CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
520-770-3500
http://www.azgs.az.gov
inquiries@azgs.az.gov

The following file is part of the

James Doyle Sell Mining Collection

ACCESS STATEMENT

These digitized collections are accessible for purposes of education and research. We have indicated what we know about copyright and rights of privacy, publicity, or trademark. Due to the nature of archival collections, we are not always able to identify this information. We are eager to hear from any rights owners, so that we may obtain accurate information. Upon request, we will remove material from public view while we address a rights issue.

CONSTRAINTS STATEMENT

The Arizona Geological Survey does not claim to control all rights for all materials in its collection. These rights include, but are not limited to: copyright, privacy rights, and cultural protection rights. The User hereby assumes all responsibility for obtaining any rights to use the material in excess of "fair use."

The Survey makes no intellectual property claims to the products created by individual authors in the manuscript collections, except when the author deeded those rights to the Survey or when those authors were employed by the State of Arizona and created intellectual products as a function of their official duties. The Survey does maintain property rights to the physical and digital representations of the works.

QUALITY STATEMENT

The Arizona Geological Survey is not responsible for the accuracy of the records, information, or opinions that may be contained in the files. The Survey collects, catalogs, and archives data on mineral properties regardless of its views of the veracity or accuracy of those data.

with copy

FORM SL-1035-A 1 M 4-70

KEEP THIS ON TOP

File No.

From to

Subject: ZINC STATISTICAL STUDY
SOUTHWEST UNITED STATES

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

June 7, 1949

TO: J. H. Courtright

FROM: S. I. Bowditch

Zinc Study
Southwest United States

Since finishing my report on statistical zinc studies I realize that I omitted to mention two mines which tend to invalidate my statement that intensive exploration has failed to uncover any important zinc deposits. My failure to think of them may be because each is more important as a lead-silver deposit, and yet each may eventually contribute substantial quantities of zinc. The two deposits are the Fed Shaft (Ruby Hill) orebody at Eureka, Nevada, and the Burgin mine of Kennecott in the East Tintic District, Dividend, Utah.

We have no recent figures on ore reserves for either mine, but in the case of the Fed Shaft (Ruby Hill body) a report by Ira Joralemon in 1949 gives 800,000 tons of ore that runs 0.192 Au, 11.52 Ag, 3.7 Pb and 9 Zn. Other estimates run over 1,000,000 tons of slightly lower grade. In its isolated location, 90 miles from the nearest railroad, it is doubtful if it will pay to make and ship a zinc concentrate.

The Burgin mine covers several ore bodies, and grade varies drastically between bodies, but may average around 8% Zn, according to published figures. There has been talk that production might be around 300 tons per day. If this tonnage and grade are correct, an annual production of 12,000 tons of zinc metal, or 24,000 tons of concentrate, would result. Reserves of over 1,000,000 tons of ore are probable.

S. I. Bowditch

SIB:cmw
cc: G. P. Pollock (2)
T. A. Snedden
R. E. Keen
R. F. Welch

MINING DEPT.

JUN 9 1965

TUCSON

S. I. B.

JUN 9 1965

New York, June 7, 1965

MEMORANDUM FOR: Mr. E. McL. Tittmann

Statistical Zinc Study - Southwestern United States and Mexico

In accordance with your recent request and my letter of May 6th to Mr. Courtright, there is attached for your information copy of Mr. Courtright's letter of June 4th with Mr. Bowditch's report dated June 3rd covering his statistical study of mine zinc production in the Southwest, including Mexico.

This summary report with the attached production graphs, charts and tabulations is quite complete. I am sure you will agree it presents the situation concisely and clearly. Mr. Bowditch's conclusions and projections are interesting and will be useful for future reference.

The graph of Mexican production shows a steady increase in zinc production with only minor changes reflected by the zinc price. This is in contrast to the Southwestern states where production fluctuations are indicated by price changes. Although Mr. Bowditch concludes that future price increases will result in progressively smaller mine production from the Southwest due to depletion of reserves, this, as Mr. Courtright points out, may be off set somewhat through byproduct zinc from open pit operations of the tactite deposits similar to Mission. Table V shows a possible additional tonnage of 55,000 tons per year from this source.

Mr. Courtright also notes that two of Asarco's former large producers, Santa Eulalia and Parral, are nearing exhaustion. He, nevertheless, notes that the outlook in general for Mexico is favorable since substantial reserves exist in mines which presently account for 90% of Mexican production.

C. P. Pollock

Enc.
CC-TASnedden
RFWelch
JHCourtright
SIBowditch

S. I. B.

JUN 4 1965

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

June 4, 1965

Mr. C. P. Pollock, Vice President
American Smelting and Refining Company
120 Broadway
New York, N. Y. 10005

ZINC STUDY
SOUTHWEST UNITED STATES AND MEXICO

Dear Sir:

This transmits Mr. Bowditch's report on the past and future of zinc in the Southwest, tributary to Amarillo, Texas.

Mr. Bowditch concludes that his price-production graphs for the Southwest indicate that the future price increases will bring out progressively smaller increases in production. But, this trend may be offset considerably by new sources of zinc in the form of a by-product from large tactite deposits operated as open-pit copper mines, such as Mission and Pima. Possible additional sources of zinc may reach a total of 35,000 tpy during the next ten years.

In Mexico, production has been less affected by price, and the over-all trend has been steadily upward. However, one large producer in the past, Santa Eulalia is now essentially mined out. The East Camp or San Antonio has substantial reserves, but also a serious water problem. Parral is another large producer which is nearing the end. In general, the outlook is favorable, since substantial reserves exist in mines which presently account for probably 90% of Mexican zinc production.

Yours very truly,

Original signed by
J. H. Courtright

J. H. COURTRIGHT

JHC/jak
Encl.
cc: CPPollock, 1 extra, w/encl.
TASneddon, w/encl.
RBHeen, w/encl.
RFWelch, w/encl.
SIBowditch, w/o encl.

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

June 3, 1965

To: J. H. Courtright

From: S. I. Bowditch

Zinc Statistical Study
Southwest United States

Introduction

In accordance with Mr. Pollock's request of May 6, I have made a statistical study of zinc production from the Southwestern states of Arizona, Colorado, New Mexico, Nevada and Utah, and from Mexico, since World War I. Figures for production were taken from the yearly volumes of "Minerals Yearbook" (originally "Mineral Resources"), published by the United States Bureau of Mines, and average prices from the Engineering and Mining Journal. The results of this compilation are given in a series of tables and graphs which are attached to this report.

In the case of both the United States and Mexico, figures are given as contained or "recoverable" metal, not as concentrates. To translate metal figures into concentrate, a multiplication by 2 would be a good first approximation. Southwestern zinc concentrates contain 50% to 60% total zinc, but the U.S.B.M. figures are for "recoverable" metal. This term is not defined, but is probably between 85% to 90% of total, so the factor of 2 I suggest for converting metal to concentrates is probably as close as it is necessary to come.

Conclusions

Mr. Pollock asked particularly if there was any trend evident, especially in relation to price. With minor exceptions, Mexico shows a steady rise in production which reflects only briefly changes in price. This probably is caused, at least in part, by the inability of the mines to close down without government permission, and the consequent cost of severance pay.

In the case of the Southwest, production has reflected changes in price, but more faithfully in declining production with a fall in price than the reverse. From the point of view of the Amarillo plant, it should be noted that the peak production was in the late forties and early fifties. This in turn reflects Arizona's peak, and most of the mines responsible for this production are now exhausted. On the whole, I would expect an increase in the price of zinc to bring out a progressively smaller increase in production from the area as time goes on. Only the discovery of a completely new district, (or new mines in old districts) will change this picture.

However, the recent installation of a zinc circuit at Mission offers the possibility that other porphyry copper mines which have appreciable limy sediments included in the ore zone may also produce zinc. Among these

are Pima and Anaconda's Twin Buttes mine. Table V shows production from these and other sources that might be expected, in addition to present production, if the price of zinc continues at its present level, and the operators decide that zinc production is possible and economic. The possible eventual net addition of 55,000 tons of metal is impressive.

History

Accompanying this report is a table (TableI) showing the production of recoverable zinc from each of the five states discussed from 1920 to 1964, as well as their combined production. From this table I have constructed two graphs (Figures 1 and 2). Figure 1 is a bar graph showing production by states and for the region as a whole, with the yearly average price shown in its proper relation above. Figure 2 is a line graph which shows more clearly the annual fluctuation in each state.

These graphs clearly show the sharp drop in price following World War I and the practically complete suspension in zinc production in 1921. Prices improved slowly up to 1925, and held steady until 1929. During this period production increased each year until 1925, and then held steady following the price curve. The main production came from Utah, New Mexico, and Colorado; Nevada production was small and Arizona negligible.

The onset of the Great Depression in 1930 caused a precipitous drop in production, and by 1932 only New Mexico and Utah were active. In Utah, where the zinc accompanies lead in the ores, the zinc concentrates were stockpiled, waiting for a better price. New Mexican production came chiefly from the Pecos mine.

Prices recovered a little in 1933, and held steady until 1939, with a short lived rise in 1937 which is reflected faithfully in the total production. However, this results chiefly from increased output in Utah; 1937 was the depression low point for New Mexico, partly because of a strike at the Pecos mine. The Central District of New Mexico (Silver City--Santa Rita area) became important during this period, and after Pecos closed in 1939 because of exhaustion of ore reserves, Central became the principal zinc mining area in New Mexico.

With the outbreak of World War II in 1939 a steady rise in price began which continued with only one small drop (1949) until 1952. During the war ceiling prices were in effect, but were also greatly modified by the Premium Price Plan. Production rose even more steeply during the early years, and in New Mexico, Colorado and Utah, peaked in 1943, and then fell off as the manpower shortage became acute. The Premium Price Plan ceased in 1947, but the rise in price offset this. Response to conditions after the war was varied from state to state. With the exception of Arizona, each state hit a low between 1945 and 1947, and then recovered. Arizona merely hesitated in its steep upward climb. At that time, in Arizona, Bisbee was far in the lead, followed by San Xavier, Johnson Camp, Mammoth-St. Anthony, and others.

Arizona peaked in 1949, and then, as Bisbee's reserves became exhausted, dropped off rapidly, even though the Korean War forced price to a record high of 18 cents in 1951. Nevada began its slide to extinction in 1951. Utah also was unable to take full advantage of the Korean high, and dropped off during this period. Only Colorado and New Mexico reflect this price peak.

The drop in price from 1951 to 1953 is faithfully reflected in production, even to an exaggerated extent. Every state experienced sharp drops, and in New Mexico all major mines were closed by October 1953, not to reopen until 1955. Nevada practically closed down. In Colorado, Kokomo had closed, and Resurrection ceased production. All the small Colorado producers also closed. In Arizona, San Xavier, the Magma Copper-Zinc area, and Mammoth-St. Anthony all closed, primarily because the ore reserves were nearly exhausted, but also because the mines could not operate under the lower price.

The upturn in price from 1953 to 1956 also caused an increase in production in all states, but the reversal in price in 1957 caused further shutdowns. Combined Metals in Pioche finally gave up the ghost after a hard struggle, and Nevada is now to all intents and purposes out of the picture. New Mexico production fell almost to nothing by 1959. In Colorado the ASARCO--Resurrection Joint Venture was shut down, and for the first time since the discovery of the camp there was no production of any kind from Leadville.

From 1957 until last year the price of zinc was fairly steady, with only one short rise (and then fall) in 1960. This sharp little price peak is not reflected in the production.

The recent rise in price has brought on renewed activity, especially in New Mexico, where ASARCO has reopened Ground Hog. Colorado production has been rising since 1960. This increase has been chiefly due to the reopening of the Keystone mine, enlargement of the Camp Bird mill (now down, but due to be reopened by Federal Resources) and the Standard Metals operation of the Sunnyside mine and Shenandoah mill. In Arizona, Iron King is the only important producer, and increased prices are not offsetting rising costs.

A comparison of possible interest is the relation of the Southwestern production to total United States production. Table II and Figure 3 show this. After World War I, Southwestern production dropped from about 7% to less than 1%, and then rose to over 22% by 1931. High mining costs compared to the Tri-State, caused the Southwestern percentage to drop to 15% by 1935, and it remained at this level until after World War II began. The lack of reserves in the Tri-State prevented this area from responding to the war demand as could the Southwest, and the Southwestern production rose to 35% of the total by 1949. About this time the Appalachian zinc field became of importance, and with the price-cost squeeze of the early fifties the Southwestern share dropped to 20%. The price increase in 1957 raised the figure to 30%, but again the price-cost pincer dropped the Southwest share to 22% by 1963. In 1964 the figure increased to 24%. This comparison illustrates how much more sensitive to price are the high cost Southwestern producers than the lower cost eastern zinc mines.

I am not sufficiently familiar with Mexico to make an analysis of that country, but for what it may be worth, Table III and Figure 4 show total Mexican production as reported by the U.S. Bureau of Mines. In general, production has increased from practically nothing in 1921 to around 275,000 tons now. This increase has been remarkably regular. The big depression low, a low at the beginning of World War II, when the usual European markets were cut off and the United States had not taken up the slack, and another in 1946, due to a strike, are the major breaks in an otherwise remarkably steady rise. As said earlier, in some respects this is due to the difficulty of shutting down a money-losing operation, so production continued even when the companies were suffering losses.

The Future

Other factors beside price enter into any forcast of future production. Chief among these are the actual exhaustion of mines, and even districts, that once were major producers, and, on the other hand, the development, or prospect of development of new mines.

While in 1949 Arizona led the five states under review, with production from Bisbee, Iron King, San Xavier, Mammoth-St. Anthony, Johnson Camp and Trench-Flux, now the Iron King is the only major producer in the state, and this mine is expected to reach its economic limit in the next two or three years. Colorado has had a fairly even production, but Kokomo is finished, and Gilman has no more than about ten years expected life. In Nevada, Pioche, the only important district, dropped off rapidly after 1950, and was closed completely by 1958. New Mexico has had tremendous fluctuations and shows most clearly a dependence on price. Utah, like Colorado, has been reasonably steady, but its two principal producers, Bingham--Lark and Park City, are nearing the end of their history as major producers. Present exploration of the lower limestones at Park City may bring about a revival, but it is too early to say yet.

In spite of considerable exploration over the last twenty years, no important new zinc deposits, or even extensions of old ones, have been found in the area. The only completely new mine known to me is the Continental Materials Mine in the Twin Buttes district in Arizona. This is a copper-zinc limestone replacement mine with a reported reserve of 1,200,000 tons of 7% zinc, 1.5% copper, and some silver and lead. A production of 500 tons of ore per day is planned. The owners are inexperienced and the operation may turn out to be unsuccessful. The ASARCO--Resurrection Joint Venture at Leadville is an almost new property, with a known reserve of 700,000 tons of 7.0% zinc along with some lead and silver. More ore must be developed to justify a mill, but I believe the chances of doing so are excellent. However, this will take several years.

A possible new source of zinc is a by-product from several of the so-called porphyry coppers which obtain a major portion of their ore from sediments. Mission already has a zinc circuit in its new by-product plant. The Imperial area of Silver Bell contains around 1% zinc in the sulphide portion, but unfortunately it is too intimately mixed with the copper to be economically recovered. It seems likely that Anaconda's new deposit at Twin Buttes, which is geologically similar to Mission, also contains appreciable zinc, and it is known that Pima has some zinc. Likewise, the tactites now being developed at Chino (Santa Rita) should carry some zinc as should the copper orebody near Hanover, New Mexico, being developed by U.S. Smelting Company. However, I have been informed that Chino does not contain sufficient zinc to consider its recovery. If all these deposits could recover zinc, the amount of recoverable metal should be important.

Of the new sources mentioned, Continental may produce 11,000 tons of contained zinc a year, ASARCO--Resurrection 16,000 tons, and Mission between 9,000 and 20,000 tons yearly, depending on the grade being mined. The grade is supposed to improve as mining continues west, but distribution of value is very irregular. Anaconda's Twin Buttes project might produce a like amount. Pima has some zinc in the arkose and more in the deeper lying hornfels, but has made no real study of the occurrence or possibility of economic recovery. A possible production similar to Mission can be guesstimated.

Table V has been prepared to reflect the ideas expressed above, and shows possible additional production which may come out in the next ten years, over and above that shown in the 1964 figures. This should be considered as only an informed guess, and is based in part on the anticipation that Anaconda and Pima will eventually recover zinc from their copper ores in the Twin Buttes district. The table also points up the probably loss of Iron King in the next two or three years. The potential is impressive (55,000 tons of zinc or 110,000 tons of concentrate by 1971), but too much depends on decisions yet to be made to consider that there is a real firmness in the figures.

To sum up, I would expect that an increase in price would be less and less reflected by an increase in production from the established producers, but to offset this there is the possibility of production from Continental, ASARCO--Resurrection Joint Venture, Pima and Twin Buttes.

Acknowledgements

In the preparation of this report I have benefitted from the advice and suggestions of Messers L. P. Entwistle, R. K. Kirkpatrick, Reed Welch, and J. H. Courtright, but they are not responsible for the ideas and conclusions expressed herein.

S. I. Bowditch

S. I. Bowditch

SIB:cme
cc: C. P. Pollock (3)

Attachments:

Table I	Zinc Production--Southwest--1920-1964
Table II	Proportion of Southwest Zinc Production to Total U.S. Production
Table III	Zinc Production--Mexico--1920-1964
Table IV	Annual Average Metal Prices
Table V	Possible Additional Sources of Zinc in Next 10 Years
Figure 1	Bar Graph of State and Southwestern Zinc Production, and Annual Average Price
Figure 2	Line Graph of State Zinc Production
Figure 3	Graph Showing Southwest Production as Precent of Total U.S.
Figure 4	Graph of Mexican Zinc Production

TABLE I
Zinc Production - Southwest
1920 - 1964
Recoverable Zinc - Short tons

Year	Ariz.	Colorado	Nevada	New Mex.	Utah	Total
1920	729	24,395	5,349	5,007	4,079	39,559
1921	--	1,180	35	114	35	1,364
1922	105	11,629	1,309	2,248	2,560	17,851
1923	260	27,076	7,083	8,248	5,665	48,332
1924	--	28,364	5,501	10,380	9,281	53,526
1925	3,666	30,811	7,411	9,246	26,306	77,440
1926	6,473	32,500	5,409	12,052	47,590	104,024
1927	1,134	35,865	3,172	29,802	49,593	119,566
1928	639	35,731	3,398	31,203	46,929	117,900
1929	1,229	29,431	8,460	34,455	51,510	125,085
1930	815	36,259	14,584	32,765	44,495	128,918
1931	--	16,187	10,431	27,866	37,291	91,775
1932	--	109	127	25,593	29,666	55,495
1933	6	1,285	6,387	30,924	29,745	68,347
1934	905	772	13,940	26,522	28,198	70,337
1935	3,337	1,202	15,536	22,126	31,307	73,508
1936	3,589	1,172	13,477	20,668	36,192	75,098
1937	5,026	4,247	14,236	23,927	48,001	95,437
1938	5,814	4,553	8,944	28,236	33,658	81,205
1939	6,711	1,830	6,228	29,356	34,526	78,651
1940	15,456	5,060	11,833	30,313	43,788	106,450
1941	16,493	15,722	15,129	37,862	42,049	127,255
1942	18,522	32,215	10,197	46,461	45,543	152,938
1943	19,677	44,094	13,647	59,524	46,896	183,801
1944	29,077	39,955	20,699	50,727	38,994	179,452
1945	40,226	35,773	21,457	40,295	33,630	171,381
1946	43,665	36,147	22,649	36,103	28,292	166,856
1947	54,644	38,745	16,970	44,103	43,673	198,135
1948	54,478	45,164	20,288	41,502	41,490	202,922
1949	70,658	47,703	20,443	29,346	40,670	208,820
1950	60,480	45,776	21,606	29,263	31,678	188,803
1951	52,999	55,714	17,443	45,419	34,317	205,892
1952	47,143	53,203	15,357	50,975	32,947	199,625
1953	27,530	37,809	5,812	13,373	29,184	113,708
1954	21,461	35,150	1,035	6	34,031	91,683
1955	22,684	35,350	2,670	15,277	43,556	119,537
1956	25,580	40,246	7,488	35,010	42,374	150,698
1957	33,905	47,000	5,292	32,680	40,846	159,230
1958	28,532	37,132	91	9,034	44,982	119,771
1959	37,325	35,388	217	4,636	35,223	112,789
1960	35,811	31,278	420	13,770	35,476	116,755
1961	29,585	42,647	453	22,900	37,239	132,914
1962	32,888	43,351	281	22,015	34,313	132,848
1963	25,419	48,109	571	12,938	36,179	123,216
1964*	25,450	51,530	270	29,600	32,000	138,850

*Preliminary

TABLE II
Relation of Zinc Production in
Southwest to Total U. S. Production
Short Ton "Recoverable" Zinc

	S. West States	Total U. S.	% Total - SW
1920	39,559	586,384	6.75
1921	1,364	256,746	.53
1922	17,851	472,032	3.86
1923	48,332	610,690	7.90
1924	53,526	637,977	8.39
1925	77,440	710,847	10.86
1926	104,024	774,563	13.43
1927	119,566	718,541	16.63
1928	117,900	695,170	16.96
1929	125,085	724,478	17.27
1930	128,918	595,425	21.65
1931	91,775	410,318	22.37
1932	55,495	285,002	19.47
1933	68,347	384,280	17.79
1934	70,337	438,726	16.03
1935	73,508	517,903	14.19
1936	75,098	575,574	13.05
1937	95,437	626,362	15.24
1938	81,205	516,703	15.72
1939	78,651	583,807	13.47
1940	106,450	665,068	16.01
1941	127,255	749,125	16.99
1942	152,938	768,025	19.91
1943	183,801	744,196	24.70
1944	179,452	718,642	24.97
1945	171,381	614,358	27.90
1946	166,856	574,833	29.03
1947	198,135	637,608	31.07
1948	202,922	629,977	32.21
1949	208,820	593,203	35.20
1950	188,803	623,375	30.29
1951	205,892	681,189	30.23
1952	199,625	666,001	29.97
1953	113,708	547,430	20.77
1954	91,683	473,471	19.36
1955	119,537	514,671	23.23
1956	150,698	542,340	27.79
1957	159,230	531,735	29.95
1958	119,771	412,005	29.07
1959	112,789	425,303	26.52
1960	116,755	435,427	26.81
1961	132,914	464,390	28.62
1962	132,848	505,491	26.28
1963	123,216	529,254	23.28
1964*	138,850	574,000	24.19

*Estimate

TABLE III
Zinc Production in Mexico
(From U.S.B.M.)

	Metric Tons	Short Tons
1920	?	
1921	1,257	1,386
1922	6,342	6,991
1923	18,481	20,768
1924	24,659	27,182
1925	51,795	57,094
1926	105,367	116,146
1927	137,724	151,813
1928	161,747	178,294
1929	174,050	191,855
1930	124,106	136,802
1931	120,307	132,614
1932	57,000	62,831
1933	89,339	98,478
1934	125,000	136,685
1935	136,000	149,913
1936	150,250	165,620
1937	154,625	170,443
1938	172,000	189,596
1939	134,000	147,708
1940	109,000	120,151
1941	154,966	170,819
1942	189,278	208,541
1943	197,199	217,372
1944	219,309	241,744
1945	209,940	231,417
1946	139,535	153,809
1947	195,814	215,845
1948	179,029	197,344
1949	178,402	196,652
1950	223,530	246,397
1951	180,064	198,485
1952	227,375	250,638
1953	226,541	249,715
1954	223,571	246,441
1955	269,403	296,961
1956	248,891	274,351
1957	243,030	267,891
1958	224,108	247,033
1959	263,939	290,938
1960	262,429	289,274
1961	268,977	296,492
1962	250,687	276,330
1963	241,100	265,763
1964	Not Available	

TABLE IV

E&MJ Annual Average Metal Prices—1899 to 1964

Year	COPPER (a) Domestic Refinery	COPPER Foreign Refinery	LEAD Common N. Y.	ZINC PW (b) E. St. Louis	TIN (c) N. Y.	SILVER (e) N. Y.	MERCURY (f) N. Y.	ALUMINUM Ingot
1899.....	16.67	.....	4.470	5.750	25.12	59.580	43.63	32.72
1900.....	16.19	.....	4.370	4.390	29.90	61.330	51.00	32.72
1901.....	16.11	.....	4.330	4.070	16.74	58.950	47.00	33.00
1902.....	11.026	.....	4.069	4.840	26.79	52.160	48.03	33.00
1903.....	13.235	.....	4.237	5.191	28.09	53.570	41.32	33.00
1904.....	12.823	.....	4.309	4.931	27.99	57.221	41.00	35.00
1905.....	15.590	.....	4.707	5.730	31.358	60.352	38.50	35.00
1906.....	19.278	.....	5.657	6.048	39.819	66.791	40.90	35.75
1907.....	20.004	.....	5.325	5.812	38.166	65.237	41.50	45.00
1908.....	13.208	.....	4.200	4.578	29.465	52.864	44.84	28.70
1909.....	12.982	.....	4.273	5.352	29.725	51.502	46.30	22.00
1910.....	12.738	.....	4.446	5.370	34.123	53.486	47.06	22.25
1911.....	12.376	.....	4.420	5.608	42.281	53.304	46.54	30.07
1912.....	16.341	.....	4.471	6.799	46.096	60.835	42.46	22.01
1913.....	15.269	.....	4.370	5.504	44.252	59.791	39.54	23.64
1914.....	13.602	.....	3.862	5.061	34.301 (d)	54.811	48.31	18.63
1915.....	17.275	.....	4.673	13.054	38.590	49.684	87.01	33.98
1916.....	27.202	.....	6.858	12.634	43.480	65.661	125.49	60.71
1917.....	27.180	.....	8.787	8.813	61.802	81.417	106.30	51.59
1918.....	24.628	.....	7.413	7.890	88.750	96.772	123.47	33.53
1919.....	18.691	.....	5.759	6.988	63.328	111.122	92.15	32.14
1920.....	17.456	.....	7.957	7.671	48.273	100.900	81.12	32.72
1921.....	12.502	.....	4.545	4.655	29.916	62.654	45.46	21.11
1922.....	13.382	.....	5.734	5.716	32.554	67.528	58.95	18.68
1923.....	14.421	.....	7.267	6.607	42.664	64.873	66.50	25.41
1924.....	13.024	.....	8.097	6.344	50.176	66.781	69.76	27.03
1925.....	14.042	.....	9.020	7.622	57.893	69.065	83.13	27.19
1926.....	13.795	.....	8.417	7.337	65.285	62.107	91.90	26.99
1927.....	12.920	.....	6.755	6.242	64.353	56.370	118.16	25.40
1928.....	14.570	.....	6.305	6.027	50.427	58.176	123.51	24.300
1929.....	18.107	.....	6.833	6.512	45.155	52.993	122.15	24.300
1930.....	12.982	.....	5.517	4.556	31.694	38.154	115.01	23.787
1931.....	8.116	.....	4.243	3.640	24.467	28.700	87.35	23.300
1932.....	5.555	.....	3.180	2.876	22.017	27.892	57.93	23.300
1933.....	7.025	6.713	3.869	4.029	39.110	34.727	59.23	23.300
1934.....	8.428	7.271	3.866	4.158	52.191	47.973	73.87	23.300
1935.....	8.649	7.538	4.065	4.328	50.420	64.273	71.99	20.000
1936.....	9.474	9.230	4.710	4.901	46.441	45.087	79.92	20.000
1937.....	13.167	13.018	6.009	6.519	54.337	44.883	90.18	19.917
1938.....	10.000	9.695	4.739	4.610	42.301	43.225	75.47	30.000
1939.....	10.965	10.727	5.053	5.110	50.323	39.082	103.94	10.000
1940.....	11.296	10.770	5.179	6.335	49.827	34.773	176.86	18.691
1941.....	11.797	10.901	5.793	7.474	52.018	34.783	185.02	16.500
1942.....	11.775	11.684	6.481	8.250	52.000	38.333	196.35	15.000
1943.....	11.775	11.700	6.500	8.250	52.000	44.750	195.21	15.000
1944.....	11.775	11.700	6.500	8.250	52.000	44.750	118.36	15.000
1945.....	11.775	11.700	6.500	8.250	52.000	51.928	134.89	15.000
1946.....	13.820	14.791	8.109	8.726	54.544	80.151	98.24	15.000
1947.....	20.958	21.624	14.673	10.500	77.949	71.820	83.74	15.000
1948.....	22.038	22.348	18.043	13.589	99.250	74.361	76.49	15.733
1949.....	19.202	19.421	15.364	12.144	99.336	71.930	79.46	17.000
1950.....	21.235	21.549	13.296	13.866	95.539	74.169	81.26	17.713
1951.....	24.200	26.258	17.500	18.000	127.077	89.368	210.13	19.000
1952.....	24.200	31.746	16.467	16.215	120.473	84.941	199.097	19.410
1953.....	28.798	30.845	13.489	10.855	95.845	85.188	193.032	20.931
1954.....	29.694	29.889	14.054	10.681	91.838	85.250	264.386	21.784
1955.....	37.491	39.115	15.138	12.299	94.735	89.099	290.348	23.668
1956.....	41.818	40.434	16.013	13.494	101.409	90.826	259.923	24.032 (g)
1957.....	29.576	27.157	14.658	11.399	96.261	90.820	246.978	25.416
1958.....	25.764	24.123	12.109	10.309	95.127	89.044	229.057	24.790
1959.....	31.182	28.892	12.211	11.448	102.053	91.202	227.484	24.738
1960.....	32.053	29.894	11.948	12.946	101.438	91.375	210.760	26.000
1961.....	29.921	27.919	10.871	11.542	113.311	92.449	197.605	25.458
1962.....	30.600	28.514	9.631	11.625	114.652	108.521	191.208	23.875
1963.....	30.600	28.413	11.137	11.997	116.652	127.912	189.451	22.623
1964.....	31.960	30.985	13.596	13.568	157.595	129.300	314.787	23.741

(a) Lake copper 1897–98: domestic market since 1932. (b) New York delivery 1898–1902. (c) 99% in 1897 to 1920, inclusive: Straits quality thereafter. (d) Average for 11 months. (e) New York market. . . . All quotations in cents per lb, except for silver, which is in cents per troy oz, and (f) mercury, which is in dollars per flask of 76 lb. See opposite page and reverse for weekly average prices for 1964. (g) Unalloyed ingot beginning 1956.

TABLE V

Possible Additional Sources of Zinc in Next 10 Years

Ton Recoverable Zinc

Source	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Mission	9,000	9,000	9,000	9,000	9,000	10,000	10,000	10,000	10,000	10,000
Continental	----	5,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000
ASARCO--Res.	----	----	----	12,000	16,000	16,000	16,000	16,000	16,000	16,000
Ground Hog	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Twin Buttes	----	----	----	----	5,000	10,000	10,000	10,000	10,000	10,000
Pima	----	----	----	----	3,000	5,000	8,000	8,000	8,000	8,000
Iron King	----	----	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Total	24,000	29,000	20,000	32,000	44,000	52,000	55,000	55,000	55,000	55,000

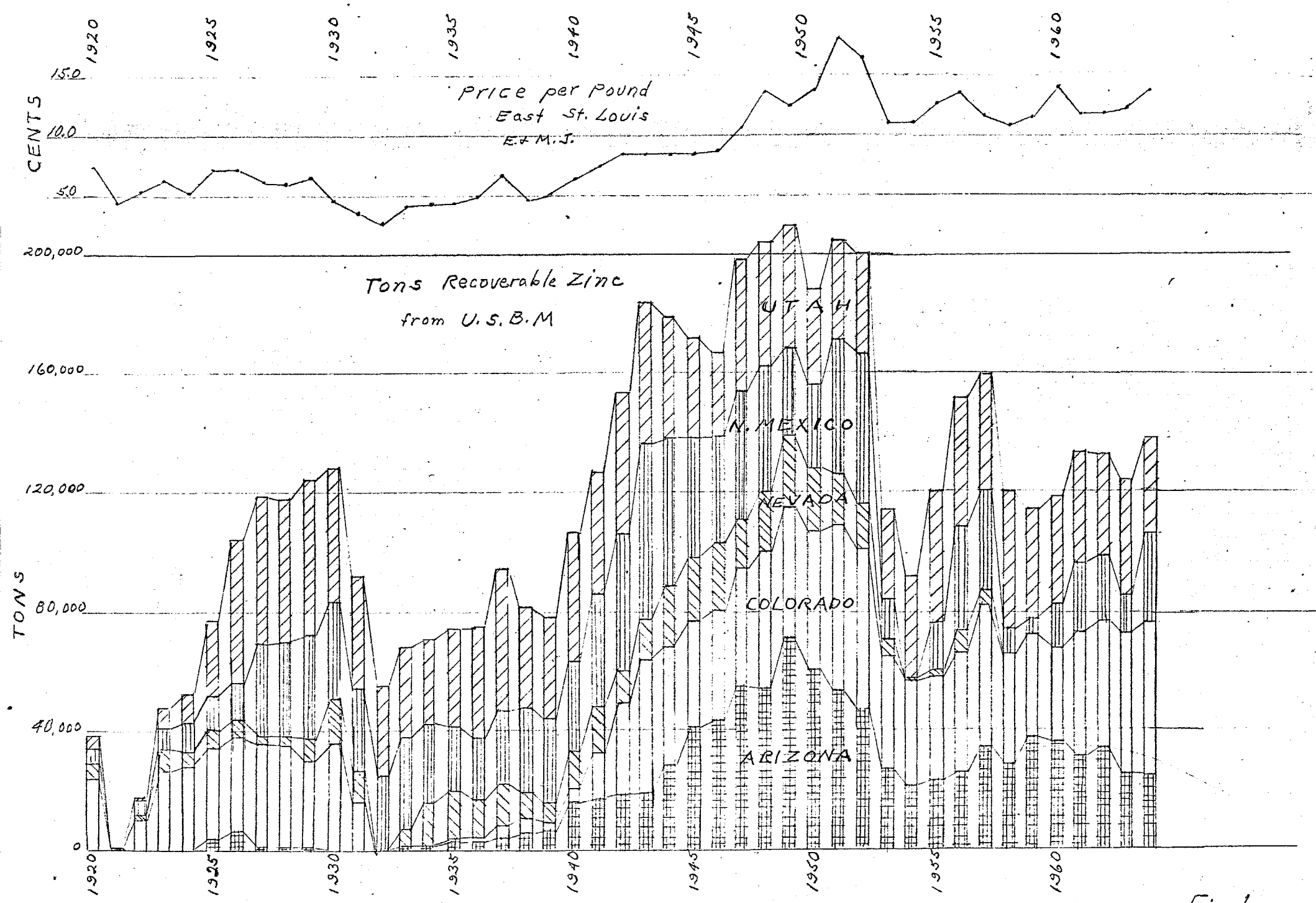

1920
1925
1930
1935
1940
1945
1950
1955
1960
15.0
10.0
5.0
CENTS
Price per Pound
East St. Louis
E.&M.J.
200,000
160,000
120,000
80,000
40,000
0
TONS
Tons Recoverable Zinc
from U.S.B.M
UTAH
N. MEXICO
NEVADA
COLORADO
ARIZONA

Fig 1

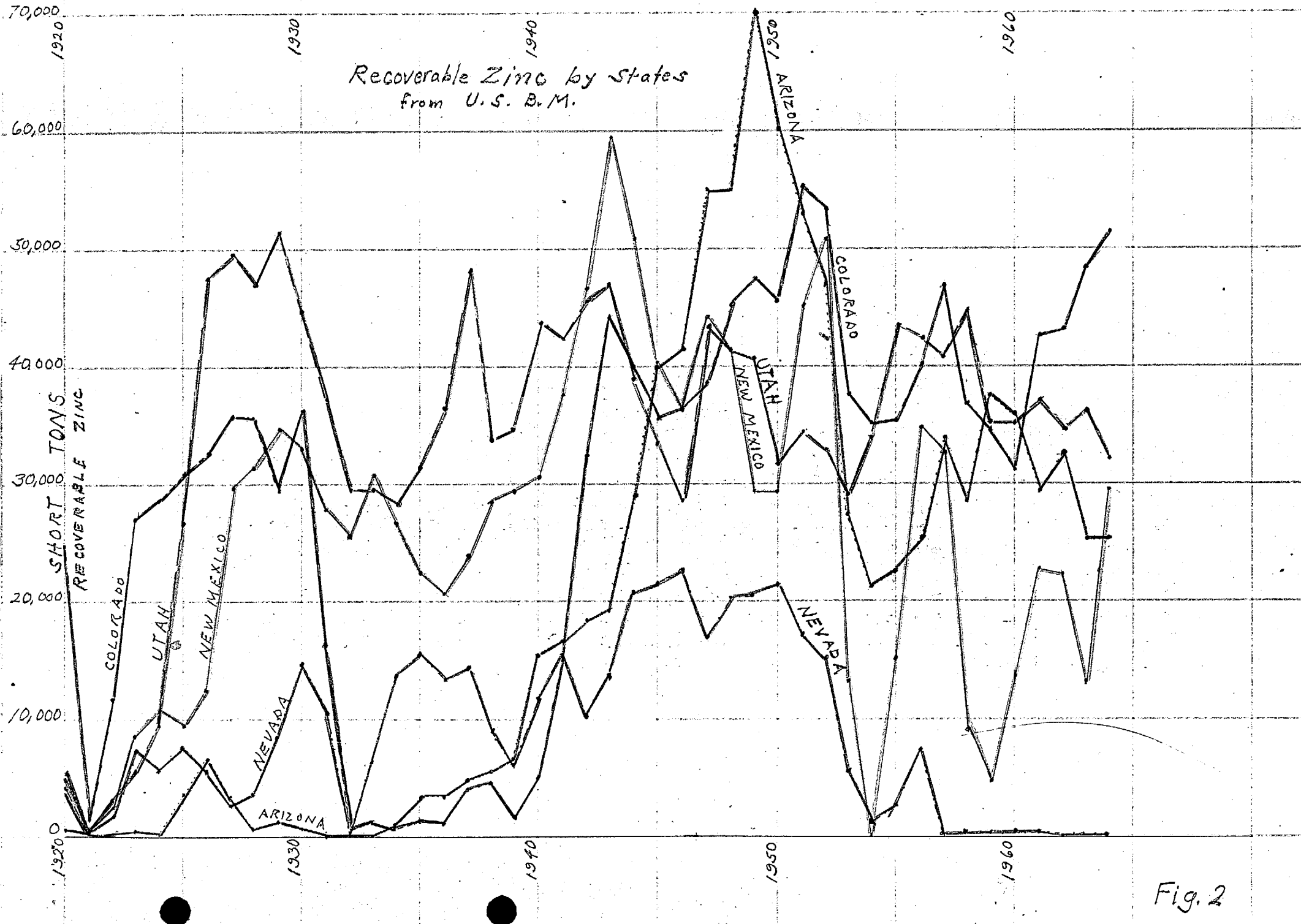

Recoverable Zinc by States
from U.S. B.M.
SHORT TONS
RECOVERABLE ZINC
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1920
1930
1940
1950
1960
COLORADO
UTAH
NEW MEXICO
NEVADA
ARIZONA
ARIZONA
COLORADO
UTAH
NEW MEXICO
NEVADA

Fig. 2

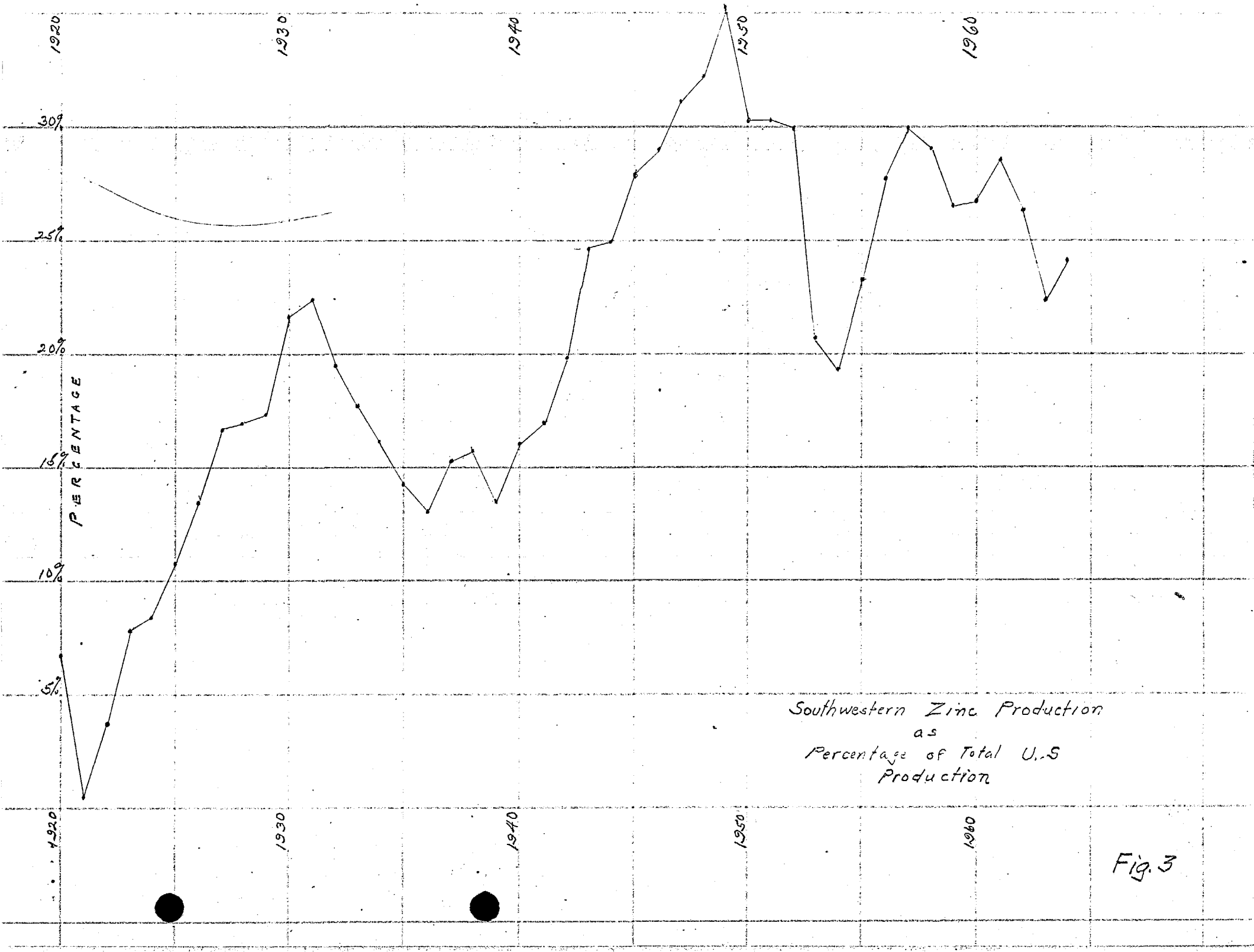
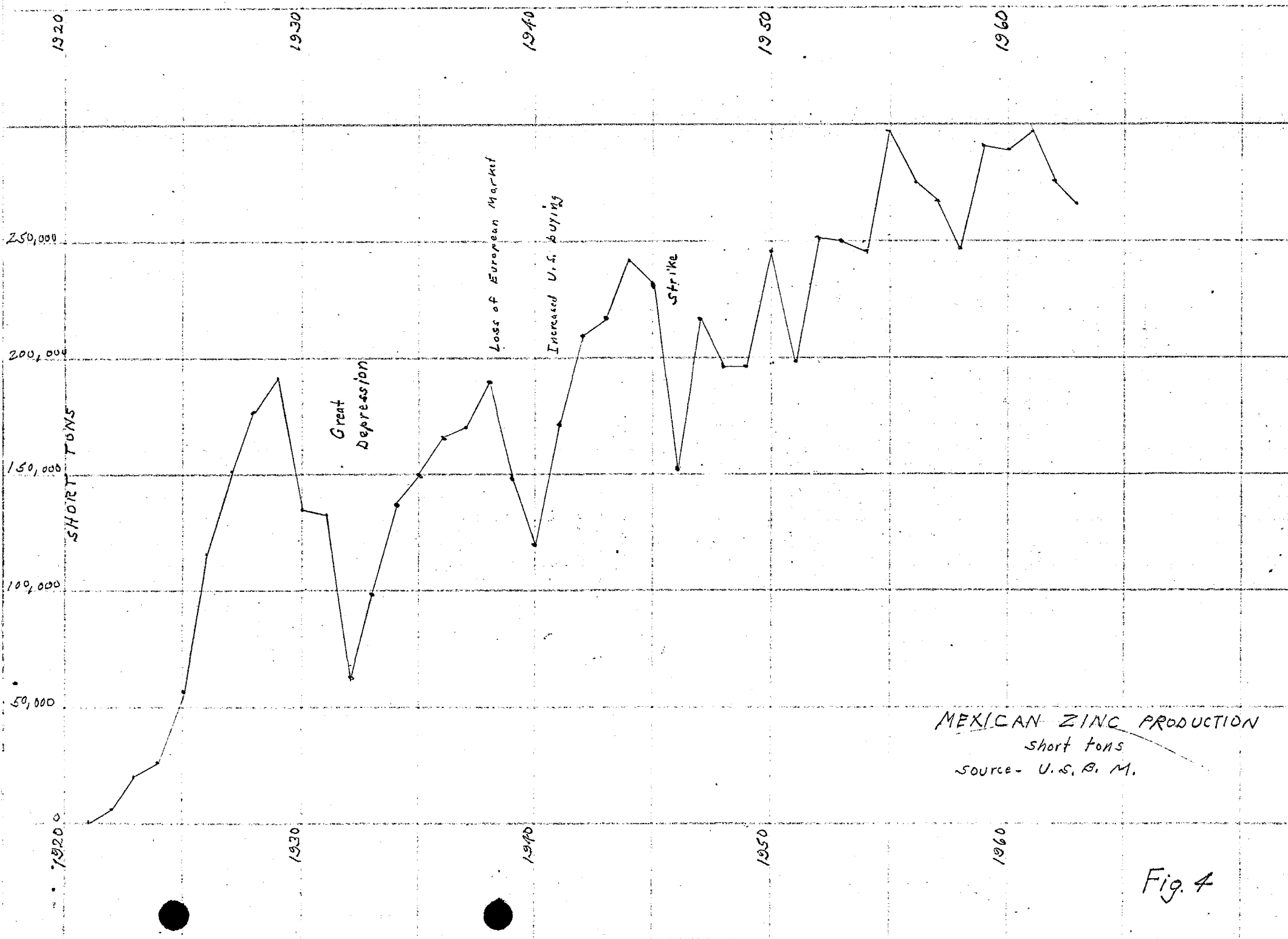

1920
1930
1940
1950
1960
30%
25%
20%
15%
10%
5%
PERCENTAGE
Southwestern Zinc Production
as
Percentage of Total U.S
Production

Fig. 3



MEXICAN ZINC PRODUCTION
short tons
source - U.S.B.M.

Fig. 4

Judy: Please copy for WES and SIB

J. H. C.

MAY 10 1965

AMERICAN SMELTING AND REFINING COMPANY
EXPLORATION DEPARTMENT
120 BROADWAY, NEW YORK 5, N.Y.

S. I. B.

MAY 10 1965

C. P. POLLOCK
VICE PRESIDENT

Air Mail

May 6, 1965

Mr. J. H. Courtright
American Smelting & Refining Company
Box 5795
Tucson, Arizona

Zinc Statistical Study - Southwest United States

Dear Mr. Courtright:

In accordance with our telephone conversation today, will you please arrange for Mr. Bowditch to make a statistical study of zinc concentrates production in the Southwest, tributary to the Amarillo, Texas plant. This would include Arizona, New Mexico, Colorado, Utah and Mexico.

We would like to determine, if possible, whether there may be a trend in mine production from the area since World War I. In case a trend is indicated, Mr. Bowditch could then project probable zinc concentrates production to 1970 and 1975 on the basis of these statistical studies.

Undoubtedly, factors other than the price of zinc enters into the pattern of production. For example, improved metallurgy in the period since World War I has made many marginal or submarginal deposits of the Southwest, economic. Likewise the discovery of important deposits and new districts as well as depletion of reserves in principal producing areas has influenced production trends. Possibly, import duties and quotas have played an important role in the rate of mine production from the Southwest.

Forecasting probable zinc concentrates production from any area, obviously, is an involved problem and is particularly hazardous if price is taken into account. Although price is an important factor and if a trend can be observed in the ratio of mine production and price, the study might be quite helpful in forecasting probable future concentrate supply from the area.

In general, it is reasonable to expect a decline in production from vein type mines in the Southwest where mass-production methods cannot be adopted. Since no major replacement occurrences of the Tennessee or metalline type deposits are known in the Southwest and with the Tri-State Mines exhausted, the outlook for increased production admittedly is not promising unless we can expect a substantial and sustained increase in the price of zinc.

CC-EMcLTittmann

Yours very truly,

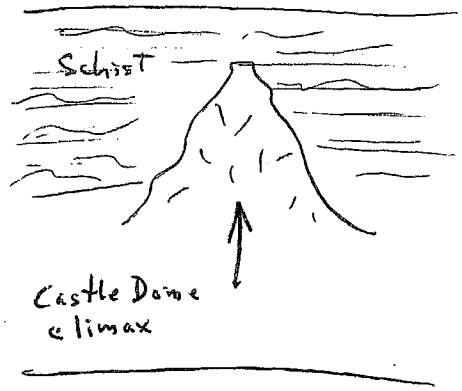
C. P. Pollock

C. P. Pollock

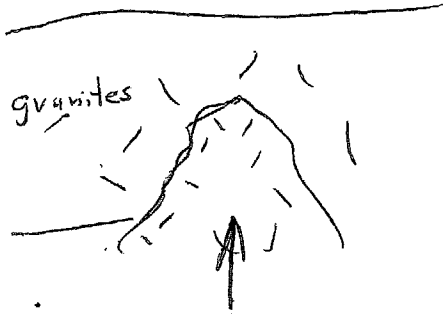
tration abilities of the process.

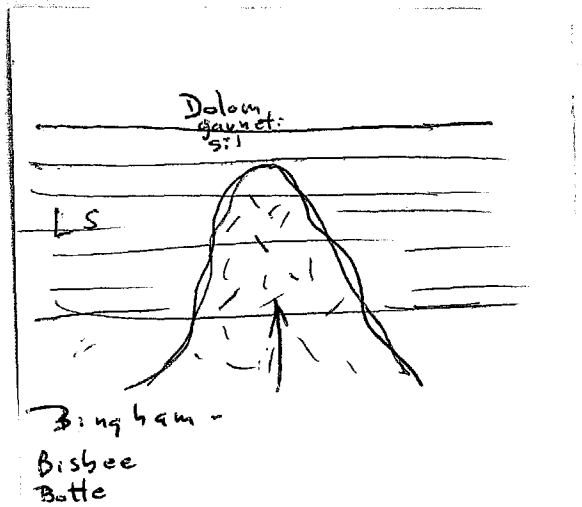
ALTERATION - - MINERALIZATION

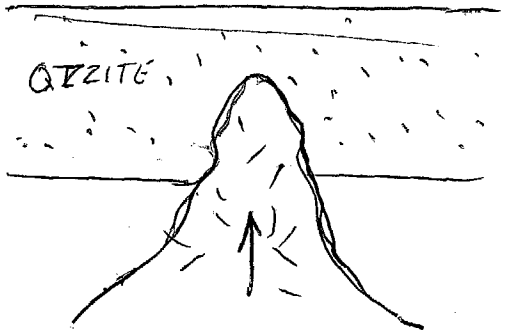
Zoning in Porphyry Ore Dep.


Schist
Castle Dome
climax

Siltstone
Argillic


granites


Dolom
garnet
sil
LS
Bingham -
Bisbee
Butte


QTZITE

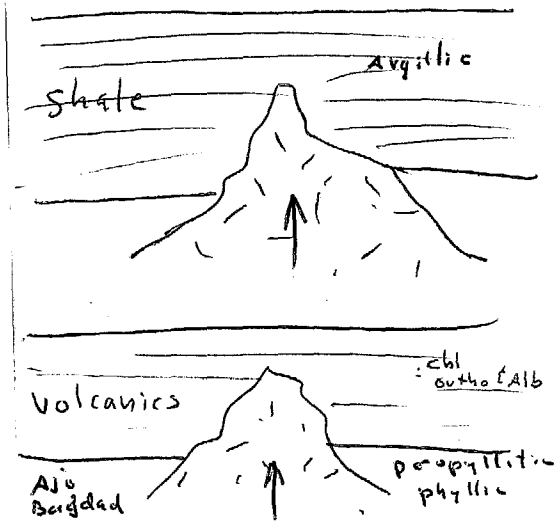

Argillic
Shale
chl
outho Alb
Volcanics
Ajo
Bagdad
propylitic
phyllic

TABLE 1. Geologic Characteristics of 27 Major Porphyry Copper and Molybdenum Deposits

ABBREVIATIONS–TABLE 1

Minerals

ab	albite
Ag	silver & silver minerals
anh	anhydrite
ank	ankerite
ap	apatite
Au	gold & gold minerals
bar	barite
bi	biotite
bn	bornite
cal	calcite
car	carbonate
cc	chalcocite
cp	chalcopyrite
chl	chlorite
clzo	clinozoisite
cs	cassiterite
cup	cuprite
cv	covellite
dck	dickite
dg	digenite
dol	dolomite
en	enargite
ep	epidote
feld	feldspar
fl	fluorite
fm	famatinite
gal	galena
gr	garnet
gyp	gypsum
hbl	hornblende
hm	hematite
hn	huebnerite
ill	illite
kaol	kaolin
mag	magnetite
mal	malachite
mb	molybdenite
mc	marcasite
mn	manganese minerals
mont	montmorillonite
py	pyrite
prp	pyrophyllite
pyx	pyroxene
Q	quartz
rc	rhodochrosite
rd	rhodonite
rt	rutile
ser	sericite
sl	sphalerite
spec	specularite
stb	stibnite
tm	tourmaline
tn	tennantite
trem	tremolite
tt	topaz
V	vanadium minerals
wf	wolframite
zo	zoisite

Rocks

alsk	alaskite
And	andesite
apl	aplite
Dac	dacite
Db	diabase
Dio	diorite
gn	gneiss
G	granite
Gd	granodiorite
lph	lamprophyre
L	latite
ls	limestone
M	monzonite
p	porphyry
peg	pegmatite
Qd	quartz diorite
Ql	quartz latite
Qm	quartz monzonite
Qmp	quartz monzonite porphyry
'Qp'	'quartz porphyry'
qtzt	quartzite
Rhy	rhyolite
sch	schist
seds	sediments
sh	shale
ss	sandstone
volc	volcanics

Geologic Time

Lar	Laramide
T	Tertiary
K	Cretaceous
Trias	Triassic
Meso	Mesozoic
Perm	Permian
Penn	Pennsylvanian
Pal	Paleozoic
p€	Precambrian

Alteration

Arg	Argillic
Phyl	Phyllic
Pot	Potassic
Prop	Propylitic

Miscellaneous

adv	advanced
bx	breccia
Cu	copper
diss	disseminated
flt	fault
irreg	irregular
μvlt	microveinlet
Mo	molybdenum
mod	moderate
ND	no data
repl	replacement
sul	sulfide
text	texture
tr	trace
vn	vein
vlt	veinlet
%	weight percent

DEPOSIT (1)	PREORE HOST ROCK (2)	IGNEOUS HOST ROCK			
		Name (3)	Age (m.y.) (4)	Controlling Structures (5)	Shape (6)
Ajo Arizona	p€ gn; Meso(?) Qm; K And, tuff	Cornelia quartz monzonite	63	steep NW fault possible control	elongate NW irregular
Bagdad Arizona	p€ volcs, sch & G	Bagdad stock	71	N70 E & N 30 W flts	irregular lenticular
Bethlehem British Columbia	Triassic volcanics	Guichon Qd & Bethlehem Qd	200	N–N 25 E flts	irregular multiple plugs
Bingham Utah	Penn qtzt > limestone	Bingham stock	37	NE & NW flts	Irregular, pipelike, steep
Bisbee Arizona	p€ sch; Pal ls, shale, sandstone	Sacramento stock	163	steep NW flt; NE flts	irregular elongate NW
Braden Chile	K–T And & seds	brecciated Dac p stock, Qd	mid–T (?)	N–S & N 55 E flts	circular & elongate dikes
Butte Montana	Pal ls, sh, ss; K And	Boulder Batholith	72	NW & EW flts	batholith elongate NE
Cananea Sonora	Pal seds; Lar volcs & intrusive rocks	La Colorada 'Qp'	59	N & NW flts	irregular stocks, plugs
Castle Dome Arizona	p€ sch & p€ G	Lost Gulch Qm, granite porphyry	64	N 40 E flts	irregular stock
Chuquicamata Chile	metaseds & volcs	Chuquicamata Mp	Lar	N & N 10 E flts	narrow, semicontinuous N 15 E belt
Climax Colorado	p€ sch	Climax rhyolite porphyry	30	N–S anticline possible control	circular, pipelike
Copper Cities Arizona	p€ sch & p€ granite	Lost Gulch Qm, granite porphyry	60	N 50 E	stock elongate NE
El Salvador Chile	K And, rhyolite	El Salvador stock	Lar(?)	NE & NW flts	elongate NE
Ely Nevada	Pal ls, ss, sh	Ely stock	109	E–W flts	irregular elongate E–W
Endako British Columbia	early Meso seds & volcanics	Topley Qm, alsk & granite	139–143	NW & ENE flts	irregular elongate NW
Esperanza Arizona	K fragmental & welded tuff & qtzt	Esperanza stock	62	NE, NW & N–S flts	irregular large stock
Inspiration Arizona	p€ sch, G, qtzt & Db	Schultze quartz monzonite	60	N 50 E flt	irregular large stock
Mineral Park Arizona	p€ metaseds & metavolcs, gneiss	Ithaca Peak stock	72	NW & NE folds, NW best	elliptical, pipelike NNW
Mission–Pima Arizona	Pal, K, Eocene sediments		60	not recognized	sill-like, tabular
Morenci Arizona	p€ G, Pal–Meso ls, ss, sh	Morenci stock	Lar	p€ NE; K NW	elongate NE
Questa New Mexico	Miocene(?) And, latite, rhyolite	Questa mine aplite porphyry	30	N, NW flts	very irregular domical
Ray Arizona	p€ seds, metaseds, Db; Pal limestone	Gronite Mt. Qm	63	ENE schistosity NNW flts	irregular masses in NE belt
Safford Arizona	K Qm, Qd, Rhy, Qt, L, Dac dikes & plugs	Weber Peak dike swarm	58	NW flts & NE shears	dike swarm elongate NE
San Manuel–Kalamazoo Arizona	p€ quartz monzonite	San Manuel Mp	67	NE & NW flts	irregular, mushroom-shaped stock
Santa Rita New Mexico	Pal–Meso (K) seds	Santa Rita stock	63	NNW & NE flts	complex, elongate NW, domical
Silver Bell Arizona	Pal & K seds	Silver Bell stock	63	NNW flt	stock elongate NW
Toquepala Peru	late K(?) Rhy, And, Dio	dacite porphyry	59	none recognized	irregular stock elongate N–S
Typical Porphyry Copper	p€–late K seds & metasediments	Qm stock	65	NE & NW flts	elongate irregular

IGNEOUS HOST ROCK—*Continued*				
Size (feet) (7)	Mode of Emplacement (8)	Stock–Dike (9)	Sequence of Intrusion (10)	Rock Types Mineralized (11)
3000 x 10,000	passive	stock	Dio → Gd → Qm → Qmp → vfg Qm	all
3000 x 6000	passive	stock	Rhy → Gd → Q Dio p → Dio p → Qmp	all
± 12,000 x 5000	probably passive	stock > dike	Qd → Gd → Dac p → Lp → Rhy	all
6000 x 9000	passive > active	stock > dike	Qd → Gd; Lp, Qlp	all + seds
5000 x 5000	passive > active	stock	'Qp' → 'feld Qp' (both altered)	all + seds
4000 x 4000	passive > active	stock > dikes	Qd → Dac p → Lp → lph	And, Qd, Dac p, Lp
150,000 x 350,000	passive	batholith	Qm (apl, peg) → Qmp	all
8000 x 25,000 cluster	passive > active	stock > dike	Dio, Gd, sy, G → 'Qp', Db	all + seds
5000 NE x 6500 NW	passive	stock > dike	Gd → Qm → Qmp → G → Gp → Db	Qm, Gp & Db
2500 x 1,000,000+	passive > active(?)	stock > dike	sodo Gd → Qd → Dio → Qm → G → apl Gd → Mp	all(?)
± 3000 x 3000	active	stock > dike	Rhy p → apl p → Gp	all
5000 NW x 13,000 NE	passive	stock	Qm → apl → alsk p → Db → Gp	all
5000 x 15,000	passive	stock > dikes, sills	Gd → Gdp → 'Qp'	all
large, elongate EW	passive	stock > dikes, sills	M, Qmp complex	all + seds
180,000 x 1,000,000	active(?)	stock > dike	Qm → G → alsk → Q feld p	all
45,000 x 60,000	passive	stock > dike	Qm → Dio → Qmp → And p	all + seds & volcs
30,000 x 60,000	passive	stock > dike	Db → Gd → G → Gp	all + metaseds
2000 x 4000	passive	stock	Qd → Qmp → 'Qp' → 'Qp' + Q	Qmp - 'Qp' - 'Qp' + Q
± 4000 x 4000	passive	sill > stock	Qmp	all + seds
± 10,000 x 50,000	passive–doming	stock; sill, dikes in wall	Dio p → Qmp → Gp → Db	Qmp + seds
15,000 x 90,000	passive	stock > dike	Mp, Gp, bio G → apl, apl p, Rhy p	all + volcs
8000 x 15,000	passive	stocks > dikes	Qd → Db → Qmp → And → Qmp → Qdp	all + metaseds
2000 x 4000	passive	dike swarm	Qlp, Rhy, Dac, Qd, Gd → Dac → Ql, L, Rhy	all + volcs
4000 x 7000(?)	passive	stock > dike	Mp → Qmp → Db	all
4000 x 7000	passive	stock > dike	Dio → Qd + hbl Gd & bi Gd → Qmp	Qd, Gd + seds
> 10,000 NE x 30,000 NW	passive	stock > sill > dike	alsk → Dac p → And p → Qmp	all + seds
1500 x 2500	active	bx pipe ≫ dike	Dac p	all + bx & volcs
4000 x 6000	passive	stock > dikes	Dio → Qm → Qmp → 'Qp'	all + seds

DEPOSIT	OREBODY			
	Outward Shape (12)	Boundaries (13)	Percent in Igneous Host (14)	Percent in Preore Rocks (15)
Ajo Arizona	oval, elongate NW	original & faults	80?	20?
Bagdad Arizona	elongate oval	original	± 90	± 10
Bethlehem British Columbia	steep, elliptical cylinder	original	± 50	± 50
Bingham Utah	pear-shaped, elongate WSW	original	75	25
Bisbee Arizona	elongate EW, oval	original & faults	± 30	± 70 (incl. bx)
Braden Chile	hollow circular cylinder	original & postore breccia pipe	25	75
Butte Montana	crudely domical	original	100	0
Cananea Sonora	pipelike	original breccia pipe	± 90	± 10
Castle Dome Arizona	oval, elongate NE	original & NW fault	100	0
Chuquicamata Chile	wedge, broad end NE n	original & fault(?)	95(?)	5(?)
Climax Colorado	nested, inverted cones	original	40(?)	60(?)
Copper Cities Arizona	oval, elongate NW	original & NE & NW faults	100	0
El Salvador Chile	oval pipe, lower grade center	original	70(?)	30(?)
Ely Nevada	?flat cylinder	original with faults above & below	80	20
Endako British Columbia	elongate oval	original	100	0
Esperanza Arizona	elongate NW oval	original	60(?)	40(?)
Inspiration Arizona	flat cylinder	original & fault	50	50
Mineral Pork Arizona	crescent, convex SW		± 100	± 0
Mission–Pima Arizona	oval	original & fault	± 10	± 90
Morenci Arizona	oval	original + fault	± 70	± 30
Questa New Mexico	irregular	original	70(?)	30(?)
Ray Arizona	irregular oval, elongate EW	original & fault	20	80
Safford Arizona	oval, dipping pipe	original	20	80
San Manuel–Kalamazoo Arizona	hollow oval cylinder	original	50	50
Santa Rita New Mexico	oval, elongate NW	original	± 70	± 30
Silver Bell Arizona	elongate oval mineral belt	original	70	30
Toquepala Peru	oval, elongate NW	original: breccia pipe	70 (bx & Dac p)	30 (walls pipe: Dio & volcs)
Typical Porphyry Copper	oval, pipelike	original & postore faults	70	30

OREBODY – *Continued*			
Dimensions (feet) (16)	Total Ore Tonnage (million) (17)	Grade Hypogene + Supergene (18)	Grade Hypogene Only (19)
4000 x 7000	< 500	0.75% Cu	0.75% Cu
1000 x 5000	< 100	0.76% Cu ± 0.025% Mo	± 0.5% Cu ± 0.025% Mo
2000 x 3000 (Jersey)	< 100	0.6% Cu	0.6% Cu
5000 x 7000 WSW	> 500	0.75% Cu 0.05% Mo	0.75% Cu 0.05% Mo
2000 x 2000	< 100	0.81% Cu	± 0.55% Cu
± 5000 x 5000 hollow cylinder	> 500	2.25% Cu 0.05% Mo	1.00% Cu 0.05% MO
5000 x 10,000 EW	> 500	0.8% Cu	0.2% Cu
250 x 1200 ring-shaped	> 500 (district)	0.8% Cu	0.5% Cu
± 1500 x 3000	< 100	± 0.70% Cu	± 0.5% Cu (?)
2500 x 10,000	> 500	± 1.7%	± 1.2% Cu
4000 x 4000	> 500	± 0.24% Mo	± 0.24% Mo
1500 x 2000	< 100	± 0.60% Cu	± 0.4% Cu
3000 x 4000	> 500	± 1.5% Cu	ND
± 1000 x 3000 x 10–20,000	< 500	± 0.9% Cu (1–2% common)	± 0.1% Cu (0.4% common)
1200 x 6000	> 100	± 0.09% Mo	± 0.09% Mo
2300 x 4200	< 100	0.51% Cu 0.028% Mo	± 0.3% Cu 0.028% Mo
2500 x 8300	< 500	0.90% Cu	0.15–1.20% Cu 0.007% Mo
2200 x 3400	< 100	0.5% Cu 0.04% Mo	0.1–0.15% Cu 0.04% Mo
5000 NW x 7000 NE	> 500	0.8% Cu	0.8% Cu
6000 x 13,000	> 500	0.88% Cu	0.1–0.15% Cu 0.007% Mo
7000 x 7000	> 500?	0.15–0.18% Mo	0.15–0.18% Mo
3000 NS x 10,000 EW	< 500	0.80% Cu	0.10–0.80% Cu
± 4000 x 5000	> 500	0.50% Cu	± 0.2% Cu
cross section: 2500 x 5000 x ± 8000 high	> 500	± 0.75% Cu 0.015% Mo	± 0.75% Cu
5000 x 7000 NNW	< 500	0.97% Cu	0.1–0.2% Cu (intr) 0.8% Cu (tactite)
2000 x 2500 & 1500 x 2500	< 100	0.75% Cu	0.3–0.4% Cu (intr) 0.8% Cu (tactite)
4000 WNW x 5000 NNE	> 500	0.9% Cu	0.3% Cu
3500 x 6000	150	0.80% Cu 0.015% Mo	0.45% Cu 0.015% Mo

DEPOSIT	HYPOGENE ALTERATION			
	Known Extent Beyond Ore (ft) (20)	Peripheral Zone (21)	Outer Zone (22)	Intermediate Zone (23)
Ajo Arizona	+ 5000		?chl, ab, zo, ser, Q, ank	
Bagdad Arizona	500 +	ND	not reported	not reported
Bethlehem British Columbia	+ 300	ND	Q, chl, ep	Q, kaol, mont
Bingham Utah	3000 +	chl, talc, kaol, ep, gr, mag, pyx	Q, chl, kaol, cal, ep	
Bisbee Arizona	7000?		chl, ep, zo, cal, ser ?	kaol, ser(?)
Braden Chile	+ 5000	chl, mag, ep, hm, tm	ep, tm, mag, spec, cal	Arg – Phyl, minor
Butte Montana	1000 +		Q, chl, ep, cal	Q, mont, kaol
Cananea Sonora	5000		chl, ep	Q, ser, kaol
Castle Dome Arizona	3000		chl, ep, py, ser, cal & clzo	mont
Chuquicamata Chile	few hundred		chl, ep, cal, spec, hm, TiOx	kaol > ser
Climax Colorado	2000?		Q, chl(?), ep(?)	Q, py, ser
Copper Cities Arizona	5000 +		ep, cal, clzo, ser	mont, Q
El Salvador Chile	1000 +		py, chl	Argillic
Ely Nevada	2000		"propylitic"	
Endako British Columbia	2000 + (?)		kaol weak, Q, cal	kaol moderate, Q, chl
Esperanza Arizona	ND		not reported	Q, kaol, mont
Inspiration Arizona	1500 +		chl, ep	Q, ser, kaol
Mineral Park Arizona	10,000	chl, ep, clzo, (latest)	Q, ser, 'clay' (Argillic)	Q
Mission–Pima Arizona	up to 5000		skarn, tactite, hornfels	present
Morenci Arizona	> 5000	skarn on SE	chl, ep	Q, mont
Questa New Mexico	2000 + (?)	ser, car, kaol, ep, chl	ser, Q, py ± cal, kaol, ill, fl	ser, Q, py ± cal, kaol, ill
Ray Arizona	1000–15,000		chl, ep, ab, cal, mont to 20,000 x 30,000	
Safford Arizona	± 12,000		ep, chl	"chloritic"
San Manuel–Kalamazoo Arizona	3000–5000		Q, chl, ep, cal	Q, kaol, chl
Santa Rita New Mexico	± 5000	tactite	tactite	chl, ep (Argillic)
Silver Bell Arizona	± 32,000 x 5000 alteration zone		chl, cal, ser, mont tactite	Q, ser, kaol tactite
Toquepala Peru	minor; < 1000			mont
Typical Porphyry Copper	2500	chl, ep, kaol, (skarn).	chl, ep, cal	Q, kaol, ser, mont

l Sequence Bottom (35)
ases
n in veins
ard
→ (cp, bn, py, mb) , bn)
→ cc → an → Ag
cp, py →
ad
racts & py:mag
depth

HYPOGENE ALTERATION – *Continued*			
Inner Zone (24)	Innermost Zone (25)	Zoning Sequence from Center (26)	Vertical Sequence from Bottom (27)
(Q, ser, py)?	Q, K fold, chl (anh)	partial overlap Pot – Phyl – Prop	
Q, ser, K fold	bi, ab, Q, K fold	Pot – Phyl	
Q, ser		Phyl – Arg – Prop	
Q, ser, K fold ± clays, chl	Q, K fold, bi, ser	Pot – Phyl – Prop	
"Qp", Q, dck, prp; "fold Qp" = Q, ser		adv. Arg & Phyl – Arg – Prop	
Q, ser, bi, anh	Q, ser, bi, anh	Pot & Phyl – Arg – Prop	Pot – Phyl
Q, ser, py; Q, dck, prp	Q, K spar, bi, ser (anh)	Por – Phyl – Arg – Prop	Pot – Phyl – Arg – Prop
Q, ser	Q, mb, bi, tm(?)	Phyl – Arg	
Q, ser, hydromica, K fold		Phyl – Arg – Prop	
Q, K fold, ser		Phyl – Arg – Prop	ND
K fold, Q, bi, fl	Q (nesting)	Q – K fold – Q, py, ser – chl, ep	Q – K fold – Q, py, ser
Q, ser, py, hydromica		Phyl – Arg – Prop	
py, Q, ser ± tm	Q → Q, K fold; anh, general bi	Pot – Phyl(?) – Arg(?) – Prop	Pot – Phyl(?) – Arg – Prop
"sericitic"	"potassic"		granitoid -p texture; ser – bi – clay
Q, ser, py, kaol	Q, K fold, bi	Pot – Phyl – Arg	ND
Q, K fold	Q, ser, K fold, bi (anh) (innermost)	Pot – Phyl – Arg(?)	not reported
Q, ser, kaol	K fold, bi, ser	Pot – Phyl – Prop	ND
Q, ser, py	Q, K fold (earliest)	Pot – Phyl – Arg – Prop	not reported
Q, ser, clay(?); skarn	Q, K fold, ser, bi; skarn	Pot – Phyl – Arg – skarn	
Q, ser, py	ND	Phyl – Arg – Prop	not reported
Q, K fold, bi ± cal, [illegible], ill	Q, K fold (anh)		
Q, ser to kaol 10,000 x 16,000?	bi, Q, ser, K fold 8000 x 8000	Pot – Phyl – Arg – Prop	ND
Q, ser, py	K fold, bi, Q, ser	Pot – Phyl – Arg – Prop	
Q, ser, py	Q, K fold, bi, anh	Pot – Phyl – Arg – Prop	Pot – Phyl(?)
Q, ser, py, tactite	Q, K fold, bi, plag, kaol, mont (anh)	Pot – Arg – Phyl – Prop	
Q, ser, tactite	Q, K fold, ser, hydromica	Pot – Phyl – Arg – Prop	ND
Q, ser, py	Q, tm, bi, K fold	poorly developed	anhydrite at depth
Q, ser, py	Q, K fold, bi, ser (anh)	Pot – Phyl – Arg – Prop	Pot – Phyl(?)

DEPOSIT	HYPOGENE MINERALIZATION			
	Peripheral Alteration Zone (28)	Outer Alteration Zone (29)	Intermediate Alteration Zone (30)	Inner Alteration Zone (31)
Ajo Arizona	spec, bar		cp, py, bn, mb, mag, hm py:cp < 1	py:cp = 1:4; py, cp
Bagdad Arizona	Au, sl, Ag, cp			py > cp > mb
Bethlehem British Columbia	cp, Ag, Au	py > cp, bn	cp > py > bn	bn > cp > py
Bingham Utah	en, fm, gal, sl, tt	py		py, cp, mb
Bisbee Arizona	sl, gal, py, cp	ND	ND	py, cp, bn, cc, mb, sl py:cp = 10:1
Braden Chile	gal, sl, Ag, stb, py	py		py > cp > bn > mb > en mb > en
Butte Montana	Mn, Ag	rc, sl, gal, rd	py, bn, cp, tn	py, cc, en, bn
Cananea Sonora	gal, sl, tt, Ag		py, cp, bn, mb, sl, gal	py, cp, bn, mb
Castle Dome Arizona	sl, gal, py, cp, mb, V, Ag, spec	py	py > cp > mb	py > cp > mb
Chuquicamata Chile	minor sl, gal, spec	py, cp	en, cp, cc, bn, py(?)	en, cp, cc, py, bn(?), mb
Climax Colorado	gal, sl, Ag(?)		py, tz, fl, hn, cs	mb, cp
Copper Cities Arizona	sl, gal, Ag	py	py > cp > mb	py > cp > mb
El Salvador Chile	gal, sl, Ag	py, spec	ND	py = cp
Ely Nevada	Au & base metals in sods			py, cp, high total sul py:cp = 5–10:1
Endako British Columbia	sl, gal, Ag	spec, cal < .05% py	mag, py, mb, < 0.15% py	py, mb, mag .5–1.0% py
Esperanza Arizona	gal, sl, Ag	py	py > cp > mb	py > cp > mb
Inspiration Arizona	cp, gal, sl, mb, V, Mn	py > cp(?)	py > cp	py > cp > mb
Mineral Park Arizona	Au, Ag, gal, sl	py, cp, sl, gal	py, cp	py, cp, mb
Mission–Pima Arizona	gal, sl, Ag	'heavy minerals'	?	py, cp, mb
Moronci Arizona	gal, sl, Au, Ag	py	py:cp = high; high total sul; py, cp	py 3–8%; cp 9.3–0.5%; py, cp, mb, sl
Questa New Mexico	py, mb, gal, sl	py, mb, cp–gal–sl	py, mb	mb, py, cp, hn
Ray Arizona	gal, sl.	py, cp, bn	py, cp, bn	py, cp, bn, mb
Safford Arizona	Ag, cp	Au, cp	ND	py, cp, mag, tt, gal, sl py 4–8%; cp ± 0.4% py:cp = 10–20:1
San Manuel–Kalamazoo Arizona	cp, gal, sl, Au, Ag	py (2%)	py (2%)	py (10%); cp (0,1–3%) mb(0–0,05%)
Santa Rita New Mexico	sl, gal, Ag, spec, cp, mc		py, 4–8%; cp < 0.4% py:cp = 40:1	py 1–4%; cp 0.4–1%; mb; py:cp = 3:1
Silver Bell Arizona	Ag, gal, sl	Ag, gal, sl(?)	py:cp = 6:1	py:cp = 1:1
Toquepala Peru	minor cp, bar	no py halo	mod py:cp low total sul	low py:cp; higher total sul; py, cp, bn, sl, mb
Typical Porphyry Copper	gal, sl, Ag, Au	py, gal, sl	py > cp > bn; mod total sul; py: cp = 23:1	py > cp > mb > bn; high (10%) tot sul; py:cp = 13:1

HYPOGENE MINERALIZATION—*Continued*

Innermost Alteration Zone (32)	Overall Abundance Major Ore Minerals (33)	Zoning Sequence from Center (34)	Vertical Sequence from Bottom (35)
mag; cp; py, bn; low total sul	cp > py > bn > mb(?)	mb → cp → py → spec	cp:bn decreases
cp > py > mb	py > cp > mb	cp → py	ND
	cp > py > bn > mb	bn → cp → py	ND
cp, bn, mb	py > cp > bn > mb	mb → bn → cp → py → (gal, sl, Ag, Mn)	Cu to Pb–Zn in veins
	py > cp > bn > cc	not reported	less py upward
py > cp > bn > mb > en	py > cp > bn > mb > en	(cp, py, bn, mb) → (py, cp) → (gal, sl, Ag)	(bn, cp, mb) → (cp, bn, py, mb) → (py, cp, mb, bn)
cp, py, mb	py > cc > en > bn > cp	mb → cp → py → cc → en → cp → tn → rd → Ag	mb → cp → py → cc → en → cp → tn → rd → Ag
py, cp, bn, mb	py, cp > bn, sl, gal	not reported	ND
	py > cp > mb	cp → py → (sl, gal, Ag)	cp → py(?)
en, py, cp, cc, bn(?), mb	py > en > cp > bn > mb	py → cp → py(?)	ND
minor mb	py = mb	mb → py → bn	three cycles mb-py-bn
	py > cp > mb	cp → py → (sl, gal, Ag)	py → cp(?)
cp = py? = bn = mb	py > cp > bn > mb	(cp, bn, mb) → (cp, py) → py → spec(?)	cp, bn, mb → cp, py → py → spec(?)
py, cp, bn, mb py:cp > 1:1	py > cp > bn, mb	(cp, bn, mb) → py → (Au, gal, sl)	ND
mag, mb, py <.15 py	mag > py > mb > cp	mag → (py, mag, mb) → (mb, cp py) → py → spec	ND
py > cp > mb(?)	py > cp > mb	cp, mb → py	ND
cp > py > mb(?)	py > cp > mb	(cp, mb) → py	ND
py, mb, wf	py > cp > mb	cp → mb → py → (gal, sl, Ag, Au) → (Au, Ag)	ND
py, cp, mb	py > cp > bn > mb > sl	(cp, py, mb) → (skarn, gal, sl)	ND
cp:py low, high py? py, cp, mb, sl	py > cp > sl > mb	(cp, sl, mb) → py → (sl, gal, Ag, Au)	not reported
mb, py, cp, bn	py > mb > cp, gal, sl	mb → (cp, py) → (gal, sl, mb)	not recognized 1000 ft
py, cp, bn, mb	py > cp > bn > mb	cp → py → (gal, sl)	ND
cp, py, bn, mb, mag, tt, gal, sl; py 0.2-1%, cp 1-2% py:cp = 0.1-1:1	py > cp > bn > mb	(cp, mb) → py → Au	mb at depth
py (1%); cp (1-3%) mb (0.01-0.05%)	py > cp > mb	cp → py → (gal, sl, Au, Ag)	cp → py
low total sul; py < 1%; py:cp = 10:1	py > cp > mb > bn	low-grade center → annular ore zone & (cp, mb) → py → (Ag, gal, sl)	py zone contracts & py:mag increases
py, cp, bn, tt, mb, sl	py > cp > mb > bn > sl	cp → py → (Ag, gal, sl)	ND
Q, tm + minor sul	py ± = cp > bn, mb	(Q, tm) → cp → py	not observed anhydrite at depth
py > cp > mb > bn; low (3%) tot sul; py:cp = 3:1	py > cp > mb > bn	(cp, mb) → py → (gal, sl, Ag, Au)	(cp, mb) → py

Inner Zone (24)
(Q, ser, py)?
Q, ser, K feld
Q, ser
Q, ser, K feld ± chl
"Qp", Q, dck, prp "fold Qp" = Q,
Q, ser, bi, anh
Q, ser, py; Q, d
Q, ser
Q, ser, hydromic
Q, K feld, ser
K feld, Q, bi, fl
Q, ser, py, hydr
py, Q, ser ± tm
"sericitic"
Q, ser, py, kaol
Q, K feld
Q, ser, kaol
Q, ser, py
Q, ser, clay(?);
Q, ser, py
Q, K feld, bi ± kaol, ill
Q, ser to kaol 10,000 x 16,00(
Q, ser, py
Q, ser, py
Q, ser, py, tac
Q, ser, tactite
Q, ser, py
Q, ser, py

DEPOSITS	OCCURRENCE OF SULFIDES			
	Peripheral Alteration Zone (36)	Outer Alteration Zone (37)	Intermediate Alteration Zone (38)	Inner Alteration Zone (39)
Ajo Arizona	veinlets	diss > μvlts		diss > μvlts
Bagdad Arizona	vns & massive replacement	vlts > diss		diss > vlts
Bethlehem British Columbia	veins	veinlets	veinlets	veinlets
Bingham Utah	veins & replacement	vns, vlts, diss	vlts, diss	diss > vlts
Bisbee Arizona	vns, vlts, mass. repl.	ND	ND	vns, vlts, diss
Braden Chile	veins	patches & vlts	vlts & patches	vlts > patches
Butte Montana	vn, vlt	vn, vlt	vn, vlt	vlt, vn, diss
Cananea Sonora	vein	veinlets	vlts, diss, mass.	vlts, diss
Castle Dome Arizona	veins	veinlets	diss > vlts	diss > vlts
Chuquicamata Chile	veins	vns & vlts	vlts > diss	vlts > diss
Climax Colorado	vns & dikes		vlts > diss	vlts > diss
Copper Cities Arizona	veins	veinlets	diss > vlts	diss > vlts
El Salvador Chile	veins	μvlts, vlts ?	μvlts, vlts ?	diss, μvlts
Ely Nevada			diss > vlt	diss > vlt
Endako British Columbia		vlt > diss	vlt > diss	vlt ± = vlt
Esperanza Arizona	veins	vns & vlts	vlts	diss > vlts
Inspiration Arizona	veins	vns & vlts	vlts > diss	vlts > diss
Mineral Park Arizona	veins	vlts, vns, stkwk 3–6'' spacing	vlts, vns, stkwk 3–6'' spacing	vlts, vns, stkwk 3–6'' spacing
Mission–Pima Arizona	vn & vlt			vlt, diss & massive
Morenci Arizona	vns, ls repl.	vlts > diss	ND	vns, vlts, diss
Questa New Mexico	veins	paint	vlts	vns & vlts
Ray Arizona	veins	vns, vlts, diss	vns, vlts, diss	vlts, diss, vns
Safford Arizona	veins	in shears, vns, dikes	in shears, vns, dikes	in veins, vlts, diss
San Manuel–Kalamazoo Arizona	veins	vlts	vlts > diss	vlts > diss
Santa Rita New Mexico	veins	vns & vlts	vns & vlts	vlts, μvlts, diss
Silver Bell Arizona	vns & tactite	vns & tactite	vlts > diss	vlts > diss
Toquepala Peru	veins		diss > vlts bx vug fillings	diss > vlts bx vug fillings
Typical Porphyry Copper	veins	vns & vlts	veinlets	vnlts > diss

OCCURRENCE OF SULFIDES—*Continued*			SUPERGENE SULFIDES (43)
Innermost Alteration Zone (40)	Breccia Pipes (41)	Crackle Zones (42)	
diss > μvlts	not reported	beyond ore limit	minor cc, cv
diss > vlts	present & mineralized	2000 x 6000 ft	cc
vlts > diss	present & mineralized	slightly larger than orebody	none
diss > vlts	in gal, sl zone peripheral	extends beyond gal, sl	cc, cv
	important; 2 stages	NE horsetail zone	cc
vlts > patches	postore with min. frag.	present	cc > cv
diss > vlt	none	horsetail zone	cc, cv, dg
vlts, diss	numerous & mineralized	present	cc, cv
	present?	present	cc, cv
vlts > diss	large central pipe	horsetail zone	cc, cv
irregular clots	minor breccia, dikes	present	none
	present	present	cc, cv
diss, μvlts	deep, central, mineralized	present	cc > cv
diss > vlt	present	present	cc, cv
diss > vlt	not reported	present	none
diss > vlt	present	present	cv, cc
vlts > diss (?)	not reported	present	cc
vlts, vns, stockwork 3–6" spacing	none	present	cc
vlt, diss & massive	ore N–S dike; cp, gal, sl, tt	poorly developed	cc, thin zone
	breccia zones, in pit	extensive	cc, cv
vns & vlts	present, important	extensive	none
vlts, diss, vns	present & mineralized	present	cc, cv
vns, vlts, diss	present & mineralized	present	cc, cv
diss > vlts	not reported	± 5000 ft diameter	cc
vlts, μvlts, diss	one 500 x 2500 ft pipe, mineralized	same area as intrusive	cc > cv
ND	none	NW horsetail zone	cc
breccia fillings & diss	large multiple & many small mineralized	present beyond breccia	cc
diss > μvlts	present & mineralized	present	cc > cv

Economic Geology
Vol. 65, 1970, pp. 920–936