeveloped deposits were worked.

The Mineral Hill district of the Wood River mining area was predominantly a silver-lead district, although some gold was produced. In the early boom days of the Wood River region, most of the production was from the Mineral Hill district. Gross production from this district was considerably more than \$16 million. Discovery of the Minnie Moore mine in 1880 marked the beginning of the most prosperous period in the area.

Discovery of the Minnie Moore has been credited to a badger who brought fragments of galena ore to the surface of its diggings. The discoverer was thus able to locate an otherwise concealed orebody. Within three years of discovery of the ore fragments, the Minnie Moore shaft had been started.

In 1884, when the Minnie Moore was sold to an English firm the mine had an estimated 3,700 tons (3,355,000 kg) of ore in sight averaging 100 ounces (2,835 g) of silver to the ton. After this ore was mined out, a lens of massive galena 90 ft (27 m) long, 4 ft (4.3 m) thick, and 3 ft (0.9 m) thick at the ends was discovered. Net smelter returns from ore mined from this body were \$1.4 million. Exploration and development continued, as the main shaft was extended to 500 ft (152 m) before the ore pinched out (Umpleby and others, 1930).

A “pinch and swell” situation, as described by the miners, was to plague the Minnie Moore and most other mines in the mining area. The problem was not that the orebody varied greatly in thickness, but that it was faulted off and the miners would run into a wall of barren rock. Relocating the displaced part of the vein was too expensive for many operators.

By 1886, all the ore in the Minnie Moore had been mined to a “pinch,” and operations were suspended. The property was later leased and the shaft was extended to the 900 ft (274 m) level where the orebody terminated against the Rockwell fault. Although, it was several years before the ore was located beyond the fault, but in 1902 ore was being shipped again. The

discovery of more ore at the Minnie Moore in 1902 initiated another period of production that lasted for several years. I.E. Rockwell, the operator during this period, estimated smelter returns at \$7,316,600. In 1905, however, a new termination, the Minnie fault, was encountered and from then on the story was one of repeated unsuccessful attempts to find more ore at the Minnie Moore.

Exploration of the Minnie Moore mine and the adjoining Queen of the Hills mine by Silver Star-Queens Mines, Inc., began in 1949. Although, this venture failed to find ore in the faulted projection of the Minnie Moore vein, significant orebodies were found in the Queen and Footwall veins of the Queen of the Hills mine. A new flotation mill designed to process the silver-lead-zinc ore was constructed to process the ore. About 27,000 tons (24,489,000 kg) of ore, much of it averaging 14.6 ounces of silver per ton (0.001 g/kg), 12.4 percent lead, and 7.95 percent zinc was mined during the period 1952–1960. Mining and exploration at the property ceased during the 1960's. The property continued to be idle as of 1990 (Kiilsgaard and Bacon, in press).

Warm Springs District

The Warm Springs mining district is located 12 mi (19 km) north of Hailey and contains three major mines, the Triumph, Independence, and North Star. The three mines are interconnected and share orebodies and history of development.

Major operations began in the district at the Independence mine in 1883 and continued in until 1923, producing more than 131,000 tons (118,817,000 kg) of ore. The mine was developed by extensive drifts and crosscuts on nine levels and was connected by means of raises to North Star workings above and to Triumph workings below. The Independence was shut down in 1923 when the known orebodies had been practically exhausted. The histories of the North Star and Triumph mines are similar with decreased activity though the 1900s to closure by 1923.

The Triumph mine, reopened in 1927 and became the largest producer of base-metal ore in the district. A total of 1,065,393 tons (966,311 mg) of ore was mined from the Triumph mine during the period 1936-1949. Production continued until 1957 when the orebodies were mined out, and the mine was idled.

References

- Anderson, A.L., and Wagner, W.R., 1946, A geological reconnaissance in the Little Wood River (Muldoon) district, Blaine County, Idaho: Idaho Bureau of Mines and Geology Pamphlet 75, 21 p.
- Ballard, S.M., 1922, Geology and gold resources of Alturas quadrangle, Blaine County, Idaho: Idaho Bureau of Mines and Geology Bulletin 5, 35 p.
- Ballard, S.M., 1924, Geology and gold resources of Boise Basin, Boise County, Idaho: Idaho Bureau of Mines and Geology Bulletin 9, 103 p.
- Gabert, G., 1978, The importance of mineral and energy inventories: Journal of the International Association for Mathematical Geology, v. 10, no. 5, p. 425–432.

- Griffiths, J.C., 1978, Mineral resource assessment using the unit regional value concept: *Journal of the International Association for Mathematical Geology*, v. 10, no. 5, p. 441–472.
- Griffiths, J.C., and Singer, D.A., 1971, Unit regional value of non-renewable natural resources as a measure of potential for development of large regions: *Geological Society of Australia, Special Publication 3*, p. 227–237.
- Kiilsgaard, T.H. and Bacon, L.D., in press, Geology and mineral deposits of the Atlanta Hill area, Idaho: *U. S. Geological Survey Bulletin 2064–Z*.
- Kiilsgaard, T.H., Fisher, F.S., and Bennett, E.H., 1987, Gold-silver deposits associated with the Trans-Challis fault system: *U.S. Geological Survey Bulletin 1857-B*, p. B22–B44.
- Koschmann, A.H., and Bergendahl, M.H., 1968, Principal gold producing districts of the United States: *U.S. Geological Survey Professional Paper 610*, 283 p.
- Metzger, O.H., 1938, Reconnaissance of placer mining in Boise County, Idaho: *U.S. Bureau of Mines IC 7028*, 34 p.
- Ross, C.P., 1936, Mining districts of the State of Idaho: *Idaho Bureau of Mines and Geology Map*, scale 1:500,000.
- Ross, C.P., 1956, Geology and ore deposits of the Seaform, Alder Creek, Little Smokey and Willow Creek Mining districts, Custer and Camas Counties, Idaho: *Idaho Bureau of Mines and Geology Pamphlet 33*, 26 p.
- Ruppel, E.T., and Lopez, D.A., 1988, Regional geology and mineral deposits in and near the central part of the Lemhi range, Lemhi County, Idaho: *U.S. Geological Survey Professional Paper 1480*, 122 p.
- Umpleby, J.B., Westgate, L.G., and Ross, C.P., 1930, Geology and ore deposits of the Wood River region, Idaho: *U.S. Geological Survey Bulletin 814*, 229 p.
- U.S. Bureau of Mines, 1924–33, Mineral resources of the United States: Washington, D.C., Department of Commerce, pagination varies.
- U.S. Bureau of Mines, 1933-74, Minerals yearbooks: Washington, D.C., Department of the Interior, pagination varies.
- U.S. Geological Survey, 1880-1923, Mineral resources of the United States: U.S. Department of the Interior, Washington, D.C, pagination varies.
- Walsh, D. A. 1979, An assessment of the mineral resources of the United Kingdom and Republic of Ireland: University Park, Pennsylvania State University, M.S. thesis, 134 p.
- Wells, M. W., 1976, Idaho an illustrated history: *Idaho State Historical Society*, 250 p.
- Wells, M. W., 1983, Gold camps & silver cities: *Idaho Bureau of Mines and Geology Bulletin 22*, 165 p.