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ASARCO

Southwestern Exploration Division

November 16, 1984

R. L. Brown, Jr.
New York Office

Silver-Lead in Carbonate
Host Rocks
Western United States

I submit the following table and attachments showing the lead and silver production-reserves in the Western United States in carbonate host rocks.

Much of the data are from D. M. Smith's report "Intrusive-related Carbonate-Hosted Ag-Pb-Zn Replacement Deposits" (December 1983), supplemented by the two USGS Mineral Investigation Resource Maps, MR-15 (Lead) and MR-34 (Silver).

The two attachments, showing lead with a silver overlay, portray the distribution for the Western U. S. in three categories. Table 1 lists the production-reserve from D. M. Smith's report with a few additions. No further attempt was made to place the actual tonnage-ounces in the remaining districts.

James D. Sell

James D. Sell

JDS/cg

Attachments

cc: WLKurtz
DMSmith

Table 1. Districts in Carbonate-Host Rocks
with Lead-Silver Production-Reserves

State/Map No.	District	Tons Lead	Ounces Silver
WASHINGTON			
1	Northport		
2	Metaline	196,700	
3	Bossburg		
4	Colville		
5	Springdale		
MONTANA			
6	Copper Cliff		
7	Scratch Gravel		
8	Barker		
9	Philipsburg		4,000,000
10	Dunkleberg		
11	Elkhorn	2,000	14,800,000
12	Castle Mountain		
13	Hecla	56,300	13,400,000
14	Rochester		
15	Tidal Wave		
16	Argenta		
17	Sheridan		
18	New World		
IDAHO			
19	Seafoam		
20	Bayhorse		
21	Texas		
22	Junction		
23	Nicholia		
24	Birch Creek		

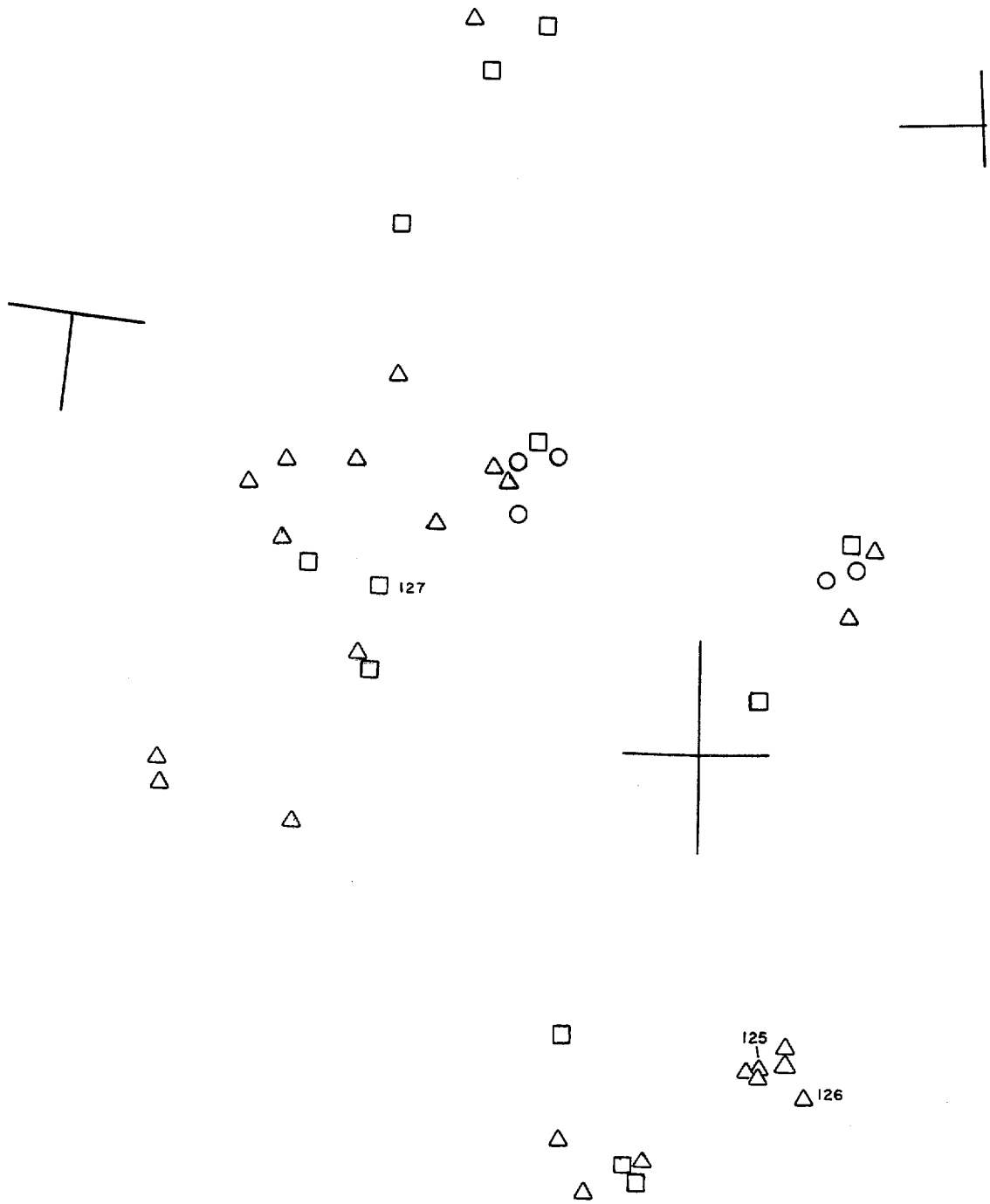
State/Map No.	District	Tons Lead	Ounces Silver
IDAHO (continued)			
25	Dome		
26	Rosetta		
27	Wood River	100,400	78,800,000
28	Alder Creek		
29	Muldoon		
30	Lava Creek		
31	South Mountain		
NEVADA			
32	Delano	7,500	1,200,000
33	Tecoma		
34	Merrimac		
35	Lewis		
36	Bullion		
37	Cortez		6,000,000
38	Railroad	11,500	1,200,000
39	Mineral Hill		
40	Union		
41	Spruce Mountain	1,000	1,300,000
42	Eureka	69,700	5,600,000
43	Hunter		
44	Aurum		
45	White Pine	101,200	21,000,000
46	Duck Creek		
47	Ely		
48	Ward		
49	Grantsville		
50	Simon		
51	Lone Mountain		
52	Quartz Mountain		
53	Groom		
54	Jackrabbit	16,700	3,900,000

State/Map No.	District	Tons Lead	Ounces Silver
NEVADA (continued)			
55	Comet		
56	Pioche	174,900	18,100,000
57	Yellow Pine	47,100	2,100,000
127	Taylor	None	18,900,000
UTAH			
58	Lucin		
59	Rush Valley		1,400,000
60	Bingham	2,100,000	125,800,000
61	Cottonwood		13,100,000
62	Park City	1,300,000	249,900,000
63	American Fork		
64	Ophir	25,800	5,900,000
65	North Tintic		
66	West Tintic		
67	Tintic	1,100,000	269,000,000
68	Mount Nebo		
69	Gold Hill		
70	Dugway		
71	Willow Springs		
72	Fish Springs	8,000	2,500,000
73	San Francisco		
74	Star		
75	Ohio		
COLORADO			
76	Gilman	148,000	66,100,000
77	Kokomo	15,400	1,800,000
78	Upper Blue River		
79	Alma		
80	Horseshoe		

State/Map No.	District	Tons Lead	Ounces Silver
COLORADO (continued)			
81	Leadville	1,200,000	245,000,000
82	Aspen	294,000	101,300,000
83	Rock Creek		
84	Taylor Park		
85	Tincup		3,000,000
86	White Pine		
87	Monarch		
88	Rico	83,900	14,500,000
CALIFORNIA			
89	Ubehebe		
90	Cerro Gordo	39,300	4,700,000
91	Lee		
92	Darwin	65,600	8,100,000
93	Modoc		
94	Slate Range		
95	Carbonate		
96	Tecopa		
97	Clark Mountains		
ARIZONA			
98	Superior	1,500	10,800,000
99	Banner		
100	Aravaipa		
101	Silver Bell		
102	Pima	16,300	1,400,000
103	Empire		
104	Tombstone	22,500	30,000,000
105	Courtland-Gleeson	3,000	1,200,000
106	Swisshelm		
107	Hill Top		

State/Map No.	District	Tons Lead	Ounces Silver
ARIZONA (continued)			
108	Harshaw	14,900	1,800,000
109	Patagonia		
110	Bisbee (Repl)	92,000	51,500,000
NEW MEXICO			
111	New Placers		
112	Magdalena		
113	Hansonburg		
114	Hermosa		1,000,000
115	Kingston		5,000,000
116	Swartz		
117	Cooks Peak		
118	Organ		
119	Tres Hermanas		
120	Victoria		
121	Hachita		
122	San Simon		
123	Central	152,500	8,800,000
124	Pinos Altos		
125	Georgetown		3,000,000
126	Lake Valley		5,800,000
TEXAS (Not on Maps)			
	Shafter	14,143	31,000,000

ATTACHMENT A
(OVERLAY)



○ Plus 100 Million Ounces of Silver

□ 10 Million–100 Million Ounces of Silver

△ 1 Million–10 Million Ounces of Silver

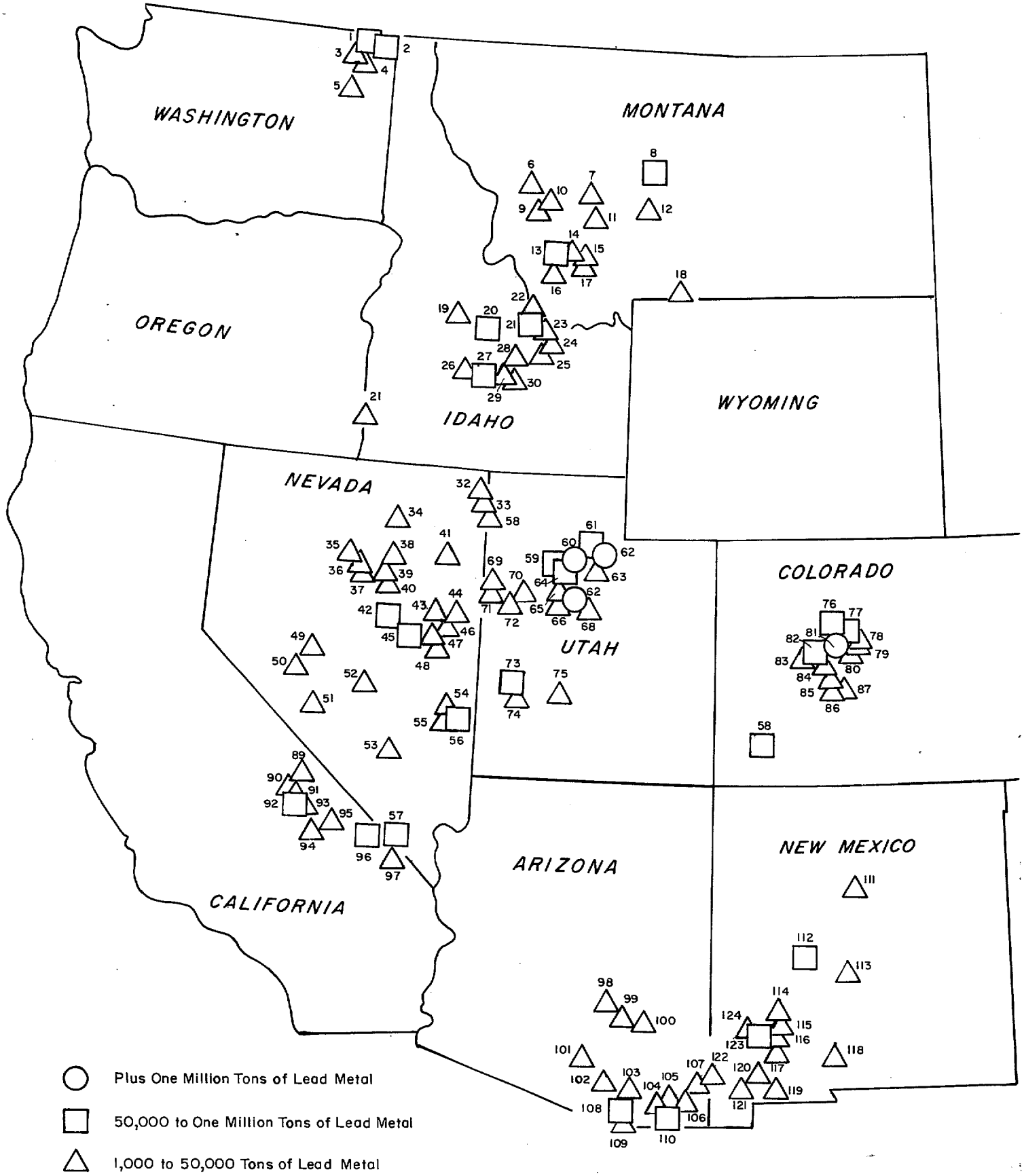
SILVER PRODUCTION - RESERVES IN CARBONATE HOST

WESTERN UNITED STATES

Approx. Scale, 1:10,000,000

J.D. Sell 11/16/84

ATTACHMENT A



LEAD PRODUCTION - RESERVES IN CARBONATE HOST

WESTERN UNITED STATES

Approx. Scale, 1:10,000,000

J.D. Sell 11/16/84

MVK-6085

Very good

ASARCO

Rocky Mountain
Exploration Division

October 8, 1984

TO: F. T. Graybeal

FROM: D. M. Smith, Jr.

Geologic criteria for evaluation of diamond drill results from projects seeking intrusion-related carbonate-hosted Zn-Pb-Ag replacement deposits

The extremely irregular forms of manto-type ore deposits can make them exceptionally difficult to intersect with drill holes, particularly from the surface of blind prospects where even the existence of mineralization has yet to be confirmed. As the depths at which these deposits are sought increases so do the costs of the search. This makes it necessary to wring the maximum amount of information out of unmineralized drill holes in order to avoid abandoning a worthwhile project or prolonging a fruitless search. Described below are criteria for the evaluation of drill core which have been drawn in large part from a literature review made last year of 80 intrusion-related carbonate-hosted Zn-Pb-Ag replacement deposits and also from personal familiarity with a number of major deposits in the U.S. and Mexico. I have assumed that the core is essentially unmineralized by sulfides and is from a hole drilled within a proper metallogenic province, but not necessarily within the boundaries of an established mining district.

Permeability--Host rock permeability is probably the single most important feature associated with replacement deposits in carbonate rocks. Without it there will be no "replacement" of the walls surrounding the hydrothermal fluid channelways. Common varieties to look for are karst (usually reported in the drillers log as "void"), sanded carbonate (calcarenite from which marine and/or diagenetic cements have been dissolved not necessarily by hydrothermal processes), zebra (diagenetic replacement of evaporite or stromatolite) and birds-eye (fenestral) textures, thrust and bedding-plane faults, dissolution collapse zones in evaporite beds, and any extensive unsealed breccias regardless of origin. A core of massive structureless limestone or dolostone is a bad sign.

Intrusive Rocks--Work in progress by D.I.Fletcher will show that the intrusions associated with these deposits have a narrowly defined chemical composition. Cutting a pluton of the proper chemistry would no doubt be comforting, but certainly is not a requirement for continuation of the project since ore can be located well away from the "source" intrusion.

Skarn--Skarn, when present, seems to be what Einaudi, Meinert, and Newberry (Econ. Geol., 75th Ann. Vol.) term "zinc skarns" which are characterized by Mn- and Fe-rich mineralogy, pyroxene as the dominant calc-silicate mineral, association of significant amounts of sulfide mineralization with pyroxene rather than with garnet or other silicate minerals, and a retrograde mineralogy of Mn-rich ilvaite, pyroxenoids, subcalcic amphibole, and chlorite. The presence of members of this mineral suite can be construed as indicating the presence of a favorable hydrothermal system.

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Hydrothermal Alteration--Any sign of hydrothermal alteration should be considered favorable. In igneous rocks it can take the form of propylitic, argillic, or quartz-sericite-pyrite, with the last-mentioned usually found in closest proximity to ore. Jasperoid in the carbonate is encouraging only (!?) when it contains significant geochemical values for such elements as Ag, Pb, Zn, Bi, Sb, Th, and Cu. The presence of tens of miles of absolutely barren jasperoid along strike in the outcrops of Paleozoic carbonates between Deming and Hillsboro, New Mexico suggest that many silica-flooded and replacement zones in carbonate rocks are probably totally unrelated to ore-forming hydrothermal activity, thus jasperoid alone is not always a positive indicator. Marmorization ranging from intense bleaching and recrystallization (generally to a larger grain size) to barely perceptible lightening of rock color along fractures is common in many deposits, but alternatively may be related to the contact effects of "dead" intrusions. An excellent sign that a hydrothermal system has been intersected is local dolomitization accompanied by coincident lightening of rock color along crosscutting fractures in limestone.

Sulfides--Diagenetic pyrite in amounts up to 5% or more is common in porous carbonate sediments. Amounts well in excess of this figure should be regarded as potentially hydrothermal in origin. Sphalerite in the intrusion-related deposits is invariably iron-rich and dark in color. Thus, as a general rule the darker the sphalerite the better; however, a number of respectable geologists claim that many of the intrusion-related deposits are really MVTs with overprints of intrusive effects. If perchance they are indeed MVTs then any feature reminiscent of MVT deposits, even "shines" of pale sphalerite, should be considered as possibly indicative of larger amounts of mineralization nearby.

Douglas M. Smith, Jr.

DMS:lb

cc: WLKurtz

cg FILE

June 7, 1984

MEMORANDUM FOR: Mr. R. L. Brown

Origin of Limestone
Replacement Deposits

The attached report by Mr. Smith represents a major research effort which started with his contribution to the general paper on silver deposits recently prepared by myself, Mr. Smith, and Mr. Vikre. It advances the concept that metals in Cordilleran-type Pb-Zn-Ag deposits such as Leadville were derived from and carried by basinal brines and deposited within large cells of convecting fluids set in motion by igneous intrusions. With the exception of igneous activity, Mr. Smith believes that ore genesis in the Cordilleran environments had many factors in common with Miss. Valley-type deposits. The paper by Cathles and Smith (1983) discussed in Mr. Smith's report should be required reading for all those interested in this subject.

Previous exploration by Asarco for carbonate replacement deposits in the Western U.S.A. was conducted adjacent to any intrusion which cut the Leadville Formation or other favorable host rock, without notable success. As a result of Mr. Smith's work, future exploration* will focus on intrusions within a specific geographic position adjacent to sedimentary basins which possess the various favorable structural and stratigraphic features discussed in his report. In addition, Mr. D. I. Fletcher has completed work which clearly demonstrates that only a limited compositional range of intrusive rock types are found in major limestone replacement districts, a feature which will permit further refinement of exploration targets. Mr. Fletcher's work was reviewed during the recent Tennessee-Missouri trip with the Knoxville office staff and will be written up when inclement field conditions permit.

*Exploration by the Denver office. Carbonate replacement work by Mr. Sell and his staff will likely continue to follow his concepts of alteration for the time being.

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The concept of a Miss. Valley-type origin is also being proposed by USGS geologists for the Sherman Mine, one mile east of Black Cloud at Leadville. Their work will be presented at the 1985 SEG Carbonate Replacement Symposium in New York City. Additional work to be discussed at the Symposium will be isotopic work done in the Gilman-Leadville area by the USGS, Tommy Thompson, and Noranda. I personally view oxygen isotope variations as particularly useful for locating and defining the shape of extinct hydrothermal systems in rocks which are megascopically unaltered. The work by Criss and Taylor (1983) discussed in Mr. Smith's paper is one example and Asarco should continue to follow the literature on this subject.

Although I like the concept advanced by Mr. Smith and endorse it's application to selection of reconnaissance targets, I have a major conceptual problem with significant differences in metal contents between Miss. Valley and Cordilleran limestone replacement deposits. Cordilleran deposits commonly contain abundant pyrite, gold, and silver, which are notoriously absent in the Miss. Valley environment. In addition, fluid inclusions are far less saline and formed at much higher temperature in Cordilleran deposits as compared to Miss. Valley-type deposits. Clearly, more remains to be learned, but in any case Mr. Smith's work permits much greater exploration focus then was previously possible.

In addition to Mr. Smith's concepts of basin-related genesis of Cordilleran limestone replacement deposits, which have not yet been widely discussed in the exploration department, we still have the on-going Smith-Sell debate over the origin of textures in carbonate rocks such as zebra, winky rock, and the like. I think the recent Miss. Valley trip was a useful attempt to place these features in a practical framework and it is likely I will ask someone to organize a similar trip this Fall to some of the Cordilleran replacements camps for Knoxville office staff and various other western-based geologists involved in carbonate replacement exploration.

F. T. Graybeal

F. T. Graybeal

cc: W. L. Kurtz no/att.
J. D. Sell "
D. M. Smith, Jr. "
D. D. Harper "

ASARCO

Southwestern Exploration Division

July 15, 1982

TO: F. T. Graybeal
F. R. Koutz
H. G. Kreis
B. C. Spencer

FROM: J. D. Sell

Limestone Replacement Note

The March-April, 1982 (Vol. 77, No. 2) issue of Economic Geology, on pages 392-412, has an excellent article on dolomitization-karst-calcite veining-ore relationships (see attached abstract). However, the triangular karst picture should be in the Fig. 23 outline and the brecciated limestone photo belongs to the Fig. 22 description. Note that the bibliography material which puts most of the text together has only Poland publications data.

Mr. Burton Devere, Jr., of Billiton International, spent the morning of July 12 in the office with Mr. Kurtz and myself. Bert has packed up his household and is moving to The Hague for 3-4 years as overseer for North American exploration. He had formerly been the Manager of North America exploration and was stationed in Denver.

In the course of many things, Bert mentioned that Billiton had taken up a large land position in the Goodsprings (Yellow Pine) District, Nevada. Bert had hired a Romanian geologist he had found wandering in the desert as a consultant and who was an excellent mapper, etc. The geologist remapped the Goodsprings area in two months time and found a persistent fault structure which contained dolomite textures, iron staining, metal values (zinc + moly + pyrite), calcite veins, etc. of the "Sell-type" (quote of B. Devere). They apparently staked over 40 kilometers of this north-trending structure.

The Potosi Mine, as shown in USGS Bulletin 1010, has stopes in the Mississippian Monte Cristo limestone which has been dolomitized in part. The Bulletin suggests these are mainly along a low-dipping Principal Thrust. Bert sketched the Monte Cristo hill and Potosi orebodies being <u>underlain</u> by a flat thrust and then to the east (assuming his section was looking north) at the base of the hill was the north-trending structure, a steep-dipping feature. On the Potosi side, the rock was Cambrian Goodsprings dolomite and across the fault was Pennsylvanian Bird Springs formation. Underlying the Bird Springs, with an unconformity, is the Mississippian Monte Cristo limestone.

Bert-Geologist-Billiton thinking was that with the leakage of all the alteration-mineralization characteristics in the fault zone, then ore bodies should be in the Monte Cristo. Five holes were drilled on 500 meter intervals, some of which were angled to cut the fault & which ended in Precambrian gneiss, others subparallel to the fault to test the favorable horizons adjacent to the feeding structure. Of the five holes none found any mineral of consequence but some stayed in good alteration characteristics.

Also south of the town of Goodsprings, and possibly on or near this same north-trending structure (projection?), Billiton drilled 4 holes in an iron-stained zone without any success (fall of '81 - spring of '82).

Billiton is now reevaluating their position.

James D. Sell

James D. Sell

JDS:mek
Att.

Economic Geology
Vol. 77, 1982, pp. 392–412

0361-0128/82/10/392-20$2.50

ASARCO

Southwestern Exploration Division

July 15, 1982

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James D. Sell

James D. Sell

JDS:mek
Att.

Economic Geology
Vol. 77, 1982, pp. 392–412

0361-0128/82/10/392-20$2.50

ASARCO

Southwestern Exploration Division

JDS

August 15, 1980 new File "Limestone Replacement"

TO: W. L. Kurtz

FROM: J. D. Sell

Classic Report on
Underlying Principles of
Limestone Replacement Deposits

The attached report by Basil Prescott is one which clearly outlines the results of a number of years' studies in the limestone replacement deposits of Mexico.

I believe his basic principles listed on page 4 are as valid today as when written. The article is recommended reading for a sound philosophical springboard to exploration and exploitation of limestone replacement deposits in general.

James D. Sell
James D. Sell

JDS:lb
Att.

xc: Rick Dingess
3/27/84

(With sincere regards
Basil Prescott)

The Underlying Principles of the Limestone Replacement Deposits of the Mexican Province

By Basil Prescott

Consulting Geologist, The American Metal Co., Ltd.; Cia. Minera de Peñoles, S. A., and Their Subsidiaries, 513 Mills Building, El Paso, Tex.

Reprinted from
ENGINEERING AND MINING JOURNAL
Vol. 122, Nos. 7 and 8—Aug. 14 and 21, 1926

The Underlying Principles of the Limestone Replacement Deposits of the Mexican Province—I

By Basil Prescott

LIMESTONE REPLACEMENT SEARCH

James D. Sell

July 13, 1979

LIMESTONE REPLACEMENT SEARCH

Summary
Size and habitat of known replacement ore bodies and districts
Production data from four major districts
Comments on mapping, sampling, interpretation, and drilling
Visual and chemical parameters
Areas investigated during 1978
References

Table One. Production-Value Data
Table Two. Tabulation of trend values in Leadville and related carbonate formations in Central Colorado

Appendix A. Summary of Skyline emission spec and Barringer MRFAPE data
Appendix B. List of previous reports containing analytical data

Plates
1. Surface plan of Iron-Rock Hill group of ore bodies, Leadville District, Colorado
2. Surface plan of mantos and chimneys in Leadville Dolomite and underlying fissure veins in quartzite and granite, Eagle Mine, Gilman District, Colorado
3. Surface plan of some ore bodies in the Aspen District, Colorado
4. Plan of mantos and chimney ore runs, Main Tintic District, Tintic, Utah
5. Surface plan of ore bodies, Chief Consolidated Mine, Tintic District, Utah
6. Vertical section ABC of the deep ore zone of the Chief Mine, Tintic District, Utah
7. Long section XYZ of the Chief ore zone, Chief Mine, Tintic District, Utah
8. Generalized section of the Gemini ore zone, Tintic District, Utah
9. Generalized section of the Iron Blossom ore zone, Tintic District, Utah
10. Plan and section of Liddia Mine and Continental Chief Mine, Leadville District, Colorado
11. Plan of workings of the Hilltop Mine, Mount Sheridan District, Colorado

LIMESTONE REPLACEMENT SEARCH

Summary

The perplexity of configuration and extent of limestone replacement ore bodies, with their usual sharp contact between ore and host unit, have long been a grey hair in the explorationist's head who searches for them. Probably more physical and chemical factors are associated with these deposits than most other types of mineral deposits, and this includes the usual stratigraphic, structural, and mineral zoning problems. Accenting the exploration problem is the rapid change in the third dimensional path of very productive ore bodies having small subcylindrical cross-section while extending in hundreds and thousands of feet along the axial direction.

Two factors appear to be able to guide the explorationist: 1) fluid movement in a carbonate terrain will leave a path and this resultant alteration-recrystallization-replacement intensity can be mapped, 2) mineral-bearing fluids add and subtract components to the units involved and the distribution intensity and trends can be outlined.

This report addresses the field and laboratory findings on the two factors.

Size and Habitat of Known Replacement Ore Bodies and Districts

The size and habitat of replacement ore bodies varies as with most ore deposits. However, the aggregate deposits found within a district are often large and the profit realized from individual ore bodies is also often large -- factors which attest to their exploration potential.

Four districts, showing the plan extent of ore bodies, are used as examples: 1) Leadville, 2) Gilman, 3) Aspen (all in Colorado), and 4) Tintic, Utah.

Leadville's known productive district extends 3-1/4 miles east-west by 2-1/2 miles north-south. In this report, the Iron-Rock Hill group of ore bodies is taken as typical of the manto type with intra-connecting channels and chimneys. Plate 1 is a tracing of Norman's (1971) compilation taken mainly from an earlier report by Loughlin (1926). Note that in plan the ore bodies range from five to ten feet and up to 400 feet in width and in length from several hundred to over 1400 feet. Height of the stoped areas is reported to be 10-20 feet and up to 100 or more feet, especially near or along cross fractures and feeder systems. As noted in the plan, overall aggregate of ore runs is substantial, but outlines of the mined shoots are very irregular with non-mined masses in the interior and isolated mined pods outside the main run or channel.

At Gilman (Plate 2), four major ore runs were mined from an area having a trapezoidal outline with the bases of 4500 and 2000 feet and a height (length) of 3000 feet. The individual ore runs have a general width of 50-80 and up to 200 plus feet and lengths of 2600-4000 feet; all of which were upwardly terminated by erosion. The runs were typically elliptical and range from several feet to 150 feet in height. The several chimneys found at the lower termination, and also along the length of the run, extend through several stratigraphic units and obtain heights in excess of 250 feet as a downward terminating cone. The widest portion of the largest chimney was in excess of 400 feet in diameter.

The Aspen ore bodies (Plate 3) are in a long string (some 3-1/2 miles long) of individual bodies ranging from 20-50 and up to 200 feet in width. The length ranged from 300-400 feet and up to 2200-2400 feet. The Aspen ore bodies also tend to form elliptical-shaped cross-sections of 20-30 feet and up to 100 feet in height. Steep folding at Aspen (see cross-section C on Plate 3) gives the impression of a number of ore bodies stacked one upon the other, but essentially they follow along a favorable horizon.

The Tintic district, Utah, has the best available maps showing the ore bodies and their configuration. The Main Tintic district of limestone replacement ore bodies extends 1.8 miles in length by 1.5 miles in width. Plate 4 is a tracing of the Main Tintic district with its three main ore runs and several cross-overs. Widths within the ore runs are commonly 30-50 feet and up to 150-200 feet connected by narrow 10-20 foot wide bodies, with the individual stoped masses being 400-1600 feet long. Heights of ore runs were 20-50 and up to 100 feet high. Numerous connecting chimneys of similar dimensions tie the ore bodies together. The string of ore bodies in the individual runs total 5000 to 10,000 feet in length.

A portion of the ore bodies at Tintic have been enlarged to give better detail as to the horizontal and vertical configurations on the mined areas. Plate 5 is a plan of the Chief Consolidated Mine, at the scale of 1" = 300', which is at the north end of the Chief Ore Zone of Plate 4. The general trend of the ore run is north-south subparallel to the strike of the bedding with subsidiary control along northeast-trending structures. Two sections accompany the plan: 1) a vertical section northeasterly through the deep ore zone (section A-B-C) is shown on Plate 6, while 2) Plate 7 is the accompanying north-south section X-Y-Z. Note that along the Chief Consolidated zone, all the ore bodies are within the Bluebell dolomite.

Two additional sections, at 1" = 300', show the Gemini ore zone to the west and the Iron Blossom ore zone to the east within the Main Tintic district. The Gemini ore zone (Plate 8) is not only in the Bluebell dolomite, but extends by long chimneys along fault zones down into underlying units which are several thousand feet stratigraphically below the Bluebell. These chimneys are 1600-1800 feet in vertical length. On the other hand, the Iron Blossom ore zone (Plate 9) is nearly a horizontal trend which on the south cuts across dipping units below the Bluebell, then through the Bluebell in the central part of the run, then finally cuts horizontally through dipping units, which were dropped across the Sioux Ajax fault, that are stratigraphically far above the Bluebell dolomite.

This propensity of ore runs to change direction and/or stratigraphic units is a general rule in the larger districts and should be looked for during any exploration program.

Cook (1957b) has described these Tintic zones quite graphically and I reproduce his pages 63-71 below. Of special note is his Figure 6 showing the distribution of the production versus the geologic units from which the production was mined. The Devonian-Silurian Bluebell dolomite and the lower Cambrian Ophir Formation produced about 45% of the total dollar value from the Main Tintic district.

D. R. Cook, 1957b, p. 63-71

Limestone Replacement Ore Bodies

Most of the ore produced from the Main Tintic district has come from limestone replacement ore bodies. An examination of Plates 3 and 4 shows that these deposits are situated at the north end of the district, occur in definite linear zones and are on the northern projection of many of the prominent fissure vein systems.

The term "ore zone" is used here although they are called ore runs in the Main Tintic district. They resemble in form and mineralogy the "mantos and chimneys" of the Mexican silver - lead province and especially the Santa Eulalia orebodies in the State of Chihuahua, Mexico. In certain respects they also resemble the limestone replacement ore bodies of Gilman, Colorado.

The four principal ore zones named from west to east are the Gemini, Chief, Godiva, and Iron Blossom. The Plutus, located between the Chief and Godiva, although of smaller magnitude, is of the same general type. The ore zones strike north, are parallel or subparallel to the bedding, and have a gentle plunge to the north similar to that of the synclinal axis. Commonly the ore zones have one long dimension and two short ones; they often contain individual ore bodies or ore shoots, sometimes side by side and sometimes one vertically above another. These shoots may be interconnected, as in the Godiva and Iron Blossom zones, or they may be isolated, as in parts of the Chief and Gemini zones. Although the general strike and plunge of the ore zones can be predicted with some degree of certainty, much development and exploratory work is necessary to find the ore shoots within the zones. This explains the repeated attempts of the mining companies and lessees to explore for individual ore shoots that might have been missed when the zone was being mined.

In many cases the ore zones show considerable modification by northeast faulting and, to a lesser extent, by northwest faulting. At intersections with faults they often enlarge in plan and section and form vertical chimneys or very rich horizontal concentrations of ore. It is safe to state that the major profits of the mines have been derived from such areas. Such ore bodies as the Granite pipe and 18-316 ore body of the Chief Consolidated mine, the Billings pipe of the Gemini mine, the California and Virginia pipes of the Centennial Eureka mine and the Mammoth pipe of the Mammoth mine have accounted for the bulk of the profits from these properties.

The persistence of the ore zones across faults and through different stratigraphic units is a very striking feature. Because of the distribution of the ore zones in the syncline and also because of the extensive faulting, ore is found through a range of 6,000 feet in a great number of formations from Cambrian to Mississippian in age (see Figure 6).

AGE		UNIT	THICKNESS	Approximate Gross PRODUCTION
Middle or Upper Eocene	Intrusive	Silver City Monzonite	Feet	(Dollars)
		Swansea Quartz Monzonite		12,000,000.
Middle Eocene	Extrusive	Laguna Latite Series		
		Packard Rhyolite Series		
8,155 Feet	Mississippian	Humbug	650	
		Deseret	875	46,500,000.
		Madison upper member	500	
		Madison lower member.	250	
	Miss-Dev.	Piñon Peak	160	43,000,000.
	Devonian	Victoria	350	
	Dev.-Sil.	Bluebell	500	110,000,000.
	Ordovician	Fish Haven	280	10,000,000.
		Opohonga	875	9,000,000.
	U. Cambrian	Ajax	640	60,500,000.
		Opex	500	7,500,000.
		Cole Canyon	600	7,000,000.
		Blue Bird	180	
	M. Cambrian	Herkimer	375	10,000,000.
		Dagmar	90	
		Teutonic	390	
	M-L. Cambrian	Ophir	440	84,500,000.
	L. Cambrian	Tintic	3,000	25,000,000.
TOTAL GROSS PRODUCTION~425,000,000.				

FIGURE 6. Distribution of the total production of the Main and East Tintic mining districts from various rock units.

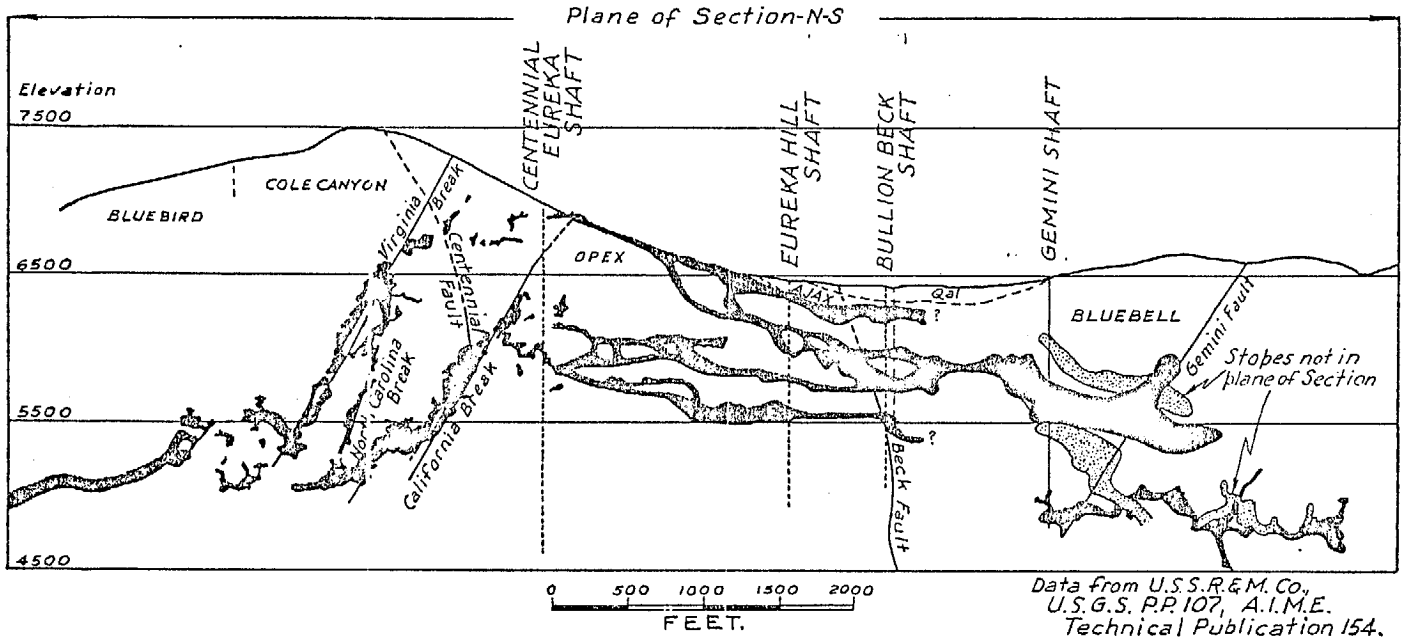
The ore zones are surprisingly continuous in their strike, persisting for distances of 8,000 to 9,500 feet. Only the Chief ore zone has been intensively mined below the water table, although recently this operation was discontinued. The failure to explore the Chief ore zone down dip and to follow the Gemini ore zone beneath the water table was entirely the result of adverse economic factors rather than exhaustion of ore. We now have reason to believe that the Gemini and Chief ore zones continue to the north, and we believe that the Godiva and Iron Blossom ore zones also continue in a northerly direction.

The habits of each ore zone differ and for this reason a brief description will be given of each.

Gemini Ore Zone: This ore zone (see longitudinal section, Figure 7) extends from the Grand Central mine to the Gemini mine, a total distance of 8,000 feet. Production is estimated to exceed $97,000,000, half of which has come from the Centennial Eureka mine. An examination of Plate 3 shows the pronounced zoning from copper to lead in following the ore from south to north.

At the south end of the zone the ore occurs chiefly in the Ajax formation and is localized by the intersection of favorable beds and northerly and notheasterly trending fissures. Near the Grand Central mine the ore zone is horizontal, but in the vicinity of the Centennial fault the principal ore bodies occur as steeply inclined chimneys. These chimneys account for the bulk of the production from the Centennial Eureka mine and are localized where the ore zone intersects a series of south dipping, east-striking crossbreaks. North from the Centennial Eureka mine and through the Eureka Hill mine, the ore zone is composed of a series of separate lenticular ore shoots lying along steep bedding planes in the Ajax formation. At the Beck fault, the ore zone forms another irregular vertical chimney of ore which passes from the Ajax formation south of the fault to the Bluebell formation north of the fault. The difference in lithology does not appear to affect the character of the ore in any respect. The Gemini mine is located on the most northerly part of the known limits of the ore zone and the ore shoots are similar to those in the Eureka Hill and Bullion Beck mines, being characterized by great irregularity and discontinuity. However, the ore zone itself is well-defined in these mines, is parallel to the bedding and plunges gently to the north. The last known ore in the Gemini mine is 2,400 feet lower in elevation than the outcrop of the ore zone a short distance south of the Eureka Hill shaft. The available information suggests that only economic factors (e. g. costs of mining below the water table) prevented the development of the ore farther to the north.

Except for a minor amount of leasing in the Bullion Beck mine, very little exploration or mining activity is being carried out along this ore zone (1957).



Data from U.S.S.R.&M. Co., U.S.G.S. P.P. 107, A.I.M.E. Technical Publication 154.

GENERALIZED SECTION OF THE GEMINI ORE ZONE

FIGURE 7

Chief Ore Zone: This ore zone (see longitudinal section, Plate 8) extends from the Mammoth mine to the Chief Consolidated mine, a total distance of 9,500 feet. Production is estimated to exceed $140,000,000 over half of which has come from the Chief Consolidated mine. It is interesting to note that at prices prevailing in 1957 this production would be valued at approximately $250,000,000. From south to north the ore shows a zoning of copper - gold - lead - silver, to lead - silver and finally to lead - silver - zinc.

The Chief ore zone begins at the impressive Mammoth ore pipe, a nearly vertical chimney 2,400 feet in vertical extent containing shoots of copper, gold, lead, and silver ores. Mining of this pipe was stopped at the water table, but it is reported that mineralization continues below this level. Unfortunately, the geology and ore controls of this great ore chimney have not been worked out in detail, but it is probable that the intersection of mineralized north-northeasterly - trending fissures and the eastward striking Sioux - Ajax fault zone is to a large extent responsible for the localization of this orebody and the associated brecciation.

From the area of the Mammoth pipe and the Mammoth fault, the ore zone plunges steeply northward along favorable beds to the Grand Central mine where the run flattens out and is localized in the steeply eastward dipping beds of the Bluebell formation. Proceedings north again along the zone, the ore shoots become increasingly complex through the Eagle and Bluebell mines and into the Chief Consolidated mine. The most striking feature of this part of the ore zone is the modification and enlargement of the ore in plan and section at its intersection with numerous cross-faults, especially those with a northeasterly trend. Within the boundary of the Chief Consolidated mine the ore zone continues persistently northward until it reaches the Beck fault where it expands and follows this fault to the northeast for 2,000 feet. Then it turns and again follows a northerly course. To date the zone has been followed about 600 feet north of the Beck fault where mining has been discontinued because of high pumping costs and the lack of development work.

In longitudinal section, the northern half of the Chief ore zone has an overall northward plunge of about 21°, roughly parallel to the plunge of the Tintic syncline. At the intersections with cross - faults (for example the 1050 fault, the Centennial fault, the Intermediate fault) steeply inclined ore chimneys are developed. The ore zone had been mined to the 2800 level at its most northerly extension and was partially developed on the 2900 level when operations were suspended in 1955 because of economic factors.

Within the Chief Consolidated mine there has been a pronounced decrease in silver and an increase in the zinc content of the ore in depth. Most of the ore above the water table is oxidized to some extent, and this may explain the high silver content in the upper part of the mine.

The last development work on its northerly extension indicates that the ore probably continues its downward plunge in the Bluebell formation.

The management of the Chief mine recently suspended all operations and at present there is very little mining activity on this ore zone.

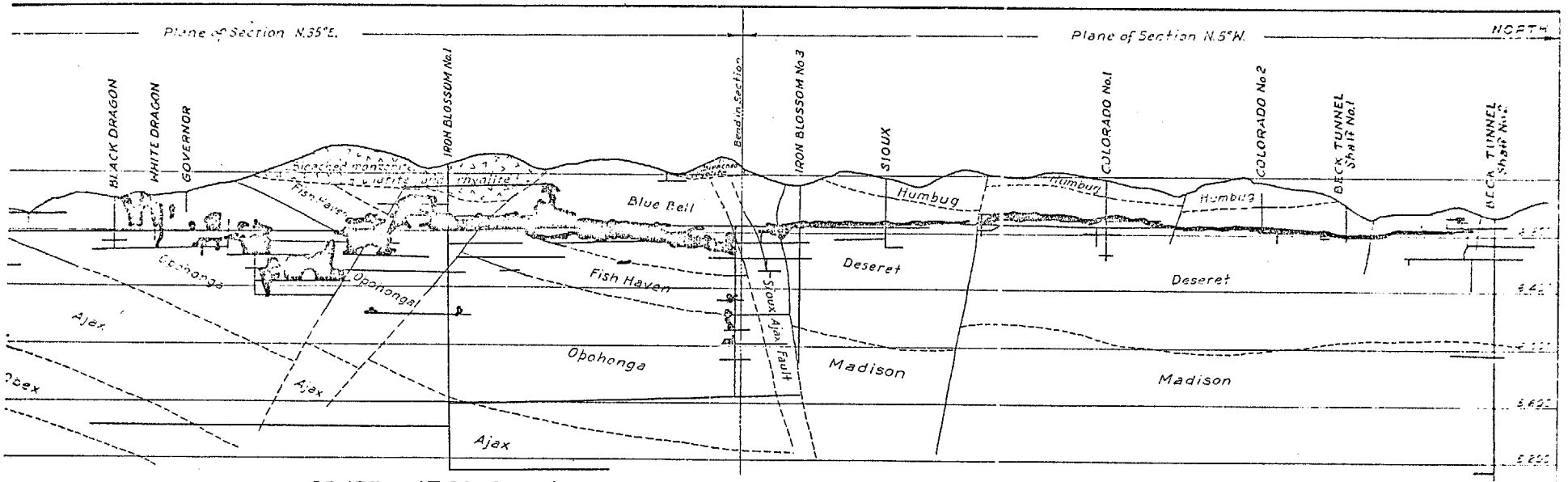
Godiva Ore Zone: This ore zone extends from the Sioux - Ajax fault to the Godiva mine, a total distance of slightly over 8,000 feet. Production figures are very scanty, but the value of ores produced is estimated to exceed $20,000,000.

This ore zone has its beginning in the extension of a well-defined system of northeasterly-trending mineralized fissures, described previously. From the Sioux - Ajax fault the ore zone extends almost due north, is generally horizontal and follows a coarse-grained limestone bed in the Deseret formation. The Deseret limestone along this ore zone is on the west limb of the Tintic syncline near the synclinal axis and dips between 30 and 60 degrees to the east. Unlike the Gemini and Chief ore zones, the Godiva ranges through only a small vertical interval, generally between 7,000 and 7,300 feet in elevation. Although the ore never crops out, it comes within 60 feet of surface in one place (low-grade jasperoid does crop out in the Little Spy and Humbug mines). North of the Godiva mine it plunges to the north, and Kildale (1936) reports that the ore becomes more siliceous and increases in zinc.

Little mining or exploration work is being done on any part of the Godiva ore zone; however, a small amount of leasing is going on in the Spy, Salvador and Mountain View mines.

Iron Blossom Ore Zone: This ore zone (see longitudinal section, Plate 6) extends from the Iron Blossom No. 3 mine to the Beck Tunnel No. 2 shaft, a total distance of approximately 5,200 feet; however, if the fissure vein system of the Iron Blossom No. 1, Governor, Martha Washington and Triumph are included, a total length of 15,000 feet is obtained (see Plate 3). Production is estimated to exceed $36,000,000. Because of the ease of mining and the high silver values, profits were unusually high; probably in the order of 33 percent of the gross.

This ore zone is similar to the Godiva, in that it is on the northern extension of a well-defined system of mineralized fissures. These fissures upon reaching the Sioux - Ajax fault die out and are aligned with north-trending replacement ore bodies. North of the Sioux-Ajax fault the ore zone can be traced for 5,200 feet and at its northern end turns northwesterly and joins the Godiva. The Iron Blossom ore in the Deseret formation is approximately along the axis of the Tintic syncline. The zone is unique in that it consists of a horizontal pipe of ore 5,000 feet in length with a width of 20 to 170 feet and a height of 20 to 60 feet. Near the Sioux - Ajax fault the controls for this zone appear to be the intersection of steep fissuring with a flat, coarse - grained limestone bed along the axis of the syncline. In the northern



GENERALIZED SECTION OF THE IRON BLOSSOM ORE ZONE

Looking Westerly

0 1000 2000 3000

FEET

PLATE 6

Modified from Mess[illegible]

Tintic Standard Mining Co.

part of the Beck Tunnel property the horizontal ore swings northwesterly out of the synclinal axis. The zone then joins the Godiva zone south of the May Day mine and individual ore shoots become more irregular and less continuous.

A moderate amount of leasing is being done (1957) in the Iron Blossom No. 1, Iron Blossom No. 3, and Colorado No. 1 mines. In the main, however, the work appears to be scavenging operations.

Mineralogical Characteristics of the Ores

The principal metals of the fissure ores are copper, silver and gold, with minor amounts of lead and zinc. Important primary minerals of the fissure ores are enargite, silver sulfides and galena. Minor amounts of sphalerite, chalcopyrite, arsenopyrite and tetrahedrite also are present. The gangue minerals most commonly are pyrite, quartz, calcite and barite.

The principal metals of the limestone replacement ores are silver and lead with lesser amounts of gold, copper and zinc. In some mines, such as the Centennial Eureka and the Mammoth, copper and gold account for the major part of the production. The more important primary minerals of the limestone replacement ores are galena, sphalerite, argentite, enargite and tetrahedrite.

The sulfide ore tends to be vuggy and crustiform while the oxide ore, from which the bulk of the production of the district has been obtained is crumbly, cellular and iron stained with an overall density lower than that of the host rock. The zone of oxidation is deep, ranging down to 2000 feet below the surface at the north end of the Main Tintic district. The larger ore bodies are seldom completely oxidized and some sulfides are often found high above the water table, especially where they have been protected from oxidation by fault gouge or shales. The more common oxidized ore minerals include malachite, azurite, chrysocolla, covellite, anglesite, cerussite, smithsonite, calamine, hydrozincite, cerargyrite, native silver and plumbojarosite as well as a host of rarer minerals. Noncommercial minerals associated with the oxidized ores include kaolin, alunite, gypsum, limonite and the manganese oxides.

This complexity of habitat of replacement ore bodies in carbonate units is typical of most of the districts.

Around the Leadville Lead Mine, located east and outside the main Leadville area, are three mines which exhibit characteristics similar to that shown previously. All three are in well-altered and recrystallized Leadville dolomite with excellent secondary features and show only limited mining activity with probably no exploration work of recent vintage having been conducted. At a scale of 1" = 100', this includes the Liddia Mine and the Continental Chief Mine in both plan and cross-section (Plate 10). These two are northwest and north of the Leadville Lead workings. South of Leadville Lead is the Hill Top Mine shown on Plate 11. Further south is the Peerless area of interest.

Production Data from the Four Major Districts

As noted in Cook's text in the previous section, individual ore bodies can be very profitable. Production data is difficult to assemble for the districts as to the tons of ore produced, but production and dollar value figures for the major metals have generally been reported and collected by government agencies. Using the figures available and some estimation of tonnage, the following tabulation is made for the Leadville, Gilman, Aspen, and Tintic districts.

Table One. Production-Value Data

1. Leadville District, 1859-1963 (Tweto, 1968). Estimated 4 million tons of ore produced.

Metal	Amount of Metal	$ Value	% of Value
Au	2,985,776 oz.	$ 66,942,109	13.2 %
Ag	240,055,514 oz.	196,259,750	38.6
Cu	53,109 tons	15,521,319	3.1
Pb	1,088,204 tons	110,542,249	21.8
Zn	785,380 tons	118,222,469	23.3
		$507,487,896	100.0 %

2. Gilman District, 1880-1972 (Lovering, et al, 1978). Estimated 7-1/2 million tons of zinc-lead ore, and 3-1/2 million tons of copper-silver ore produced.

Metal	Amount of Metal	$ Value	% of Value
Au	393,491 oz.	$ 11,379,892	3.5 %
Ag	66,070,544 oz.	50,457,484	15.3
Cu	104,801 tons	28,643,454	8.7
Pb	148,444 tons	28,517,001	8.7
Zn	857,862 tons	210,239,328	63.8
		$329,237,159	100.0 %

3. Aspen District, 1880-1952 (Bryant, 1972, and Henderson, 1926). Estimated 5 million tons of ore produced.

Metal	Amount of Metal (Bryant 1880-1952)	$ Value (Henderson 1880-1923)	% of Value
Au	neg.	neg.	neg.
Ag	103,110,000 oz.	$ 73,340,613	72.6 %
Cu	565 tons	197,443	0.2
Pb	294,000 tons	25,781,812	25.5
Zn	11,000 tons	1,659,909	1.7
		$100,979,777	100.0 %

4. Tintic District
   A) Lindgren (1919), production 1869-1916, with estimated 5 million tons of ore from Main Tintic district.

Metal	Amount of Metal	$ Value	% of Value
Au	1,532,926 oz.	$ 31,688,389	18.7 %
Ag	119,712,919 oz.	78,762,811	46.5
Cu	76,188 tons	25,063,297	14.8
Pb	353,485 tons	32,341,622	19.1
Zn	7,810 tons	1,470,129	0.9
		$169,326,248	100.0 %

   B) Cook (1957b) reported production 1880-1957 of approximately 12.1 million tons of ore from the Main Tintic district.

Metal	$ Value*	% of Value
Au	$ 50,400,000	16.0 %
Ag	137,025,000	43.5
Cu	31,500,000	10.0
Pb	89,775,000	28.5
Zn	6,300,000	2.0
	$315,000,000	100.0 %

*Cook gave total dollar figure and the percentage of value and I calculated the individual metal dollar value.

   C) Shepard (1968) (Amount of Metal) and Bush (1957) (Value and percent) reported about 3.8 million tons of ore produced from the East Tintic district (1916-1957).

Metal	Amount of Metal	$ Value	% of Value
Au	537,439 oz.	$ 32,770,000	29.0 %
Ag	62,808,012 oz.	46,330,000	41.0
Cu	13,827 tons	3,390,000	3.0
Pb	371,485 tons	30,510,000	27.0
Zn	14,220 tons	not valued	not valued
		$113,000,000	100.0 %

*Bush reported only the total dollar value and the percentage of value of Au, Ag, Cu, and Pb. I calculated the individual dollar value. If the value for zinc would have been included, then the percentage of value for the other metal would be lowered slightly.

Comments on Mapping, Sampling, Assaying, Interpretation, and Drilling

In mapping, the primary requirement in the carbonate terrain is identical to that of porphyry copper exploration -- the recognition of the changes from the normal. Thus, mapping in initial stages is only a matter of looking and observing at the degree of dolomitization and recrystallization. As the degree becomes apparent and thicker packets of sedimentary units become involved, and as fracture and fault control become evident, then mapping can proceed on a systematic basis to outline and delineate the patterns present. The several stages as categorized in Appendix A are subdivisions applicable, but it must be remembered that the alteration process is an ongoing event and gradational effects are the rule. Remember also that initial carbonate depositional characteristics have a profound effect in the initial reaction or changes, thus a medium crystalline, fossiliferous limestone will exhibit effects long before a fine-grained dolomite unit will indicate the amount of alteration activity which has taken place in the district. Separation of initial sedimentary packets is necessary (generally chemically distinct units, i.e., limestone, dolomite, shale, sandstone, etc., which in general have been initially separated out by the rock unit mappers of previous surveys) in order to determine the degree and extent of involvement.

Contacts between units are especially favorable for alteration effects and subsequently ore, whether this be a lower dolomite-upper limestone as at Aspen (both Mississippian), or shale beds, unconformities, or various igneous dikes and sills. Most districts exhibit a "most favorable bed," but note that all districts show a range of deposits throughout most of the stratigraphic section.

As at Magma and Christmas, Arizona, the basal portion of the Devonian limestone shows the most lateral extent of alteration-mineralization, but the bulk of the ore is within the Mississippian unit. At Leadville, Colorado, the uppermost unit of the Mississippian is the best host and contains the largest production tonnage, but excellent ore bodies extend to or are found in lower units.

Because of the apparent control often shown by the original carbonate unit and its reaction to the alteration-recrystallization-mineralizing fluids, it is important during sampling that the type of unit, the amount of alteration, nearby structures, and igneous masses, etc. should be noted.

In order to establish trends it is necessary to know the background or normal value of the rock chemistry. In the replacement limestone search it is critical to have sufficient samples within each stratigraphic unit or sub-unit so as to have confidence in the range of values found and their apparent favorable directional increase. Sample size should be sufficient to be representative of the area in question. As stratigraphic position is also critical, then density of sample number along strike and dip of an individual entity packet (which may range from several feet to perhaps a hundred feet) or the thickness of recognized alteration sub-unit can be at a wider spacing than sampling up and down the stratigraphic section where individual entity packets vary rapidly and usually along very sharp boundaries. Concentration of sampling along the most favorable bed(s) and along structures will soon evolve as experience is gained in correlating visual alteration changes with probable chemical content.

Changes in the pattern of metal content point to areas of increased interest. With individual replacement beds being the host for mineralization it is necessary to pay attention to the various sub-units within the area to gain the important clues leading to a mineral body. Thus grid sampling is of less importance than several lines up and down section to establish the visual-chemical parameter variations.

Each district undoubtedly has its favorable suite of elements and, as the overall change in a number of elements and their pattern is the initial step in locating a favorable district, it is suggested that the 31 element emission-spec be used as the first pass. This ES gives iron, calcium, magnesium, silver, barium, manganese, molybdenum, copper, lead, zinc, arsenic, antimony, and 19 others at a cost of about $12.00 per sample (plus preparation) versus nearly 2-1/2 times that for the individual geochem analyses of the element listed. Skyline Labs with their 6-step incremental value reporting has the most usable format of reporting as well as precision nearly equal and consistent to that of AA or conventional geochem analysis.

As noted in the Tables reported in Appendix A, a wide range of values is noted within the specific group separations. The range points up the fact that sufficient sample values must be accumulated for evaluation purpose, and, further, that any one element variation is probably not as indicative as a suite of sample element values.

At the present state-of-the-art, specific knowledge as to the nearness of ore from a specific sample has not been pinpointed, but certainly it appears that identification of most favorable target areas within the sampled area can be suggested (see the Black Cloud report on underground sample results for insight into the problem). The detailed work being done this summer in the Leadville District should add new information on the problem.

Some mineral zoning appears in the districts. In most districts which contain manganese, it tends to be widespread but increases in the outer silver-manganese zone. Copper, barite, gold, and possibly moly, tend to increase in the quartzitic units and in the fissure veins cutting the sedimentary units. These mineral elements may also reflect the center portion of the mineralized system. Antimony and arsenic are very common, being tied up in the original base metal and silver-bearing sulfosalts. Silver occurs throughout the system but tends to be rich in the lead portions. The monitoring of calcium, magnesium, and iron, along with manganese and silver, are clues to the alteration and mineralization effects, which have taken place, long before the obvious visual characteristics are developed.

In districts where structural and cover conditions obscure the total relationship (and this is where the remaining blind ore bodies and subdistricts and, hopefully, a whole brand new district will be found) the integration of a multitude of facets and facts on scraps of data points is ever important.

As noted in Cook's (1957b) Tintic paper, the Godiva Ore Zone (reproduced on page 8 of this report) was slightly over 8,000 feet long and produced some $20 million and never outcropped. It did come within 60 feet of the surface and other workings got close to it and encountered its low-grade jasperoid

shell prior to its actual interception by another group. Knowledge of the habitat of the Tintic ore bodies coupled with analytical data from the jasperoid shell might have prompted discovery of this channel earlier in the history of the camp.

The very erratic and discontinuous outlines of the ore bodies, as shown on the four district maps of this report, makes for difficult drilling evaluation. Any trends, especially mineralized structural trends, should be closely outlined. As noted in all districts, ore runs and chimneys may not be manifested by a large fault obvious to all concerned, yet the dominant fracture pattern appears to guide the general trend of ore runs within the district. The large manto ore runs at Tintic trend subparallel to the strike of the formations, whereas at Gilman they trend with the dip of the formation. In both cases, strong shearing and fissures are found in the lower competent rock units subparallel to the overlying ore runs.

How then does one go about it within an area which is obviously a packet of well-altered, recrystallized, and geochemical anomalous units and fissures? The experience at Leadville Lead and at Santa Eulalia, Mexico, may indeed be the best approach. Both groups follow fractures as they are aware that most ore concentrations are along side one of these fractures and its intersection with favorable replacement units. At Leadville Lead, it was apparent that they spent some time on the visual fractures that came in on a cross-trend to the main direction of ore run. At Santa Eulalia, after finding a fracture which may or may not contain visible mineralization and knowing where they are in relation to their "most favorable" sequence, they step out only a short distance (generally less than ten feet) away from the fissure and fan a series of holes parallel to the fissure trend and into the elevation of their favorable replacement horizon. Since several horizons are favorable, they drill into the closest zone in relation to the drill station. Of course if mineral is noted in the fissure they also drill horizontal holes, also in the plane of the fissure, in hopes of hitting one of the large productive chimneys which intraconnect the different horizons of ore runs.

Surface drilling would be similar by drilling for an intercept where a fissure and the replacement horizon are in proximity. The testing of multiple favorable horizon adjacent to or near a fissure would also best be accomplished by a hole parallel to the plane of the fissure. They have found that this gives them the best control on where they are at within the sequence at all times and, of course, tests for small isolated bodies which are often found throughout the section. In moderately deep drilling, an angle hole may, by numerous causes, not intercept the favorable horizon in proximity to a projected fissure-horizon intercept, and would not test other zones along the fissure.

Multiple fracture intersections are very productive in most districts, but all multiple intercepts do not necessarily cause an additional ore run along the cross-trend nor does it necessarily cause an increase in ore values. However, the probably increased structural breakage in the vicinity of premineral intersections will enhance the ore potential. Thus, drilling a series of holes in the vicinity of intersections would be prime target areas, especially if the intersection is premineral in age.

In reviewing the cross-sections of the Tintic District, it is well shown that if possible the drill hole should be continued even after finding a mineral horizon because of stacked lenses, etc. Likewise, a "barren" hole near to a mineralized hole should be carefully checked in order to establish nearness criteria on internal blocks and embayments.

Understanding the master direction of ore trend is desirable early in the program as it is an evident control on the width of the ore run. Note that along the edges of most runs, a number of tongues of ore go out irregularly into the wall. These are often controlled by small visible fractures and faults which persist outward but do not continue to carry ore. Leadville Lead spends some time drifting on these visible fractures hoping to find more ore, but in general this fails because it is too far from the master fracture or trend (which may show up only as the dominant overall trend to the mined ore). However, careful mapping may reveal a strike slip fault of small magnitude as being the prime directional control.

Visual and chemical parameters

It has long been indicated that wall-rock changes have occurred around the replacement deposits in carbonate host rocks of the western states. That the bulk of the Colorado deposits and districts are in dolomitic units was also established. Part of the past, and still continuing, problem is the separation of wide-spaced basin dolomitization versus that dolomitization imprint imposed as a result of mineral fluids which led to the development of ore bodies and district mineralization.

Perhaps the best of the recent publications on dolomitization related to ore is in the Lovering-Tweto-Lovering USGS Prof. Paper 1017 concerning the work and observations in the Gilman, Colorado district. They clearly say that they cannot differentiate the two types, but I believe that their own observations coupled with the chemical data and visual characteristics establish patterns which indicate the existence of mineral districts and their contained mineral deposits. Additional research is necessary before pinpointing ore bodies, but certainly their existence can be strongly indicated.

The basic premise that replacement deposits are formed by the removal of some constituents and the addition of others, with attendant visual and chemical changes, provides the handle to open the door.

Table Two summarizes the visual and chemical changes which are noted from a traverse outside the district to inside the district to near ore and in ore.

The field test using 10% hydrochloric acid to differentiate limestones from dolomite works quite well, but it has been found that in some cases of hydrothermal dolomitized units, which have undergone other changes and end up with a very low magnesium content, will not fizz with acid. As an alternative, a solution similar to that used by petrologists for staining carbonate sections has been found to be useful in separating calcium-bearing units from calcium-magnesium (dolomite) units. The reagent-solution (0.2 grams of Alizarine Red-S in 100 cc. of 1.5% HCl solution) will immediately stain the calcium carbonate a bright purplish-red while not affecting dolomite. (Note: If the dolomite is crushed or the solution is allowed to stand on the rock surface for a considerable length of time, then a deeper purple coloration

Table Two -- Tabulation of Trend Values in Leadville and Related Carbonate Formations in Central Colorado

→ → Increasing → Trend → Values

Outside District

→ → → → →

Limestone (see Note 1): variable bedding; variable grain size; variable coloration.

Dolomite (see Note 2): variable bedding; variable grain size, but generally microcrystalline; variable but tends to be a dark grey coloration.

Vugs: rare, except as a result of tectonic process.

Megacrysts: none, other than original detrital material.

Common descriptive names: microcrystalline, lithographic, nondescript, block chocolate conchoidal.

Thickness of original units are variable with mixed initial lithology.

Inside District

→ → → → →

Marble or dolomitic limestone: less distinct bedding; fine to medium, 2-5 mm, crystallinity; white to light grey coloration; marble generally coarse grained.

Dolomite: less distinct bedding; 2-5 mm mosaic crystallinity; mouse grey coloration.

Vugs of miarobitic openings along crystal boundaries and along irregular fractures, with minor filling by secondary calcite, dolomite, or quartz crystals.

Megacrysts of variable calcite or dolomite crystals as isolated individual crystals, to small splotches, and irregular alignment; fine, delicate isolated quartz crystals along fractures.

Common descriptive names: saccharoidal, pin-points of light, weak replacement texture, crinkly, irregular.

Most susceptable units recrystallized with increased thickness of uniform "look-alike" units.

Near Ore Zone

→ → → → →

Marble, or dolomite, or "quartzite": massive appearing; generally 2-3 mm of uniform crystallinity but may be quite coarse (especially marble); color is white to light to medium mouse grey to dusky grey, may have reddish tint especially as silica content increases; siliceous and gritty when replaced by silica to form chert masses and pseudo-quartzite.

Dolomite: massive appearing; generally 2-3 mm uniform crystallinity; mouse to dusky grey, some dark grey, may have reddish tint; siliceous and gritty when replaced by silica to form pseudo-quartzites and "crystalline" chert.

Vugs are partially to completely filled with secondary white calcite or dolomite crystals and having halo of secondary material; lines of secondary crystal development often connect vug alignment.

Megacrysts of complete overgrowths by calcite and dolomite in crystal vugs and as lines, bands, and veins of interlocked crystals, and in pods, masses, knots; quartz crystals in secondary vugs and along fracture openings; scattered grit of silica-quartz coalescing to complete conversion to a pseudo-quartzite; replacement of original microcrystalline chert into a crackle-mosaic "shattered" silica-chert-sandstone-quartzite.

Common descriptive names: recrystallized texture, marble, pearly, birdseye, rod, and zebra textures, sanding and sand runs.

Entire column of favorable packet of units is altered and recrystalllized to uniform textures with loss of individual bedding plane continuations.

Ore Zone

→

Replaced by base metal sulfides and iron-manganese with variable precious metal content; with and without chert as jasperoid material in interior or as outer shell. Oxidation products formed which may be mobilized and removed from outcrop except in siliceous or jasperoid material.

As above.

Vugs often remain within the ore as partial or filled vugs with secondary halo material surrounding vug. Identical to those found near ore.

Megacrysts often as near ore, as interstitial to base metal sulfides similar to those found near ore.

Common descriptive names: zebra ore, coon-rings, banded, massive.

Structural and stratigraphic control on partial to complete replacement as above.

Emission-Spec. Values	Outside District	Inside District	Near Ore Zone: Dolomite	Near Ore Zone: Mineral Jasperoid	Ore Zone
Iron, %	less 1%	less 5%	less 5%	10-15%	10-20%
Calcium, % (in Lms) (see Note 3)	greater 20%	15%	15-20%	less 5%	less 5%
Calcium, % (in Dolomite) (see Note 3)	5-10%	15-20%	10-15%	less 5%	less 5%
Magnesium, % (in Lms) (see Note 3)	less 5%	greater 5%	greater 5%	less 1%	less 1%
Magnesium, % (in Dolomite) (see Note 3)	less 5%	10-15%	10-15%	less 1%	less 1%
Silver, ppm	less 1 ppm	1-2 ppm	greater 5 ppm	greater 50 ppm	greater 50 ppm
Arsenic, ppm (see Note 4)	less 500 ppm	less 500 ppm	less 500 ppm	1000 ppm	greater 500 ppm
Barium, ppm	less 10 ppm	less 20 ppm	10-20 ppm (see Note 5)	greater 500 ppm	10-20 ppm (see Note 5)
Copper, ppm (see Note 6)	less 5 ppm	5-10 ppm	5-plus 10	greater 100 ppm	greater 1000 ppm
Manganese, ppm	200 ppm	500-1000 ppm	greater 1000 ppm	greater 1000 ppm	greater 5000 ppm
Molybdenum, ppm	less 3 ppm	2-3 ppm	2-5 ppm (see Note 5)	greater 10 ppm	greater 10 ppm
Lead, ppm (see Note 6)	less 50 ppm	50-100 ppm	100-plus 1000 ppm	greater 1000 ppm	greater 1000 ppm
Antimony, ppm (see Note 4)	less 100 ppm	less 100 ppm	less 100 ppm	greater 100 ppm	less 100 ppm
Zinc, ppm (see Note 6)	less 200 ppm	200-300 ppm	200-500 ppm	greater 1000 ppm	greater 1000 ppm

Note 1. Original limestone carbonates may stay in the calcium carbonate mode and transform into marble with the attendant features of metacryst development also staying in the calcium carbonate mode or, with magnesium addition, will follow the calcium-magnesium carbonate path. If it stays in the calcium carbonate mode, then in general the zones of alteration-recrystallization intensities are measureable in tens of feet instead of hundreds of feet as in the calcium-magnesium carbonate zones and the geochemical intensity values are generally lower and stay closer to the ore zone.

Note 2. Original dolomites show less effect of alteration-recrystallization effects from magnesium additions in relation to altered-recrystallized limestone until both trend line paths reach the point of the original dolomites being out of equilibrium with the advancing solutions and then both carbonates advance along similar alteration-recrystallization paths to full conversion and addition.

Note 3. Calcium to magnesium ratios generally reflect the effect of alteration-recrystallization more graphically by the change from 4 to 1, 2 to 1, 1 to 1, calcium % to magnesium %, as one traverses from outside the district to inside and to near ore zones.

Note 4. Arsenic and antimony values are generally low, but where found reflect the complex Cu-Pb-Zn sulfosalts with attendant silver values.

Note 5. Barium and molybdenum values of greater than plus 500 and plus 5 ppm, respectively, generally suggest ore egress channelways, main solution pathways, and centers of mineralization.

Note 6. Copper, lead, and zinc are very mobile in the oxidized zone and show very erratic values, but tend to remain in entrapped silica and in mineralized jasperoids, and in the wall rock around sulfide bodies below oxidation effects.

will slowly develop.) When the reagent-solution is dispensed from a squeeze bottle it is an easy method for determining the extent and configuration of mixed calcite-dolomite veining and vug filling sequences. As with acid, the rapidity of staining effect denotes increased amounts of calcium carbonate. Dolomite will normally not react if the solution is placed on the surface and the excess shaken off or allowed to spread out.

Your handy petrographic lab or chemical supply house can supply the Alizarine Red-S reagent, while the local assay office will be glad to prepare the solution. The storage bottle should be kept covered and cool for best stability, although Western Petrographics has had no problem with lab shelf stability of the prepared reagent-solution. (Note: The petrographic solution is much more dilute than the field rock staining solution and must be made up separately.)

Visual Changes. Primary limestone and dolomite are found in a variety of colors and textures and this variability is in itself significant. As dolomitization or alteration takes place it selectively changes the most susceptible units first into a relatively fine-grained interlocking mosaic of dolomite of a soft medium-grey coloration. If this dolomitization is the result of widespread regional or basinal derived source, many hundreds of feet of section may be changed to varieties of dolomite textures, but will retain a variation in size and colors along with bedding plane separations, shale interbeds, fossil identification, etc., and in general show a variability.

As hydrothermal mineral fluids are superimposed on this, or indeed is a continuum of the process, then the textures become more uniform as well as a more uniform mouse-grey coloration with variable abundance of dolomite facets that reflect the light into a myriad of pinpoints. Also accompanying this dolomitization or recrystallization is a reduction in volume which appears first as a scattering of miarolitic-type cavities. With increased intensity of alteration, and a probable increase in magnesium content which releases the calcium radical, small cracks and seams of white calcite/dolomite will be scattered throughout the units, often connecting the open cavities which now may contain an infilling of white calcite/dolomite. By visual identification the fossil content is rapidly dropping and former bedding planes are not nearly as noticeable. (Thus, the noting that in mineral districts the stratigraphers tend to start lumping units into broader subdivisions whereas outside the districts they have a field day in numbering numerous beds and units.) At this stage, the abundant variability of color and texture has given way to a more uniform color and texture (soft mouse-grey to grey-black).

Increased recrystallization, alteration, and addition bring about a pervasive appearance to the unit and in isolated outcrop the assignment of the outcrop as to its relative position within the unit becomes less sure. The cavities often increase in size and become lined and filled with secondary dolomite crystals, while secondary dolomite crystals form layers, streaks, veins, and discontinuous masses and nodules. Quartz crystals may line portions of the cavities, form within the rock mass, and ultimately form jasperoid types.

The coloration may become a dusky grey with the increase in manganese content and ultimately manganiferous dolomite is identifiable which grades into manganese replacements. Other visible minerals such as iron as pyrite and amorphous masses, barite, and base metals become noticeable.

As with any alteration effects, the increased pervasiveness of the recrystallization cutting across all previous rock types such as primary limstones and dolomites, and shaly sediments; the involvement of thicker packets of units; the increased chemical content whether it be addition or remobilization of the original rock unit calcium and magnesium into increased visual calcite crystallization and discrete dolomite crystals, seams, and nodules, or the increase in metallic mineral trace and visual content -- all indicate that hydrothermal fluids capable of replacing carbonate host with metallic mineralization has taken place within the system or area affected.

In central Colorado, the recrystallization effects have been termed "pearly," "birdseye," and "zebra" textures based on their characteristic and these indeed indicate the strength and involvement of a changing chemical system. The interpretation of these in relation to ore is based not on their characteristics as an entity, but the total involvement of these characteristics and the rock column in which they are distributed. Thus, a good zebra texture found adjacent to a fault zone cutting only weak and poorly recrystallized limestone-dolomite would not be as indicative to the nearness of ore (or a district) as would be that same feature found within an ever increasing thickness packet of well and pervasively recrystallized units. However, the zebra-textured fault zone may point to an area of increased interest not observable from the present position either because of cover conditions or position within the stratigraphic sequence. Anomalous values of silver, barium, manganese, moly, etc. would indicate a feeder zone and further checking laterally and stratigraphically at the junction with the feeder system and the most favorable replacement unit would be in order.

Chemical Changes. The visual changes are accompanied by chemical changes and those associated with the ore deposits are most indicative. One element by itself is not as interpretive as a suite of elements. With the previous encouragement of the use of Skyline Labs, and the emission-spectrographic analysis, it was suggestive that iron, calcium, magnesium, silver, arsenic, barium, manganese, molybdenum, antimony, along with copper, lead, and zinc, are the most useful. Although sometimes reported in anomalous amounts are the elements cadmium, cobalt, chromium, nickel, titanium, vanadium, and zirconium (with an occasional other element), it was not found that these elements could be interpreted with assurance, but probably would be of interest in some cases. Silica and gold are not reported by E-S but undoubtedly would be useful.

A recap of the first group of elements has been compiled in Appendix A where the sample has been categorized into the various groups: 1) Leadville limestone, 2) Leadville dolomite with weak recrystallized texture and only minor secondary features, 3) Leadville dolomite with pervasive recrystallization and abundant secondary features but low visible iron-manganese, 4) Leadville dolomite with pervasive recrystallization and replaced in bulk by iron and manganese, various sulfides, and various silica-jasper types, 5) Karst and cave-fill types ranging from normal weathering, to cold-water solution, to hydrothermal cave-fill, and mineralized karst replacement, 6) Ore, and 7) thru 11), the various rock-type units ranging from Precambrian to Tertiary porphyries which contain replacement ore bodies or are in close proximity to host-unit distribution.

The full E-S results of the samples are appended to the original reports on the sample site and can be consulted in those reports.

It should be noted that some samples probably are anomalous in the category in which they were originally placed and these should be further reviewed. However, the Appendix will indicate the relative change in the rock unit as alteration (recrystallization) and mineralization increase.

In general, the Leadville limestone has high calcium values and generally lacks any metal values (additional comments will be made later about ore districts such as Aspen, Colorado which are partially in a limestone host). The Leadville dolomite attains a magnesium content with a ratio of around 2 calcium/1 magnesium and low and variable silver, barium, manganese, molybdenum, lead, and zinc values. Increased pervasive replacement texture brings in additional silver, manganese, with variable lead-zinc, but may also accompany a de-dolomitization, i.e., loss of magnesium, in the unit.

The iron-manganese jasperoids show a jump in silver, barium, and manganese as well as retaining the values of copper, lead, and zinc. The multiplicity and variability of the elements reflect the mineralized versus barren jasperoids. The karst material shows increased values toward ore types and in addition to high silver, barium, copper, manganese, moly, lead, and zinc, often have anomalous arsenic and antimony.

Mineral zoning of the system undoubtedly influences the trace element distribution. Barium and moly appear to favor mineral channel zones and centers of mineralization. High silver, arsenic, and antimony, with or without copper, suggest the silver-copper sulfosalt zone which in general is interior but may be exterior to the overall zone. Manganese and silver tend to increase on the outer zone. Copper, lead, and zinc are very mobile in the oxidized zone (unless retained by silica-jasperoids), but in general in mined districts show a central or deeper copper zone followed outward and upward by zinc then lead, followed by manganese. As noted, precious metal values, principally silver, will occur throughout.

Cook (1957b) has described the Tintic district metal and mineral zoning and the general arrangements follow my own and others' observations. His text is reproduced below.

D. R. Cook, 1957b, p. 71-72

Metal and Mineral Zoning

A broad zonal arrangement of metals is suggested in the Main Tintic district with dominantly copper-gold giving way northward to silver-lead ores and finally to lead-zinc ores. The exact interpretation of this zoning is made difficult by the differences in mineralogy between fissure ore and bedding ore, and by the differences in mineralogy between ores of the vertical chimneys and the horizontal shoots in the same locality.

The following facts seem to be well established:

1. Copper - barite - gold is a characteristic assemblage of the fissure vein type of mineralization even where bedding replacement ores are in juxtaposition.

2. Lead - silver - zinc is a characteristic assemblage of the bedding replacement ores. Zinc increases in both the Chief and Godiva ore zones where they plunge steeply north at their northerly extensions.
3. The chimneys or pipes associated with the ore zones are higher in lead, zinc and silver than the average ore from the zone and contain considerably more gold and copper. In many of the chimneys, however, gold - copper and lead - silver ore shoots have been found side by side, and in the Mammoth pipe rich copper ore bodies were found to overlie those rich in lead and silver.
4. An examination of Plate 3 shows a definite increase in copper at the south end of both the Gemini and Chief ore zones. However, this apparent horizontal zoning might be due to the chimneys at the southern end of these zones.

The values in other rock types need to be examined for any suggestive trend. Other replaceable limestone-dolomite units react similarly to the Leadville sequence in recrystallization, visual, and chemical additions and changes.

It should be noted that a primary dolomite unit (such as the Dyer) will not show the same early dolomitization effects as that acting on a limestone unit until the secondary superimposed phase of crystal growth and mineral addition is reached.

At Aspen, it was noted that in the Leadville limestone surrounding ore bodies, the limestone reacted using a calcium carbonate system instead of a magnesium carbonate system. That is, crystal growth, vug filling, and veining formation showed forms of calcite instead of dolomite. In general, the alteration front was measurable in tens of feet rather than hundreds of feet. Metal distribution was similar in both systems, but somewhat reduced in the limestone front.

The Barringer Research MRFAPE system (Multi-element Radio Frequency Argon Plasma Emission) was also used on some of the samples with a variety of E-S samples cross-checked. In addition to most of the wanted elements reported by E-S, the MRFAPE also reported silica, alumina, and K_2O, along with a few others. It was originally thought that the more precise value reporting level would be beneficial; however, for reconnaissance and comparative values this is probably not a valid consideration.

The full range of values is reported in the previous individual reports and is recapped in the Appendix A attached. The MRFAPE values are similar to those reported by E-S.

In sampling it was noted that in general the three directions around a sub-cylindrical mineral mass will show the same intensity of trace metal addition, but at various distances from the mineral mass. The farthest expression of the mass is found along the extension of the long axis in the same bedding units; the next intermediate expression is at right angles to the long axis,

i.e., parallel to the cross-sectional area, and in the same bedding units; while the closest reflection of anomalous values is found in other beds perpendicular to the long axis and the right angled cross-section axis, i.e., stratigraphically above and below the bedding units which host the subcylinder.

Areas Investigated During the Limestone Search Program

A number of areas in Arizona and Colorado were investigated where the various favorable sedimentary units were present. The visual and chemical criteria were built up during the investigation and reported in individual area memos. Appendix B is a listing of these reports and should be consulted for the full analytical and compiled data results.

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Atts.

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Appendix A. Compilation of Selected Elements of Emission-Spec Values from Colorado limestone replacement search

To clarify the visual and chemical parameters found to be useful in the various units encountered in the Limestone Replacement Search, the following compilation is presented. Full 31 element ES results are found in the original reports on the individual study areas listed in Appendix B. The study indicated that iron, calcium, magnesium, silver, arsenic, barium, copper, manganese, molybdenum, lead, antimony, and zinc were the most useful in delineating patterns and trends.

Table One. Leadville limestone description: generally original depositional features with rare secondary features such as silica, calcite, vugs, or iron oxides-jasper development.

Table One A. Emission-Spec Values of Leadville Limestone. Note lack of metal values and high calcium values.

Table Two. Leadville dolomite: exhibiting recrystallized replacement textures in various degrees, but with only minor secondary features (such as zebra and birdseye development, secondary dolomite, and quartz crystal growth) and weak iron and manganese additions.

Table Two A. Emission-Spec Values of Leadville dolomite with only minor secondary features. Note abnormal magnesium versus calcium values, variable but often abnormal silver, barium, manganese, molybdenum, lead, and zinc values. Note also that limestone samples generally show lower values even though they have some otherwise favorable secondary characteristics.

Table Three. Leadville dolomite: pervasive recrystallized replacement texture with abundant secondary features such as zebra and birdseye development, secondary dolomite crystals replacing zebra stripes, knots, and filling vugs, also quartz crystal growths which are often iron stained, vug development, sanding development, silica development, and brecciation, with variable, but generally low to non-observable, iron-manganese addition and replacement.

Table Three A. Emission-Spec Values of Leadville dolomite with pervasive replacement texture and abundant secondary features. Note the often dedolomitization values in magnesium as well as the increase in magnesium values versus calcium. Also the silver and especially manganese increase with variable lead-zinc.

Table Four. Leadville dolomite: originally pervasive recrystallized replacement type replaced to a high degree by iron-manganese, various sulfides, and various silica-jasper types; now totally oxidized and forming various iron-manganese pseudomorphs.

Table Four A. Emission-Spec Values of iron-manganese oxide jasperoids. Note the general jump in silver values as well as barium plus the increased manganese and retention of copper, lead, and zinc values. The multiplicity of elements and variability reflect the mineralized versus barren jasperoids.

Table Five. Karst and cave-fill type material ranging from normal weathering (terra rosa), to cold water solution, to hydrothermal cave-fill and mineralized karst replacement.

Table Five A. Emission-Spec Values of Karst and Cave-fill Material. Note blah values in terra rosa and cold water (drip-stone) deposits versus the very high silver, arsenic, barium, copper, manganese, moly, lead, antimony, and zinc values which reflect the original mineral species found in the mineralized (non oxidized) karst and cave-fill material.

Table Six. Sulfide ore values from Manitou Dolomite and Leadville Dolomite, Black Cloud Unit, Leadville, Colorado.

Table Six A. Emission-Spec Values of Sulfide Ore. Note increase in all values other than calcium and magnesium. Arsenic and antimony also low in Black Cloud samples.

Table Seven. Cambrian Sawatch Quartzite descriptions.

Table Seven A. Emission-Spec Values in Sawatch Quartzite. Any increase in values should be carefully evaluated in terms of the total system as trends to solution and metal transport.

Table Eight. Ordovician Manitou Dolomite descriptions.

Table Eight A. Emission-Spec Values of Manitou Dolomite samples from sulfide zone of Black Cloud Unit. The Manitou is also a favorable host unit and reacts similar to the Leadville Dolomite, but in general has more subtle features.

Table Nine. Devonian Dyer Dolomite descriptions.

Table Nine A. Emission-Spec Values of Dyer Dolomite samples. The Dyer is also a favorable host unit and reacts similar to the Leadville dolomite. Textured and chemical parameters of interest are equal to those of the Leadville; i.e., increased magnesium values, silver, manganese, moly, lead, and zinc are favorable characteristics as well as the visual zebra, dolomite crystals, quartz crystals, vugs, sanding, etc.

Table Ten. Pennsylvanian Belden Shale description. Generally, the Belden is dirty black, shiny, thin-bedded, platy shale, but when in areas of hydrothermal-mineralization activity the shale often becomes dirty brown-black, manganese-soot appearance, with gypsum flakes and white efflorescent material along partings and disentegration mud debris, and with variable yellow iron oxides as films, small knots and nodules, and often fine pyrite in cross-cutting seams.

Table Ten A. Emission-Spec Values of Belden Shale. The Belden is often the capping shale to the ore zones and hence any hint of leaking up into and through the shale should be carefully evaluated in overall context. Erratic values of boron, chromium, strontium, vanadium, and possibly zirconium may reflect original basin depositional values.

Table Eleven. Tertiary Porphyry, generally the Pando or Gilman sill type. In areas of mineralization the porphyry generally exhibits increased fracturing, alteration features, and increased iron and manganese limonites.

Table Eleven A. Emission-Spec Values of porphyry units. Titanium is undoubtedly part of the rock-forming elements, but increases in barium, manganese, and moly should be treated as possible leakage features and evaluated in total context.

Table Twelve. Other rock unit descriptions: includes Precambrian granite, Cambrian Peerless Shale, Devonian Parting Quartzite, Pennsylvanian-Permian Maroon formation, and recent smelter slag.

Table Twelve A. Emission-Spec Values of various units and material. These units and values should be evaluated as passage and leakage trends in relatively unreactive units.

Abbreviations of the sampled areas are listed below:

ASP - Aspen
BC - Black Cloud (Underground)
C - Cooper Mountain
CL - Carbonate Hill
DC - Deep Creek
FM - Four Mile
G - Gilman
GC - Glenwood Canyon
GOC - Gold Cup
L - Black Cloud Mine Area
LL - Leadville Lead
M - Missouri Hill
OCC - Opposite Cattle Creek
OI - Ouray-Ironton
PM - Pennsylvania-Mosquito Creek
SMS - South Mount Sopris
TC - Trout Creek
WP - Weston Pass

All samples were run by Skyline Lab, Denver using ES method, except for the following which were run by Barringer Research, Denver-Toronto, using MRFAPE: Series ASP-1 thru -6; FM-20 thru -25; GOC-1 thru -12; and OI-1.

Appendix B. List of Completed Reports on the Limestone Replacement Search Program with Analytical Data

GENERAL

1. Replacement Limestone Assays -- Queen Creek Area, Magma Copper Co., Arizona. July 10, 1978.
2. Limestone Replacement Search -- Compilation of Emission-Spec. Values. Sept. 20, 1978.
3. Limestone Replacement Search -- Hand Specimen Collection Notes. Sept. 21, 1978.
4. Glenwood Springs Progress Report, by F. Gomez. Sept. 26, 1978.
5. Limestone Replacement Search -- Comparison of Values from Pulps submitted to Skyline Labs and Barringer Labs, Colorado. Dec. 14, 1978.

LIMESTONE REPLACEMENT SEARCH (SERIES), COLORADO

1. Weston Pass Area (WP-series). Aug. 7, 1978.
2. Gilman Area (G-series). Aug. 7, 1978.
3. Missouri Hill (M-) and Cooper Mtn. (C-series) Areas. Aug. 8, 1978.
4. Carbonate Hill Area (CL-series). Aug. 9, 1978.
5. Black Cloud Ore -- #6 Ore Body. Aug. 11, 1978.
6. Opposite Cattle Creek Area (OCC-series). Aug. 15, 1978.
7. South Mount Sopris Area (SMS-series). Aug. 15, 1978.
8. Glenwood Canyon Area (GC-series). Aug. 16, 1978.
9. Deep Creek Area (DC-series). Aug. 16, 1978.
10. Trout Creek Area (TC-series). Sept. 22, 1978.
11. Fourmile Area (FM-series). Sept. 25, 1978.
12. Pennsylvania-Mosquito Creek Area (PM-series). Sept. 26, 1978.
13. Black Cloud Mine Area (L-series). Sept. 26, 1978.
14. Leadville Lead Area (LL-series). Sept. 27, 1978.
15. Ouray-Ironton Area (OI-series). Dec. 14, 1978.
16. Aspen Area (ASP-series). Dec. 18, 1978.
17. Gold Cup Area (GOC-series). Dec. 19, 1978.
18. Addendum -- Fourmile Area (FM-series). Dec. 20, 1978.
19. Possible Ore Trend Values, Black Cloud Unit (BC-series). March 5, 1979.

Table One - Leadville limestone descriptions.

DC-4 Fine vugs with brecciation.

TC-1 Conchoidal fracturing, trace calcite, FeOx.
TC-2 Silica bands and chert, trace zebra texture.
TC-3 Conchoidal fracturing, weak silica and yellow-orange jasper.

ASP-5 Slight recrystallization, minor yellow FeOx on fractures.

Table One A - ES Values of Leadville Limestone

Sample No.	DC-4	TC-1	TC-2	TC-3	ASP-5 (1ms)
Element					
Fe	<0.05%	0.1%	0.1%	1%	0.1%
Ca	>20%	>20%	>20%	10%	37.6%
Mg	5%	0.1%	2%	5%	1.0%
Ag	<1	<1	<1	<1	ND
As	<500	<500	<500	<500	ND
Ba	20	<10	<10	<10	23
Cu	<2	2	<2	5	4
Mn	50	200	200	200	222
Mo	3	3	3	2	ND
Pb	<10	10	10	30	55
Sb	<100	<100	<100	<100	
Zn	<200	<200	<200	<200	49
				SiO_2	0.61

Table Two - Leadville dolomite, recrystallized, but with minor secondary features (Z, zebra; B, birdseye; D, dolomite crystals; Q, quartz crystals).

Section Minus - relatively less and weaker characteristics.

CL-6 Trace Z and minor Fe-Mn.
FM-9 Fine crystalline black cut by medium white.
G-5 Upper shaly unit with calcite veins.
GC-3 (limestone) Lower fetid unit, calcite, FeOx limonite.
LL-12 Trace Z, B, and D.
WP-6 Minor D, Q, iron pseudomorphs.
BC-9 Minor sanding, siliceous-chert, fault zone gouge.
FM-23 Gilman ss member, leached, minor yellow FeOx.
OI-1 (limestone) marble with weak Mn stain and fracture filling.

Section Plus - relatively more and varied characteristics.

FM-4 Manganiferous.
FM-7A Crosscutting Z and D.
FM-11 Z, D, Q.
G-2 Upper unit, D vugs and veins.
GC-4 (limestone) Ocher, dog spar, FeOx nodules.
L-4 D, rare Q, weak FeOx.
LL-6 Minor silica, trace D, trace FeOx.
LL-9 Minor Z, D, Q, weak FeOx-jarosite.
LL-10 Minor pyrite, yellow-orange limonite, silica, trace D.
LL-15 Trace Z, D, Q, and minor FeOx.
ASP-1 (limestone) silicified, dark brown, sanded, manganese dust.
ASP-3 (limestone) weak FeOx in siderite-ankerite-barite, w/vugs.
ASP-6 (dolomite) manganese repl., siliceous, qtz xls, barite xls.

Table Two A - ES Values of Leadville Dolomite, recrystallized, with minor secondary features

	Section Minus									Section Plus												
Sample No.	CL-6	FM-9	G-5	GC-3	LL-12	WP-6	BC-9	FM-23	OI-1	FM-4	FM-7A	FM-11	G-2	GC-4	L-4	LL-6	LL-9	LL-10	LL-15	ASP-1	ASP-3	ASP-6
Element																						
Fe	0.5%	2%	5%	2%	2%	0.01%	2%	2.4%	0.5%	3%	0.5%	0.2%	0.5%	7%	0.2%	3%	2%	1.5%	0.2%	2.5%	5.6%	8.6%
Ca	10%	15%	0.7%	15%	10%	15%	0.03%	13.9%	35.0%	15%	15%	15%	15%	0.7%	15%	20%	10%	15%	10%	21.0%	13.1%	11.4%
Mg	15%	15%	1%	0.3%	10%	15%	0.2%	2.6%	1.4%	15%	10%	15%	15%	0.1%	15%	15%	15%	10%	7%	4.3%	3.6%	3.1%
Ag	1	1	<1	<1	2	<1	<1	ND	ND	5	5	<1	<1	<1	<1	100	10	3	1	29	11	106
As	<500	<500	500	<500	<500	<500	<500	420	ND	<500	<500	<500	500	500	<500	<500	<500	<500	<500	210	3470	ND
Ba	<10	200	10	20	<10	<10	<10	76	22	<10	<10	<10	<10	2000	<10	10	<10	<10	10	48	273	286
Cu	2	10	5	3	5	<2	2	11.7	35.9	20	100	2	<2	15	<2	200	50	20	2	75	74.6	197
Mn	500	1500	300	1000	300	200	3000	770	2550	1500	1000	500	2000	700	1500	700	1000	1000	1500	9680	3540	27420
Mo	<2	3	2	3	2	<2	2	ND	20	<2	2	2	<2	5	2	3	5	<5	<2	10	40	10
Pb	100	2000	10	20	30	10	50	60	310	1000	1500	50	20	50	10	3000	200	150	100	60000	2500	55000
Sb	<100	<100	<100	<100	<100	<100	<100	--	--	<100	<100	<100	<100	<100	<100	200	<100	<100	<100	--	--	--
Zn	300	<200	<200	<200	<200	700	200	194	2860	<200	300	<200	5000	200	<200	<200	200	300	<200	1510	3630	39700
SiO_2								48.4	2.38											8.5	37.4	12.2

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Table Three - Leadville dolomite, recrystallized with abundant secondary features and variable iron-manganese oxides.
(Z, zebra; B, birdseye; D, dolomite crystals; Q, quartz crystals; V, vugs; S, sanding)

CL-3 Z, B, D, V, minor Fe-MnOx.
DC-2 D, Q, V, S, ocher.
FM-1A Z, D, Mn dusting.
G-8 Z, D, V.
GC-2 (Gilman ss) S, dog spar, limonite.
GC-5 (limestone) FeOx ocher, silica, jasper, dog spar.
GC-6 (limestone) FeOx ocher, S, brecciation, dog spar.
GC-7 (limestone) FeOx ocher, silica, dog spar.

L-1 D.
L-2 S.
L-5 S, mangano-siderite.
L-7A Weak Z, D, and mangano-siderite.
L-7B S, iron-manganese replacement.
LL-1 Z, D.
LL-3 B.
LL-4 B, D, S, brecciation, weak FeOx knots.
LL-7 Z, B, FeOx films.
LL-8 Z, D, minor Q, silica, barite.

LL-9A Z, D, manganese limonite.
LL-13 Z, D, weak FeOx.
LL-15A Z, D, Q, S, barite, breccia, trace galena.
LL-16A Z, D, crosscutting FeOx.
TC-16 Z, D, Q, V, abundant yellow FeOx.
BC-1 B, D, few V.
BC-2 Z, D.
BC-4 Z, D.
BC-5 Z, B, D, pearly.
BC-6 Z, B, D, pearly.

BC-7 D, siliceous.
BC-8 D.
BC-10 Z, D.
BC-11 Z, D.
BC-11B Z, D.
BC-12 B(sparse), D.
BC-15 D.
BC-17 D, siliceous.
BC-18 B, D.

BC-19 D.
BC-20 Z, B, D.
BC-21 B, D.
BC-23 D.
BC-24 B.
BC-25 Z, B.
BC-26 Z, B.
BC-27 B, siliceous.
BC-28 Z, B, D.
BC-29 D, V.

BC-30 S, FeOx.
BC-31 B, V (minor).
BC-32 B, D.
BC-33 B, D.
BC-34 D (minor).
BC-35 B, D, siliceous.
BC-36 D (stockwork).
BC-37 B, D.
BC-41 D.

BC-42 D (around chert).
BC-43 D, siliceous.
BC-44 Z (minor), D.
BC-45 B (minor), D.
BC-46 B, D.
BC-47 B, D, chert.
ASP-2 (limestone) high Mn, trace py, calcite As, Q xls.
GOC-10 qtz bx w/calcite; strong Mn repl.
GOC-11 orange-blk limonite & FeOx, gal-zinc carb, Q druse.
FM-20 high grade galena, sph; w/trace azurite-malachite, D, Q, silic, minor Mn.
FM-24 D, silica druse, weak Fe-MnOx in rault zone.

Table Three A - ES Values of Leadville Dolomite, recrystallized, with abundant secondary features.

Sample No.	CL-3	DC-2	FM-1A	G-8	GC-2	GC-5	GC-6	GC-7	L-1	L-2	L-5	L-7A	L-7B	LL-1	LL-3	LL-4	LL-7	LL-8	LL-9A	LL-13	LL-15A	LL-16A	TC-16	BC-1	BC-2	BC-4	BC-5	BC-6	BC-7	BC-8	BC-10	BC-11	BC-11B	BC-12	BC-15	BC-17	BC-18
Element																																					
Fe	0.5%	1%	0.5%	0.2%	2%	1.5%	1%	0.5%	3%	5%	1%	0.5%	1%	2%	5%	5%	1%	5%	7%	2%	0.2%	0.5%	0.5%	0.5%	1%	0.5%	1%	0.5%	5%	10%	0.7%	1%	1%	0.7%	7%	1%	0.7%
Ca	20%	15%	10%	20%	7%	1%	20%	15%	20%	1%	20%	15%	7%	20%	>20%	15%	15%	10%	15%	15%	7%	15%	15%	10%	15%	10%	7%	15%	0.7%	0.2%	10%	15%	15%	20%	15%	10%	15%
Mg	15%	0.2%	7%	15%	0.3%	1%	0.3%	0.5%	15%	7%	15%	10%	1%	15%	15%	10%	15%	15%	15%	15%	3%	10%	15%	5%	10%	7%	5%	10%	0.2%	0.15%	7%	10%	10%	15%	7%	5%	7%
Ag	2	<1	30	<1	<1	<1	<1	<1	<1	1	10	10	7	1	<1	1	10	5	2	15	100	7	<1	<1	1	2	<1	<1	10	15	<1	<1	<1	<1	1	<1	<1
As	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500
Ba	10	<10	10	<10	20	20	500	100	<10	10	10	50	<10	<10	<10	<10	<10	100	<10	20	>10000	20	<10	<10	10	<10	<10	2000	<10	<10	<10	<10	<10	10	<10	<10	<10
Cu	<2	3	500	<2	2	3	2	2	15	5	3	3	5	5	<2	10	50	20	5	10	50	3	10	5	10	15	<2	5	2	3	2	10	1000	100	3	2	3
Mn	2000	700	700	300	200	500	700	700	7000	2000	>10000	10000	>10000	500	1000	700	700	1500	3000	1000	1000	500	700	>10000	1000	10000	1000	2000	10000	2000	2000	5000	7000	10000	>10000	1500	2000
Mo	<2	5	<2	<2	2	3	2	3	3	2	2	2	3	2	3	3	2	5	3	3	2	2	<2	<2	5	2	2	2	10	7	2	5	3	3	2	2	2
Pb	500	10	5000	<10	30	20	30	<10	30	200	200	100	500	20	10	150	500	200	100	100	5000	50	500	200	70	500	20	150	30	150	100	500	10000	3000	200	30	20
Sb	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	100	200	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Zn	500	<200	200	<200	<200	<200	<200	<200	<200	<200	300	500	1000	<200	<200	300	<200	<200	200	<200	2000	<200	500	<200	<200	500	<200	<200	>10000	>10000	<200	<200	<200	<200	500	200	200

Sample No.	BC-19	BC-20	BC-21	BC-23	BC-24	BC-25	BC-26	BC-27	BC-28	BC-29	BC-30	BC-31	BC-32	BC-33	BC-34	BC-35	BC-36	BC-37	BC-41	BC-42	BC-43	BC-44	BC-45	BC-46	BC-47	ASP-2	GOC-10	GOC-11	FM-20	FM-24
Element																														
Fe	2%	2%	0.2%	1%	0.5%	0.5%	0.3%	1%	0.5%	10%	5%	2%	0.5%	1%	0.3%	1%	2%	7%	1.5%	0.5%	0.5%	0.5%	0.2%	0.2%	1%	2.9%	1.3%	8.8%	3.0%	1.9%
Ca	15%	10%	10%	10%	15%	15%	10%	7%	10%	1%	7%	15%	10%	10%	10%	10%	15%	7%	10%	15%	15%	10%	15%	15%	10%	18.7%	27.5%	9.4%	6.0%	1.2%
Mg	7%	5%	7%	5%	7%	7%	7%	5%	5%	0.15%	0.5%	10%	10%	5%	10%	10%	10%	5%	10%	15%	15%	10%	10%	10%	10%	0.2%	0.5%	0.6%	2.9%	0.4%
Ag	<1	1	<1	<1	<1	<1	<1	1	<1	70	5	2	<1	2	<1	<1	<1	10	1	1	<1	<1	<1	<1	2	ND	ND	537	726	ND
As	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	200	ND	ND	ND	ND
Ba	<10	200	<10	10	<10	50	<10	<10	20	<10	<10	2000	<10	70	70	<10	<10	7000	<10	<10	<10	200	<10	<10	<10	99	699	928	429	48
Cu	1000	3	1000	150	500	2	2	2	5	<2	3	5	20	7	700	2	3	150	50	5	3	3	2	2	5	45.2	16.2	1040	5660	44.2
Mn	1500	3000	1000	2000	1000	10	1500	5000	100	2000	2000	2000	3000	7000	5000	5000	10000	>10000	3000	1500	5000	3000	2000	1000	7000	2282	8130	1330	4100	2300
Mo	5	5	2	2	2	2	<2	2	3	5	10	2	2	2	3	2	5	15	10	5	5	2	2	2	3	20	ND	810	40	20
Pb	>110000	500	30	5000	7000	70	20	50	100	20	20	100	500	300	10000	10	100	2000	3000	50	100	200	100	10	100	2000	190	67500	60000	35
Sb	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	100	<100	<100	<100	<100	<100	<100	<100	--	--	--	--	--
Zn	200	300	<200	<200	<200	<200	<200	500	<200	>10000	5000	300	200	<200	500	<200	<200	10000	1000	<200	<200	<200	<200	<200	200	351	552	14200	18300	35
SiO_2																										35.9	24.4	33.3	44.7	91.0

Table Four - Leadville dolomite, with high degree of replacement by iron-manganese, and various sulfides; now totally oxidized, often with various silica-jasper types.

L-3 Sulfide Ore from Black Cloud No. 6 Orebody.
CL-2 Black jasper and silica with zinc carbonate.
CL-4 Fe-Mn-Silica jasper.
CL-5 Orange-brown to red-black Fe-Mn jasper.
DC-1 (limestone) FeOx-silica jasper.
FM-1 Q, S, bx, barite, FePbZn pseudomorphs.
FM-3 (Gilman ss) FeOx sinter, PbOx?
FM-6 (Gilman ss) Siliceous bx, sparse galena, tetrahedrite.
FM-7 D, siliceous, with galena, tetrahedrite.

G-3 Red-black hematite, minor jasper.
G-4 Manganese-specularite.
L-4A Fe-MnOx, weak jasper.
L-5A Fe-Mn replacement.
L-6 Orange jasper with black FeOx.
LL-13A Q, barite, FeOx, pyrite pseudomorphs.
LL-13B Q, barite, silica bx, azurite, malachite, sphalerite.
LL-17 D, Q, silica, FeZn pseudomorphs.

M-1 Fe jasper.
M-2 Fe jasper with Z, D, Q.
P-1 Orange-brown jasper with magnetite-hematite.
TC-7 V, silicified, FeOx, and silica-jasper.
TC-8 Complete replacement by FeOx and py-sphal pseudomorphs.
TC-13 (Gilman ss) Silica, red-yellow FeOx, weak jasper.
TC-14 (Gilman ss) Weak replacement by yellow-pink FeOx and silica-jasper.
TC-17 Silicified yellow-red ocher and silica-jasper with Q.
WP-2 FeOx-jasper-quartz grains in sanded unit.
WP-6A FeOx sinter.

WP-8 Fe sinter and pyrite pseudomorphs, weak jasper.
ASP-4 (limestone) yellow-brown jasperoid w/qtz druse.
ASP-4A (limestone) mod. strong red-blk FeOx, siliceous, porous.
GOC-1 high iron-garnet jasperoid.
GOC-2 pulverulent dark yellow-brown FeOx and blk FeOx, cuts GOC-1
GOC-3 silicified, Q xls, tr malachite, barite, sooty FeOx-MnOx.
GOC-4 Fe-Mn-qtz-dolomite-siliceous, w/zn carb & tr azurite.
GOC-5 dense blk Fe-Mn jasperoid, minor garnet, Q xls.
FM-21 blk FeOx sinter w/leached yellow-orange FeOx, Z, Mn.

FM-22 dense yellow-orange jasperoid.
FM-22A red-blk FeOx, Q xls, jasperoid, cuts FM-22.
FM-25 strong FeOx repl; massive to sinter texture.

Table Four A - ES Values of Leadville Dolomite with high degree of replacement by Iron-Manganese Jasperoids.

Sample No.	L-3	CL-2	CL-4	CL-5	DC-1	FM-1	FM-3	FM-6	FM-7	G-3	G-4	L-4A	L-5A	L-6	LL-13A	LL-13B	LL-17
Element																	
Fe	10%	10%	1%	10%	15%	7%	15%	0.7%	1%	20%	5%	10%	7%	10%	10%	2%	15%
Ca	2%	0.7%	0.5%	0.1%	10%	0.1%	0.1%	1%	2%	0.05%	0.1%	5%	0.5%	0.2%	2%	5%	0.2%
Mg	0.5%	0.1%	0.2%	0.1%	0.3%	0.03%	0.05%	0.5%	1%	0.03%	0.03%	0.03%	0.03%	0.03%	1%	15%	0.05%
Ag	50	100	15	10	<1	200	150	500	1000	1	10	200	150	150	2	1000	50
As	500	<500	<500	<500	<500	<500	500	<500	1500	<500	<500	1000	2000	5000	<500	<500	1000
Ba	5000	5000	50	500	20	>10000	100	50	50	<10	<10	7000	7000	5000	10	>10000	>10000
Cu	700	5	150	20	2	1500	500	1000	3000	300	50	200	30	100	30	5000	500
Mn	5000	>10000	>10000	>10000	700	100	10	200	300	500	>10000	>10000	>10000	>10000	1000	300	200
Mo	20	10	<2	5	7	5	3	<2	2	10	2	20	10	10	7	2	100
Pb	10000	5000	200	500	20	>10000	10000	7000	>10000	3000	1500	10000	7000	5000	200	>10000	10000
Sb	<100	<100	<100	<100	<100	500	500	500	5000	<100	<100	200	100	100	<100	3000	150
Zn	>10000	>10000	>10000	7000	<200	2000	1000	10000	>10000	7000	>10000	2000	10000	3000	500	>10000	2000

Sample No.	M-1	M-2	P-1	TC-7	TC-8	TC-13	TC-14	TC-17	WP-2	WP-6A	WP-8	ASP-4	ASP-4A	GOC-1	GOC-2	GOC-3	GOC-4	GOC-5	FM-21	FM-22	FMM-22A	FM-25
Element																						
Fe	15%	15%	20%	2%	20%	0.5%	0.5%	0.7%	5%	20%	20%	7.4%	26.9%	35.5%	31.5%	1.6%	1.2%	38.2%	12.8%	4.5%	110.4%	47.2%
Ca	5%	0.05%	0.02%	0.2%	0.2%	0.5%	5%	1%	0.5%	1.5%	0.1%	0.2%	0.1%	0.1%	0.1%	13.9%	8.0%	0.1%	0.1%	1.2%	0.1%	4.7%
Mg	0.1%	0.1%	0.03%	0.05%	0.05%	0.3%	1.5%	0.1%	0.2%	0.2%	0.05%	0.2%	0.1%	0.7%	1.9%	0.8%	2.1%	0.05%	0.1%	0.5%	00.04%	0.3%
Ag	1	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	ND	213	357	178	152	678	131	14	ND	ND	11
As	<500	<500	<500	<500	<500	<500	<500	<500	<500	5000	5000	430	3420	1730	1300	ND	ND	660	2600	ND	11730	3470
Ba	10	<10	20	<10	10	<10	<10	100	<10	<10	10	405	208	43	113	1070	81	ND	4970	17	330	2070
Cu	150	700	200	2	100	<2	2	<2	2	5	10	51.4	526	1070	1020	804	11200	1560	1650	5.6	773.4	157
Mn	3000	500	100	100	500	200	100	1000	200	50	50	5030	4890	1190	3090	56770	30670	3140	79770	2910	33360	350
Mo	10	20	15	2	15	<2	<2	2	<2	10	10	60	20	20	30	50	80	80	260	ND	70	ND
Pb	10	10	<10	<10	<10	10	15	20	150	50	70	1200	41000	6250	10500	16500	32000	62500	60000	65	950	11500
Sb	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	--	--	--	--	--	--	--	--	--	--	--
Zn	<200	200	1000	<200	500	<200	<200	<200	200	<200	200	595	17300	3430	20400	48200	159000	5400	2390	62	724	14400
											SiO_2	85.2	34.4	28.0	40.8	42.3	29.3	18.7	49.9	79.1	80.4	6.98

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Table Five - Karst and Cave-fill Type Material ranging from cold water solution, to sanded cave-fill, to mineralized cave-fill-karst deposits.

DC-3 Terra rosa karst.
TC-2A Karst of cold water solution bx, calcite, dripstone, wk terra rosa.
FM-2 Karst with FeMnOx replacement, galena, tetrahedrite.
LL-2 Cave-fill, tan, sanded dolomite.
LL-5 Karst with D, Q, FeOx.
LL-5A Karst with azurite-malachite.
LL-16 Karst, fine D, Q, silic dolomite with weak FeMn.
PM-3 Karst, late D, Q, S, bx, Mn-massive sulfide, trace malachite.
TC-15 Karst and other material, V, silic bx, py, dog spar, FeOx.

Table Five A - ES Values of Karst & Cave-Fill Type material.

Sample No.	DC-3	TC-2A	FM-2	LL-2	LL-5	LL-5A	LL-16	PM-3	TC-15
Element									
Fe	1%	5%	10%	2%	10%	7%	2%	7%	1.5%
Ca	20%	20%	0.15%	20%	7%	1%	10%	0.7%	10%
Mg	0.2%	5%	0.05%	15%	2%	2%	7%	0.02%	2%
Ag	<1	<1	500	3	100	7000	10	200	<1
As	<500	1000	1000	<500	<500	1500	<500	<500	700
Ba	<10	50	500	200	50	5000	500	5000	50
Cu	2	100	5000	5	2000	>10000	15	1500	3
Mn	700	2000	700	2000	700	1000	10000	10000	100
Mo	2	5	5	2	10	5	5	20	7
Pb	<10	500	>10000	150	5000	>10000	100	10000	<10
Sb	<100	<100	1000	<100	200	>10000	<100	<100	<100
Zn	<200	200	>10000	500	>10000	10000	300	10000	<200

Table Six - Sulfide Ore Values

A. Manitou Dolomite

BC-53	mixed py-sph-gal in dolomitic-quartzitic w/clay seams.
BC-59A	banded py-qtz-sph with residual dolomite clots.
BC-60	banded py-qtz-sph-gal-abundant carbonate.
BC-61	banded py-sph-gal with carbonate-qtz seams.
BC-62	vein, carbonate walls w/massive qtz-sph-gal center.
BC-63	banded py-qtz-sph-gal-carbonate seams and vugs.
BC-69	banded py-qtz-sph-abundant dolomite bands.
BC-70	banded py-sph-gal-carbonate.
BC-71	vein, py-sph-gal with carbonate stringers.
BC-72	banded, py-sph-gal-carbonate.

B. Leadville Dolomite

L-3	from conveyor belt, Black Cloud No. 6; py-qtz-sph-gal.
BC-3	massive py, sph, gal, and carbonate.
BC-16	massive py, sph, gal, with 20% carbonate-silica.

Table Six A - ES Values of Sulfide Ore.

	A. Manitou Dolomite										B. Leadville Dolomite		
Sample No.	BC-53	BC-59A	BC-60	BC-61	BC-62	BC-63	BC-69	BC-70	BC-71	BC-72	L-3	BC-3	BC-16
Element													
Fe	15%	15%	20%	20%	10%	15%	20%	20%	15%	10%	10%	10%	15%
Ca	2%	1%	1%	1%	7%	5%	7%	1%	3%	5%	2%	0.2%	1%
Mg	0.5%	0.5%	0.2%	0.2%	0.5%	0.5%	1%	0.5%	1%	2%	0.5%	0.1%	0.2%
Ag	150	100	150	50	50	20	50	30	100	10	50	70	20
As	500	500	1000	700	500	<500	500	1000	<500	<500	500	500	500
Ba	<10	10	20	10	200	10	<10	<10	<10	<10	5000	<10	<10
Cu	2000	3000	5000	1500	2000	1500	1500	1000	2000	300	700	15	5
Mn	5000	5000	7000	3000	5000	5000	>10000	5000	10000	>10000	5000	>10000	1500
Mo	7	7	15	7	10	7	50	7	30	5	20	15	15
Pb	10000	10000	7000	7000	>10000	7000	>10000	7000	>10000	5000	10000	50	200
Sb	<100	<100	<100	<100	<100	<100	<100	<100	200	<100	<100	100	<100
Zn	>10000	>10000	>10000	>10000	>10000	>10000	>10000	>10000	>10000	>10000	>10000	>10000	>10000

Table Seven - Cambrian Sawatch Quartzite description.

PM-1	Sandy with weak FeOx.
TC-9	Sandy, yellow-red ocher.
TC-10	Sandy, chrome green with yellow FeOx.
TC-11	Sandy, yellow FeOx and red-brown jasper.
TC-12	Sandy, bx, quartz, abundant yellow-red FeOx.
WP-3	Fault breccia with FeOx.
WP-9	Chrome green grains (may be lower Peerless).
WP-10	Sanded, FeOx seams.

Table Seven A - ES Values of Sawatch Quartzite

Sample No.	PM-1	TC-9	TC-10	TC-11	TC-12	WP-3	WP-9	WP-10
Element								
Fe	2%	10%	3%	7%	7%	5%	10%	5%
Ca	0.5%	0.05%	0.05%	0.15%	1%	0.03%	0.1%	0.02%
Mg	0.5%	0.05%	0.1%	0.05%	1%	0.03%	0.1%	0.03%
Ag	<1	<1	2	<1	<1	<1	<1	<1
As	<500	2000	<500	<500	<500	2000	<500	500
Ba	150	200	1000	<10	<10	<10	<10	<10
Cu	5	20	3	10	10	100	100	50
Mn	1000	3000	2000	50	100	200	100	50
Mo	<2	5	2	<2	2	2	2	2
Pb	<10	<10	15	15	30	<100	<100	<100
Sb	<100	<100	<100	<100	<100	<100	<100	<100
Zn	<200	200	<200	<200	<200	<200	<200	<200

Table Eight - Ordovician Manitou Dolomite descriptions.

BC-50 Quartzitic, minor Fe-Mn.
BC-51 Quartzitic and siliceous with py-sph-gal, tr. malachite.
BC-54 Trace recrystallization.
BC-55 Fine recrystallized texture, clay seams.
BC-56 Bleached, silicic bands, minor pyrite, tr. oxidation.
BC-57 Bleached, pyrite along bedding, clay-FeOx seams.
BC-58 Bleached, pyrite, FeOx on bedding.
BC-59 Bleached, coarse recrystallization, silicic, pyrite.
BC-64 Bleached, silicic, pyrite, clay-carbonate seams.
BC-65 Bleached, weakly silicic, pyrite.
BC-66 Fine crystalline, few carbonate seams.
BC-67 Bleached, silicic, black pyrite-sulfide seams.
BC-68 Bleached, clay-silica seams.

Table Eight A - ES Values of Manitou Dolomite.

	Manitou Dolomite (in sulfide zone)												
Sample No.	BC-50	BC-51	BC-54	BC-55	BC-56	BC-57	BC-58	BC-59	BC-64	BC-65	BC-66	BC-67	BC-68
Element													
Fe	7%	10%	5%	2%	7%	5%	2%	5%	5%	2%	5%	5%	3%
Ca	1%	0.1%	15%	15%	5%	15%	10%	10%	10%	3%	10%	10%	10%
Mg	0.2%	0.5%	10%	10%	1%	10%	10%	7%	10%	1%	7%	10%	10%
Ag	5	10	5	<1	<1	<1	1	2	10	10	1	10	3
As	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500
Ba	200	10	<10	<10	300	<10	20	100	<10	<10	20	<10	<10
Cu	15	150	50	3	50	20	10	100	100	50	10	20	15
Mn	3000	5000	3000	3000	5000	7000	7000	>10000	>10000	>10000	5000	3000	5000
Mo	2	15	5	3	3	2	2	5	5	2	5	5	5
Pb	700	5000	1000	50	30	50	50	500	300	200	100	300	1000
Sb	<100	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Zn	1500	>10000	2000	<200	500	200	<200	1000	1000	500	500	1000	1000

Table Nine - Devonian Dyer Dolomite descriptions.

GC-1	Weak FeOx and sanding.
GC-8	Yellow ocher, minor silica, and red FeOx.
PM-2	Sandy, minor black-brown manganese.
TC-13A	Partly recrystallized, sandy, vuggy, minor FeOx.
WP-1	Q, iron, red-brown jasper.
WP-1A	Recrystallized with galena.
BC-48	Laminated, fine grey-brown, fine recrystallization.
GOC-6	Weak manganese stain.
GOC-9	Patchy Z, dolomite clots, weak crystal stripes (Note: this may be lower Leadville dolomite).

Table Nine A - ES Values of Dyer Dolomite.

Sample No.	GC-1	GC-8	PM-2	TC-13A	WP-1	WP-1A	BC-48	GOC-6	GOC-9
Element									
Fe	5%	7%	3%	0.1%	20%	1%	1.5%	1.0%	0.3%
Ca	7%	0.7%	7%	15%	0.05%	5%	10%	23.2%	21.9%
Mg	0.1%	0.05%	1%	10%	0.03%	10%	10%	7.1%	10.6%
Ag	<1	<1	100	<1	15	10	<1	196	ND
As	<500	<500	<500	<500	<500	<500	<500	ND	ND
Ba	<10	100	5000	<10	<10	<10	200	1110	60
Cu	3	20	200	2	200	100	2	265	2.7
Mn	700	2000	>10000	300	100	300	3000	16110	1190
Mo	2	5	20	2	50	<2	5	ND	ND
Pb	10	20	2000	30	10000	>10000	10	2980	20
Sb	<100	<100	100	<100	<100	<100	<100	--	--
Zn	<200	200	2000	<200	10000	>10000	<200	1610	202
							SiO_2	3.86	0.59

Table Ten - Pennsylvanian Belden Shale descriptions.

FM-10	Yellow ocherous spots.
LL-11	Bright yellow FeOx.
TC-4	Nodules of weak FeOx.
TC-6	Limestone lens with blackjack (zinc).
WP-4	Gypsiferous, fine pyrite.
WP-11	FeOx knots and pyrite pseudomorphs.
GOC-12	Red-black, partially oxidized FeOx nodules and lenses.

Table Ten A - ES Values of Belden Shale.

Sample No.	FM-10	LL-11	TC-4	TC-6	WP-4	WP-11	GOC-12
Element							
Fe	2%	0.5%	15%	2%	2%	10%	45.3%
Ca	0.07%	0.1%	0.2%	20%	20%	0.1%	0.05%
Mg	0.2%	0.2%	0.05%	0.2%	2%	0.15%	0.1%
Ag	<1	<1	<1	<1	<1	<1	ND
As	<500	<500	<500	<500	<500	<500	100
Ba	200	200	<10	700	<10	10	465
Cu	3	2	20	3	5	30	87.8
Mn	<10	10	1000	500	500	70	1010
Mo	3	3	5	7	<2	3	30
Pb	50	20	20	10	20	<10	115
Sb	<100	100	<100	<100	<100	<100	--
Zn	<200	<200	500	<200	<200	<200	955
						SiO_2	12.8

Table Eleven - Tertiary Porphyry (Gilman sill type), except where noted otherwise.

C-1	Lincoln porphyry, weak clay.
CL-1	Argillic with Fe-MnOx.
FM-8	Orange-yellow FeOx.
G-1	Argillic with fine manganese and limonites.
L-7	Argillic with FeOx.
M-3	Weak clay.
TC-5	Hornblende diorite, fresh.
WP-5	Sulfidized ferromags with trace pyrite.
BC-13	Johnson Gulch; fragmental, argillic, pyrite.
BC-14	Johnson Gulch; fragmental, argillic, pyrite.
BC-22	Johnson Gulch; argillic, weak FeOx on fractures.
BC-38	Johnson Gulch; argillic (dirty sample).
BC-39	Johnson Gulch; weak argillic, silicic (dirty sample).
BC-40	Johnson Gulch; weak argillic, silicic (dirty sample).
BC-58A	White porphyry, weak argillic (in Manitou).

Table Eleven A - ES Values of Porphyry Types.

Sample No.	C-1	CL-1	FM-8	G-1	L-7	M-3	TC-5	WP-5	BC-13	BC-14	BC-22	BC-38	BC-39	BC-40	BC-58A
Element															
Fe	2%	0.5%	5%	1%	10%	3%	10%	0.07%	1%	2%	1.5%	0.5%	2%	0.5%	5%
Ca	0.07%	0.02%	0.5%	0.1%	0.07%	0.07%	3%	1%	1%	1.5%	0.7%	0.2%	0.7%	5%	2%
Mg	0.05%	0.1%	0.15%	0.1%	0.05%	0.2%	1%	0.2%	0.5%	0.5%	0.2%	0.3%	0.5%	1%	1%
Ag	<1	<1	<1	<1	2	<1	<1	<1	<1	1	<1	<1	<1	<1	<1
As	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500
Ba	<10	100	1000	300	50	200	700	50	<10	<10	<10	50	500	200	1000
Cu	2	2	10	<2	2	5	30	2	3	10	<2	2	<2	3	2
Mn	100	200	1000	500	2000	150	1500	150	>10000	1500	700	1000	3000	7000	3000
Mo	<2	<2	2	<2	5	<2	<2	<2	2	5	7	5	2	3	<2
Pb	10	30	100	15	50	20	<10	10	500	20	15	100	70	100	30
Sb	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Zn	<200	<200	<200	<200	<200	<200	<200	<200	500	500	500	500	200	300	<200

Table Twelve - Other Rock Unit descriptions.

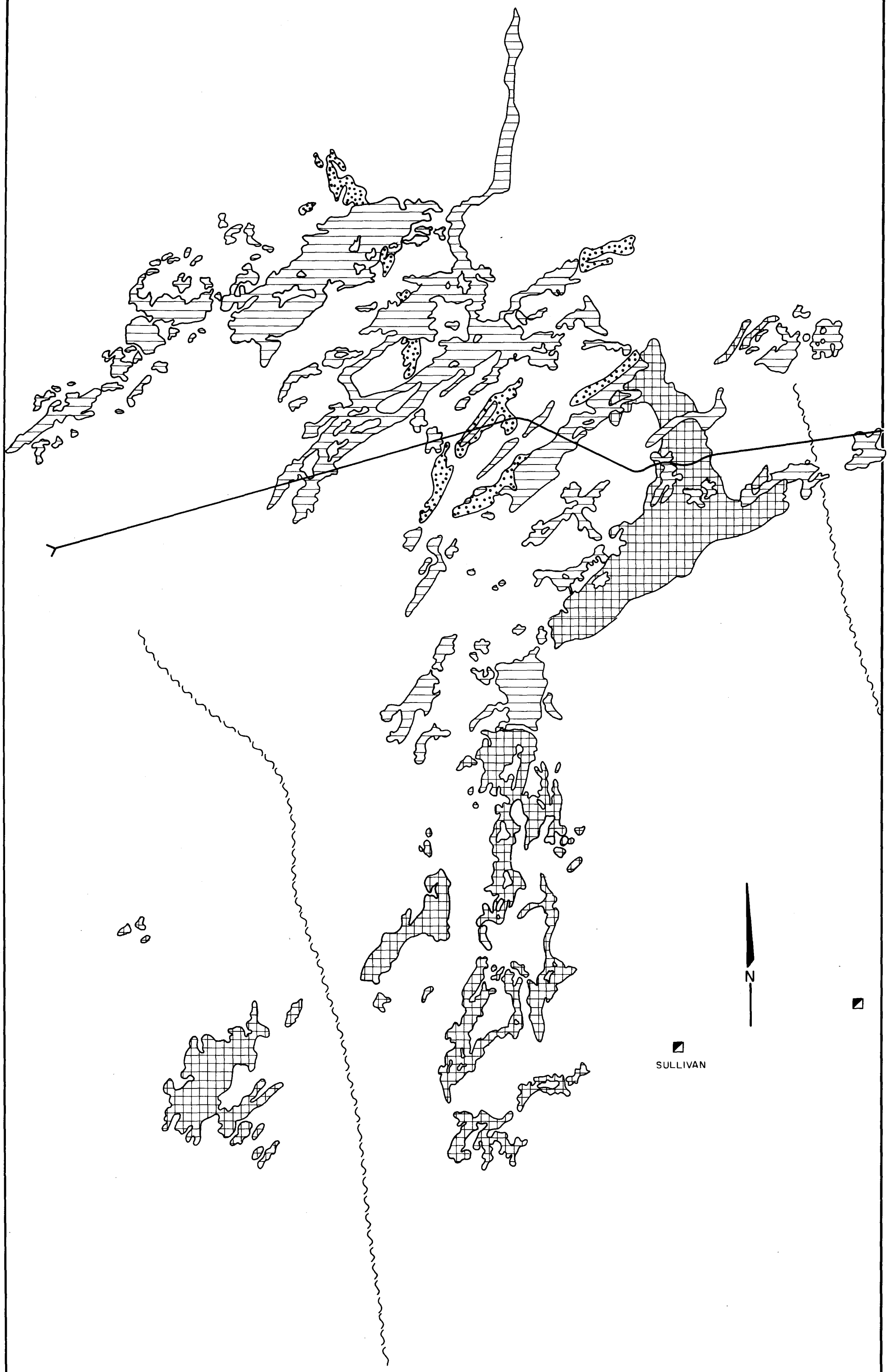
G-6	Precambrian biotite granite gneiss with Fe-MnOx films.
WP-7	Precambrian granite with quartz-sericite and pyrite pseudomorphs.
G-7	Peerless Shale, sandy dolomite with orange-brown limonite.
LL-14	Parting Quartzite with FeOx intragranular and along sheeting.
BC-73	Parting Quartzite, dense vitreous, w/patchy sulfides.
BC-74	Parting Quartzite, dense vitreous, w/patchy sulfides.
BC-75	Parting Quartzite, dense vitreous, dolomitic lenses, patchy sulfides.
GOC-7	Parting Quartzite, quartz shear zone cutting quartzite.
OCC-1	Maroon Sandstone, burnt yellow.
OCC-2	Maroon Sandstone, white.
OCC-3	Maroon Sandstone, black residuals.
OCC-4	Maroon Sandstone, limestone lens with replacement texture and dog spar.
SMS-1	Maroon Sandstone with quartz crystals, pyrite, magnetite, and ocher.
SMS-2	Maroon Sandstone, total ocher, sanded.
SMS-3	Maroon Sandstone, sanded breccia, minor yellow ocher.
BC-11A	Ontario, 1250 Level, Black Cloud.
BC-52	Ontario, 1500 Level, Black Cloud.
BC-49	Hellena, 1250 Level, Black Cloud.
FM-5	Smelter (1890) slag.

Table Twelve A - ES Values of Miscellaneous Units & Slag.

	pЄ Granite		Peerless Shale	Parting Quartzite					Maroon Sandstone							Fault Gouge			Smelter Slag
Sample No.	G-6	WP-7	G-7	LL-14	BC-73	BC-74	BC-75	GOC-7	OCC-1	OCC-2	OCC-3	OCC-4	SMS-1	SMS-2	SMS-3	Ontario BC-11A	Hellena BC-49	Ontario BC-52	FM-5
Element																			
Fe	2%	1%	5%	0.5%	1%	2%	1%	7.3%	1%	0.7%	0.5%	0.7%	10%	10%	0.7%	1.5%	1.5%	0.7%	>20%
Ca	0.2%	0.05%	2%	0.7%	2%	1.5%	1%	0.1%	15%	2%	20%	15%	10%	0.1%	0.05%	0.1%	5%	15%	1%
Mg	0.7%	0.1%	1%	0.2%	0.2%	0.2%	0.2%	0.1%	0.7%	0.2%	0.3%	0.15%	0.05%	1%	1%	0.2%	1%	10%	0.2%
Ag	<1	5	<1	5	<1	<1	<1	442	<1	<1	<1	<1	<1	3	<1	<1	<1	<1	10
As	500	<500	500	<500	<500	<500	<500	ND	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500
Ba	100	20	20	20	300	50	500	122	100	50	200	70	<10	<10	50	<10	100	<10	>10000
Cu	10	150	2	20	2	2	<2	749	<2	<2	5	3	7	100	3	2	3	3	700
Mn	200	50	200	1000	2000	5000	200	6980	700	100	500	700	2000	30	150	7000	2000	5000	500
Mo	<2	<2	<2	<2	7	<2	20	40	3	2	3	5	3	5	2	2	2	3	10
Pb	10	200	<10	150	200	100	20	8500	20	<10	10	10	100	500	10	50	50	100	>10000
Sb	<100	<100	<100	<100	<100	<100	<100	--	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	300
Zn	<200	1000	<200	200	<200	<200	<200	3960	<200	<200	<200	<200	700	500	<200	200	300	500	5000

SiO_2 77.4

5139 w



Ore Bodies in Leadville Dolomite

Ore Bodies in Leadville or Dyer Dolomite

Ore Bodies in Manitou and Peerless Formations

Fault at Surface

Yak Tunnel

Shaft

PLATE-I

SURFACE PLAN
OF
IRON-ROCK HILL GROUP
ORE BODIES

LEADVILLE DISTRICT, COLORADO

(MODIFIED FROM G.W.H. NORMAN, 1971)

0 500' 1000'

1" = 500'

mn 5139a dam

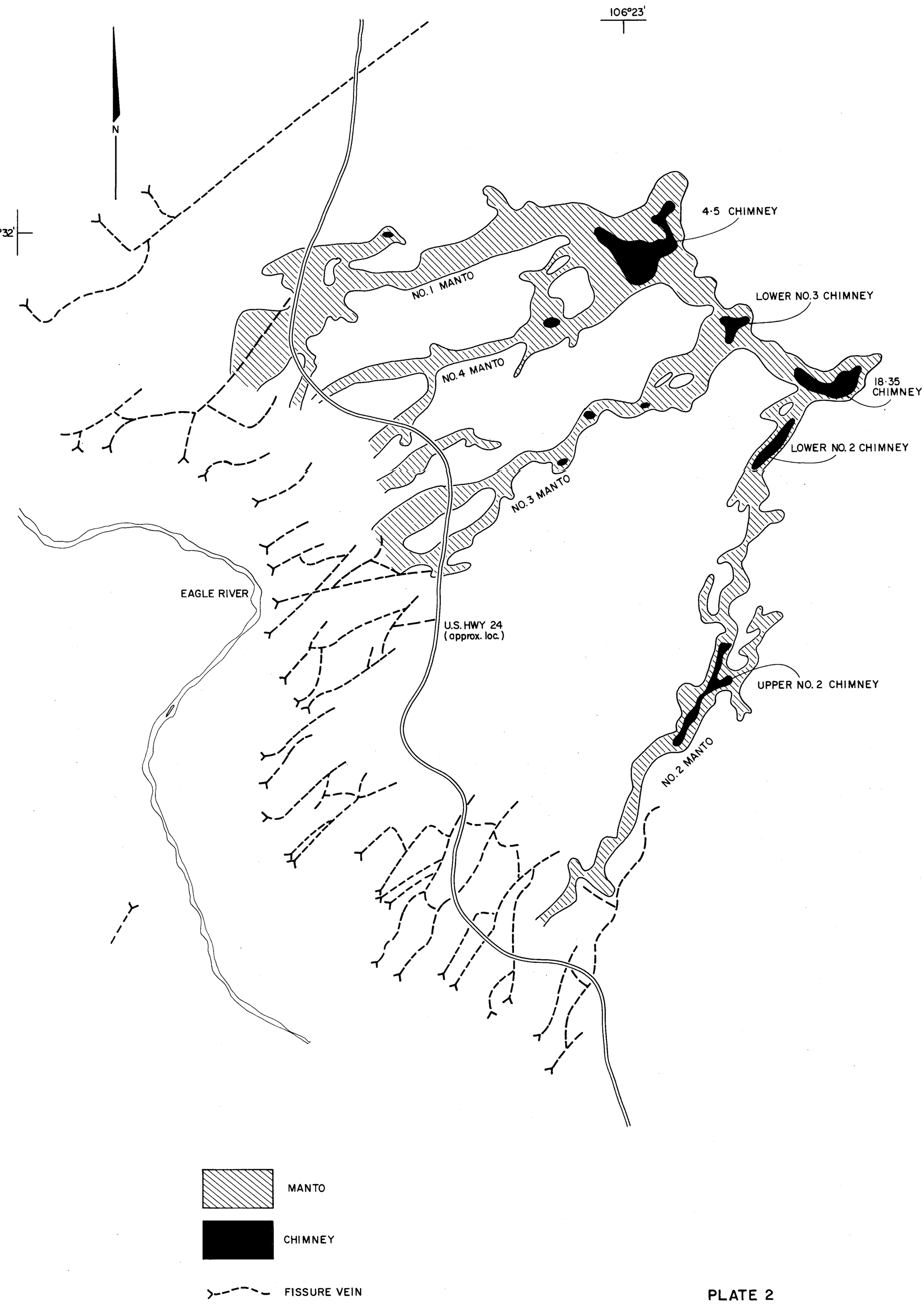


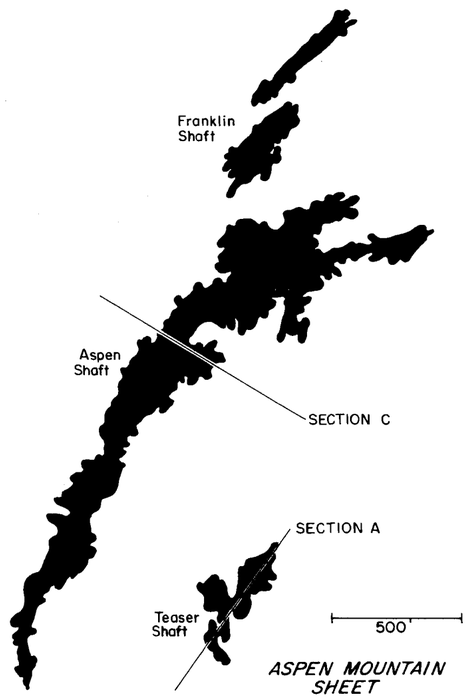
PLATE 2

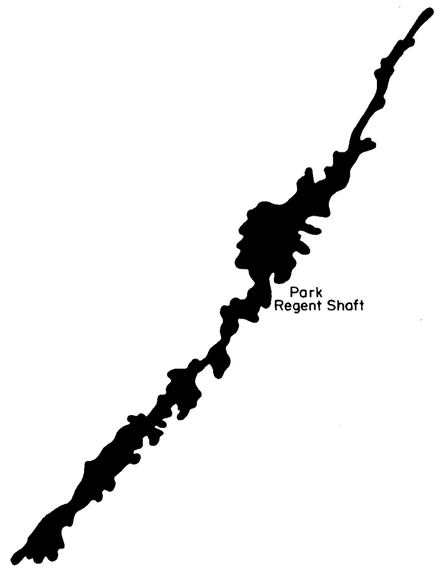
SURFACE PLAN OF MANTOS AND CHIMNEYS IN LEADVILLE DOLOMITE AND UNDERLYING FISSURE VEINS IN QUARTZITE AND GRANITE

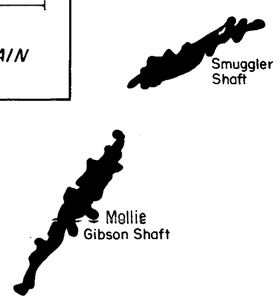
EAGLE MINE, GILMAN DISTRICT, COLORADO

(Modified from Radabaugh, et al, 1968)

mn 5139b dam

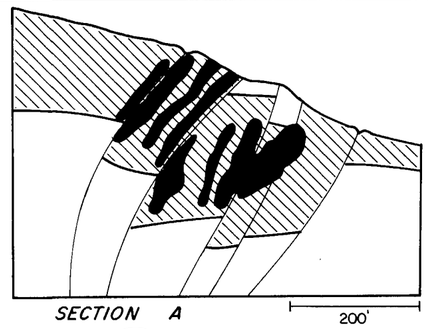


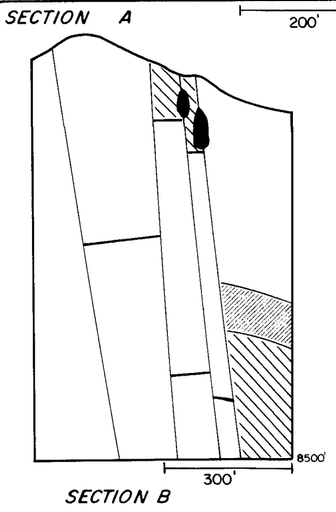


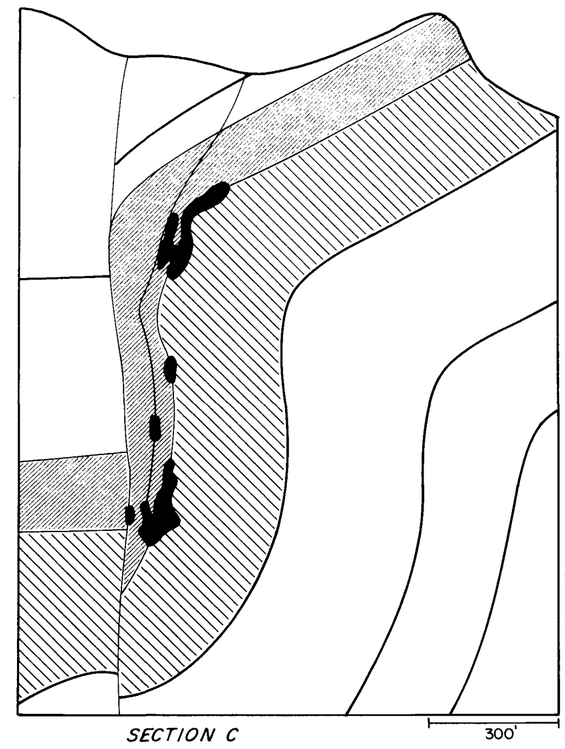


SMUGGLER MOUNTAIN SHEET

500'







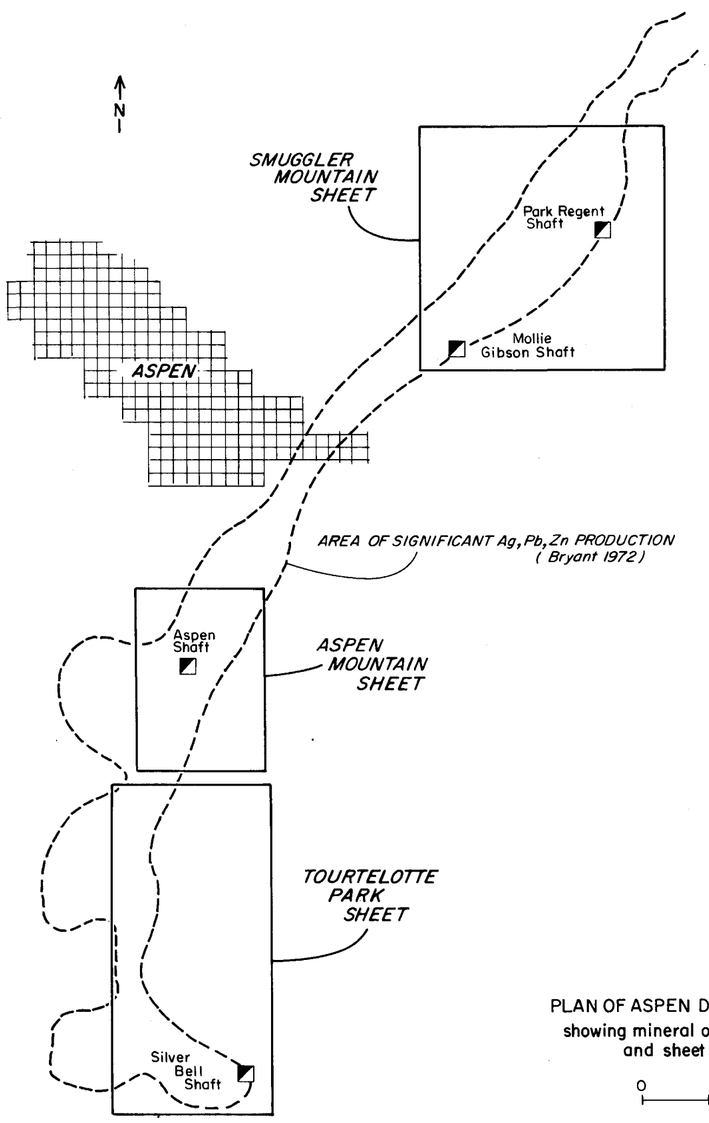
Leadville Limestone

Leadville Dolomite

Ore

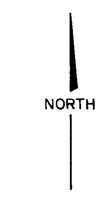
TOURTELOTTE PARK SHEET

500'



PLAN OF ASPEN DISTRICT, COLORADO
showing mineral outline, shafts, and sheet index

0 2000'



ORE

PLATE 3

SURFACE PLAN OF SOME ORE BODIES IN ASPEN DISTRICT, COLORADO

(Modified from Spurr, 1898)

scale (various)

mn 5139c dam

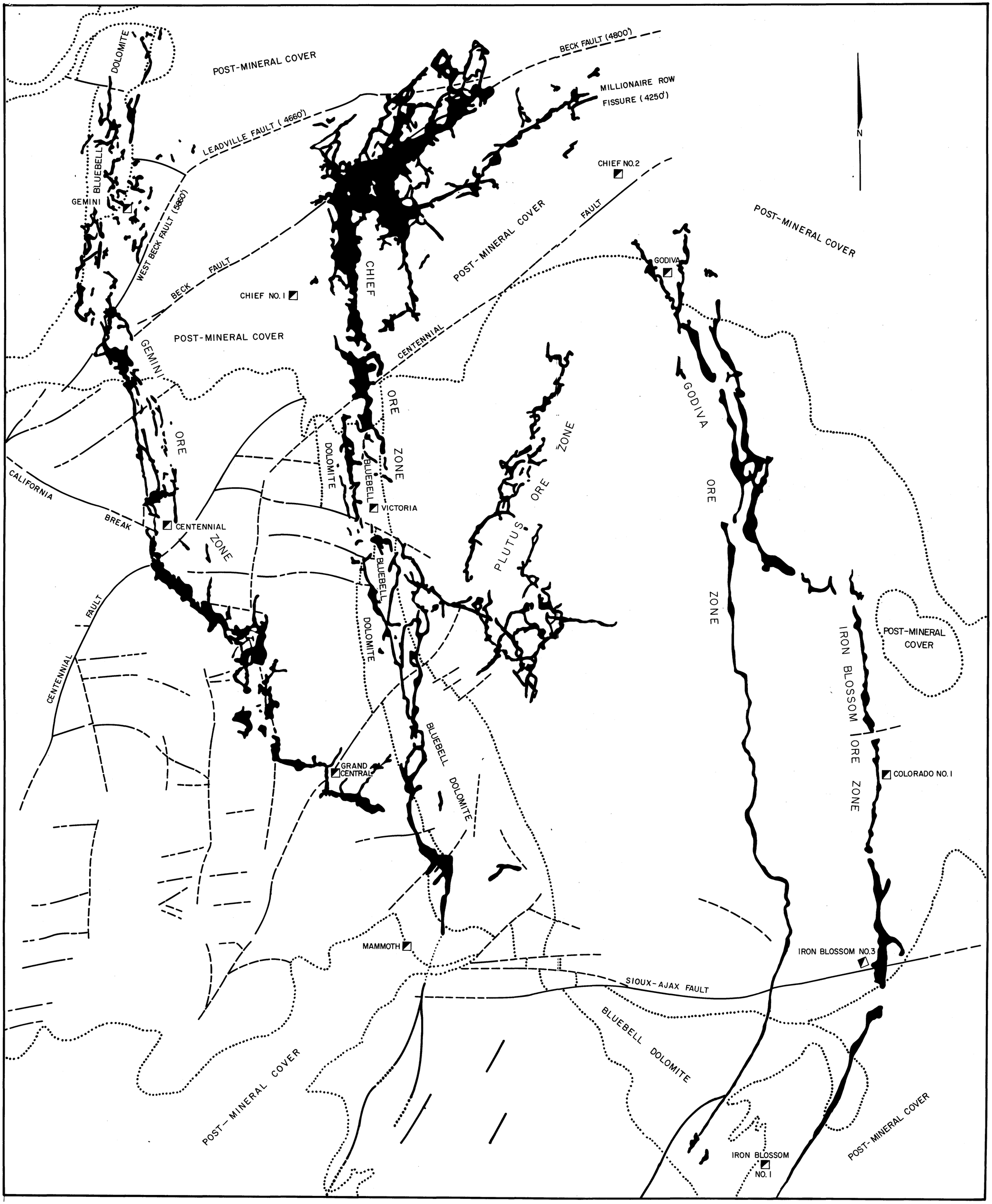


PLATE 4

PLAN OF MANTOS AND CHIMNEY ORE RUNS MAIN TINTIC DISTRICT TINTIC, UTAH

(MODIFIED FROM COOK, 1957 b)

0 500 1000
scale 1" = 500'

mn 5139d dam

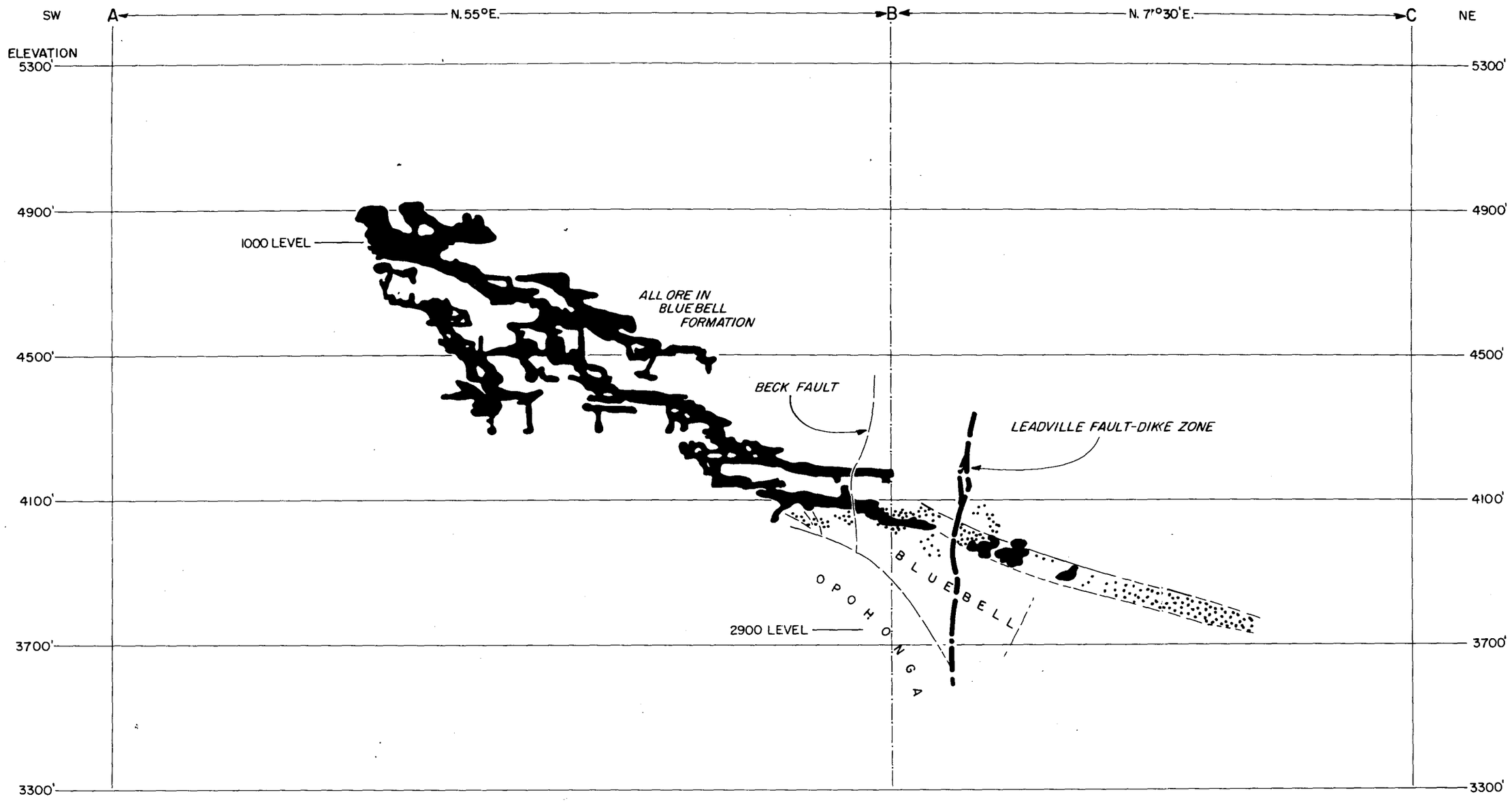
PLATE 5

SURFACE PLAN OF ORE BODIES
CHIEF CONSOLIDATED MINE
TINTIC DISTRICT, UTAH

(MODIFIED FROM EVANS, 1957)

0 150' 300' 600'
scale 1" = 300'

mn 5139e dam



0 100' 200' 400' 600'
scale 1" = 300'

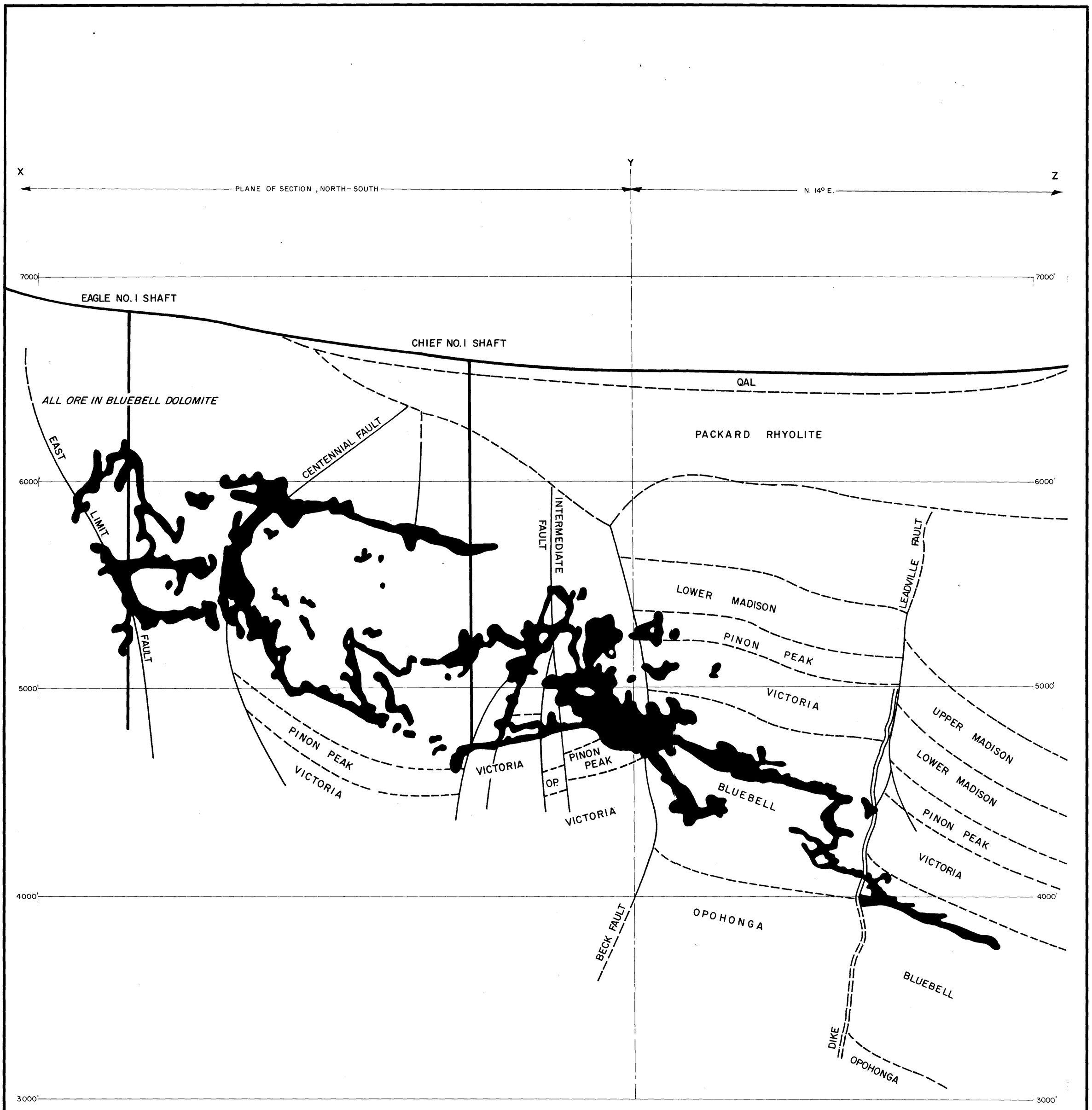
PLATE 6

VERTICAL SECTION ABC OF THE DEEP ORE ZONE OF THE CHIEF MINE

TINTIC DISTRICT, UTAH

(MODIFIED FROM EVANS, 1957)

mn 5139f dam



PLATE·7

LONGITUDINAL SECTION XYZ OF THE
CHIEF ORE ZONE, CHIEF MINE
TINTIC DISTRICT, UTAH

(MODIFIED FROM EVAN, 1957)

0 300' 600'

scale 1" = 300'

mn 5139 g dam

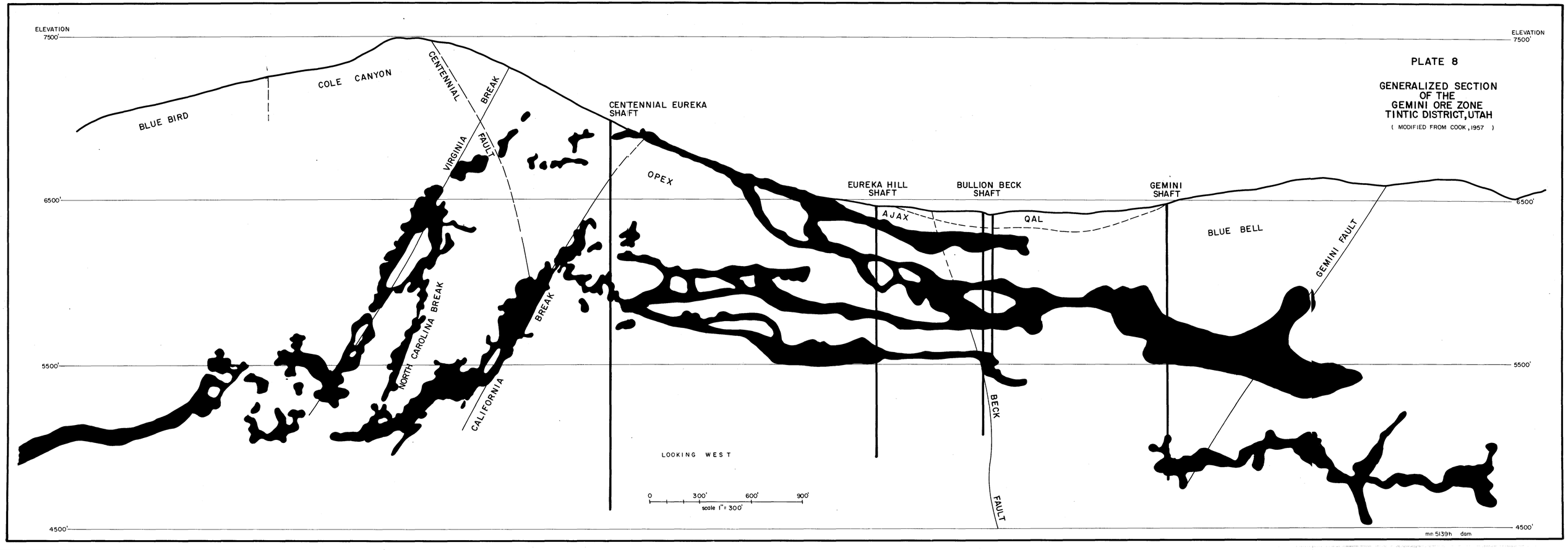
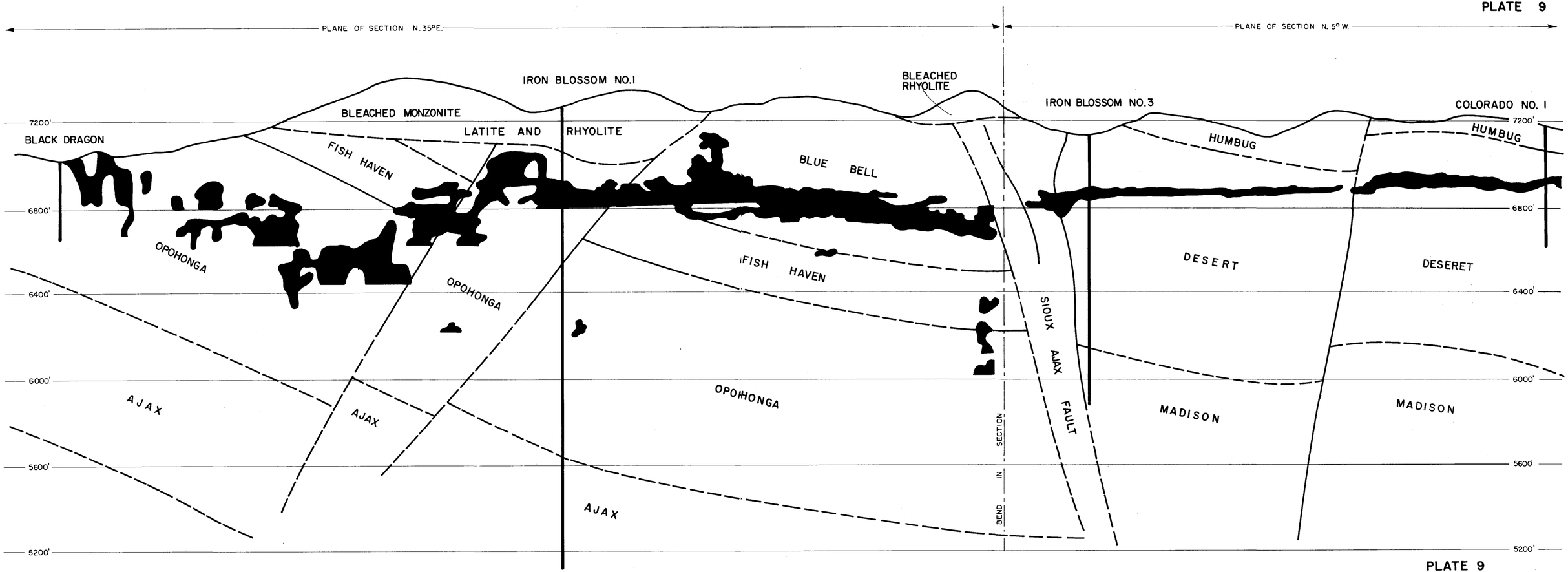


PLATE 8

GENERALIZED SECTION OF THE GEMINI ORE ZONE TINTIC DISTRICT, UTAH

(MODIFIED FROM COOK, 1957)



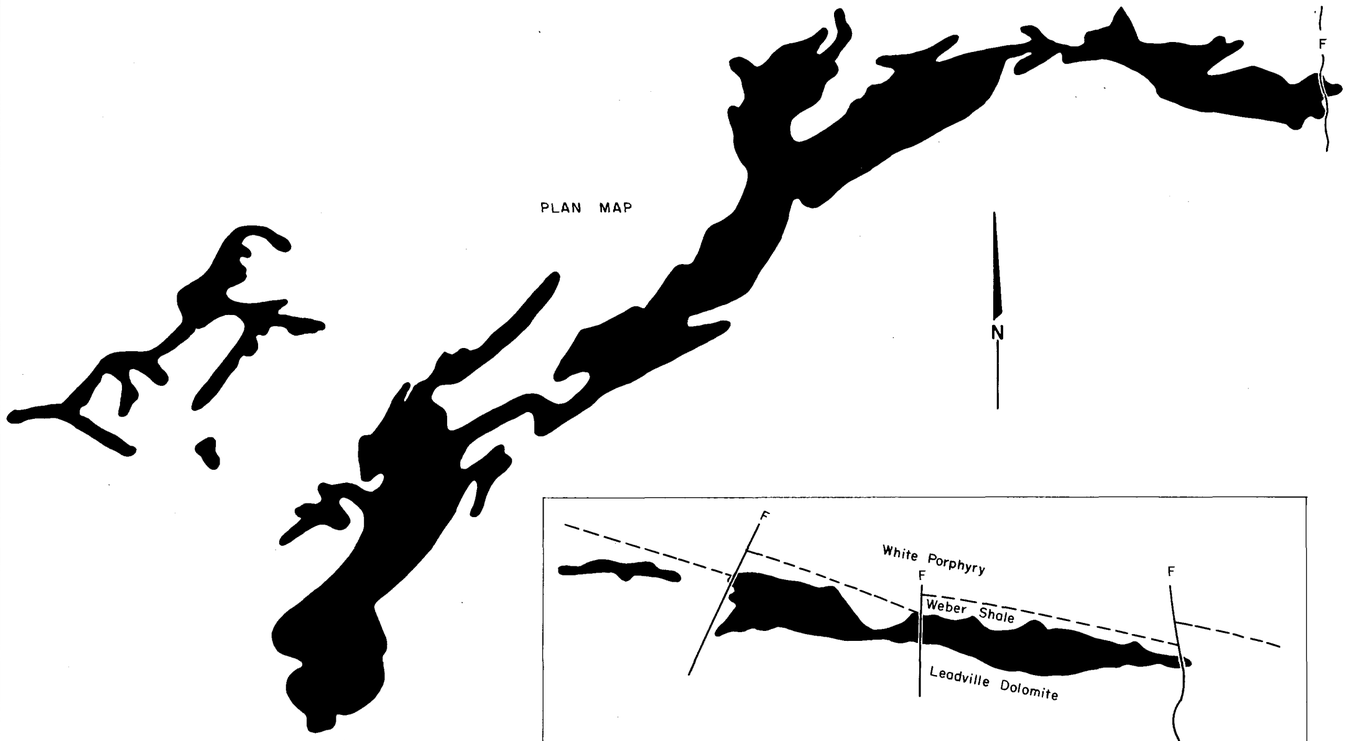
0 300' 600' 900'
scale 1" = 300'

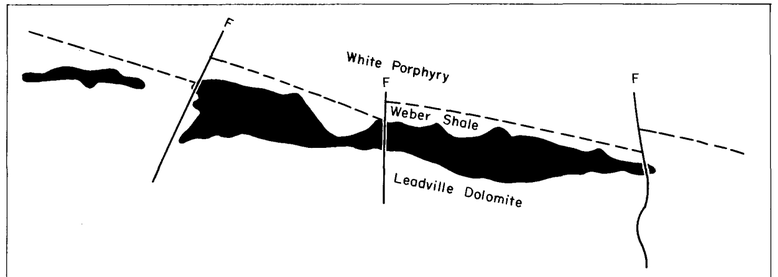
PLATE 9

GENERALIZED SECTION OF THE IRON BLOSSOM ORE ZONE TINTIC DISTRICT, UTAH

(MODIFIED FROM COOK , 1957)

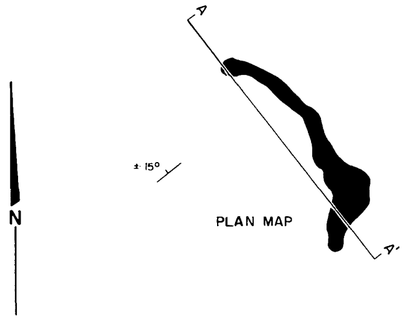
mn 5139i dam

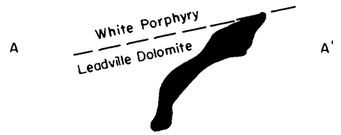




VERTICAL SECTION (PARTIAL) OF LOWER PORTION OF PLAN MAP

CONTINENTAL CHIEF MINE





SECTION A-A'

LIDDIA MINE

PLATE 10

PLAN AND SECTION OF
LIDDIA MINE
AND
CONTINENTAL CHIEF MINE
LEADVILLE DISTRICT, COLORADO

0 50' 100' 200'

scale 1" = 100'

(MODIFIED FROM BEHRE, 1953)

mn 5139j dam

PLATE II

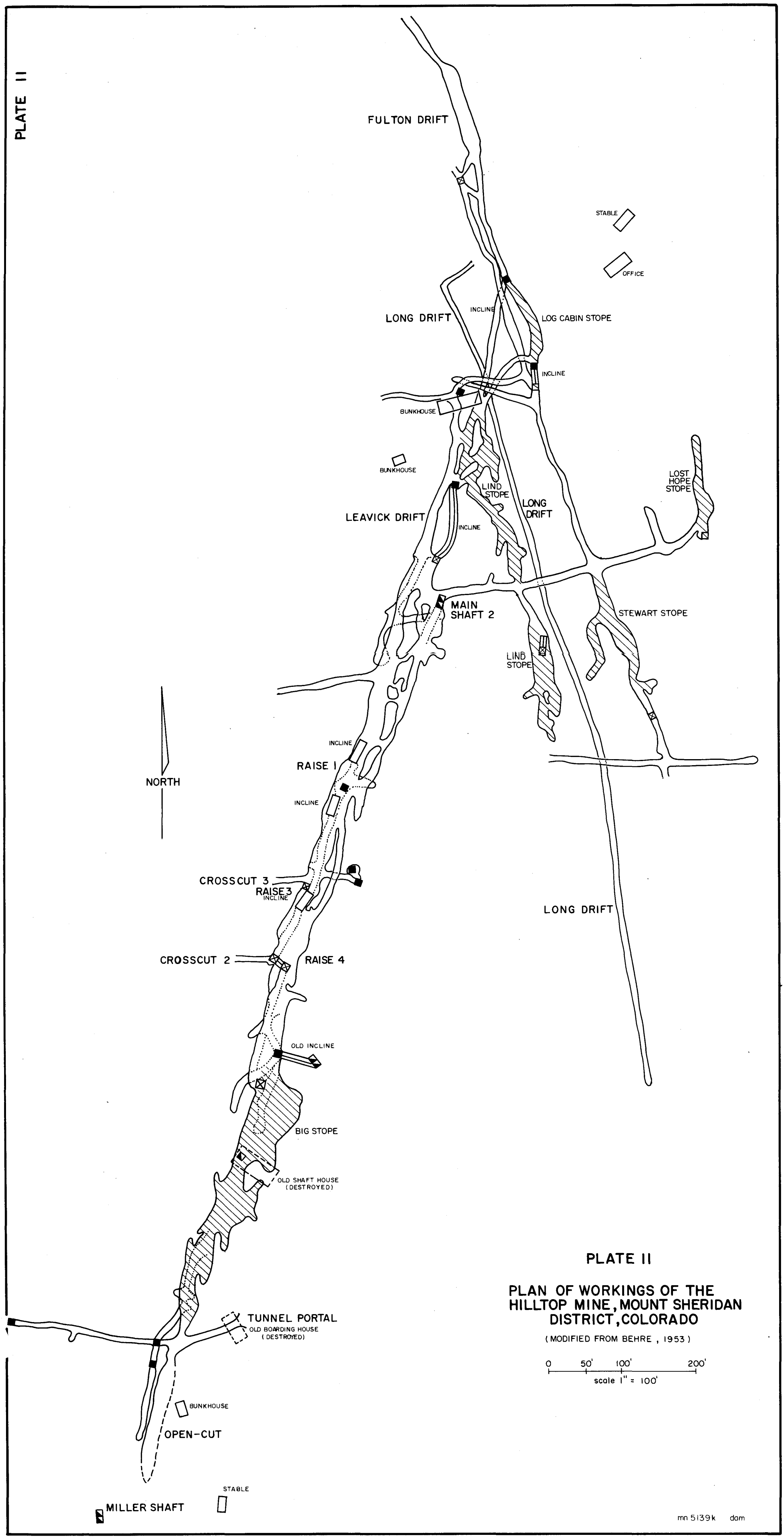


PLATE II

PLAN OF WORKINGS OF THE HILLTOP MINE, MOUNT SHERIDAN DISTRICT, COLORADO

(MODIFIED FROM BEHRE, 1953)

0 50' 100' 200'

scale 1" = 100'

mn 5139k dam