CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

The following file is part of the JABA, Inc. Tombstone Mining Records

ACCESS STATEMENT

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

CONSTRAINTS STATEMENT

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

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

QUALITY STATEMENT

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

TOMBSTONE MINING DISTRICT
COCHISE COUNTY, ARIZONA

GEOLOGY & LAND RESEARCH

VOLUME I
GEOTECHNICAL REPORTS
BOOK 3
CHARLESTON MINE AREA
PAGE 364 to 588

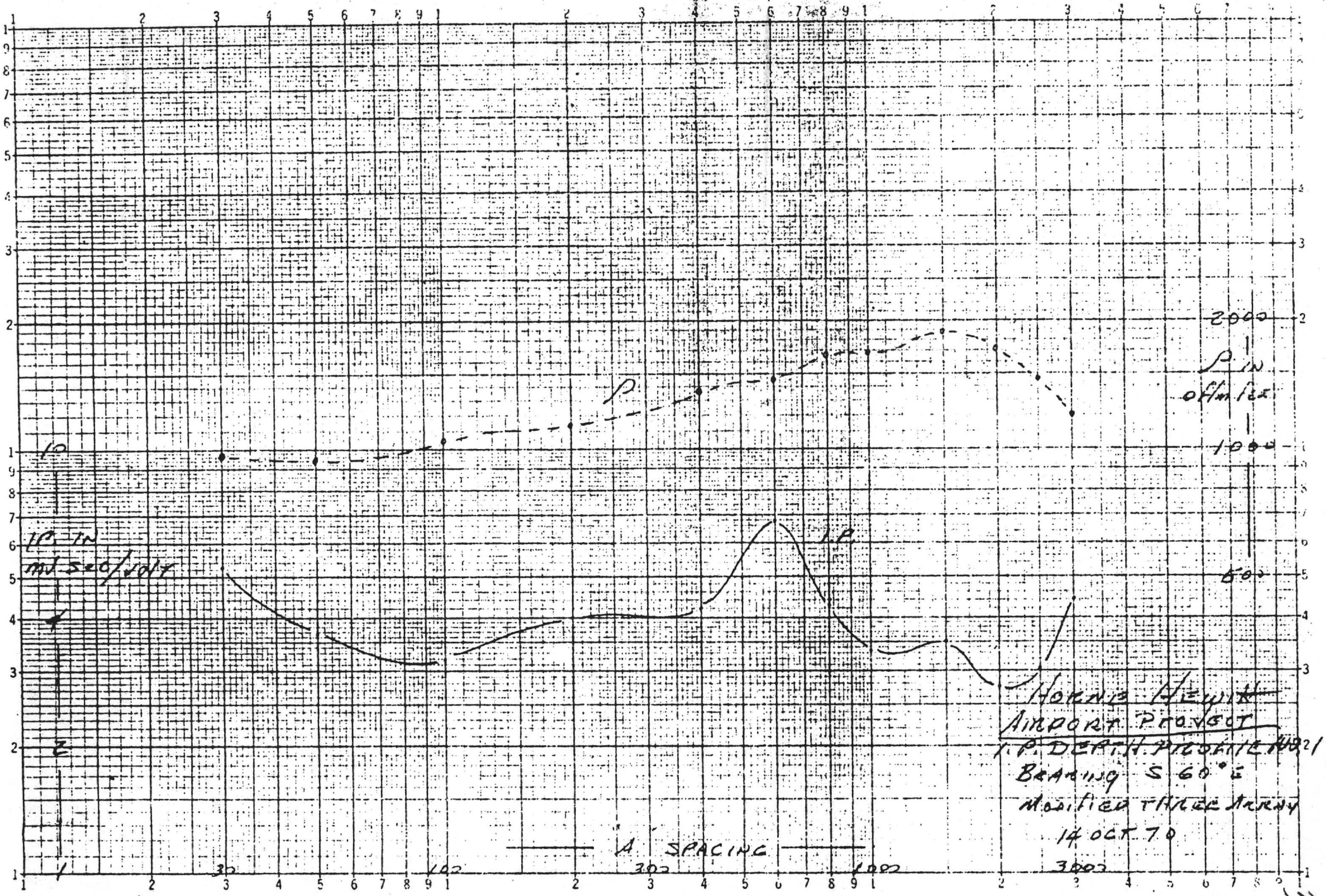
JAMES STEWART COMPANY
AUGUST, 1984

PREPARED BY:
JAMES A. BRISCOE & ASSOC., INC.
TUCSON, AZ

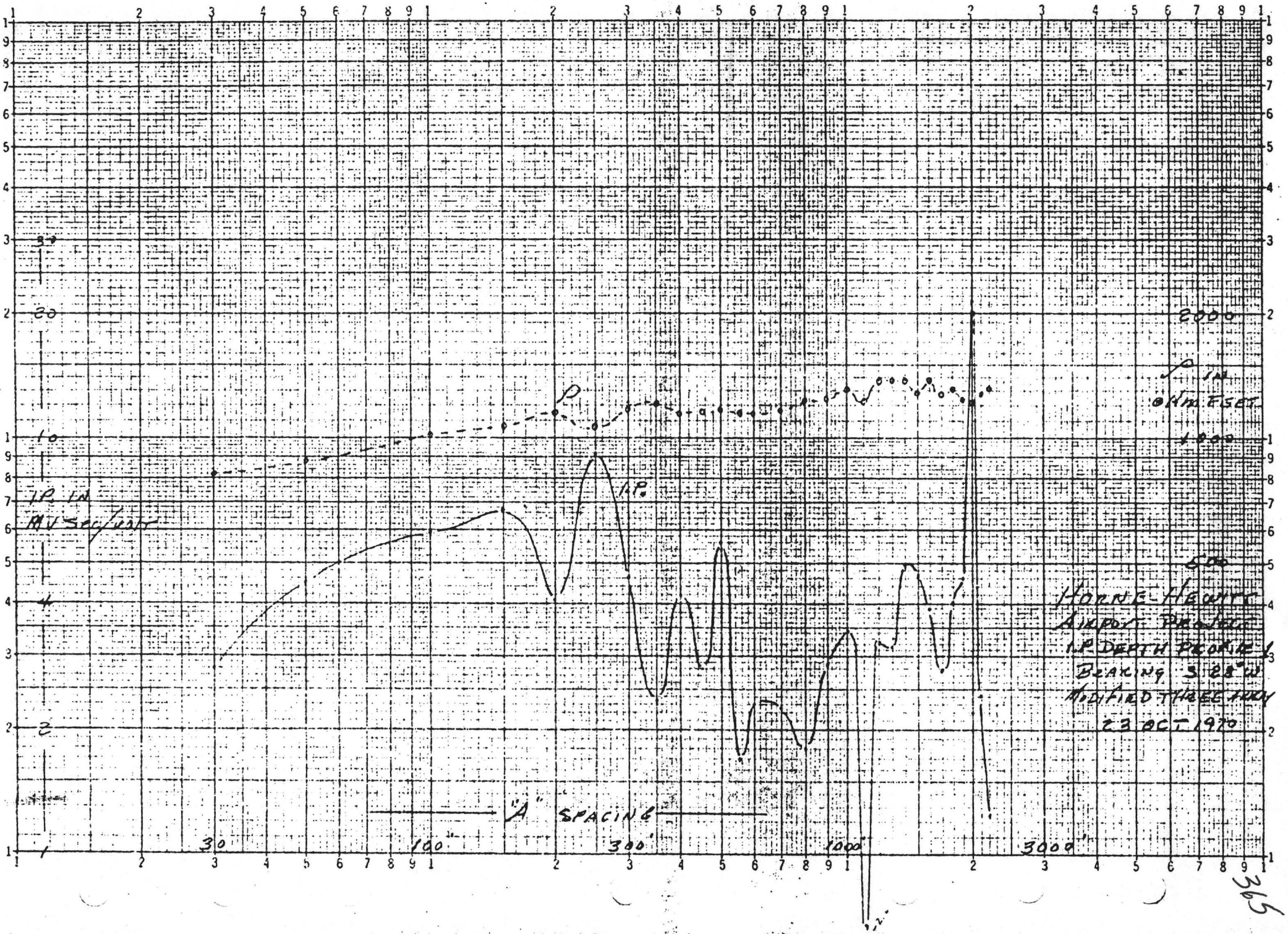
I.P. AIRPORT AREA
STEWART MINES

Tstone GSLR
VI - VIV BK#2

K•E LOGARITHMIC 2 X 3 CYCLES
KEUFFEL & ESSER CO.
46 7320

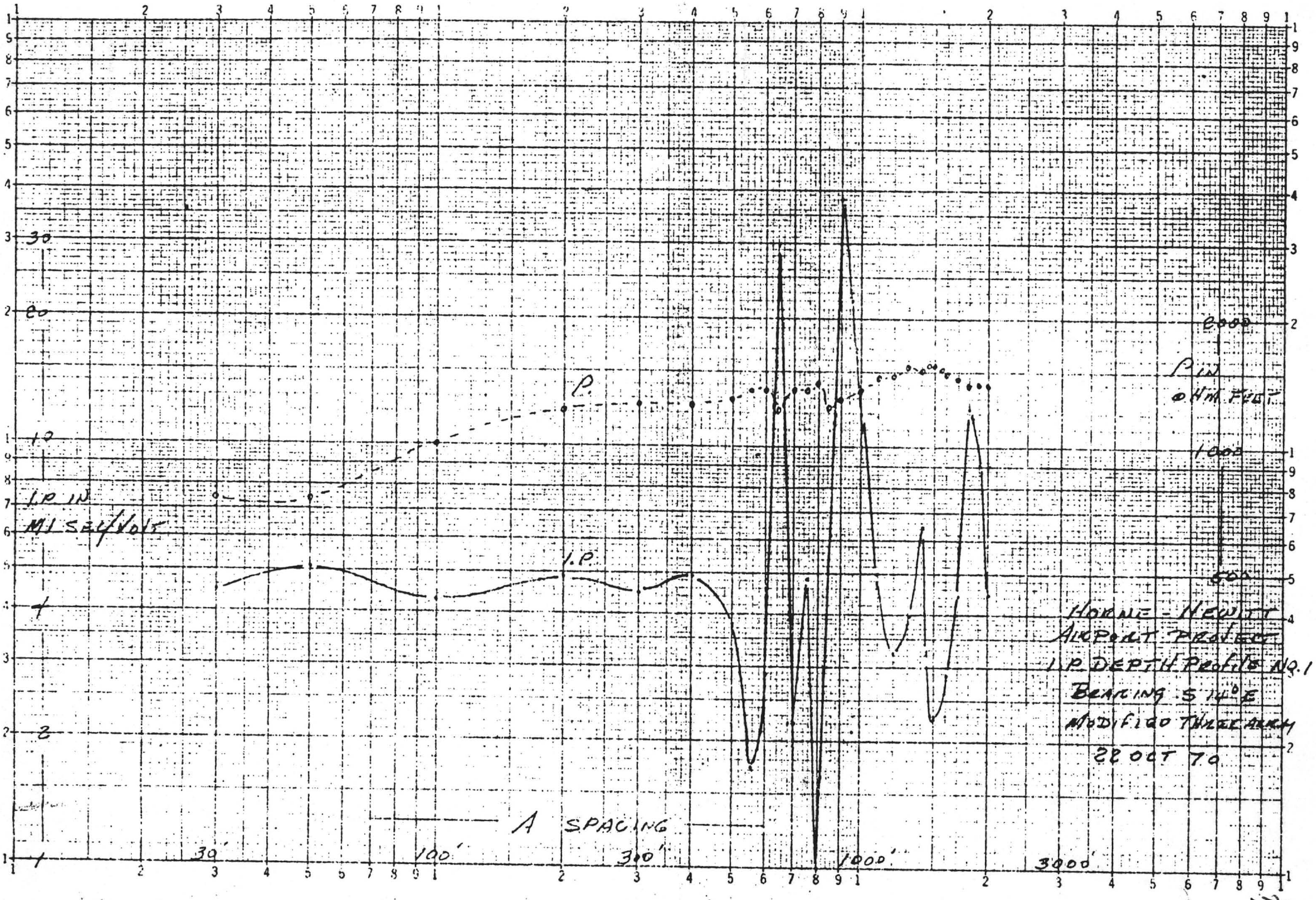


Horne Height
Airport Project
I.P. Depth Profile No. 21
Bearing S 60° E
Modified Three Array
14 OCT 70



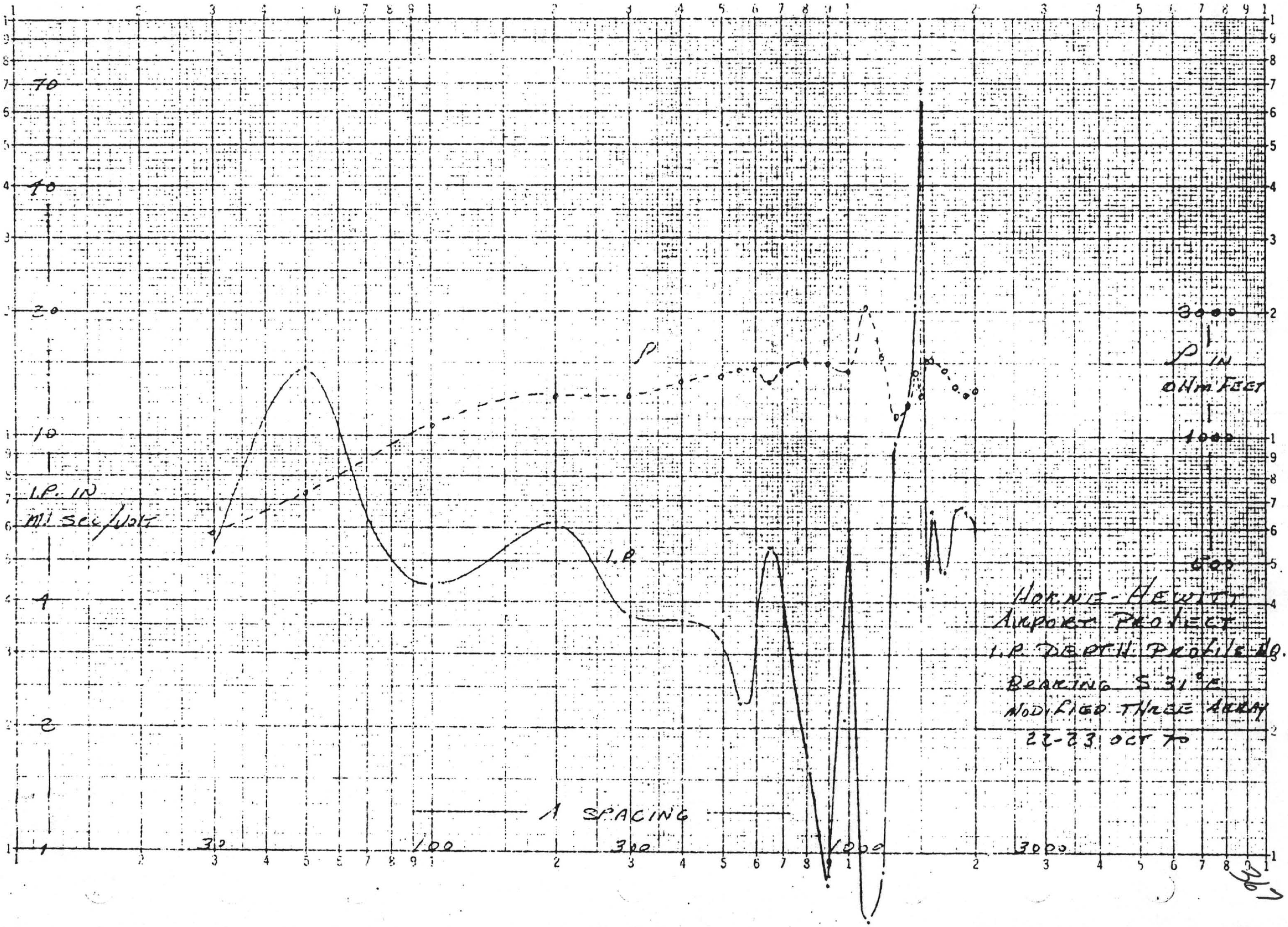
HORNE-HEWITT
AIRPORT PROJECT
IP DEPTH PROFILE 1
BEARING S 28° W
MODIFIED THREE ARRAY
23 OCT 1970

K&E LOGARITHMIC 46 7320
KEUFFEL & ESSER CO.



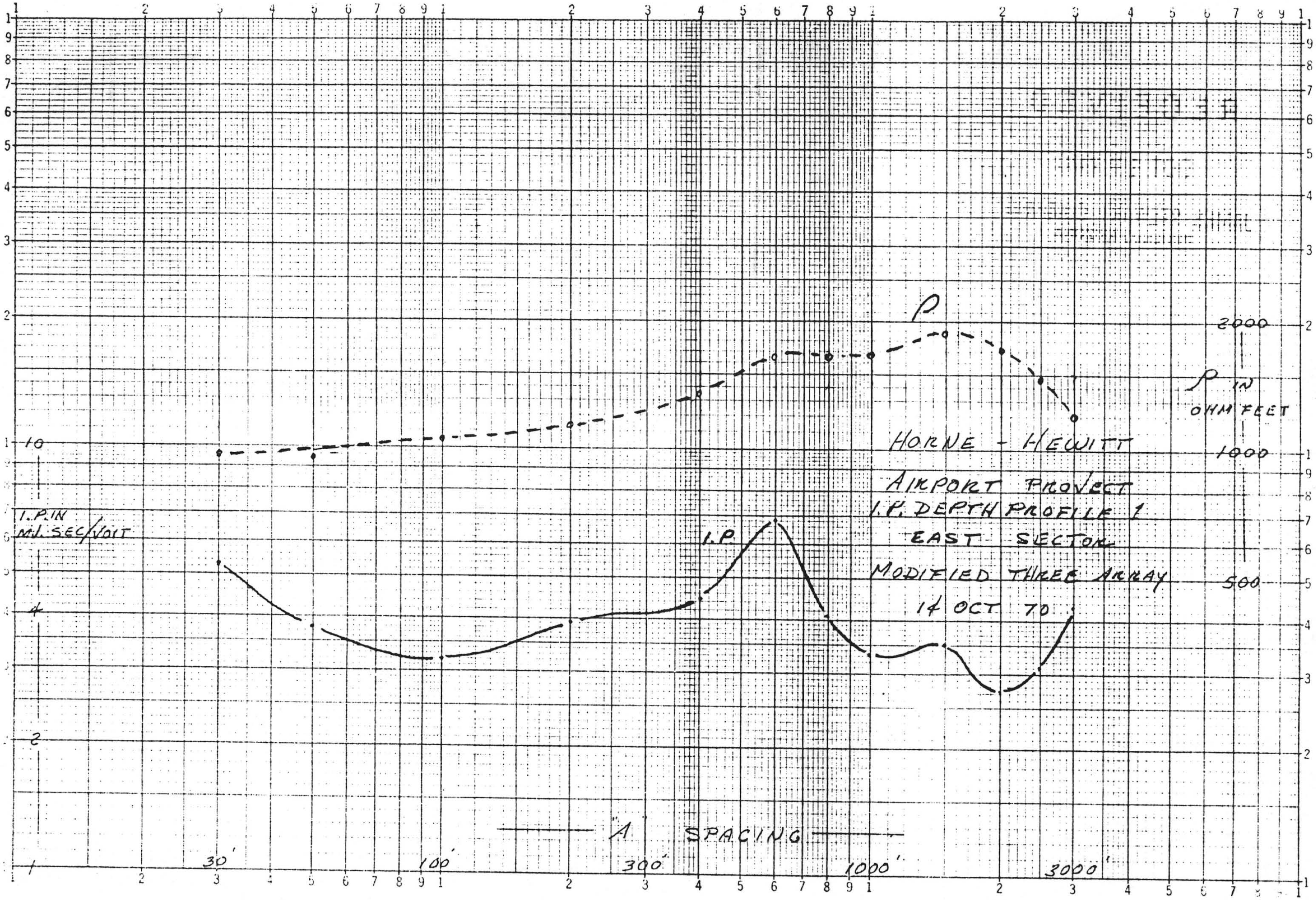
HORNE - NEWITT
AIRPORT PROJECT
I.P. DEPTH PROFILE NO. 1
BEARING S 14°E
MODIFIED THREE ARRAY
22 OCT 70

K&E LOGARITHMIC 46 7320

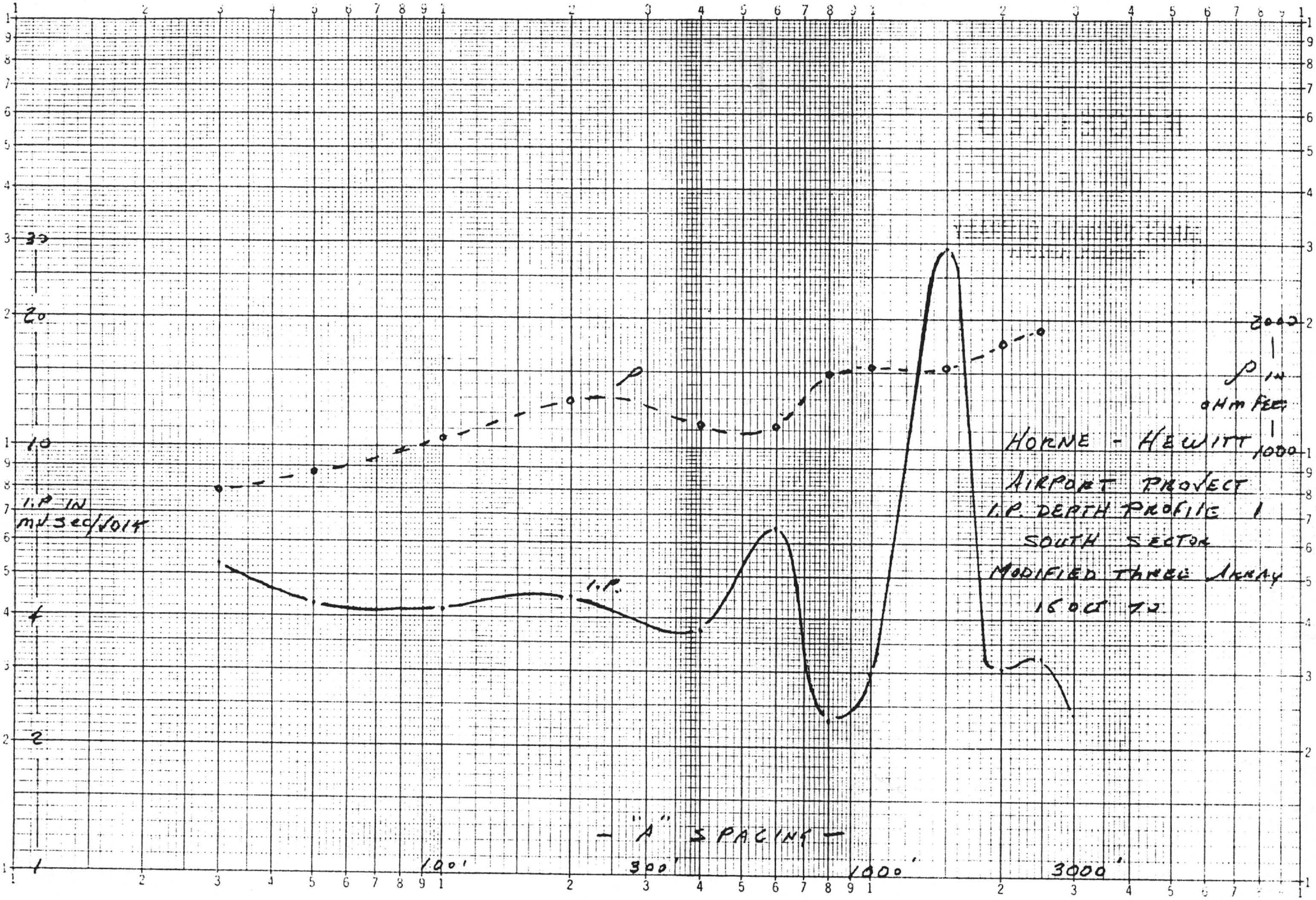


HORNE-HEWITT
AIRPORT PROJECT
I.P. DEPTH PROFILE NO. 1
BEARING S 31° E
MODIFIED THREE ARRAY
22-23 OCT 70

f86 - Airport Tomentone

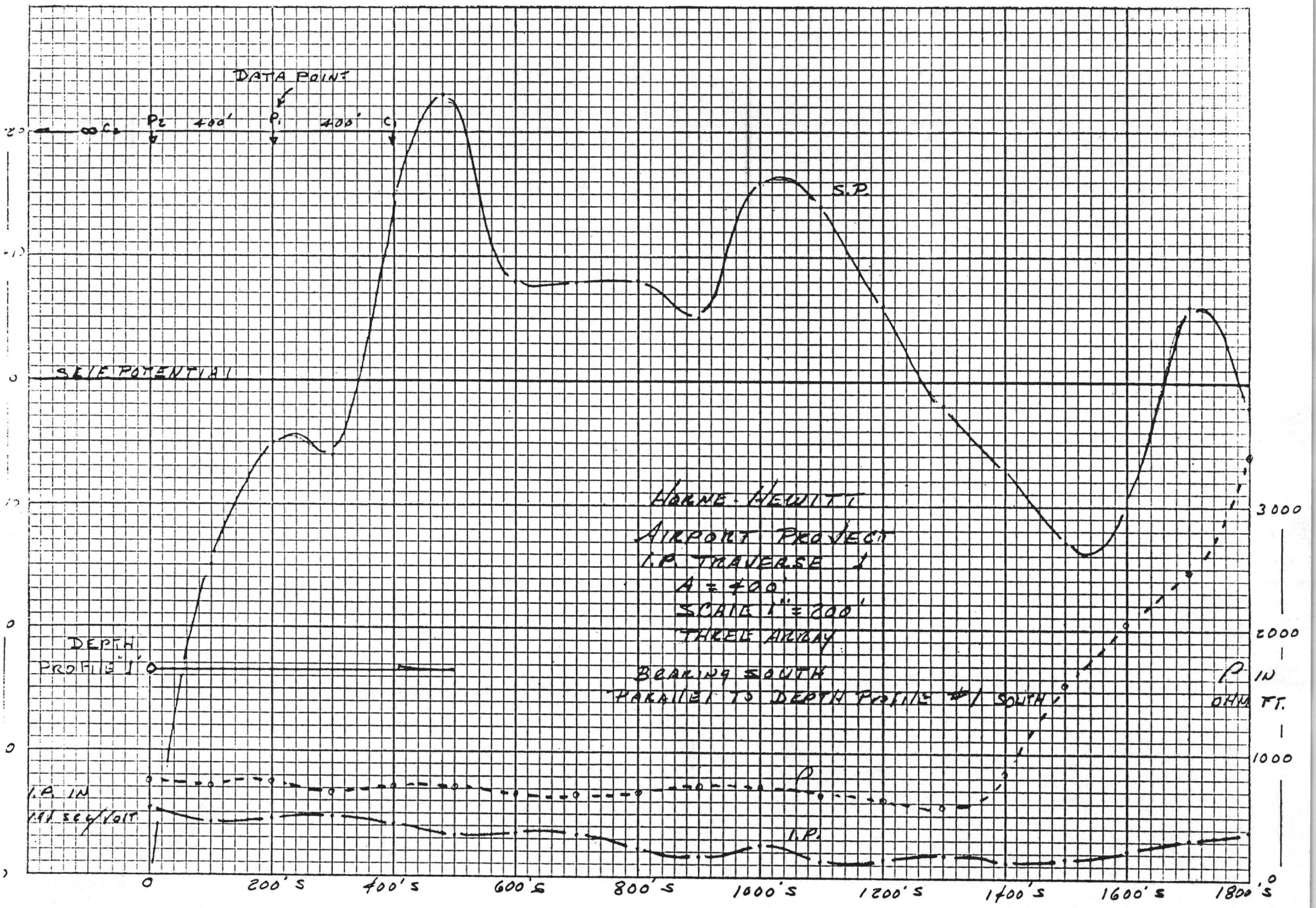


HORNE - HEWITT
AIRPORT PROJECT
I.P. DEPTH PROFILE 1
EAST SECTOR
MODIFIED THREE ARRAY
14 OCT 70



HORNE - HEWITT
AIRPORT PROJECT
I.P. DEPTH PROFILE 1
SOUTH SECTOR
MODIFIED THREE ARRAY
16 OCT 72

369

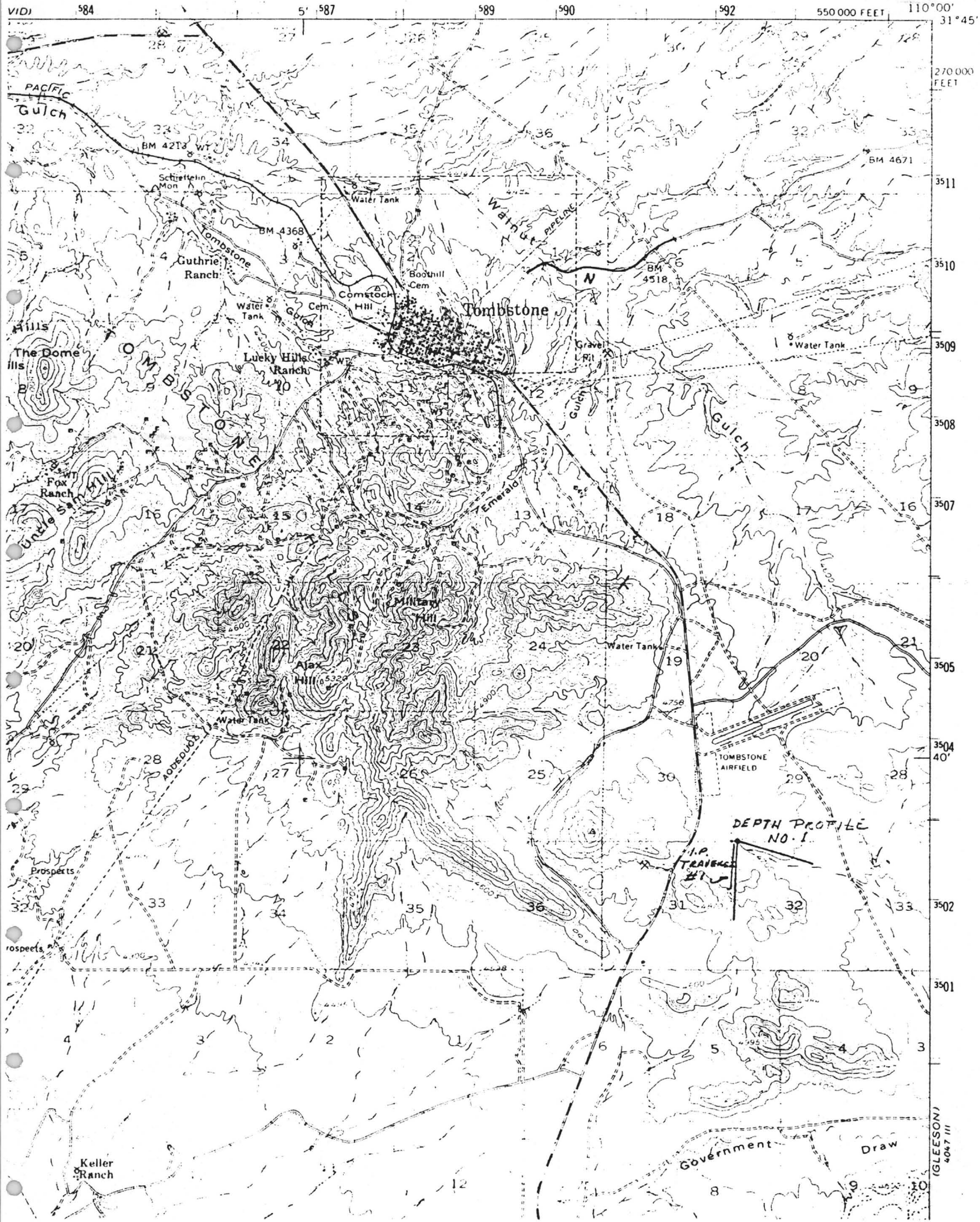

HORNE HEWITT
AIRPORT PROJECT
I.P. TRAVERSE 1
A = 400'
SCALE 1" = 200'
THREE ARRAY
BEARING SOUTH
PARALLEL TO DEPTH PROFILE #1 SOUTH
DATA POINT
∞C₂
P₂
400'
P₁
400'
C₁
S.P.
SELF POTENTIAL
DEPTH
PROFILE 1
ρ
ρ IN
OHM FT.
I.P.
I.P. IN
M SEC/VOLT
3000
2000
1000
0
0
200' S
400' S
600' S
800' S
1000' S
1200' S
1400' S
1600' S
1800' S
20
10
0
0
0

371

TATES
THE ARMY
GINEERS

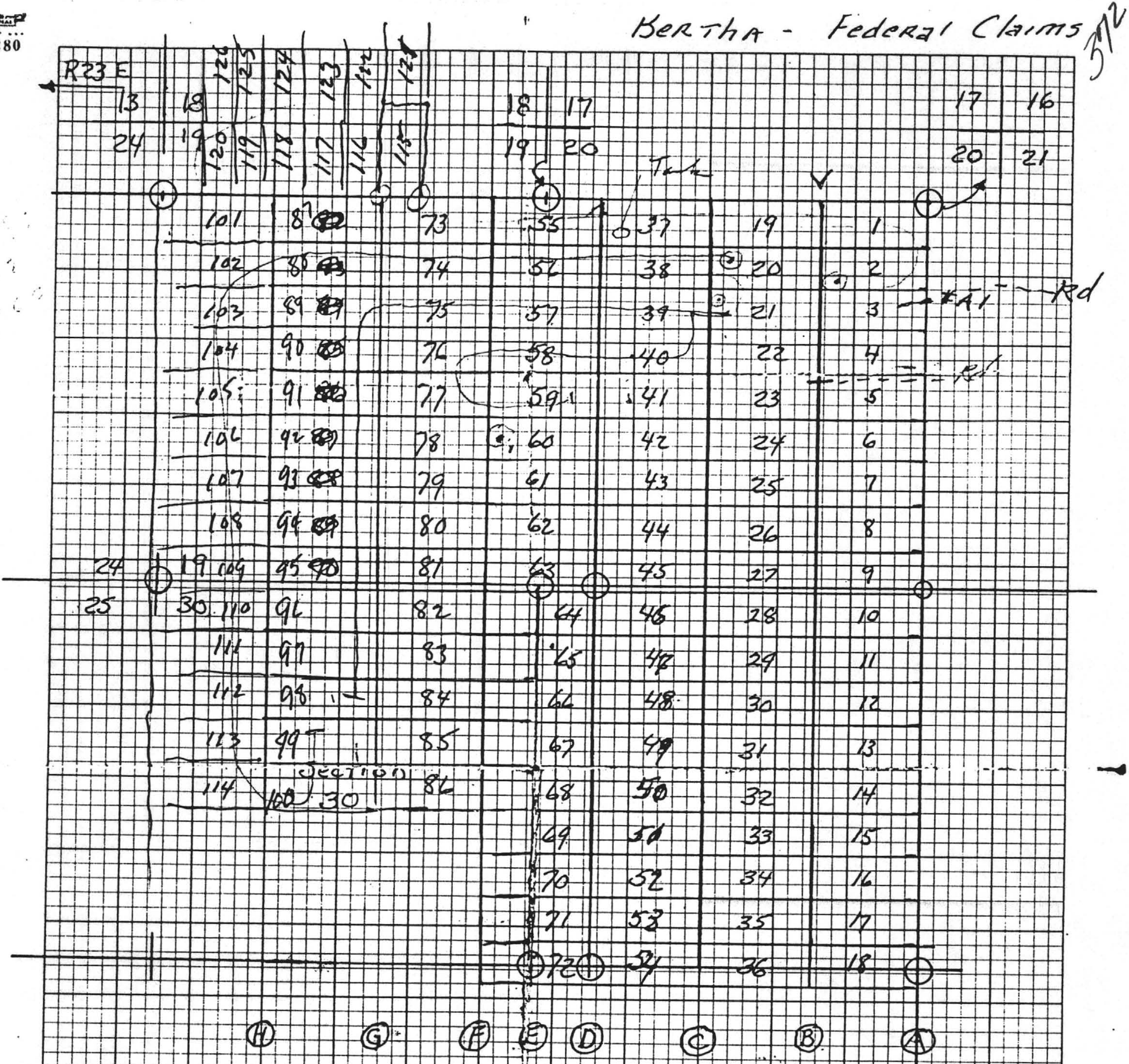
TOMBSTONE QUADRANGLE
ARIZONA—COCHISE CO.
15 MINUTE SERIES (TOPOGRAPHIC)

4047 IV
(PEARCE)



BERTHA AREA
S19 & 20 T.20S. R23E

Bertha - Federal Claims



T21S R24E

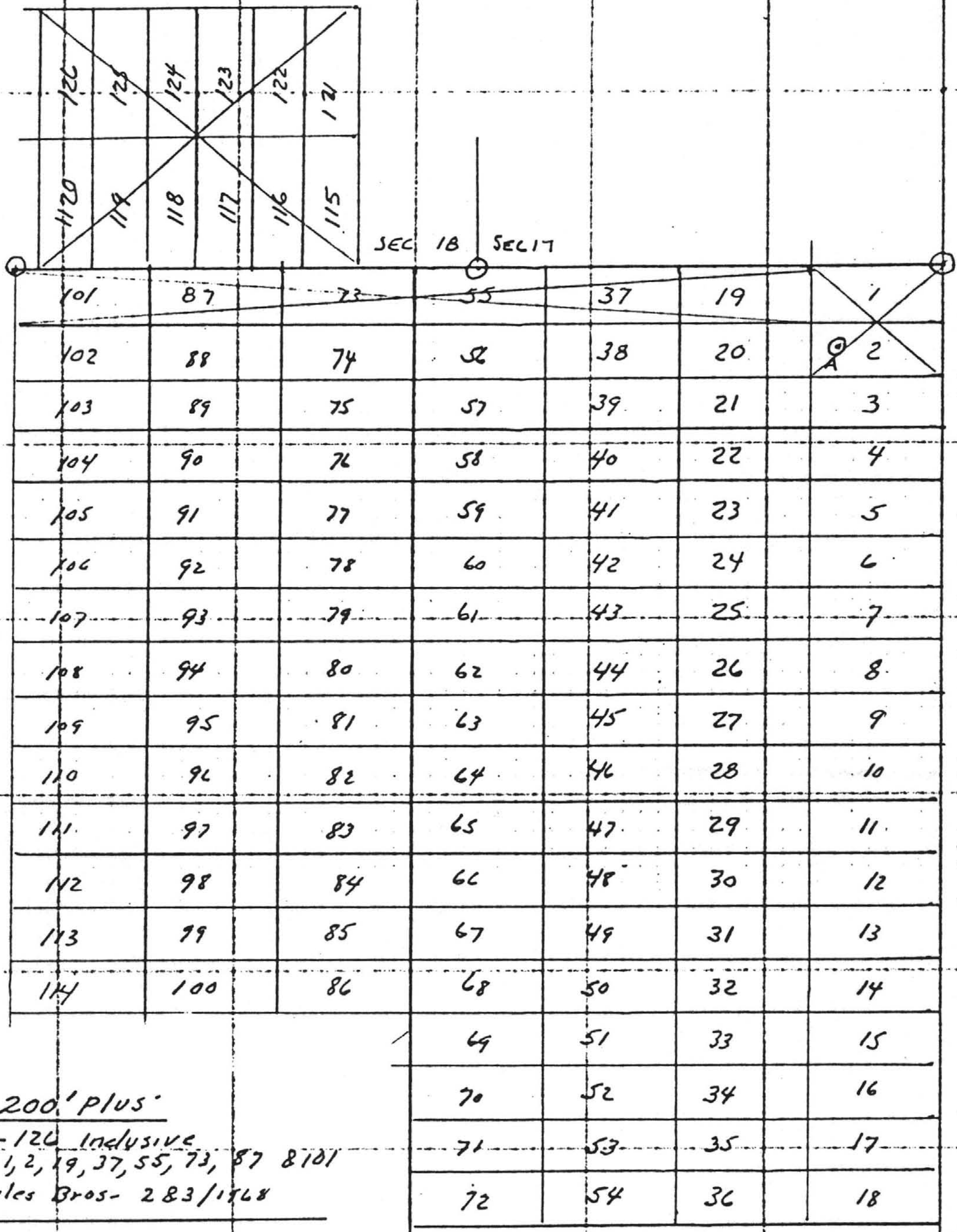
NOTE: All Claims Except #64 thru #72 Shall be 1500' x 600'

~~Claims 64 thru 72 Shall Be 600' Wide By Actual Length To Close With Section Line East Line Section 30.~~

James Stewart Company
3033 N Central
Phoenix Ariz

1/1/68

BERTHA - MINE
FEDERAL CLAIMS -
LOCATION WORK - 1968
Field Work Copy - CAC.



126	125	124	123	122	121
120	119	118	117	116	115

101	87	73	55	37	19	1
102	88	74	56	38	20	2
103	89	75	57	39	21	3
104	90	76	58	40	22	4
105	91	77	59	41	23	5
106	92	78	60	42	24	6
107	93	79	61	43	25	7
108	94	80	62	44	26	8
109	95	81	63	45	27	9
110	96	82	64	46	28	10
111	97	83	65	47	29	11
112	98	84	66	48	30	12
113	99	85	67	49	31	13
114	100	86	68	50	32	14
			69	51	33	15
			70	52	34	16
			71	53	35	17
			72	54	36	18

D. Drill Hole · Ⓐ 200' plus

Claims 121 - 126 Inclusive
plus 1, 2, 19, 37, 55, 73, 87 & 101
Drilled By Boyles Bros- 283/1968

BERTHA ASSAYS.

		Cu	oz Au	Oz Ag	% Pb	% ZN		
1-	400'±	.075						A A
2 -	900±	.04	Tr	.3				A-A
3 -	1135	.035	Tr	.3				A-A
3A	1232 , *	.035	Tr	.4				
4 -	1250	.055	0.35	Tr				V.A
5 -	1560'	.055	Tr	.3			3/29/68	A.A
6 -	1750-± Rochin	0.10	TR	4.2	0.75	0.80	4/8/68	Roch.
7 -	1780	0.08	Tr	Tr	0.73	0.17	4/15/68	✓
8 -	1794-1804*	0.045	Tr	.4			4-12	AA
	1814-1825	0.05	Tr	.4			4-12	A A
	1825 - 1834	0.04	Tr	.4			4-12	A A
	1834-1844	.06	Tr	.4			4-12	A A
	1891-1901	.06	Tr	.4			4-12	A A
	1901 - 1911	.115	Tr	.4			4-12	A A
	1780 Spectograph	.054	0	0.32 oz	0.26	0.75	4-24	Minerals Engineering Co of LA
	2135	0.14	Tr	Tr	0.15	Tr	5-2	Rochin
	2170-72	0.055		~~.32~~				A-A
	2294	.12	TR	.36				
	2514	.055	.03	.9				
	2558	Nil	Tr	.6				
	2300	.07	Tr	Tr				
	2286	.05	Tr	Tr				
	1600 Dike		Tr	.4				
	1714		Tr	.4				
	1725		Tr	.4				
	1753		Tr	.4				
	2518		Tr	.4				
	5/29/68	✓	✓	✓				
	2784	✓	✓	✓				
	2373		✓					
	1433-39		✓					
	1948		✓					
	1357		✓					
	700							

Shop No 2107

File No. 2049 ST

Date 12 APRIL 1968 [redacted]
(Registered)

815 North First Street
Phoenix, Arizona
P. O. Box 1148

Arizona Assay Office

Phone ALpine 3-4001

VALUES
Latest Quotation

1 oz. Gold
1 oz. Silver
1 lb. Copper
1 lb. Lead
1 lb. Zinc

THIS CERTIFIES
Samples submitted for assay contain as follows:

JAMES STEWART CO
PHOENIX ARIZONA 85012

Short Ton	2000 Lbs.
Short Ton Unit	20 Lbs.
Long Ton	2240 Lbs.
Long Ton Unit	22.4 Lbs.

MARKS	SILVER PER TON		VALUE PER TON	GOLD PER TON		VALUE PER TON	TOTAL VALUE PER TON of Gold & Silver	PERCENTAGE				REMARKS
	Ozs.	Tenths		Ozs.	100ths			COPPER				
Charleston # 3 -2107		.40						0.04				
B B 1232		.40		TRACE				0.035				
BERTHA # 1 BOX 188 1794-1804		.40		NIL				0.045				
BERTHA BOX 190 1814 - 1825		.40		TRACE				0.05				
BOX 191 1825 -1834		.40		TRACE				0.04				
DIKE - BOX 192 1834 - 1844		.40		TRACE				0.06				Bertha - 19.00
BERTHA- BOX 195 1891 - 1901		.40		TRACE				[illegible]	(0.06)			Lime - 45.50
BERTHA - BOX 196 1901 - 1911		.40		TRACE				0.115				Ch - 5.50
L - 1 - 139								0.03				$70.00
L - 1 - 143								0.02				
L - 1 - 144								0.03				
L - 1 - 148		.40		TRACE				0.02				
L - 1 - 150								0.05				
L - 1 - 153								0.05				

Bertha

Bertha

Limestone Project

Charges $ 70.00

Assayer

E. A. STONE
DEC. 31

ANDY CHUKA, PRINT

375

Shop No. 149
File No. 2037 ST

Date 18 March 1968

Charleston

Arizona Assay Office

815 NORTH FIRST STREET
Phone: 253-4001

Phoenix, Arizona 85001
P. O. BOX 1148

VALUES
Latest Quotation

1 oz. Gold
1 oz. Silver
1 lb. Copper
1 lb. Lead
1 lb. Zinc

THIS CERTIFIES
Samples submitted for assay contain as follows:

JAMES STEWART CO
Phoenix Arizona

Short Ton	2000 Lbs.
Short Ton Unit	20 Lbs
Long Ton	2240 Lbs.
Long Ton Unit	22.4 Lbs.

MARKS	SILVER PER TON		VALUE PER TON	GOLD PER TON		VALUE PER TON	TOTAL VALUE PER TON of Gold & Silver	PERCENTAGE	REMARKS
	Ozs.	Tenths		Ozs.	100ths			COPPER	
E-1-1135		.3	$ .45	TRACE				0.035	
3-2077								0.05	

Charge 9.00

Assayer

JACK. STONE REG. No. 5479

3/16

Charleston

Shop No. 141
File No. 2036 ST
Date 11 MARCH 1968

Arizona Assay Office

815 NORTH FIRST STREET
Phone: 253-4001

Phoenix, Arizona 85001
P. O. BOX 1148

VALUES
Latest Quotation

1 oz. Gold
1 oz. Silver
1 lb. Copper
1 lb. Lead
1 lb. Zinc

JAMES STEWART CO
PHOENIX
ARIZONA

Short Ton	2000 Lbs.
Short Ton Unit	20 Lbs.
Long Ton	2240 Lbs
Long Ton Unit	22.4 Lbs.

THIS CERTIFIES
Samples submitted for assay contain as follows:

MARKS	SILVER PER TON Ozs.	Tenths	VALUE PER TON	GOLD PER TON Ozs.	100ths	VALUE PER TON	TOTAL VALUE PER TON of Gold & Silver	PERCENTAGE COPPER	REMARKS
B - 1 - 960		.3	$.45	TRACE				0.04	
B - 1 - 900								0.04	
1980								0.04	
[illegible]	Charleston								

Charges 11.50

Assayer Jack Stone
JACK A. STONE
DEC. 3
JACK STONE REG. NO. 5479

377

Shop No. 270
File No. 2046 ST

Date 25 April 1968

Arizona Assay Office

815 NORTH FIRST STREET
Phone: 253-4001

Phoenix, Arizona 85001
P. O. BOX 1148

VALUES
Latest Quotation

1 oz. Gold..........
1 oz. Silver..........
1 lb. Copper..........
1 lb. Lead..........
1 lb. Zinc..........

JAMES STEWART CO
PHOENIX ARIZONA

Short Ton	2000 Lbs.
Short Ton Unit	20 Lbs.
Long Ton	2240 Lbs.
Long Ton Unit	22.4 Lbs.

THIS CERTIFIES
Samples submitted for assay contain as follows:

MARKS	SILVER PER TON Ozs.	SILVER PER TON Tenths	VALUE PER TON	GOLD PER TON Ozs.	GOLD PER TON 100ths	VALUE PER TON	TOTAL VALUE PER TON of Gold & Silver	PERCENTAGE COPPER	REMARKS
B B - 1 [illegible] 2040		.40		TRACE				0.045	
L-1 - 2668		.40						0.04	
#3 - 2218		.40						0.035	

JACK STONE
DEC 31, 68

Charges $ 17.50

Assayer..........
JACK STONE Reg. No. 5479

ANDY CHUKA, PRINT

ECTOR C. ROCHIN
MANAGER
REGISTERED ASSAYER
RIZONA REG. No. 4073

ROCHIN ENGINEERING AND ASSAY OFFICE
P. O. BOX 218 PHONE 364-8092
DOUGLAS, ARIZONA - 85607

HECTOR A. ROCHIN
MINING ENGINEER AND
LAND SURVEYOR
ARIZONA REG. No. 2472

CERTIFICATE OF ASSAY

ame James Stewart Co. Address 3033 N. Central Phoenix, Arizona

	GOLD OZS	SILVER OZS	COPPER %	LEAD %	Zn %				
ab 23235 B-1-1780 (Core)	Tr	Tr	0.08	0.73	0.17				

4073
H. C. ROCHIN
Date Signed

REMARKS:	DATE:	CHARGES
	15 Apr 68	$ 11.20

379

Shop No. 134
File No. 2034 ST

Date 7 MARCH 1968

Arizona Assay Office

815 NORTH FIRST STREET
Phone: 253-4001

Phoenix, Arizona 85001
P. O. BOX 1148

VALUES
Latest Quotation

1 oz. Gold
1 oz. Silver
1 lb. Copper
1 lb. Lead
1 lb. Zinc

JAMES STEWART CO
PHOENIX ARIZONA 85012

Short Ton	2000 Lbs.
Short Ton Unit	20 Lbs.
Long Ton	2240 Lbs.
Long Ton Unit	22.4 Lbs.

THIS CERTIFIES
Samples submitted for assay contain as follows:

MARKS	SILVER PER TON		VALUE PER TON	GOLD PER TON		VALUE PER TON	TOTAL VALUE PER TON of Gold & Silver	PERCENTAGE				REMARKS
	Ozs.	Tenths		Ozs.	100ths			COPPER				
206-L-1								0.18				
RED CORE ~ Bertha - 500± zone								0.075				

RECEIVED
MAR 11 1968
JAMES STEWART COMPANY
PHOENIX, ARIZONA

Charges $ 5.00

Assayer
JACK STONE Reg. No. 5479

ANDY CHUKA, PRINT

LIMESTONE PROJECT
STEWART MINES

38'

MEMORANDUM TO FILE March 4, 1968

RE: Mining - Limestone

Disc of Hole →

Diamond drilling of this deposit was authorized on February 29. Drill location was picked near the limestone outcropping which occurs on State Land Section 7, T 20 S, R 22 E. However, actual drilling is on Federal Land approximately 15 feet west of east section line and on the Claim Horne #123 near the east end center post.

Geophysics of the hole reveals:

~~Depth to Cu~~	~~825'~~
~~Ore Thickness~~	~~1080'~~
~~"A"~~	~~12.6~~
~~"B"~~	~~11.6~~

~~Geophysics of spot 175' southeast~~

~~Depth of to Cu~~	~~750'~~
~~Ore Thickness~~	~~1365'~~
~~"A"~~	~~10.5~~
~~"B"~~	~~7.7~~

MEMORANDUM TO FILE

March 7, 1968

RE: Limestone - Boyles Brothers Drilling - HOLE L-1

Wednesday evening, March 6, 1968 - 4 p.m. - Hole at 250' depth. Now in the U. S. Porphry - fairly good alteration zones in preceding 100'. A sample taken at 206' to be assayed.

C. A. Cosgrove

CAC:ef

Shop No. 2107
File No. 2040 ST

Date 12 APRIL 1968 [illegible]
(Registered)

Arizona Assay Office

Phone ALpine 3-4001

815 North First Street
Phoenix, Arizona
P. O. Box 1148

VALUES
Latest Quotation

1 oz. Gold
1 oz. Silver
1 lb. Copper
1 lb. Lead
1 lb. Zinc

JAMES STEWART CO
PHOENIX ARIZONA 85012

Short Ton .... 2000 Lbs.
Short Ton Unit .... 20 Lbs.
Long Ton .... 2240 Lbs.
Long Ton Unit .... 22.4 Lbs.

THIS CERTIFIES
Samples submitted for assay contain as follows:

MARKS	SILVER PER TON Ozs.	SILVER PER TON Tenths	VALUE PER TON	GOLD PER TON Ozs.	GOLD PER TON 100ths	VALUE PER TON	TOTAL VALUE PER TON of Gold & Silver	PERCENTAGE COPPER	REMARKS
Charleston # 3 -2107		.40						0.04	
B B 1232		.40		TRACE				0.035	
BERTHA # 1 BOX 188 1794-1804		.40		NIL				0.045	
BERTHA BOX 190 1814 - 1825		.40		TRACE				0.05	
BOX 191 1825 - 1834		.40		TRACE				0.04	
DIKE - BOX 192 1834 - 1844		.40		TRACE				0.06	
BERTHA- BOX 195 1891 - 1901		.40		TRACE				[illegible] (0.06)	
BERTHA - BOX 196 1901 - 1911		.40		TRACE				0.115	
L - 1 - 139								0.03	
L - 1 - 143								0.02	
L - 1 - 144								0.03	
L - 1 - 148		.40		TRACE				0.02	
L - 1 - 150								0.05	
L - 1 - 153								0.05	

Charges $ 70.00

Assayer

REGISTERED ASSAYER
CERTIFICATE EXPIRES
DEC. 31, 19
ARIZONA, U.S.A.

OY CHUKA, PRINT

Shop No 270 ~~2046 ST~~

File No.

Date 25 April 1968

Arizona Assay Office

815 NORTH FIRST STREET

Phone: 253-4001

Phoenix, Arizona 85001

P. O. BOX 1148

VALUES
Latest Quotation

1 oz. Gold

1 oz. Silver

1 lb. Copper

1 lb. Lead

1 lb. Zinc

JAMES STEWART CO
PHOENIX ARIZONA

Short Ton	2000 Lbs.
Short Ton Unit	20 Lbs.
Long Ton	2240 Lbs.
Long Ton Unit	22.4 Lbs.

THIS CERTIFIES
Samples submitted for assay contain as follows:

MARKS	SILVER PER TON Ozs.	SILVER PER TON Tenths	VALUE PER TON	GOLD PER TON Ozs.	GOLD PER TON 100ths	VALUE PER TON	TOTAL VALUE PER TON of Gold & Silver	PERCENTAGE COPPER	REMARKS
EB - 1 2040		.40		TRACE				0.046	
L-1 - 266 Limestone 2669?		.40						0.04	
#3 - 2218		.40						0.038	

Charges $ 17.50

Assayer

JACK STONE Reg. No. 5479

ANDY CHUKA, PRINT

DOHERTY REPORT

385

TOMBSTONE PACKET

COMPILED JERRY E. DOHERTY

TOMBSTONE SUMMARY

By Jerry E. Doherty

December 30, 1976

The information available for the Tombstone Mining District on the subject of ore reserves and ore potential is quite vast. This report is a summary of numerous reports and evaluations by geologists, engineers, mine operators, consultants and promoters written on the Tombstone Mining District at a previous time.

DISCOVERY

The Tombstone Mining District was discovered by Ed Schieffelin in 1877. He was camping in the vicinity when he noticed rock similar to the gold-silver bearing rock he had seen at other mines. Subsequent sampling and assaying disclosed that Schieffelin had made a most important discovery which would result in one of the most famous mining camps in the United States. Within three years Tombstone was a prosperous city with thousands of residents.

EARLY MINING

Early mining was on the outcropping ledges and fissures of high grade ore in the area. This "glory hole" mining yielded considerable quantities of ore. Large tonnages of high grade ore were also mined near the surface from the apexes of anticlinal structures that predominate in the vicinity of the Toughnut Mine.

Subsequent mining was concentrated on the anticline structures (general plunge easterly), fissures, replacement beds and veins, and along the contacts of the near vertical dikes that strike north-south through the district. These structures were pursued down to the water table and laterally for considerable distances. Many unknown structures were disclosed as a result.

GEOLOGIC HISTORY

Pre-mineral ground preparation in any mining district is critical. The channelways for mineralizing fluids must exist and be of such a nature as to carry the mineralizing solutions away from their source and keep them contained until the chemical, temperature and pressure controlled exsolution point of the various minerals is reached and they precipitate out forming ore bodies. The nature and chemical composition of the rock types comprising the channelway is also a factor: the more reactive the rock type is to the hydrothermal fluids, the more likely it is to be mineralized. Tombstone was well prepared.

An intrusion of quartz latite porphyry (Uncle Sam Porphyry) came into sedimentary units comprised of limestone, shales, cherts, sandstones, quartzites, etc. already folded and faulted by tectonic activity, causing some doming activity which undoubtedly opened up weaknesses, existing joints and faults producing wide spread fissuring. Into many of these fissures came intrusions of andesite porphyry and slightly later intrusions of rhyolite porphyry dikes along many of the same and some additional fissures.

Next a series of steeply dipping north-northeast trending fissures developed probably as a result of stresses built up in the rock from the final intrusion of Schieffelin granodiorite. Subsequent to this episode and most likely related to it came a magmatic segregation of gold, silver, copper, manganese, lead, zinc and various other minerals of lesser economic importance in an aqueous solution. This solution migrated away from its source along the various faults, fissures, joints, breccia zones, and open bedding planes until exsolution occurred producing the mineralized structures observed throughout the district. It would be safe to say that nearly every structure occurring within the structurally induced syncline that comprises the Tombstone Mining District is mineralized at some point. Some structures are mineralized throughout their extent.

TYPES OF STRUCTURES AND ORE CHARACTERISTICS

According to the University of Arizona Bulletin No. 143, the most productive deposits, in order of their decreasing importance, were those associated with north-south dike fissures, faults, anticlines and northeast fissures only. Much depended on the rock type encountered by the ascending ore solutions. In general, it seems that porous or broken limestone capped by shale or other impermeable units were the most favorable host rocks.

The hosts themselves can also be listed in order of decreasing importance as producers. In order they are mineralized fault breccias and gouges, blue limestone, novaculite, "10-foot" and "6-foot" limestones, shales and sandstones of the Bisbee formation, Naco limestone and dike material.

The accompanying table graphically shows these structure-rock character relationships. As an example, the best ore has been produced from the areas where the northeast fissures have intersected fault breccias and gouge, or the fissures are made up of these two materials. Less importance is an intersection of a northeast fissure with the "10-foot" and "6-foot" limestone units of the Bisbee formation. Of lesser importance is the intersection of the north-south dike fissures with these same units. The least productive combination would be dike material in an anticline or roll.

The effect of accessory minerals in the rock on mineral deposition is not known but appears to be minimal.

Generally all ore mined to date has certain characteristics: it occurs in broken or porous rock, some type of alteration invariably occurs around the mineralized zone, ore shoots are almost always continuous and connect to a main fissure at some point, and ore is usually associated with various oxide and some carbonate minerals, but changes to the character of auriferous to argentiferous sulfides below the water table.

WATER TABLE

The water table is approximately 4115 feet above sea level or about 500 feet below the surface. It was known that the gold-silver values continued undiminished for short distances below the water and believed that they should continue for hundreds of feet.

In an effort to exploit this possible ore, attempts were made to dewater the Tombstone mines. These proved only temporarily successful as political hassles, carelessness, mechanical failures and caving ground forced the suspension of pumping. However, the 1000 foot level in the vicinity of the Grand Central and the Contention Mines was reached and the water was being successfully controlled before trouble closed the deep levels.

Even though dewatering operations eventually failed, much data was gained. It was proved that the ore continues down wherever it has been pursued. Some subwater table mining was done in the Contention, Grand Central, Luck Sure, Emerald, West Side and Silver Thread mines. It was discovered that not only does the ore continue, but the gold and silver content tends to increase with gold showing the greater gain. In addition, quite good values in lead, zinc and some manganese sulfides have been encountered.

It was further proven that by continuous pumping at a rate of 4500 gallons per minute the dewatering could be effected to the 1000 foot level and a steady gain on dewatering the Tombstone basin was made. A substantially lower pumping rate of about 2100 gallons per minute is all that would be required to reach the 800 foot level.

PRODUCTION

In trying to arrive at an overall production figure, a great many unknowns were encountered. Ore from company operations outside of Tombstone was grouped with ore from Tombstone branch operations on occassion. Some mines kept no records of ore shipped to the many custom mills that operated in the Tombstone Mining District. Some high grade ore was not milled but sent directly to the smelter, and other mines had their own mills at the mine site and usually kept no records or poor records at best. Portions of mines were leased out to private individuals. The price of gold and silver fluctuated considerably and many production reports were given in dollars and cents rather than ounces of gold and silver or pounds of other recovered elements (lead, zinc, copper and manganese). Three major factors unmentioned in any publication but nevertheless important in an estimate of total production must be the possible falsifying of mill and smelter records, the high penalties placed on the ore by these concerns to increase their profits, and the practice of "high-grading" or stealing of high grade ore, free gold and native silver by the miners themselves. Taking these factors into consideration, it is easily seen that any given figure will have to be up-graded by an unknown percentage.

Based on production figures and records from several different sources and by applying known and assumed facts to calculate unknown values and quantities, this writer arrived at a set of figures giving production from 1879 through 1936. These calculations showed 1,587,195 tons of ore shipped valued at $38,000,000. This ore contained 217,118.52 ounces of gold and 33,803,559 ounces of silver. In addition, there was in excess of 2,500,000 pounds of copper, 25,000,000 pounds of lead, 1,000,000 pounds of zinc and an unknown amount of manganese derived from the Tombstone mines.

Dr. C. J. Sarle's report on the Melgren Mines of the Tombstone Mining District of September 5, 1928 gives a production figure of "approximately $79,000,000" contributed by the twenty odd mines in the main Tombstone area. No details are given as to how Dr. Sarle arrived at this figure. Elsewhere he states, "The ores of the whole Tombstone Mining District may be classified as high grade. The earlier operators shipped and milled ore having an average value of $100 per ton or better and hundreds of tons were shipped from Tombstone running a thousand dollars or more". (Per ton)

A report by William P. Blake to the Development Company of America entitled "Tombstone and its Mines, a Report Upon the Past and Present Condition of the Mines of Tombstone, Cochise County, Arizona", gives the value of aggregate production of gold and silver from the mines of Tombstone placed by "competent judges" from records and estimates at not less than $34,000,000. This report is dated 1902. Tombstone would continue limited production for another 34 years! Blake's "competent judges" also give an average value of $45 per ton of ore based on samples and smelter returns.

Butler, Wilson and Rasor in their 1938 "Arizona Bureau of Mines Geological Series No. 10, Bulletin #143," give a grand total for all ore from 1879 through 1936, including copper, lead and zinc, of $37,103,008. Their figures are based on old records, "other sources" and published figures in the Mineral Resources of the United States.

In summary, it can be said that whatever set of figures the reader decides to believe, they will still show the ore mined in Tombstone is some of the richest yet produced in the United States.

CLOSING OF THE MINES

It is generally assumed that the water encountered in the mines was the reason for the closing of the Tombstone operations. Previous work had shown that the water could be controlled with proper management and maintainance of equipment. The cost of pumping had only a slight cost effect on the overall operations. Other factors must be blamed for bringing an end to mining.

Most of the known easy to reach high grade ore had already been mined. The cost of developing additional ore was not only expensive but economically infeasible as it was generally remote from the few remaining hoisting facilities. Milling and treating the ore was again a problem since most mills had been closed. The price of silver remained below $1.25 per ounce.

If a single blame had to be given to any one thing, it would probably be poor coordination of efforts ~~on the part of the various management~~ personnel for not instigating a program of steady development in advance of actual mining which would include systematic dewatering to make more ground available for developing, and increasing the efficiency of the mining and hauling techniques.

Noteable is the fact that many hundreds of thousands of tons of good milling ore were bypassed or broken and left in the stopes and the stopes allowed to cave because of the quest for only high grade ore. With proper procedures this ore also could have been mined at a profit.

RECENT ACTIVITY

Periodically some work is done in Tombstone. Some of the surface dump material and underground gob is screened to recover the gold and silver in the fine material. An occassional bit of ore is mined from a pit or high grade pocket near the surface but most efforts are met with little profit.

Thousands of feet have been drilled in an effort to prove ore reserves and the continuation of ore at depth, however much of this data is unavailable for evaluation. Those few assays that can be matched with structure samples show mineralization in varying degrees indicating that the ore shoots persist below the 1,000 foot level. The spotty nature of the ore and the surprising fact that some soft oxide ore occurs well below the water table should cause concern as to the validity of drilling results to give a true picture of the mineral value of a structure over any lateral or vertical extent. Associated with many of Tombstone's structures are wide voids and solution cavities which cause loss of both diamond drill core and cutting recovery.

Some geophysical and geochemical work has been undertaken by various companies but the results were not conclusive and added little to what was already known about the district.

The most recent work has been done by 1971 Minerals Ltd. This work has primarily been a cyanide heap leaching of the waste dumps and setting up of an in situ underground leaching system to recover gold and silver from the gob remaining in the Goodenough Stope which is one of the large manto deposits on the crest of an anticline. 1971 Minerals Ltd. has also done some shallow drilling in the vicinity of the Tranquility and Silver Thread mines in an unsuccessful effort to prove some shallow open pit mineable ore reserves.

FUTURE POTENTIAL

Within the Tombstone Mining District are many large areas with little or no development work other than a few small pits, shafts, or adits. At least 100,000 feet of structures have been mapped on the surface and all belong to one of the systems of known ore producers. Many of these structures have been mined to some extent, but many have not been touched either on the surface or underground. In addition, many known producing structures and horizons have no known surface exposures. Undoubtedly, some ore remains at the surface that can be mined by open pit methods. A systematic detailed areal geologic mapping project in conjunction with a surface sampling program placing special emphasis on the projections of known ore bearing structures from the underground workings will delineate these areas.

The large manto stopes on the apexes of the anticlines contain roughly 100,000 tons of gob which carries good values in gold and silver. No average grade has been computed due to lack of data but a figure in excess of 10 ounces of silver and .15 ounces of gold per ton would not be unreasonable as these were some of the first structures mined and "take only high grade" was the rule.

Huge tonnages of low grade ore are piled at various places throughout the mines or used as back fill in much of the workings. Because almost all development work has been driven on mineral bearing structures, we could anticipate that most of the gob is mill grade ore and need only be hoisted to the surface for processing.

In order to arrive at a feasible mining plan it will be necessary to initiate a program of sampling and measuring all gobbed areas to get an accurate tonnage and grade figure.

Few sections along the mined structures are available due to poor records and unsystematic mining procedures. Those that are available show a very interesting trend in that the amount of mining adjacent to the shafts is considerable but diminishes drastically with distance from the hoisting facility. This trend applies to all Tombstone structures but to a lesser extent with the manto stopes in the rolls or anticlines. Occasionally this is due to the shafts being sunk on higher grade ore, but more commonly it is due to the inconvenience and extra work of a longer tramming distance. The result has been a considerable tonnage of developed but unmined ore.

Due to the stable nature of the ground in the district, dike fissures excepted, most of the workings are open and readily accessible. As a result, an excellent estimate of the value of this ore can be obtained by channel sampling the developmental drifts and raises and sampling within the blocks of ore between levels and raises where stoping provides access into the blocks.

Further exploration of the Tombstone ore body can be done in two ways. They are, drilling either from surface or from stations cut at various locations underground, and subsurface exploration with drifts, crosscuts and raises. Both ways have their advantages.

The most accurate assay value of a structure at any one point is given by a sample cut perpendicularly across the structure to avoid the affects of mineral zonation within the structure. The problem of accurate sampling is made more complicated by secondary enrichment and oxidation which has tended to form local pockets of high grade ore. The mineralized zones have been further complicated by more recent faulting and decalcification which has produced additional open fissures and solution cavities.

It is the writer's opinion that accurate assay data probably cannot be obtained from the upper 600 feet of the district by drilling. However, due to the decrease in the effects of oxidation and enrichment, the credibility of the assays will undoubtedly increase with depth.

Many drill holes, both diamond and rock bit, have lost all returns due to intensely broken ground and voids in and adjacent to the structures. Several hundred thousand dollars have been spent drilling to intersect ore zones at depths of up to 1,200 feet only to lose some or all of the core or the cuttings throughout the intersection itself. The newer reverse circulation drills offer the best solution to this perplexing drilling problem.

Using the reverse circulation drilling method, it is possible to drill for considerable distances down the heart of these mineralized faults and fissures or drill at small acute angles to the structures in order to get longer and therefore more representative sections and still get cutting returns after penetrating voids in broken or loose ground. This plan of drilling should not be misinterpreted as giving a completely true representation of the mineralized material between and adjacent to the structural boundary. But, the information and reliability is a great improvement over that provided by other drilling techniques.

Drilling's major advantage over drifting for structure testing is the ability to quickly test and pursue structures in remote and untested areas. Another advantage is that of being faster than conventional underground mining techniques to develop ore reserves. However, in the Tombstone type of deposit, the reliability of the data is questionable at best.

By driving a drift on a structure, it is possible to see the dimensions and rock characteristics of the ore shoot and to thoroughly sample it. Small high grade pockets may be sampled and easily averaged into the remainder of the vein to give the overall grade.

Conventional drifting costs about $50 per foot of advance. Drilling costs are about $25 per foot of diamond drilling, $12 per foot of reverse circulation drilling and $7 per foot for down hole percussion hammer drilling. Drilling is of course cheaper than drifting per foot of advance, but when comparing drifting and drilling from the standpoint of dollars spent per foot of vein proven or disproven, it is easily seen that drilling is many times more expensive and the information gained is inconclusive.

The manto deposits are not confined to any one particular stratigraphic unit. In several instances, the mining began in one horizon and shifted upward or downward to another higher grade rock unit. Study of these ore occurrences has shown that there are a number of rock units in each anticline that are potential ore producers. In some instances, these units are completely untested. Also there are possible extensions to the manto deposits that have not been tested as yet, as well as two rolls that are virtually untouched. Checking these targets is a simple matter of getting in the proper rock unit on the apex of the roll and drifting.

TOMBSTONE EXTENSION AND THE WESTERN TOMBSTONE AREA

There are two additional areas sometimes included in the Tombstone Mining District that have not been previously mentioned. They are the Tombstone Extension and the Western Area.

Mining in both areas has been conducted on vein or fissure type deposits and along dike filled fissures. Generally it can be said that except for the absence of known manto deposits, both areas are nearly identical in ore occurrences to the main Tombstone District. All three areas most likely owe their origin to the same sources of structuring and mineralization.

The Tombstone Extension which lies about 7,000 feet southeast of the town of Tombstone is wholly in the upper Bisbee Formation. It has had only a small total production of lead ore from three mines, the Tombstone Extension, Carper and the San Diego Mines. Most of the lead type ore contained about .071 ounces gold per ton. The Tombstone Extension Mine was the largest producer of lead in Arizona in 1932-1933.

Total production from the Tombstone Extension District is reported to be 15,195.65 tons of ore carrying 1,082.64 ounces gold, 180,490.66 ounces silver and 6,335,743.64 pounds of lead. The Total gross value of all ore shipped was, at the original prices, $408,941.08.

The Western District, located about 12,000' southwest of Tombstone, is in the Bisbee sediments and in the Uncle Sam quartz latite porphyry. The best known mines are the State of Maine, Bonanza, Chance, Joseph and San Pedro.

Limited development work was done to the water table which stands at about 4,400 feet elevation, or about 200 feet below the sufface at the Bonanza Shaft. As with the Tombstone Mining District, many tons of ore were developed and left unmined for various reasons. Nearly all mining has been carried out on only five of the 23 known veins. The other 18 are practically virgin of any exploration.

Much high grade ore was mined in the Western District. Some 1,000 ounces of silver and several ounces of gold per ton ore was often found. One small shipment of 4½ tons from the Joseph #1 assayed at 5,005 ounces silver and 5.01 ounces gold per ton. The biggest producer was the State of Maine at $3,500,000. Its ore was reported to average about $60 per ton which represents approximately 55 ounces silver and .10 ounces gold per ton. A "very low estimate" of the average value of ore from the entire Western Mining District is $25.00 per ton according to C.J. Sarle in his 1928 report on the Mellgren Mines.

The total production for the entire district is reported to be around six to eight million dollars at the old prices. Unfortunately, only very poor and sketchy production records are available.

393

COPPER POTENTIAL

There is a very real possibility that the structures in the Tombstone Mining District will eventually become major copper veins at depth. Abundant copper oxide minerals are seen in nearly all structures. Some copper credit was given to the mines by the mills and smelters in the early days. As should be expected, the copper content of the ore increases with depth and locally heavy copper sulfides were reported from some of the deeper workings below the water table.

The standard porphyry copper zoning of (from perimeter to source), gold silver, lead, manganese, zinc, arsenic-antimony, copper and molybdenum seems to be holding generally true for the Tombstone deposit. All evidence points to the possibility of a large vein type copper deposit lying at depth beneath Tombstone. This vein deposit is quite possibly resting on a disseminated porphyry copper deposit typical of other deposits in south and central Arizona.

This opinion has been expressed by many qualified mining personnel who are familiar with porphyry copper deposits and this writer enthusiastically concurs.

STRATIGRAPHIC UNITS ASSOCIATED WITH TOMBSTONE'S ORE DEPOSITS

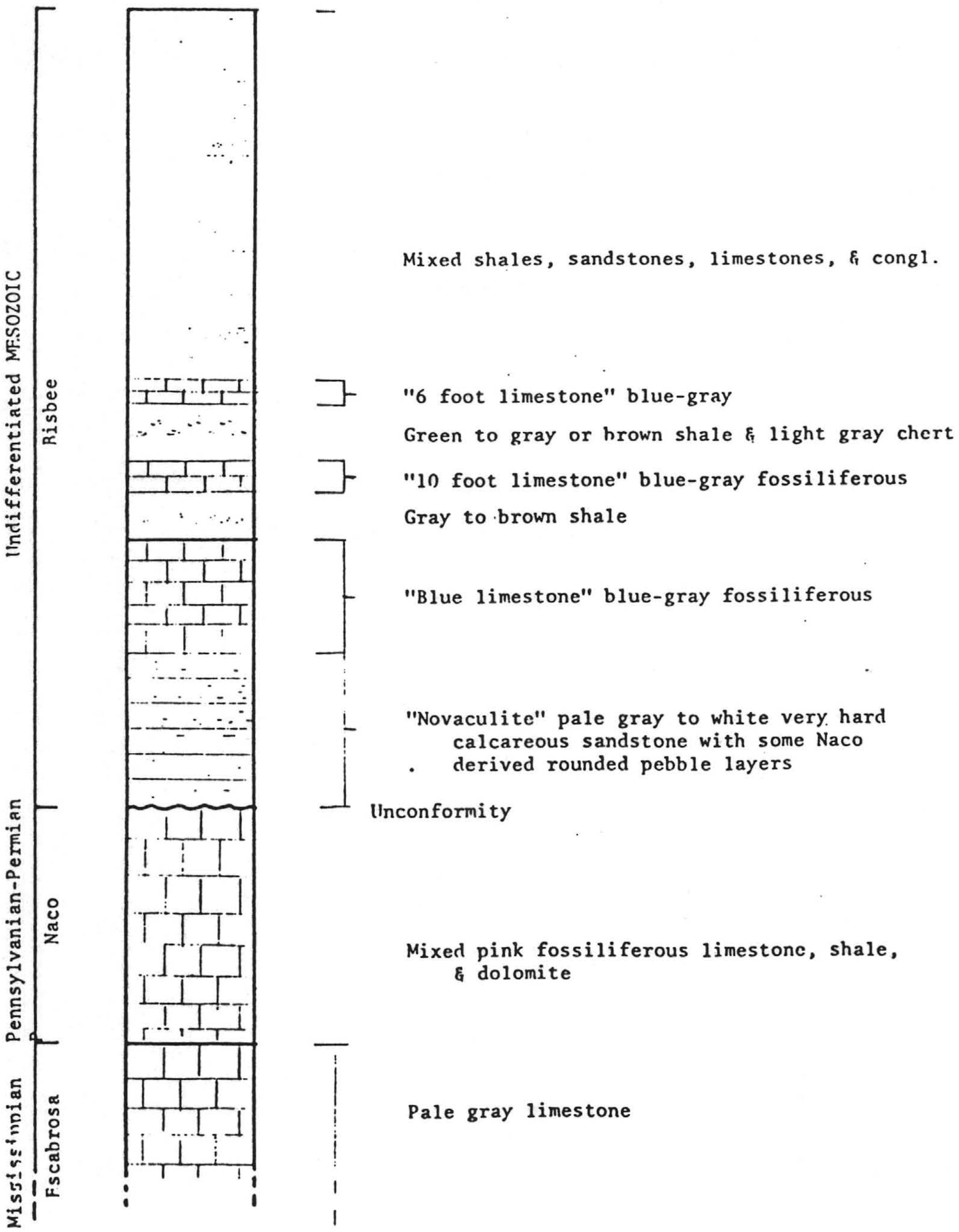
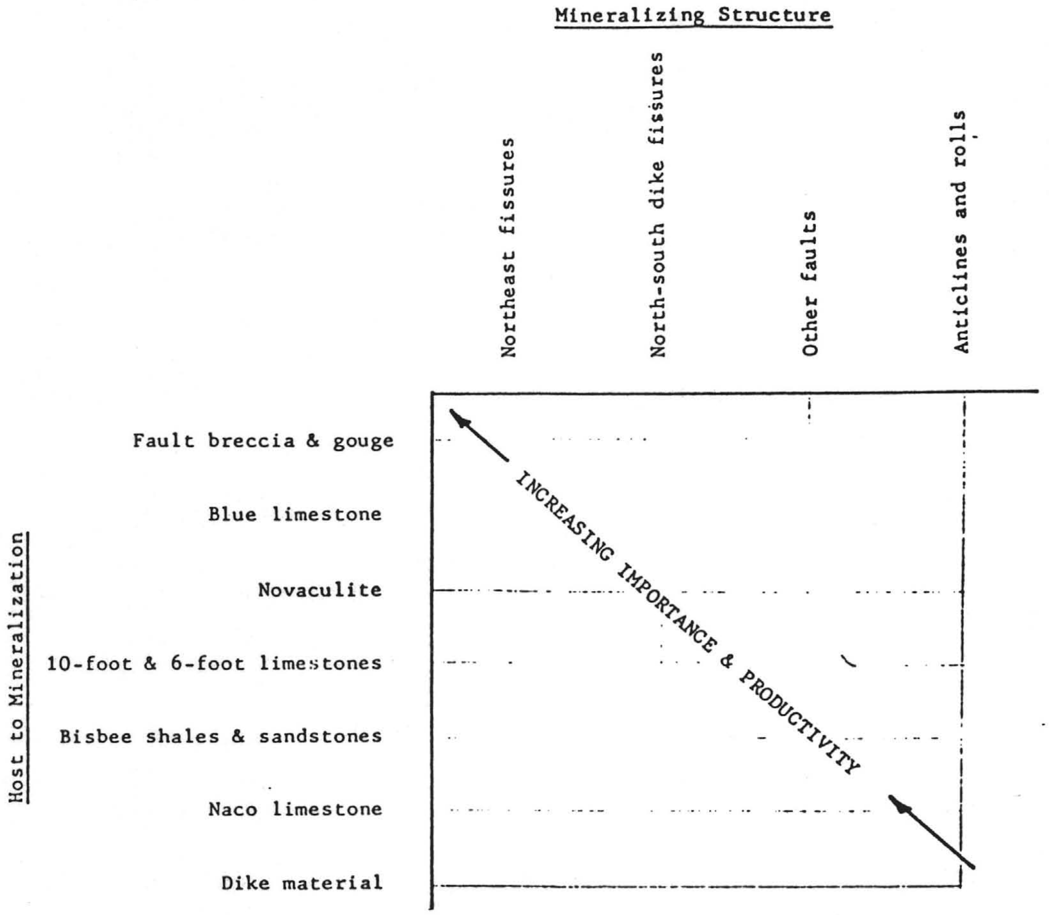


TABLE SHOWS THE RELATIONSHIP OF STRUCTURES TO ROCK UNITS IN REGARDS TO MINERALIZATION



COMPILED PRODUCTION RECORDS
OF THE
MAIN TOMBSTONE MINING DISTRICT

EAR	TONS	OZ. GOLD	$/OZ.	VALUE	OZ. SILVER	$/OZ.	VALUE
.879-1880	55,567.63	5,219.06	20.71	108,086.71	1,889,299.40	1.17	2,210,480.30
81	128,452.02	9,312.09	"	192,853.33	4,367,369.00	1.11	4,847,779.
82	131,296.23	9,798.81	"	202,541.46	4,464,072.00	1.05	4,955,120.00
83	75,248.76	9,440.80	"	195,519.06	2,558,458.00	"	2,686,381.00
84	33,582.35	8,783.08	"	181,897.58	1,141,800.40	"	1,198,890.50
85	31,735.78	9,078.25	"	188,010.52	1,079,016.60	"	1,132,967.50
86	25,885.45	8,628.48	"	178,695.86	880,105.25	.99	871,304.20
87	14,500.00	5,559.16	"	115,130.17	494,765.13	.98	484,869.83
88	14,510.79	6,578.23	"	136,235.06	493,366.95	.94	463,764.94
89	5,511.82	3,022.61	"	62,598.23	187,401.77	1.00	187,401.77
1890	13,537.11	5,636.18	"	116,725.21	460,261.70	1.05	483,274.79
91	15,361.77	7,356.34	"	152,349.80	522,300.20	1.00	522,300.20
92	13,573.48	4,273.13	"	88,496.56	461,498.20	.87	401,503.44
93	14,126.68	3,638.72	"	75,357.81	480,310.50	.78	374,642.19
94	11,213.11	2,888.23	"	59,815.15	381,245.79	.63	240,184.85
95	11,213.11	2,888.23	"	59,815.15	381,245.79	"	240,184.85
96	11,213.11	2,888.23	"	59,815.15	381,245.79	"	240,184.85
897-1901	135,607.73	15,409.97	"	319,140.45	2,034,116.00	.60	1,220,469.60
902-1906	224,602.14	25,522.97	"	528,580.72	3,369,032.10	"	2,021,419.30
07	48,443.60	5,504.95	"	114,007.60	726,654.00	"	435,992.40
08	51,266.00	4,097.83	"	84,866.00	357,414.00	"	595,690.00
09	27,123.00	2,275.18	"	47,119.00	201,700.00	"	336,166.66
1910	4,619.00	1,059.73	"	21,947.00	116,520.00	"	69,912.00
11	8,797.00	2,155.49	20.67	44,554.00	224,098.00	"	134,458.80
12	7,405.00	1,363.18	"	28,177.00	158,377.00	.584	92,492.17
13	5,760.00	1,229.56	"	25,415.00	126,392.00	"	73,812.93
14	6,063.00	1,380.36	"	28,532.00	108,868.00	"	65,320.80
15	9,003.00	1,216.01	"	25,135.00	100,115.00	.67	67,077.05
16	57,200.00	3,950.36	"	81,654.00	343,453.00	"	230,113.51
1917	57,474.00	3,373.05	"	69,721.00	444,139.00	"	297,573.13
18	19,507.00	1,389.40	"	28,719.00	283,412.00	.28	79,355.36
19	27,445.00	1,945.82	"	40,220.00	450,366.00	"	126,102.48
1920	28,946.00	1,787.76	"	36,953.00	456,855.00	"	127,919.40

COMPILED PRODUCTION RECORDS
OF THE
MAIN TOMBSTONE MINING DISTRICT

AR	TONS	OZ. GOLD	$/OZ.	VALUE	OZ. SILVER	$/OZ.	VALUE
1921	18,594.00	1,506.58	.67	31,141.00	423,688.00	.28	118,632.64
22	44,347.00	2,322.45		48,005.00	613,700.00	1.12	687,344.00
23	32,770.00	3,092.60	"	63,924.00	495,943.00	"	555,456.16
24	15,448.00	2,458.64	"	50,820.00	247,642.00	"	277,359.04
25	27,760.00	2,676.73	"	55,328.00	241,381.00	"	270,346.72
26	47,708.00	2,989.65		61,796.00	226,579.00	.90	198,521.10
27	31,196.00	3,132.90	"	64,757.00	159,944.00	"	143,949.60
28	24,172.00	2,296.61	"	47,471.00	164,161.00	"	147,744.90
29	15,601.00	1,670.54	"	34,530.00	99,423.00	"	89,480.70
1930	8,734.00	1,874.50	"	38,746.00	74,937.00	.3876	29,045.58
31	15,623.00	2,203.92	"	45,555.00	101,504.00	.3075	31,212.48
32	5,067.00	501.50	20.00	10,030.00	48,021.00	.2739	13,152.95
33	7,016.00	1,846.42	19.95	36,836.00	100,323.00	.2591	25,993.69
34	3,701.00	3,685.04	35.15	129,529.00	296,737.00	.6383	189,407.22
35	12,907.00	3,287.38	36.68	120,581.00	243,087.00	.7458	181,294.28
36	9,305.00	2,921.81	34.99	102,234.00	147,218.00	.7687	113,166.47
TAL	1,635,638.70	217,118.52	21.371	$4,639,966.00	33,803,559.00	$.904	$30,559,196.00

DRILLING SUMMARY
1930's TO DATE

Consultants in:
- base & precious metals • uranium
- coal • geothermal • environment
- remote sensing • color aerial photography
- interpretation-image processing
- worldwide Mobilization

Cochise Co. 4500 E. Speedway, Suite 14
Tucson, Arizona 85712
(602) 795-6097

298

James A. Briscoe, President
Registered Professional
Geologist

Southwestern
Exploration Associates, Inc.

RECEIVED

DEPT. OF MINERAL RESOURCES
PHOENIX, ARIZONA

February 28, 1979

TOMBSTONE DRILLING SUMMARY

Drilling Group	Date	Drill Hole No.	Depth	Location
Bunker Hill	1936	DD-1	23'	T.D.C. Claims
Bunker Hill	1936	DD-2	75'	T.D.C. Claims
Bunker Hill	1936	DD-3	123'	T.D.C. Claims
Bunker Hill	1936	DD-4	151'	T.D.C. Claims
Bunker Hill	1936	DD-5	78'	T.D.C. Claims
Bunker Hill	1936	DD-6	20'	T.D.C. Claims
Bunker Hill	1936	DD-7	6'	T.D.C. Claims
Bunker Hill	1936	DD-8	40'	T.D.C. Claims
Bunker Hill	1936	DD-9	56'	T.D.C. Claims
Bunker Hill	1936	DD-10	180'	T.D.C. Claims
Bunker Hill	1936	DD-11	211'	T.D.C. Claims
Bunker Hill	1936	DD-11	75'	T.D.C. Claims
Bunker Hill	1937	CDH-1	380'	T.D.C. Claims
Bunker Hill	1937	CDH-2	75'	T.D.C. Claims
Bunker Hill	1937	CDH-3	460'	T.D.C. Claims
Bunker Hill	1937	CDH-4	430'	T.D.C. Claims
Bunker Hill	1937	CDH-5	385'	T.D.C. Claims
Bunker Hill	1937	CDH-6	295'	T.D.C. Claims
Bunker Hill	1937	CDH-7	506'	T.D.C. Claims
Bunker Hill	1937	CDH-8	298'	T.D.C. Claims
Bunker Hill	1937	CDH-9	295'	T.D.C. Claims
Bunker Hill	1937	CDH-10	385'	T.D.C. Claims
Bunker Hill	1937	CDH-11	400'	T.D.C. Claims
Bunker Hill	1937	CDH-12	215'	T.D.C. Claims
Bunker Hill	1937	CDH-13		T.D.C. Claims
Newmont	1954	DD-7	1650'	Silver Thread
Newmont	1955	DD-9	667'	West Side

Drilling Group	Date	Drill Hole No.	Depth	Location
Duval	1967	RDH-1	247'	T.D.C. Claims
Duval	1967	RDH-2	250'	T.D.C. Claims
Duval	1967	RDH-3A	250'	T.D.C. Claims
Duval	1967	RDH-3	108'	T.D.C. Claims
Duval	1967	RDH-4	80'	T.D.C. Claims
Duval	1967	RDH-5	50'	T.D.C. Claims
Duval	1967	RDH-6	250'	T.D.C. Claims
Duval	1967	RDH-7	219'	T.D.C. Claims
Duval	1967	RDH-8	148'	T.D.C. Claims
Duval	1967	RDH-8A	148'	T.D.C. Claims
Frankovitch	1959	DDH-1	230'	T.D.C. Claims
Frankovitch	1959	DDH-2	95'	T.D.C. Claims
Frankovitch	1959	DDH-3	51'	T.D.C. Claims
Frankovitch	1959	DDH-4	40'	T.D.C. Claims
Frankovitch	1959	DDH-5	270'	T.D.C. Claims
Frankovitch	1959	DDH-6	188'	T.D.C. Claims
Frankovitch	1959	DDH-7	90'	T.D.C. Claims
Frankovitch	1959	DDH-8	192'	T.D.C. Claims
Frankovitch	1959	DDH-9	125'	T.D.C. Claims
Frankovitch	1959	DDH-10	511'	T.D.C. Claims
Frankovitch	1959	DDH-11	287'	T.D.C. Claims
Frankovitch	1959	DDH-12	180'	T.D.C. Claims
Frankovitch	1959	DDH-13	146'	T.D.C. Claims
Frankovitch	1959	DDH-14	329'	T.D.C. Claims
Frankovitch	1959	DDH-15	350'	T.D.C. Claims
Frankovitch	1959	DDH-16	160'	T.D.C. Claims
Frankovitch	1959	DDH-17	205'	T.D.C. Claims
Frankovitch	1959	DDH-18	77'	T.D.C. Claims
71 Minerals	1976	RDH-1A	75'	Skip Shaft Area
71 Minerals	1976	RDH-101	55'	Skip Shaft Area
71 Minerals	1976	RDH-106	60'	Skip Shaft Area
71 Minerals	1976	RDH-107	60'	Skip Shaft Area
71 Minerals	1976	RDH-108	60'	Skip Shaft Area
71 Minerals	1976	RDH-109	60'	Skip Shaft Area
71 Minerals	1976	RDH-110	60'	Skip Shaft Area
71 Minerals	1976	RDH-111	60'	Skip Shaft Area
71 Minerals	1976	RDH-112	60'	Skip Shaft Area
71 Minerals	1976	RDH-113	60'	Skip Shaft Area
71 Minerals	1976	RDH-114	80'	Skip Shaft Area
71 Minerals	1976	RDH-115	60'	Skip Shaft Area
71 Minerals	1976	RDH-116	60'	Skip Shaft Area
71 Minerals	1976	RDH-117	80'	Skip Shaft Area
71 Minerals	1976	RDH-118	80'	Skip Shaft Area
71 Minerals	1976	RDH-119	80'	Skip Shaft Area
71 Minerals	1976	RDH-120	60'	Skip Shaft Area

Drilling Group	Date	Drill Hole No.	Depth	Location
Austral Oil	1968	DD-1	252'	West-Fox
Austral Oil	1968	DD-2	876'	West-Fox
Austral Oil	1968	DD-3	550'	West-Fox
Austral Oil	1968	DD-4	98'	West-Fox
Austral Oil	1968	DD-5	216'	West-Fox
Austral Oil	1968	DD-6	257'	West-Fox
Austral Oil	1968	H-1	300'	West-Fox
Austral Oil	1968	H-2	215'	West-Fox
Austral Oil	1968	H-3	500'	West-Fox
Austral Oil	1968	H-4	300'	West-Fox
Austral Oil	1968	H-5	250'	West-Fox
Austral Oil	1968	H-6	250'	West-Fox
Austral Oil	1968	H-7	250'	West-Fox
Austral Oil	1968	H-8	100'	West-Fox
Austral Oil	1968	H-9	140'	West-Fox
Austral Oil	1968	H-10	426'	West-Fox
Austral Oil	1968	H-11	250'	West-Fox
Austral Oil	1968	H-12	270'	West-Fox
Austral Oil	1968	H-13	250'	West-Fox
Austral Oil	1968	H-14	250'	West-Fox
Austral Oil	1968	H-15	250'	West-Fox
Austral Oil	1968	H-16	170'	West-Fox
Austral Oil	1968	H-17	285'	West-Fox
Austral Oil	1968	H-18	313'	West-Fox
Austral Oil	1968	H-19	490'	West-Fox
Austral Oil	1968	H-20	300'	West-Fox
Austral Oil	1968	H-21	270'	West-Fox
Austral Oil	1968	H-22	290'	West-Fox
Austral Oil	1968	H-23	207'	West-Fox
Austral Oil	1968	H-24	270'	West-Fox
Austral Oil	1968	H-25	290'	West-Fox
Austral Oil	1968	H-26	500'	West-Fox
Austral Oil	1968	H-27	200'	West-Fox
Austral Oil	1968	H-28	230'	West-Fox
Austral Oil	1968	H-29	235'	West-Fox
Austral Oil	1968	H-30	280'	West-Fox
71 Minerals	1973	HRD-1	265'	Seth Horn Claims
71 Minerals	1973	HRD-2	120'	Robbers Roost
71 Minerals	1973	HRD-3	120'	Robbers Roost
71 Minerals	1973	HRD-4	10'	Robbers Roost
71 Minerals	1973	HRD-5	10'	Robbers Roost
71 Minerals	1973	HRD-6	10'	Robbers Roost
71 Minerals	1973	HRD-7	35'	Robbers Roost

40'

Drilling Group	Date	Drill Hole No.	Depth	Location
71 Minerals	1976	RDH-120A	80'	Skip Shaft Area
71 Minerals	1976	RDH-121	60'	Skip Shaft Area
71 Minerals	1976	RDH-122	60'	Skip Shaft Area
71 Minerals	1976	RDH-123	73'	Skip Shaft Area
71 Minerals	1976	RDH-124	80'	Skip Shaft Area
71 Minerals	1976	RDH-125	130'	Skip Shaft Area
71 Minerals	1976	RDH-126	60'	Skip Shaft Area
71 Minerals	1976	RDH-127	80'	Skip Shaft Area
71 Minerals	1976	RDH-128	80'	Tranquility Shaft Area
71 Minerals	1976	RDH-129	70'	Tranquility Shaft Area
71 Minerals	1976	RDH-130	70'	Tranquility Shaft Area
71 Minerals	1976	RDH-131	65'	Tranquility Shaft Area
71 Minerals	1976	RDH-132	70'	Tranquility Shaft Area
71 Minerals	1976	RDH-133	73'	Tranquility Shaft Area
71 Minerals	1976	RDH-134	80'	Tranquility Shaft Area
71 Minerals	1976	RDH-135	80'	Tranquility Shaft Area
71 Minerals	1976	RDH-136	65'	Tranquility Shaft Area
71 Minerals	1976	RDH-137	55'	Tranquility Shaft Area
71 Minerals	1976	RDH-138	50'	Tranquility Shaft Area
71 Minerals	1976	RDH-139	50'	Tranquility Shaft Area
71 Minerals	1976	RDH-140	50'	Tranquility Shaft Area
71 Minerals	1976	RDH-141	50'	Tranquility Shaft Area
71 Minerals	1973	AT-1	55'	Unpatented T.D.C. Claims
71 Minerals	1973	AT-2	50'	Unpatented T.D.C. Claims
71 Minerals	1973	AT-3	75'	Unpatented T.D.C. Claims
71 Minerals	1973	AT-4	65'	Unpatented T.D.C. Claims
71 Minerals	1973	AT-5	50'	Unpatented T.D.C. Claims
71 Minerals	1973	AT-6	80'	Unpatented T.D.C. Claims

2/28/79

Drilling Group	Date	Drill Hole No.	Depth	Location
71 Minerals	1973	AT-7	100'	Unpatented T.D.C. Claims
71 Minerals	1973	AT-8	104'	Unpatented T.D.C. Claims
71 Minerals	1973	AT-9	100'	Unpatented T.D.C. Claims
71 Minerals	1973	AT-10	100'	Unpatented T.D.C. Claims
71 Minerals	1973	AT-11	100'	Unpatented T.D.C. Claims
71 Minerals	1973	TDC-1	50'	Unpatented T.D.C. Claims
71 Minerals	1973	TDC-2	45'	Unpatented T.D.C. Claims
71 Minerals	1973	TDC-3	48'	Unpatented T.D.C. Claims
71 Minerals	1973	TDC-4	10'	Unpatented T.D.C. Claims
71 Minerals	1973	TDC-5	10'	Unpatented T.D.C. Claims
71 Minerals	1973	TDC-6	10'	Unpatented T.D.C. Claims
71 Minerals	1973	TDC-7	48'	Unpatented T.D.C. Claims
71 Minerals	1973	TDC-8	48'	Unpatented T.D.C. Claims
71 Minerals	1973	TDC-9	48'	Unpatented T.D.C. Claims
71 Minerals	1973	TDC-10	48'	Unpatented T.D.C. Claims
71 Minerals	1973	TDC-11	48'	Unpatented T.D.C. Claims
71 Minerals	1973	RD-1	210'	Unpatented T.D.C. Claims
71 Minerals	1974	RD-1	608'	TMR Claims
71 Minerals	1974	RD-2	10'	TMR Claims
71 Minerals	1974	RD-3	185'	TMR Claims
71 Minerals	1974	RD-4	32'	TMR Claims
71 Minerals	1974	RD-5	500'	TMR Claims
71 Minerals	1974	RD-6	415'	TMR Claims
71 Minerals	1975	WWP-1	270'	State Of Maine
71 Minerals	1975	1-75	175'	Fox

Drilling Group	Date	Drill Hole No.	Depth	Location
71 Minerals	1973	E-1	50'	So. Charleston Lead Mine
71 Minerals	1973	E-2	50'	So. Charleston Lead Mine
71 Minerals	1973	E-3	50'	So. Charleston Lead Mine
71 Minerals	1973	F-1	35'	So. Charleston Lead Mine
71 Minerals	1973	F-2	50'	So. Charleston Lead Mine
71 Minerals	1973	F-3	50'	So. Charleston Lead Mine
71 Minerals	1973	F-4	50'	So. Charleston Lead Mine
71 Minerals	1973	F-5	50'	So. Charleston Lead Mine
71 Minerals	1973	F-6	50'	So. Charleston Lead Mine
71 Minerals	1973	F-7	50'	So. Charleston Lead Mine
71 Minerals	1973	F-8	50'	So. Charleston Lead Mine
71 Minerals	1973	F-10	55'	So. Charleston Lead Mine
71 Minerals	1973	E-4	85'	So. Charleston Lead Mine

404

1930 DRILLING SUMMARY

Diamond Drill Hole No.	Location	Remarks
1	West Side - 300 Level	Gold ore in very brecciated dark shale - last hole.
2	West Side - 300 Level	Slight mineralization
3	West Side - 300 Level	Slight mineralization
4	Sulphuret - 500 Level	Good - Au, Ag, & Pb in blue ls.
5	Sulphuret - 500 Level	Very Good - Au, Ag, Pb, & Zn in blue ls.
6	West Side - 300 Level	Slight mineralization in shale
7	Empire - 300 Level	Good - Au, Ag in Kaolin fault breccia
8	Empire - 300 Level	Slight - Ag in blue ls.
9	Sulphuret - 500 Level	Fair - Ag in blue ls.
10	Sulphuret - 500 Level	Some Au, Ag, Pb, & Zn in blue ls.
11	Sulphuret - 500 Level	Very Good - Au & Ag in ls.
12	Sulphuret - 500 Level	Some Ag in blue ls.

1930 DRILLING SUMMARY

Churn Drill Hole Number	Location	Remarks
CDH - 1	Blue Monday Claim	Very weak mineralization
CDH - 2	So. Ext. Toughnut	"
CDH - 3	Toughnut Claim	Weak mineralization
CDH - 4	"	Some weak silver
CDH - 5	"	Weak Au & Ag
CDH - 6	"	Weak Ag
CDH - 7	Mesquite Claim	Qual.
CDH - 8	Manzanita Claim	Qual. & Bisbee
CDH - 9	Taco Tecalote Claim	Qual. & Bisbee
CDH - 10	Cholla Claim	Qual. & Bisbee
CDH - 11	Cholla Claim	Qual. & Bisbee
CDH - 12	Nogales Claim	Qual. & Bisbee

NEWMONT DRILLING SUMMARY

Diamond Drill Hole Number	Location	Remarks
DDH- 7	Silver Thread	Intervals of very high-grade Ag, Pb, Cu, & Zn.
DDH- 9	West Side	Same as above.

407

DUVAL DRILLING SUMMARY

Rotary Drill Hole No.	Location	Remarks
1	Contention Area	weak mineralization, ore below Novaculite
2	So. Tranquility	weak mineralization, ore in Novaculite.
3A	Contention Area	weak mineralization, low-grade ore in silty quartz sandstone
3	Contention Area	Los Hole in Novaculite
4	Contention Area	weak mineralization
5	Silver Thread Area	weak mineralization, last hole in stope
6	So. Tranquility	weak mineralization, ore in siltstone, shale, meta siltstone member
7	No. Empire	weak mineralization
8	E. Empire	weak mineralization
9	E. Empire	very weak mineralization

408

FRANKOVITCH DRILLING SUMMARY
(No Assays Shown)

Diamond Drill Hole No.	Location
1	Silver Reef Property
2	Silver Reef Property - Governor Henderson Claim
3	Silver Reef Property
4	Silver Reef Property
5	Silver Reef Property
6	Silver Reef Property
7	Silver Reef Property
8	Silver Reef Property
9	Silver Reef Property
10	Silver Reef Property
11	Silver Reef Property - #2 Claim
12	Poor X Claim
13	?
14	?
15	Roll 614
16	?
17	Ingersol Anticline
18	Vigina - Tribute Drift

TOMBSTONE DEVELOPMENT CO. - UNPATENTED CLAIMS
(18 Unpatented Claims)

Drill Hole No.	Remarks
AT-1	55' deep, no mineralization
AT-2	50' deep, good silver mineralization
AT-3	75' deep, very weak silver
AT-4	65' deep, no mineralization
AT-5	50' deep, no mineralization
AT-6	80' deep, some Ag
AT-7	100' deep, some Ag
AT-8	104' deep, good Ag
AT-9	100' deep, some good Ag
AT-10	100' deep, some very good Ag
AT-11	100' deep, weak Ag

Rotary Drill Hole No.	Remarks
TDC-1	very weak mineralization
TDC-2	weak mineralization
TDC-3	weak Ag, Cu, Pb, Zn
TDC-4	weak Ag & Cu
TDC-5	very weak mineralization
TDC-6	very weak mineralization
TDC-7	some weak Cu, Pb, & Zn
TDC-8	some weak Cu, Pb, & Zn
TDC-9	fair Pb & Zn
TDC-10	weak Au, Ag, Cu, Pb, & Zn
TDC-11	weak Au, Ag, Cu, Pb, & Zn
RD-1	210' feet

410

71 MINERALS DRILLING

Rotary Drill Hole No.	Location	Remarks
1A	Skip Shaft Area	Qual. - no samples
101	Skip Shaft Area	Qual. - no samples
106	Skip Shaft Area	Fair - mineralization
107	Skip Shaft Area	Fair - mineralization
108	Skip Shaft Area	Weak - mineralization
109	Skip Shaft Area	Weak - mineralization
110	Skip Shaft Area	Weak - mineralization
111	Skip Shaft Area	Weak - mineralization
112	Skip Shaft Area	Weak - mineralization
113	Skip Shaft Area	Weak - mineralization
114	Skip Shaft Area	Fair - hit stope
115	Skip Shaft Area	Fair
116	Near Skip Shaft Fissure	High-Grade Intervals
117	Skip Shaft Area	Qual. - no samples
118	Skip Shaft Area	Qual. - no samples
119	Skip Shaft Area	Qual. no samples
120	Skip Shaft Area	Qual. - no samples

41)

Rotary Drill Hole No.	Location	Remarks
120A	Skip Shaft Area	Qual. - no samples
121	Skip Shaft Area	Qual. - no samples
122	Skip Shaft Area	Qual. - no samples
123	Skip Shaft Area	Qual. - no samples
124	Skip Shaft Area	Weak - mineralization
124	Skip Shaft Area	Weak - mineralization
125	Skip Shaft Fissure	Some High-Grade Intervals
126	Skip Shaft Area	Weak - mineralization
127	Skip Shaft Area	Fair - mineralization
128	Skip Shaft - Tranquility Area	Good - mineralization
129	Tranquility Shaft Area	Weak - mineralization
130	Tranquility Shaft Area	Weak - mineralization
131	Tranquility Shaft Area	Weak - mineralization
132	Tranquility Shaft Area	Good - mineralization
133	Tranquility Shaft Area	Good - mineralization
134	Tranquility Shaft Area	Weak - mineralization
135	Tranquility Shaft Area	Fair - mineralization
136	Skip Shaft Area	Weak - mineralization

Rotary Drill Hole No.	Location	Remarks
137	Skip Shaft Area	Weak - mineralization
138	N. Skip Shaft	Good - mineralization
139	Empire Shaft Area	Weak - mineralization
140	Empire Shaft Area	Weak - mineralization
141	Empire Shaft Area	Weak - mineralization

TOMBSTONE MINERAL RESERVES

Escapule, J.

Hillman, C.

Scraper - 60 hrs. @ $35.00 per hr. $2000.00

Dozer - 60 hrs. @ $45.00 per hr. $2700.00

Road work done in Sec. 27, 28, 33, 34.

Work completed August 31, 1973. C.B.E.

TOMBSTONE DEVELOPMENT CO.

Labor - $453.00

Rig Rental - $475.00

Fuel & Oil - $89.76

Bits - $146.10

Assaying - $1260.00

Driller - Waterson - Helper - McNeely

TRACK RIG 3" bit

Total hole depth 903

Work done on 18 claims East of Tombstone - Sec.

Work completed prior to August 31, 1973 C.B.E.

HORN PROPERTY

Labor - $756.00

Fuel - $180.00

Mud Gel - $40.00

Sampling @ $700.00

Repair parts for Rig - $330.00

Bits - $425.00

Driller - Henderson, T. - Helper - Henderson G.

ROTARY RIG 4 3/4" bit

Total hole depth 510'

Tot. cost $2,431 ÷ 510' = $4.76/foot

Work done in Sec. 30.

Work completed August 31, 1973. C.B.F.

HORN PROPERTY

Labor - $222.00

Fuel - $82.25

Bits - $92.00

Sampling - $273.00

Rig Rental - $122.25

Driller - Henderson, T. - Helper - Henderson, G.

ROTARY RIG

Total hole depth 195' 4 3/3" bit

Tot cost 791.5 ÷ 195' = 4.05/foot

Work done in Sec. 36.

Work completed August 31, 1973. C.B.E.

HORN PROPERTY

Labor - $575.60

Fuel - $80.00

Rig Rental - $580.00

Sampling - $1029.00

Bits - $151.50

Tot. 2,015.50 ÷ 733' = $2.75/foot

TRACK RIG

Driller - Waterson - Helper - McNeely

Total hole depth 733'   3" bit

Work done in Sec. 36. Work completed August 31, 1973. C.B.E.

Total Drill costs ÷ Total footage = cost/foot

$5,238 ÷ 1,438 = $3.64.

MISC.

TOMBSTONE EPITAPH, TOMBSTONE, ARIZONA, THURSDAY, OCTOBER 10, 1968

[redacted]

[redacted]

417

PHOENIX GAZETTE
12/9/74

[redacted]

US DEPT AG.
SEISMIC REPORT

418

SEISMIC REFRACTION STUDIES OF THE SUBSURFACE GEOLOGY OF WALNUT GULCH EXPERIMENTAL WATERSHED, ARIZONA

August 1970 ARS 41-164
Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

419

ACKNOWLEDGMENTS

The authors acknowledge assistance provided by the following organizations and individuals: John S. Summer, professor of geophysics, Department of Geology, University of Arizona, who freely gave constructive criticism and permitted the loan of equipment from the Geophysics Laboratory; Charles M. Glickman, senior electronic technician, Electrical Engineering Department, University of Arizona, who faithfully provided the electronic engineering-technical services associated with the Century 408 seismic instrumentation; and the ranchers and other residents on and around the watershed, who gave permission to trespass and furnished much helpful information.

420

ABSTRACT

Seismic methods, combined with well and geologic data, were used to define the subsurface hydrologic and geologic conditions of the Walnut Gulch Experimental Watershed and its peripheral area, near Tombstone, Ariz. Surface geology of the watershed indicates an alluvium-filled area between igneous intrusive and sedimentary rocks that support the Tombstone Hills on the southwest and the Dragoon Mountains on the northeast.

In 11 areas, 52 seismic refraction profiles, aggregating a length of 115,550 feet of in-line seismic profiling, were conducted. Velocities derived from reversed seismic profiles and profiles conducted over outcrops averaged 2,200 f.p.s. for channel fill, 5,000 f.p.s. for unconsolidated alluvial deposits, 8,800 f.p.s. for conglomerates, and, depending on the particular unit, 12,300 to 15,600 f.p.s. for basement-type rocks. In many areas seismic determinations revealed depths to the water table ranging from near zero at the confluence of Walnut Gulch and the San Pedro River to 475 feet in the central portion of the watershed. The accuracy of predicting the depth to either groundwater or basement was ± 6 percent, while that for groundwater alone was ± 10 percent.

Analysis of the time-distance data and correlations with surface geology, gravity, and well data provided a framework from which geologic sections were constructed. These sections reveal the identification, depth, attitude, and extent of geologic units comprising the basement and alluvium complex. Extensions of many surface structural features to depth were noted.

42

SEISMIC REFRACTION STUDIES OF THE SUBSURFACE GEOLOGY OF WALNUT GULCH EXPERIMENTAL WATERSHED, ARIZONA[1]

F. Libby, D. E. Wallace, and D. P. Spangler[2]

Seismic refraction studies were initiated on Walnut Gulch Experimental Watershed in the summer of 1967 and were completed in 1968. This watershed is an outdoor hydrologic laboratory near Tombstone, Ariz. (fig. 1), under the direction of the Agricultural Research Service, USDA. It is the subject of intensive hydrologic and sediment yield studies.

The purpose of the seismic study was to provide information concerning substrata conditions affecting the disposition of ephemeral stream channel water losses and groundwater movement and storage. The geophysical study area was increased to 290 square miles by including a peripheral area around the 58-square-mile watershed.

Ephemeral stream channel losses have been measured on Walnut Gulch by comparing inflow-outflow data on several channel segments. These measured losses have been explained in relation to the channel and subchannel geologic materials and related phenomena. The transmission losses need to be related to the channel geologic material to enable extrapolation of the data for design projects on unmeasured areas. A study of groundwater movement and storage in the watershed is continuing, with information needed on the piezometric surface and the extent of aquifer alluvium.

Specific objectives of the seismic survey were to:

1. Identify and map subsurface hardrock units, giving particular attention to those units underlying and bordering major stream channels;
2. Measure the thickness and extent of watershed aquifer alluviums; and
3. Determine the depth of regional water table.

Fifty-two seismic profiles, aggregating a length of 115,550 feet of in-line seismic profiling, were conducted in 11 areas (fig. 1).

Previous Work

Geological investigations have been conducted in conjunction with mining activities in the Tombstone Hills (part of which constitutes the southwest portion of the watershed) since the latter part of the 19th century. In the earliest reference, Blake (2)[3] referred to the general geology and some local ore occurrences. Church (4) applied local stratigraphic names and enlarged on the general geology after further mine developments.

Jones and Ransome (10) published the first comprehensive work with a regional geologic map in a report dealing primarily with the occurrence of manganese ores. Rasor (13) submitted a mineralogic and petrographic study of the Tombstone Mining District to the University of Arizona as a dissertation.

Butler, Wilson, and Rasor (3) increased the scope of Ransome's original work, including a more detailed description of the geology. Gilluly (6) concluded this series of notable investigations with a regional study of the stratigraphy and bedrock geology of the Tombstone Hills, Dragoon Mountains, and the northern half of the Mule Mountains.

Hollyday (9) made a geohydrologic analysis of mine dewatering and water development in the Tombstone Hills.

A number of mining companies have been involved in exploration programs on and around the watershed. An aeromagnetic survey of Tombstone and vicinity by Andreasen, Mitchell, and Tyson (1) has been released to the U.S. Geological Survey open file. Spangler and Libby (16) conducted a reconnaissance gravity survey covering 290 square miles (including the watershed) as part of an integrated geophysical study of the area.

---

[1] Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture, in cooperation with the Arizona Agricultural Experiment Station.

[2] Research geologist, geologist, and geologist and University of Arizona graduate student, respectively, Southwest Watershed Research Center, USDA, Tucson, Ariz.

[3] Underscored numbers in parentheses refer to literature cited, p. 14.

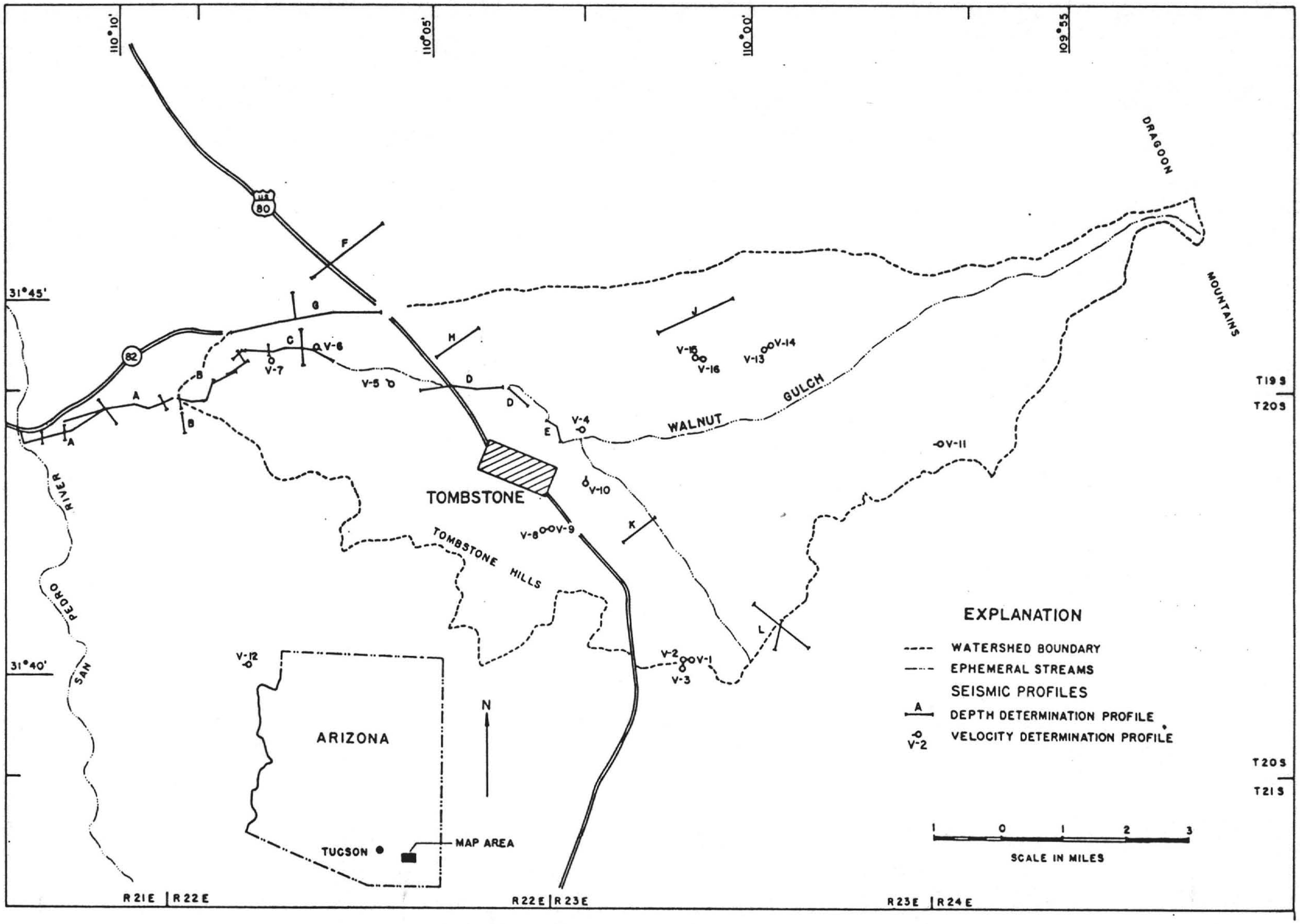


Figure 1.–Location of Walnut Gulch Experimental Watershed and periphery showing seismic study areas.

GENERAL GEOLOGY

The survey area, with isolated mountain blocks separated by a broad alluvium-filled basin, is typical of Basin and Range physiography.

Deep-seated igneous intrusions and accompanying high-angle reverse faults are responsible for the high relief areas that comprise the Tombstone Hills on the west and the lower Dragoon Mountains on the east (fig. 2). Great thicknesses of sedimentary rocks (mostly limestone) make up the topographic relief of the Tombstone Hills, which are underlain by, and adjacent to, large igneous bodies of Tertiary age. The igneous lower Dragoon Mountains of Triassic-Jurassic age have no sedimentary caprock; the only residual sedimentary rocks in this area are small limestone drag blocks along fault zones.

Late Tertiary volcanics in the southeast portion of the study area are relatively thin beds of andesite-rhyolite flows and tuffs and are in an overthrust position. Minor amounts of later Tertiary and early Quaternary rhyolite and basalt occur as intrusive dikes, sills, and plugs in the south and central portions of the area.

The alluvium that fills the intermontane basin consists of deep Tertiary and Quaternary sand, gravel, clay, and caliche conglomerate. Previous data indicate the alluvium is more than 1,200 feet deep in places and contains a large volume of groundwater. Much of the conglomerate is extremely well cemented, approaching the strength and appearance of structural concrete. These conglomerates act as rock units and exert much structural control on surface stream channels and groundwater flow.

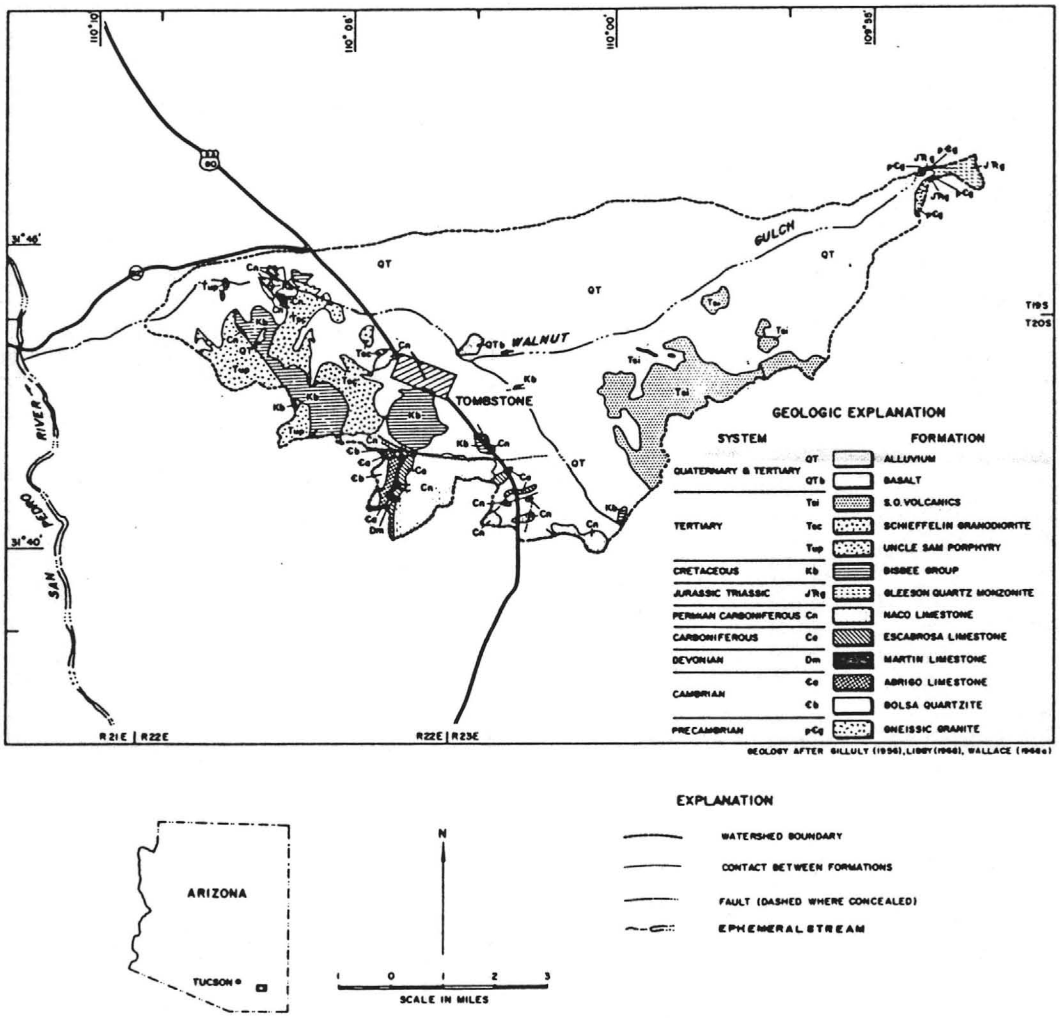


Figure 2.–Geologic map of Walnut Gulch Experimental Watershed.

SEISMIC SURVEY

A network of 360 gravity stations established over the watershed and its peripheral area helped define configuration of the basement complex, provided depth approximations of the deep alluvium, and determined the bearings for subsequent seismic traverses (16). Criteria for choosing the areas for seismic study were (1) areal priorities for the information, (2) control from surface geology and well data, or both, (3) a gravity survey, (4) terrain conditions, (5) distribution to provide coverage of the study area, (6) capabilities of the equipment, and (7) permission for ingress and egress on private land. Geologic and scheduling conditions required the use of a long geophone spread with sensitive equipment to speed survey progress in the field, and provide the depth penetration capability required to measure the thicknesses of alluvium in the watershed without using excessive explosives.

Fifty-two individual seismic profiles were made which, if put end to end, would make a line about 22 miles long (table 1). Most of the profiles were completed in the stream channel of the mainstem of Walnut Gulch, where large transmission losses occur during flow events (11). Several profiles were made in the deep alluvium portions of the watershed, where past drilling efforts had never reached bedrock but had shown alluvium depths in excess of 1,200 feet.

Instrumentation

The two sets of seismic instruments used were an Electro-Tech Port-Seis Interval Timer on loan from the Geophysics Laboratory of the University of Arizona and a refraction system designed by the Electrical Engineering Department of the University of Arizona in cooperation with the Agricultural Research Service.

TABLE 1.–Number and length of seismic profiles in the watershed area

Name of profile	Area (fig. 1)	Number of shot-profiles	Total length of profiles
			feet
San Pedro River to flume 1	A	13	24,950
Fume 1 to Montijo Flats	B	8	12,850
Lamb's Draw	C	7	12,500
Rifle Range	D	4	9,200
Gleeson Road	E	1	2,300
Willow Wash	F	3	10,600
Highway 82	G	7	15,750
City Dump	H	1	4,100
Bennett Ranch Road	J	3	10,050
Lime Tank	K	2	5,750
New Cowan Road	L	3	7,500
TOTAL		52	115,550

The first system was portable and provided 12 data traces, plus a shot-instant trace and 100-c.p.s. (cycles per second) timing marks on 4- by 5-inch Polaroid film. Reading accuracy was ± 1 msec. (millisecond). Recording time was adjustable between 200 and 400 msec. Twelve 30-cp.s. geophones could be attached to either a 600-foot cable with takeouts every 50 feet or an 1,800-foot cable with takeouts every 150 feet. Transistorized amplifiers, coupled to 125-c.p.s. galvanometers, transferred the seismic signal from the geophones to the film. A 90-volt blaster was used to detonate the explosives.

The second system, mounted in a 4-wheel-drive van, used a Century Model 408 oscillograph that provided 24 data traces with the shot-instant on trace 12 or 13. Data traces and 10- and 100-c.p.s. timing marks were made on Kodak Linagraph No. 809 paper. The paper was developed in the field by wet chemical processing in an aerial photographic film-developing unit. Reading accuracy was ± 1 msec. Recording time could be as long as desired and could be controlled manually or automatically. Twelve Geospace 7.5-c.p.s. geophones were premanently attached to a 1,355-foot cable with takeouts every 110 feet. Two cables were used with 100-foot lead-ins to the recording van, which was located in the middle of the spread. Vacuum tube amplifiers, coupled to 100-c.p.s. galvanometers, were used during the summer of 1967. A 120-VAC generator mounted on the front of the van provided power. Before the summer of 1968, the system was modified to use solid-state amplifiers, powered by wet cell batteries. This latter system produced greater amplification and eliminated vibrations from the generator. A 255-VDC blaster with insulated telephone wire from a mounted power reel was used to detonate the explosives.

Field Procedure

Field procedure varied with site conditions and information requirements, but the maximum spread length procedure was used most. The 12-channel unit had an 1,800-foot spread length, and the 24-channel unit had a 2,200-foot spread length. Where very deep subsurface penetration was required, the shotpoint was placed well away from its nearest geophone, whereas relatively shallow strata could be recorded using a close-in shotpoint. Most of the profiling was done with a spread length of 2,200 feet and an in-line shotpoint offset 50 feet from each end. Many of the offsets in the deep alluvival deposits were determined by a combined study of the gravity and well data. The seismic profiles were shot from both ends, giving reversed time-distance data.

Three variations of the in-line profiling were used in the survey. A continuous series of reversed profiles was made in the channel and in area G. Short reversed profiles, crossing approximately at right angles, and spaced along the continuous profiles, permitted closer control of velocity, depth, and dip. Discontinuous profiling was selected for areas where terrain was rugged or partially inaccessible and greater distribution was desired.

Shotholes up to 20 feet deep were loaded with Apache Powder Company 60-percent Amogel in 2-inch, 1-pound sticks, and the charges were detonated with Atlas no-delay electric blasting caps. This combination propagated a satisfactory seismic wave. Charges ranged from 1 pound to 28 pounds per shot, with 3 pounds being most common on a 2,200-foot spread with a 50-foot offset.

INTERPRETATION

If boreholes or sonic logs are not available, the velocities must be determined by measurements along the surface (7). Velocity determinations were conducted on surface exposures (fig. 1) of geologic units to interpret the seismic profiles and extrapolate useful relationships to density. Locations were selected to give 250 feet or more of fresh in-line exposure on a level surface.

Several refraction velocities were taken from the reversed seismic-profile records in which nearby exposures of well-control data justified a direct identification of rock type. Velocities for the channel and alluvial deposits also were determined from several seismic-profile records. These data were then used to compile a table of seismic velocities (range and average) representative of the study area (table 2).

The range of velocities agrees very well with the histograms of seismic-wave velocities for similar rock units presented by Grant and West (7). One exception—the lower end of the velocity range for the Uncle Sam porphyry—may have been caused by fracturing. Because the high end of the range of velocities for channel deposits is represented by only one value, the true range is probably closer to 1,150 to 3,500 f.p.s. (feet per second). Only two values represent the low end of the range for unconsolidated alluvium, with the true range probably closer to 4,000 to 6,000 f.p.s.

A convenient plot of density versus velocity, using values from table 2, indicates that bulk densities tend to increase with seismic velocity (fig. 3). Relationships of velocity versus density have been described as a function of lithification accompanying age and compaction (7).

TABLE 2.—Seismic velocities and densities of geologic units in the watershed

Geologic unit	Geologic symbol	Velocity range	Velocity average	Density average
		ft./sec.	*ft./sec.*	*g./cm.³*
Recent channel deposits	Qal	1,150-4,900	2,200	--
Quaternay-Tertiary alluvial deposits	QT	--	--	--
Unconsolidated		3,350-6,000	5,000	2.02
Conglomerates		6,000-12,350	8,800	2.34
Quaternary-Tertiary basalt	QTb	--	[1]15,600	2.80
S. O. volcanics	Tsi	--	[1]12,300	2.33
Pre-S. O. volcanic sedimentary rocks	Ts	7,550-10,925	9,700	2.48
Schieffelin granodiorite	Tsc	12,300-17,700	15,450	2.68
Uncle Sam porphyry	Tup	10,100-16,400	13,350	2.61
Bisbee group	Kb	12,100-16,400	13,650	2.70
Naco limestone	Cn	11,850-16,000	13,350	2.69

[1] Values based on a single unreversed velocity profile.

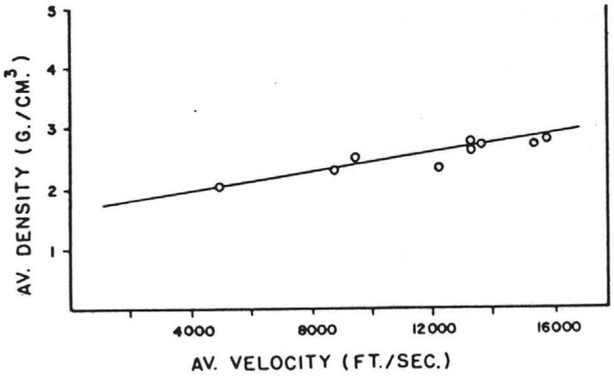


Figure 3.—A plot of bulk density versus seismic velocity for geologic units in the watershed

The magnitude and sign of the total error in seismic-calculated depths are functions of field techniques, instrumental compatibility, and interpretation. Assuming proper field techniques and instrumental compatibility, Northwood (12) classified interpretative refraction errors by their causes under three general headings: (1) errors caused by incorrect reading of data; (2) errors caused by incorrect assumptions; and (3) errors caused by incorrect geologic interpretation of the velocity layers.

Using this type of analysis for the watershed, seismic-calculated depths to the groundwater table and basement were compared to actual depths derived from data on a nearby well. Figure 4 illustrates this comparison graphically. In general, the deviations do not suggest a systematic error one might expect if all the calculated depths were greater, or less, than the actual depths. The accuracy of predicting the depth to either groundwater or basement was ± 6 percent. The accuracy of predicting the depth to groundwater alone was ± 10 percent, and that for basement alone was ± 4 percent.

The prediction becomes less accurate with greater depths. Northwood (12) explained this as a function of reading errors caused by greater offset distances. Greater offset distances cause decreases in the signal amplitude and an attenuation of the higher frequency components. Errors were kept to a minimum by increasing the charge and depth of shothole. For example, shotholes 4 feet deep and 50 feet in-line from a 550-foot spread contained 2-pound charges, whereas shotholes 20 feet deep and 1,300 feet in-line from a 2,200-foot spread contained 21-pound charges.

The prediction of depth to the groundwater table was less accurate than the prediction of depth to the basement. This difference may be explained by the greater horizontal distances over which the groundwater depths were projected from individual wells to the seismic profiles. Changes in groundwater level between the time of reading and the time of the seismic profile also may have caused minor errors. Finally, the capillary zone and its variable thickness and effect on seismic response are unknown and need further investigation.

The seismic data were interpreted by the critical distance and time intercept methods (8) (5). Interpretations were most commonly based on 2- and 3-layer

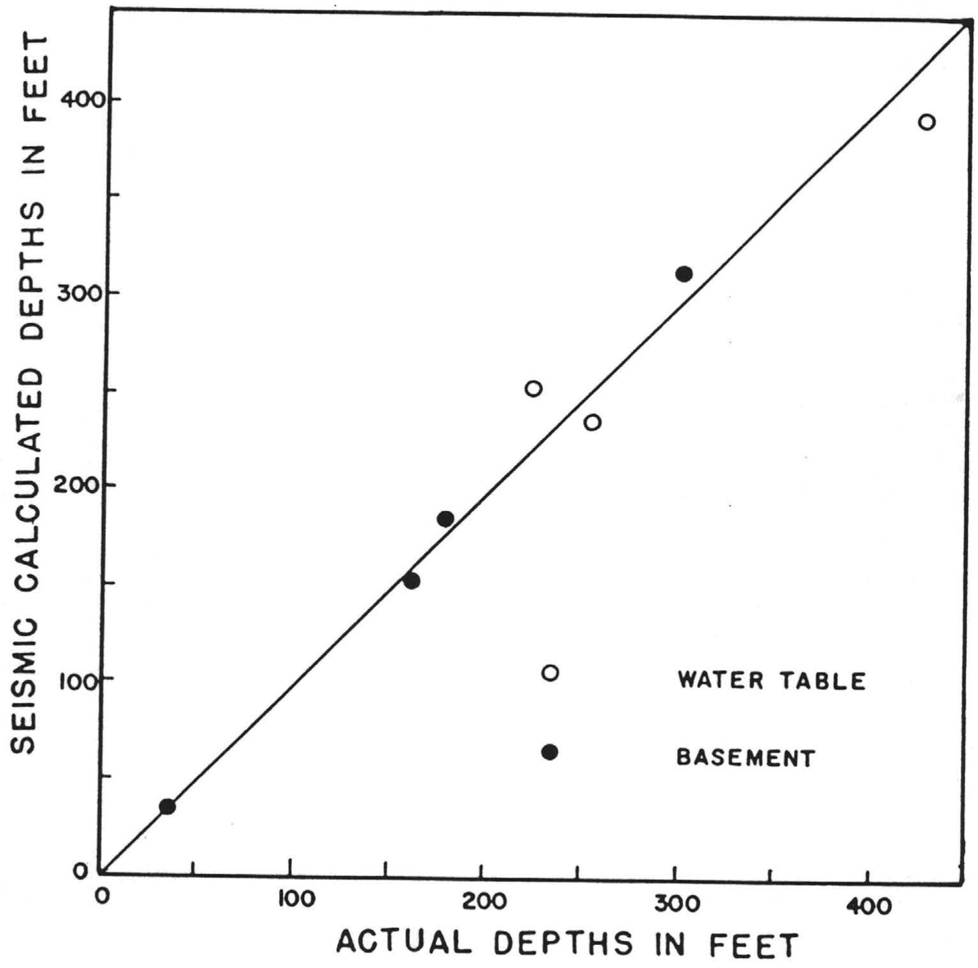


Figure 4.–A plot of seismically calculated depths versus depths derived from well logs.

horizontal and dipping interfaces. In a few instances, 4-layer and fault solutions were applicable.

San Pedro River to Flume 1 (Area A)

A continuous seismic profile, containing seven reversed profiles and one overlapping, unreversed profile, was conducted up the channel of Walnut Gulch for 2.5 miles, starting 1,200 feet downstream from the confluence of Walnut Gulch and the San Pedro River. Plate 1 presents these data and several profiles across the channel, and contains (1) an equal-scale planimetric map showing the location of all traverses in area A; (2) time-distance diagrams showing travel time to individual geophones; and (3) geologic interpretations based on the time-distance diagrams. For orientation, the geologic sections are noted by the four compass quadrants. Flume 1–a prerated, critical-depth, concrete structure for measuring the total streamflow from the upper 58 square miles of the Walnut Gulch drainage basin–is located 100 feet from the northeast end of the profile (plate 1).

The dominant geologic structure in area A, an alluvium-filled trough, was first noted by the gravity survey which predicted a north-trending structural depression 800 to 1,200 feet beneath the channel and centered 1.2 miles below flume 1. Surface geological investigation revealed the Uncle Sam porphyry exposed in several locations near area A. Using this information and velocity determinations (table 2), the basement rock forming the trough was interpreted as the Uncle Sam porphyry. The porphyry dips 12° toward the center on the right flank and 10° on the left flank. Profile A1 on the left flank indicates the porphyry rises to within 125 feet of the bed of the San Pedro River 1,200 feet downstream from the Walnut Gulch confluence. If the flanks maintained this attitude, the trough would be 1,300 feet deep at its center.

Because no recorded refractions from the basement could be identified on the time-distance diagrams in the center of profile A1A-A7′, a 2,300-foot reversed spread with shotpoints offset 850 feet was attempted in profile A10. Although refracted arrivals cannot be positively identified from the basement on this profile, the two most distant points on the reversed curve may be recording basement refractions. Because this is the earliest time interval at which a basement refraction could occur, a minimum thickness of the alluvial deposits can be estimated. To make such an estimate, we calculated a basement velocity of 13,000 f.p.s. between the points. The results of true velocities on the flanks, and the reported value in table 2 of 13,350 f.p.s. for the Uncle Sam porphyry, show that 12,000 f.p.s. is reasonable. The assumption that the basement is flat in this area for estimating purposes is reasonable from an inspection of gravity gradients and because projections from the flanks in profile A1A-A7A′ indicate a greater depth than that calculated from gravity results. The intercept time of possible basement refraction is 0.194 second. A minimum total thickness of 650 feet for the sedimentary section was determined using the velocities from the seismic profile. The trough has: a minimum depth of 650 feet based on the earliest possible refractions from profile A10; a maximum depth of 1,300 feet if the flanks in profile A1A-A7A′ maintain the same slopes; and an estimated depth range of 800 to 1,200 feet based on gravity data. Until more data (i.e., a longer seismic spread in the channel or a drill hole to basement near the axis) become available, a depth of 1,000 feet to the Uncle Sam porphyry seems reasonable near the center of the trough.

The sediments in the trough may be grouped into two broad units: Tertiary and Quaternary alluvial deposits; and Recent channel and flood plain deposits. The oldest and thickest unit contains the Tertiary and Quaternary alluvial deposits that are exposed in the east bank of the San Pedro River at profile A1 and outside the channel of Walnut Gulch below flume 1. Remnants of the older alluvium remain along Walnut Gulch approaching the San Pedro River flood plain. Surface exposures of the remnants are shown in profiles A10 and 11, in which offsets in the time-distance curves could have been misinterpreted as faults. A similar offset in the time-distance curve of profile A4 is interpreted as a buried erosional scarp that has 32 feet of relief. From a geomorphological viewpoint, the buried scarp expresses, in a subsurface manner, topographic evidence of the edge of the San Pedro River flood plain.

In general, the time-distance diagrams reveal a decrease in velocity within the older alluvial deposits as the axis of the trough is approached. A relatively shallow water table tends to give uniformity to the seismic results. Apparently the alluvial deposits become younger and less consolidated as the center of the trough is approached. Assuming the subsurface deposits in the center are not composed of claylike material (which can give similar velocities), we concluded that the area occupied by profiles A4, A5, A11, and A12 is best suited to future groundwater testing and development. This area also contains large thicknesses of low-velocity Recent channel fill that imply greater transmission losses during flood flows. Finally, the irregular interface between the two units, as suggested by the erratic travel times in profile A5, may provide temporary storage areas for the transmission losses until the losses are depleted by percolation to the groundwater table (17).

The Recent channel and flood plain deposits within the San Pedro flood plain were divided into two subunits, based on an intermediate slope in the time-distance diagrams. The two units, channel fill and subchannel fill, reach a maximum thickness of 200 feet on the northwest end of profile A9. The interface between these deposits and the older alluvial deposits in profiles A8 and A9 indicates a gradient of 2 to 4 percent, which is four times the present gradient of the San Pedro River. Although the profiles are oriented approximately parallel to the strike of the river, very recent changes in its course are evident in the field and on topographic maps. The steeper gradients may represent apparent slopes within much older meander loops. Tilting or change in erosional regime may be other explanations.

Mapping the water table by seismic methods in area A was hindered by (1) insufficient water-level data to correlate with slope intercepts on the time-distance plots, and (2) near coincidence with other interfaces. These interfaces were between the channel fill and subchannel fill in the San Pedro River flood plain, the channel fill and older alluvial deposits in the center of the area, and the older alluvial deposits and the Uncle Sam porphyry near flume 1.

A theoretical plane surface connecting the bed of the San Pedro River with the known occurrence of groundwater immediately above flume 1 could approximate the water table. This theory assumes that the water table has a constant slope, and the San Pedro River is effluent. The first assumption appears valid from solutions of the time-distance curves of profiles A6 and A7, in which an interface exists in the deep alluvium at a depth of 130 feet. The second assumption may have minor local departures. For example, 40 feet of dry, low-velocity channel fill was determined on profiles A2 and A2A near the Southern Pacific Railroad (plate 1). When projected, this establishes the water table 20 feet below the San Pedro River. Therefore, the recently formed reach of the river has not had sufficient time to entrench itself into the well-cemented alluvial deposits exposed on its eastern bank. If this is true, the local nature of the river is influent, creating a groundwater mound at the Walnut Gulch confluence. Finally, any flow beneath Walnut Gulch channel may be diverted to an old meander of the San Pedro River.

Flume 1 to Montijo Flats (Area B)

Between flume 1 and the lower end of Montijo Flats, the channel of Walnut Gulch consists of a series of meanders deeply entrenched in the Tombstone Pediment. The planimetric map illustrates the limits such meanders place on the longer seismic spreads (plate 2, area B). Because the spread had to cross one of the meander loops in profile B1, older alluvium is noted in the profile midsection.

The four spreads in the channel in area B are shown as a composite cross section in profile B1A-B4A′. Profiles outside the channel were discontinuous, with varying lengths to avoid serious topographic effects. Except for the short profiles of B7 and B8 in Montijo Flats (where 300 feet of alluvium had been penetrated by a well), all profiles were sufficiently long to record refractions from the basement. Evidence from the longer profiles of B3 and B4 in the channel indicates depths of 450 feet to the basement, which is the Uncle Sam porphyry in area B.

Probably the most striking feature of area B is the amount of relief on the porphyry. This relief varies from the 3,620-foot elevation in profile B4 to a surface exposure at 4,075 feet in profile B6. Surface relief on the porphyry is even more pronounced southeast of area B in the flanks of the Tombstone Hills. True velocities of the porphyry ranged from 10,100 f.p.s. to 14,100 f.p.s. and averaged 12,200 f.p.s. Although the lower velocity suggests some weathering, drilling several holes confirmed the presence of fresh rock.

An old meander loop has been interpreted from the delay times on the time-distance plot of profile B1. The asymmetrical cross section of the old buried channel appears entrenched 80 feet into the porphyry. A 3,760-foot elevation on the channel bottom and a similar one in the southeast section of profile B5 suggests lateral continuity. Wallace and Renard (17) mentioned the presence of an old meander loop from surface evidence in this area. This loop is considered more recent than the one entrenched within the porphyry. Seismic response did not indicate the presence of the stratigraphic boundaries within the alluvium that might be expected from a buried channel. The buried channel may show as a structure only on the interface between the porphyry and the alluvium. Later deposition within and above the depression must have been relatively uniform.

A buried porphyry ridge crosses the Walnut Gulch channel between profiles B1 and B2. If the ridge is consistent with other plunging ridges noted along the edge of the porphyry, it will plunge to the northwest. Indications from seismically determined depths to the regional water table and from the magnitude of relief on the ridge beneath the channel are that most subsurface movement of water in the saturated zone is deflected away from the channel to the northwest.

Mapping of the water table northeast of the buried ridge to Montijo Flats was successful because a sufficient thickness of alluvium existed between the water table and the porphyry. The water table, 250 feet deep, approximately parallels the land surface slope. Drillers' logs from wells in the Montijo Flats helped correlate seismic velocities with the saturated zone (fig. 4). West of the ridge in profiles B5 and B1, the water table could not be detected because of the proximity of the interface to the porphyry. Soske (15) described a similar problem as the blind zone problem.

Seismic velocities above the porphyry and below the water table north of the buried ridge suggest well-cemented alluvial deposits of Quaternary and Tertiary age (table 2). Velocities ranged from 8,575 f.p.s. to 10,125 f.p.s., with an average of 9,375 f.p.s. Southwest of the buried ridge, the absence of well-cemented deposits suggested that the ridge may have been a boundary between sedimentational regimes during deposition. Loosley to partially cemented alluvium above the water table had seismic velocities ranging from 4,250 f.p.s. to 6,000 f.p.s., with an average of 5,230 f.p.s. Overlying the 250 feet of alluvium is a thin veneer of Recent channel fill averaging 18 feet in thickness, with a velocity of 2,200 f.p.s.

Lamb's Draw (Area C)

Three bedrock types—the Naco limestone, the Bisbee group, and the Uncle Sam porphyry—occur in the subsurface interpretation of profile C1A-C4A' (plate 2, area C). Internal contacts in area C were interpreted from the geologic map in figure 2 because the seismic velocities of the three formations show little contrast (table 2). The Naco limestone crops out in the hills on both sides of profile C4 and is folded and faulted in a complex manner. In several areas below the concrete apron (an old highway crossing), the channel fill deposits are swept clean, and the exposed rock resembles marble. Profiles C6 and C7 show a fairly uniform slope to the north and northwest, although the time-distance data of profiles C3 and C4 indicate that the interface between the Naco limestone and the overlying alluvium is uneven. The Bisbee group is exposed between the Uncle Sam porphyry and the Naco limestone in a wide outcrop one-half mile southeast of profile C2 and has a strike that lends itself to this projected interpretation. From the seismic data, we could not determine if the contact was intrusive or faulted. A sharp ridge of the Uncle Sam porphyry is exposed immediately south of profile C5 and deflects the channel from a southwest to northwest course. Profile C5 shows that the ridge plunges sharply beneath the channel to the north.

From west to east in profile C1A-C4A', 375 feet of Tertiary and Quaternary alluvial deposits thin to approximately 80 feet over the buried, plunging porphyry ridge, thicken to 200 feet over the Bisbee Group, and lens out beneath the channel fill in the midportion of profile C4. Velocities within the alluvial deposits beneath cross profiles C5, C6, and C7 indicate a range of consolidation from loose to partially cemented. The profile velocities beneath the channel imply a slightly higher degree of consolidation because of the higher moisture content.

The water table was not detected in area C, although it was known to be 250 feet deep in the west and southwest portions of area B. The western time-distance curve of profile C1 would be expected to show a 9,000-f.p.s. segment between the 6,750-f.p.s. velocity and the 12,650-f.p.s. velocity if the saturated zone was to be detected. This omission is similar to the western profiles in area B. East of the plunging porphyry ridge in area C, the regional water table was not detected, although it was believed to be near the contact with the Bisbee group.

Recent channel deposits average 25 feet in thickness and increase from zero in certain portions of the channel on profile C4 to between 35 and 40 feet in profiles C2 and C3. Seismic velocities within these channel deposits are similar to those in areas A and B. The 3,200-f.p.s. velocity in the thicker deposits is 1,000 f.p.s. higher than the average and may be a function of saturation, because the traverse was conducted shortly after a runoff event.

Rifle Range (Area D)

A continuous, in-line seismic profile up the Walnut Gulch channel and intersecting U.S. Highway 80 northwest of Tombstone is shown as area D in plate 2. A 1.5-mile channel length between areas C and D was omitted in this study because exposures of the Naco limestone and the Schieffelin granodiorite eliminated the need for seismic coverage. The geology and hydrogeology of a shallow, perched water aquifer within pockets of the Schieffelin granodiorite, one-half mile west of area D, had already been studied intensively (14).

Time-distance graphs from profile D1A-D4A' reveal an interface of granodiorite sloping east toward the deeper alluvium. The 4° slope shown in the geologic cross section and derived from the time-distance curves is only an apparent slope. A northwest structural trend, and geologic, hydrogeologic, and other geophysical data suggest a maximum gradient oriented N.35° to 45° E. These integrated data conclusively show a subsurface drainage pattern almost the reverse of that suggested by the surface slope of the channel. Transmission losses to the channel fill in the area of U.S. Highway 80 do not have subsurface hydraulic continuity with the shallow, perched water aquifer to the west and down channel. Although we do not know the exact location of the groundwater divide created by the Schieffelin granodiorite between these two areas, the seismic data indicate its presence immediately west of profile D1.

Inspection of the time-distance graphs in profiles D1 and D2 reveals similar downdip velocities of 13,500 f.p.s. and 12,300 f.p.s., respectively. On the other hand, an updip velocity of 19,200 f.p.s. in profile D1 is almost twice that of 10,180 f.p.s. in D2. These data indicate that the slope of the granodiorite determined in profile D1 does not extend at the same rate beneath all of profile D2. The slope was extended as far as the seismic data would justify and was terminated by a normal fault. A fault interpretation appears reasonable from an inspection of drilling logs that reveals the basement at a depth of 160 feet immediately southwest of the profile with at least 1,160 feet of alluvium to the northeast. Spread lengths in the seismic profiles were not sufficient to determine the depth to basement on the downthrown side of the fault.

Time-distance graphs east of the fault (plate 2, area D) indicate three apparent facies of the Tertiary and Quaternary alluvial deposits. These facies are believed to result primarily from consolidation or cementation. Scattered exposures along the channel bed did not show visible differences in the conglomerates.

A high-velocity conglomerate at a depth of 250 feet in profile D3 correlated with a hard, gray conglomerate logged in a well one-half mile south at a depth of 280 feet. This conglomerate is the controlling factor of the water table's position in this area.

The 6,000- to 9,000-f.p.s. velocity for the conglomerates exposed in the channel suggests minimum transmission losses in the areas traversed by profiles D3 and D4. Conglomerates are not exposed in the channel bed in profile D2, and the seismic velocity for the channel fill is higher than average. This area has been interpreted as a gradational zone between the high-velocity, well-cemented conglomerates in the basin proper and the channel fill overlying the Schieffelin granodiorite.

Gleeson Road (Area E)

Area E in plate 2, approximately one-half mile up the Walnut Gulch channel from area D, reveals channel fill 10 to 20 feet thick and two facies of the Tertiary and Quaternary alluvial deposits. The upper facies, with an average seismic velocity of 5,750 f.p.s., increases in thickness from 70 feet up channel to 160 feet down channel. This facies is thought to correlate with a partially cemented, cobble and boulder conglomerate in a thick, cutbank exposure immediately up channel. A lower facies, with a velocity of 8,550 f.p.s., correlates with exposures 1,000 feet down channel. This indicates the unit is either downthrown by faulting, or that an 8° rise is necessary to return it to the channel surface between areas D and E. The lack of high-velocity slopes on the time-distance graphs shows that basalt, exposed 500 feet east of profile E, does not extend beneath the channel. This tends to confirm the presence of a fault, discussed under area D.

Willow Wash (Area F)

Area F consists of a seismic profile with a bearing of N. 55° E. located 1 mile northwest of the watershed boundary of Walnut Gulch in Willow Wash (fig. 1 and plate 2). Information from well and gravity data west of U.S. Highway 80 indicated that the basement rocks exposed in the Tombstone Hills extended northwest, north, and northeast beneath the alluvial deposits. Therefore, knowledge of the basement attitude in area F was necessary to strengthen this indication. Information on groundwater occurrence in area F and the nature of the overlying alluvium was also essential to substantiate a "noselike" extension in a preliminary water table map.

Geologic interpretations of profile F1A-F3A' in plate 2 revealed a very thick deposit of alluvium overlying a sloping basement identified as the Bisbee group. To determine the degree of slope and identify the rock type, we had to depend on information from the drilling logs and the first arrival times from profile F1. This analysis is limited by the assumption of uniform dip and the use of an apparent velocity in the depth calculation. Nevertheless, the 8° to 10° northeast slope compares favorably with the 12° to 14° approximation from gravity data. The velocities and slope intercepts derived from the time-distance graphs suggest that the Tertiary and Quaternary alluvial deposits extend to a depth of at least 1,200 feet on the northeast and consist of three horizons.

A depth determination of 900 feet to the lower horizon was based on the unreversed travel-time curve of profile F3. A constant interface was extended west as a dashed line in the cross section and was based on the lack of offsets in the travel-time curve. Profile F2 was too short to provide sufficient penetration to the lower horizon. Also, the final three traces in profile F3 imply a slower velocity above the basement and beneath profile F2. The 11,750-f.p.s. velocity would place this material in the well-cemented conglomerate range (table 2). With the water table as an upper interface and an average velocity of 10,000 f.p.s., an intermediate horizon has a 600-foot thickness that decreases southwest over the basement. The velocities shown in table 2 suggest this horizon is also well-cemented conglomerate. The 4,875-f.p.s. velocity in the upper horizon of profile F3 is typical of the loosely to partially cemented alluvial deposits above the water table in the Walnut Gulch Experimental Watershed. A veneer of Recent channel deposits completes the section.

Highway 82 (Area G)

Area G (plate 3) extends 2.5 miles east-west along Arizona Highway 82 and lies between area C (one-half mile south) and Area F (1 mile north) (fig. 1). In general, the data from area G corroborated findings in areas C and F. The basement complex supporting the Tombstone Hills plunges beneath the alluvium to the northwest, north, and northeast. In the central portion of area G, depths to basement were 275 to 325 feet. The basement was not detected in the most westerly profile, indicating a thick alluvial cover there. The most easterly profile revealed a basement slope to the northeast of 10° with a final depth of 575 feet. This slope agrees with findings is most of the other profiles oriented northeast. Based on the seismic velocities and projections in figure 2, the 13,000- to 15,000-f.p.s. basement velocity east of center was interpreted as the Bisbee group. The highest velocities could indicate the Schieffelin granodiorite. Wallace and Cooper (18) inferred its presence beneath this area from a chloride ion concentration map derived through a water-quality study of the groundwater. A velocity of 12,000 f.p.s. for the basement west of center was interpreted as Naco limestone. A profile oriented to the northwest near the center, and showing a small dip, confirms the presence of a shelflike feature that was previously inferred from gravity data.

Overlying the basement are Tertiary and Quaternary deposits ranging in velocity from 5,000 to 7,000 f.p.s. First arrivals necessary for correlation to a water table were not positively identified in area G. We postulated that the high elevation of the basement did not permit development of the regional water table, although the overlying alluvium is 300 feet thick. The presence of a 300-foot dry hole that penetrated the basement immediately east of area G appears to confirm this postulate.

City Dump (area H)

In area H, large offsets of the shotpoints prohibited first arrivals of the upper layer from showing in the time-distance graphs (plate 3). For depth calculations, we assumed a 5,200-f.p.s. velocity for the loose Tertiary and Quaternary alluvial deposits from an average of several adjacent profile areas. Based on this assumption, a thickness of 125 feet on the southwest increased to 275 feet on the northeast. A second interface, 425 feet in depth and increasing to 500 feet on the northeast, separates two layers with velocities greater than 10,000 f.p.s. A lithologic interpretation of well-cemented conglomerates for both layers is based partly on drillers' logs from a well to the southeast, which showed that basement was not penetrated in a total depth of 1,160 feet. The interface also correlates with a deep interface in area D to the southeast and area F to the northwest (plate 2).

Bennett Ranch Road (Area J)

Beneath area J in the north-central portion of the watershed, Tertiary and Quaternary alluvial deposits extend the full 1,000-foot depth explored by the seismic profiles (plate 3). This finding is substantiated partly by drillers' logs from wells to the southwest and northeast, which show alluvial deposits the full extent of their respective depths of 500 and 662 feet. An inspection of gravity profiles reveals a thickness of 2,000 feet for the alluvial deposits beneath area J. Time-distance graphs showed three velocity layers of 4,875, 9,000, and 11,350 f.p.s. The upper interface between loose alluvium and conglomerate is irregular and has a maximum depth of 150 feet. The lower interface is interpreted as the water table and reveals a depth of 400 feet on the southwest, increasing to 475 feet on the northeast. This gives the impression of a water table inclined toward the Dragoon Mountains. However, a 2.5-percent slope in the topography gives a net 0.8 percent water-table gradient to the southwest beneath area J.

Lime Tank (Area K)

We chose a seismic traverse in area K (plate 3) for exploring the extent of a normal fault inferred from seismic data in areas D, E, and H (plates 2 and 3). A layer coincident with the land surface, and 530 feet in depth beneath the southwest portion of area K, had a velocity of 13,050 f.p.s. This velocity could represent either the Bisbee group or the Naco limestone (table 2). An exposure of the Naco limestone and the Bisbee group in a faulted complex one-fourth mile southwest and an exposure of the Bisbee group three-fourths mile north did not offer a positive means of choosing between them (fig. 2). A tentative assignment of the Bisbee group beneath area K was based on the nature and location of the northern outcrop. Because first arrivals from the Bisbee group were not detected on the time-distance graph of a long seismic profile extending to the northeast, an offset was inferred in the interface that was determined from a shorter spread to the southwest. We calculated the minimum depth to the interface to be

780 feet, making 250 feet a minimum estimate for the displacement on the fault. Based on seismic velocities and exposures northwest and southeast of area K, the section overlying the Bisbee group was interpreted as pre-S.O. volcanic sedimentary rocks. These exposures, limited to the beds and banks of washes, were too small in area to show in figure 2. A surface veneer of Tertiary and Quaternary alluvial gravels thickens to 75 feet on the northeast. A water table interface may be associated with a change in velocity from 8,300 to 10,825 f.p.s. This occurs at a depth of 200 feet on the southwest and 300 feet on the northeast. A mining shaft one-half mile northwest revealed a depth of 254 feet to water.

New Cowan Road (Area L)

In area L, 5 miles southeast to Tombstone, seismic profiling was conducted across the watershed boundary to determine if the groundwater and surface water divides were coincident (plate 3). Figure 2 indicates that Naco limestone crops out one-half mile to the southwest and the S.O. volcanics one-fourth mile to the northeast. Table 2 indicates an average velocity of 9,700 f.p.s. for the pre-S.O. volcanic sedimentary rocks and an average velocity of 8,800 f.p.s. for the Tertiary and Quaternary conglomerates.

Geologic cross sections, interpreted from the time-distance data in profiles L1, L2, and L3 (plate 3), show an average depth of 65 feet for the loose alluvial deposits with a velocity of 4,500 f.p.s. This depth increases to 95 feet to the southeast in profile L2 and decreases to 41 feet to the north in profile L3. The attitude of the interface between the loose Tertiary and Quaternary alluvial deposits and the underlying pre-S.O. volcanic sedimentary rocks is approximately the same as the surface attitude.

An interface within the sedimentary rocks has been interpreted as separating a sandstone-mudstone facies from a conglomerate facies. This interpretation is based on the time-distance graphs, a limestone conglomerate outcrop 2,000 feet west of area L, and a driller's log from the nearest well, 1 mile southeast. Several minor steplike faults have been interpreted from the displacements in the time-distance graphs of profiles L1 and L3. The attitude of the interface derived from profile L3 suggests that the pre-S.O. volcanic sedimentary rocks dip beneath the S.O. volcanics, which crop out immediately to the northeast. This supports field observations by Gilluly (6) in adjacent areas.

DISCUSSION

Although the velocity with which a layer transmits seismic waves cannot be used to clearly identify its exact lithology and its hydrologic characteristics, the velocity can be used successfully in calculating or predicting depth to the layer. Errors caused by incorrect geologic and hydrogeologic interpretation of velocity layers can be reduced if a framework of control can be established from a few wells in an area, and if a number of velocities are first determined directly on known outcrops. Problems of interpretation may still arise if the ranges or averages of velocities of several different formations group around common values (as noted in table 2 with the Naco limestone, Bisbee group, and the Uncle Sam porphyry).

Rock fracturing and weathering may influence the arrival times in velocity determinations over outcrops. In this study, we chose the highest value derived from the time-distance graph as representative. Placing the geophones and charges properly in rock, to get a good signal on the record, also involved problems.

Water-saturated alluvial deposits had significantly higher seismic velocities than their unsaturated equivalents. The large velocity range in the conglomerates (table 2) was primarily a function of cementation or saturation or both. A partially cemented, nonsaturated conglomerate occupied the lower end of the range, extending from 5,000 to 7,000 f.ps. A well-cemented, fully saturated conglomerate occupied the upper end of the range, extending from 9,000 to 12,000 f.p.s. Without well logs for control, it is difficult to relate a change in slope on the time-distance curves from the 4,000- to 7,000-f.p.s. range to the 7,000- to 9,000-f.p.s. range to a change in stratigraphy or to the effects of the water table.

One of the usual assumptions made in seismic-refraction interpretation, which may not represent field conditions precisely, is that velocity layers are recognizable as first breaks. Soske (15) referred to significant deviations from this assumption as the blind zone problem and pointed out that such deviations frequently occur where the water table is near the interface with the underlying bedrock. In our study, efforts to detect groundwater levels were more successful in areas where a thick, saturated alluvium with an intermediate velocity overlies a high-velocity bedrock. Seismic profile B4 (plate 2) gives an example of a time-distance graph and interpreted profile showing an increase in seismic velocity caused by the groundwater interface. In portions of areas A, B, C, D, and G, the water table was not detected because the returning signal from a high-velocity bedrock overtook and cut off the signal from the water table.

As Dobrin (5) noted, refraction shooting across a fault may reveal parallel, displaced linear segments on the time-distance graphs. In this case, the segments correspond to the upthrown and downthrown sides of the fault, and the throw is determined by the difference between the intercept times of the two segments. However, the displaced segments do not appear on the time-distance graphs in area D. Seismic profile D2 (plate 2), reveals a dipping interface of Schieffelin granodiorite. If the granodiorite had maintained the same slope beneath the reverse shot on the southeast, an apparent updip velocity would have been much higher than the noted 10,180 f.p.s. Well data and seismic profiles east of profile D2 reveal deep alluvium, and therefore justify the fault interpretation.

SUMMARY AND CONCLUSIONS

The seismic refraction survey method used in Walnut Gulch Experimental Watershed has proved to be a useful and rapid method of collecting information on subsurface structural geology, groundwater depths, and densities of geologic materials.

Fifty-two seismic refraction profiles were conducted in 11 areas in and around the watershed, aggregating a length of 115,550 feet of in-line seismic profiling (fig. 1 and table 1). In general, the seismic refraction profiles provided sufficient data to construct geologic sections for each of the 11 areas. These sections revealed (1) the identification, depth, attitude, and extent of geologic units comprising the basement complex; (2) the identification, depth, attitude, and extent of geologic units comprising the alluvium complex; (3) structural features such as faults, buried ridges, and buried channels; and (4) the presence, depth, and attitude of the regional water table.

The usual seismic spread length was 2,200 feet. The complete field unit consisted of 24 geophones, solid state amplifiers, a dry paper recording oscillograph, a d.c. power source, and a 4-wheel-drive van for transport.

We presented seismic profiles at scales of 1:6,000 and 1:12,000 and discussed the surface and subsurface geology. Seismically measured water table depths and depths from well logs were compared graphically, and a graph was prepared to show the correlation between seismic velocities and densities of geologic material.

Like all survey methods, the seismic refraction survey method has certain limitations. The most serious limitation we found was that of depth penetration. Because of excessive noise amplification with increasing spread lengths, we could not measure the complete section of alluvium in portions of the watershed.

Analysis of geophysical, borehole, and geologic data provided a basis for interpreting the hydrogeology of the Walnut Gulch Experimental Watershed. In general, surface and subsurface boundaries of the watershed are not coincident. Mapping of the water table in many areas revealed depths from near zero at the confluence of Walnut Gulch and the San Pedro River to 475 feet in the central portion of the watershed. The accuracy of predicting depths to either groundwater or basement by the seismic method was ± 6 percent, whereas that for groundwater alone was ± 10 percent. Recent alluvial history of channel deposits was inferred from the geologic sections and interpretations in areas A, B, C, D, and E.

The alluvium can be classified on the basis of seismic velocities into a loose, gravel-type deposit with a velocity of 5,000 f.p.s. and a thickness of up to 300 feet. An intermediate velocity of 5,000 to 9,000 f.p.s. represents partially cemented conglomerates. The lower boundary of these conglomerates near the margins is the basement, and within the graben structure, the lower boundary is a high-velocity conglomerate. The upper boundary of the high-velocity conglomerate appears to be a controlling factor on the water table in areas D and J northeast of Tombstone. In area F, the upper boundary of the high-velocity conglomerate is 900 feet in depth, and the water table is developed at the upper boundary of the lower velocity conglomerate.

Nogales AMS Sheet.

June 11, 1965

434

LITERATURE CITED

(1) Andreasen, G. E., Mitchell, C. M., and Tyson, N. S.
1965. Preliminary aeromagnetic map of Tombstone and vicinity, Cochise and Santa Cruz Counties, Arizona. U.S. Geol. Survey open-file rpt.

(2) Blake, Wm. P.
1882. Geology and veins of Tombstone, Arizona. Amer. Inst. Mining Engin. Trans. X: 334-345.

(3) Butler, B. S., Wilson, E. D., and Rasor, C. A.
1938. Geology and ore deposits of the Tombstone District, Arizona. Ariz. Bur. Mines Bul. 143, 114 pp.

(4) Church, J. A.
1903. The Tombstone, Arizona mining district. Amer. Inst. Mining Engin. Trans. 33: 3-37.

(5) Dobrin, Milton B.
1960. Introduction to geophysical prospecting. 446 pp. New York.

(6) Gilluly, James.
1956. General geology of central Cochise County, Arizona. U.S. Geol. Survey Prof. Paper 281, 169 pp.

(7) Grant, F. S., and West, G. F.
1965. Interpretation theory in applied geophysics. 583 pp. New York.

(8) Heiland, C. A.
1946. Geophysical exploration. 1013 pp. New York.

(9) Hollyday, Este F.
1963. A geohydrologic analysis of mine dewatering and water development, Tombstone, Cochise County, Ariz. Univ. Ariz. M.S. Thesis, 90 pp.

(10) Jones, E. L., Jr., and Ransome, F. L.
1920. Deposits of manganese ore in Arizona. U.S. Geol. Survey Bul. 710: 96-119.

(11) Keppel, R. V., and Renard, K. G.
Transmission losses in ephemeral stream beds. Jour. Hydraul. Div., Proc. Amer. Soc. Civil Engin. 88(HY-3): 59-68.

(12) Northwood, E. J.
1967. Notes on errors in refraction interpretation. Seismic Refraction Prospecting, Soc. of Exploration Geophysicists: 459-465.

(13) Rasor, C. A.
Mineralogy and petrography of the Tombstone mining district, Arizona. Univ. Ariz., Ph. D. Dissertation.

(14) Renard, K. G., Keppel, R. V., Hickey, J. J., and Wallace, D.E.
1964. Performance of local aquifers as influenced by stream transmission losses and riparian vegetation. Amer. Soc. Agr. Engin. Trans. 7(4): 471-474

(15) Soske, J. L.
1959. The blind zone problem in engineering geophysics. Geophysics 27: 198-212.

(16) Spangler, Daniel P., and Libby, F.
1968. Application of the gravity survey method to watershed hydrology. Groundwater 6(6): 21-26.

(17) Wallace, D. E., and Renard, K. G.
1967. Contribution to regional water table from transmission losses of ephemeral streambeds. Amer. Soc. Agr. Engin. Trans. 10(6): 786-790.

(18) Wallace, D. E., Cooper, L. R.
1969. Natural chemical dispersion in groundwater from various rock types in a portion of the San Pedro River Basin, Arizona. Jour. Hydrol. 2, ART. 477: 121-135.

U.S. DEPT. AG.
GRAVITY SURVEY

436

Application of the Gravity Survey Method to Watershed Hydrology

by Daniel P. Spangler and Fred J. Libby

Reprinted from the November-December, 1968, Volume 6, Number 6 issue of Ground Water

43

Application of the Gravity Survey Method to Watershed Hydrology[a]

[redacted]

[redacted]

[redacted]

result then is simple Bouguer values.

late Tertiary and early Quaternary rhyolite and basalt

KENYON RICHARD
REPORT

KENYON RICHARD
Mining Geologist
1501 MIRACLE MILE
TUCSON, ARIZONA 85705

602-622-0953

443

August 9, 1973

Mr. Richard F. Hewlett
Sierra Mineral Management
4741 East Sunrise Drive
Skyline Bel Aire Plaza
Tucson, Arizona 85718

Tombstone District
Arizona

Dear Sir:

Two days were spent in the Tombstone District, July 5 with Jim Briscoe and July 11 with you and Briscoe.

Beforehand I had reviewed Butler and Wilson's U. of A. --Arizona Bureau of Mines Bulletin on Tombstone, Jan. 1938. The authors of this bulletin must have had many old mine maps in order to portray the geologic structure, the stratigraphy and the mine workings in such remarkable detail. They show no assays, probably because the map (and property?) owners would not permit publication of such data.

I get the impression from reading the history that, despite the fairly substantial gross production of $37 million, profit was mostly non-existant. Cost-price ratios were not much different than they are today, even with the current high silver price. The reason I believe that relative costs were so high during the district's hey-day was that too many feet of underground workings had to be driven for each ton of ore discovered and extracted. They did not have diamond drills, modern pumps or bulldozers.

Therefore, it seems to me that exploration today has a chance----rather long-shot----to find small but commercial ore bodies.

In order to accomplish this, old maps showing assays <u>must</u> be found. You have said that you expect to get maps of this kind from property owners with whom you are dealing.

The western part of the district where you are setting up your present operations received but little old-time mining activity as compared to the main, eastern portion. This doubtless was due to the presence of stronger surface expressions of mineralization in the east than in the west. This is meant in the overall mineralization sense, not just more small pockets of horn silver at the surface which was the principal ore guide of the <u>earliest</u> prospectors. The miners and engineers who quickly appeared in the district were, for the most part, good "mining geologists" by experience, though the name, as such, was not respected, nor was the capability even admitted except by crude terms like, "He has a nose for ore."

These early miners had good recognition of stratigraphy, structure, mineralogy, vein intersections, and the economic differences and significance between hypogene and supergene minerals.

The point is, you cannot beat these old operators at their own game, except (1) by consolidation of properties, (2) by reconstruction of the geometry of all mineral occurrences (in this connection Briscoe's detailed current field mapping is very important), (3) by determination of the actual distribution of values in the old mines and prospects, and (4) by use of bulldozers and diamond drills.

You will be lucky if you can keep your mill running very long. But the above four points will improve your luck quite a bit.

Without old assay maps in hand for analysis, it seems likely that, at best, actual undiscovered ore bodies are very small exploration targets in either the western or eastern portions of the old district. When all information has been put together, I would expect that a few relatively shallow drillholes will be recommended.

The large area of alteration with several small breccia pipes and dikes situated between the Tombstone and Charleston Districts proper is quite interesting. It is by far the strongest and largest zone of hydrothermal activity in the region. (I have not yet seen the old Charleston District.) It has several characteristics of porphyry copper deposits. (A reminder: There are a number of long, expensive steps between "deposit" and "ore" body----and longer financial steps between "ore body" and "production at continuing profit.")

The occurrence of small, relatively higher grade base and precious metal ore bodies is common around the fringes of some porphyry copper districts. Tombstone and Charleston may be in this category.

There are practically no surface occurrendes of oxidized copper or silver minerals in this large alteration zone. This may have been due to a larger proportion of pyrite over copper, silver and other sulphides, with acid leaching having removed the latter from the surface and near-surface. Also, a good deal of the altered area is covered by alluvium.

There is a little limonite-after-chalcocite in local fracture zones and breccia pipes in the alteration zone, but not enough to indicate that substantial amounts of ore-grade material existed in the leached outcrops. Quartz-sericite alteration is fairly strong in most places.

The alteration mostly is in Uncle Sam porphyry, although some altered outcrops appeared to have clastic textures. In any case clastic units of the Bisbee Group are known to exist nearby. Much of the ore in the Tombstone (and maybe the Charleston) Districts occurred as hypogene replacements in limey beds in the lower horizons of the Bisbee and in the upper Paleozoic carbonate beds.

In the western part of the Tombstone area the Uncle Sam porphyry seems to be a thick sill. I would expect, though, that in the altered area under consideration it is a stock.

I would expect the altered stock and surrounding altered clastic sediments to contain disseminated pyrite with some chalcocite and chalcopyrite. These might constitute relatively shallow ore bodies, and that possibility is interesting enough to warrant drilling. First, though, the mapping should be

447

finished, particularly the reconnaisance mapping including the Charleston area, which was discussed when we all were in the field.

Since you mentioned that several drillholes have been put down in the Charleston District, a couple of which had deep but long intercepts of 0.7(?)% Cu, I have been thinking that those intercepts might be mineralization in favorable carbonate beds in the lower Bisbee or the Paleozoic formations. This thought certainly enhances exploration possibilities where the same horizons probably extend into the alteration zone described above. Reconnaisance mapping of the region probably will give us a fair idea as to the depth of these limey beds. Even if surface exposures of these beds are too far away or too widely spaced to permit reasonable estimations of depth, this exploration possibility is sufficiently good right now, even with my presently rather limited knowledge of the region, for me to recommend two drillholes: (1) 1000' deep, inside the alteration zone in the Uncle Sam porphyry--preferably within one of the breccia pipes and (2) 2000' deep, outside of the porphyry but near it and hopefully, inside the alteration zone in carbonate rocks. The alteration zone should spread out in the carbonate horizons.

This drilling would not be conclusive, unless only disseminated pyrite is encountered.

Yours very truly,

Kenyon Richard

Kenyon Richard

Copies: one extra to Hewlett

TENNECO AIRPORT
PROJECT DRILLING

448

TENNECO OIL COMPANY

TOMBSTONE AIRPORT PROSPECT

Geologic Report, Drill Hole No. T71-4
Cochise Co., Arizona

TOMBSTONE AIRPORT PROSPECT

Geologic Report Drill Hole No. T71-4 Cochise Co. Arizona

This hole was drilled to test a moderate, isolated, sharply defined magnetic anomaly southeast of Tombstone, Arizona. This anomaly is located in an area where the only visible outcrops are Paleozoic limestone. Some Tertiary, rhyolite sills and dikes crop out in the vicinity. Associated with the rhyolite, is some minor fluorite and siderite mineralization. Ground magnetics over the anomaly were performed by A. M. Rugg. In addition some magnetic profiles were carried over typical outcrops of rhyolite; the rhyolite was found to be essentially non-magnetic whereas the anomaly indicated the presence of a strongly magnetic body under relatively thin cover. The nearest outcrops (all limestone) were 200 to 300 feet away from the anomaly.

A drill site was located on the northern portion of the anomaly. Three feet below the surface, the drill entered a grey and brown, fine-grained quartz latite. The hole was continued to 175 and stopped; no signs of mineralization were seen. The rock is moderately magnetic and clearly the source of the isolated magnetic anomaly.

Conclusions: The airborne survey has been proven capable of finding moderate anomalies with small lateral extent. The rock, found in drilling represents a heretofore unknown intrusion in the district. Probable age of the rock is Tertiary and it is thought to be related to the rhyolite dikes in this area. No significant mineralization was observed; no further work is recommended.

John Beeder
John Beeder
Senior Geologist

DRILL HOLE NO. T71-4
COLLAR ELEVATION 4775'
COORDINATES

Tombstone Airport PROJECT
Cochise COUNTY. Arizona

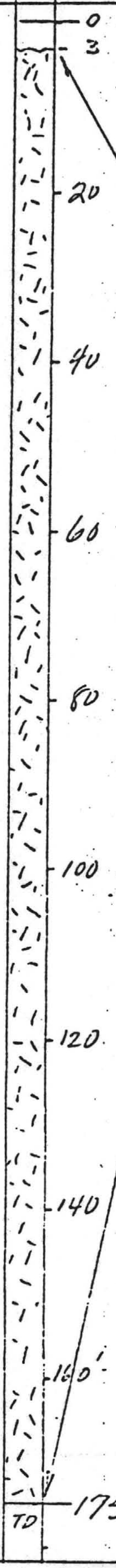
PAGE 1 of 1
BY JRB
450

BEARING
INCLINATION Vert.
SCALE 1" to 20'
DEPTH 175'
STARTED 6/4/71
COMPLETED 6/6/71

% Core Recovery | Structure | Alteration | Mineralization | Rock Type

GEOLOGY

CORE ASSAYS
INTERVAL: FROM | TO
MINERAL



0 to 3' caliche w/numerous limestone boulders

3' to 175' Grey and brown fine grained qtz latite, very wthr'd and decayed 3-20,' moderately magnetic

153-157 fresh unweathered phase

bright red & orange FeO stain on fractures assoc. with calcite - no signs of sulfide min'z.

ALTERATION
☐ SERICITE
☐ KAOLIN
☐ SILICA
☐ CHLORITE
☐ GARNET
☐ SERPENTINE

MINERALIZATION
☐ PYRITE
☐ CHALCOPYRITE
☐ CHALCOCITE
☐ MOLYBDENITE
☐ MAGNETITE
☐ GALENA
☐ SPHALERITE
☐ SPECULARITE

172'
[illegible]
175'

DRILL HOLE REPORT

Project Tombstone Airport Prospect County of Cochise State of Ariz.

Drill Hole No. 1 T. 20S R. 23E Sec. 30

Date Started June 4, 1971 Coord. 750' E. and 850' S. of NW Cor. Sec. 30

Date Finished June 6, 1971 Elevation 4755'

Total Tours 3 Total Depth - 175'

Footage drilled Rotary: Alluv. ____ Rock 12' Dia. 8½

Percussion: 12' 175'

Footage cored from 172' to 175' size NXC

Average core recovery ____

Casing used 12' Size & type 6-5/8 Black Iron Pipe

Type Rig G-D 2000 Drilling Contractor (1) Whatley Drilling Co.

(2) ____

Driller ____ Helper ____

Total Cost: Footage	$ 946.00
Rig rental	160.00
Roads & drill site prep.	
Mob. & Demob.	430.00
Materials	27.28
Bits & type	
Misc.	
Supervision	
Total Cost	$ 1,563.28

Cost/Foot $8.93

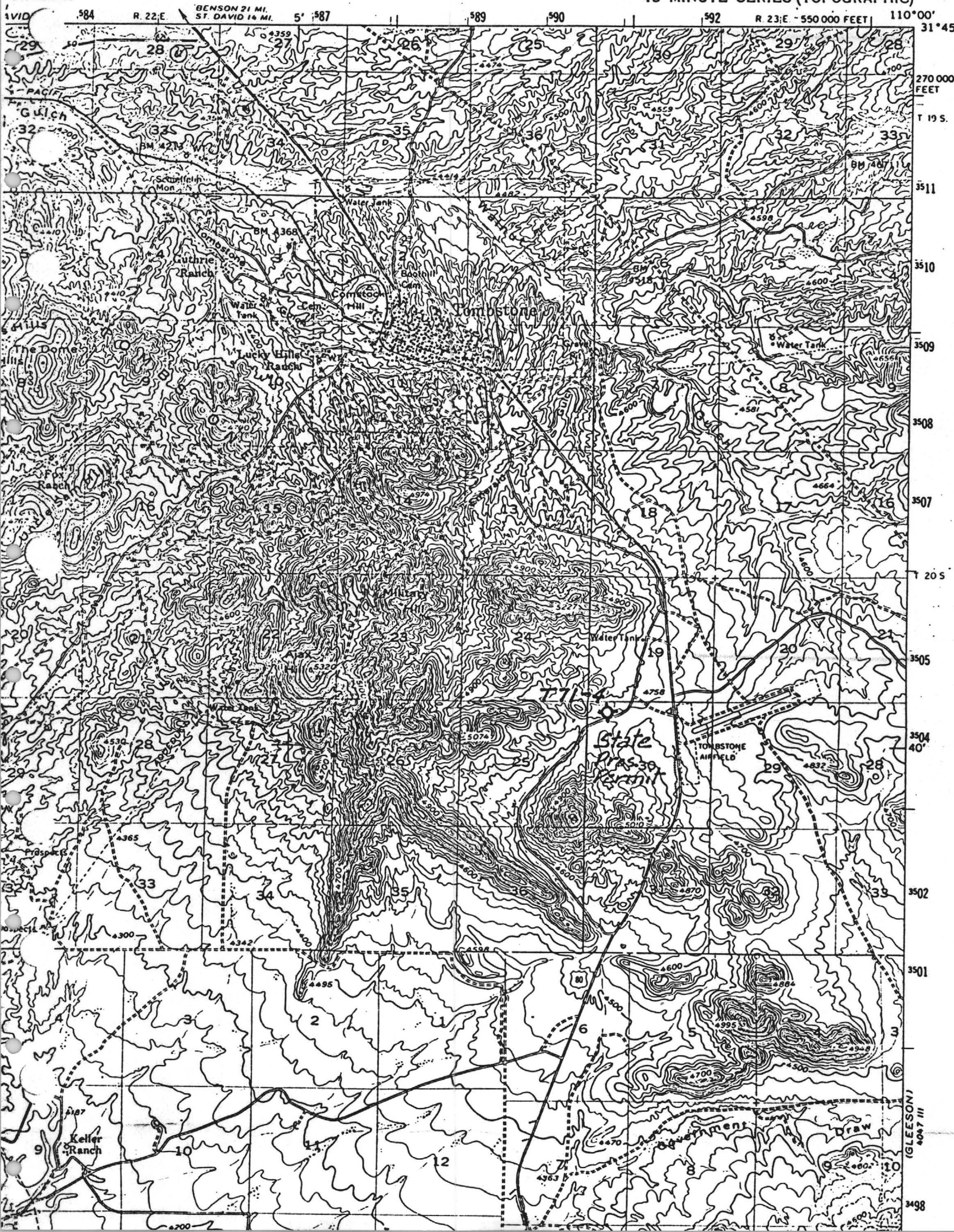
Remarks: ____

TATES
F THE ARMY
IGINEERS

Tombstone Airport Prospect 452.

TOMBSTONE QUADRANGLE
ARIZONA—COCHISE CO.
15 MINUTE SERIES (TOPOGRAPHIC)

4047 IV
(PEARCE)



R.F. HEWLETT
REPORT

SIERRA MINERAL MANAGEMENT

R. F. HEWLETT
President

4741 EAST SUNRISE DRIVE
SKYLINE BEL AIRE PLAZA
TUCSON, ARIZONA 85718
602 / 299-9736

TOMBSTONE PROJECT

Possibilities for mine production by early 1974 are:

1. Waste dumps
2. Small high-grade underground production
3. Potential medium-sized open pit.

Cash requirements and potential cash flow are:

Project	Capital Requirement	Amount
Waste dumps	Plant (lease)	$250,000
Small underground	Mine equipment (lease)	50,000
Open pit	Exploration	50,000
		$350,000

Project	Potential Profit	Year
Waste dumps	$650,000	1974
Small underground	150,000	per year
Open pit	0-500,000	per year

Schedule of Activities follows:

1. Placer will analyze metallurgy and feasibility of moving Whitehall plant (on lease from MECL) to Tombstone.

2. Placer will review feasibility of mining "State of Maine" and we will then move down from Cordero (on lease from MECL) all required mining equipment (hoists, slushers, dozers, loaders, etc.)

3. " 71 ML" is attempting to form a corporation and merge Tombstone Mineral Reserves to obtain their plant (500 t.p.d.) and their 358 mining claims with gold-silver-and copper mineralization.

4. A lease has been proposed to Tombstone Development Corporation to explore and mine their patented claims that constitutes the largest holdings in the district.

5. A lease has been proposed to the Escapules for exploring, developing and mining the "State of Maine" and Santa Ana mines.

Activity	Amount
Move Plant	$100,000
Move Cordero Equipment	10,000
Tombstone Reserves	$ 25,000 to $100,000
Tombstone Development	$ 25,000
Escapules	$ 50,000
	$210,000 to $285,000

TECHNICAL EXPLANATION

"71 Minerals" strategy is to tie up the entire Tombstone district to allow us enough time to select claims or mines that are desireable and drop claims that don't have much potential before the assessment deadline of September 1, 1973.

The mining property in the Tombstone district is owned by (in decreasing order of importance):

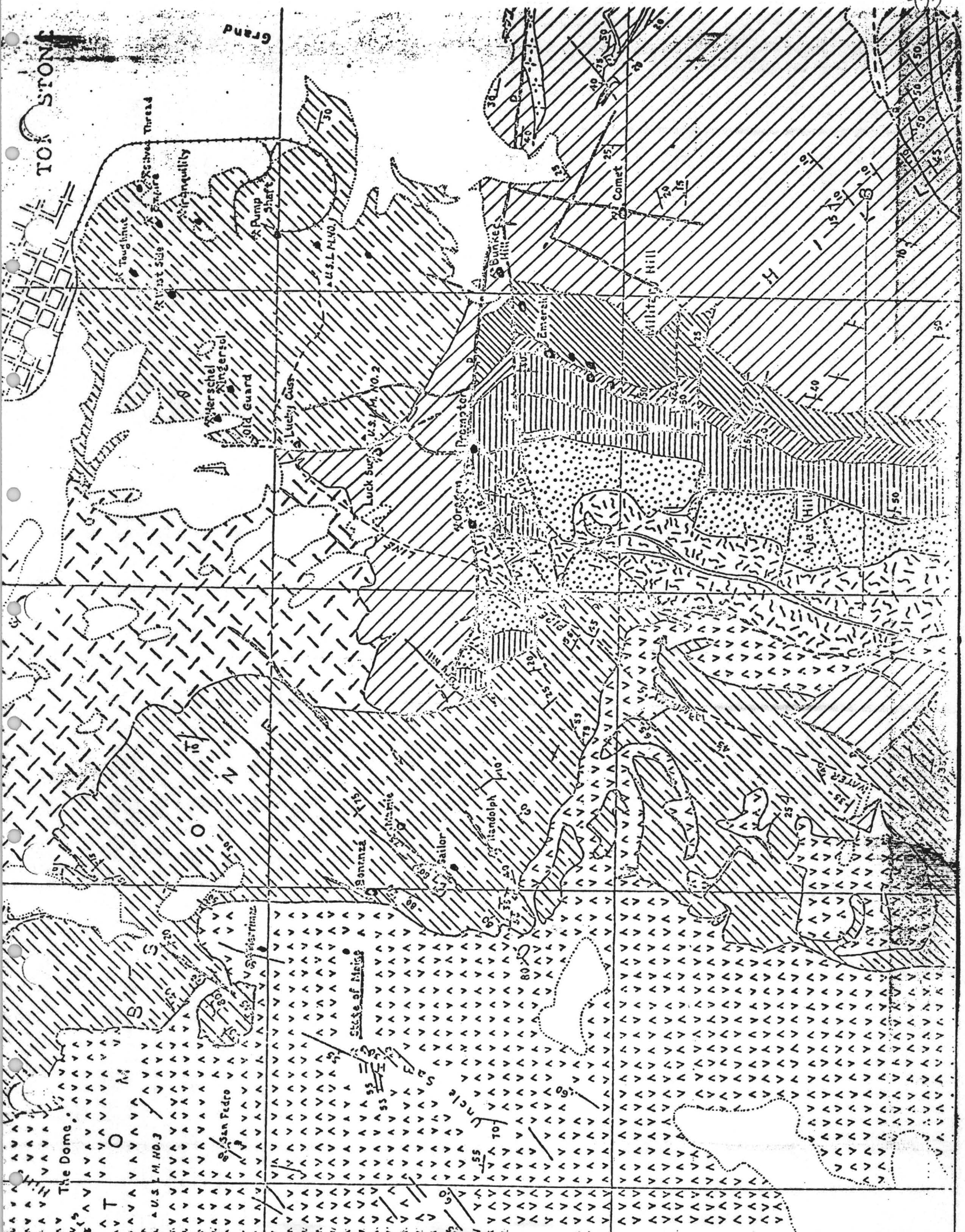
1. Tombstone Development
2. Escapules
3. Tombstone Mineral Reserves
4. Grace-Bonanza
5. Wayne Winters
6. Numerous small trusts, churches, etc.

On the map (on the following page) are shown the following:

Ownership Group	Location of Claims
1. Tombstone Development	All orange dots east of "State of Maine"
2. Escapules	Around and including "State of Maine"
3. T. Mineral Reserves	Unpatented claims south and east of 41° N. (Military Hill)
4. Grace-Bonanza	Bonanza mine due east of "State of Maine"
5. Wayne Winters	North of Military Hill and south of Emerald

Tombstone Development

All orange dots south of Tombstone (excluding "State of Maine" and Bonanza) are waste dumps owned by T.D. The detailed report on waste dump and open-pit potential is in exhibit A.


TOMBSTONE
Grand
Toughnut
Restless Thread
Empire
Tranquility
Pump Shaft
West Side
U.S.L.M. NO.
Herschel
Ningersol
Old Guard
Lucky Cuss
U.S.L.M. NO. 2
Luck Sure
Prompter
Bunker Hill
Comet
Emerald
Military Hill
Ajax Hill
LINE
PIPE
WATER
Randolph
Sailor
Bonanza
State of Maine
Uncle Sam
San Pedro
The Dome
U.S. L.M. NO. 3
T O M B S T O N E
H I L L S

Escapules

This property ("State of Maine") should be optioned and put into small scale underground production. This can be done for $30,000 excluding a plant. The potential for this property are:

1. Waste dumps (4.5 oz. Ag)
2. Small underground operation
3. Potential of a large underground operation
4. Potential for open pit ore.

Exhibit B shows the extent of the underground workings. I have examined these workings by ladder and rope and have taken some samples running from 147 to 225 ounces per ton. The average grade of gobb (old low-grade fill) is about 20 ounces which can be mined first.

The advantage of the old "State of Maine" workings is that we can put the mine back into production for relatively low start-up costs.

In addition to the "small" potential, there is the distinct possibility that there will be the same large high-grade bonanza one at depth as over in the Tombstone basin (due south of the town site). This is illustrated in exhibit C, where the ore is shown in cross-section as mined out stopes or levels. Notice that the ore is at and especially above the Naco limestone (8 level-bottom) up into the "Novaculite", blue limestone and Bisbee group limestones. The bottom of the "State of Maine" shaft is just going into Bisbee group limestones from a porphyry rock that is mineralized (that is where the past production came from). Therefore, there is a good chance that larger ore bodies exist at depth. (We can at least make money on the existing "lower grades".)

As I mentioned before, I have a tax lien on the San Juan mine.

Tombstone Mineral Reserves

This company is in bankruptcy and is an excellent possibility for us to control 358 unpatented mining claims with gold-silver mineralization and copper potential. Their 500 t.p.d. plant could be utilized in part by us with our White Hall plant. The T. Mineral Reserves plant is about two (2) miles from the "State of Maine" mine. Our electrolytic-oxidation process is superior to any in the district and we would have the only operating plant and could joint-venture or treat ore on a "custom basis".

Grace-Bonanza

This property is near Escapules and Mr. Grace contacted me recently and wants to make a deal with "71 ML".

483

Wayne Winters

"71 ML" has 15 mining claims under option in and around the Tombstone district. He has given us much free time for $100 per month. He is very helpful to us in consolidating property and arranging meetings for "71 ML". The value of his claims are discussed in Exhibit D.

EXHIBIT A

Tombstone Development

I

INTRODUCTION

TOMBSTONE DISTRICT

The Tombstone mining district is in the Tombstone Hills, about 21 miles northwest of Bisbee, and about 24 miles southeast of Benson, Arizona. The maximum elevation for this area is about 5300 feet above sea level.

PROPERTIES EXAMINED

Twenty-three (23) patented mining claims were selected, mainly those with mine dumps sufficiently large in tonnage to warrant rehandling and milling them or those in an area of geological interest.

The patented mining claims evaluated are tabulated in TABLE I.

II

SAMPLING PROCEDURE

Bulk samples were taken from each of the mine dumps and reduced in size for assay. Weight of bulk samples ranged from fifty (50) to one hundred (100) tons each. The size and location of the bulk samples was dependent on the size of the mine dumps and the area of expected influence. Bulk samples were coned and quartered using the backhoe-loader equipment until they were reduced in size to about two (2) tons, then they were trucked to a crusher-conveyor site, crushed, coned and quartered and finally split with a Jones splitter to a final weight of about ten (10) pounds. It is believed that the final samples represent very closely the content of the dumps sampled, at least to within the area of influence. The tonnage calculated for the dumps take this into consideration.

The method used to obtain and prepare samples for assay was decided upon in collaboration with Dr. Willard C. Lacy, Professor and Head of the Mining and Geological Engineering Department, College of Mines, University of Arizona, Tucson, Arizona.

III

ASSAY RESULTS

Samples for assay were sent to Hawley and Hawley, Assayers and Chemists, Tucson, Arizona, to be assayed for gold, silver, lead, copper and in many cases for zinc, molybdenum and a few for manganese. The assay values are tabulated in TABLE II.

Copies of the original assay results from Hawley are included in APPENDIX I. of this report.

Arithmetical averages for grades of all the mine dumps sampled are as follows: gold, 0.018 oz./ton; silver, 1.86 oz./ton; lead, 0.55%; copper, 0.07%, for 28 samples; zinc, 0.76% for 11 samples; molybdenum, 0.004%, for 20 samples; and manganese, 4.56%, for 5 samples.

These averages are interesting as they somewhat indicate the grade of the mineralized material considered waste during certain active periods of mining in this district. However, it should be mentioned that many of the mine dumps have been selectively reworked and the concentrate shipped to smelters. Actually, these averages should be considered as minimums.

In contrast to these minimum values, perusal of the "Ore Shipping Records, from April 3, 1920 to February 28, 1923", gratefully furnished by Mr. Pete Giacomi of Tombstone, a copy of which is included in APPENDIX II of this report, indicate what was considered ore grade during this period and the arithmetical averages of grade and tonnage for selected mines are tabulated in TABLE III.

IV

TONNAGE AND METAL CONTENT OF MINE DUMPS

The selected mine dumps were surveyed and their respective tonnages calculated. The total tonnage calculated for the twenty-three mine dumps sampled was 524,900 tons, and are considered accurate to ±10%. This tonnage excludes dump material which was considered waste and dump material outside of the area of sampling influence. Access to certain areas of larger dumps, that were not sampled, and to isolated smaller mine dumps would considerably increase the total tonnage, however, for this feasibility study, the additional expense did not seem justified. A value of 17.5 cubic feet per ton was used in calculating the tonnages of the mine dumps. This value was determined after weighing known volumes of average size distribution dump material.

The tonnages calculated and the metal content of the mine dumps sampled are tabulated in TABLE IV.

V

ECONOMIC CONSIDERATIONS

An attempt to place dollar value to the mine dump material generated the following data:

1. Weighted averages for grade of all the mine dumps sampled were: gold, 0.021 oz./ton; silver, 1.36 oz./ton; and lead, 10.9 lb./ton. Weighted averages for grade of copper, zinc, molybdenum and manganese, based on available assays were: copper, 1.19 lb./ton, for 338,300 tons; zinc, 2.41 lb./ton, for 108,600 tons; molybdenum, 0.099 lb./ton, for 326,700 tons; and manganese, 48.9 lb./ton, for 14,500 tons.
2. Metal content of mine dumps sampled: gold, 10,975 oz.; silver, 715,500 oz.; lead, 5,707,320 lb.; copper 461,780 lb., based

on 388,300 tons; zinc, 261,134 lb., based on 108,600 tons; molybdenum, 31,346 lb., based on 326,700 tons; and manganese, 708,340 lb., based on 14,500 tons. Metal content of copper, zinc, molybdenum and manganese was based on tonnages covered by available assays. Because gold and silver were the metals of prime importance in the feasibility study, the other metals were assayed to assist in determining their distribution and their importance for inclusion in metallurgical testing to develop an economically feasible flowsheet for their extraction.

3. Assuming 90% extraction for the gold and 85% extraction for the silver content of the dumps, at the following market price of $90.00/oz. for gold and $2.41/oz. for silver, gives the recoverable dollar value of $888,975 for gold, and $1,464,678 for silver, or a gross of $2,354,677; this gross excludes lead, zinc, copper, molybdenum and manganese. The exclusion of these elements in this economic evaluation is justified until laboratory testing indicates the feasibility of extracting them. However, their presence is certainly significant in the overall evaluation as they have potential dollar value.
4. An estimate for handling and treatment costs would be about $2.75 per ton, in a 200 TPD pilot production type plant or approximately $1,444,000, leaving a net gross of $910,677.
5. Assuming the pilot production plant would cost approximately $250,000 for a 200 TPD operation, one would realize a nice profit from an operation of this type, and the advantages derived would be meaningful. Advantages would be the familiarity with ore treatment characteristics, resulting in refinement of the flowsheet, which of course would have to be developed by

laboratory testing, which would include all the recoverable values in the mine dump material. The recoverable dollar value of lead could be approximately $720,000, based on a lead price of $0.14/lb., and the copper, zinc, molybdenum and manganese would also enhance the recoverable dollar value that could be expected from treating the mine dump material.

The decision to consider construction of a pilot production plant should be based on the following criteria:

1. An active exploration program, to determine if potential open pit type mining sites exist in this area, and the ore reserves that could be expected.
2. The development of an effective flowsheet, by laboratory testing, to economically extract all or most of the valuable metals in the mine dumps and/or developed ore.

VI

OPEN PIT MINING POTENTIAL

During the field work of this feasibility study, potential open pit type mining sites were under consideration. One of the areas which appeared to warrant further consideration is that area of Tombstone Basin which contains the Silver Thread, Tranquility, Head Center, Contention, Empire, Toughnut, and West Side mines, and another area would be the Lucky Cuss-Herschel Zone.

In the first area, it is reported by B.S. Butler, E.D. Wilson, and C.A. Rasor, in the "Geology and Ore Deposits of the Tombstone District, Arizona," that the ore occurs (1) in the faulted segments of the dike, (2) in brecciated footwall zones of these segments, and (3) in limestone beds of the shale sequence.

From the same reference, the second area of interest, the Lucky Cuss-Herschel Zone has the following statement: that the ore deposits in and associated with the Lucky Cuss fault zone are of three types -- veins in the Lucky Cuss fault, veins in the northeast fissures, and limestone replacement deposits associated with the northeast fissures. Mining in both areas of interest was developed to the surface.

These areas should offer excellent targets, for a detailed evaluation by geological, geophysical, drilling and computer techniques.

VII

METALLURGICAL CONSIDERATIONS

The prime metals considered in this report are gold and silver which could be beneficiated by using the cyanidation method. Concern is expressed by some as to the expected recovery of silver from manganiferous ores. This could present a problem in dump material of high manganese content. However, most of the dumps sampled appear to be not too high in manganese content.

Two processes which have been developed to treat silver ores high in manganese are the Caron Process and the McClusky Process. The Caron Process utilizes a roast in a reducing atmosphere, the higher manganese oxides are reduced to manganous oxides which render them amenable to cyanidation. Laboratory tests followed by plant-scale testing gave the following results: Direct cyanidation of ore containing 2-10% MnO_2 gave 50% extraction of the silver, the Caron Process extracted 92% of the gold and 90% of the silver. The McClusky Process utilizes a sulphur dioxide treatment which dissolves the manganese minerals which are then precipitated by a lime emulsion and oxidized to the manganic state by aeration. In this state the manganese no longer affects the extraction of silver by cyanidation.

To fully exploit the potential dollar value of the Tombstone ores, a comprehensive laboratory testing program is recommended. The testing program should include flotation tests, pressure leaching tests, to solubilize the base metals present and possibly effect their extraction, and liquid ion exchange for upgrading and separation. New chemical extraction techniques should definitely be explored.

TABLE I. PATENTED MINING CLAIMS EXAMINED

NAME OF MINE	LOCATION
Bob Ingersoll	Sec 11, T 20 S, R 22 E
Boss	Sec 11, T 20 S, R 22 E
Bunker Hill	Sec 14, T 20 S, R 22 E
Comet	Sec 23, T 20 S, R 22 E
Contention	Sec 11, 12 & 14, T 20 S, R 22 E
Little Joe Shaft	
Pump Shaft	
Main Workings Shaft	
Defence	Sec 11, T 20 S, R 22 E
Emerald	Sec 14 & 23, T 20 S, R 22 E
Empire	Sec 11 & 12, T 20 S, R 22 E
Free Coinage	Sec 9, T 20 S, R 22 E
Grand Central	Sec 14, T 20 S, R 22 E
Herschel	Sec 11, T 20 S, R 22 E
Lucky Cuss	Sec 11 & 14, T 20 S, R 22 E
Old Guard	Sec 11, T 20 S, R 22 E
Oregon	Sec 14, T 20 S, R 22 E
Prompter	Sec 14, T 20 S, R 22 E
Rattlesnake	Sec 14, T 20 S, R 22 E
San Pedro	Sec 8, T 20 S, R 22 E
Silver Plume	Sec 14 & 23, T 20 S, R 22 E
Silver Thread	Sec 11 & 12, T 20 S, R 22 E
Toughnut	Sec 11, T 20 S, R 22 E
Tranquility	Sec 11 & 12, T 20 S, R 22 E
West Side	Sec 11, T 20 S, R 22 E

TABLE II. MINE DU ASSAY RESULTS

SAMPLE NO. AND NAME OF MINE	Gold oz./T	Silver oz./T	Lead lb./T	Copper lb./T	Zinc lb./T	Moly lb./T	Manganese lb./T
B.I. #1 (Bob Ingersoll)	0.005	1.08	6.4	0.8	28.8	0.02	---
BS #1 (Boss)	0.037	2.39	9.2	1.8	9.0	---	---
B.H. #1 (Bunker Hill)	0.030	3.59	26.4	3.8	48.0	0.10	---
B.H. #2 (Bunker Hill)	0.007	3.10	24.0	---	36.6	---	---
CMT #1 (Comet)	0.015	0.91	3.8	0.6	---	0.02	---
L.J. #1 (Contention)	0.017	1.07	10.0	0.2	8.0	0.02	---
CONT #1 (Contention)	0.022	1.06	6.0	0.6	---	0.02	---
CONT #2 (Contention)	0.010	0.77	4.2	---	---	---	---
CONT #3 (Contention)	0.027	1.33	6.4	---	---	---	---
DF #1 (Defence)	0.010	1.25	7.8	0.6	24.2	---	---
EMER #1 (Emerald)	0.020	1.59	21.8	3.0	---	0.02	---
EMER #2 (Emerald)	0.020	2.10	22.4	5.6	---	0.02	---
EMER #3 (Emerald)	0.010	0.90	7.6	1.2	---	0.02	---
EMP #1 (Empire)	0.080	1.90	15.6	1.4	---	0.30	---
F.C. #1 (Free Coinage)	0.005	0.95	0.5	0.2	0.2	0.02	8.6
G.C. #1W (Grand Central)	0.010	0.22	2.6	---	---	---	---
G.C. #2 (Grand Central)	0.010	0.97	23.8	0.2	3.2	0.02	---
HER #1 (Herschel)	0.015	3.47	6.0	1.4	---	---	---
L.C. #1 (Lucky Cuss)	0.040	2.98	20.8	1.4	15.2	0.02	---
O.G. #1 (Old Guard)	0.015	1.34	6.0	0.8	10.8	---	11.6
ORE #1 (Oregon)	0.005	5.52	14.2	2.8	---	---	159.0
ORE #2 (Oregon)	0.002	3.27	12.8	2.8	---	---	139.0
PRMT #1 (Prompter)	0.005	3.63	16.0	---	---	---	138.0
RTLS #1 (Rattlesnake)	0.005	2.33	11.6	1.4	---	---	---
S.P. #1 (San Pedro)	0.005	4.48	5.4	2.2	---	0.06	---
SLP #1 (Silver Plume)	0.002	0.45	4.2	0.6	---	---	---
S.T. #1 (Silver Thread)	0.025	1.33	13.0	0.6	---	0.12	---
SET #1 (Sulphuret)	0.022	0.66	6.2	0.6	3.6	0.10	---
TN #1 (Toughnut)	0.015	0.87	10.0	1.0	---	0.18	---
TN #2 (Toughnut)	0.005	0.36	3.8	0.2	---	0.04	---
TR #1 (Tranquility)	0.060	3.22	19.8	1.8	---	0.16	---
TR #2 (Tranquility)	0.022	0.85	4.8	0.4	---	0.04	---
W.S. #1 (West Side)	0.012	1.36	11.8	1.0	---	0.12	---
ARITHMETICAL AVERAGE	0.018	1.86	11.1	1.4	17.1	0.07	91.2

TABLE III. ARITHMETICAL AVERAGES OF ORE SHIPMENTS

APRIL 1920 THROUGH MARCH 1921

NAME OF MINE	TONNAGE	Gold, oz./T	Silver, oz./T
Bunker Hill	99.5	0.035	15.45
Emerald	118.5	0.010	8.00
Grand Central	1,437.5	0.140	13.75
Lucky Cuss	5,559.5	0.056	16.92
Oregon	3,865.5	0.013	23.00
Prompter	9,688.0	0.017	16.50
San Pedro	431.5	0.170	27.15

APRIL 1920 THROUGH FEBRUARY 1923

Contention	3,639.0	0.198	13.57
Empire	158.5	0.240	13.48
Head Center (Yellow Jacket)	1,738.0	0.200	14.50
Silver Thread	4,738.0	0.270	25.47
Toughnut	5,203.0	0.170	27.45
Tranquility	1,977.5	0.320	22.46
West Side	1,237.5	0.560	38.58

TABLE IV. MINE D S METAL CONTENT

SAMPLE NO.	TONNAGE ± 10%	Gold Total oz.	Silver Total oz.	Lead Total lb.	Copper Total lb.	Zinc Total lb.	Moly Total lb.	Manganese Total lb.
B.I. #1	10,500	52.5	11,340	67,200	8,400	426,800	210	
BS #1	3,400	125.8	4,624	31,280	6,120	30,600		
B.H. #1	15,300	459.0	54,927	403,920	58,140	734,400	1,530	
B.H. #2	10,500	73.5	32,550	252,000		384,300		
CMT #1	13,000	195.0	11,830	49,400	780		260	
L.J. #1	2,000	34.0	2,140	20,000	400	16,000	40	
CONT #1	11,800	259.6	12,508	70,800	7,080		236	
CONT #2	97,700	977.0	75,229	410,340				
CONT #3	16,300	440.1	21,679	94,320				
DF #1	24,200	242.0	30,250	188,760	14,520	585,640		
EMER #1	40,000	800.0	63,600	872,000	120,000		800	
EMER #2	1,600	32.0	3,360	35,840	8,960		32	
EMER #3	7,000	70.0	6,300	53,200	8,400		140	
EMP #1	41,100	3,288.0	78,090	641,160	57,540		12,330	
F.C. #1	200	1.0	190	100	40	40	4	1,720
G.C. #1W	10,000	100.0	2,200	26,000				
G.C. #2	10,000	100.0	9,700	238,000	2,000	32,000	200	
HER #1	6,800	102.0	23,596	40,800	9,520			
L.C. #1	18,200	728.0	54,236	378,560	25,480	276,640	364	
O.G. #1	10,200	153.0	13,668	61,200	8,160	110,160		118,320
ORE #1	1,000	5.0	5,520	14,200	2,800			159,000
ORE #2	1,500	3.0	4,905	19,200	4,200			208,500
PRMT #1	1,600	8.0	5,808	27,200				220,800
RTLS #1	3,000	15.0	6,990	252,000	4,200			
S.P. #1	1.500	7.5	6,720	8,100	3,300		90	
SLP #1	12,000	24.0	5,400	50,400	7,200			
S.T. #1	17,000	425.0	22,610	221,000	10,200		2,040	
SET #1	4,100	90.2	2,706	25,420	2,460	14,760	410	
TN #1	18,000	270.0	15,660	180,000	18,000		3,240	
TN #2	32,000	160.0	11,520	121,600	640		1,280	
TR #1	9,200	552.0	29,624	182,160	16,560		1,472	
TR #2	29,200	642.4	24,820	140,160	11,680		1,168	
W.S. #1	45,000	540.0	61,200	531,100	45,000		5,500	
	524,900	10,974.6	715,500	5,707,320	461,780	261,134	31,346	708,340
					(388,300T)	(108,600T)	(326,700T)	(14,500T)

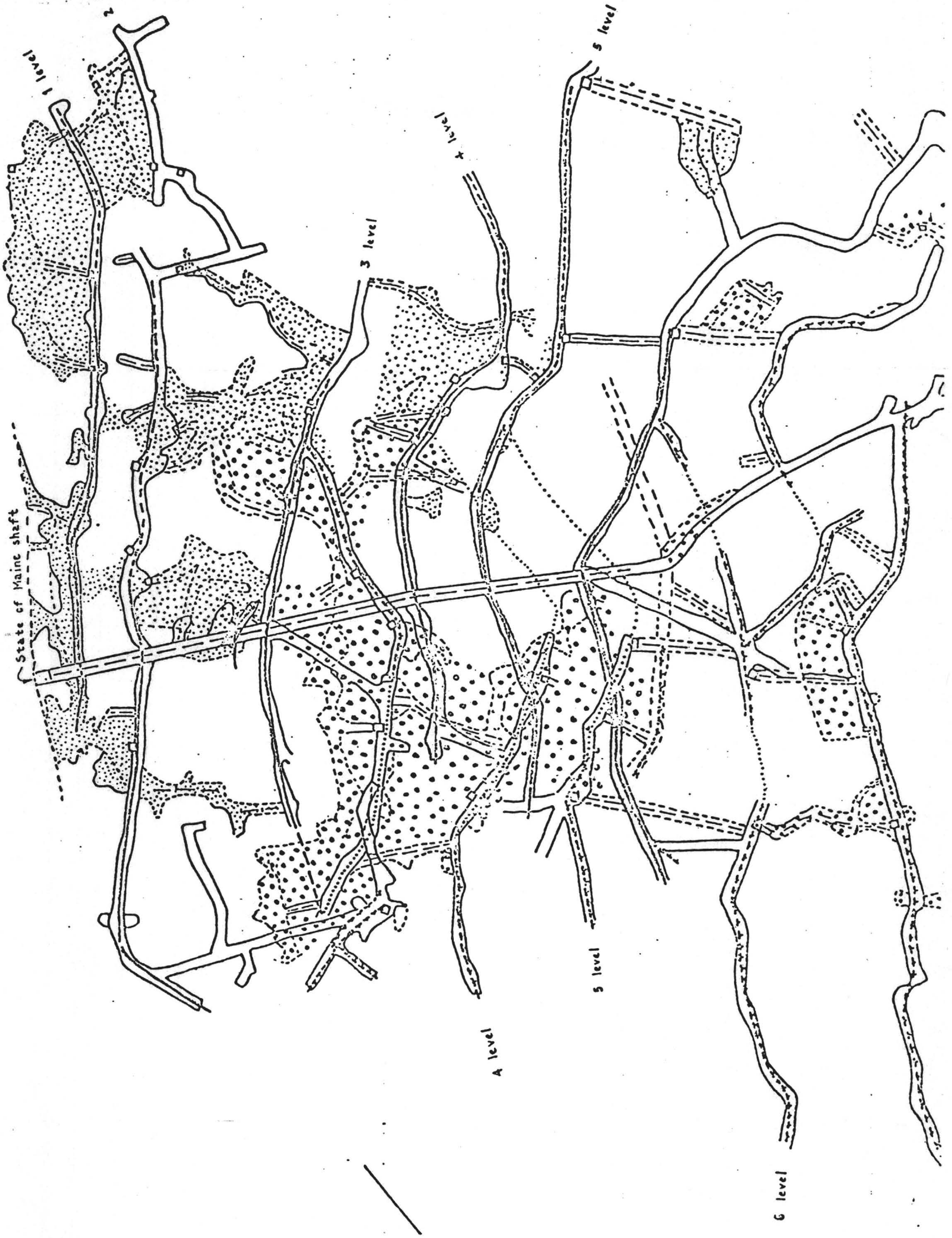
TOTALS BASED ON ABOVE TONNAGES

E X H I B I T B

"State of Maine"

underground workings

and other data


1 level
2 level
3 level
4 level
5 level
State of Maine shaft
4 level
5 level
6 level
5 level

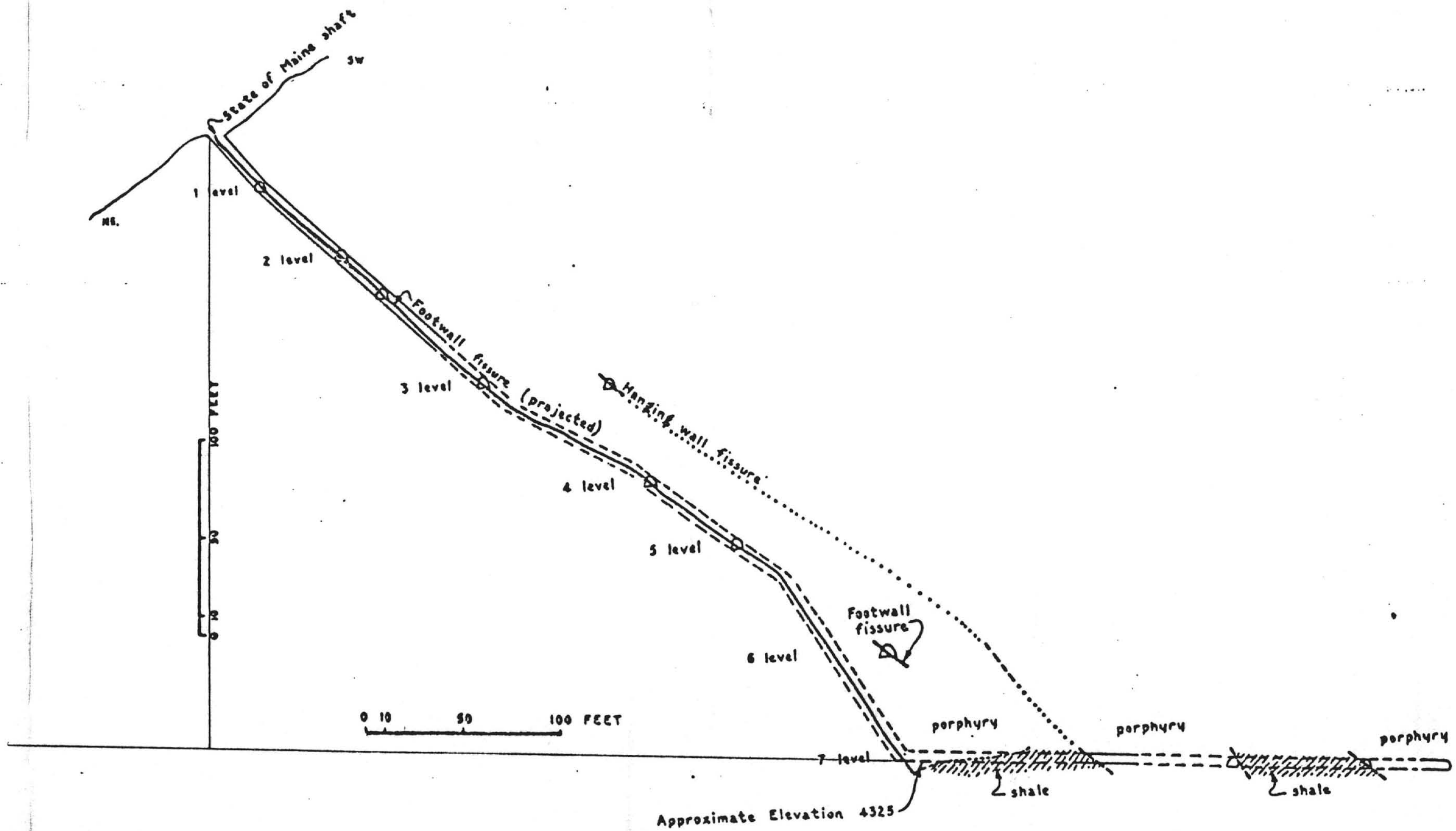
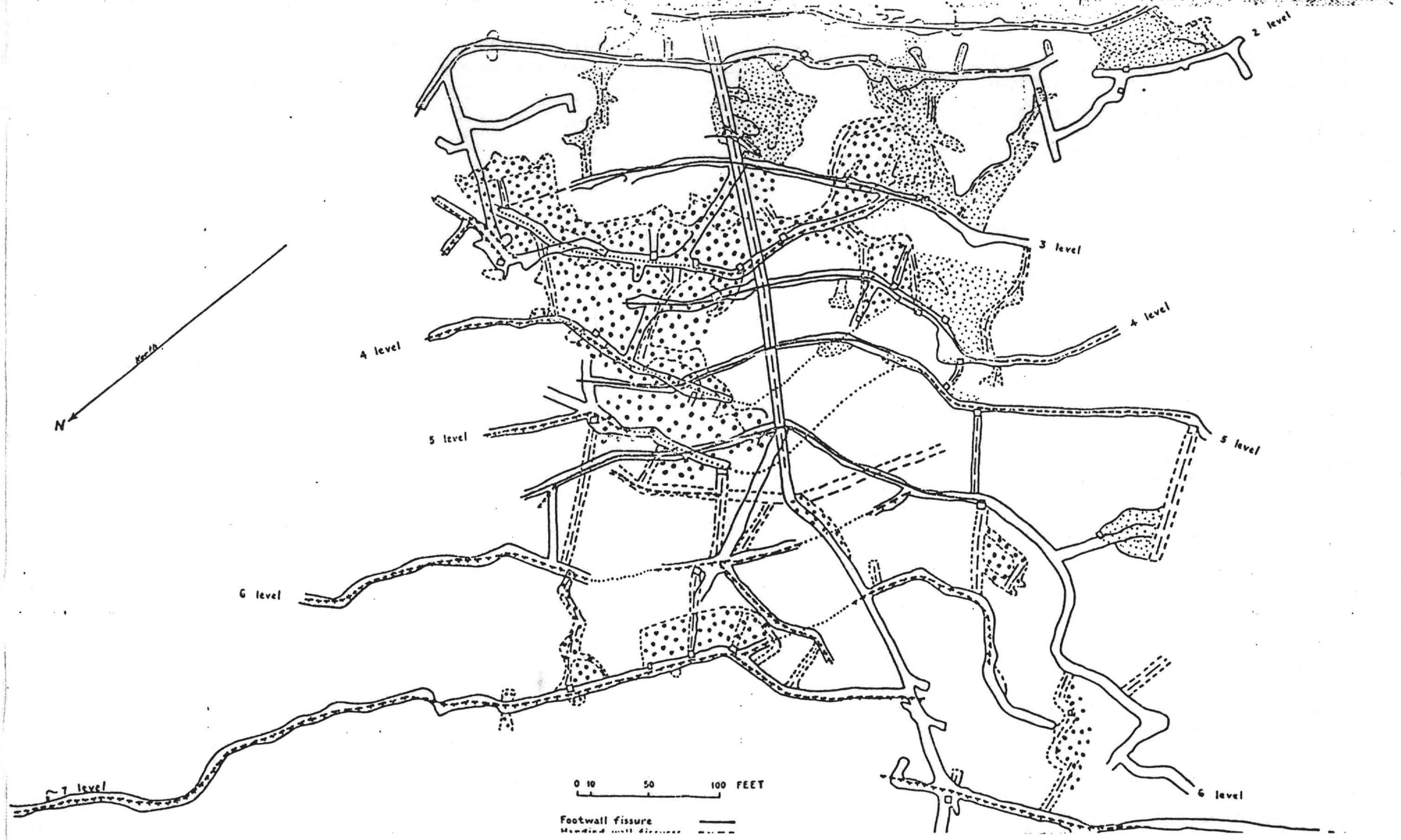
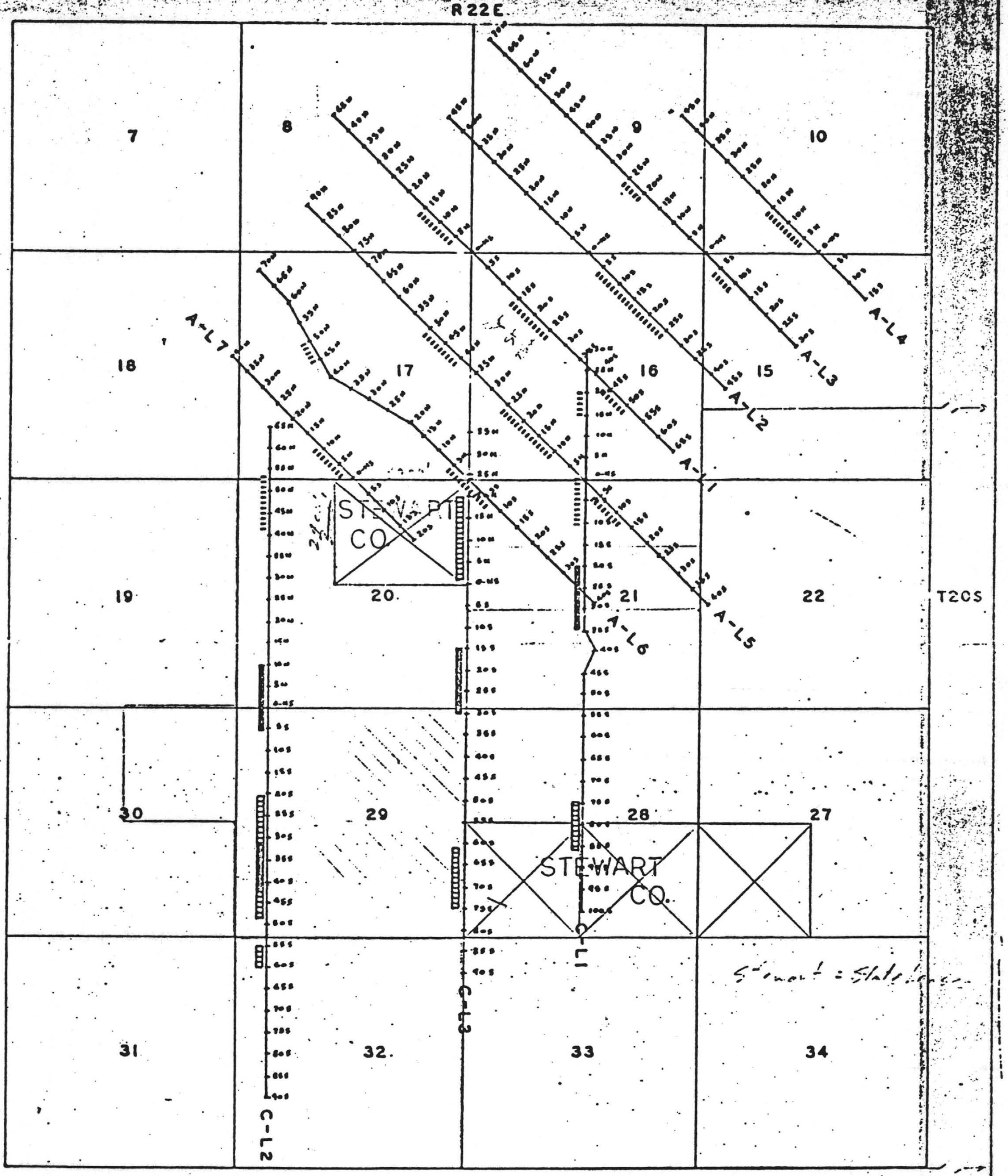


Plate XXVI.—Cross section through State of Maine Mine, looking southwest.


2 level
3 level
4 level
4 level
5 level
5 level
6 level
6 level
7 level
North
N
0 10 50 100 FEET
Footwall fissure



SUFACE PROJECTION
OF ANOMALOUS ZONES
DEFINITE ▬▬▬
PROBABLE ▭▭▭
POSSIBLE ⋯⋯⋯

INDUCED POLARIZATION AND RESISTIVITY SURVEY
COMPOSITE OF CAB AND AUSTRAL SURVEYS
TOMBSTONE AREA, COCHISE COUNTY, ARIZONA
SCALE 1:24000

I.P. LINES
A = AUSTRAL
C = CAB

STATE LEASE

G

NOV 19

475

SOUTHWESTERN ASSAYERS & CHEMISTS, Inc.

REGISTERED ASSAYERS

FELIX K. DURAZO
WIL WRIGHT
ARIZONA REG. NO. 5675

P. O. BOX 7517
TUCSON, ARIZONA 85713

710 E. EVANS BLVD.
PHONE 602-294-5811

Austral Oil Company
2700 Humble Building
Houston, Texas

JOB # 002703
RECEIVED 6-27-68
REPORTED 6-27-68

SAMPLE NUMBER	GOLD OZ.*	SILVER OZ.*	LEAD %	COPPER %	ZINC %		MOLYBDENUM %
# 7 fine StateMaine	Nil	4.54					
# 8 StateofMaine (course:	Nil	4.94					

5675
D. WRIGHT

CHARGE $ 8.00

476

		CaO % calcium	MgO % mag.	Fe % iron	S % sulphur	SiO2 % silica	INSOL %	Al2O3 % aluminum
	6	.52	.30	2.79	.34	72.5	2.8	4.5
[illegible] J. of m.	⑦	.56	.27	3.06	.22	75.0	11.1	3.9
[illegible]	⑧	.65	.22	2.30	.16	73.5	12.7	3.5
	9	.93	.23	3.50	.14	76.5	.80	3.4
	10	3.95	.39	3.45	.07	70.0	11.7	3.0
	11	16.6	.98	3.40	.05	47.50	7.7	4.1
B.J.	⑫	1.99	.65	2.97	.04	67.7	13.1	3.9
	13	2.07	.44	3.01	.09	70.7	8.8	5.1

$ 431.00 less 10% quantity discount of 43.10

dumps

CHARGE $ 432.90

* Gold and Silver reported in troy oz. per 2,000 lb. ton.

INVOICE

A77

SOUTHWESTERN ASSAYERS & CHEMISTS, Inc.

REGISTERED ASSAYERS

FELIX K. DURAZO
WIL WRIGHT
ARIZONA REG. NO. 5875

P. O. BOX 7517
TUCSON, ARIZONA 85713

710 E. EVANS BLVD.
PHONE 602-294-5811

Austral Oil Company
2700 Humble Building
Houston, Texas

JOB # 002740
RECEIVED 7-2-68
REPORTED 7-7-68

SAMPLE NUMBER	GOLD OZ.*	SILVER OZ.*	LEAD %	COPPER %	ZINC %		MOLYBDENUM %
95L: ✓							
190 ND. ✓		.06					
30 S. ✓	Nil	3.00					
50 W. ✓		.34					
433 L: 105 NW ✓	Nil	2.34					
60 S ✓	Nil	5.24					
175N50W ✓	Nil	.62					
195L: 76 S ✓	Nil	7.26					
105 ND. ✓	Nil	8.66					
356L 136ND. ✓	Nil	9.28					
356L100 ND. ✓	Nil	1.52					
300L 77ND. 41W ✓	Nil	8.12					
141L-30S ✓	.003	21.06					
161L 35 ND. ✓	Nil	6.32					
480L 164S 117W	Nil	Trace					
dumps #12 Brother Jonathan	Nil	1.94					

5375
WIL WRIGHT

st. of Maine

1-27/69

478

Doré beads.

#96 = 17.8 mg WINZE S of M

#97 = 52.3 " RAISE E.J.

#98 = 16.6 " 30' N of S. end 1st level

#99 = 14.3 " Pilot #2 Heads

#100 = 16.3 " Pilot #1 Heads

#101 = 8.4 " 10' N of S. end

#102 = 7.0 " S. side of WINZE

#104 = 13.0 " 50' N of WINZE

#108 = 4.0 " 10' N of S. end

#109 = 6.5 " B.J. S. end.

#110 = 3.3 " Pilot #1 TAILS

#111 = 13.0 " Point of High Dump E.J.

#118 = 4.0 " Pilot #2 TAILS

SKYLINE LABS, INC.
Hawley & Hawley, Assayers and Chemists Division
P.O. Box 50106, 1700 W. Grant Rd., Tucson, Arizona 85703

CERTIFICATE OF ANALYSIS

SAMPLE IDENTIFICATION	GOLD oz/ton	SILVER oz/ton	LEAD	ZINC	COPPER	MO	Mn %		
# 1	< 0.005	224.95					0.011		
# 2	< 0.005	146.80					0.009		

TO: Sierra Minerals
4741 East Sunrise Drive
Tucson, Arizona 85718

REMARKS:
Single determination

CERTIFIED BY:

CHARGES:

PREPARATION $	1.80
ANALYSIS $	14.00

ACCT.: SIERRA MINERALS

DATE REC'D: 2/28/73

DATE COMPL.: 3/5/73

tuc 346954

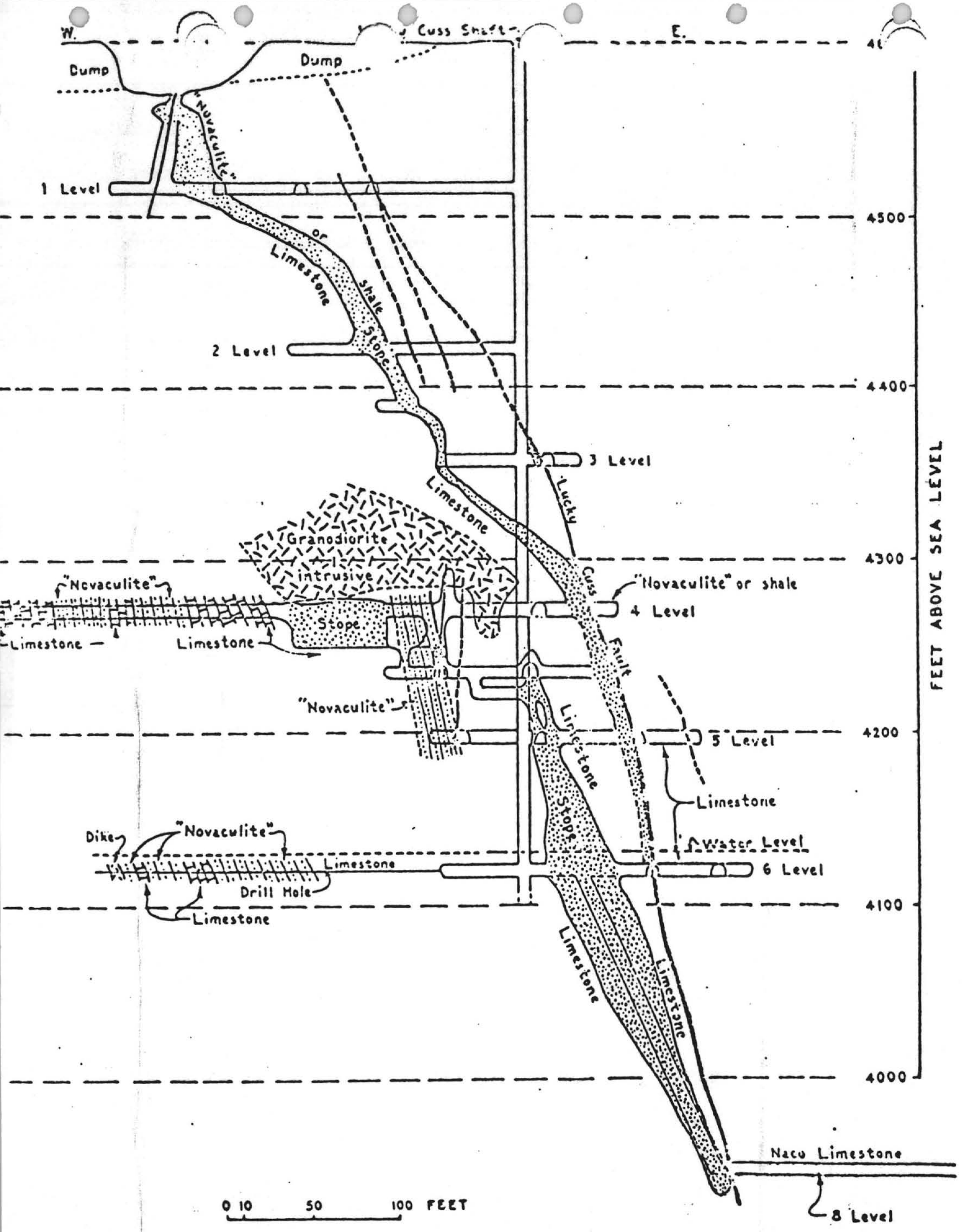
$ 15.80

480

EXHIBIT C

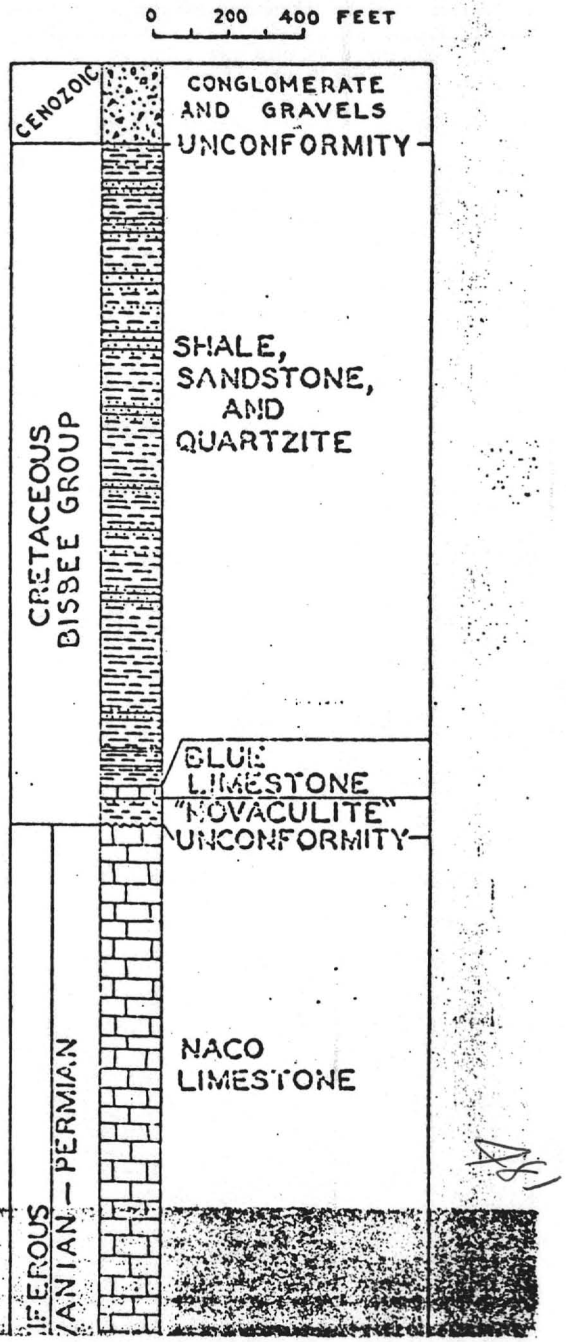
"State of Maine"

deep potential



ate XIII.—Cross section through Lucky Cuss workings at main shaft, looking north. (After F. L. Ransome and C. L. Poindexter.)

GENERALIZED COLUMNAR SECT
TOMBSTONE, ARIZONA



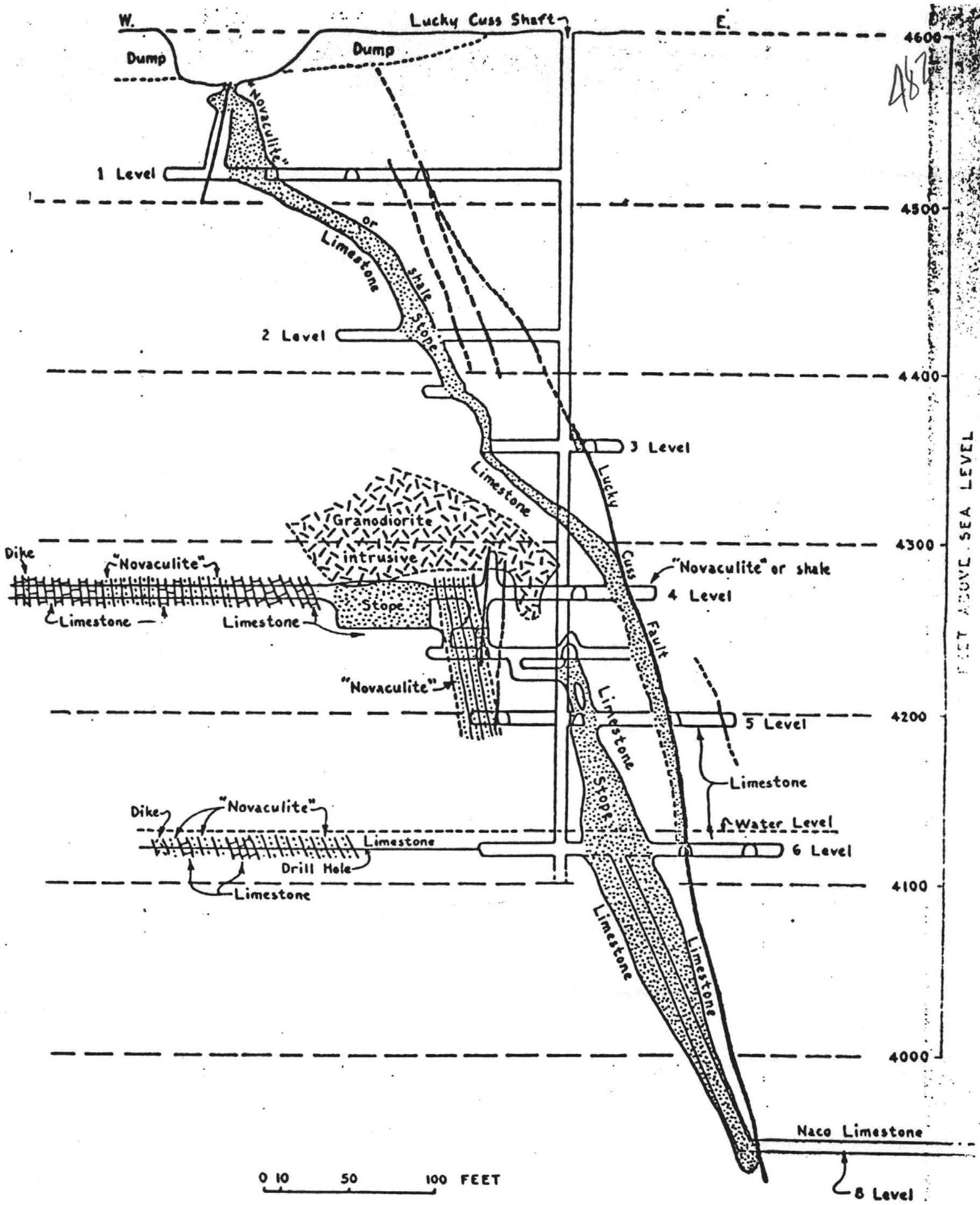


Plate XIII.—Cross section through Lucky Cuss workings at main shaft, looking north. (After F. L. Ransome and C. L. Poindexter.)

GENERALIZED COLUMNAR SECTION
TOMBSTONE, ARIZONA

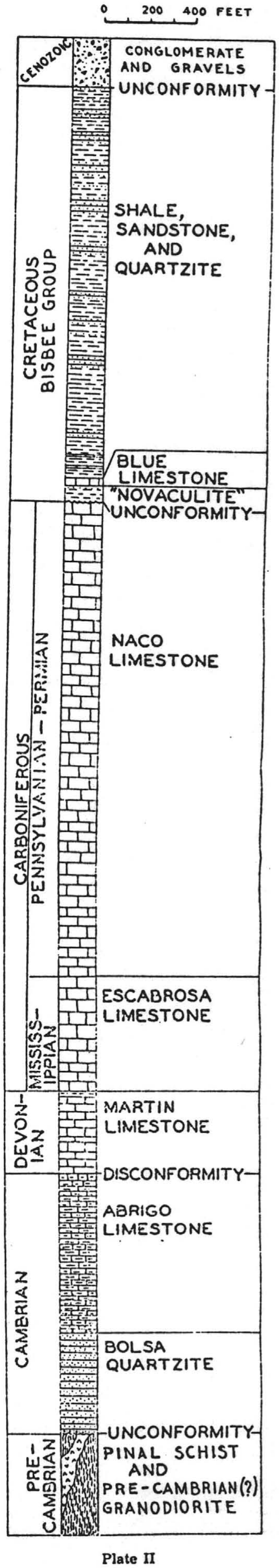
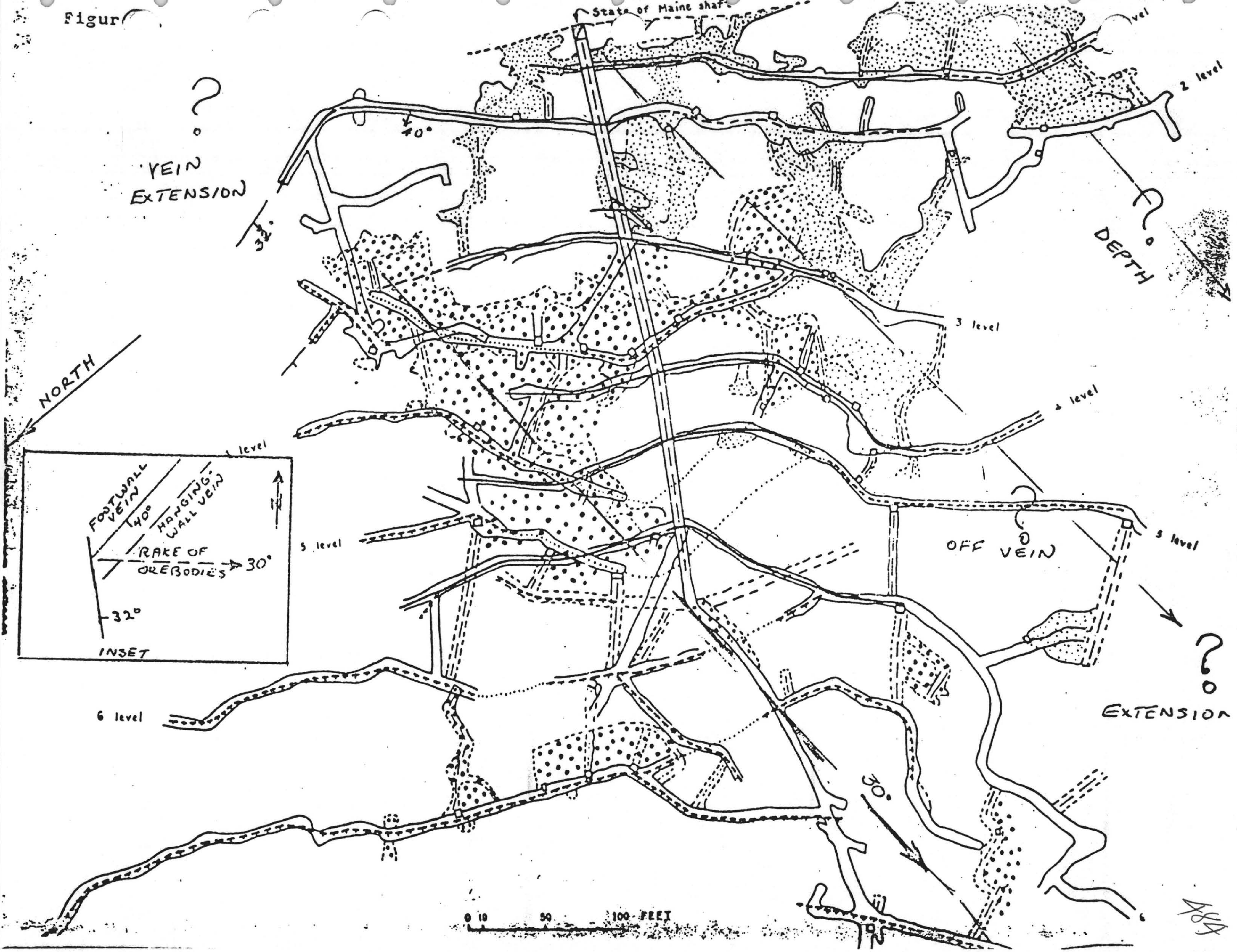


Plate II

Figur


State of Maine shaft
2 level
40°
32°
VEIN EXTENSION
?
DEPTH
?
3 level
4 level
5 level
5 level
5 level
6 level
6
OFF VEIN
?
EXTENSION
?
30°
NORTH
FOOTWALL VEIN
40°
HANGING WALL VEIN
RAKE OF OREBODIES
30°
32°
INSET
N
0 10 50 100 FEET

E X H I B I T D

Wayne Winters Properties

TOMBSTONE DISTRICT--Solely owned by Winters.

Patented:

Side Wheel--Developed to the point where production could be started from underground on a small scale within five shifts.

Rattling Boy--Ore developed for surface mining where production could begin on the first shift.

Wauban--Minerals only. Can be reached eventually by drifting underground from Side Wheel shaft. Some anomolies (IP) on ridge.

Hugenot--Unprospected in recent years.

Honeycomb--An old working. Some ore showing in 250-foot inclined shaft. Needs thorough prospecting.

Nicholas--An old operation currently undergoing additional exploration. Appe to be an excellent prospect.

TOMBSTONE DISTRICT--Properties in which Winters has an interest.

Sultana patented claim--Owns 10 percent of the mineral rights. A possible prospect. Did produce a little lead carbonates in the early da

Blue Top Group--Five unpatented claims in Section 15. Associates on these.

Black Beauty Claim--Small fraction that adjoins the Wauban on the east. Associates on this.

HARTFORD DISTRICT--Solely owned by Winters.

Pinetree, New Strike, #2, White Fawh, Mountain Lion, Mammoth, Lost Chance. (Mineral survey #1811). 101.895 acres in Secs. 34 & 35--23 20. Forest Service owns surface. Winters owns patented minerals. (Lutz tunnel, etc.)

ORO BLANCO DISTRICT--Solely owned by Winters.

LAURA Patented lode claim (gold). 20 acres.

Doran's Folly--Unpatented gold placer, 20 acres. Currently contested in Unit States District Court by the Forest Service.

BRISCOE REPORT

58

487

INTERUM GEOLOGIC REPORT ON THE TOMBSTONE MINING DISTRICT COCHISE COUNTY

with particular emphasis on
THE STATE OF MAINE MINE AREA

Submitted to: Richard F. Hewlett, President
Sierra Mineral Management Company
4741 East Sunrise Drive
Tucson, Arizona

Submitted by: James A. Briscoe
Consulting Geologist
6418 Santa Aurelia
Tucson, Arizona

October 16, 1973

468

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ATTACHMENTS

Attachments

1. Geologic and Alteration Outcrop Map of The State of Maine Area
2. Sample Overlay Map showing location and Assays of Samples in the State of Maine Area

Cross Sections

3. A-A Scale 1"=1,000 feet geology taken from Gilulley Map of the Tombstone Mining District and J. A Briscoe field work.
4. B-B' Scale 1" = 200" from Att. 1
5. C-C' " " "
6. D-D' " " "
7. E-E' " " "
8. F-F' " " "
9. G-G' " " "
10. H-H' " " "
11. I-I' " " "
12. Property Map, Tombstone Mining District, as of August 1, 1973
13. Copy of Geology Map of Central Cochise County, Arizona (uncolored), Plate 5 of U.S.G.S. Professional Paper 281, Showing location of Cross Section Attachment 3, A-A' of this report.
14. Transparent overlay showing approximate outline of hydrothermal alteration visible on color air photos, and distance relations of mineral zones in the District.
15. General Geologic Map of the Tombstone District (Modified from F. L. Ransome) copied from Ariz. Bur. of Mines Report No. 10, Bull. 143, Jan. 1, 1938 Plate III (Hand Colored) Scale 1" = approx. 2,000 feet.
16. Geologic Map of the Tombstone District, Arizona Plate IV, Bull. 143, Scale 1"=500 feet.
17. Plate V, Bull. 143 Cross Sections from Plate III.
18. Plate VI, Bull. 143, Transparent overlay for Plate III (15)

19. Plate VII, Bull. 143, Transparent overlay for Plate IV (16)
20. Plate VIII Bulletin 143
21. Plate IX " "
22. Plate X " "
23. Plate XI " "
24. Plate XII " "
25. Plate XIII " "
26. Plate XIV " "
27. Plate XV " "
28. Plate XVI " "
29. Plate XVII " "
30. Plate XVIII " "
31. Plate XIX A & B " "
32. Plate XX " "
33. Plate XXI " "
34. Plate XXII " "
35. Plate XXIII " "
36. Plate XXIV " "

REFERENCES USED IN PREPARATION OF THE PRECEEDING REPORT INCLUDE:

1. Geology and Ore Deposits of the Tombstone District, Arizona Bureau of Mines, Geological Series No. 10, Bulletin No. 143, by B. S. Butler, E. D. Wilson, and C. A. Rasor, University of Arizona Press, 1938

2. General Geology of Central Cochise County, Arizona, U.S.G.S. Professional Paper 281 by James Gilluly, U. S. Government Printing Office, 1956.

3. Journal of the Alberta Society of Petroleum Geologists, Vol. 10 No. 3, Special Issue on Folding, March 1962.

4. Field Geology, F. H. Lahee, McGraw Hill, New York 1961.

5. Structural Geology, Second Edition, M. P. Billings, Prentice-Hall, Englewood Cliffs, N.J., 1958.

6. Elements of Structural Geology, E. Sherbon Hills, John Wiley & Sons, New York, 1963.

494

INTERUM GEOLOGIC REPORT ON THE TOMBSTONE MINING DISTRICT, COCHISE COUNTY

with particular emphasis on
THE STATE OF MAINE MINE AREA

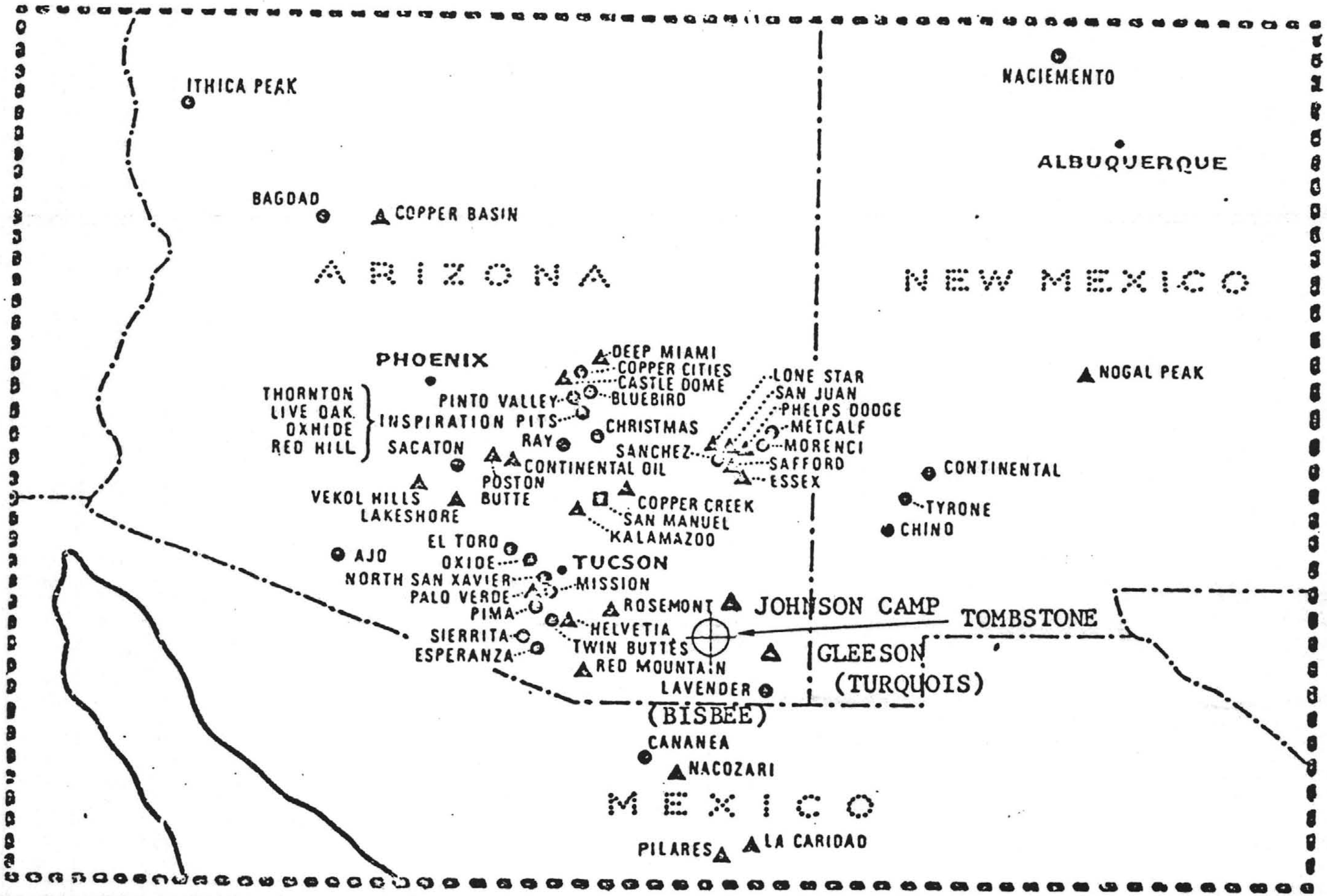
INTRODUCTION

In April of this year, the writer was engaged by Mr. Dick Hewlett, President, Sierra Mineral Management Company, to examine and geologically map the State of Maine area in order to determine the potential for the discovery of additional mineralization and to assess its mining potential. Sierra had at that time consummated lease-option agreements with Messrs. Ernest Escapule Sr., Jr., Charles, and Lewis Escapule which covered patented and unpatented mining claims in the general State of Maine area. It was anticipated that Sierra would work toward obtaining the ground within the Tombstone basin on lease-option basis and adjacent ground to the north owned by Joe Escapule (Att. 12). In short, the objective was to consolidate the entire district in order to facilitate exploration and production of base and precious metals.

It was anticipated that bonanza-type ore bodies within the State of Maine would be relatively small and high grade requiring detailed geologic mapping. Therefore the first order of business was to obtain a detailed, accurate topographic map. A first order ground triangulation survey tied to the State survey was put in. All pertinent claim corners and other important geographic features were targeted, and aerial photography flown. A topographic map was prepared photogrammetrically by Cooper Aerial Survey of Tucson, at a scale of 1"=200', with a

495

5-foot contour interval. All claim corners and other monuments were surveyed photogrammetrically to the nearest ½ foot. Detailed geologic outcrop mapping and alteration mapping was then performed using the topographic base and air photos enlarged to the same scale. Detailed channel type rock chip samples across veins were collected by Mr. J.T. Stockdale. Geologic and assay results are plotted on the 1"=200' base map (Atts. 1 & 2).



SOUTHWESTERN PORPHYRY COPPER PROVINCE has the greatest concentration of copper mines in world. The mines shown on this map produce about 1,250,000 tons of copper per year and production is increasing as new mines constantly are being developed.

Figure 1 LOCATION MAP, TOMBSTONE MINING DISTRICT

SUMMARY AND CONCLUSIONS

The Tombstone Mining District was discovered in 1877 by Ed Schieffelin and was active from that time up until approximately 1937. It is generally thought that production in the district was halted because of large quantities of water which were encountered in the mines. A more important reason for cessation of production however, was depressed metal prices. Prices for silver, lead, zinc, and copper were so low at the time the mines were closed that economic operation could probably not have sustained even had there been no water problem.

Value of the total Tombstone mineral production has been substantial. Using approximate figures for current metal prices of: silver at $3 per ounce, gold at $100 per ounce, copper at $0.80 per pound, lead at $0.20 per pound and zinc at $0.25 per pound, the value of metals produced between 1877 and 1936 would be approximately 145,400,000 dollars.

The geologic history of the Tombstone Mining District has been exceedingly complex. Paleozoic and Mesozoic sediments have been folded and thrust-faulted by two periods of tectonic compression. Igneous rocks of various types have intruded the area during five distinguishable episodes. Hydrothermal fluids have saturated an area of approximately 42 square miles and implaced lead, zinc, and silver mineralization at Tombstone and Charleston.

Discovery of porphyry copper type breccia pipes and associated porphyry copper type alteration has been one of the most important accomplishments of this current study. Presence of this type of alteration in the Tombstone district makes it possible to apply modern concepts of porphyry copper zoning which appear to explain salient aspects of the district. It is now apparent that the Robbers Roost breccia pipe area is the central part of a very large alteration zone. Tombstone and Charleston, which are approximately equidistant from the breccia pipe area represent opposing lead-zinc-silver zones peripheral to the porphyry copper alteration center. Exploration for economic ore bodies of copper associated with the area of breccia pipes is complicated by sub-horizontal geologic features in the area, including: the thin Uncle Sam quartz latite porphyry sill, and alluvial cover over layers of Bisbee Group pelitic sediments which in turn overlie favorable ore horizons in Paleozoic limestones.

The great majority of the production in the Tombstone district has come from ore bodies associated with anticlinal structures in the so-called Tombstone Basin, a large syncline in the Bisbee Group sediments located on the south edge of the town of Tombstone. Detailed geologic mapping in the State of Maine area has revealed that similar fold structures occur in the same rock types, which lie beneath a thin sill of Uncle Sam quartz latite porphyry. Recognition of several windows of sediments exposed in the main body of the sill is probably the second most important discovery resulting from this study. Careful plotting of these features on accurate cross sections indicates the Uncle Sam is at most a few tens to a few hundreds of feet thick in the State of Maine area.

Detailed mapping has shown that vein zones in the area have a greater continuity than had been previously realized.

Favorable structural and chemical horizons formed by folded beds below the Uncle Sam porphyry make attractive ore targets where they are intersected by projections of strongly altered surface vein zones. These vein zones appear wider and stronger than similar veins in the old part of the district. This might be expected since they are closer to the apparent source of mineralization -- the porphyry copper breccia pipe zone toward Charleston. The width of the veins suggests potential for disseminated near-surface ore, though to date surface samples, albeit strongly leached, have not been particularly encouraging.

Thus, this study suggests potential for two types of mineralization occurring in economic grades and tonnages. The first would be near surface values in vein zones within the Uncle Sam porphyry which might be minable by surface methods. Higher grade shoots of this type of mineralization might also be found along more narrow zones comprising ore of the type mined in the State of Maine mine. Extensions of this type of ore might be localized along newly discovered parts of the Maine vein in the Brother Jonathan area. Vein intersections on the Clipper and San Pedro veins might also be productive. The second type of ore would be replacement orebodies in favorable structural traps in sedimentary horizons in the Bisbee Group and Paleozoic sediments beneath the Uncle Sam porphyry.

Two types of exploratory drill programs are proposed to test these two possibilities. To test ore potential in the Uncle Sam porphyry, within 100 feet of the surface along mapped vein zones, holes should be drilled with an air track percussion drill. If encouraging results are obtained, up to two hundred

500

such holes should be drilled. The cost per foot should be in the range of $2.00 and the cost of the program, including assays, should be in the range of $65,000 for 20,000 feet of drilling.

Exploration for replacement ore in sediments beneath the Uncle Sam should be done with a rotary drill rig in the initial stages. Twenty-five holes have been proposed, each testing various specific targets while yielding information on thickness of the Uncle Sam sill and structure of underlying sediments. Considering an average depth of 500 feet, this program would entail 13,000 feet of drilling. Approximate cost including sampling and assaying would total $62,000. If the deeper penetration suggested on several holes were made, about $10,000 would be added to the cost. Total cost of both programs would be about $127,000 and require two to four months for completion.

Exploration of the porphyry copper target in the Robbers Roost area will require additional geologic and alteration mapping to define meaningful drill targets. Geochemical surveys in the area may also prove to be a valuable exploration tool. Induced polarization surveys will be of little value since they only indicate the presence of sulfides without respect to base or precious metal content -- and there is already abundant indication of sulfides in surface exposures. Magnetic surveys may be helpful in indicating magnetite associated with possible replacement type copper ore in limestone horizons.

A thorough knowledge of the geology of the district in three dimensions will probably be the most productive exploration method in the Tombstone district, -- for both precious and base metals. Careful geologic mapping and drill hole logging should therefor be of the first priority in future work in the district.

HISTORY

In 1877, Ed Schieffelin, Army scout at Camp Huachuca, took leave from his duties to go prospecting in the nearby hills. At that time, Apaches were running rampant over the area and his companions tried to dissuade him from going alone into the mountains, telling him that the only thing he would find would be his tombstone. Undaunted, Schieffelin set out and when he made a discovery of rich silver outcrops in the hills to the east of Camp Huachuca, he determined to call the new district "Tombstone" in honor of his companions' warnings.

News of Schieffelin's discovery spread quickly and Tombstone soon became a boom camp with thousands of fortune seekers moving into the area. Between the discovery date of 1877 and 1880, the price of silver was averaging $1.20 per ounce (a price not again to be attained until almost 100 years later). Production amounted to approximately 2½ million dollars at the then current metal prices. The greatest production of the camp was between 1881 and 1886 during which time silver ranged from $0.99 to $1.14 per ounce, and the mines produced almost 17 million dollars in metal. This rate of production was never again attained, decreases being due to lower metal prices and depletion of rich surface ores. The district has mainly been affected by economic events, experiencing buoyant periods during high metal prices and depressed conditions during low metal prices. One of the most buoyant periods was 1918-1922, when production was stimulated by the Pittman Act which supported the price of silver at $1.12 per ounce.

Water was encountered in the mines in 1882 and the 1,000-foot deep Pump shaft was sunk to dewater the district in the 1897 era. In 1909 a defect in the pumping system caused the lower levels of the Pump Shaft to be flooded and the pumps were lost in the lowest levels. This flooding of the pumps was generally thought to be the reason for the closing of the district. However, if silver prices had held at previously high levels, pumping would have been resumed and production continued. An examination of mineral prices during the life of the district suggests that low metal prices coupled with increasing mining costs precluded economic operation of the mines (Fig. 2), causing the death of the camp.

Period	Price of silver	Production	Remarks
1877-80	$1.15 -$1.20	$ 2,318,567	Discovery and early development. Mills built on San Pedro River.
1881-86	0.99 - 1.14	16,877,175	Active development and large production. Water encountered in mines in 1882, and mills built at Tombstone.
1887-96	0.63 - 1.05	4,564,650	Decreased production due to depletion of many of the large ore bodies above water level.
1897-1911	0.52 - 0.68	5,575,900	Consolidation of principal properties and attempted unwatering of district by a 1,000-foot pump shaft.
1912-14	0.553- 0.615	379,917	Lessee operations.
1915-17	0.507- 0.824	1,117,687	War period. Considerable production of manganiferous silver ore and concentrates.
1918-32	0.282- 1.12	5,150,789	Mainly lessee operations. Production of silver during 1918-22 stimulated by Pittman Act.
1933-36	0.35 - 0.77	1,118,325	Production stimulated by increased price of gold and silver.

FIGURE 2

GENERAL GEOLOGY OF THE DISTRICT

The Tombstone Mining District lies within the southwestern porphyry copper province. Nearby large porphyry copper deposits are located at Bisbee some 25 miles to the southeast, and the newly discovered deposits at Dragoon are some 25 miles to the northeast. Exploration drilling on porphyry copper at Gleeson, about 15 miles northeast, is presently underway.

The Tombstone area itself has had a complex geologic history which includes sedimentation, folding, thrust-faulting, several stages of intrusion by igneous rocks, and mineralization from hydrothermal solutions. Basement rocks are Precambrian granodiorite, and Pinal schist. Over this are deposited approximately 5,000 feet of Paleozoic sediments consisting, for the most part of limestone. Mesozoic sedimentation includes the Bisbee Formation consisting of approximately 4,000 feet of sandstones, minor limestones, mudstones, and shales. Tertiary surface volcanic rocks include the Bronco volcanics, which are comprised of a lower andesite breccia overlain by a quartz latite welded tuff. The Bronco volcanics are interesting in that they are co-relative, at least in time and composition, to the Silver Bell andesite complex and the Cat Mountain rhyolite. Work by Richard and Courtright show that these units occur rather pervasively throughout the porphyry copper province in southeastern Arizona and are closely associated with porphyry copper mineralization. Recent sediments within the Tombstone area include cemented conglomerates of the Gila type and normal alluvial material occurring in the stream drainages and the valley of the San Pedro River.

The tectonic history has been complex. At least two episodes of folding and thrust faulting have taken place (Gilluly, p. 122 through 130). It is apparent (Gilluly, p. 128) that an earlier period of deformation created eastward-trending features and later deformation formed northward-trending and oblique features. During the first stage, north-south compression formed east-trending folds and minor thrusts with a north strike and northerly low-angle dips. After this structural episode, the Bronco volcanics were deposited on erosion surfaces formed on Bisbee Group sediments. The disconformity is in general low angle, the volcanic units being subparallel to the pre-existing Bisbee. Following extrusion of the Bronco volcanics, the area underwent southwest-northeast compression, which produced thrust faults of northwesterly trend and was probably responsible for the large features visible in the district today, including the Tombstone Syncline, the Ajax Hill fault, the Prompter fault, and the Horquilla fault. After this structural episode, the Uncle Sam quartz latite porphyry was injected into the area. Feeder dikes of Uncle Sam porphyry are seen to the west of Ajax Hill. The large expanse of porphyry in the western Tombstone Hills and the State of Maine area is apparently a very large sill, which was intruded along a pre-existing thrust plane. Over most of its expanse, the Uncle Sam porphyry is replete with xenoliths and near its basal contact with underlying Bisbee sediments, the amount of xenoliths increase until they comprise 10 percent or more of the total rock volume. Since there are for practical purposes, only occasional windows through the Uncle Sam sill, we can only surmise at the rock type lying beneath. Because of its thrust-fault relationship, prediction as to the type of underlying rock is further complicated. All exposures in the State of Maine area seen to date have been of Bisbee Group sediments.

After the implacement of the Uncle Sam porphyry northeast-trending shearing developed within the district. This zone of shearing is expressed topographically and can be easily noted on topographic maps and aerial photos of the area. After development of northeast-trending shears, the area was invaded by andesite porphyry dikes. After solidification of the andesite dikes the area was intruded by rhyolite porphyry dikes, following parallel and sometimes the same fissures as the andesite dikes. This relation is seen near the Gold Bug workings in the State of Maine area, where a composite dike of rhyolite and andesite is exposed. The andesite comprises the central part of the dike with rhyolite intruding on either side of the andesite. The relative age is indicated by numerous sphereoidal xenoliths of andesite in the rhyolite. Extrusive equivalents of these rocks may have been deposited on the surface. However, there are no surface exposures which can be related to the dikes, and it is assumed their extrusive equivalents have been eroded away.

Emplacement of the Schieffelin granodiorite was the next intrusive event. The granodiorite forms a stock of northwesterly trend on the northern edge of the district, north of the Ajax fault, and it is quite possible that the granodiorite was intruded along this structural feature.

Subsequent to the granodiorite intrusion and possibly associated with it, hydrothermal solutions invaded the district and formed the known ore bodies at Tombstone and Charleston and were responsible for porphyry copper type mineralization, alteration and formation of breccia pipes in the Robbers Roost area. Examination of new color air photographs of the Tombstone District show red areas of probable hydrothermal alteration extending from the northern edge of the Tombstone district south to Lewis Springs--a distance of some 11 miles. The width of this alteration zone is approximately 4 miles, giving a total of some 42 square miles of hydrothermal alteration. If it is assumed that the Robbers Roost breccia pipe area, which is approximately 3,000 feet in diameter is the central part of this alteration zone, then the Tombstone Mining District is approximately the same distance from the breccia pipe center as is the Charleston area. Typical mineral zoning, characteristic of large porphyry copper deposits, would thus be the source of the Tombstone and Charleston lead-zinc-silver mineralization with porphyry copper occurrences to be expected in the Robbers Roost area. These relations are shown diagrammatically on Attachment 14 which is a transparent overlay for James Gilluly's map of the area (Att. 13). Possible mineral zones are shown as circular features with the center point being in the Robbers Roost breccia pipe area. The radii of the hypothetical zones are; the outward edge of the Tombstone district and the inner edge of the Tombstone basin, the outer edge of the State of Maine area, and the inner edge of the State of Maine area, and the Charleston mine. It is interesting to note that by using these radii, the Charleston circle falls on the point where copper staining was noticed west of the T.M.R. mill

(Section A-A', Att. 3), suggesting the possible peripheral zone of copper mineralization. Further, the State of Maine zone coincides almost exactly with the Charleston zone, while the Tombstone zone falls into the Lewis Springs area, outside of known mineralization. As was noted previously, there is a strong northeast-trending shear direction prevalent in the district as indicated by northeast-trending faults, veins, and topographic alignments. This northeast trend is one of the most typical features of porphyry copper alteration zones in the southeast Arizona area. In response to this fracture pattern it can be expected that proposed alteration zones may take an elliptical rather than circular pattern, being elongated in the northeast and southwest direction. As noted, alteration visible on the color air photos is elongate, in a northeast-southwest direction (Att. 14) corresponding to the above observation. It has also been noted in the Arizona porphyry copper province that in a predominant number of the productive districts, there is more than one center of mineralization, and are in some cases, numerous centers which contain economic mineralization. Examples of this would include the Silver Bell district, the Safford district, the Pima district, and the Globe-Miami district. It is conceivable then, that there may be other centers of porphyry copper type mineralization located along the alteration trend in addition to the exposures at Robbers Roost. The circular Tombstone basin area in fact could possibly represent a porphyry copper center with the copper zone being at great depth below the present horizon of erosion. Certainly circular features are also typical of porphyry copper deposits as exemplified by

Copper Creek and Copper basin near Prescott, Red Mountain at Patagonia, and the Safford district (verbal communication, Grover Heinrichs).

Geologic interpretation as related to mineral deposits within the Tombstone district is greatly complicated by the presence of almost horizontal geologic units. These would include: (1) Quaternary soil and alluvial cover; (2) the pre-mineral Uncle Sam porphyry sill forming a thin veneer (Section A-A', Att. 3) over Mesozoic and Paleozoic sediments; (3) Bronco volcanic units, which are sub-horizontal; (4) apparently almost horizontal thrust plane(s), which involve Paleozoic, Bisbee Group, and Bronco volcanic sedimentary units; and (5) Bisbee formation and Paleozoic limestone units of unknown orientation. Because of the greatly differing chemical composition and reactivity of these various units to ascending hydrothermal solutions, and uncertainties as to the presence or absence of these features in any one given spot, interpretation of surface exposures of alteration and mineralization--or lack of it--are made extremely difficult. For example, strongly altered vein systems in Uncle Sam porphyry could be indicative of great potential for substantial bodies of replacement type mineralization, if the Uncle Sam is underlain by reactive limestone units. On the other hand, should such reactive units be absent, the presence of hydrothermal veining may have no significance directly relating to economic mineralization lying below. The corollary of this might be; if areas of poorly altered Uncle Sam porphyry, which would seem to have essentially no potential for mineralization, were underlain by a thick sequence of reactive lime, presence of the lime--which tends to react vigorously with hydrothermal solutions--might be indicated by the very absence of hydrothermal effects in the Uncle Sam porphyry. It is obvious then that a very thorough understanding of the detailed geologic aspects of the district will be necessary before a meaningful porphyry copper drilling program can be laid out. The extensive amount of pyritic mineralization as indicated by the coloration on the color air photos suggests that induced polarization surveys, which merely show the presence or absence of pyritic mineralization, will be of little use in determining areas which have greater content of base and precious metals. However, because of the presence of Paleozoic and Mesozoic limy sediments throughout the district, there appears to be great potential for the occurrence of significant replacement ore bodies within these limy units. Since magnetite generally accompanies this type of mineralization, magnetic surveying might be a useful guide. It should be remembered, however, that magnetic response falls off as the inverse square of the distance from the magnetic source and thus, small bodies with low magnetic susceptability if even moderately buried, show little or no magnetic response, even though they may carry significant ore grade mineralization. The most reliable guide to ore within the district will be an intimate knowledge of the geologic and alteration features of the district, both on the surface and related to the subsurface.

SURFACE GEOLOGY IN THE STATE OF MAINE AREA

GENERAL STATEMENT

The major part of the writer's time has been spent in detailed mapping within the State of Maine area in order to delineate geologic targets that would relate to production anticipated from the old State of Maine workings and processing of gob from the old stopes. Since potential was for relatively small, but rich bonanza type ore bodies, it was felt that a very detailed map would be required. The first order of business, then was to obtain an accurate topographic map at a scale of 1"=200' with 5-foot contour intervals. The base triangulation survey for this map was surveyed by Florian and Collins, Civil Engineers of Tucson, Arizona. Control was tied to the State survey, using the benchmark at the public library in Tombstone. Primary control points were surveyed using theodolites and a Hewlett-Packard distance measuring device. The survey is first order in nature and adheres to minimum Government specifications. In addition to the primary control points, all identifiable claim monuments and posts were targeted with white, 24-inch wide butcher paper, in the form of a "Y" with the monument in the center and legs extending outward 10 feet in length. In addition to claim monuments, fence corners, other property boundaries of interest, and some power poles were thus targeted. Although no accurate count was kept, probably at least 200 points were so identified. The area was then flown by Cooper Aerial Survey and photographed with black and white film using a Wild RC-10 mapping camera. The map was compiled using Kelsh plotters.

Each of the targeted claim monuments and other points of interest were surveyed on the Kelsh with their.location and elevation being noted to the nearest 1/2 foot. Thus, in addition to the topographic lines, there are numerous permanent points of reference scattered throughout the map area. Patent corners of the patented claims were thus accurately located and claim lines were plotted on the map. Topographic features were scribed on mylar scribcoat and a screened mylar, right-reading base map sheet was then photographically reproduced from the scribcoat master. The scribcoat master remains on file at Cooper Aerial, and additional mylar copies can be made at any time.

Geologic features were plotted on this topographic base and black and white photos at the same scale were used as an assist to mapping. The technique of geologic outcrop mapping was employed. That is; only features that were actually seen in outcrop were plotted on the map. Little or no interpretive material has been added. Further, actual rock outcrops are shown in darker color (Att. 1) while talus-covered slopes on which bedrock was indicated by presence of only one type of rock detritus are indicated by lighter colors. For the most part, it was impossible to trace small vein or dike features through areas of detrital soil cover. To aid in exploration, numerous bulldozer roads and cuts were put in, an effort being made to anticipate future drill sites. More of the dozer cut work was laid out than has been completed as of this writing because of unanticipated breakdowns in the bulldozer equipment. As more dozer cuts and roads are made, it is probable that more

514

vein exposures and hence a better knowledge of the area will be gained.

In addition to the surface geologic mapping, the black and white air photos were examined stereoscopically and linear features identified. These linear features are shown on Attachmant 1 as heavy dashed blue lines. They probably represent fault or shear zones of substantial magnitude, although their effect can rarely be seen on the ground.

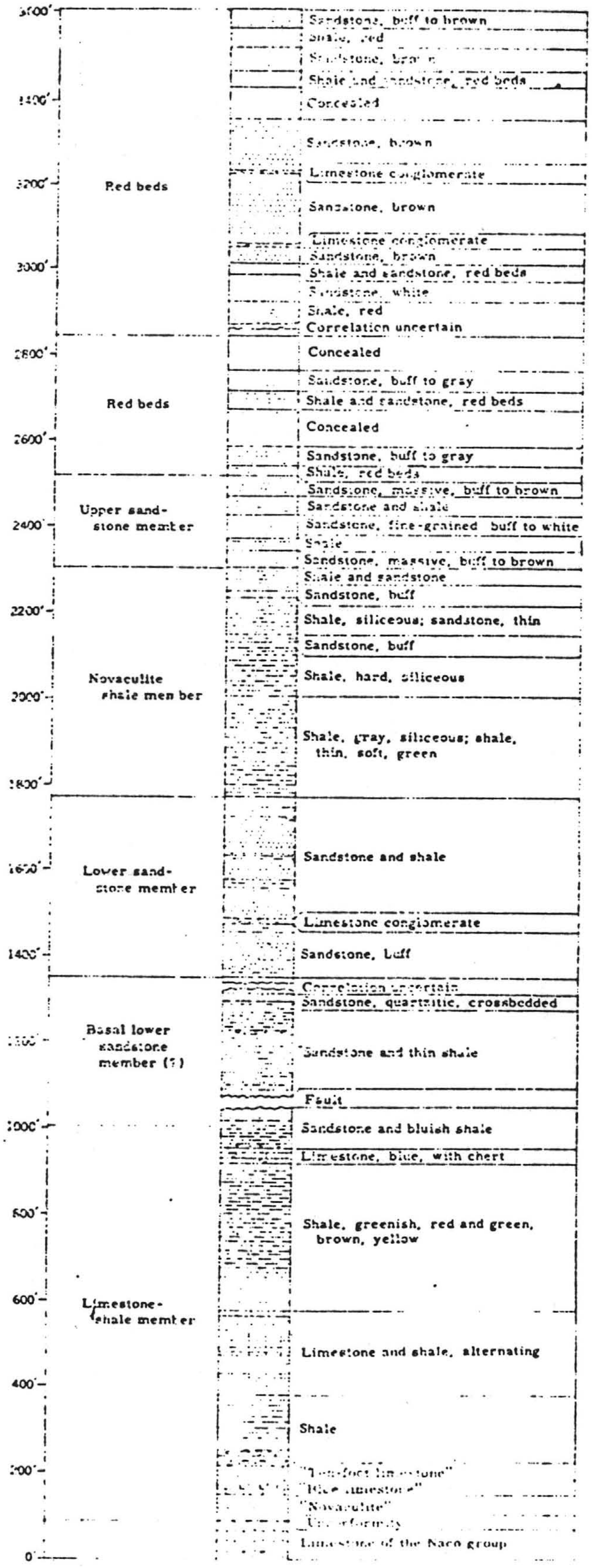
SEDIMENTARY ROCKS

Quaternary Alluvium

Quaternary alluvium consisting, for the most part of stream wash, is located in valley bottoms. The thickest accumulations of Quaternary alluvium occurs in the north-trending drainage directly east of the Free Coinage claim where it is probably ten to a few tens of feet thick. In this area, it obscures the contact between Bisbee Group sediments and Uncle Sam porphyry. It is locally up to 15 or more feet thick in the Fox Ranch area as indicated by scraper cuts. However, in the remaining wash areas it is probably 5 feet or less in thickness. The contact of the alluvium with bedrock is generally arbitrary and marked with a dashed line. There was insufficient time to map in detail all of the small outcrops within the stream drainage areas marked Quaternary alluvium on the map. In the Fox Wash area in particular, there are numerous windows of bedrock sticking through alluvium, which are not shown on Attachment 1. As time is available, the Project Geologist should endeavor to detail the outcrops in this area as it may shed light on alteration and mineralization patterns. Since the stream drainages are obviously structurally controlled, they are probably also the loci of veins which may carry significant mineralization and for this reason they should not escape continued effort at detailed mapping. This is particularly true of the northeast-trending drainage directly below the State of Maine dump. In this area several caved shafts have penetrated alluvium and strongly altered Uncle Sam porphyry can be seen on their dumps. To test this drainage, I have suggested the drilling of several air-track holes (See Att. 1).

Bisbee Group Sediments

The great preponderance of sedimentary outcrops within the bounds of the State of Maine 200-scale map are nondescript Bisbee Group sediments--probably equivalent of the Morita and Cintura formations as described in the Bisbee area. The sediments can generally be characterized as red bed units consisting of sandstones, quartzites, and arkosic sandstones, shaley mudstones, and shales (Figs. 3&5). Over most of their exposures within the map area, these sediments are soil covered; rock type indicated only by detrital fragments. Because of this rapid weathering to soil, few exposures show sufficient bedding to determine strike and dip. Where seen, divergent attitude of bedding precludes meaningful comment regarding the detail structure of Bisbee Group sediments in this area (Att. 16). It is suggested by regional aspects, however, that the beds are generally tilted to the east so that by progressing in a westerly direction, the base of the unit is approached. This idea is reinforced by the presence of limestones cropping out north-northwest of the Free Coinage claim (about 1,600 feet north of the Uncle Sam shaft)



RE 5.—Composite section of the Bisbee formation in the Tombstone mining trict. After Lyden, O'Donnell, Hernon, and Hi[illegible]en (unpublished mine rept.,).

The lowest and thickest is as much as 40 feet thick in places. These six beds of blue-gray and silty limestone contain abundant marine fossils. The formation contains at least two other beds of limestone 2 miles to the southwest; these contain fresh-water faunules. About 2 miles east of Dragoon Camp (Black Diamond), several thin beds of blue-gray shaly limestone occur in the Bisbee formation at a horizon that is many hundreds of feet stratigraphically higher (with respect to the local base of the formation) than these southern beds. The limestones near Dragoon Camp also contain a marine fauna, but so poorly preserved as to be of little service in correlation. The fauna is principally of interest because it shows the persistence, at least at times, of marine conditions during the deposition of the Bisbee formation as far north as Dragoon Camp.

Everywhere in the area the top of the Bisbee formation is an erosion surface, either ancient or recent. Accordingly, even if exposures were much better and structural complexities much less, it would be impossible to determine the original thickness of the formation. Under these conditions it is possible only to estimate the minimum thickness of the rocks. A careful study of the much-faulted and metamorphosed strata exposed in the mining district at Tombstone has been made by Messrs. J. P. Lyden, R. M. Hernon, Neil O'Donnell, and C. E. Higdon, who kindly supplied the following composite generalized section, synthesized from many partial sections measured in the Tombstone district.

Generalized composite section, Bisbee formation, Tombstone Hills.

	Feet
Erosion surface.	
1. Sandstone and shale, alternating; a few 10-foot limestone conglomerate beds; shale members chiefly red or maroon; sandstone beds buff to brown, a few gray or white; sandstone members range from 20 to 170 feet in thickness, predominate over the shale	1, 040±
2. Sandstone, buff, gray, and white, some interbedded gray-green hard shale; thick bedded	220
3. Shale, gray to green, hard and siliceous, a few thin buff sandstone beds	540
4. Sandstone, buff, white, and brown, a few green shale beds, at least one thin bed of limestone	422±
5. Shale, green and bluish, some conglomerate	58
6. Limestone, massive, blue, cherty	25
7. Shale, green, mottled red and green, brown, and yellow	345
8. Limestone	10
9. Shale, some sandy beds	29
10. Shale and limestone, alternating in thin beds	15
11. Shale, greenish, some limy beds	30
12. Limestone	5
13. Shale, poorly exposed	53
14. Limestone	4
15. Shale, gray, green, and black	43
16. Sandstone, yellow	9
17. Shale, red and brown	65
18. Shale, black	14
19. Shale, green and gray, siliceous	42
20. Limestone, "Ten-foot bed" of miners	10
21. Shale, with arkose at base	24
22. Limestone, "Blue limestone" of miners	34
23. "Novaculite," silicified shale, local intercalations of limestone conglomerate	60
Total	3, 097±

The above section cannot be considered accurate because it represents the synthesis of at least four partial sections, the correlations between which are all dubious. Nevertheless, as it was based on very detailed and careful work, there can be little doubt that it is as fair a representation of the stratigraphy of the formation at Tombstone as it is possible to give with the present exposures. It is shown graphically in figure 5. The formation elsewhere in the area is lithologically much the same.

No effort was made to measure a section of the Bisbee formation in the Dragoon Mountains; but from the dips and width of outcrop, it can be seen that there is about 15,000 feet of Bisbee rocks in the section northeast of Walnut Springs, where neither base nor top is exposed. This thickness, though large, is not surprising, as the aggregate thickness of the Bisbee group in the Mule Mountains was measured by Ransome (1904, p. 56) as 4,750 feet, with the top eroded. In the Little Hatchet Mountains, N. Mex., 80 miles to the east, Lasky (1938, p. 524–540) has found a section of Comanche rocks over 17,000 feet thick, of which fully 15,000 feet are of late Trinity (Glen Rose) age. The thinning of the Mural limestone northward from the Bisbee area does not, of course, imply the northward thinning of the clastic rocks above and beneath it. At any rate, whatever the a priori probabilities, the consistent attitudes and gradual changes in strike and dip of the section exposed northeast of Walnut Springs strongly oppose the idea that this section has been greatly repeated by faulting, despite the structural complexities of the mountains to the west.

CONDITIONS OF DEPOSITION

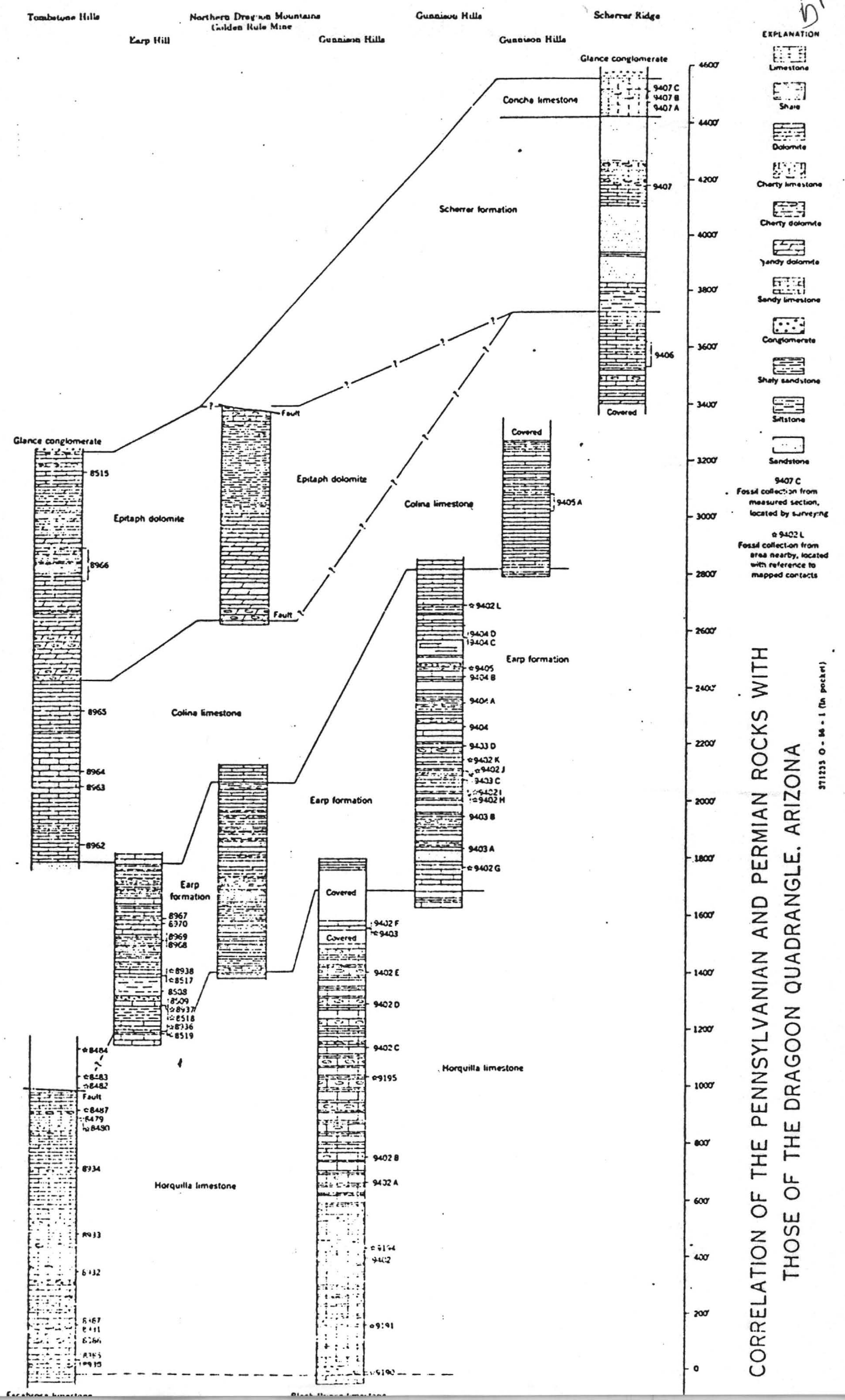
The Bisbee formation contains a few beds of definitely marine origin, at least as far north as the foothills east of Black Diamond Peak. On the other hand, fresh-water fossils have been found in the formation between Charleston and the Tombstone Hills. The fossils are confined to a few thin beds, and the great bulk of the rocks are unfossiliferous.

The sandstone beds are commonly current-bedded, with scour on their bases, ripple marks, and considerable grit or even fine conglomerate, and thus give evidence of shallow water at the time of their deposition. The mudstones are generally red, brown, maroon, or and also exposed in the window in the Fox Ranch area (Att. 1). These limestone units are probably corelative of either the Ten Foot or the Blue limestone (Fig. 5). Further evidence of this is suggested by the presence of a quartzite pebble conglomerate, exposed in the Fox Ranch window. This conglomerate is probably the Glance conglomerate. In most of the Tombstone area the Glance is not present; however, as shown in Figure 4 and Figure 5, Gilluly and other workers in the district do show the Glance to be present, at least locally. In a small outcrop 2,000 feet north-northwest of the Uncle Sam shaft (at the site of P-17) there is exposed bleached quartzite breccia, which may be the equivalent of the Novaculite. Similar limestones appear to be absent in the Solstice Hill area and thus, although not conclusive because of small outcrops and structural complexities, it is presumed that the limestones exposed north of the Uncle Sam shaft and in the Fox Creek window are basal Bisbee formation --a critical point since this implies that Paleozoic Naco limestone should be present within a short distance, either horizontally or vertically (see Sections A through I, Atts. 3-11).

Paleozoic Sediments

No Paleozoic sediments have been mapped within the State of Maine area 200 scale map, Attachment 1. Geologic relations indicating that lower Bisbee sediments are exposed in the central part of the mapped area (as discussed above) suggest that Paleozoic sediments should be located shallowly beneath the lower Bisbee in the Fox Ranch area. Further, it is possible that Paleozoic limes may surface beneath the Uncle Sam sill as shown in Sections B through I (Atts. 4-11).

579



CORRELATION OF THE PENNSYLVANIAN AND PERMIAN ROCKS WITH THOSE OF THE DRAGOON QUADRANGLE, ARIZONA

IGNEOUS ROCKS

Schieffelin Granodiorite

The Schieffelin granodiorite is a holocrystalline rock. In hand specimen it is light greenish-gray or pinkish-gray and mildly porphyritic (Gilluly, p. 103), weathering to a buff color. Petrographically, it is intermediate between quartz monzonite and granodiorite and could easily be called a quartz monzonite (Gilluly, p. 102). No outcrops of this rock were mapped within the State of Maine area, although outcrops could occur in the poorly covered area to the north and northwest of the Free Coinage claim. A complete petrographic description is given in Gilluly, p. 103.

Rhyolite Dikes

Several discontinuous rhyolite porphyry dikes crop out in the central part of the mapped area and can be traced from the area of the Gold Bug prospect to the north end of the Clipper claim. The dikes generally have a steep northwesterly dip, although in the Brother Jonathan area one dip of 42° is recorded. Flow structure generally parallels the walls of the dikes. However, a large dike on the Clipper claim shows turbulent flow structure. The dike outcrops are generally limonite-stained from disseminated pyrite content and are occasionally cut by vein structures. The spatial relationship of the rhyolite porphyry dike swarm to the productive part of the State of Maine vein suggests some subtle relationship to mineralization. What this is, however, is not clear and numerous assays of dike material show only background amounts of base and precious metals.

Andesite Porphyry Dikes

Andesite porphyry dikes were mapped on the State of Maine map in only one area which is slightly south and west of the Gold Bug prospect. Dikes of the same type, however, were observed south of the southwest endline of the Chance claim. Lack of time, however, precluded detailed mapping in this area. Similar dikes are very prevalent in the Robbers Roost breccia pipe area. The dike rock consists of a dark-green chloritic looking matrix, in which are set white feldspar phenocrysts. The dikes are pre-mineral in age and also predate the rhyolite porphyry. In the one andesite dike mapped southwest of the Gold Bug area, rhyolite porphyry invades both the hanging wall and foot wall of the dike and is younger in age as indicated by spherical xenoliths of andesite porphyry in the rhyolite.

Uncle Sam Quartz Latite Porphyry

Uncle Sam quartz latite porphyry comprises the largest area of outcrop within the State of Maine area. The high peaks of Three Brothers Hill, the Dome, Main Hill, and Uncle Sam Hill are all composed of the Uncle Sam porphyry.

The porphyry has an aphanetic ground mass with phenocrysts of quartz and plagioclase feldspar. Xenoliths of Bisbee Group sediments are prevalent throughout its exposures and where it is in contact with the underlying Cretaceous Bisbee Group, the xenolith content increases and the rock appears to almost grade into the sediments. The tops of the higher hills appear to be composed of a more resistant unit of the Uncle Sam. It is unclear whether this is a primary rock feature or a secondary alteration feature. Preliminary examination of color air photos covering the area shows light coloration, possibly due to a horizontal alteration front, occurring at an approximate equi-elevation line in the Uncle Sam. The suggestion is that the hard capping facies of the Uncle Sam atop the prominent ridges is then due to alteration rather than a primary rock feature.

The Uncle Sam shows sill-like relations in most of the State of Maine area (Atts. 4-11). However, its contacts with the Bisbee Group, approximately 600 feet northeast of the northeast sideline of the Merrimac claim, appears to be vertical as indicated by its lack of deviation across steep contours in the area. At the northern exposure of the State of Maine vein, 1,100 feet north of the Uncle Sam shaft, the exposure appears to be flat and sill-like, again indicated by topography while a couple of hundred feet north, it again appears to dip steeply. It is concluded that while in gross aspect, most of the Uncle Sam exposure in the State of Maine area shows sill-like relations; in all probability there are areas which are feeder dikes and as such, have continuity in depth.

STRUCTURAL FEATURES OF THE STATE OF MAINE AREA

General Statement

Structural features within the State of Maine area can be broken down into two broad categories--steeply dipping features and horizontal and sub-horizontal features. Steeply dipping features which can be easily traced and mapped on the surface would include veins, vein zones, dikes, post mineral faults and photo-linears. Horizontal and sub-horizontal features would include thrust fault planes, bedding and fault planes with an angle of dip of less than 20 degrees and the basal contact of the Uncle Sam porphyry. These features are either poorly exposed or not exposed at the surface, and can only be inferred from detailed surface geologic mapping. Only the steeply dipping features will be discussed in this section, while the low angle features will be discussed under the heading Sub-Surface Geology, State of Maine Area.

Vein Zones

The strongest direction of structural shearing within the Tombstone Mining District is north approximately 55 degrees east. This is the typical northeast fracturing direction which is invariably seen in the Arizona porphyry copper deposits. The shearing is represented by topographic alignments of ridges and stream drainages, by rhyolite dikes, and andesite dikes, and by the vein system which is responsible for most of the mineralization within the district. In the Tombstone Basin, northeast of the north-trending Ajax fault, these northeast trending fractures dip to the southeast, while in the State of Maine area, west of the Ajax fault, most of the veins dip to the northwest. The exception to this observation is the Fox vein which dips southeasterly at about 50 degrees. Right lateral movement along the northeast trending veins is suggested by antithetic faults occurring along the shallowly dipping State of Maine structure and the Clipper vein zone (Att. 1). The strongest antithetic structure is the Triple X vein which appears to be continuous between the State of Maine vein and the Clipper vein zone. Apparent antithetic structures along the San Pedro vein also suggest right lateral movement.

One fracture zone within the State of Maine area trends almost north-south with a vertical dip. This is the San Pedro vein just north of the Fox Ranch. The vein appears to bend to the northeast where it intersects the Fox vein and continues in a northeasterly-trending arc through the San Pedro workings, and is lost in the alluvium to the East.

Dikes

Two types of dike rock crop out within the State of Maine area. The most predominant type being rhyolite with only a few exposures of subordinate andesite being seen. The dikes are probably related closely in time and are both pre-mineral. The andesite predates the rhyolite as is indicated southwest of the Gold Bug area where a composite rhyolite-andesite dike shows spherical xenoliths of andesite in rhyolite. Discontinuous and irregular outcrop patterns of the rhyolite suggest intrusion into tension fractures.

Post-Mineral Faults and Photolinears and Topographic Alignments

Surface evidence of significant post-mineral faulting has only been seen in a few areas. A possible fault was noted in the southwest corner of the May claim, apparently being responsible for a bold ridge of Uncle Sam porphyry a few hundred feet long. One small probable left lateral fault was noted a few feet southwest of the Triple X shaft. This fault apparently offsets a rhyolite dike. A few small strike-slip faults were noted in the window in the Fox Ranch area, offsetting limestone beds in the Bisbee sediments. The most significant fault could not be identified in the field, yet is indicated by its left lateral offset of the composite andesite-rhyolite dike southwest of the Gold Bug prospect. This liner appears to correspond with a poorly defined structure visible on aerial photographs. The structure can be traced on the color air photos approximately 4000' to the south, but apparently terminates against another photolinear northwest of the Gold Bug area (Att. 1).

Topographic alignments, which have not been specifically delineated on Attachment 1 except in the case of the Fox Wash zone, probably also represent structural features. The washes probably represent vein zones along which there may have been post mineral movement; at any rate they are the least resistant areas of rock exposure, and alteration generally appears stronger along their trend. Preliminary examination of the color air photos shows red coloration localized along the drainages while absence of this coloration on the ridge tops suggests fresh resistant rock.

Examination of the 1"=200" enlargements of the black and white photographs reveals linears which are shown on Attachment 1 as heavy dashed blue lines. The linears are for the most part topographic, vegetation or small drainage alignments, and cannot generally be seen from the ground. They appear to be post mineral and one of the most prominent, a north-trending feature traceable for in excess of a mile north of Fox Wash, appears to make a right lateral offset in the Fox Wash vein zone. The photolinear which trends east-west and cuts through the top of the State of Maine hill (Att. 1) projects through the State of Maine shaft and essentially parallels the State of Maine wash which is alluvial covered. Dump rock on old caved prospect shafts along this wash show fragments of strongly altered Uncle Sam porphyry. The intersection of the structure with the State of Maine shaft suggests that it may be pre-mineral and may have had some influence on mineralization. For the most part, however, it still appears most of these features are post-mineral and may be quite recent. Except in the case of the fracture which offsets the Gold Bug area dike, there is no way at present to measure their dynamic effect on the rocks in the area. It may be, however, that these features bound structural blocks which have been displaced in a vertical sense, either up or down in relation to each other. For this reason, they may have an important bearing on the spatial positions of ore bodies within the area and thus their correct interpretation may be of economic significance. Knowledge of their location may be critical in correct interpretation of drill-hole data.

MINERALIZATION

Hydrothermal solutions associated with vein mineralization in the area appear to be mesothermal in nature. Alteration along the veins in the Uncle Sam porphyry consists of emplacement of pyrite, minor galena, possibly some sphalerite and primary manganese minerals. Wall rock has been silicified to varying degrees and alteration to clay and sericite has taken place in the reactive feldspars. Where alteration and vein intensity is greatest, sericite is dominant, while in poorly altered vein areas, argillization is the primary effect. Pyrite is represented at the surface by jarosite and red and yellow limonites. In the most strongly altered veins, maroon, red "relief" or "live limonite" is present on fractures. In the most poorly altered areas, occasional suggestions of pseudomorphs of pyrite are seen. All of the dumps in the area, with the exception of the San Pedro dump show only oxidized material. Examination of the sulfide bearing fragments on the San Pedro dump show them to be intensely bleached and altered Uncle Sam porphyry with finely disseminated white pyrite along siliceous fractures and disseminated through the rock. Accessory gangue minerals in the veins consist of silica and some manganese. Barite is seen only in the Gold Bug area. Manganese appears to be more prevalent in the San Pedro area with lower amounts being seen in the Gold Bug, Lowell, and State of Maine areas. No primary manganese minerals have been identified in the State of Maine area to the knowledge of the writer.

The only silver mineral which has been identified within the area is bromyrite (AgBr). It is a pistachio green, waxy mineral which occurs in the oxide zone on fracture planes and is termed horn silver by the local miners. It is essentially the equivalent of cerargyrite (AgCl) and can only be differentiated by chemical analysis. The probable source of the silver is argentiferous galena. Numerous assays show a strong geochemical presence of lead ranging up to multiple thousands of parts per million. The lead is probably present as cerussite, or anglesite, but no specimens of these minerals have been identified as yet. Silver is probably also tied up as argentojarosite or plumbojarosite and in the manganese oxide minerals.

In spite of very careful observation of the rock in several hundred assay samples, there appears to be no way of judging silver content by eyeballing the rock, unless horn silver is present, in which case high assays can be anticipated. Traces of copper oxide were seen in the San Pedro area and also the dump of the Brother Jonathon shaft, but no copper sulfides have been noted.

Mineralization in the sediments consists of silicification and disseminated limonite after pyrite. There also appears to be a greater manganese content than in the Uncle Sam porphyry. Alteration is less noticeable, possibly because argillic and sericitic alteration of the Uncle Sam porphyry yields white bleached zones which have been subsequently stained red and orange by limonite while in the sediments alteration has been confined to silicification and a rather minor amount of limonite staining.

The veins in the State of Maine area can best be described as vein zones rather than discreet sharp-sided vein features consisting of emplaced hydrothermal minerals. Put another way, they are actually narrow alteration zones with numerous discreet fractures, all sub-parallel, along which mesothermal solutions have traversed, altering the rock present, and depositing base and precious metal sulphides, silica, and in some areas manganese and barite. Subsequent weathering has resulted in oxidation of the sulphides and deposition of various limonites and oxide minerals.

The most significant feature of the veins in the State of Maine area is their width. The State of Maine vein itself appears to be only about 15 feet wide, however, the Gold Bug vein zone is silicified and strongly altered over width of about one hundred feet and shows moderate to strong alteration over a width of approximately 300'. The Fox Wash vein zone is approximately 100' wide and sub-parallel fracture zones associated with the Fox Wash vein zone appear to be up to 300' in maximum dimension. The north-trending San Pedro vein in the area of the Fox Ranch windmill is intensely altered over a width of 30' and shows moderate to strong alteration over a width of approximately 20 to 30 feet. A parallel structure which is intensely silicified but has not been mined, shows a width of 10 to 25 feet. A zone southeast from the San Pedro shaft (in the area of Hole P-12) shows disseminated sub-parallel fracture zones over a width of approximately 400 feet. This zone apparently continues across alluvial cover to intersect the north-trending San Pedro vein in the area of hole P-9.

In the Three Brothers shaft area (the vicinity of hole P-10) altered rock containing sub-parallel fractures is approximately 300' wide. Throughout the general area of the True Blue claim, Three Brothers shaft, San Pedro and Fox veins, the Uncle Sam porphyry shows sub-parallel and intersecting veining, the rock being pervasively altered over an area approximately 400 to 700 feet in width and about 1500' in length. In the area of the Lowell claim, a vein zone which may be the extension of the State of Maine vein, alters rock over a width of up to 200', and a length of three or more hundred feet. The Clipper Free Coinage claims are located on what the writer has termed the Clipper Zone. This zone consists of sub-parallel fractures showing weak- to strong-hydrothermal alteration over a width of from 20 feet to about two hundred feet and a length of at least 3500 feet.

The width and intensity of mineralization of these veins suggest greater volume and intensity of mineralization than that present in the Tombstone Basin area. Further, when it is considered that these vein structures are underlain by reactive limestone units, which would have the effect of diluting any ascending hydrothermal solutions, their apparent potential is further emphasized. Since they appear to be closer to the source (the Robbers Roost porphyry copper center) it would be reasonable to assume a greater intensity of mineralization than that present in the Tombstone Basin. The best targets for ore bodies, of course, would occur where the hydrothermal vein zones intersect the chemically and structurally reactive host rocks -- the tightly folded lower Bisbee and upper Paleozoic sediments.

SUBSURFACE GEOLOGY STATE OF MAINE AREA

GENERAL STATEMENT

As mentioned previously under general geology of the district, low angle structures caused by two episodes of thrust faulting are responsible for some of the complexities of the sub-surface geology within the Tombstone mining district. The Uncle Sam porphyry which comprises the major portion of the outcrops in the western part of Tombstone Mining District is actually a very thin remnent of a sill which has probably been intruded along the plane of a pre-existing thrust fault. This fact is verified by several windows of sediments peeking from beneath the sill and also the intersection of Bisbee Group sediments in the bottom of the State of Maine shaft. The low angle of this structure is also attested to by its semi-circular outcrop on its eastern edge caused by topographic effects. Recent color aerial photography reveals a probable fault of normal displacement paralleling the San Pedro River which is not shown in any pre-existing geologic map. This fault or faults are most probably downthrown on the west side, tending to give the impression of greater thickness of the Uncle Sam porphyry than is the probable case. One outcrop of Permian Colina limestone on the northwest edge of May's Hill (on the up-side of the fault) indicates the relative thinness of the Uncle Sam. Were it not for the normal faults occurring to the west of this outcrop, Bisbee Group sediments and Paleozoic limes might also be exposed along the western margin of the Uncle Sam porphyry to the west of Uncle Sam Hill. Examination of cross section A-A' which is drawn at 1"=1000' (Att. 3) shows the true thickness of the Uncle Sam as related to its surface contacts and elevations of windows which the writer has located and mapped. To further complicate the vertical picture, the pre-Uncle Sam, pre-thrust Bronco volcanic series also forms a thin veneer over Bisbee Group sediments which in turn overly, at apparent low angles, Paleozoic sediments. All of the planar formations which predate the Uncle Sam porphyry (including the Bronco volcanics, the Bisbee Group and Paleozoic sediments) have been involved in thrust faulting. How many layers of thrust sheets are present is not known. Thus, good ore horizons which would include basal Paleozoics and basal Bisbee Group sediments, could lie either near the surface or at great depth depending on their involvement with thrust and other faults. The only method of determining what the true layer cake nature of the district is would be additional detailed geologic mapping at a scale of 2000 or possibly 1000 feet per inch followed up by exploratory drilling.

THICKNESS OF THE UNCLE SAM QUARTZ LATITE PORPHYRY

In order to determine what the sub-surface beneath the Uncle Sam porphyry in the State of Maine area was like, eight structural cross sections--Sections B through I (Atts. 4-11) were constructed from the surface geologic map (Att. 1). On these sections, the vertical scale is equal to the horizontal scale so that no graphic distortion is involved. All surface contacts and strike and dip information were used on these maps. On each cross section, apparent angles of dip were plotted from tables dependent on their angle of intersection with the plane of the section. Thus, features such as surface contacts, angles of strike and dip, locations of proposed drill holes, geographic features and projections of planar features such as dikes and veins can be considered real and accurate. Curving features such as bedding, folds, etc. were drawn in using general background knowledge of the district. They must be considered only typical of what could be found in the sub-surface but it should be understood that sub-surface data are at this point too scanty to allow the accurate projection of such complex features as folded sediments and true contacts of curving features. The approximate thickness of the Uncle Sam porphyry in various places is plotted from its surface contacts and the intersection of the State of Maine shaft with the Bisbee Group sediments. Additional data used in plotting the possible location of the bottom contact of the Uncle Sam include: verbal report of intersection of sediments in the bottom of the Escapule drillhole southeast of the Fox Ranch windmill (reported to have cut sediments at approximately 90 feet), exposures of sediments in windows in the Uncle Sam sill to the west of Sections D, C, and B, and to the south of F, G, and H.

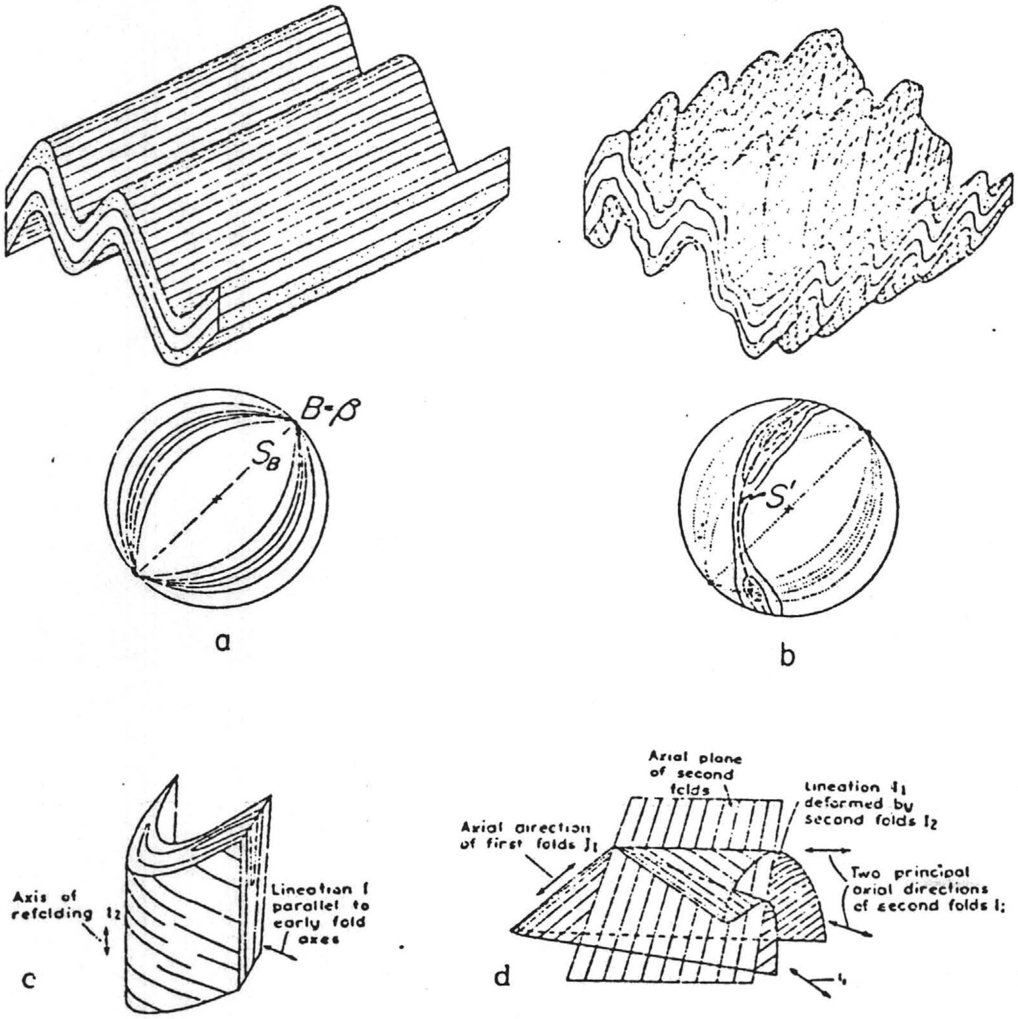
Using these data, it is apparent that the thickness of the Uncle Sam ranges from several hundred feet from the tops of the highest hills to a few tens of feet in the bottoms of the washes. The thin areas would be exemplified by the San Pedro Mine area where the porphyry appears to be 300 feet or less in thickness (Section F-F'). It should be remembered, however, that since the Uncle Sam is an intrusive rock, it could very easily have an undulating contact with the underlying sediments. Thus, the geologic projections from surface outcrops can only generalize its true angle of contact and it may thicken and thin in a complex fashion. Another factor may be important in determining the true thickness of the Uncle Sam from spot to spot are the photo linears indicated by heavy blue dashed lines on Attachment 1. As mentioned previously, they may define fault blocks which have been randomly jumbled up and down so that one block may have been downdropped considerably, giving an apparent increase in thickness to the Uncle Sam, while an adjacent block may have been relatively upthrown, thus giving a thin aspect to the sill. There are, however, enough exposures of sediments in the various windows to suggest that the thicknesses of the sill displayed on Sections B through I are probably fairly accurate.

STRUCTURE OF SEDIMENTARY ROCKS BENEATH THE UNCLE SAM SILL

The Bisbee Group sediments are rather massive nondescript sandstones, siltstones, and mudstones over most of their exposure with the State of Maine area. However, north and east of the Free Coinage claim, and in the Fox Ranch area, marker horizons which show structure are exposed. These marker horizons are limestone beds which may be the equivalent of either the Blue limestone occurring near the base of the Bisbee, or the so-called Ten-Foot limestone occurring slightly above the Blue limestone. Mapping of the sediments exposed in the window on the north end of the State of Maine vein show they are warped into a tight anticline plunging to the East. The type of fold and direction of plunge appears to be the equivalent of folds within the Tombstone Basin. It is preliminarily concluded that they were due to the same tectonic forces. In the Fox Ranch window there are exposed two limestone beds and one bed of conglomerate. It is assumed the conglomerate is the Glance conglomerate, and thus the limestones appear to be overturned. Section G-G' shows this bedding sequence to represent a recumbent fold. Several other fold structures might be proposed to explain the geometry of the exposed features. However, until more data are acquired by drilling, the recumbent fold seems to fit the general geologic environment as well as any. Remembering that at least two events of folding and thrust faulting occurred in this area, it is quite probable that folds developed during the first episode were again folded during the second episode, thus creating extremely complex fold surfaces (Figs. 6 through 9).

It was assumed in drafting the cross sections that the folds were generally trending northwest-southeast as they are in the Tombstone Basin and would be similar to that known within the Tombstone Basin. Considerable artistic license was used in diagrammatically showing what the subsurface sediments might be like and no attempt was made for each cross section to adhere exactly to what had been portrayed in the other cross sections as far as the folded sediments are concerned. Instead, an attempt was made to illustrate various possibilities. It should, however, be noted that on Sections B, C, and D rather open structures were portrayed which would be the case if the sections were indeed drawn obliquely through northwest-southeast-trending folds. Thus, the projections of the veins, dikes, and Uncle Sam contact is probably accurate as it exists. However, the locus of intersection of veins with potentially reactive sediments is only generalized, and is not presented as

536



Figs. 16a and 16b.—Superposed cylindroidal folding with oblique axes, as drawn by Weiss, showing stereographic projections of the bedding and fold axes (from Weiss, 1959, Fig. 5). 16c and 16d.—Superposed deformation of early lineated folds (from Ramsay, 1960, Figs. 1 and 2). Axes and directrices are oblique.

B, C, the sections parallel to the respective fold systems are shown in his Plate IVA and traces on oblique surfaces are shown in his Plate V. Oblique intersection of superposed folds is shown in his Plate IC, IIB, C and IIIA,C and Text-figs. 1, 4, 5 and 6, which show that the resulting domes and basins have sigmoid fold axes which have right or left echelon according to the relative angles of shear of the two interfering fold limbs. It is commonly assumed that such echelon sigmoid anticlines indicate wrenching transcurrent movements. However O'Driscoll emphasizes that nothing but vertical transport is involved in producing these sigmoid echelon patterns. Offset occurs whenever the interfering fold axes are parallel or have a common component of movement (i.e. they are not orthogonal). These offsets cause the sigmoid

537

patterns (offset in opposite senses on either side of the composite crest) and may cause migration of crests or culminations below an unconformity (see O'Driscoll, Text-fig. 9).

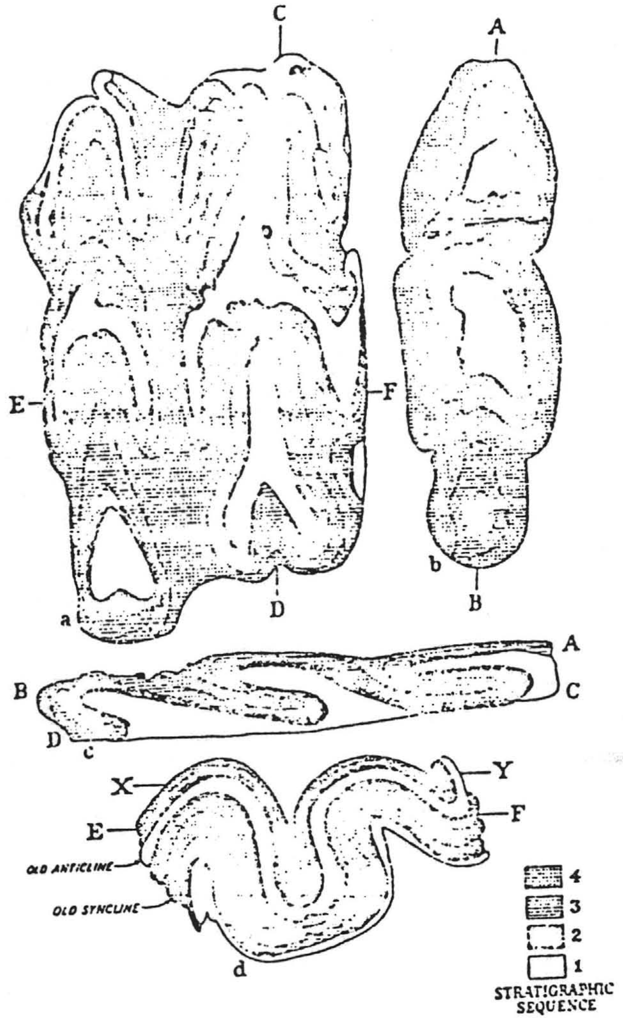


Fig. 17.—Superposition of similar folds with orthogonal strikes and divergent directrices (from Reynolds and Holmes, 1954, Text-fig. 13). EF is the axial direction of the first folding and CD (or AB) that of the second. (a) Surface outcrops after slicing. (b) Surface outcrops on the right-hand side only, as seen at a higher level than that of (a). (c) Section of the model, before slicing off its top, cut along CD of (a) and AB of (b). AB and CD represent the levels at which (b) and (a) were respectively sliced. (d) Section of the model, before slicing off its top, cut along EF of (a). XY and EF represent the levels at which (b) and (a) were respectively sliced.

Weiss (1959) has studied the same kind of cases as O'Driscoll by statistical analysis of S-planes (see Fig. 16).

Reynolds and Holmes (1954) have investigated by field mapping and petrofabric analysis, confirmed with plasticene models, a case of overprinted folding where the strikes are orthogonal but the directrices are oblique. They have shown that under these conditions the traces on a horizontal surface (corresponding to Figs. 19 and 20 of O'Driscoll) develop trident-, heart-, stirrup- and anchor-shaped outcrops (Fig. 17).

When the orthogonal axes of Reynolds and Holmes are made oblique, with the fold directrices also divergent, the same patterns are produced in a skewed form, as shown in Fig. 18. The obliquity also results in sigmoidal axial traces for the same reasons as in O'Driscoll's common directrix case.

In the left hand column of Fig. 18 the fold axes are at right angles to each other. In the right hand column they intersect at 30°. In Fig. 18a both folds are symmetrical but one has twice the wave length of the other. In Fig. 18b the first is overturned. In 18c the first folds are overturned but crestlines are at different heights, although the axial lines for all folds are horizontal and wave lengths are equal. Fig. 18d shows conditions identical to

FIGURE 8

direction of domal migration from f to f′ depends on the attitude of the inclined surface DEF with respect to the horizontal surface ABC. Where the strike of surface DEF is parallel to BC, EF becomes horizontal and the dome f′ moves in the direction of BA; where the strike of DEF is parallel to BA, DE becomes horizontal and f′ moves in the direction of BC.

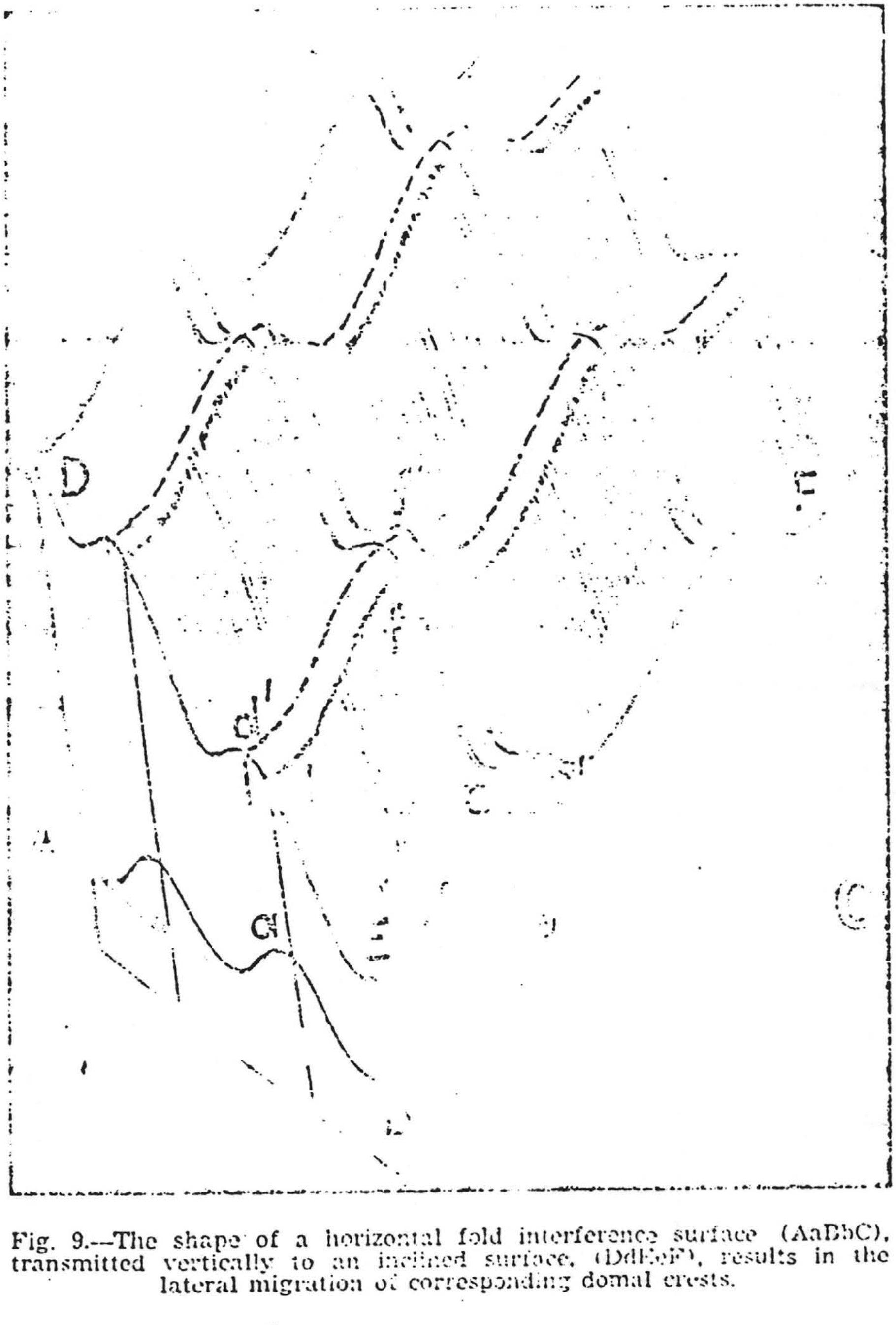


Fig. 9.--The shape of a horizontal fold interference surface (AaBbC), transmitted vertically to an inclined surface, (DdEeF), results in the lateral migration of corresponding domal crests.

FIGURE 9

Fig. 8 shows a specimen of the type of card used in the models to be described. As used, the cards are unmarked except for the succession of similar fold profiles printed upon them. For the purpose of this description, notations have been added ot the specimen card in Fig. 8. The similar fold profiles represent the "first" fold system, with vertical axial planes parallel to A-A and S-S, which mark the anticlines and synclines of the accentuated stratum on the card. The lines P-P mark the loci of maximum shear on the limbs of the folds. In the figure they have equidistant spacing. The line M-M represents the slopes of a larger structure on which the smaller fold profiles have been imposed. It may be regarded as a "regional" gradient or differential. For reasons already described the axes A-A and S-S are therefore not equidistantly spaced. Although terminology in these matters is not confirmed, the writer has rather loosely employed the prefixes "micro-" and "mega-" to denote scales relative to the basic elements. In this way the line M-M has been regarded as the slope of a "mega-structure" on which the basic profile is imposed. The profiles in Fig. 8 have been described as anticlines on a "meganticline" (or domes on a "mega-dome") and the line M-M has accordingly been described as defining the "mega-slope."

Plate IV (A) shows a printed card model in which the continuous interference surface of domes and basins is seen intact in the upper foreground. On the vertical plane X of the cards may be seen the printed profile of the first fold system. On the vertical plane Y is the profile representing the second fold system. Where the cut edge of a card intersects a printed fold trace, a dark spot shows on the edge, and when a stack of cards is guillotined or

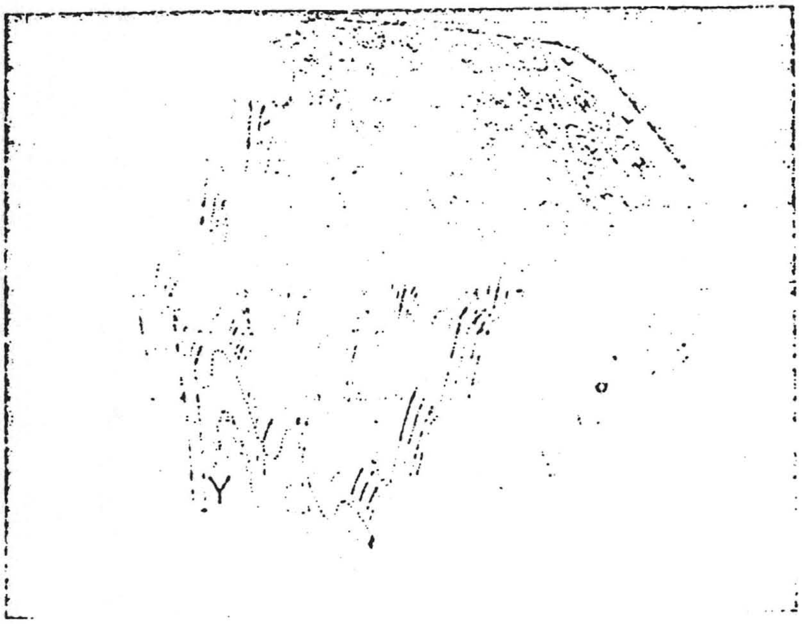


Plate IV (A).—Printed card model showing interference surface intact in foreground, and truncated in background to expose traces of successive surfaces.

an estimation of their true locus in space. The true position and shape of these folded sediments will only be known after numerous holes have been drilled and detailed plots made of the subsurface information.

MINERAL POTENTIAL

Within the Quartz Latite Porphyry

Mineral potential within the Uncle Sam quartz latite porphyry might be generalized in two categories. Category 1 would consist of very near surface low-grade open pittable material. The economics would be based on the cheapness of handling and would be dependent on (a) its degree of dissemination and thus ease of bulk mining within some of the pervasively altered rock areas such as the Gold Bug prospect, the San Pedro area, or the Fox Wash area, (b) the development of a cheap method of bulk treatment such as drum leaching (as suggested by Mr. John White) or some type of cheap agitation leaching (as suggested by Mr. Nicholas Caruso), or dump leaching. Category 2 would be relatively high-grade supergene oxide type ore shoots such as were mined in the State of Maine workings. These would consist of bromyrite (horn silver) in fissures ranging from a few feet to possibly as wide as 15 feet. It is apparent from numerous samples that the surface material is strongly leached, and that silver mineralization begins some several feet below the present erosion surface. It is possible that richer supergene ore bodies might be found at the water table interface along vein structures such as the State of Maine, Gold Bug, San Pedro, Fox Wash, etc. Exploration for these narrow zones would be by underground methods or surface drilling using air track equipment.

Replacement Ore Bodies in Lower Bisbee Formation and Paleozoic Sediments

The writer feels the greatest potential in the State of Maine area is for intermediate size bonanza type ore bodies located below the Uncle Sam sill at intersections of veins with chemically reactive beds and favorable structural traps. In this respect, the State of Maine area is very much like the East Tintic district of Utah wherein a previously productive precious metal district was extended by correct interpretation of alteration zoning in pre-mineral cover rock. If we adhere to the hypothesis that the Robbers Roost area is a central part of a porphyry copper zone, and Tombstone and Charleston lead-zinc-silver mineralization is peripheral to this zone; then, since the State of Maine area is closer to the source, it may be reasonable to expect stronger mineralization.

As indicated on Butler, Wilson, and Rasor's Bulletin 143, cross sections Attachments 27 through 36, the best horizons in the Tombstone Basin area were the Blue limestone, the Novaculite, and the Naco formation, although ore was also encountered within the Bisbee Group redbeds. Ore was not, however, found preferentially in any one of these formations, first being in one formation to the exclusion of the others and then another. It is not clear what caused a particular horizon in one spot to be preferable. However, it may have been some combination of favorable structure and/or chemistry. It is apparent, as indicated on Attachment 36, that fractures along the crests of anticlines or "rolls" were the best locales for ore deposition. Since these structures are present within the State of Maine area and beneath the Uncle Sam porphyry, as indicated by the outcrops north of the Uncle Sam shaft and in the Fox Ranch area, exploration drilling should be designed to delineate and test these structures.

Because of the complex sub-Uncle Sam structure in the sediments, it might not be impossible that lower Paleozoics could lie near the surface, only covered by Uncle Sam porphyry. Thus, stratigraphic units like the Devonian martin limestone which form rich horizons in other districts may also have potential for production within the State of Maine area.

In addition to favorable stratigraphic and strato-structural targets, the intersection of strong veins may also have potential for forming important ore bodies. Examples of this would include the intersection of the Fox and San Pedro veins which on the surface, are heavily pitted by prospects (Section C-C', Att. 5). Less obvious, but possibly even more significant, would be the intersection of the Free Coinage vein and the unnamed vein (Section D-D', Att. 6, and H-H', Att. 10). Further, it can be seen by inspection that if the surface structures have continuity in depth, there is potential for 3-way intersections as exemplified by the intersection of the Triple X vein with the intersection of the Free Coinage and unnamed vein-cylinder of intersection (Section H-H', Att. 10). Further complicating the three-dimensional aspects, this three-way intersection might (or might not) fall on the crest of an anticline (or at the bottom of a syncline) within favorable (or unfavorable rocks) which would tend to enhance (or decrease) the ore making potential of the structure. It appears then, that the best exploration tool within the State of Maine area will be detailed surface mapping, projection of strong structures to the sub-surface, determination of their loci by descriptive geometry and testing by exploration drilling. Careful logging of exploration drill holes will yield additional data regarding the geometry of faulted Mesozoic and Paleozoic sediments, changes in trend of vein and dike structures, and the gradual refinement of geologic targets. As this process of data gathering continues, a more accurate understanding of the geometry of the sub-surface features will be gained, and thus a sharpened aim of exploration drilling.

544

PROPOSED DRILLING PROGRAM IN THE STATE OF MAINE AREA

GENERAL STATEMENT

Two objectives are paramount within the State of Maine area. The first is to delineate near surface ore bodies within the Uncle Sam porphyry, preferably those which could be mined by open pit methods to form immediate mill feed or feed for a heap leach operation. The most rapid and efficient means of doing this will be rotary percussion drilling using an air track drill.

The other objective is to test veins below the Uncle Sam porphyry sill for potential replacement bodies within the lower Bisbee group and upper Paleozoic section. Because of the problem at hand, three primary objectives in order of their importance become obvious. These are:

1. Determination of the thickness of the Uncle Sam porphyry by drillhole intersection.
2. Determination of the thickness, approximate geometry and location of Bisbee units and their relation to underlying Paleozoic units.
3. Determination of grade of mineralization in veins within the Bisbee or upper Paleozoic sections.

Since pinpointing the exact location of potential ore bodies will be exceedingly difficult until the information points 1 and 2 are known, i.e. thickness of the Uncle Sam and location of receptive beds within the sedimentary units, it is more important to determine those two points at the expense of detailed sampling than it is to have careful sample assays of each foot of exploratory drillhole. Therefore, because of the rapidity of drilling and the low cost, the writer suggests that air rotary drilling above the water table and water circulation or mud circulation rotary drilling below the water table, be used for the initial holes. Good samples can be obtained from the air rotary drilling, while with water circulation, these samples will be much less accurate, but will reflect rock type, and certainly strong mineralization, so that no significant ore bodies will be missed. If interesting structures are intersected, spot cores can always be taken with the drill rig. Cost of this drilling using Sierra equipment should be no more than \$3 to \$3.50 per foot, to a depth of 500 to 800 feet. This compares with a commercial cost of \$5 to \$6 per foot for comparable rotary drilling or a cost of approximately \$10 a foot for diamond drilling.

AIR TRACK DRILLING

Purpose and Objectives

The purpose of the air track drilling is to test the various vein structures present in the State of Maine area to a depth of approximately 100 feet. Surface sampling suggests that all of the values have been completely leached from the surface, and therefore the only feasible way of making rapid tests is by drilling. The air track has the capability of drilling either vertical or inclined holes to a depth of approximately 100 to 120 feet. The holes are approximately 3½ inches in diameter and are drilled by percussion with air cleaning and circulation in the hole. Progress is quite rapid and should amount to 200 to 300 feet per shift. Cost should be in the \$1 to \$2 per foot range. Drill cuttings can be sampled every 5 feet and compiled on core boards for geologic logging.

Since ore may occur in shoots within the vein structures relatively close sampling of the veins will probably be necessary to delineate all the ore present. On Attachment 1, suggested hole locations have been indicated by black dots. These locations are spaced at approximate 100-foot intervals along the various vein structures. Determination of whether the hole should be drilled vertically or at some inclined angle--so to intersect the vein in a perpendicular fashion--can best be made in the field, and thus no attempt was made to give specific orientations. Further, exact hole placement should also be done in the field rather than adhering exactly to the locations plotted on Attachment 1. It may be that in some areas the Uncle Sam is thin enough so that the air track drilling will give some information regarding the underlying sediments. It will, therefore, be important carefully to log all of the drill cuttings within these holes in addition to the normal assay logs.

ROTARY DRILLING

Purpose and Objectives

The purpose and objectives of the 25 proposed holes plotted on Attachment 1 is to explore mapped vein structures within and below the Uncle Sam porphyry and to determine the type and structure of sediments lying below the Uncle Sam.

Sample Handling and Logging

The total sample from each hole should be collected and split down to approximately 2 quarts in volume, using a Jones type splitter. From this 2-quart sample, 1 quart should be split again and retained in permanent storage. From the other quart, a pint of assay material should be split out and approximately the same volume should be taken for construction of core boards. Atomic absorption determinations for silver, gold, lead, zinc, and copper should be made routinely on each 5-foot sample. Core boards should be made for each hole, including a panned fraction for each sample. These should be logged immediately and the results posted on cross sections so that the sub-surface work can be continually updated.

FIGURE 10

TOTAL COST OF PROPOSED DRILLING PROGRAM

SIERRA ROTARY DRILL PROGRAM

Cost per foot to 500 feet = $3.50/foot	
" " " 500-1000 " = 4.50/foot	
25 holes 500' deep = 12,500' @ $3.50 =	$43,750
12,500 ÷ 5' sample intervals = 2,500 Assay samples	
Geochem Assays for Au, Ag, Pb, Zn, Cu	
Hawley & Hawley Discount Price	
Cu, Pb, Zn,- $2.10; Au, Ag - $3.32 = $5.42	
Assay & Sample Preparation ($1.00) = $6.42 x 2,500=	16,050
	$60,675

AIR TRACK - PERCUSSION DRILL PROGRAM

200 holes x 100' deep each = 20,000 feet at $2.00/foot =	$40,000
Sampling at 5' intervals = 4,000 samples	
Assay cost (with Hawley & Hawley Discount)	
$5.42 for Au, Ag, Pb, Zn, Cu + $1.00 Sample Preparation = $6.42 x 4,000	25,680
	$65,680

Total cost	$126,355

Objectives of Each Hole

The positions of proposed rotary drill holes are shown on the geologic map of the State of Maine area (Att. 1), and cross sections at a scale of 1"=200' (Atts. 4-11).

Hole P - 1

P-1 is located on the ridge above and to the northwest of the Brother Jonathon inclined shaft. Assuming the State of Maine vein is approximately 15 feet in thickness and dipping at approximately 40°, P-1 should cut the State of Maine vein at a depth of 195 feet to 230 feet. The hole should be drilled a minimum of 250 feet deep, and close track should be kept of cuttings near the bottom. If it continues in altered rock the hole should be deepened until fresh rock is encountered. As indicated on Section H-H' (Att. 10) the base of the Uncle Sam porphyry sill should be encountered at approximately 450 to 500 feet. It is the writer's opinion that this hole should be drilled to at least 500 feet, or until the sediments below the Uncle Sam porphyry are intersected. If these sediments show alteration, then drilling should continue at least some distance into the sediments in order to determine their character. Ideally, a core sample should be cut at the bottom of the hole.

Hole P - 2

Hole P-2 is located with respect to the intensely silicified zone at the Gold Bug prospect north of the Lowell claim. Its purpose is to test the alteration at the Gold Bug prospect and penetrate through the Uncle Sam porphyry

550

to determine if replacement type ore bodies are located within the underlying sediments. It should be drilled to a minimum depth of 500 feet. It would be preferable to drill to a depth of 1000 feet in order to get a clear idea of the sedimentary sequence lying beneath the Uncle Sam in this area, and to test possible extension of other veins which might project toward the hole (Section F-F'). The base of the Uncle Sam porphyry should be intersected at approximately 150 feet (See Section F-F'). Between 320 feet and 400 feet it might well encounter the composite rhyolite andesite dike which crops out to the southwest of the hole location.

If the decision is made to bottom the hole at 500 feet, then it should be filled with mud so that it could possibly be re-entered at a later date. In any event, should it encounter mineralization it should be deepened until the mineralization is penetrated.

Hole P - 3

Hole P-3 is located on the Fox Wash structure. Its purpose is to test grade of mineralization within this structure in the Uncle Sam porphyry and for possible replacement mineralization in sediments beneath the Uncle Sam. The hole will probably cut the bottom of the Uncle Sam at about 240 to 300 feet, and should be drilled to a minimum depth of 500 feet to gain information about the underlying sediments.

Hole P - 4

Hole P-4 is located to the East of the shop area on the Clipper claim, and along the Clipper structure (Att. 1, and Section I-I', Att. 11). Its purpose is to cut the zone of intersection between the Triple X vein structure and the Clipper vein structure at the interface between the sediments and the Uncle Sam porphyry. This should occur at approximately 120 feet, and drilling should be continued to a minimum depth of 500 feet in order to determine the nature of the underlying sediments (Cross Section I-I', Att. 11 and Section B-B', Att. 4).

Hole P - 5

Hole No. 5 is located 1600 feet north of the Uncle Sam shaft on the crest of an anticline in lower Bisbee Group sediments (Section H-H', Att. 10). Its purpose is to test for mineralization in favorable horizons along the crest of the anticline and also along the projection of the State of Maine vein. It should be drilled to a minimum depth of 500 feet or to a depth where the Bisbee Novaculite has been penetrated, and the Naco limestone unquestionably cut. Preferably it could be drilled to a depth of 1500 feet in order to cut the zone of intersection of the Free Coinage vein and the Unnamed vein (See Section H-H'). However, this deep drilling could be postponed until the Unnamed vein and the Uncle Sam vein have been tested by Holes P-25, and P-18 in order to determine their continuity. Further, a better location might be chosen so that a deep hole could penetrate the 3-way intersection of the Free Coinage, the Unnamed vein, and the Triple X vein structure as shown on Section H-H'. At any rate, Hole P-5, if drilled to a shallow depth, should be mud filled and capped for later re-entry.

Hole P - 6

Hole P-6 is located in the Fox Ranch area on the extension of what appears to be the San Pedro vein and collars in altered Uncle Sam porphyry. Its purpose is to test the thickness of the Uncle Sam, the tenor of the altered rock in the Uncle Sam, and to test for replacement deposits within the lower Bisbee sediments below the Uncle Sam porphyry. It should be drilled to a minimum depth of 500 feet.

Hole P - 7

Hole P-7 is located in the northeast corner of the Lowell claim, and collars in altered Uncle Sam porphyry. The vein responsible for the alteration at the hole collar dips approximately 42° to the north and may be the continuation of the State of Maine vein. P-7 is designed to test the tenor of the altered Uncle Sam porphyry, the depth to the Uncle Sam sediment interface, and to determine whether there is mineralization in the sediments beneath the Uncle Sam. It should penetrate the Uncle Sam at approximately 200 feet (Section G-G', Att. 9). And should be drilled to a minimum depth of 500 feet.

Hole P - 8

P-8 is located approximately 300 feet west of the Escapule Mill at the Fox Ranch. It is designed to test the alteration zone which appears to parallel the Fox Wash and to penetrate the Uncle Sam sill and test the sediments lying below. It should be drilled to a minimum depth of 500 feet (Section B-B', Att. 4).

Hole P - 9

Hole P-9 is located approximately 350 feet north of the Fox Ranch windmill on the San Pedro claim on the San Pedro vein at its intersection with a northwest-trending vein zone. It is designed to test the tenor of mineralization along the San Pedro vein both in the Uncle Sam porphyry and in sediments lying beneath the Uncle Sam porphyry. It should be drilled to a depth of 500 feet and should penetrate the base of the Uncle Sam at approximately 100 feet (See Section C-C', Att. 5).

Hole P - 10

Hole P-10 is located approximately 250 feet southeast of the Three Brothers shaft on the Fox vein system. P-10 is designed to test the tenor of the Fox vein alteration zone in the Uncle Sam porphyry and in the sediments beneath the Uncle Sam porphyry. The hole should penetrate the Uncle Sam at approximately 120 feet, and should be drilled a minimum depth of 500 feet. Altered rock will probably be cut for the total length of the hole.

Hole P - 11

Hole P-11 is located approximately 440 feet north of the Fox Ranch windmill, and approximately 100 feet northwest of hole P-9. It is located so as to intersect the plane of intersection of Fox vein and San Pedro vein within Bisbee Group sediments (Section C-C', Att. 5). P-11 should penetrate the Uncle Sam at approximately 100 to 120 feet and cut the point of intersection of the two vein systems at 200 to 250 feet. It should be drilled to a minimum depth of 500 feet.

Hole P - 12

P-12 is located approximately 350 feet south of the San Pedro shaft on a strong northeast-trending vein system which is in total almost 400 feet wide. P-12 is collared in what appears to be the strongest part of the vein system, and is designed to test its tenor in the Uncle Sam porphyry and in sediments which lie beneath. It should cut the Uncle Sam porphyry in the vicinity of 200 feet and should be drilled to a minimum depth of 500 feet. It should intersect altered rock throughout its total length.

Hole P - 13

Hole P-13 is located approximately 250 feet northeast of the San Pedro shaft on the San Pedro vein zone. It is designed to test the tenor of this vein zone in both the Uncle Sam porphyry and the sediments lying beneath. It should penetrate the Uncle Sam porphyry at 250 to 300 feet and should be drilled a minimum depth of 500 feet. It should be in mineralized rock throughout its length. However, it may cut the most strongly altered part of the vein system between 10 and 40 feet. When the exact location of this hole is spotted in the field it may be better to move it 50 to 100 feet to the south in order that a greater section of the intensely altered vein material be cut.

Hole P - 14

P-14 is located 170 feet southwest of the San Pedro shaft along the San Pedro vein and between surface stopes on that vein. Copper oxide mineralization crops out to the north of the proposed hole location. P-14 is designed to test this intensely altered vein area both in the Uncle Sam porphyry and the sediments below as seen on Section F-F' (Att. 8). It should cut the Uncle Sam porphyry at about 200 feet, and should be drilled to a minimum depth of 500 feet.

Hole P - 15

Hole P-15 is located approximately 550 feet to the northeast of the San Pedro shaft and is collared in Quaternary alluvium. It is on the projection of the very wide San Pedro vein zone, while the north-south trending area of alluvium may represent an intersecting zone of alteration. It is designed as a further test of San Pedro vein zone, both in the Uncle Sam porphyry and in underlying sediments. It should cut the Uncle Sam porphyry at about 300 feet and should be drilled to a minimum depth of 500 feet.

Hole P - 16

P-16 is located approximately 750 feet east of the San Pedro shaft on the projection of the alteration zone tested by P-12. P-16 is designed as another test of this alteration zone for tenor of rock both in the Uncle Sam porphyry and in the sediments beneath. It should be drilled to a minimum depth of 500 feet and should penetrate the Uncle Sam at a depth of approximately 100 feet (Section D-D', Att. 6).

Hole P - 17

P-17 is located 400 feet north of P-5 and approximately 2000 feet north of the Uncle Sam shaft. It is collared on a brecciated and strongly manganese oxide mineralized quartzite breccia, and is designed to test this zone in depth. It should be drilled to a minimum depth of 300 feet, or until it penetrates the breccia zone and goes into unaltered, unmineralized rock.

Hole P - 18

Hole P-18 is located approximately 200 feet west of the Free Coinage vein system (Section D-D'). It is designed to test the grade of the Free Coinage vein system below existing workings and hopefully within the Bisbee Group sediments. It should intersect the Free Coinage vein between 120 and 170 feet. The hole should be drilled a minimum depth of 500 feet in order thoroughly to test the Bisbee Group sediments in this area.

Hole P - 19

Hole P-19 is located approximately 150 feet northwest of the quarter corner marker for sections 9 and 16, and is located on the Merrimac claim. It is designed to test the Free Coinage vein system and sediments lying beneath that area. It should be drilled to a minimum depth of 500 feet and will probably remain in altered rock over that depth.

Hole P - 20

Hole P-20 is located approximately 1000 feet north of the Uncle Sam shaft, and collars in Uncle Sam porphyry along the projection of the State of Maine vein. It is designed to test the grade of mineralization of the State of Maine vein in both the Uncle Sam and the Bisbee Group sediments which shallowly underly this location. It should be drilled to a minimum depth of 300 feet.

Hole P - 21

Hole P-21 is located approximately 380 feet south-southwest of the quarter corner marker of section 9 and 16 and lies on the Merrimac claim. It is designed as another test of the strong Clipper vein system both in the Uncle Sam porphyry and underlying sediments. It should be drilled to a minimum depth of 500 feet and it is expected to remain in altered rock over this entire depth.

Hole P - 22

This hole is located approximately 250 feet from the State of Maine mine office in the State of Maine canyon. It is collared in alluvium, but is designed to test for the presence of a strongly altered structure projecting along State of Maine canyon. It should be drilled to a minimum depth of 500 feet and should penetrate the Uncle Sam porphyry at approximately 100 feet. If drilled to a depth of 1000 feet it would also penetrate the strong Clipper alteration zone within Bisbee Group sediments or possibly the Naco limestone (See Section I-I', Att. 11).

Hole P - 23

P-23 is located approximately 150 feet northwest of the Bonanza shaft and lies on the Red Top claim. It is designed to test the grade of mineralization along the Bonanza-Solstice-Chance vein and should be drilled to a minimum depth of 500 feet. It should remain in altered rock over this entire distance, and will probably penetrate an andesite porphyry dike with associated mineralization at about 300 feet (See Section C-C', Att. 5).

Hole P - 24

P-24 is located approximately 700 feet northeast of the mine gate in Maine Wash and is on the projection of the Clipper vein zone. It is designed as another test of the Clipper vein zone and as another penetration of the Uncle Sam porphyry. It collars in alluvium, but should penetrate the base of the Uncle Sam at approximately 50 feet and enter Bisbee Group sediments (Section C-C', Att. 5).

Hole P - 25

P-25 is located approximately 350 feet southwest of the Uncle Sam shaft, and is designed to penetrate the State of Maine vein in this area below known workings. It should cut the State of Maine vein at approximately 280 feet which is also the base of the Uncle Sam porphyry. It should be drilled to a minimum depth of 500 feet (Section I-I', Att. 11).

Supervision and Revision of Objectives

Because present knowledge of the sub-surface is so scanty, new data obtained by drilling might radically change the nature and objectives of the ensuing program. Recognition, therefore, that objectives might change with continued drilling should be made and the drilling work should be very closely supervised from a geologic standpoint so advantage can be taken of new information. It is suggested that the geologist in charge have enough assistants so that his time will not be occupied with routine sample preparation and handling duties. Rather, he should occupy himself in continued surface mapping or of plotting drill results and updating sub-surface maps. Continued and timely updating of sub-surface information to get an accurate and complete three dimensional picture of the area will be critical to ore finding.

PORPHYRY COPPER EXPLORATION

GENERAL STATEMENT

As mentioned previously, the discovery of porphyry copper breccia pipes in the Robbers Roost area is probably the single most important discovery resulting from this study. Recently obtained color air photos which cover approximately 234 square miles of the Tombstone District and its environs, show that Tombstone, Charleston, and the Robbers Roost area are part of one continuous alteration zone which is about 11 miles long, 4 miles wide and covers approximately 42 square miles. Thus the Tombstone Mining District, rather than being an epithermal precious metal district is part of a large porphyry copper type alteration zone. Identification of the district as a porphyry copper zone allows the application of knowledge of porphyry copper zoning criteria to salient geologic features of the district. The features mapped in the Tombstone district fit very well in the general porphyry copper picture and are easily explained in that context. These features would include:

1. Laramide stocks of quartz monzonitic to granodioritic composition represented by the Schieffelin granodiorite.
2. Silver Bell-type volcanic rocks represented by the Bronco volcanic units.
3. Strong northeast grain to fault and mineralized structures.
4. A zone of intense quartz-sericite alteration accompanied by breccia pipes and porphyritic dike rocks.
5. A large, continuous zone of disseminated sulfides (approximately 42 square miles at Tombstone).
6. Metal zoning. In the Tombstone district this is indicated by the occurrence of copper near the breccia pipe center and lead, zinc, silver mineralization near the town of Tombstone and at Charleston.

56

Although the Tombstone district has all necessary ear marks which identify it as a porphyry copper .type alteration zone, as yet there is no known economic copper mineralization. Such mineralization may be obscured and hidden by both pre- and post-mineral cover rocks, partially as a result of numerous horizontal features existing in the district including; horizontal to sub-horizontal sedimentary beds, thrust faults, and the flat sill of Uncle Sam Quartz latite porphyry. Exploration methods must take into account these features if they are to be fruitful.

GEOLOGY BETWEEN THE STATE OF MAINE MINE AND CHARLESTON

Surface Geology

The major rock type cropping out between the State of Maine and Charleston is Uncle Sam quartz latite porphyry. Over much of the area thin soil covers the porphyry while in places, it is totally obscured by alluvium (Att. 13). Drainage and topography follow the northeast trending fracture and vein zones. Cutting the Uncle Sam in a northeasterly trend are greenish andesite dikes of the same type exposed near the Gold Bug prospect and elsewhere in the district. The dikes are particularly abundant in the Robbers Roost area. Alteration shows that they are probably late pre-mineral in age and fragments of the dike rocks are occasionally seen in the breccia pipes.

Intense quartz-sericite is seen in the Robbers Roost breccia pipe area, while pervasive argillic alteration is seen in the surrounding area. Northeast trending vein zones, in places up to 100 or more feet wide, also show sericite alteration.

Bronco volcanics are exposed in Charleston Hill. They are composed of a lower laharic andesitic breccia unit equivalent of the Silver Bell andesite complex. The upper unit where seen by the writer consists of a light-colored quartz latite welded tuff which displays eutaxitic texture and is similar in appearance to the Cat Mountain rhyolite. The top of Charleston Hill is a plug of Uncle Sam quartz latite porphyry as indicated by Gilully's map (Att. 18).

To the east and southeast of the Charleston-Tombstone road Bisbee Group sediments are exposed. The writer has only briefly visited a few of these outcrops and it is not known whether the upper- or lower-Bisbee is represented in the outcrops. Gilully's map shows a nearly conformable contact between the Bisbee and Bronco volcanics which are both dipping at shallow angles to the west in this area.

Subsurface Geology

Plotting of the basal contact of the Uncle Sam quartz latite sill on carefully constructed cross sections shows the sill to be very thin over its total exposure (Section A-A', Att. 3). The rock lying beneath the Uncle Sam in all exposures seen to date is Bisbee Group sediments. Contorted bedding and the possible presence of hidden thrust faults will probably necessitate drilling to obtain data regarding depth to Paleozoic sediments, although some idea of their depth might be gained by geologic mapping.

The base of the Uncle Sam sill appears to be tilted toward the San Pedro River. Normal faulting which can be identified on recent color air photos appears to drop the Uncle Sam down along the river, exaggerating its apparent thickness in that direction.

PROPOSED EXPLORATION PROGRAM

Photogeologic and Ground Geologic Mapping

Excellent quality color air photos over an area of 234 square miles comprising all of the Tombstone district and its environs were flown for Sierra by Cooper Aerial Photo. These photos which are at a scale of 1"=2000' feet show excellent color contrast and zones of alteration can easily be mapped using a stereoscope to observe the photos in 3 dimension. It is therefore suggested that photogeologic interpretation using the color photos be performed over the entire district and compared with existing maps. At the same time a photo alteration map should be prepared to show the geometry of alteration patterns within the area. During this mapping enough field trips should be made into the area so the photo interpreter can identify the various rock and alteration units visible on the photography. In this manner critical areas will be identified for ground follow-up. Ground reconnaissance mapping at a scale 1"=1000" should be done to plot the location of alteration zones, breccia pipes, windows in the Uncle Sam porphyry and other features which may not be visible on the color air photos. Another objective of the ground reconnaissance mapping would be to identify marker horizons in the exposed Bisbee Group sediments so that as the tectonic picture is reconstructed, some idea as to depth to receptive Paleozoic horizons may be gained.

When the broad scale characteristics of the district have been adequately mapped to define centers of mineralization, detailed mapping of the target areas should be done. Base mapping scale for the detail map(s) should be in the range of 1"=400 feet. The technique of outcrop mapping should be used and alteration features as well as structure and geology should be plotted.

Geochemistry

During the field mapping, geochemical profile lines should be run across significant features. If these initial lines show the presence of geochemical contrasts or anomalies, a gridded survey should probably be run.

Geophysics

Preliminary examination of the color air photography shows the presence of red coloration probably due to disseminated pyrite over an area of approximately 42 square miles. The induced polarization method only gives an indication of the intensity of pyritic mineralization, so therefore, IP surveys will probably be of little use in defining drilling targets.

Since it would be expected that mineralization may occur within the Paleozoic limestones or lower Bisbee Group sediments, possibly accompanied by magnetite, low level aeromagnetic surveys may be useful as might detailed ground surveys.

Drilling

The geologic mapping should have the objective of trying to determine at what depth receptive Paleozoic horizons such as the Martin limestone might be expected. Initial drilling should probably be by rotary methods to take advantage of low cost and rapid progress. Cuttings from the drill holes should be sampled at 5-foot intervals, and the samples compiled on core boards for logging. The holes should then be logged and the data plotted on structural sections so that an accurate understanding of the sub-surface geology is obtained.

James A. Briscoe
Consulting Geologist

566

VTN consolidated inc.
ENGINEERS ARCHITECTS PLANNERS
2301 CAMPUS DRIVE, IRVINE, CALIFORNIA 92664 (714) 833-2450 (P.O. BOX 1890, NEWPORT BEACH, CALIFORNIA 92660)

January 14, 1974

Mr. James A. Briscoe
6418 Santa Aurelia
Tucson, Arizona 85715

Dear Jim:

Reference is made to your letter of November 29, 1973, and our subsequent telephone conversation regarding the aerial photography and photogrammetric mapping of your Milagros Project near Zacatecas, Mexico.

We have reviewed your requirements and the project maps you sent, and it would appear that color aerial photography of your overall 800 square mile area would require approximately 300 exposures at a scale of 1" = 2000', considering normal 60% overlap and 30% sidelap between strips. I feel that you should budget about $3,500.00 for the aerial photography and processing of the color negatives. The cost of making one set of LogEtronic color contact prints, one set of black & white contact prints, and a photo index map showing the relative location of the individual contact prints would probably run about $2,100.00 additional. If you decide to have this photography mosaicked and reproduced at a scale of 1" = 500' in the form of Cronaflex film positives or Cronapaque reproductions, I feel that you should budget the sum of about $10,000.00 for this phase of the work. To summarize, the color aerial photography and mosaic compilation, along with delivery of the related reproductions will probably run you in the neighborhood of $15,600.00

Tot = 5,600

1 = 166'

You had also requested a quotation for compilation of topographic maps at a scale of 1:2000 with one (1) meter contour interval covering areas 1 and 2, which were outlined in green. We would recommend that these areas be photographed at a scale of 1:15,000. Six exposures - a total of five stereoscopic models will be required to cover the area. It will also be necessary for you to target six control points, one approximately at each corner of the area, plus two across the middle of the area and establish horizontal and vertical control on these points. The horizontal control will have to close about 1:20,000 and the vertical control should be accurate within one-half foot. We would then extend this basic control by means of analytical aerial triangulation and establish six horizontal and vertical control points on each stereoscopic model. The topographic maps will be compiled directly at a scale of 1:2000 with a one meter contour interval using our first-order Wild A-10 stereoscopic plotters. The topographic maps will be scribed and reproduced on .004" Cronaflex

January 14, 1974

Mr. James A. Briscoe
Tucson, Arizona

film for final delivery. The cost for mapping areas 1 and 2, based on your furnishing the necessary aerial photography and field control surveys is $7,970.00.

1" = 500'

You also requested a price for mapping areas 3 through 7 at a scale of 1:6000 with a two (2) meter contour interval from photography at a scale of 1:24,000. After checking the size of these areas, it would appear that it would be to your advantage to have all five areas flown separately at a scale of 1:25,000.

Area 3 would require 3 exposures, 2 stereoscopic models, and 6 horizontal and vertical control points, one at each corner of the job plus two across the middle. The cost for compiling the topographic map of this area and delivering finished map sheets would run $2,650.00.

Area 4 can be covered with 4 exposures, 3 stereoscopic models at a scale of 1:25,000, and it would be necessary to establish six horizontal and vertical control points. The cost of topographic maps and delivery of finished sheets will be $4,500.00, based on your furnishing the aerial photography and field control.

Area 5 will require 6 exposures, 5 stereoscopic models at a scale of 1:25,000 and it will be necessary to establish 6 horizontal and vertical control points on this area similar to the foregoing areas. The cost of the topographic maps based on your furnishing the photography and field control will be $6,000.00.

$15,150 total
for areas 3-6

Area 6 can be covered in one stereoscopic model, 2 exposures, at a scale of 1:25,000. The area requires 4 horizontal and vertical control points and the topographic mapping will run $2,000.00.

I am unable to give you a quotation on area 7 since you were not able to furnish a map and I do not know the configuration of the area.

Jim as you suggested, I am returning your project maps on which I have indicated on an overlay the approximate layout of the stereoscopic models and location of the required control points.

I hope that this will furnish you with the information you need.

vtn

568

January 14, 1974

Mr. James A. Briscoe
Tucson, Arizona

I apologize for my delay in getting this information to you, but your inquiry was received at a time when we were extremely busy in the office.

Very truly yours,

Dudley

Dudley W. Line
Vice President
Photogrammetric Division

DWL/md

Enclosures.

vtn

569

STANFORD UNIVERSITY
STANFORD, CALIFORNIA 94305

DEPARTMENT OF APPLIED EARTH SCIENCES
Economic Geology
Environmental Geoscience
Mineral Economics
Mining Engineering
Mineral Processing
Extractive Metallurgy

January 8, 1974

James A. Briscoe
6418 Santa Aurelia
Tucson, Arizona 85715

Dear Jim,

Enclosed are the U-2 internegatives for the Tombstone area, and also a reference map of the coverage I am interested in from your photography. The reference map has some field numbers on it , which you can ignore.

I hope the internegatives will be useful to you. It is important to tell the processor that these were made from copies, and not from originals, so as to avoid having the prints reversed. I would like to have the internegatives returned when you are finished with them.

Good luck.

Yours very truly,

Roger

Roger A. Newell

TOMBSTONE
M+M Comp

TOMBSTONE, ARIZONA, Mar. 30th 1894

COPY

To Mr. W. J. CHEYNEY, General Manager,

And the Directors of The Tombstone Mill & Mining Co.,

Philadelphia, Pa.

Gentlemen:

The imminent closing of the Company's mines here on account of our inability to longer make their operation self-supporting, suggests to me the propriety of noting down some facts regarding them which may be of interest and which are the results of observations extending over the period of my connection with the Company, now nearly eleven years. My design is to point out as briefly as possible the salient facts regarding the structure of the ground covered by the Company's mines, the position and trend of the chief ore deposits, and upon these facts base a few remarks regarding what appears to me to be the course which development work must follow in the future to have the best chances of successful issue.

Two maps accompany this letter to illustrate the points discussed. One is a general map showing the relative locations of the principal claims in the District, with the workings on them, and the other a cross-section through some of the workings, showing the relative vertical positions of the levels and illustrating the structure of the ground transversely through the Toughnut and Goodenough claims and longitudinally through the West Side.

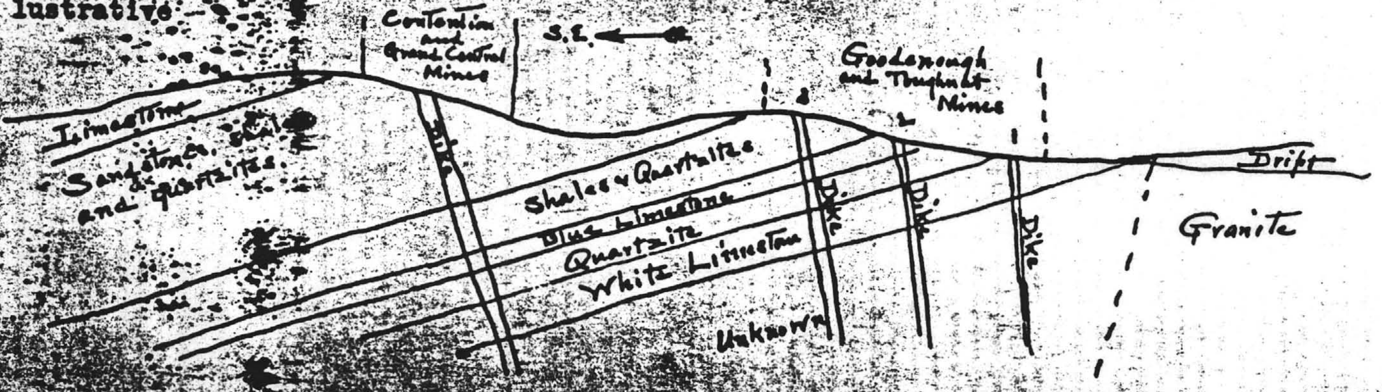
Some of the most important facts relating to the geology and ore deposits of Tombstone are noted below.

ROCKS. - The rocks immediately on the Company's claims are shales, limestones, quartzites, and an intrusive porphyritic rock occurring in steeply dipping dikes. In addition to these are the felsitic layers within the limestone beds. To the southeast of the Company's mines, upon the Grand Central and Contention row of mines, are other shales and quartzites with occasional layers of what may be called fine grained sandstones. Still further to the east and south are heavy beds of blue lemestone lying upon the Grand Central rocks, which, in turn, lie upon those of this Company's mines. The rocks of Tombstone have been so well described by Mr. Church, in his report to the Company, as examining engineer, in 1880, that it seems needless to go further into particulars here.

The ground at the south end of the Company's property, including the Lucky Cuss, differs so much in kind, structure, and in the character of the deposits which it contains from that at the north end that it has necessarily been considered separately, and what immediately follows refers only to the north end mines.

STRUCTURE. In the report above referred to, Mr. Church has given a clear account of the geological structure of so much of the District as concerns the Company's interests. His description clearly pictures the situation as it appeared at that time, but the limited extent of the underground openings then existing necessarily left much in doubt which subsequent explorations have explained and we now have a vastly greater array of facts upon which to base generalizations.

The general structure of the District, in the light of what we now know is shown in the following sketch, which is to be understood as merely illustrative –



572

To the west of the town is a heavy mass of granite which bears every evidence of being eruptive in character. Lying upon its eastern side and tilted to the east and southeast are the beds of sedimentary rocks which contain the Tombstone mines. Whether or not the upheaval of the granite has been the cause of the eastward tilting is uncertain, but probably it has, especially as we find indications of a contrary dip in the strata to the westward of it. We have at any rate the physical fact of the tilting of the easterly strata, however caused. The situation is so far simple enough, but has been further complicated by the squeezing of the strata in a northeasterly and southwesterly direction, corrugating them into ridges, or a succession of anticlinal folds, the crests of which still dip to the southeast as did the strata in their original condition. This result is probably due to side pressure from a cause at present obscure, but however it may have occurred, we have the fact of a succession of anticlinal folds, the axes of which are nearly parallel and dip gently to the southeast. The folding affects all strata so far penetrated and must have antedated a heavy erosion of the surface, for the superincumbent weight has been so great that the limestones were bent as though plastic and in many cases without crushing. The apexes of some of the folds in the limestone are exceedingly sharp and yet apparently without fracture. In others the slope is more gentle, the curve resembling more the arc of a large circle.

The circumstance of this side pressure and folding was noted by Mr. Church in his report and its effects in permitting the introduction of felsite at the tops of the anticlinals, afterwards more or less replaced by ore, were clearly described. The limited openings at that time did not, however, appear to suggest the far reaching importance of the matter in its relation to the true course of the waters which have given rise to the ore deposits. One would infer that, while at that time the folding was recognised as a fact having an important bearing upon the formation of the ore bodies, yet it was not supposed that the folds were very persistent axially, being more dome-shaped than otherwise. It appears from further explorations, however, that they are of great extent axially, extending throughout the opened ground and doubtless beyond, and that their thorough understanding is of the utmost importance to the proper development of the mines. It is doubtless true that there are many subsidiary folds and dome-like developments of no great extent and indeed, it would be surprising were it not so, considering what is known of the mode ~~af~~ in which the corrugation of the rocks was accomplished; but the main folds are persistent, practically in southeast-narthwest lines, so far as our underground works have extended.

The axis of the largest fold passes through the open cut or Quarry near the main shaft on the Toughnut claim, running thence, one way, through the southeasterly corner of the Goodenough, across the Hawkeye and into the Empire mine, and the other way to the Northwest mine. Next to this, towards the West Side, comes one extending from the Northwest mine centrally through the Toughnut and to the farthest southeasterly point reached in the Girard. A little farther towards the West Side is another one, shown clearly and unmistakably in the Toughnut 1st and 2nd levels, but which has never been followed far either way from the point of discovery. There are plain indications of its existence, however, on the 2nd level at the old Toughnut main shaft. Its point of crossing the Northwest works is thought to be known, but ~~the~~ intermediate openings are needed to make this certain. From the axis of this last mentioned smaller anticlinal the strata dip steeply down, the blue limestone belt passing below water level and again emerging within the West Side claim, where it rises near the No.3 shaft to the summit of another anticlinal, the axis of which passes transversly across the West Side, running to our farthest southeasterly work in the Sulphuret and showing plainly near the Defence shaft to the northwest. There are really two ridges near the West Side No. 3 shaft, but it is yet indeterminate whether or not the more southerly one is a local manifestation having comparatively little longitudinal extent. It shows in the workings of the Boss mine, but we are in the dark regarding its northwesterly extension. To the southward from the West Side shaft, the descent is less abrupt than to the north, and the strata again rise as the southerly end line is approached, presumably indicating the formation of another anticlinal; and indeed, the workings of the Ingersoll mine give strong evidence of the existence of one. The blue limestone belt is strong in the Ingersoll mine but thins out to the south of that and disappears. The Tribute mine is entirely in the shales and quartzite, its deepest working not having yet penetrated to the blue limestone. The ground is too much disturbed and the amount of openings too small to permit of certainty in describing its relations.

Returning now to the Quarry, and passing to the northeast, the strata dip gently, then rise again, bringing the blue limestone to the surface and forming a large fold, one side of which almost merges with the Quarry fold, the other dips gently at first and afterwards very steeply at the side line of the Goodenough. The axis of this fold runs probably through the Combination and Vizina mines in one direction and certainly through the southeast end line of the Goodenough, across the Hawkeye and into the Empire in the other. The strata, when last seen dipping into the Gilded Age, Way-Up and Little Wonder, stand very steep, probably from 50 to 60 degrees, or at much the same angle at that at which they enter the West Side on the other side of the Toughnut. What shape they take to the northeast, beyond the Goodenough, is a matter of some uncertainty for two reasons,- first, the rock is covered with a heavy mass of drift, and second, it is also covered by the town, both of which circumstances have tended to prevent exploration from the surface. In fact, except for the diamond drill hole bored on the Gilded Age, to which reference will be made further on, the conditions are much the same as they were beyond the Toughnut, in the West Side, at the time Mr. Church's report was written; that is, the last seen of these strata they were dipping steeply and had ceased to carry ore.

FAULTING. Ground which has been so remarkably twisted and deformed as this has been could hardly have escaped extensive faulting, nor do we find it so. Fractures and faults innumerable are found, but for the most part they are unimportant and the throw inconsiderable, which is remarkable, considering the magnitude of the forces that have been at work and their other effects. The most important fault is that passing through the Quarry and running thence southeast. It shows plainly where crossing the Northwest works and has been followed by drigting on the Toughnut 3rd level to the Empire line. Another fault traverses the Toughnut claim lengthwise and centrally and is parallel to the first. There are other minor ones parallel to these and also another quite extensive system crossing them at about right angles. I do not, however, in the light of what we now know, regard the faults on the Company's property as having played any very important part in the genesis of the ore deposits, except in the case of the West Side vein, which is apparently an ore-bearing fault-fracture of considerable extent, acting as a receptacle, and for the most part quite different from the replacement ore bodies of the Goodenough and Toughnut mines.

DIKES. In addition to the disturbing influences of side pressure and faulting referred to above, the rocks have been invaded by a system of dikes of porphyritic material which have certainlyplayed a part in the formation of some of the ore deposits, although an obscure and probably secondary one. In the earlier openings they were known only as masses of more or less kaolinized rock, the largest exposures being at the Northwest shaft and in workings in the vivinity of the Quarry on the Toughnut claim. Later workings have proved them to be clearly defined dikes of very great longitudinal extent and persistent to the greatest depths attained in our workings. So far as opened, they are found to be much decomposed and their much greater softness than the country rock has been taken advantage of where possible in the driving of working levels. Indeed, had it been possible to know of their existence in the first place, much money could have been saved in the avoidance of hard rock and the mines opened in better shape, for it so happens that their strike carries them across the lines of ore deposition. Their average width is four or five feet, although in places they expand to ten or fifteen and again contract to one or two. As stated, they are for the most part greatly decomposed, the material being sometimes soft enough to work with the pick and bearing little semblance to its original state, which is seen in but few places and is that of an exceedingly hard, compact, dark greenish, porphyritic rock. The dip is slightly to the west and the strike a little east of north. They are wonderfully straight, considering that they cut such a disturbed country, made up of so many beds of rock of widely varying degrees of hardness and dip. There is no evidence of metamorphism of the adjacent country rock to indicate that they were introduced in a molten state, and they are probably the result of plastic flow under enormous pressure. They have apparently come since the folding and after the main lines of ore deposition were established, for they cut some of the ore bodies cleanly. What effect the dikes have had on the ore deposits has probably been of a secondary nature and owing to the chemical reactions resulting from their decomposition under the influence of the percolation of surface waters and of atmospheric agencies. Three dikes are recognised on the Company's property. What is for convenience called the No. 1 dike, passes through the Northwest mine at the shaft, extending northward through the Vizina claim, (where it forms the westerly boundary of the ore bodies of that mine), and southward across the West Side, through the Tribute workings and into the Hard-up claim. Its known length is nearly 4000 feet and it is still strong at both ends. The

No. 2 dike passes through the Quarry, running thence south, across the easterly corner of the West Side, across the westerly corner of the Sulphuret and on through the Boss mine. To the northward of the Quarry it has been followed by the 1st and 3rd levels, the latter to a distance of nearly 800 feet from the main shaft, where it has been thrown by a fault and lost. The 6th level of the West Side mine has also been driven on it from its intersection with the vein, northward to the main Toughnut fault. It was squeezed to a small thickness in the northerly portion of this drift and lost by a small fault but found again by cross-cutting on the main fault. The No. 3 dike was first discovered in the northerly end of the Hawkeye claim below the 3rd level. It has since been cut in the south end of the same claim and on the 3rd and 5th levels of the Sulphuret mine, whence it continues its southerly course, showing again in the Mayflower workings.

Practically parallel to these dikes are many minor fractures, cutting the ore shoots transversely. The other system of faults, alluded to above under "Faults", has apparently come since both the dikes and ore bodies, for both are cut and slightly thrown by faults belonging to it. The main southeasterly fault passing through the Quarry is an illustration, the throw of the dike where cut on the 3rd level being about 15 feet.

POSITION OF THE ORE BODIES. Under the head of "Structure" the peculiar corrugation and folding which the rocks have undergone was referred to at length and the fact pointed out that the folds were of great extent axially and for practical purposes could be considered parallel and running southeast, although not strictly so. Attention was also called to Mr. Church's description of this phenomenon and to his account of the useful purpose it had served in preparing the ground for the reception of the ore bodies. The more extended opening of the ground by our mining works has developed a fact of extreme importance in this connection which could hardly have been foreseen at that time. It is the fact that nearly every important ore body is at or near the axis of one or other of the anticlinal folds and practically conforms to that axis in course and pitch. A further important fact is, that in following these ore bodies, or shoots, as they may be more appropriately called, none have given out when followed in the direction of axial extension; that is, southeast. True they have become small and poor at times, too much so to be profitably mined, but beyond these places there has been improvement and they signify only that, although in the channel of the mineralizing waters, the conditions have been locally unfavorable to deposition. Another fact of importance is the striking increase in the proportion of gold to silver in the shoots as they make to the southeast. Apparent variations from this rule occur at the points of intersection of the shoots with the dikes, but there has been generally great local enrichment in both gold and silver, (but particularly in gold), at these points.

In speaking of the folding, it has been said that all strata are affected which we have penetrated in our workings. It appears, however, that in the mines there are, stratigraphically, two principal positions carrying the bulk of the ore; one the blue limestone belt and the other the contact between the white limestone and the quartzite which underlies the blue limestone. In the West Side mine there was a large development of ore in the aluminous shales and quartzites immediately over the blue limestone and at the crossing of the vein and the main anticlinal axis of the mine. So, also, in the Tribute mine, the ore was in these upper rocks, but in the Toughnut and Goodenough nothing of importance has been found above or below the positions indicated. The cross-section map which accompanies this letter is deceptive, as the section is taken along a line of great disturbance and the ore has formed indiscriminately in the shattered rocks. Either way from this line the ore shoots are confined very strictly to the positions described.

It is assumed that the mineralizing waters followed naturally the lines of least resistance, and a little consideration will show that while these were obviously, in most cases, closely coincident with the axes of the anticlinal folds, local obstructions might easily have diverted the flow slightly to one side or the other, giving rise to bodies apparently conforming in dip to that of the flank of the fold. Many of these exist, but are invariably found to become poorer and poorer as followed down, until they finally tail out into the country rock, and it is necessary to return to the apex of the fold to follow the true course of the ore. Many of the earlier workings, some of considerable magnitude, were planned and executed on the theory that these side shoots indicated the true dip and course of the ore bodies. Such works were invariably unsuccessful in following the ore and were abandoned after pushing beyond the ore and in some cases, far into the country rock.

The disposition of the ore along the lines of the anticlinals is not a mere theory but a well ascertained fact, as far as our workings extend. No ore of any consequence has ever been found in the synclinals. There are, indeed, the semblances to nearly vertical veins, easily mistaken for such with limited exploration, but apparently all of them have received their mineral contents from cross flow through the anticlinal folds.

The line of the axis of the folds has been spoken of as that of least resistance to the flow of the mineralizing waters. That it should be so will become at once apparent from a consideration of the only mode of formation of the folds which we can conceive of as possible, that is, side pressure. Evidently, the effect of such pressure would be to compress the material till there was no longer room for yielding laterally. The pressure continuing, lines of weakness were developed and the strata buckled up along parallel lines, the effect naturally being that the strata composing the sides of the folds, and the valleys

580

between, were compressed tightly together, while the tops of the folds were left, not open, for there was still an enormous pressure upon them, but at least more fractured and permeable than either the valleys or the sides. This would be especially so in the case of the limestones which carried sheets of more friable felsitic material which would crush, whereas the more massive layers of limestone would simply bend.

More has been said on this subject of anticlinals than perhaps it will be thought it deserves, but it is really one of great importance. The truth of the proposition laid down above as to the disposition and course of the ore shoots has been tested time and again, and indeed, it may be said that the very profitable work of the past few years has been entirely based upon it. Starting with the mines apparently exhausted, they have been made very productive and would still be so but for the obstruction of property lines and the present very low price of silver. It can hardly longer be called an hypothesis but rather an established fact.

THE FUTURE. Excluding the Lucky Cuss mine from the discussion, as belonging to a different system of ore deposition and to be necessarily treated separately, attention should be confined for the present to the northerly group of mines comprising the West Side, Sulphuret, Girard, Toughnut, Goodenough, Wayup, Gilded Age and the Defence, and to the ground adjacent to them. Let us review the facts, so far as the ore deposits and structure of the ground of these mines is known and concerned.

1.- The rocks dip to the southeast.

2.- Anticlinal folds exist, the axes of which pitch southeast conformably with the country.

3.- Practically all known ore has been located along these anticlinal axes and pitching, therefore, southeast. This is true in spite of much work in other situations which would have disclosed ore had it existed.

4.- So far as known, the ore on this group of mines has been mostly confined to two situations, viz: in the blue limestone and at the contact of the white limestone and the quartzite which underlies the blue limestone. Some, however, in the shales and quartzites of the West Side and Tribute mines.

5.- Great local enrichment and expansion of ore in size at the crossings of shoots and dikes.

The conclusion seems irresistable that the future of the mines depends upon extension along the axes of the anticlinals and upon the discovery of other similar ore-bearing folds in adjacent unexplored ground.

Considering the first of these possibilities, the question naturally arises; does the same folded structure of the ground extend far to the southeast of the Company's mines? This question it is impossible to answer satisfactorily for the reason that I have never had an opportunity of personal inspection. I have been led to believe that it does, from verbal descriptions and especially by the fact that the line of greatest ore deposition in the Flora Morison, south end of Contention and north end of Grand Central mines appears to correspond with the axis of the main West Side anticlinal, and that we found the condition well marked to the farthest limit of our southeasterly work in the Sulphuret mine. An inspection of the general map accompanying this letter will show this correspondence. The Head Centre and Tranquility mines may be supposed to correspond with the Girard anticlinal and the Empire, Silver Thread and North Point with the Goodenough anticlinal. It must be remembered that the Hill mines were entirely in rocks lying above ours geologically and that consequently our ore shoots would, in all probability pass beneath any of the workings of the mines named, in most cases even below water level. Their intersection with the large Grand Central and Contention dike would be points of great interest and by all precedent should be accompenied by a

582

large development of ore. I do not believe that in any of the Hill mines was close attention paid to the structure of the ground and its relation to the ore deposits, and further, those mines being located in the more friable shales and quartzites which overlie our harder rocks, and being fractured, disturbed and decomposed by the large dike, such details would be necessarily more obscure and less easy of detection than in our ground. It is unfortunate that the outlines of the main ore bodies in the Hill mines cannot be given on the map.

But whatever may be the facts as to the extension of our ore shoots to the southeast, they have reached our property lines in that direction except in the case of the Girard shoot, which is small and poor at present. The recent agreement with the Empire Company will permit of some extension in that direction and much depends upon its results.

Regarding the second possibility, that of the discovery of other ore-bearing folds, practically the only unexplored ground where such discovery would be likely is that of the Way-up and Gilded Age claims, neither of which has been much explored for reasons previously given. The last fold in the Goodenough carried the Vizina, Combination and east Goodenough ore bodies. The rocks dip steeply into the Gilded Age and Way-up, precisely as they do into the West Side to the south of the Toughnut. Do they rise again as in the West Side, forming another fold? And, if so, is the fold ore-bearing as all the others have been? These are the questions upon which the future of the mines in that direction depends. An attempt was made to solve these questions by the use of the diamond drill. A vertical hole was bored to a depth of 436 feet on the rear end of Lot 10, Block 20, corner of 5th and Fremont Streets, (see map), cutting the shales, blue limestone, quartzite and white limestone precisely as they are found in the mines. Here the main body of the blue limestone was found much higher than it would have been had it continued dipping as last seen on the edge of the Goodenough, and besides

583

this, many other indications of a fold, the existence of which was finally confirmed by crosscutting from the shaft sunk through the drift to permit of starting the drill. To the question of mineralization, the drill returned but an unsatisfactory answer. Near the bottom of the blue limestone, seven feet of ore-like material was cut, assaying 3.2 oz. silver per ton, and, speaking generally, the appearance of the cores indicated proximity to ore, but none was found in the hole.

I do not intend to convey the idea that all of the ground within our lines is either exhausted of ore or demonstrated to be barren. The greater part of it is so, beyond doubt, but there are still unexplored portions of the anticlinal folds which may yield ore even in considerable quantity. The exploration of such places will, however, involve much expense, the recovery of which under the present price of silver is at least doubtful. From the list of such places may be cited two which are of the greatest promise,- the raise in the Toughnut 3rd level north drift in Way-up ground and the southwest drift on the 150 foot level of the Northwest mine making towards the Defence. The raise was put up to search for the southeasterly extension of the Combination shoot and is 300 feet from where that shoot was abandoned. It was located as nearly as possible on the line of the fold and found the shoot at about 75 feet above the level. Unfortunately, the ore is of very low grade at the point cut, but the shoot is large and much work will be required to thoroughly explore it. It belongs to the class of shoots lying under the quartzite and on the white limestone and the discovery of good ore in it at this point would be a fact of great significance. The other place mentioned, the drift into the Defence, is designed to cross the axis of the large anticlinal which passes through the Sulphuret, West-Side and Intervenor. I have long believed that ore existed to the westward of the West Side mine along this axis but efforts to find it from that mine have not been successful. In addition to the above there are many other unexplored sections of folds which, under a more favorable condition of the silver market it would be wise to explore, but such work cannot be recommended under the present conditions.

LUCKY CUSS MINE. This mine is so essentially different from the others, both in character of its deposits and the rocks in which they are enclosed, that it is necessary to consider it separately. It is needless to go into an extended description of the workings and ground but I wish to call attention to a few of the more prominent facts which have been brought out by the working of the mine.

Through the centre of the claim runs a large and remarkably well defined fissure vein, dipping about 70 degrees to the east and cutting the quartzites and white limestones which compose the country rocks and which dip about 45 degrees, a little to the north of east. This vein is slightly mineralized throughout, but in few places sufficiently so to be of value. Its walls, in many places, show heavy striated clay selvages common to such veins. The principal ore body of the mine was not, however, in the vein at all, but in the footwall of it and about 400 feet from the north end line. It pitched to the northeast, gradually approaching the vein, which it reached at a depth of 340 feet. At this point it faulted back into the foot wall and again resumed its approach towards the vein, reaching it this time at a depth of about 600 feet, where it was lost. Further north, and extending from the 6th level to the surface, but in the vein, was another shoot connected to the first one by a smaller ore channel. The first and larger shoot carried no gold at the surface, the gold increasing almost proportionately to depth to the end of the shoot. In the other shoot the gold increased from the surface to the connecting link, below which there was no appreciable increase, while this link was unusually high in gold. The evidence is very convincing that the first mentioned shoot is the main one, through which the mineralization, not only of the second one, but of many other smaller ones which ramify from it and from the first, has been accomplished:- in fact, that it has made the mine and that the future of the mine depends upon its rediscovery and

585

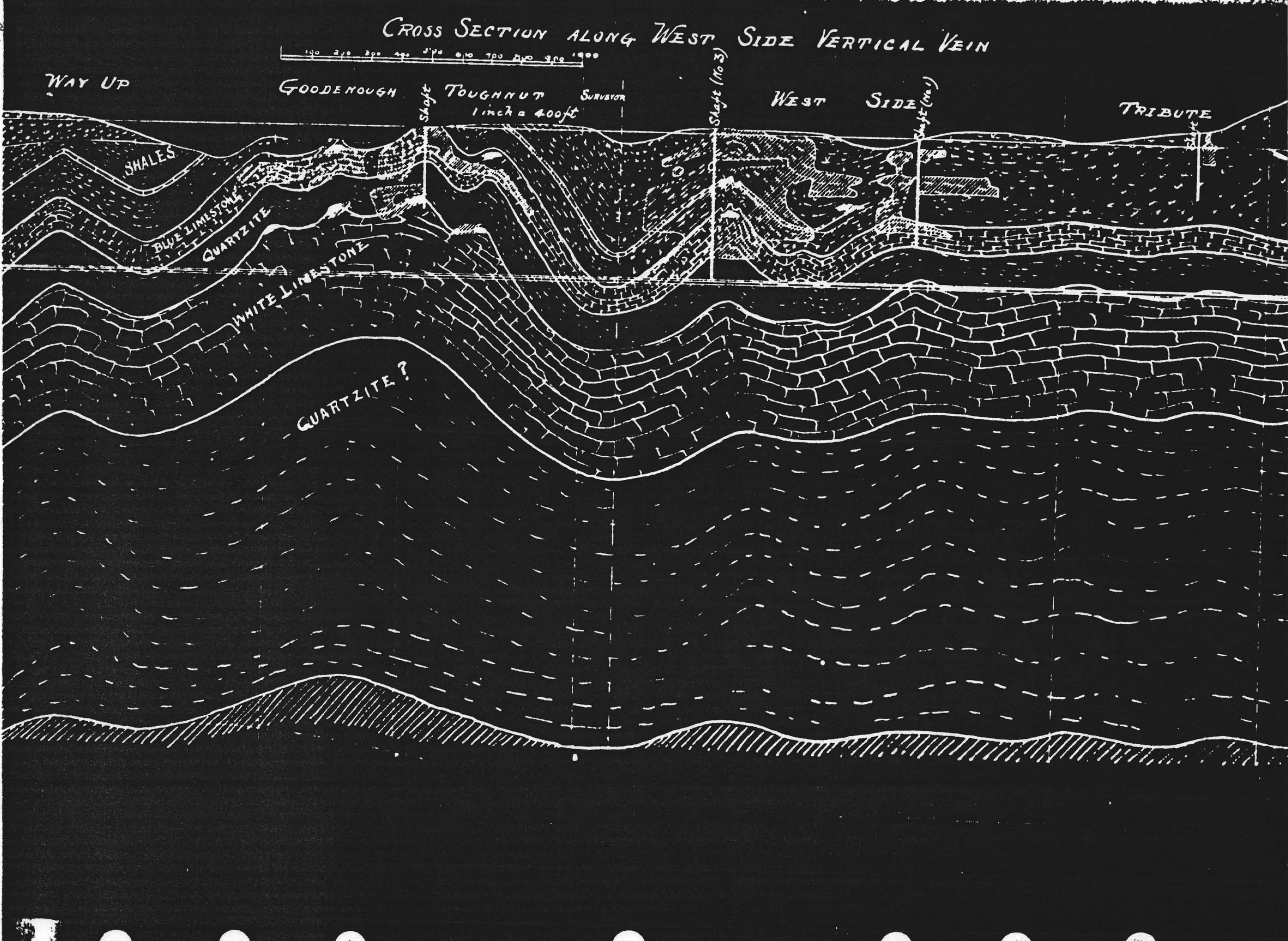
following to greater depths. One unfamiliar with the history of the development of the mine might easily conclude from an inspection of the workings as they now stand that the bottom has been reached. Twice before this, however, there was every appearance of exhaustion and yet each time the shoot was found, richer in both gold and silver than before, and I believe we would have been successful in our last search had it not been for the low price of silver, which precluded any attempt at supporting the expense of enlarged pumping facilities and deeper explorations by ore shipments from other parts of the mine. I cannot advise any further work at present: the expense would be too heavy to be incurred for 59 cent silver.

RESUMÉ. - I have endeavored in the preceding pages and with the assistance of the maps accompanying them to describe, first, the indisputable physical facts regarding the structure of the ground in which the Company's mines are located: second, the also indisputable facts regarding the position and trend of the main ore bodies, and then to follow these two groups of facts to what seem to me to be the only logical conclusions permissable regarding the lines along which the development must proceed to stand a reasonable chance of successful issue.

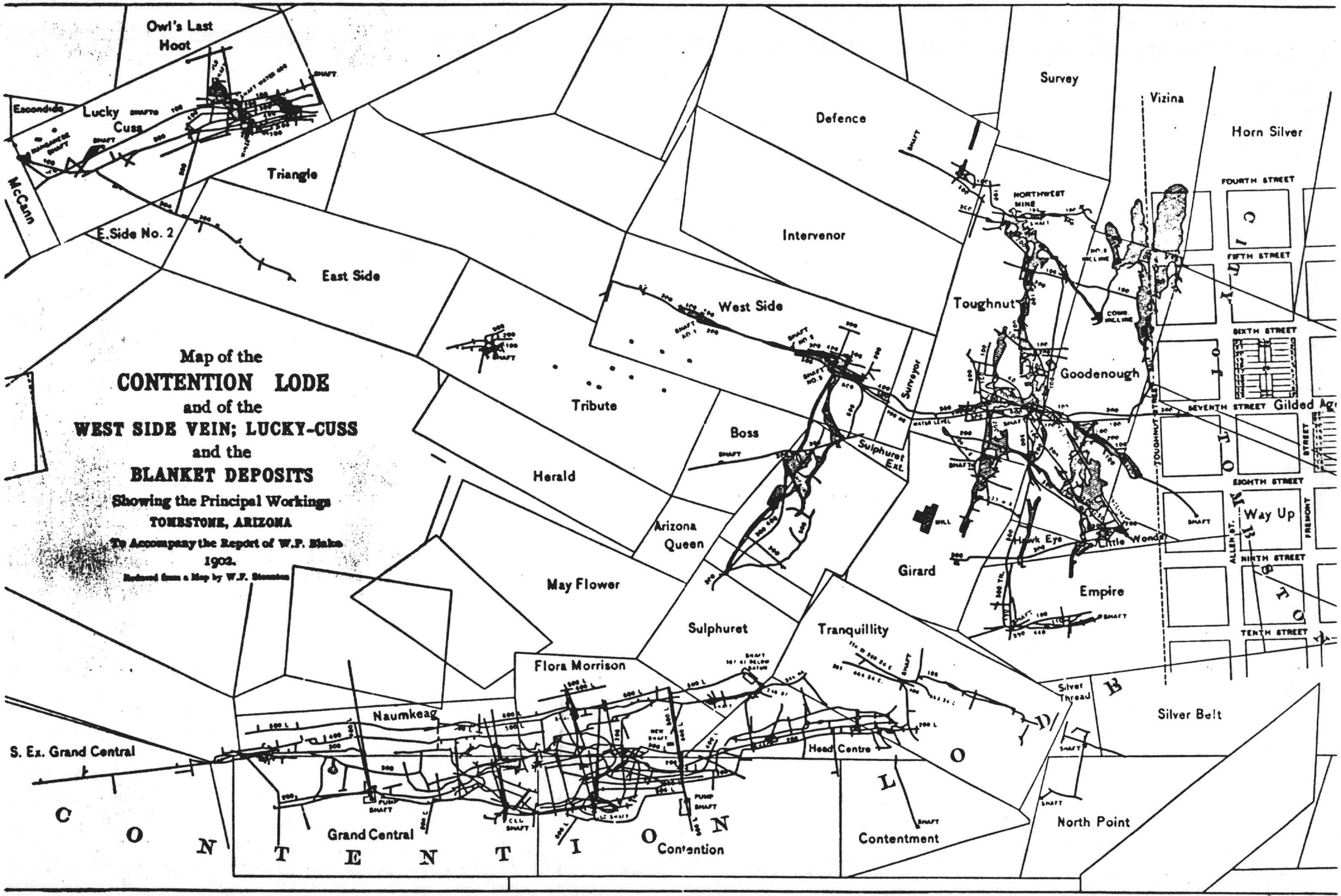
The possibility of the repetition of the folds or saddles to much greater depths than we have attained, and of their being ore-bearing, has been purposely left out of the discussion from the feeling that it verged too closely upon the hypothetical. The saddles probably do continue to greater depths but as to the existence of ore, we are entirely in the dark. What evidence we have, that of the 6th level of the West Side mine, which was run under the Toughnut works, is not encouraging. Of analogies in other mining districts, I know of but one where the resemblance is at all marked,- that of the Bendigo gold district in Australia. There the folds are repeated in regular succession and are ore-bearing to immense depths, but when we come to the enclosing rock, the analogy ceases to have force, for at Bendigo the country rock consists of sandstones and slates in successive layers while here we have the thinner beds of shales, quartzites and blue limestone, resting on a massive bed of white limestone. The following reference to the conditions at Bendigo, from the pen of Mr. T. A. Ricard, is almost descriptive of our own conditions. "The most marked characteristic of these sandstones and slate beds is the extreme bending, folding and contortion which they have undergone, accompanied, as might be expected, by a varying amount of fissuring and faulting. The anticlinal and synclinal undulations are often remarkably sharp and exhibit every gradation in extent, from a few feet to miles. - - - - - - The main anticlinal axes strike N.N.W. and S.S.E."

Considering the mines at the north end of the property as a group by itself, and aside from the minor discoveries which may result from further explorations along the lines of our present shoots, the future of the mines must be sought in the ground to the southeast and under the workings of the other mines already existing in that ground, and also in similar southeasterly shoots to those already worked, which may exist in the Gilded Age and Way-up claims. To the southeast we meet the obstacle of other ownership of property, and were this removed, there would remain the uncertainty and expense of very deep workings, with the probability of water to contend with at an early day. In the Gilded Age and Way-up the chances for bonanzas at moderate depth, that is, above water level, are good but the expense of exploration would be heavy and cannot be recommended unless the Company is prepared to cheerfully stand the loss, should the work prove unproductive. Apparently the most feasible and least expensive mode of conducting this work would be by means of a shaft on the No. 2 dike, somewhere near the centre of the Gilded Age claim.

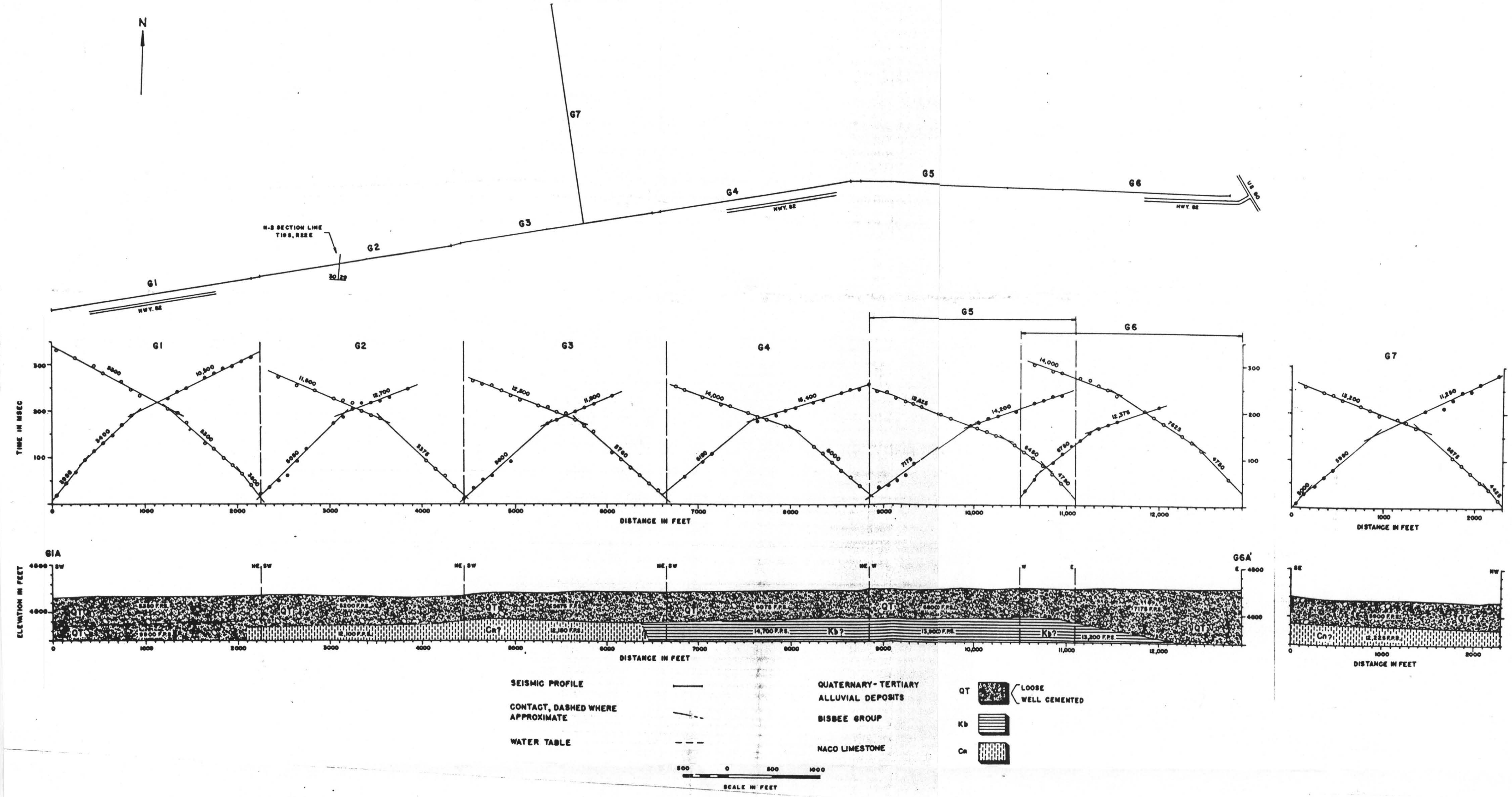
(signed) W. F. Staunton.



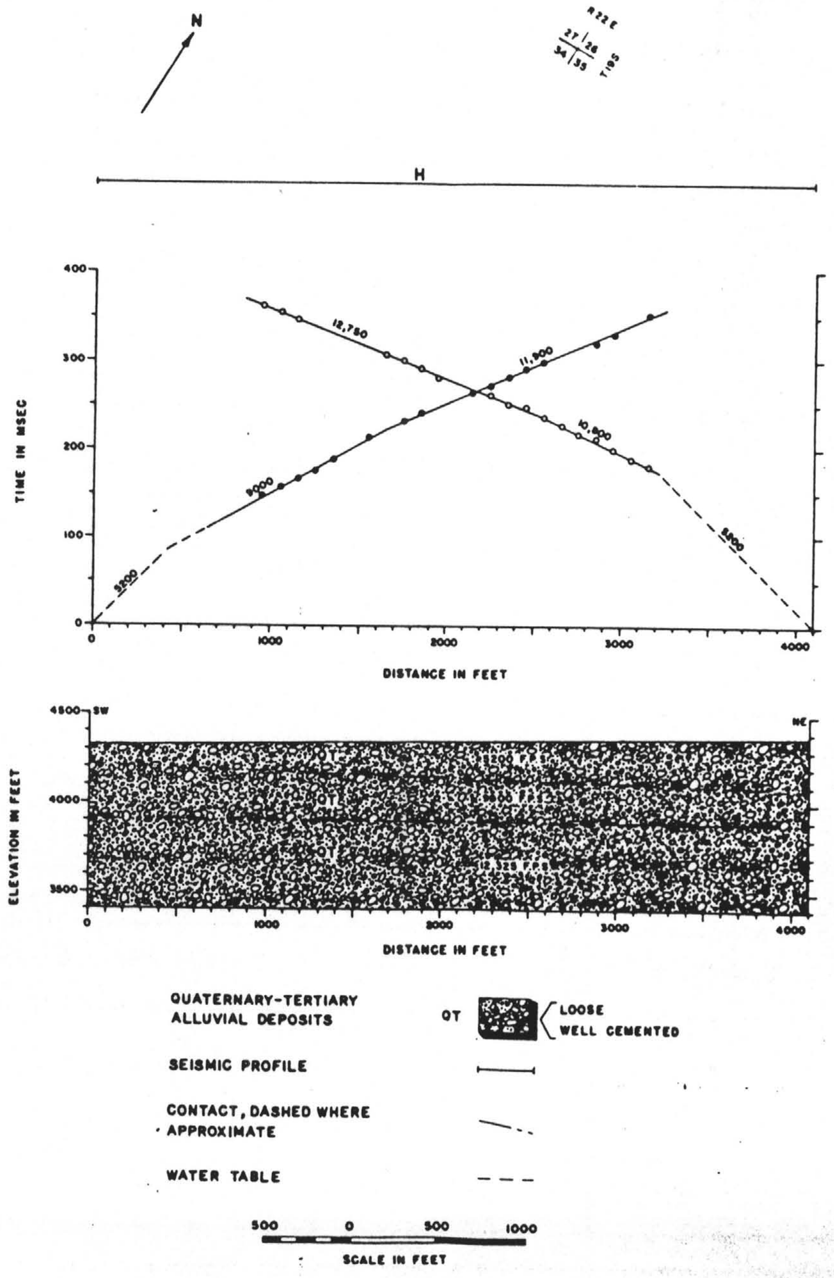
Cross Section along West Side Vertical Vein



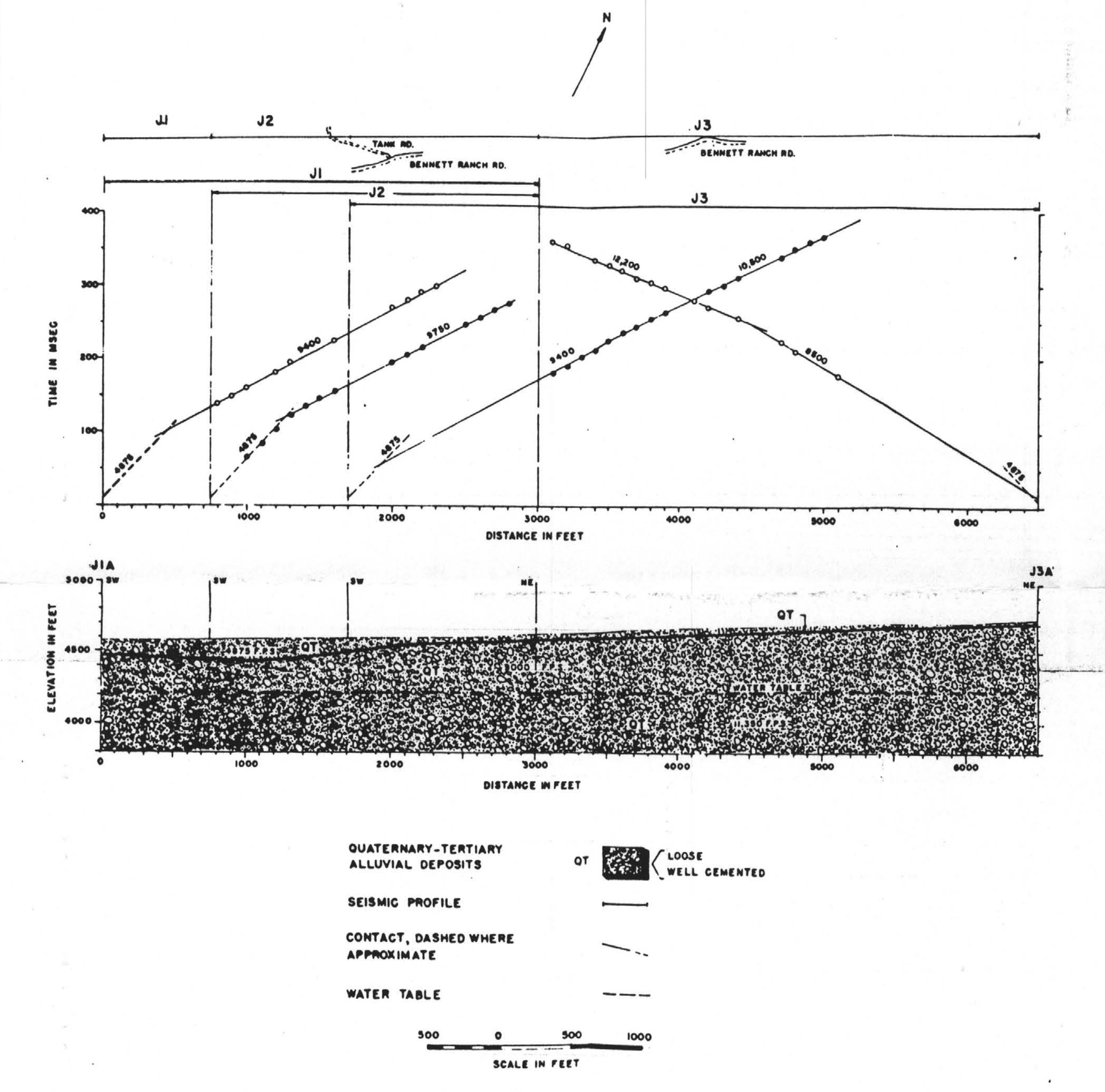
Map of the
CONTENTION LODE
and of the
WEST SIDE VEIN; LUCKY-CUSS
and the
BLANKET DEPOSITS
Showing the Principal Workings
TOMBSTONE, ARIZONA
To Accompany the Report of W.P. Blake
1902.
Reduced from a Map by W.F. Staunton



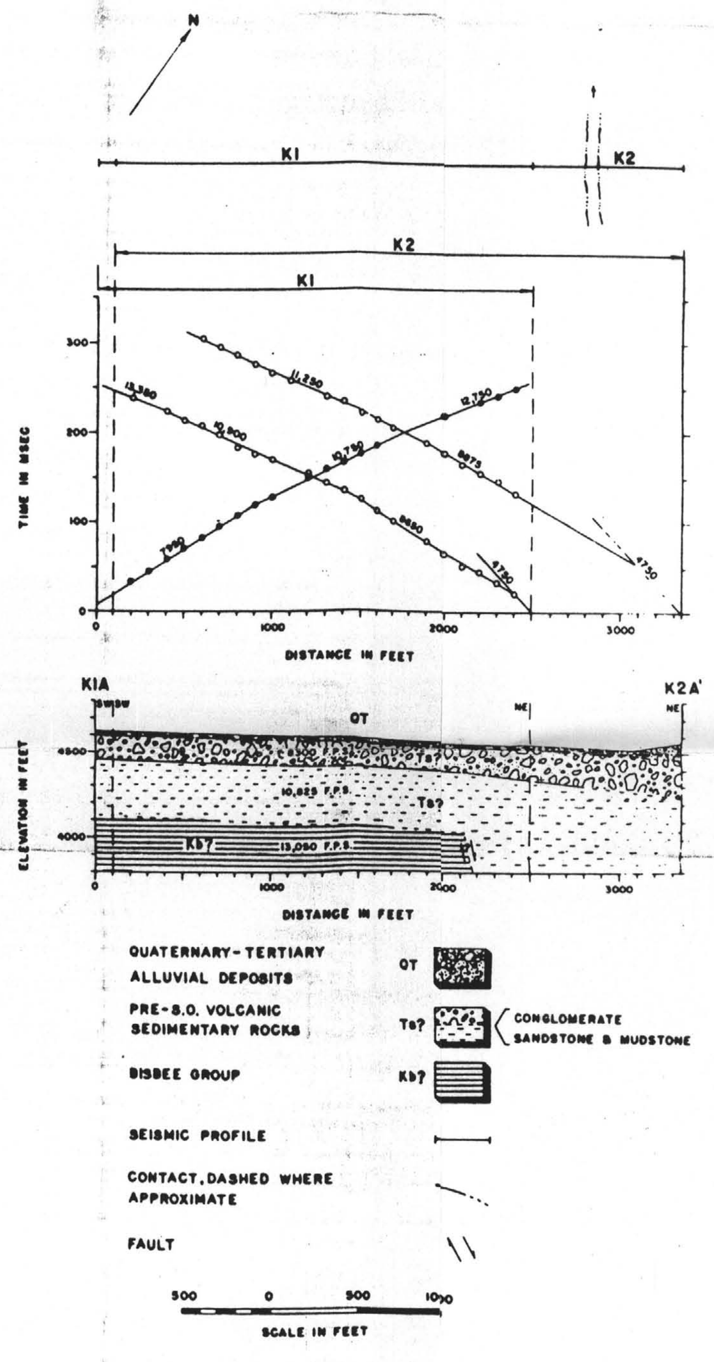
GEOLOGIC INTERPRETATION OF AREA G SEISMIC PROFILES
(HIGHWAY 82)



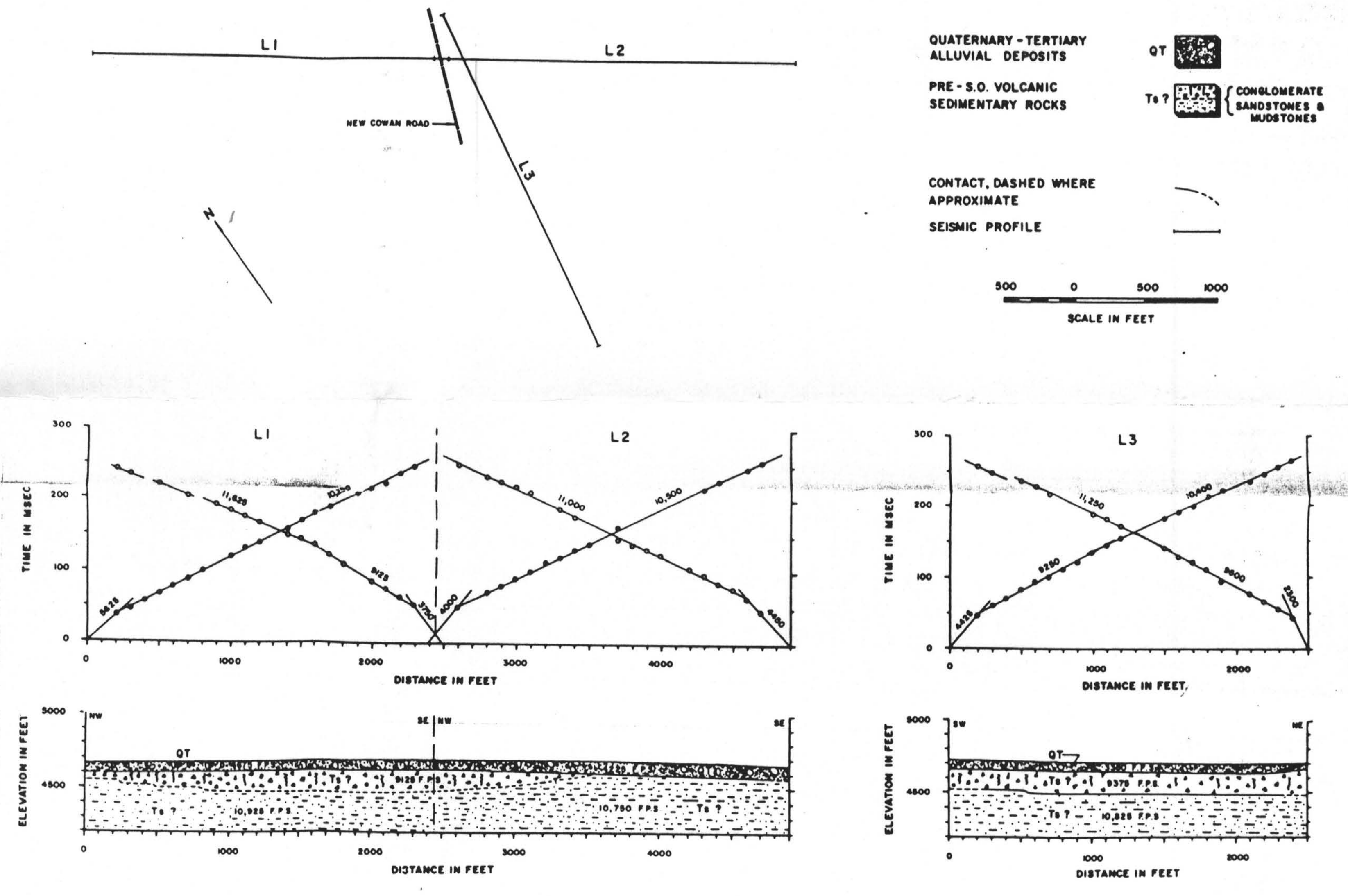
GEOLOGIC INTERPRETATION OF AREA H SEISMIC PROFILES
(CITY DUMP)



HYDROGEOLOGIC INTERPRETATION OF AREA J SEISMIC PROFILES
(BENNETT RANCH ROAD)

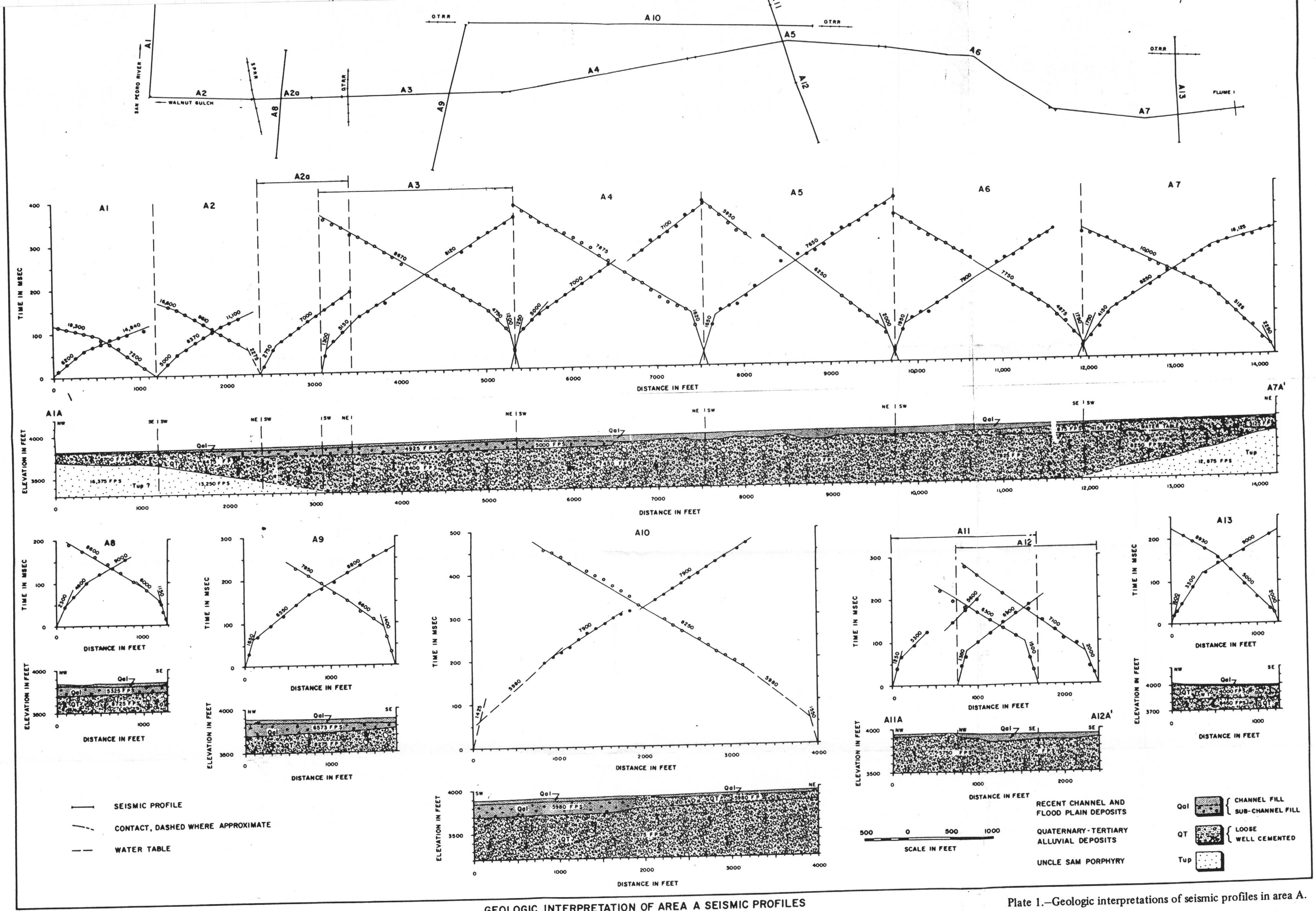


GEOLOGIC INTERPRETATION OF AREA K SEISMIC PROFILES
(NORTHWEST OF LIME TANK)



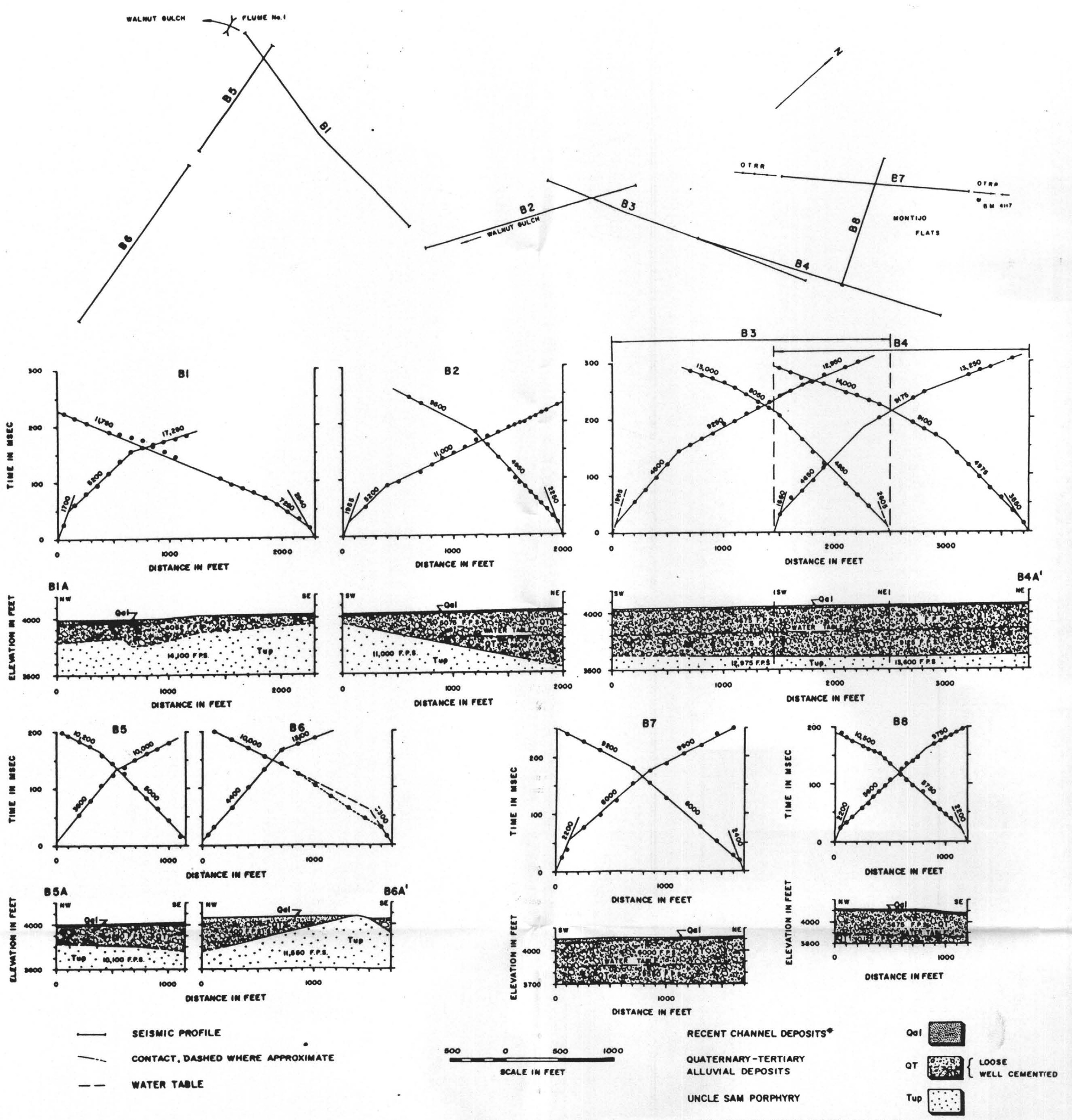
GEOLOGIC INTERPRETATION OF AREA L SEISMIC PROFILES
(NEW COWAN ROAD)

Plate 3.–Geologic interpretations of seismic profiles in areas G, H, J, K, and L.

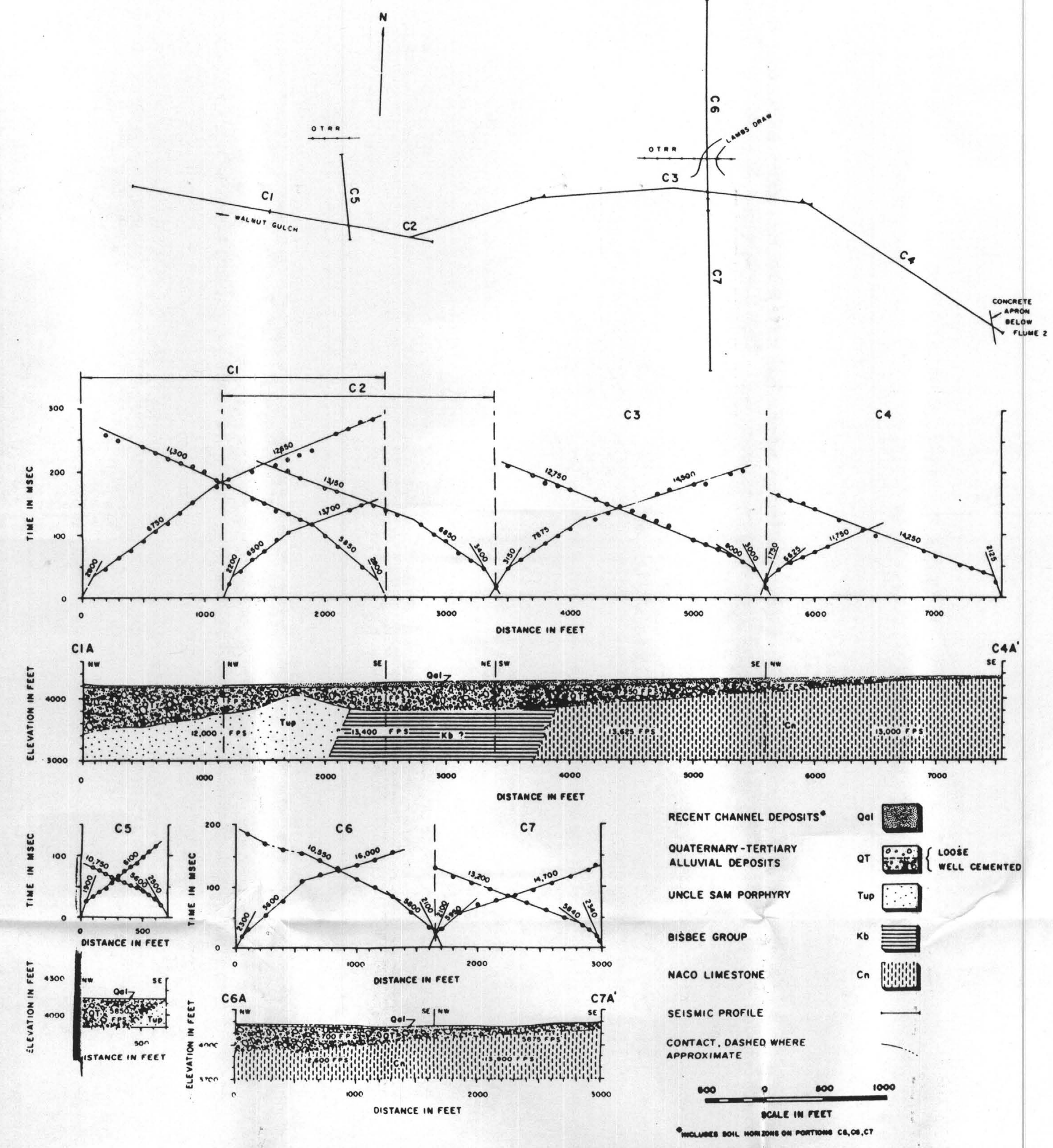


GEOLOGIC INTERPRETATION OF AREA A SEISMIC PROFILES
(SAN PEDRO RIVER TO FLUME I)

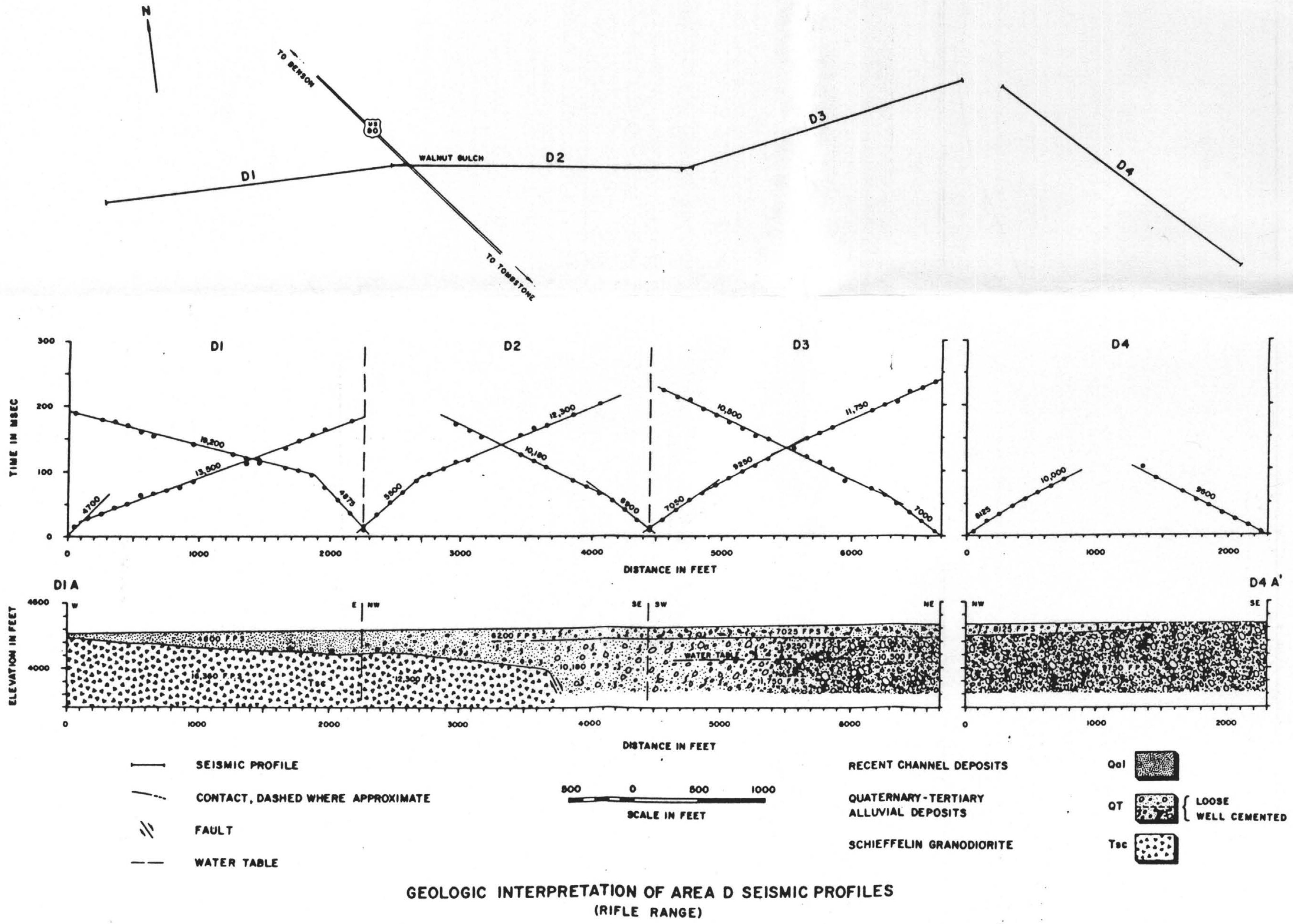
Plate 1.—Geologic interpretations of seismic profiles in area A.



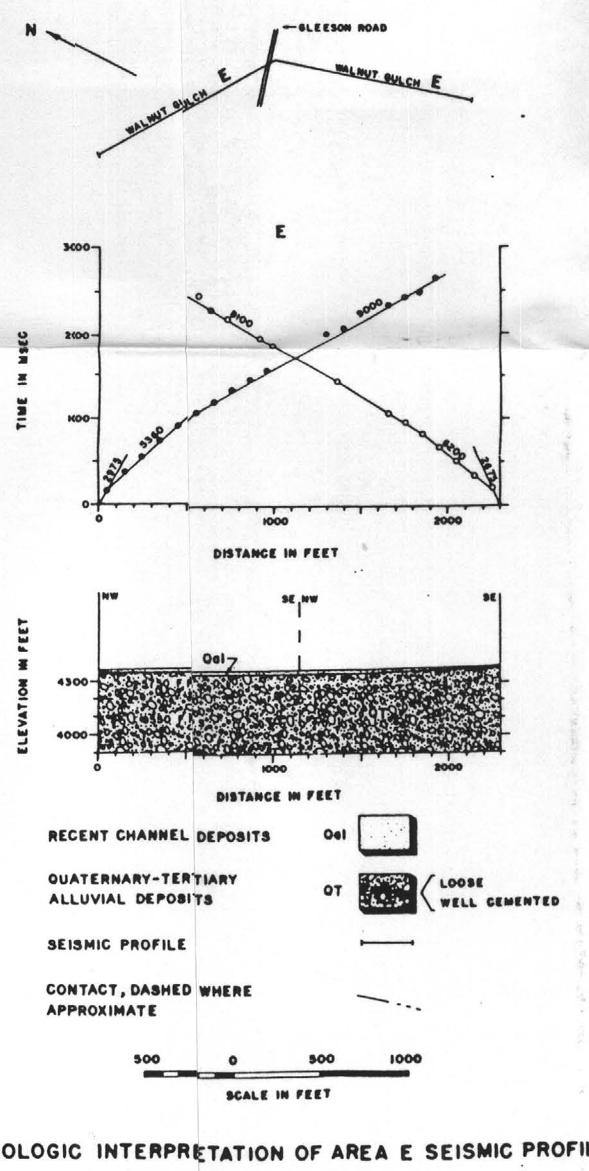
HYDROGEOLOGIC INTERPRETATION OF AREA B SEISMIC PROFILES
(FLUME 1 TO MONTIJO FLATS)



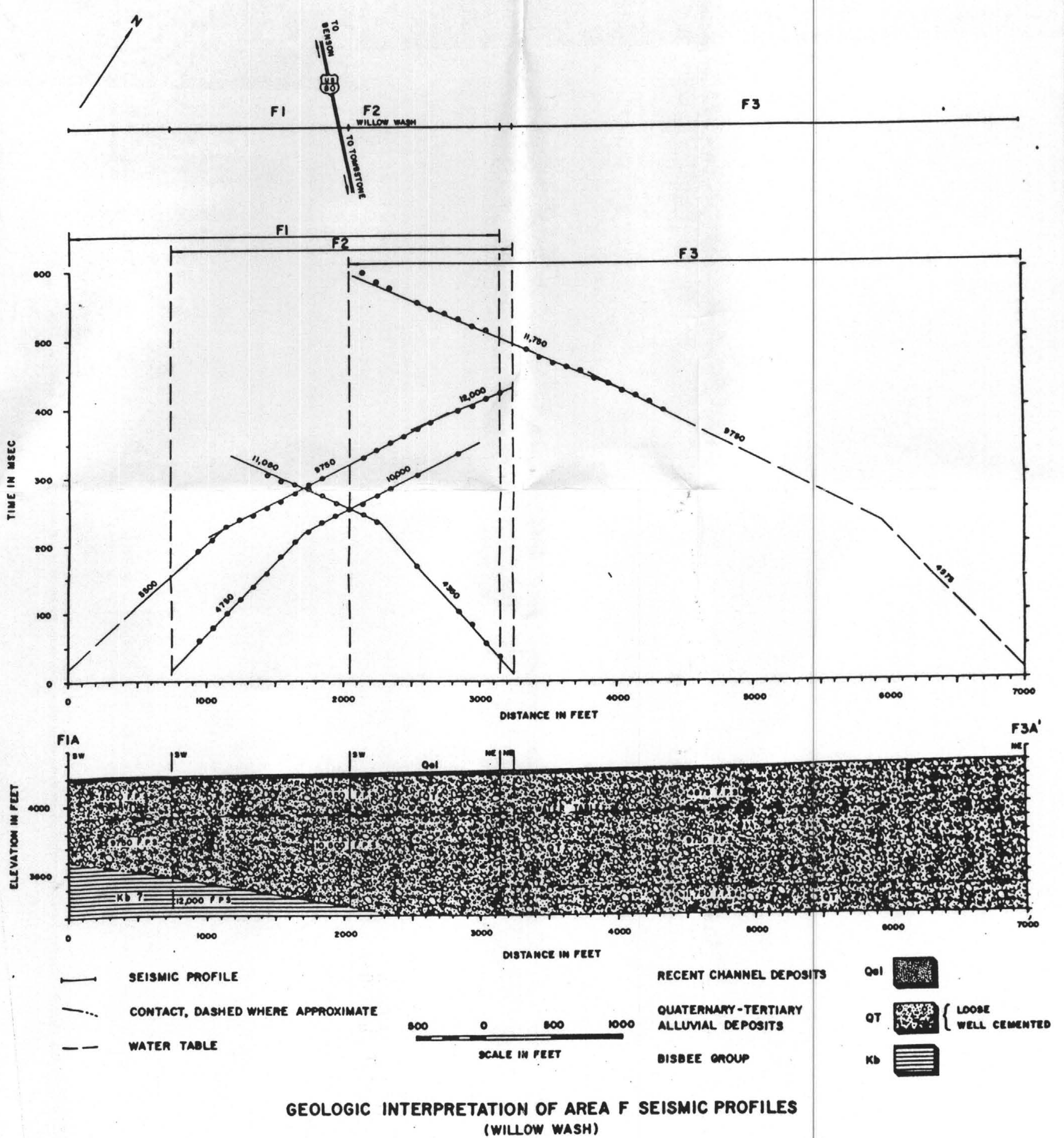
GEOLOGIC INTERPRETATION OF AREA C SEISMIC PROFILES
(LAMBS DRAW)



GEOLOGIC INTERPRETATION OF AREA D SEISMIC PROFILES
(RIFLE RANGE)



GEOLOGIC INTERPRETATION OF AREA E SEISMIC PROFILES
(WALNUT GULCH - GLEESON ROAD)



GEOLOGIC INTERPRETATION OF AREA F SEISMIC PROFILES
(WILLOW WASH)

Plate 2.—Geologic interpretation of seismic profiles in areas B, C, D, E, and F.