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The crustal heritage of silver and gold ratios in Arizona ores

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The AZGS Core Repository

by

John T. Duncan and Jon E. Spencer

Arizona Geological Survey
Open-file Report 93-2

March, 1993

This report is preliminary and has not been edited or reviewed for conformity with Arizona Geological Survey standards

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In 1992 the Arizona Geological Survey (AZGS) organized a repository in which diamond drill core that the AZGS has accumulated through donations is stored and available for public inspection. The repository is presently located in the basement of the Corbett Building (210 E. 7th Street) in Tucson, Arizona. Core samples in the facility represent almost 300 individual drill holes and approximately 150,000 linear feet of hole. All the core has been skeletonized (either by the donor or by AZGS geologists) to varying degrees, with from 20% to less than 1% of the original core retained. All fourteen Arizona counties are represented in the storage facility by at least one drill hole, with Apache, Cochise, Maricopa, and Mohave Counties containing the most individual holes. The core represents various projects ranging from geotechnical site assessments to metallic mineral exploration.

Only the core drilled and donated by the U.S. Bureau of Mines (BOM) and Bendix Field Engineering Corp. is described in published reports, which are listed below. AZGS files contain unpublished reports and drill logs for some of the core, but much is without any documentation other than this report. A complete inventory of the contents of the AZGS core repository is tabulated below. Available location diagrams have been reproduced from original sources and appended to the end of the inventory table. Anyone wishing to inspect any of the core should contact the Arizona Geological Survey by telephone at (602) 882-4795 or by mail at 845 N. Park Ave., #100, Tucson, AZ 85719.

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APACHE COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
AZ POTASH-ST.JOE (Holbrook Basin)	1	0-1408	1408	NW NW NW SEC 24 T18N R25E	n.a.
	2	0-1240	1245	NW SEC 26 T18N R25E	
	3	730-1818	1818	NW NW SEC 34 T18N R25E	
	5	0-1530	1543	NW NW SEC 12 T17N R25E	
	6	0-1590	1594	NW NW SEC 6 T17N R26E	
	8	0-1428	1428	SE SE SEC 10 T17N R25E	
	9	1216-1388	1388	NW NW SEC 16 T17N R25E	
	10	1260-1380	1380	SE SE SEC 4 T18N R26E	
	11	1172-1312	1312	NW NW SEC 16 T18N R26E	
	12	1137-1252	1252	NW NW SEC 20 T18N R26E	
	13	1082-1182	1182	NE NE SEC 12 T18N R25E	
KERR-McGEE BARFOOT (Holbrook Basin)	1	995-1088		NW SE NW SEC 32 T20N R27E	n.a.
KERR-McGEE #2 (Holbrook Basin)	H-3	20-1145		NE NW SE SEC 34 T20N R26E	n.a.
KERN COUNTY LAND (Holbrook Basin)	1	905-1085	1085	SW SEC 2 T18N R24E	n.a.
	3	1184-1388	1388	SW NE NE SEC 6 T17N R25E	
	6	812-1021	1021	NE SEC 6 T17N R25E	
	7	1402-1560	1600	NE NE SEC 2 T17N R25E	
	8	1285-1420	1420	SW SE SE SEC 24 T18N R25E	
NAVAJO (Holbrook basin)	46	1601-1743		SE SW SEC 9 T19N R27E	n.a.
	49	1870-1968		NE NW SEC 6 T18N R27E	
	50	2039-2061		SE NW SEC 8 T18N R27E	
	51	1686-1786		SE SE SEC 18 T18N R26E	
	52	1228-1268		NE SE SEC 8 T18N R26E	

COCHISE COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
AGH	1	259-805		Center SEC 2 T13S R31E	n.a.
AKW	1	716-1505		NW SEC 22 T12S R31E	n.a

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
COURTLAND-GLEESON (Turquoise Dist.)	B-4	146-955		SEC 28 T19S R25E *	AZGS files (Fig. 2)
	B-8	20-1032		"	
	B-10	258-1501		"	
	B-11	96-1201		"	
	B-12	21-591		"	
	B-15	52-956		"	
	B-19	112-884		"	
	B-23	81-841		"	
	B-24	50-618		"	
	B-25	100-678		"	
	B-26	110-745		"	
	B-28	12-725		"	
	M-1	40-532		"	
	M-2	25-556		"	
	M-3	97-510		"	
	M-5	127-562		"	
	M-6	0-322		"	
	M-7	82-217		"	
	M-8	391-688		"	
	M-9	168-232		"	
	M-10	286-417		"	
	M-12	0-106		"	
	M-14	54-220		"	
	M-18	0-55		"	
	M-20	0-160		"	
	M-21	0-30		"	
	M-23	211-216		"	
	M-24	53-690		"	
	M-25	131-841		"	
	M-27	224-960		"	
		980-1290			
	M-28	98-549		"	
	M-29	20-460		"	
		480-1140			
	M-30	16-304		"	
		318-1150			
	M-31	20-1023		"	
	M-32	60-843		"	
	M-33	10-675		"	
	M-34	437-521		"	
	M-35	244-884		"	
	M-36	72-408		"	

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
	M-37	277-766		"	
	M-38	292-516		"	
	M-39	43-450		"	
	M-40	23-421		"	
	M-41	82-798		"	
	M-42	66-599		"	
	M-43	49-139		"	
		149-489			
	M-44	36-577		"	
	M-45	52-323		"	
	M-46	46-352		"	
	M-47	19-409		"	
	M-48	21-347		"	
	M-49	87-407		"	
	M-56	0-550 (Chip board)		"	
	M-57	0-405 (Chip board)		"	
	M-58	0-505 (Chip board)		"	
KEYSTONE (Cochise Dist.)	1	0-789	790	NE NW SEC 36 T15S R22E *	4 (Fig. 1)
	2	0-382	410	"	
	3	0-245	276	"	
	4	0-165	321	"	
	5	0-391	391	"	
	6	0-367	406	"	
	7	0-330	330	"	
	8	0-112	167	"	
	9	60-276	281	"	
	10	0-364	364	"	
	11	0-147	335	"	
		162-335			
	12	0-354	354	"	
	13	0-586	586	"	
	14	0-495	516	"	
	15	0-592	592	"	
	16	21-461	461	"	
	17	0-392	484	"	
	18	9-87		"	
	19	24-179		"	
	20	113-228		"	
	21	0-212		"	
	22A	376-444		"	
	22	0-599	599	"	

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
	23	0-104 130-209 246-603	603	"	
	24	0-604	604	"	
	25	0-561	566	"	
	26	30-566	566	"	
MIDDLEMARCH (Middlemarch Dist.)	M-1	22-1745	1746	NW NE NE SEC 11 T18S R23E	AZGS files
	M-2	1-942	942	NW SE NW SEC 12 T18S R23E	
	M-3	0-535	535	SE SW SE SEC 12 T18S R23E	
MANSFIELD CANYON (MC) (Mansfield Dist.)	1	0-2999	3000	SE SE SE SEC 8 T21S R15E	AZGS files
	2	0-3405	3350	NW NW SE SEC 8 T21S R15E	
	3	23-470	470	NW SW SW SEC 9 T21S R15E	
STEINS PASS	1	0-1745 1763-2993		NW SEC 14 T14S R32E	n.a.
	6	741-1804		N½ SEC 20 T14S R32E	
WHETSTONE (Whetstone Dist.)	1	0-840	840	SW NW SW SEC 25 T18S R19E	AZGS files
	2	0-500	500	SE SE NE SEC 26 T18S R19E	
	3	0-840	840	SE SE NE SEC 26 T18S R19E	
	4	0-1133	1133	SW SE NW SEC 25 T18S R19E	

COCONINO COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
ROY OWENS #1	5	3353-3411	3628	NE NE NW SEC 12 T20N R11E	n.a.

GILA COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
CHRISTMAS (Christmas Dist.)	23B	4-562	562	NE SEC 30 T4S R16E *	9 (Fig. 3a-3d)
	23D	45-915	915	"	
	24A	5-200	200	"	
	24B	4-731	781	"	
	24C	4-110	200	"	
	24D	5-302 419-436	436	"	
	24E	8-441	660	"	

GRAHAM COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
SANCHEZ	429	0-1702	1705	NE SE NE SEC 26 T6S R27E	AZGS files
	445	100-1320	1325	SW SW NW SEC 25 T6S R27E	
	450	0-2105	2105	NW SE NE SEC 26 T6S R27E	
	468	570-2000	2000	NW SE SEC 26 T6S R27E	

GREENLEE COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
BEE (Blue River Dist.)	A34-1	146-2710 2850-5011	5016	SE SEC 6 T1S R31E	AZGS files

LA PAZ COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
QUARTZSITE (La Paz Dist.)	Q-4	240-514	514	SW NE SW SEC 31 T4N R20W	AZGS files
	Q-5	0-269	790	NE NW SW SEC 31 T4N R20W	
	Q-6	0-1142	1142	NE NW SW SEC 31 T4N R20W	
SWANSEA (Swansea Dist.)	J1	366-970	1050	NE NW NE SEC 32 T10N R15W	AZGS files
	J2	351-1053		SW NW NE SEC 32 T10N R15W	
	J6	236-634		SW NW NE SEC 32 T10N R15W	

MARICOPA COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
ENSCO MOBIL W.R.A.	B-6	311-799		SW NE SW SEC 32 T4S R1W	AZGS files
	B-9	321-327 407-413 600-700		SE SW NE SEC 32 T4S R1W	
	B-10	313-694		SE NW NE SEC 32 T4S R1W	
	B-11	229-237 430-450 520-669		SW SW NE SEC 32 T4S R1W	
	B-12	6-49		SW SW NE SEC 32 T4S R1W	
	B-13	20-48 160-161		SW SW NE SEC 32 T4S R1W	
	B-14	4-45		SW SW NE SEC 32 T4S R1W	

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
	B-15	25-200		SW SW NE SEC 32 T4S R1W	
	B-16	9-160		SW NE NE SEC 32 T4S R1W	
		164-700			
	B-17	6-90		SE NW NE SEC 32 T4S R1W	
	B-18	5-99		SE NW NE SEC 32 T4S R1W	
	P-5	50-403		SE NE NW SEC 32 T4S R1W	
		590-675			
	P-7	632-641		SE SW NE SEC 32 T4S R1W	
SSC-MARICOPA	MD-1R	46-1255		SE SEC 2 T7S R1W	AZGS files
	MD-3R	12-125	125	NE SEC 29 T5S R1E	
	MD-5R	11-475	475	SW NW SEC 24 T4S R3W	
	MD-10	30-700	700	SEC 17 T4S R2W	
	MD-11	10-100	100	NW SEC 13 T5S R3W	
	MD-12	14-354	354	NE NE NE SEC 12 T7S R2W	
	MD-13	10-125	125	SW SEC 33 T5S R1E	
UCSD-ARIZONA	2	38-794		SE SE SEC 3 T3S R4W	n.a.

MOHAVE COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
ANTLER (Hualapai Dist.)	1	13-206	308	NE SE SEC 4 T17N R16W *	3 (Fig. 4)
		256-266			
		276-304			
	2	0-306	396	"	
	3	213-380	380	"	
	4	0-430	430	"	
	5	0-376	459	"	
	6	0-309	309	"	
ARTILLERY PEAK (Artillery Dist.)	A-1	1-267	267	NW NE SEC 31 T12N R13W *	1 (Fig. 5a, 5b)
	A-2	45-169	169	"	
	A-3	0-151	234	"	
		207-234			
	A-4	0-243	243	"	
	A-5	0-135	241	"	
		168-241			
	A-6	0-263	263	"	
	A-7	22-242	242	"	
	A-8	13-253	253	"	

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
	A-9	0-94		"	
		139-241			
	A-10	0-233	233	"	
	A-11	0-237	237	"	
	101 up	0-16	16	"	
	102 up	0-15	25	"	
	103 up	0-25	25	"	
	103 down	0-12	12	"	
	104 up	12-23	26	"	
	104 down	0-12	12	"	
	105 up	0-18	18	"	
	105 down	13-21	21	"	
	106 up	0-14	14	"	
	106 down	0-24	24	"	
	107 up	0-28	28	"	
	107 down	0-11	11	"	
	108 up	0-22	23	"	
	108 down	0-12	12	"	
	201 up	15-22	23	"	
	202 up	0-19	19	"	
	202 down	0-12	12	"	
	203 up	0-12	24	"	
	203 down	0-12	12	"	
	204 down	8-16	16	"	
	205 up	0-24	24	"	
	205 down	0-13	13	"	
	301 up	0-27	27	"	
	301 down	0-12	12	"	
	302 up	0-20	30	"	
	303 up	0-32	32	"	
	303 down	0-12	12	"	
	304 up	0-22	28	"	
	304 down	0-12	12	"	
	305 up	0-25	25	"	
	305 down	0-12	12	"	
	306 up	0-12	20	"	
	306 down	0-5	12	"	
	309 up	0-19	19	"	
	309 down	0-12	12	"	
	310 up	0-16	20	"	
	310 down	0-12	12	"	

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
BAGDAD/HILLSIDE (Eureka Dist.)	H-1	0-526	526	NE SW SE SEC 16 T15N R9W	AZGS files
	H-2	0-1331	1331	NE SW SE SEC 16 T15N R9W	
	H-3	0-1145	1145	SE NW SE SEC 16 T15N R9W	
	H-4	462-1429	1429	NE NW SE SEC 16 T15N R9W	
	H-5	0-1863	1863	SE SE NW SEC 16 T15N R9W	
	H-6	42-70	70	SE NW SE SEC 16 T15N R9W	
	H-7	5-87	87	NE NW SE SEC 16 T15N R9W	
BENDIX	PQ-8	2433-2442	2456	SW SE NW SEC 20 T11N R16W	2
	PQ-9	1987-1997 4239-4245	5191	SW NE SW SEC 18 T15N R16W	
	PQ-10	3190-3223	5000	NE SW NW SEC 12 T16N R14W	
	PQ-12	1758-1764	1819	SE SE SEC 31 T16N R16W	
	PQ-25	2798-2808	5008	NE SEC T16N R13W	
	PQ-26	3420-3428	3434	NE SEC 12 T15N R13W	
	PQ-27	4336-4354	5000	SW SEC 9 T17N R13W	
	PQ-28	2850-2858 2880-2885	4122	SE SW SW SEC 20 T18N R13W	
	PQ-29	3401-3410	3528	SE SW NE SEC 28 T15N R12W	
	PQ-32	1618-1624	1624	SW NE SE SEC 8 T24N R12W	
RED LAKE		misc. unmarked		SE SE SE SEC 30 T26N R16W	n.a.

NAVAJO COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
APACHE (Apache Iron Dist.)	8	392-472	472	E½ T9N R15 *	7 (Fig. 6)
	9	358-407	407	"	
	11	349-477	477	"	
	12	263-330	330	"	
	19	456-511	511	"	
	21	402-445	445	"	
	23	262-300	300	"	
	24	254-306	306	"	
	25	150-235	235	"	
HPP (Holbrook Basin)	54	753-904		NW NW SEC 2 T16N R20E	n.a.
	55	665-907		SE NW SEC 34 T16N R21E	
	56	918-1021		SE SE SEC 2 T16N R18E	

PIMA COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
AMARGOSA (ESPERANZA) (Pima Dist.)	1	5-385	385	NE SEC 17 T18S R12E *	8 (Fig. 7)
	2	15-600	600	"	
COPPER GIANT (Ajo Dist.)	1	50-325 367-796	797	SE SE NW SEC 15 T13S R6W *	6 (Fig. 8)
	2	62-491 630-745	745	SW SW NE SEC 15 T13S R6W	
	3	27-510		SEC 15 T13S R6W	
DUVAL ROADSIDE (Roadside Dist.)		1805-2494		W Center SEC 11 T16S R8E	n.a
P-D SAN XAVIER (Pima Dist.)	SX-1	219-883		NW SE SE SEC 26 T16S R12E *	n.a. (Fig. 9)
	SX-4	156-544		NE NE SW SEC 14 T16S R12E	
	SX-5	369-1672		NE SE SE SEC 11 T16S R12E	
	SX-6	170-364		SE SW SW SEC 2 T16S R12E	
SEDIMENTARY HILLS (Sed. Hills Dist.)	47	37-486 508-1027 1052-1400		SW SW NW SEC 27 T14S R12E	AZGS files
	49	70-450 470-1000 1010-1402 1530-2100		SW SW SW SEC 33 T14S R12E	
SELLS (Cababi Dist.)	EM-1	0-300	300	SE NW SEC 17 T16S R5E *	AZGS files (Fig. 10)
	EM-2	0-311	311	SW SE SEC 4 T16S R4E	
	EM-3	0-615	615	NE SW SEC 35 T15S R4E	
	GS-1	0-761	761	SW NW SEC 34 T15S R4E	
	IP-3A	0-355	355	NE NE SEC 21 T16S R4E	
	IP-4	0-893	893	NE SEC 5 T16S R4E	
	IP-9	0-600	600	SW SEC 18 T16S R5E	

PINAL COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
ACE	64-1 64-2	14-1064 7-642 674-943 954-1244 1261-1632	1118 1640	SEC 23-24 T2S R13E SEC 23-24 T2S R13E	AZGS files
ASARCO GLOBE	QDC-5	140-1374 1461-1900 2038-2660 2716-3221 3329-4408		NW NW SW SEC 18 T2S R14E	n.a.
ASARCO SUPERIOR EAST	A-12	3-1499	1499	NW SE SW SE SEC 23 T1S R13E	n.a.
ASARCO SUPERIOR #4	A-13	12-1614	1614	SW SW SE SW SEC 23 T1S R13E	n.a.
COPPER CREEK	3 4	0-876 0-1605	876	Center SEC 18 T8S R18E NE SEC 13 T8S R17E	n.a.
DEVILS CANYON	DC-2	558-2109 2120-2739		SE NW SW SEC 7 T2S R14E	n.a.
GRANITE (Mineral Creek Dist.)	1	40-2314	3260	NE NE NE SEC 21 T3S R13E	AZGS files
KELVIN/RIVERSIDE (Riverside Dist.)	K-1 K-8 3	20-570 41-802 72-775	2100 802 1386	SE SW SE SEC 11 T4S R13E NW SE SW SEC 11 T4S R13E SW SW SE SEC 14 T4S R18E	AZGS files
LAKESHORE (Lakeshore Dist.)	D-1	0-204	204	SE SEC 25 T10S R4E *	5 (Fig. 11)
RIPSEY (Ripsey Dist.)	1 2 3	10-762 123-1472 60-940	3360 3240 3120	SE SE SW SEC 11 T5S R13E SW SW SE SEC 11 T5S R13E SW SW SE SEC 11 T5S R13E	AZGS files
VEKOL	V-2	1100-1405	1405	SW SW SE SEC 7 T9S R1E	AZGS files

SANTA CRUZ COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
FOUR METALS (Patagonia Dist.)	42	38-2161		W Center SEC 29 T23S R16E	n.a.
IVANHOE (Ivanhoe Dist.)	IV-2	0-3007	3007	SE SE NW SEC 3 T22S R15E	AZGS files

YAVAPAI COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
BENDIX	PQ-1	2945-2948	2948	NE SE NE SEC 11 T9N R6W	2
	PQ-2	2133-2137 2610-2621	2621	SW NW SEC 2 T9N R8W	
	PQ-3	3928-3941 4326-4333	4333	SW NE SE SEC 29 T10N R10W	
	PQ-4	5194-5208	5491	NE NE NE SEC 3 T9N R9W	
	PQ-5	2510-2522 4480-4489	5044	NW SEC 29 T10N R10W	
	PQ-6	986-991 1681-1691 2508-2528	2998	NW SW SEC 31 T11N R10W	

YUMA COUNTY

PROJECT NAME	HOLE #	FOOTAGE STORED	T.D.	LOCATION	REFERENCE
UCSD-ARIZONA	3	171-952		SE NE SEC 28 T9S R15W	n.a.

n.a. = no reference available for this project.
* = see appended figure for more precice drill hole locations for this project.

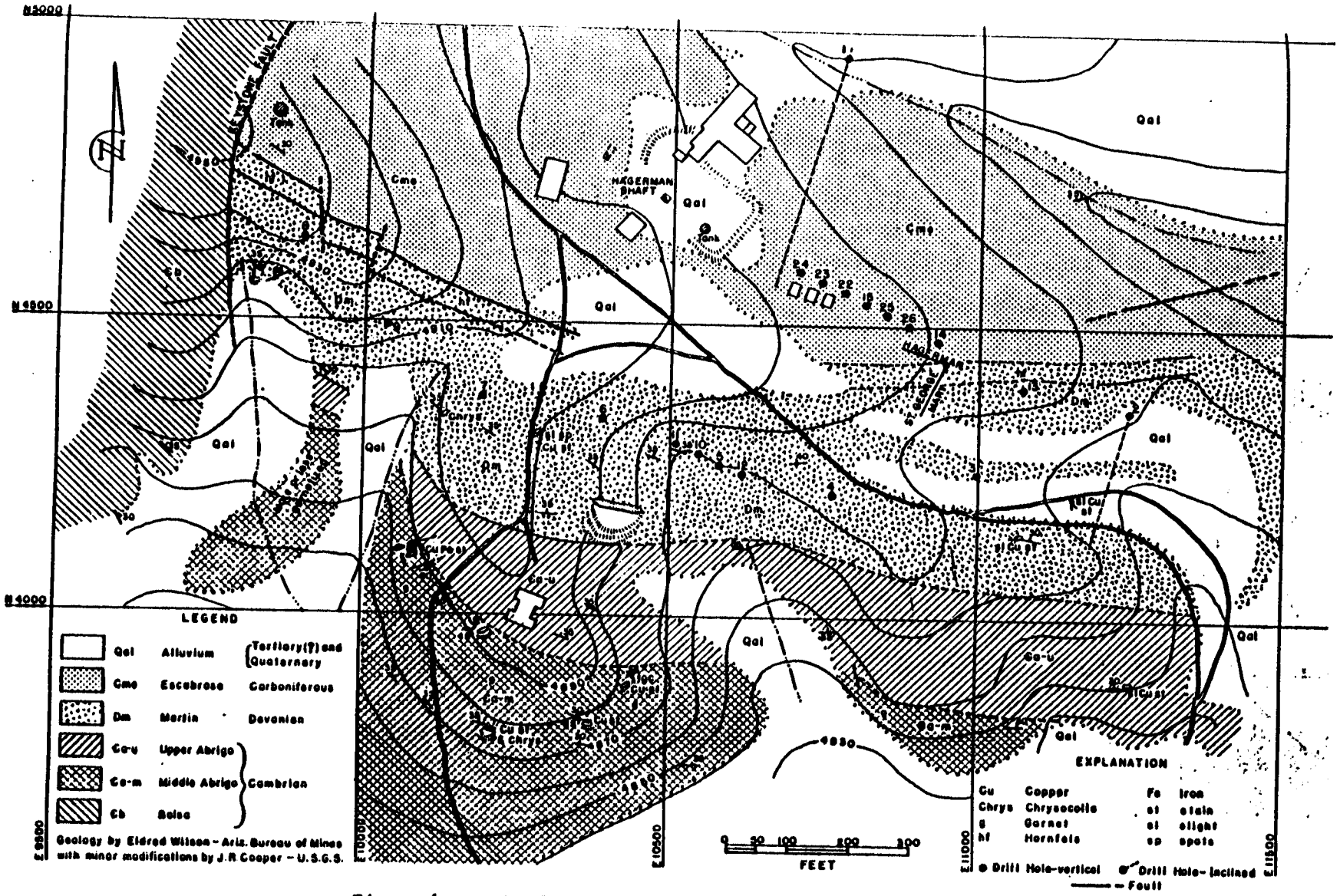


Figure 1a. - Geologic map of Hagerman shaft area.

Location map for Keystone drill holes, Cochise Co., from Romslo (1948).

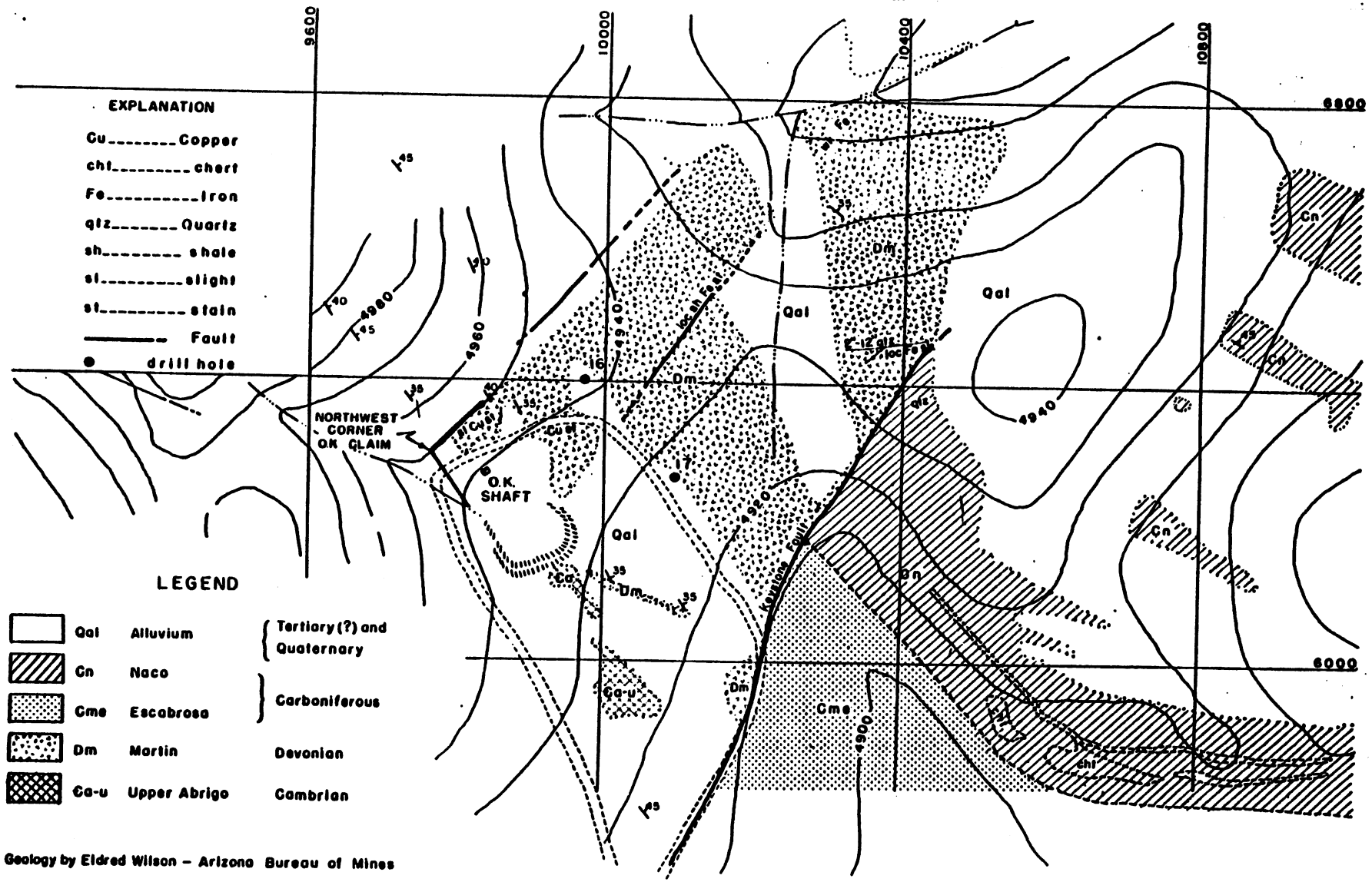


Figure 1b. - Geologic map of O. K. shaft area.
Location map for Keystone drill holes, Cochise Co., from Romslo (1948).

Section 28, T. 19 S., R. 25 E.

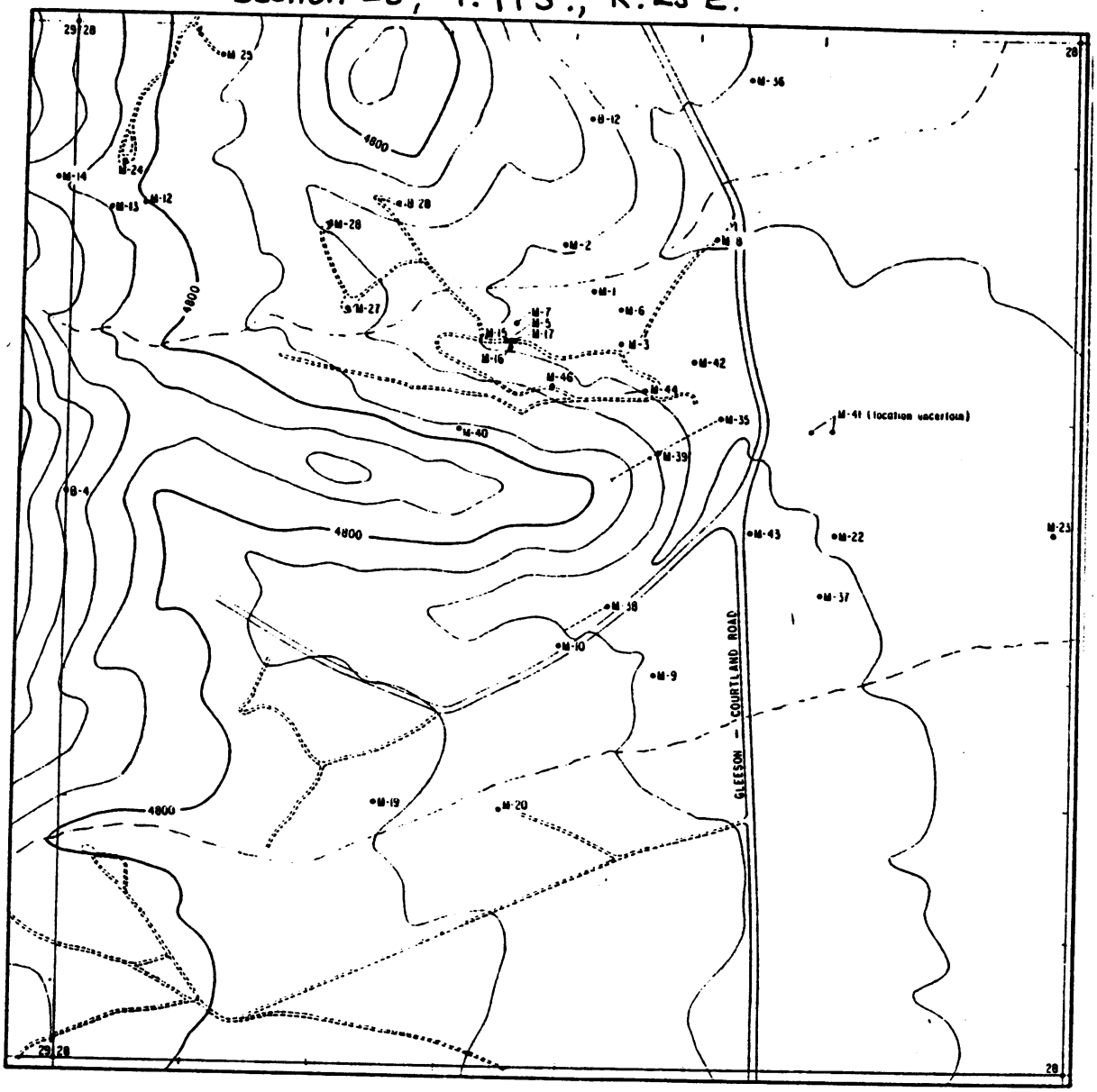


Figure 2 - Location map for Courtland-Gleeson drill holes, Cochise Co.

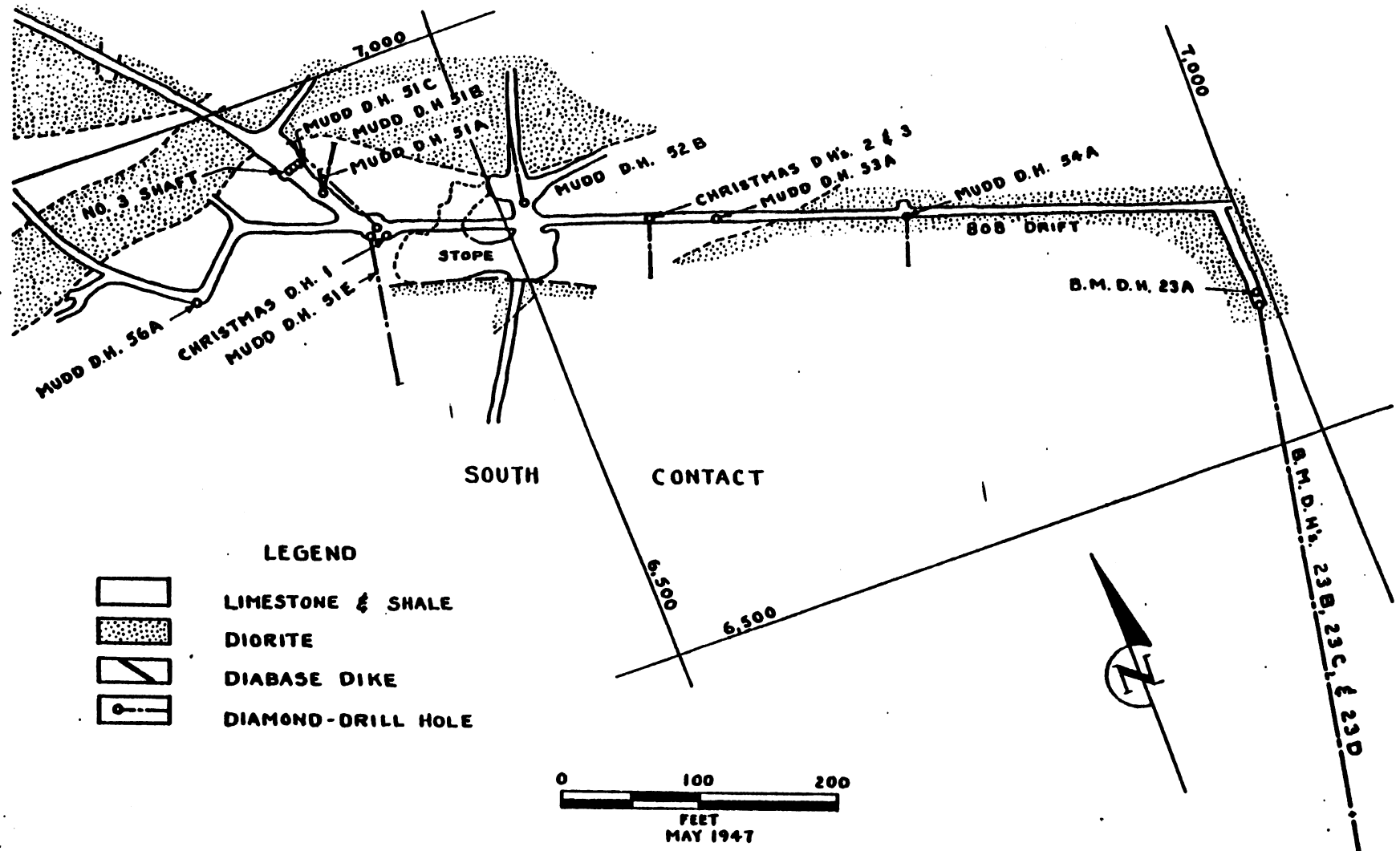


Figure 3a. - Plan of portion of 770 level, showing location of drill holes.

Christmas Mine. from Tainter (1948).

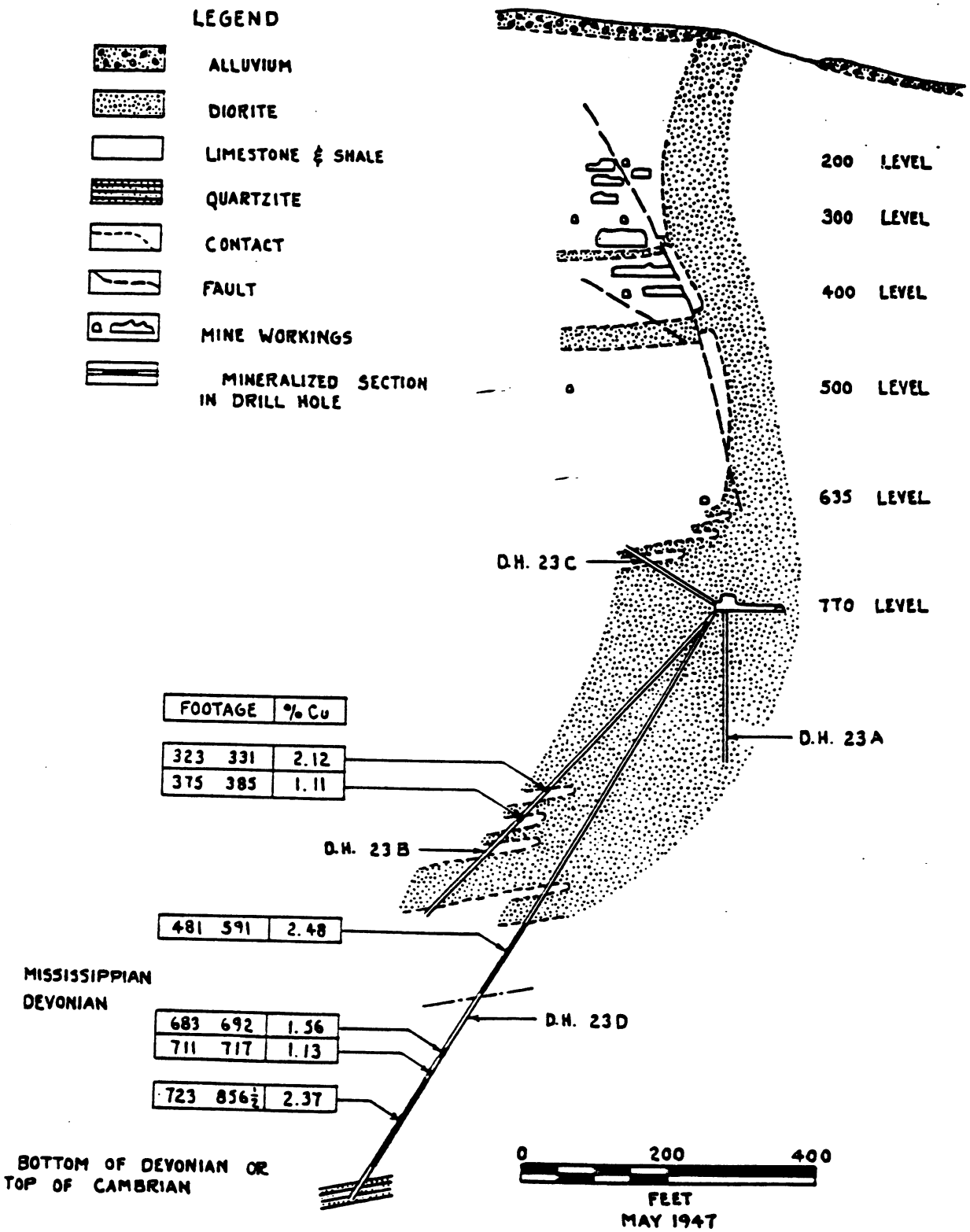


Figure 3b. - Section through holes drilled from 770 level. Geology by Federal Geological Survey. Christmas Mine.
From Tainter (1948).

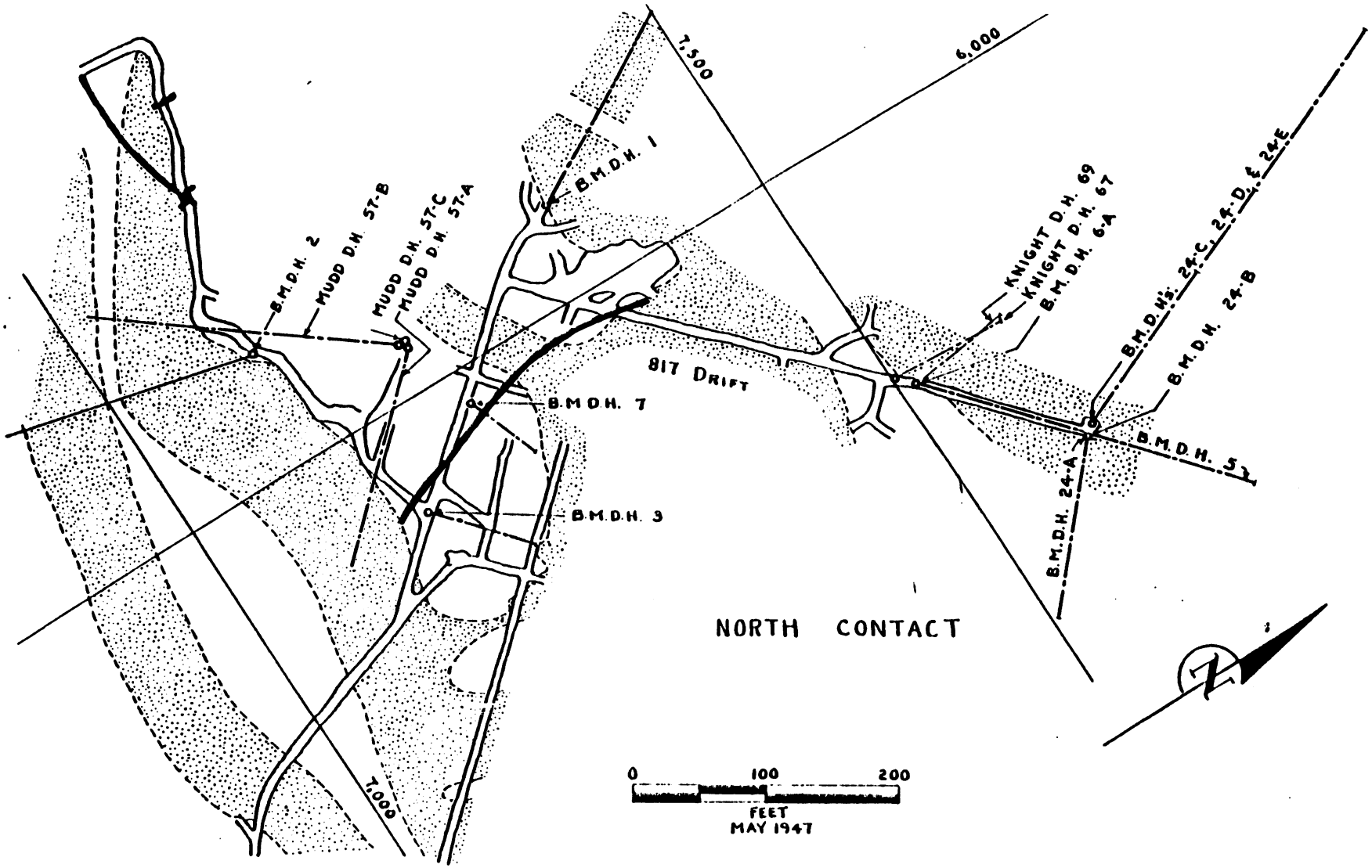


Figure 3c. - Plan of portion of 770 level, showing location of drill holes.
Christmas Mine. From Tainter (1948).

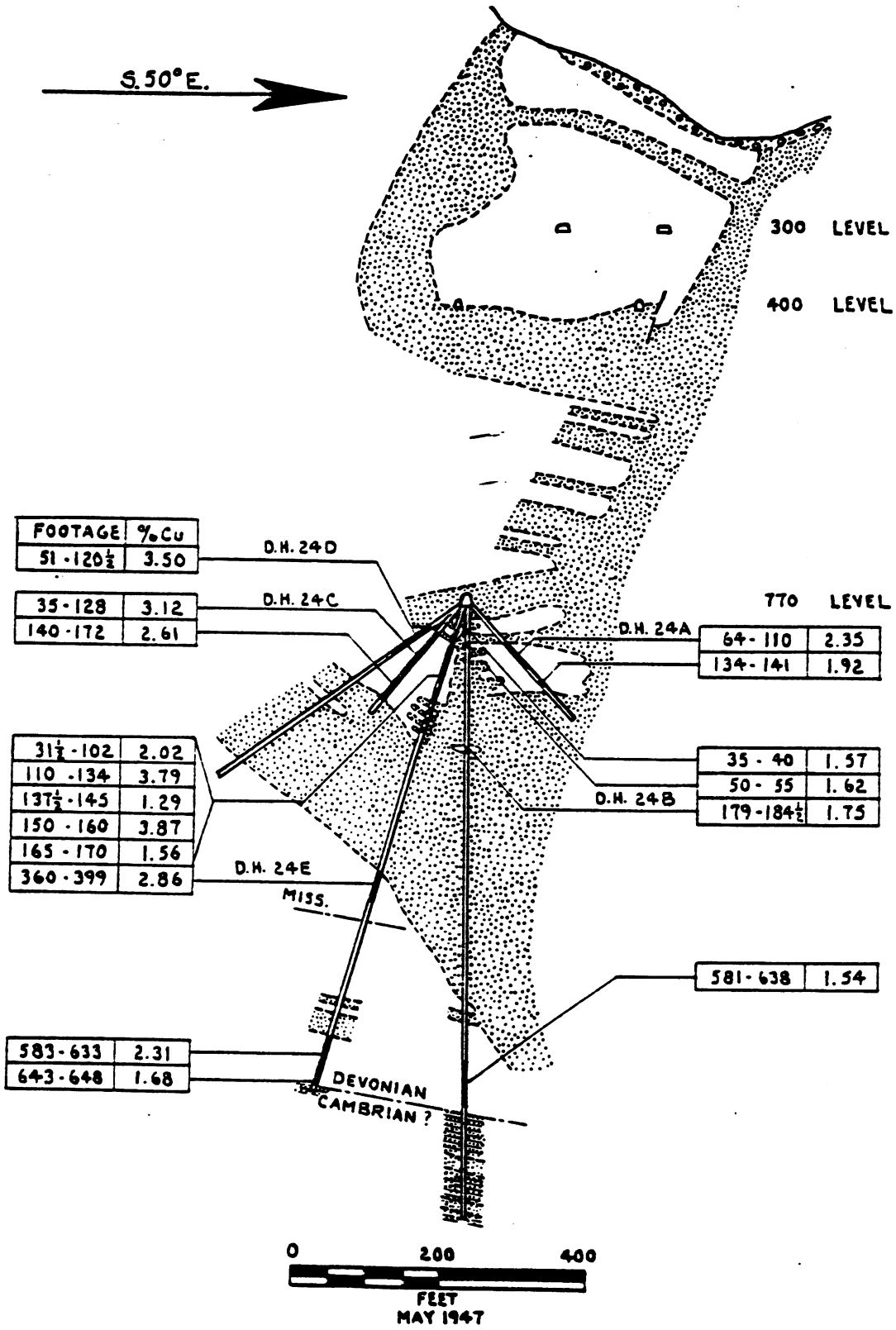


Figure 3d. - Section through drill holes from 770 level. Geology by Federal Geological Survey. Christmas Mine. From Tainter (1948).

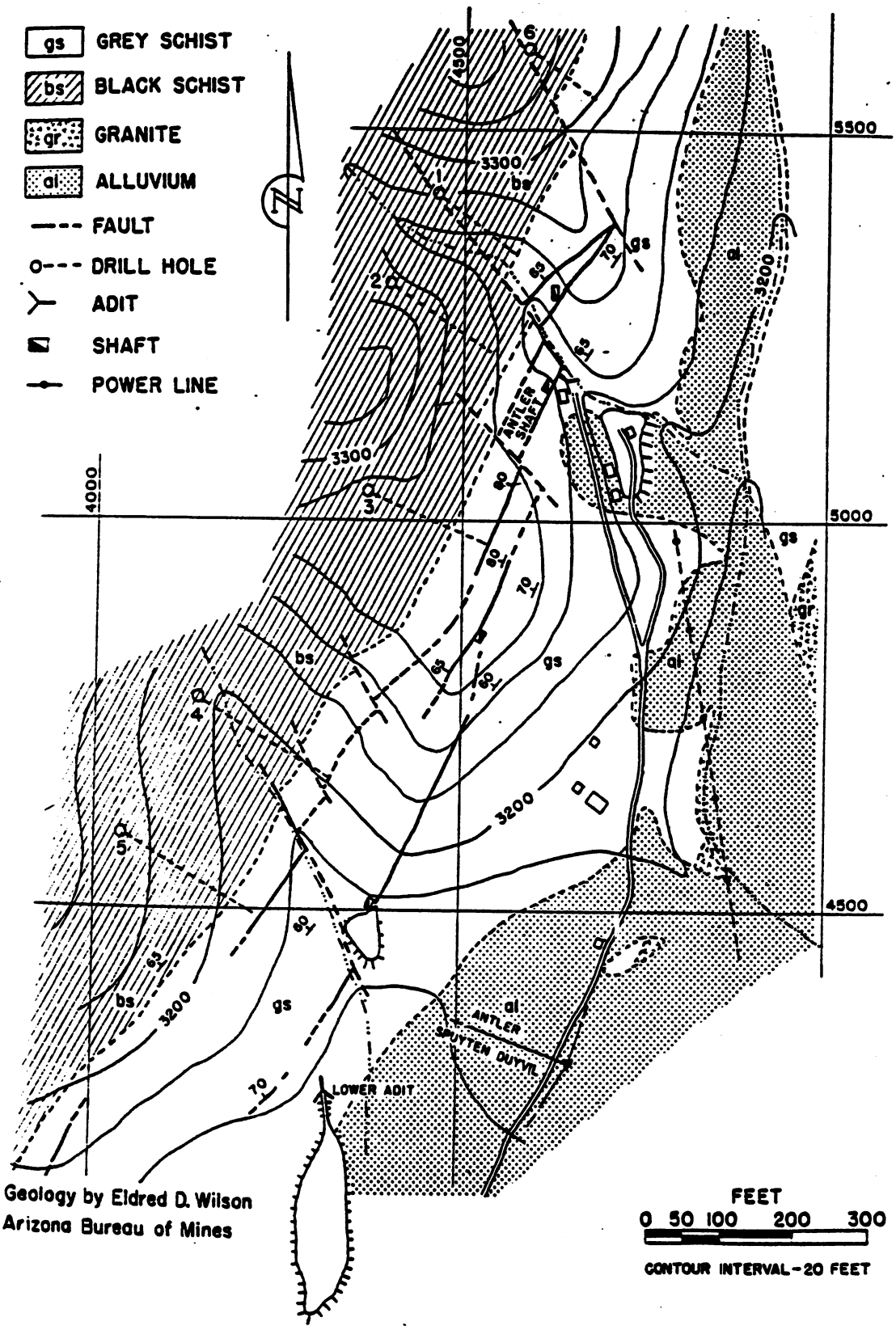


Figure 4. - Geologic map, Antler copper-zinc deposit, Mohave County, Ariz.
From Romslo (1948).

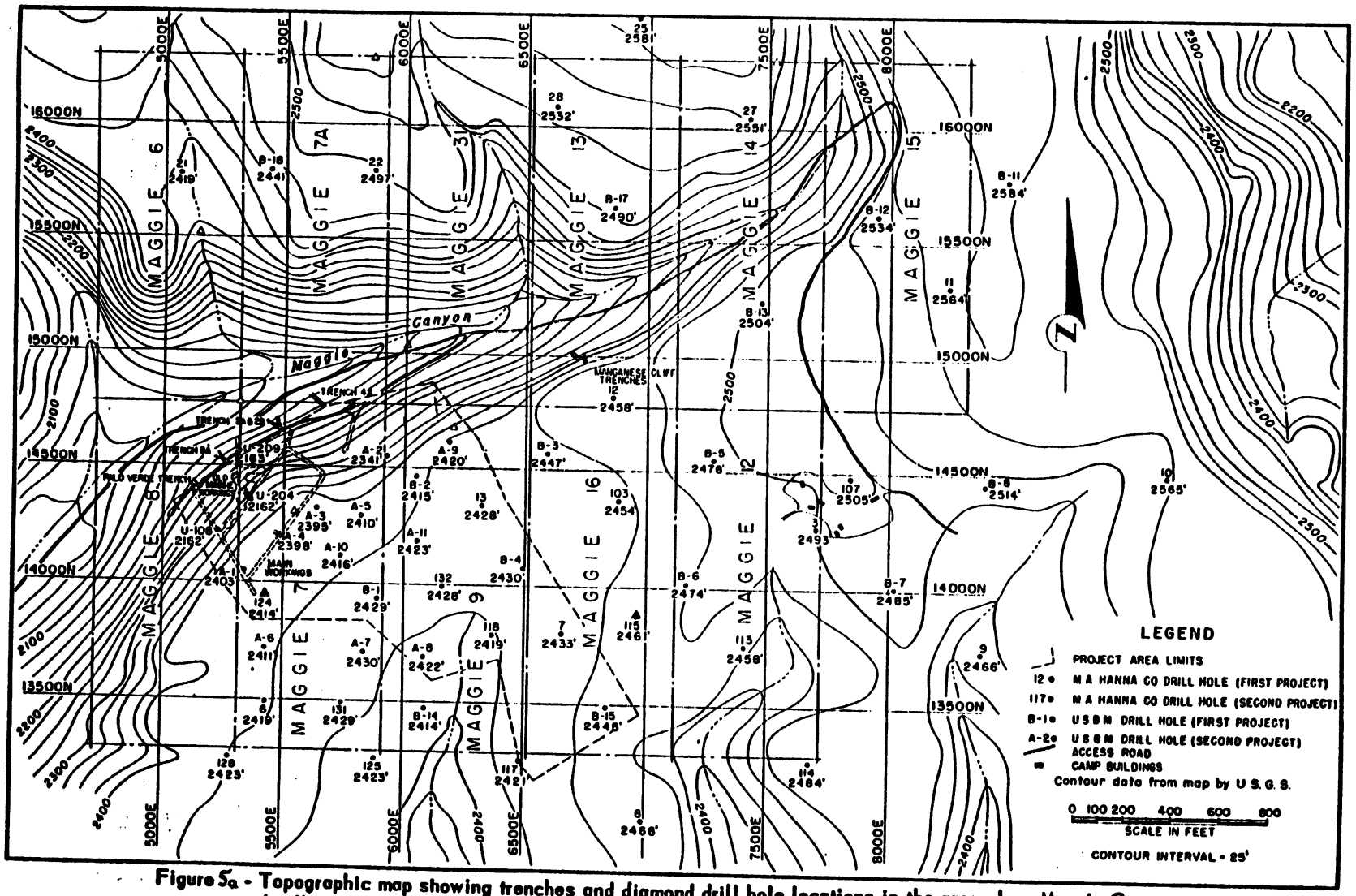
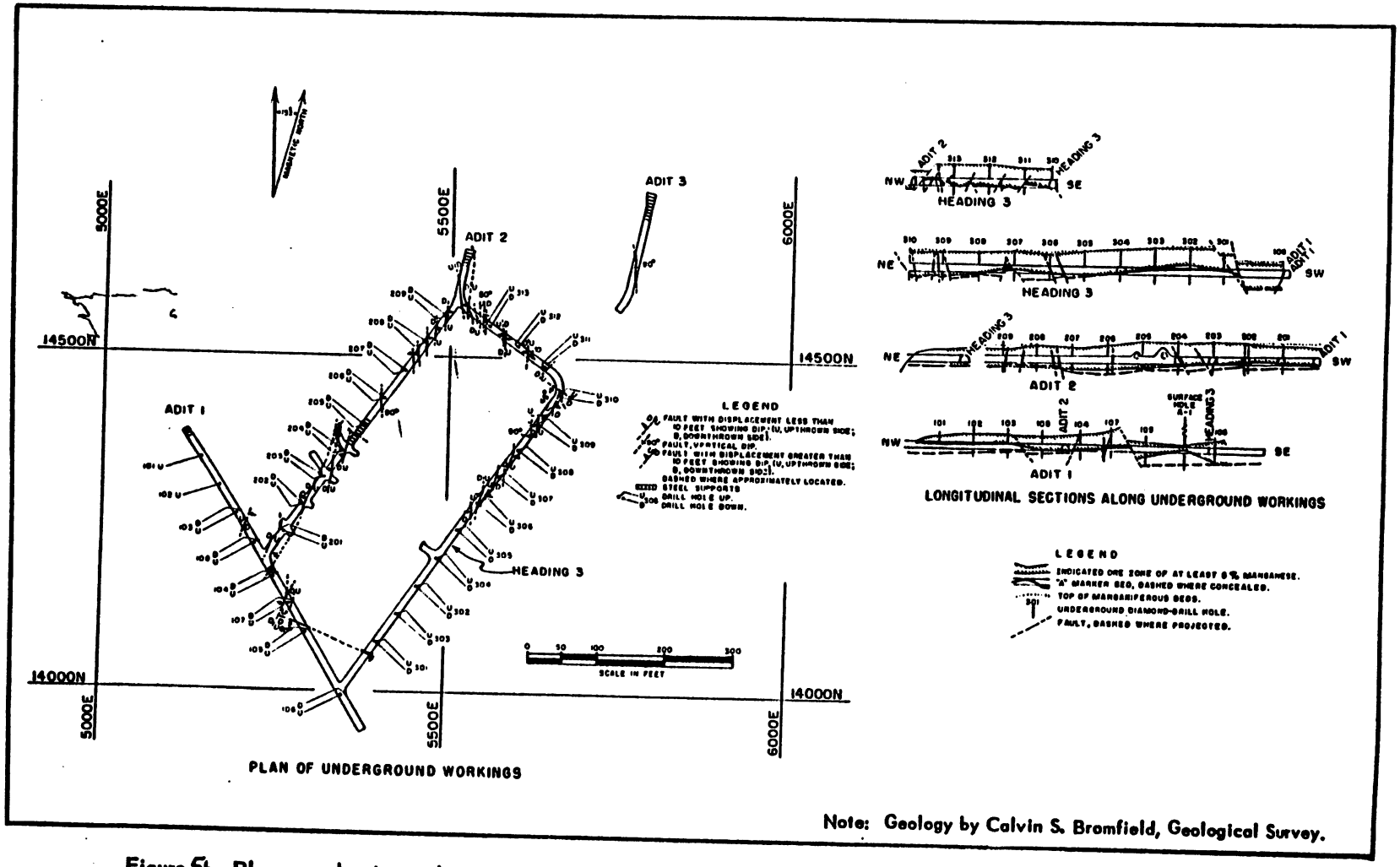


Figure 5a - Topographic map showing trenches and diamond drill hole locations in the area along Maggie Canyon, Artillery Mountains, Ariz.

From Kumke and others (1957).



Note: Geology by Calvin S. Bromfield, Geological Survey.

Figure 5b - Plan map showing underground geology and drill holes in Maggie Canyon mine, Artillery Mountains, Ariz.

From Kumke and others (1957).

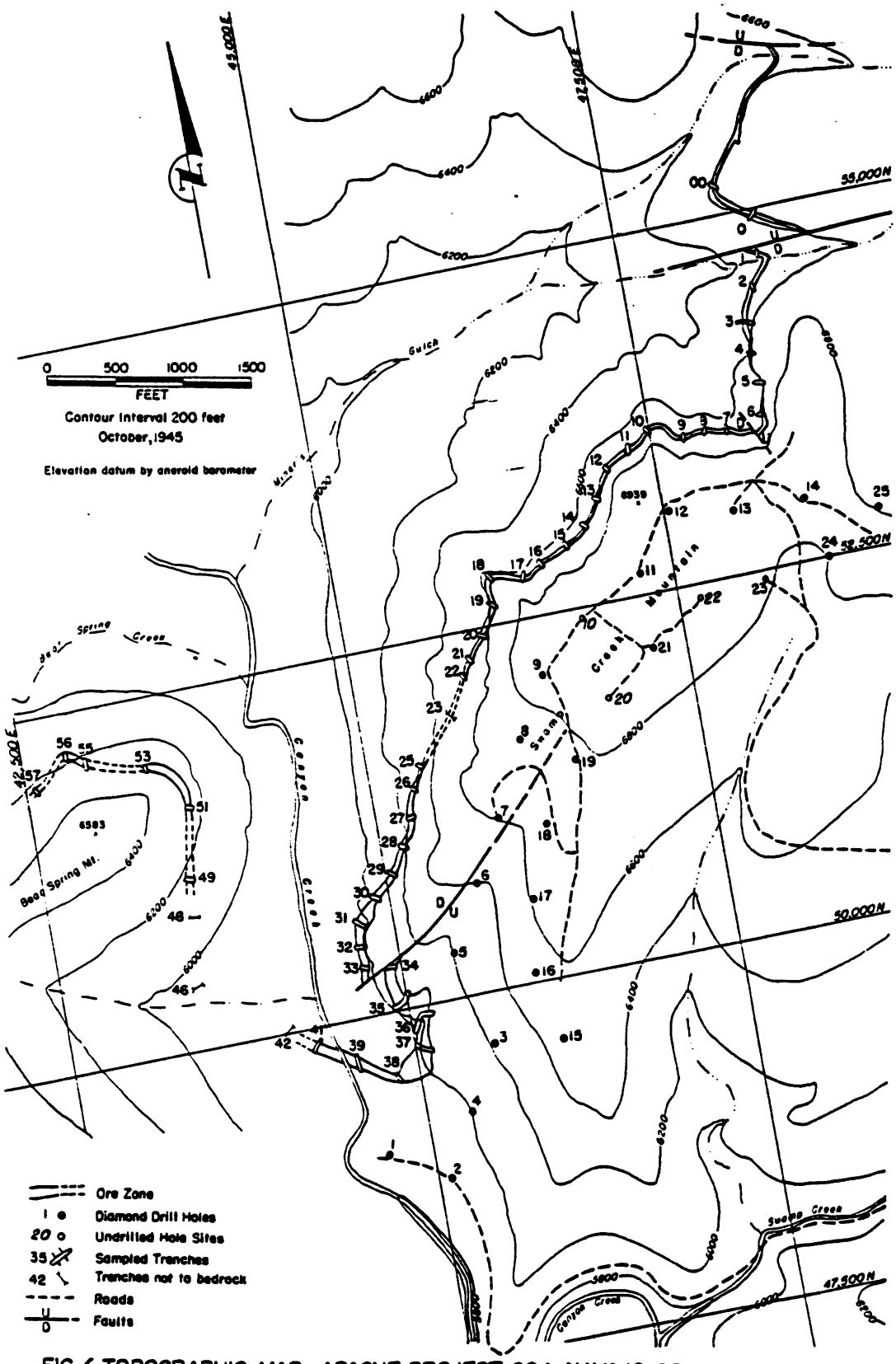


FIG. 6-TOPOGRAPHIC MAP, APACHE PROJECT 904, NAVAJO CO., ARIZONA

From Stewart (1947).

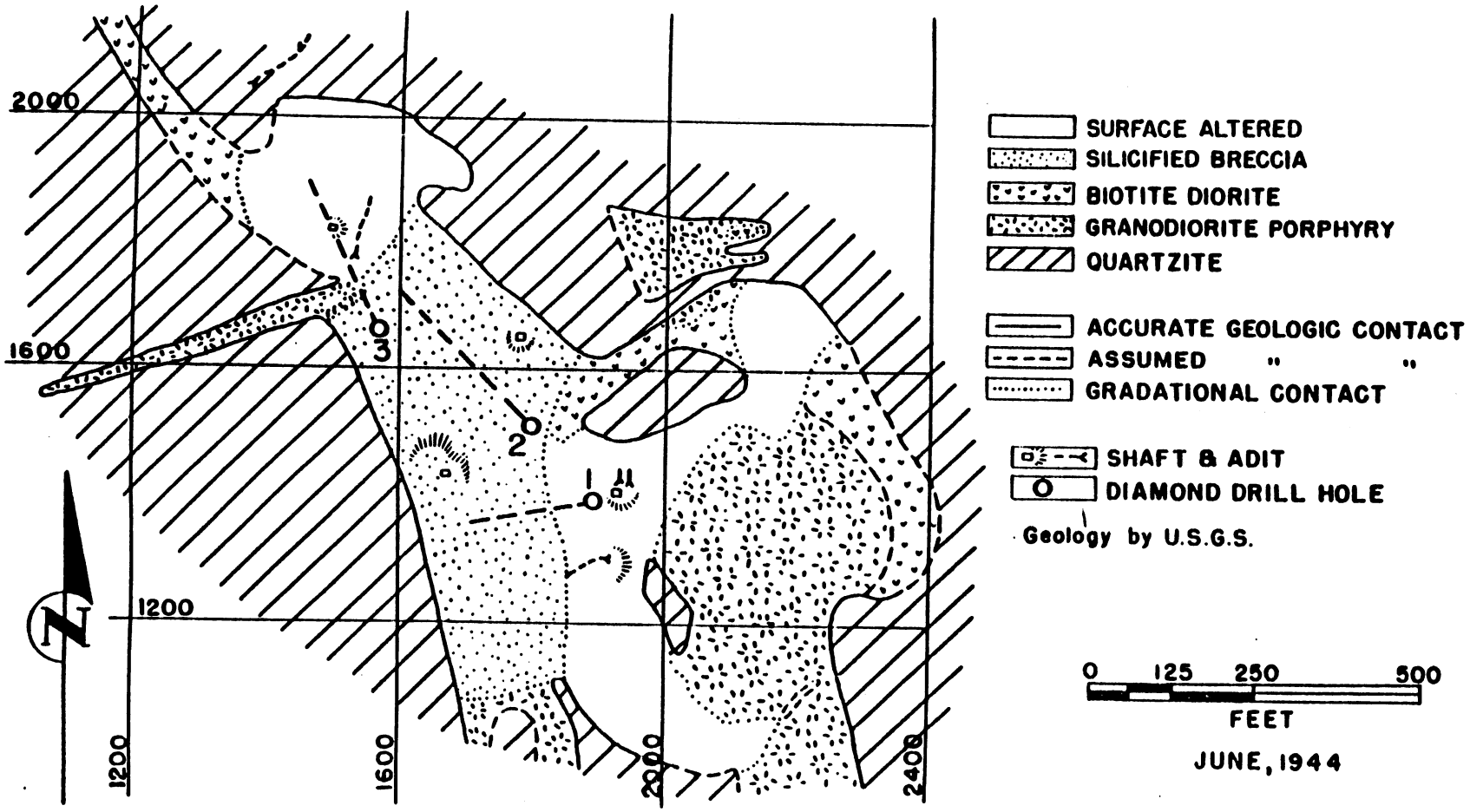
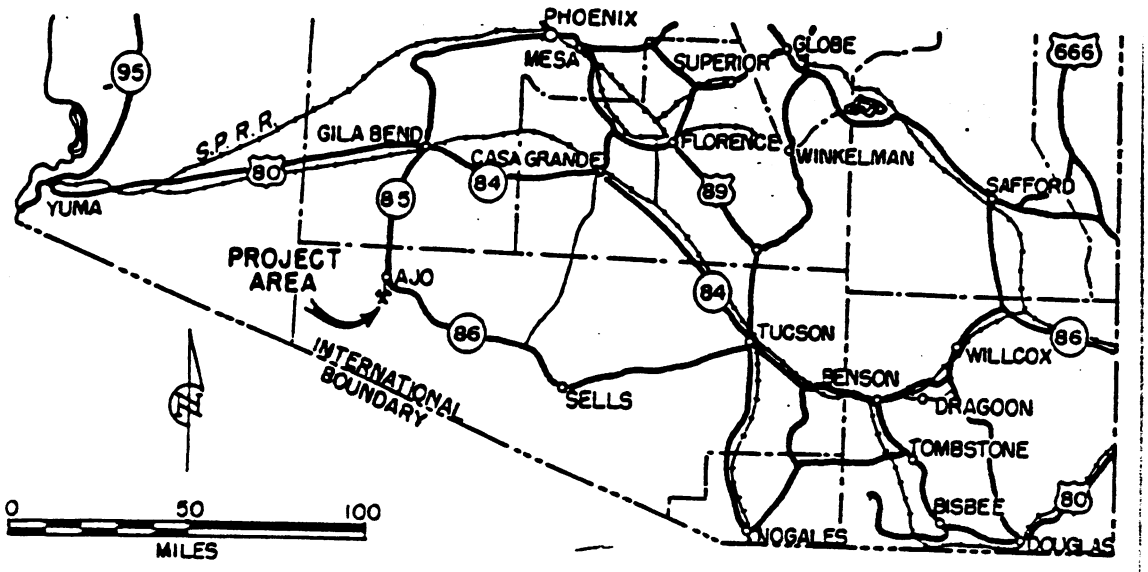


FIG. 7 - GEOLOGIC PLAN OF ESPERANZA DEPOSIT, AMARGOSA PROJ. 1709, PIMA CO., ARIZONA
From Tainter (1947).



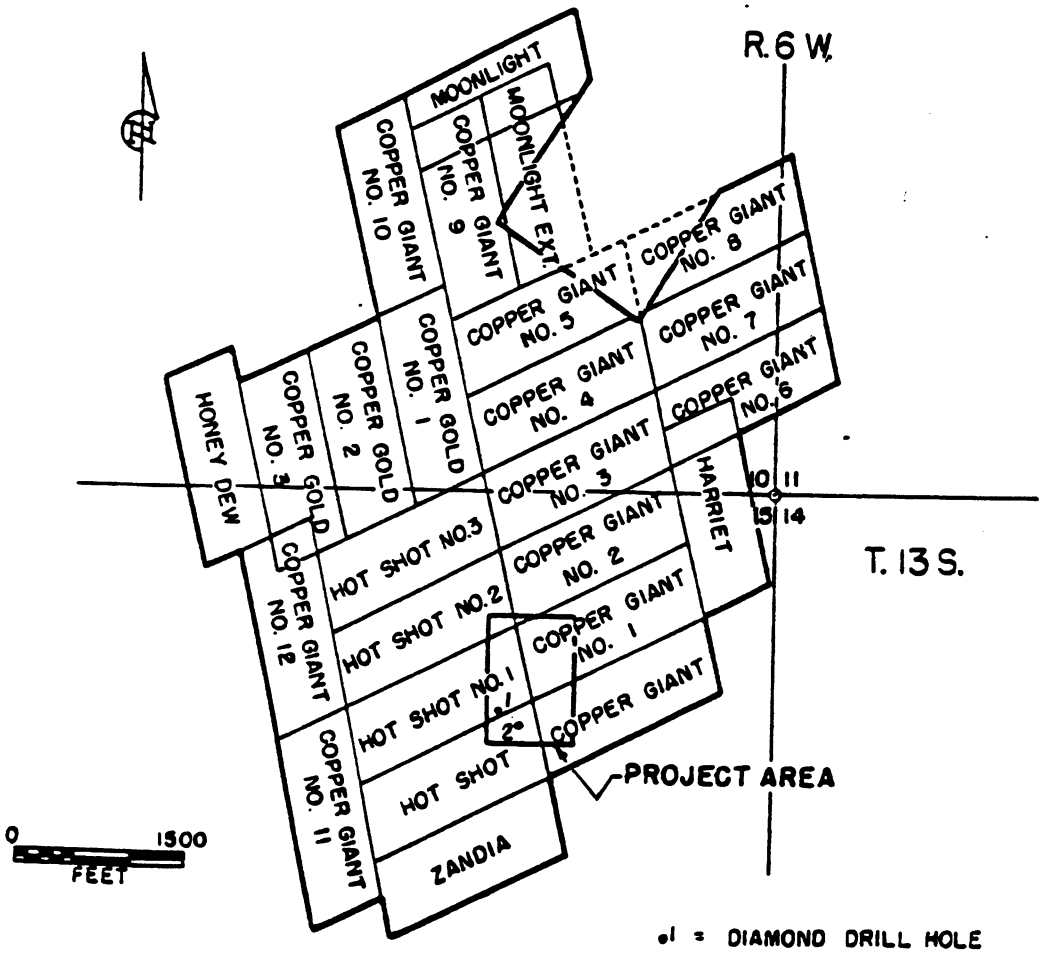


Figure 8 - General location and claim map, Copper Giant deposits, Ajo mining district, Pima County, Ariz.
From Romslo and Robinson (1952).

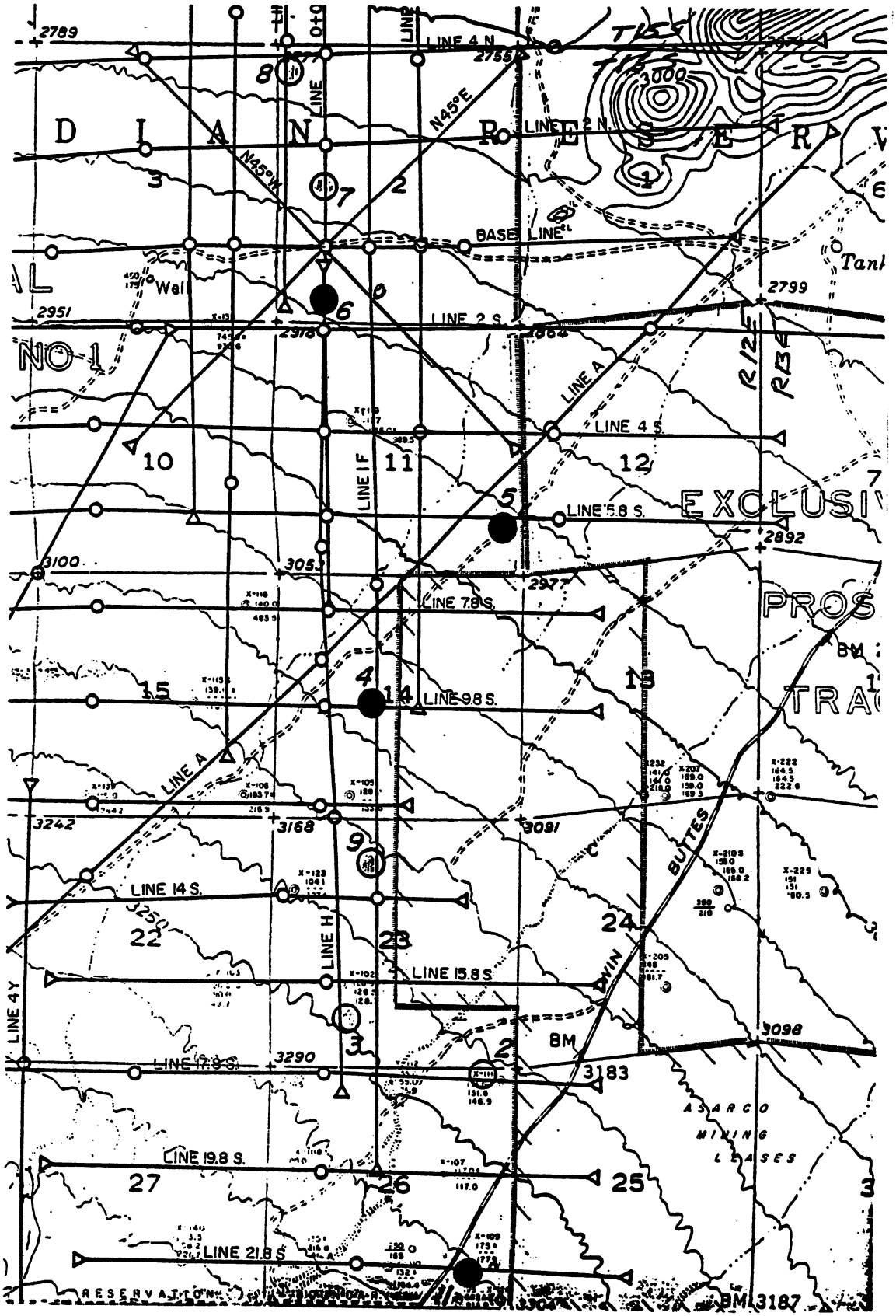


Figure 9 - Location Map for P-D SAN XAVIER drill holes, Pima Co.

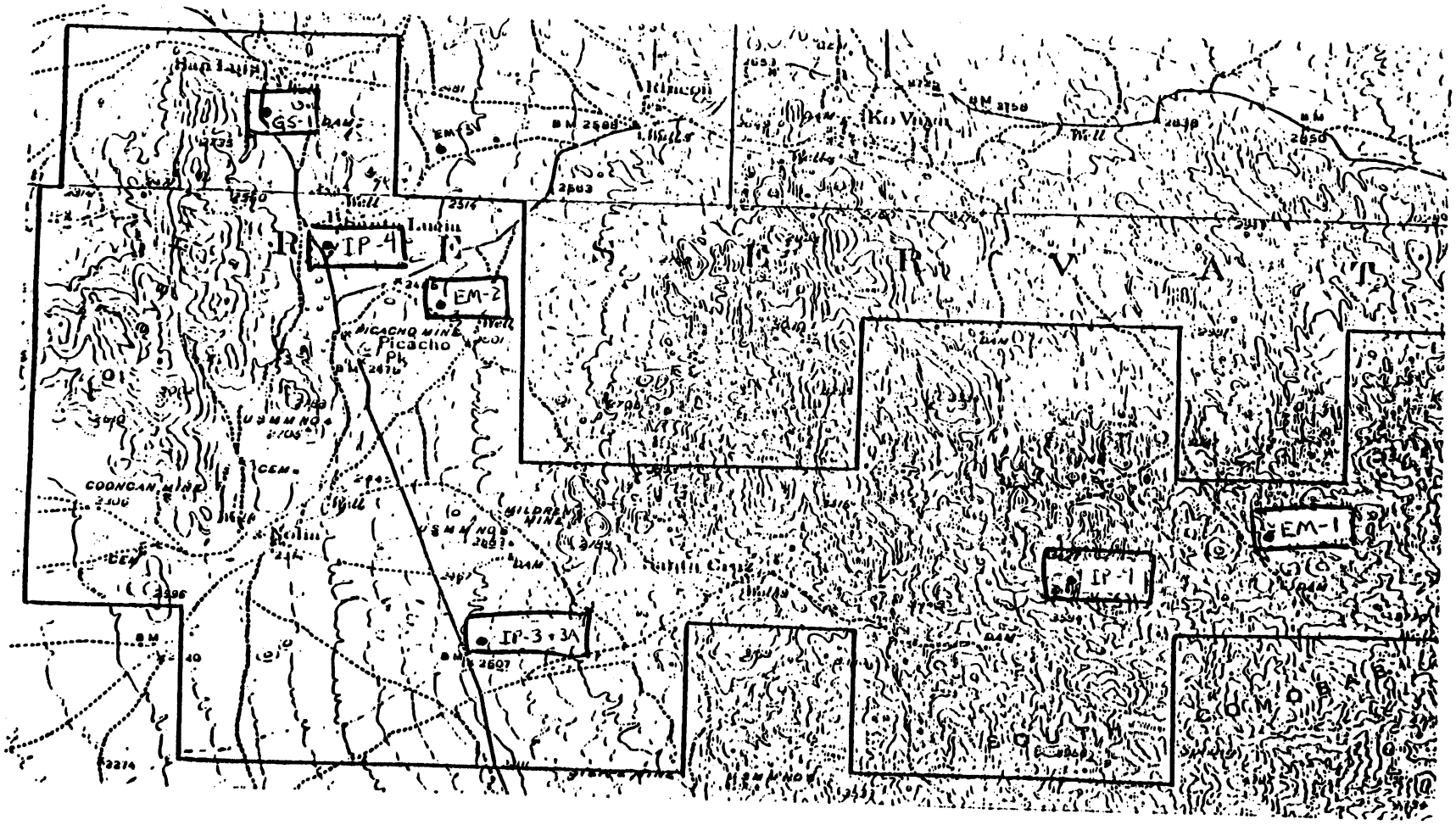


Figure 10- Location Map for SELLS drill holes, Pima Co.

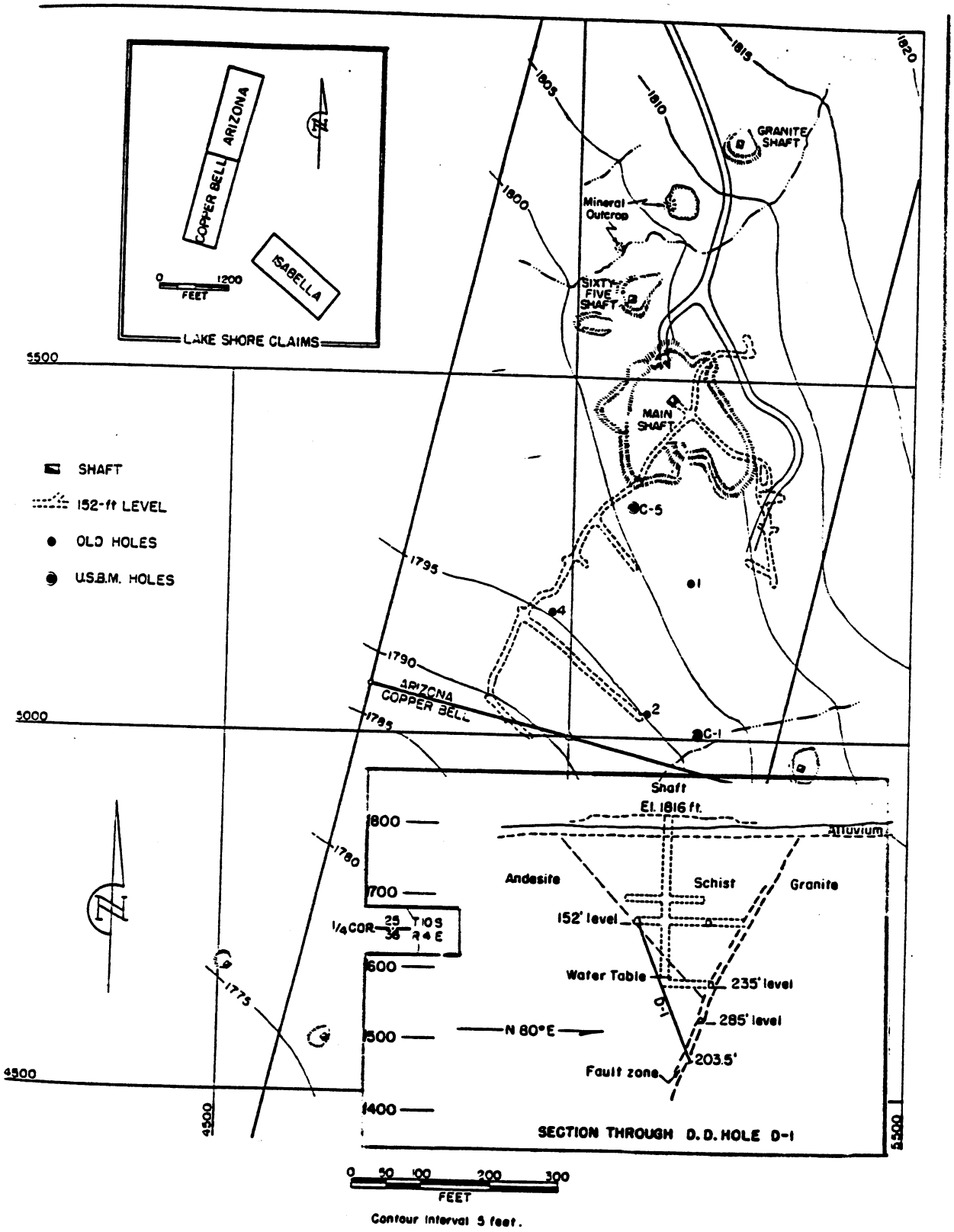


Figure 11 - Surface map, Lake Shore copper deposits, Pinal County, Ariz.

Section shows location of drill hole D-1 relative to main shaft. From Romslo (1950).

A2 Bull 137

Cty.	Dist.	Mine
Yavapai Cty.	- Eureka Dist.	- Southern Cross Mine - flat vein
	Cherry Creek	- Bunker } similar, 3 flat veins
		Golden Idol
	Walker	- Sheldon
		Mudhole
	Bugbing	- Iron King
		Union
		Little Jessie } same vein?
		Poland-Walker Tunnel
	Hassayampa	- Oro Flame - Sterling
		- Jersey Lily
		- Tillie Starbuck
		- Trapshooter, Rally Prop
	Black Canyon	- Golden Turkey
		Golden Belt
		Silver Cord
		French Lily
		Richinbar
	Pine Grove	- Fairview Tunnel
	Tiger	- OroBelle - Grey Eagle
	Black Rock	- Oro Grande
		- Gold Bar
		- Gram
	Weaver	- Octave
	Martinez	- Congress
Mohave	- Gold Basin	- Cyclopic
	Northern Black Mtns	- Mocking Bird
		- Pilgrim
	Oatman	- Tom Reed
		United Eastern

- Gold Road
- Moss
- Gold Dust
- Leland
- Sunnyside
- Iowa
- Hardy
- Gaddis - Perry
- Mossback

Union Pass - Katherine - Arabian
- Tyro
- Fresco
- Black Dyke
- see Schrader, USGS Bull 397

Chloride - Pay Roll
- Rainbow

Mineral Park - Tyler Mine

Cerbat - Golden Gem
- Cerbat
- Oro Plata

Cochise - Dos Cabezas - Dives, "Big Ledge"
Gold Prince

Golden Rule - Golden Rule or Old Terrible (possible zsporid)

Tombstone - Various

also Turquoise and Huachuca Distr. (not described)

~~Yuma~~ -

Yuma - Ciénega - see Bancroft, USGS Bull 451
- Rio Vista Northside mine (possible zsporid)
- Capilano
- Sue

Planet - Planet

Ellsworth - Bonanza or Hanquahola

- Socorro
- Hidden Treasure (possible gypsum)
- Alaskan (possible gypsum)

Florosa - Dutchman (disseminated in shale)
- Blue Slate

LaPoz or Weaver - Goodman (see USGS Bull 620)

Kofa is within the Kofa Natl. Wildlife Area

Kofa - King of Arizona
- North Star (need 1/4 Au to mine)

Alamo Region -

Sheep Tanks - Sheep Tanks
- Davis
- Others

Tank Mtns - (see AZ Bur. Mines Bull 134)
Gila Bend Mtns - " " "
Trigo Mtns - " " "
Walton Hills or La Posa
La Fortuna - Fortuna Mine

Maricopa - Vulture - Vulture (EMJ v. 111, no. 7 p 298-302, Min. ~~Eng~~ Jour. v14, p 9-11, 2830

Sunrise

Big Horn - El Tigre (flat fault-vein
Cave Creek - many mines
Agua Fria, White Picacho, Medway (Saddle Mtn.)
not discussed

Pinal -

Goldfields - Young or Mammoth
Pinal (Superior) - many, Belmont
Mammoth - many
other Districts not discussed - Saddle Mtn.,
Cottonwood, Old Hat, Owl Head

Pima - Baboquivari Mts. - West. Portion
- Old Hat, Greaterville, Arivaca dists. not discussed

Gila - Payson - Ox Bow
Gowan
Spring Creek or Young and Globe and Banner dists.
not discussed (see USGS PP 115)

Greenlee - Morenci - many mines (see USGS PP 43)
Twin Peaks Dist. not discussed

Santa Cruz - Oro Blanco - Old Glory (EMJ v. 96, p. 1006)
- Amsterdam (Econ. Geol., v. 39, p. 159)
- Margarita
not discuss Wrightson Dist.

Graham - Lone Star - one
Rattlesnake - Powers
Knothe

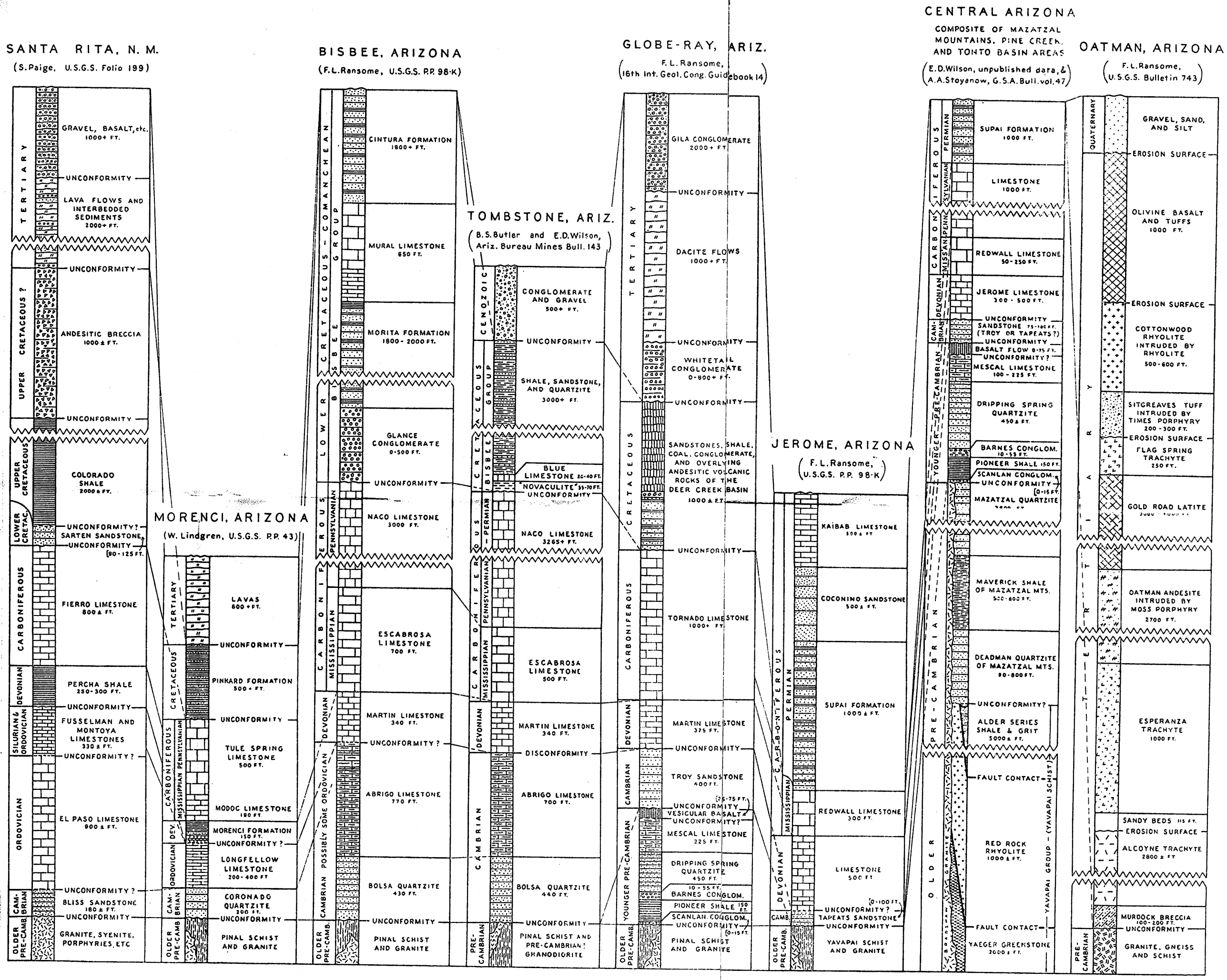


Plate III.—Generalized columnar sections.

R. I. 4097,
July 1947.

REPORT OF INVESTIGATIONS

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

ARIZONA MANGANESE-SILVER ORES[1]

By T. M. Romslo[2] and S. F. Revitz[3]

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INTRODUCTION

During 1940 and 1941 the Bureau of Mines examined a large number of silver mines in Arizona for their possibilities as producers of manganese ores. Although very little manganese ore had been produced from these mines, it was generally known that manganese oxides in appreciable amounts were associated with the silver ores. Following the examinations, the Bureau further investigated some of the ore deposits by diamond drill and other types of sampling. The results of these investigations, from the viewpoint of manganese, were discouraging. The investigations, however, did indicate that appreciable tonnages of manganese-silver ores have been left in some of the mines by the earlier operators. Most of these ores were too low-grade for direct-shipping as ores of manganese or silver and their beneficiation by ordinary processes was not economic. Exploitation of the ores appeared to be dependent upon the development of a low-cost milling method, which will yield a marketable manganese product and recover a high percentage of the silver.

Later, the Bureau of Mines constructed an experimental mill at Salt Lake City, Utah, for the treatment of manganiferous ores by the dithionate process, designed to recover manganese as a high-grade product. The dithionate residues can be treated by other processes for the recovery of additional values that may be present in the ore. This development focused attention on the manganese-silver ores of Arizona and led to setting up Bureau project No. 370,[4] which is the subject of this report.

1/ The Bureau of Mines will welcome reprinting of this report, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Report of Investigations 4097."
2/ Mining engineer, Bureau of Mines.
3/ Metallurgical engineer, Bureau of Mines.
4/ Chas. A. Kumke, project engineer.

On this project, five large samples of ore, totaling 66 tons, were mined from selected deposits during the period from September 1944 to May 1945 and were shipped to Salt Lake City. Each ore was tested for manganese extraction by the dithionate process and by other processes for the recovery of additional values.

ACKNOWLEDGMENTS

In its program of investigation of mineral deposits, the Bureau of Mines has as its primary object the more effective utilization of our mineral resources to the end that they make the greatest possible contribution to national security and economy. It is the policy of the Bureau to publish the facts developed by each project as soon as practicable after its conclusion. The Mining Branch, Lowell B. Moon, chief, conducts preliminary examinations, performs the actual investigative work, and prepares the final report. The Metallurgical Branch, O. C. Ralston, chief, analyzes samples and performs beneficiation tests.

With respect to the investigations reported in this paper, the functions of the Mining and Metallurgical Branches were carried out under the supervision of J. H. Hedges and S. R. Zimmerley, respectively. The dithionate laboratory and semipilot-plant tests were carried out by A. E. Back, W. F. Wyman, and K. E. Tame under the direction of S. F. Ravitz, the author of the metallurgical section of this report. The cyanidation and flotation tests were made by T. G. Chapman, Dean, College of Mines, University of Arizona, and consulting engineer to the Bureau at Tucson, Ariz., and by H. G. Poole and W. G. Sandell at the Salt Lake City laboratories.

LOCATION AND ACCESSIBILITY

Tombstone District

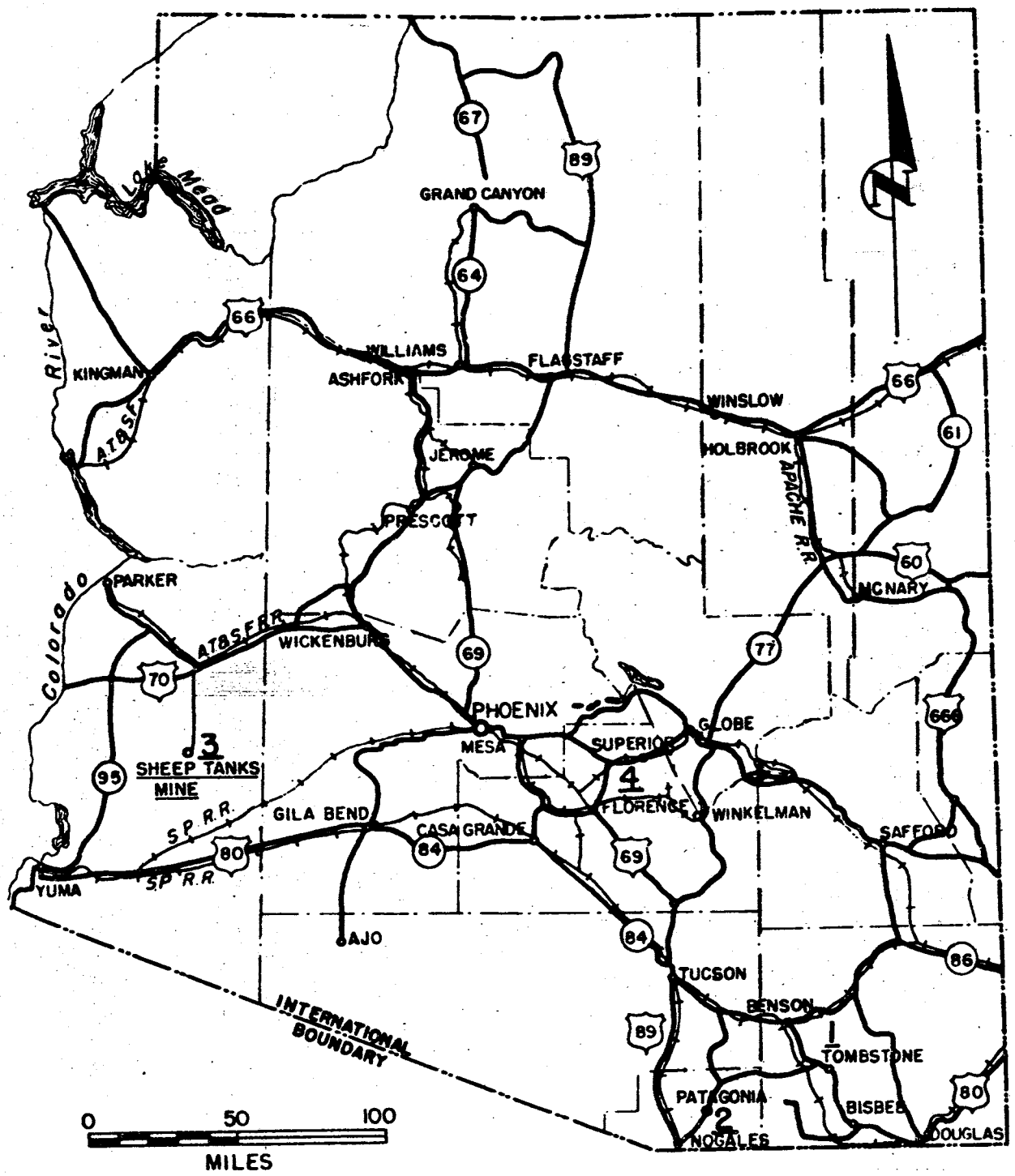
The Tombstone district is in western Cochise County in the extreme southeastern part of Arizona (fig. 1). Most of the mines are within a short distance of the town of Tombstone, which is on U. S. highway 80 and is also served by a standard-gage branch line from Fairbanks, a station on the Southern Pacific Railway.

Salvador Mine

The Salvador mine is in the Harshaw mining district in central Santa Cruz County, (fig. 1). It is about 12 miles south of the town of Patagonia, which is on Arizona highway 82 and is also served by the Southern Pacific Railway. It can be reached from Patagonia by traveling over an unimproved road to the village of Harshaw, thence three-quarters of a mile on the road to Mowry, thence to the left on a road of rather steep grade for half a mile, to the Hardshell-mine ore bins. Beyond the ore bins, $\frac{1}{4}$ mile of rough creek-bed road extends to the Salvador workings.

Sheep Tanks Mine

The Sheep Tanks mine, in the mining district of the same name, is in the east-central part of Yuma County (fig. 1). It can be reached from the



1. TOMBSTONE DISTRICT
2. SALVADOR MINE
3. SHEEP TANKS MINE
4. REYMERT MINE

FIG. 1-GENERAL LOCATION MAP, MANGANESE-SILVER ORES, PROJ. 370, ARIZ.

town of Salome, which is served by the Atchison, Topeka & Santa Fe Railroad, by traveling 8 miles west on U. S. highway 60, thence 27 miles south over a dirt road to the property.

Reymert Mine

The Reymert mine, in the Superior (Pioneer) mining district, is in the northeastern part of Pinal County (fig. 1). It is about 2½ miles southeast of the town of Superior, which is served by the Magma-Arizona Railroad and U. S. highways 60 and 70. It can be reached from Superior by traveling 6 miles southwest over the above-mentioned highway, thence 2 miles south over a good unimproved road to the property.

PHYSICAL FEATURES AND CLIMATE

Relief

Tombstone district. - The Tombstone Hills, in which the district is located, consist of a group of low, scattered mountains. They extend northwestward from the Mule Mountains and rise some 800 feet above the surrounding plain to an altitude of 5,339 feet. The plain slopes westward to the San Pedro River. The town of Tombstone, near the northwestern edge of the area, is at an altitude of 4,530 feet.

Salvador mine. - This mine is on the easterly slope of the Patagonia Mountains. The mountain system trends north-south and individual summits near the mine rise to altitudes of over 6,000 feet. The mine is in Hardshell Canyon at an altitude of 5,200 feet. Drainage is eastward to the Santa Cruz River.

Sheep Tanks mine. - The Sheep Tanks mine is at an altitude of 2,000 feet near the southern edge of the Little Horn Mountains. It lies within a northwest-trending belt, up to 2 miles wide, of rough, narrow ridges and peaks, which rise to a maximum elevation of about 2,800 feet. Canyon systems trend north, east, and west from a divide near the mine.

Reymert mine. - This mine is in a fairly rugged area, which, near the mine, has a maximum relief of about 700 feet. The main Alaska shaft (collar elevation 3,097 feet) is located a few hundred feet above the floor of a gulch on the west slope of a ridge that trends north-south. From a divide a short distance north of the mine, drainage is north to Queen Creek and south to the Gila River.

Climate and Vegetation

The climate of the several districts is typical of the intermediate altitudes of southern Arizona. It tends to be pleasant from October through April, with high temperatures generally prevailing during the remainder of the year. Annual precipitation in the districts ranges from a minimum of 6 inches near the Sheep Tanks mine to nearly 18 inches in the vicinity of the Reymert mine.

Vegetation is typical of the desert regions of southern Arizona.

HISTORY AND PRODUCTION

Tombstone District5/

The Tombstone district proper was discovered in 1877 and was developed to large production by 1880. Some of the mines had reached water level by 1882, and pumping was undertaken. Subsequently, metallurgical plants previously situated on the San Pedro River were established at Tombstone. Many of the large ore bodies had been mined out and others were down to water level by 1886. Production then took a sharp drop but, varying with conditions, has averaged more than a third of a million dollars a year to the present.

The approximate total production through 1936 has been estimated at $37,000,000. Of this amount, silver has accounted for 80 percent, the remainder being made up by gold, lead, and copper. During World War I, some high-grade manganese concentrates of ores from several mines in the district were shipped as chemical-grade ore.

Salvador Mine

This property was located and patented in 1880. It was first operated for a short period as a silver mine. Several years ago, after a long period of inactivity, mining operations were begun on a large outcrop of manganiferous-silver ore. Several open cuts and two stopes were opened. It proved difficult to mine and market the ore profitably for either its silver or manganese content. A few manganese shipments were made, but the ore proved too siliceous to meet the requirements of steel mills. The property is now idle.

Sheep Tanks Mine

The first mineral discovery in the Sheep Tanks district was an argentiferous-galena vein upon which J. G. Wetterhall located the Resolution claim in 1909. Location of other claims followed, but very little work was done until 1926 or 1927, when the Sheep Tanks Mine Co. of Nevada opened part of the Resolution vein. During the period starting late in 1928 and ending October 1929 the mine was operated by the Ibex Mines Co. In 1931, the Anozira Mining Co., which later became the Sheep Tanks Consolidated Mining Co., obtained the 12 original claims. This corporation located additional claims and during 1932 carried on extensive prospecting and development work. A 100-ton mill was installed and operated during 1934 and 1935. The mill was designed to extract the manganese by leaching with sulfur dioxide and the gold and silver by amalgamation and cyanidation. After treating 15,167 tons of ore, all operations were terminated. The property was purchased in 1935 by E. W. Mills, who had been general manager of the Sheep Tanks Corp. During 1939, J. Dillard, lessee, operated the property and shipped approximately 500 tons of ore. M. J. Toner, lessee, shipped 776 tons of ore from the property in 1940. Most of the ore from these two operations was sorted from dumps.

5/ Mainly from B. S. Butler, E. D. Wilson, and C. A. Rasor, Geology and Ore Deposits of the Tombstone District, Arizona: Arizona Bureau of Mines Bull. 143.

The gross value of ore shipped from the property is approximately $200,000. The mine has been idle since 1940.

Reymert[6]

The Reymert mine was located in 1886 by John Reymert and associates. A short time later it was sold to the Reymert Mining Co., which was controlled by a Mr. Van Dyke of Milwaukee, Wis. The company operated the mine until 1891 and during part of the period treated the ore in a mill by chloridization and panamalgamation.

In 1912, the Gunn-Thompson interests obtained an option to purchase the property and during 1913-14 sank the Alaska shaft to a depth of 410 feet. The property was explored no further until 1919 and 1920. During this period the Lincoln Issues Co. (affiliated with the Gunn-Thompson interests) and the Magma Copper Co. put down seven diamond-drill holes.

In 1925, W. Forbach and associates leased the property and operated the mine intermittently until 1941. James Tod, lessee, then took over and operated until the middle of 1944, when the mine was again leased to Forbach and associates. Most of the ore produced during recent years was shipped to the Magma smelter and the International smelter, at Superior and Miami, respectively.

Approximately 2,284,000 ounces of silver are reported to have been produced from the mine to 1945.

GEOLOGY AND ORE OCCURRENCE

Tombstone District[7]

The rocks of the Tombstone district range from pre-Cambrian to Quaternary in age. The oldest rock, Pinal schist, has been intruded by granitic and porphyritic rocks. Overlying this rock is the Bolsa quartzite, which is succeeded by a series of limestones. The Naco limestone, the uppermost of this series, has been intruded by dikes and sheets of quartzose porphyry. Above the Naco formation is the Bisbee group, which consists of a series of conglomerate, sandstone, quartzite, shale, and limestone. Following deposition of the Bisbee group, the rocks of the district were folded, faulted, and intruded by quartz latite porphyry and granodiorite. Later, the lower parts of the district were covered with rock detritus and some layers of sand and silt. The lower areas are now covered with a few feet of Quaternary gravel, sand, and silt. At least one basaltic eruption and some faulting occurred after the filling process.

In general, ore deposits are controlled by northeasterly striking fissures. Most of the ore occurs as replacement deposits at the junction of the fissures with folds or faults, although some deposits occur in the fissures away from other structures. Limestone is the most favorable host rock, although some deposits occur in shale and sandstone. The ore bodies are steeply dipping veins ranging from a few inches to 20 feet or more in thickness and extending vertically from 10 feet to as much as 200 feet. They are very irregular in shape, both horizontally and vertically.

6/ Mainly from letter report to Bureau of Mines by G. M. Colvocoresses, mining and metallurgical engineer, Phoenix, Ariz.

7/ See footnote 4.

Manganese minerals are closely associated with silver, which has been found in metallic form and in the minerals argentite, hessite, argentiferous-tetrahedrite, stromeyrite, bromyrite, and cerargyrite. The manganese occurs mainly as psilomelane, pyrolusite, and manganite.

Salvador Mine

The rocks occurring in the vicinity of the Salvador mine range in age from pre-Cambrian to recent. They consist of limestone, quartzite, conglomerate, and intrusive rhyolite and felsite. Boundaries between the various types of rocks are generally irregular, owing to faulting and the manner in which the intrusives have invaded the quartzite and limestone.

At the mine, mineralization occurs in a brecciated zone between siliceous limestone and rhyolite. The contact trends N. 35° W., and dips about 35° northeast. Manganese oxides fill cracks and coat breccia fragments and also occur in irregular bunches. The chief manganese mineral is pyrolusite.

Sheep Tanks Mine[8]

The rocks in the vicinity of the Sheep Tanks mine range in age from Tertiary to Quaternary. The oldest exposed rock is rhyolite. Resting upon the rhyolite, except at one place where a rhyolite and dacite breccia up to 10 feet thick is present, is a dacite flow. Rhyolite and dacite have been intruded by diorite porphyry, which forms large, irregular, crosscutting masses together with sills, and dikes. Overlying these rocks are irregular areas of breccia. An agglomerate overlying the rhyolite, dacite, and diorite-porphyry outcrops in one place. The area is surrounded by basalt and tuff, which is in contact with the older rocks. A mantle of gravel, sand, and talus covers the canyon bottoms.

The region has been affected by faulting, which has occurred during at least four periods. A fault zone occupied by the Resolution vein dips northward at low angles. The maximum dimensions of this vein, as indicated by outcrops and mine workings, are about 800 feet north to south by 700 feet west to east. Its thickness ranges from a few inches to about 40 feet.

The vein filling consists of irregular masses and streaks of limonite, pyrolusite, quartz, calcite, and porphyry. Gold and silver also are present, as is barite, which occurs in places as veinlike masses. Other minerals also are present.

Reymert Mine[9]

In the vicinity of the Reymert mine, Pinal schist has been intruded by dikes of a basic rock and later intrusions of rhyolite. Locally, the schistosity of the Pinal formation, which strikes north-south and dips to the east, has been affected by the intrusive dikes. The schist is partly covered by thin recent gravels and soil.

8/ Mainly from Eldred D. Wilson's Geology and Mineral Deposits of Southern Yuma County, Arizona: Arizona Bureau of Mines Bull 134.

9/ See footnote 5.

A steeply dipping shear zone in which the ore occurs strikes N. 10° W. and outcrops prominently for more than 3,000 feet. In many places the zone attains widths of more than 50 feet. Where exposed, mineralization occurs throughout the full width, but the higher-grade material is confined to narrow zones along both walls of the vein. The walls, where exposed by mining of the higher-grade portions of the vein, are schist.

The better grade of ore consists mainly of fine calcite, quartz, barite, fluorite, and manganese-iron oxides. Silver has been found as the minerals cerargyrite and argentite, but probably most of it is in some form that has not been identified.

WORK BY BUREAU OF MINES

Tombstone District

A 16-ton sample was obtained from the following properties: Oregon-Prompter, Lucky Cuss, Comet, Lucky Sure, Emerald, and Randolph.

Oregon-Prompter. - The timbered, 2-compartment Oregon shaft, as well as the headframe and hoist, were found to be in fair condition. The hoist was overhauled and repaired to permit entry to the mine.

The various manganese showings were examined, and five sites were selected where ore suitable for experimental purposes could be mined - one on the 100 level, south end (S1 stope), three on the 300 level between the shaft and Prompter claim, and one on the 300 level on the Prompter claim.

All the ore from the Oregon-Prompter was mined by single-jacking and was transported to the Oregon shaft partly by tramming in mine cars, partly by wheelbarrows, and some by carrying partly filled sacks.

Approximately 11 tons of ore was hoisted to the surface, but of this amount only about 6 tons was taken to make up the Salt Lake shipment. The remainder was left at the collar of the shaft.

Lucky Cuss. - Most of the manganese ore in the Lucky Cuss mine is in the south end of the property. The 100, 200, 300, and 400 levels were examined, and two places were selected for obtaining the required sample ore. The first was the south-end winze on the 300 level, approximately 1,200 feet south of the shaft. The other was on the 500 level about 1,000 feet south of the shaft.

Approximately 8 tons of ore was mined from these two places and hoisted to surface. In the final sacking, about 5½ tons was included in the Salt Lake shipment. The remainder was left at the collar of the shaft.

Comet. - The shaft and headframe at the Comet property were in very poor condition and not safe for use. No hoist or surface equipment of any sort was left on the property. The 200 and 300 levels were inaccessible. About 200 feet south of the shaft an old open raise from the 50-foot level to surface was examined and prepared for entry. A collar platform and windlass were built over the surface opening, and approximately 1 ton of sample ore was mined from the vein at the foot of this raise. The ore here was slightly over 4 feet in width.

Luck Sure. - The Luck Sure property joins the Lucky Cuss on the south. The workings of the Luck Sure mine are inaccessible. A number of years ago, Mr. Macia of Tombstone sank a 50-foot winze on a manganese showing on the Luck Sure property, close to the Lucky Cuss line. He found some manganese ore that carried about 8 to 10 ounces silver per ton. He mined about 60 tons of this ore and shipped one carload. His returns did not justify further work and some 15 or 20 tons were left on the dump. Mr. Macia stated that in his opinion considerable ore might be developed that would assay better than 20 percent manganese and 7 to 10 ounces silver per ton. About 1 ton of the remaining dump ore was sacked and included in the Salt Lake shipment.

Emerald. - The Emerald mine, one of the oldest and deepest of the district, also is inaccessible. Not much information about the mine workings was obtainable locally, but Macia, a resident of Tombstone for over 40 years, stated that he was in charge of operations for the Tombstone Development Co. during the 10 years when an effort was made to lower the water level in the mines of this district, and that as the water level was slowly lowered, mining operations in the Emerald mine were carried on down and that considerable ore was found that carried up to 20 percent manganese, 8 to 12 ounces silver per ton, and 2 or 3 percent lead. A grab sample was taken at one of the major dumps. This dump contains several thousand tons and, according to local miners, has been sorted for silver ore. The grab sample contained 6.59 percent manganese, 7.8 ounces per ton silver, 2.11 percent lead, and 70 cents per ton in gold. About 1 ton of this dump material was sacked and included in the Salt Lake shipment.

Randolph. - The Randolph mine is on the western end of the Tombstone district. There are several old shafts and some openings where stopes broke through to surface. Neither the shafts nor the stope openings are safe for use as an entry. According to Macia, the Randolph mine contained several ore bodies that ran about 20 percent manganese and also assayed 12 to 20 ounces per ton silver. A grab sample from one of the surface dumps (about 300 tons) assayed 17 percent manganese and 17 ounces per ton in silver. Approximately 1½ tons of this ore was sacked and included in the Salt Lake shipment.

Samples

The following samples were taken from the selected locations prior to obtaining the 16-ton experimental shipment:

Sample	Location	Mn, percent	Ag, ounces/ton
5341..	Prompter mine, 300 level...	12.71	4.1
5343..	Emerald mine dump.....	6.59	7.8
5344..	Lucky Cuss mine, 300 level.	36.90	3.3
5345..	Lucky Cuss mine, 300 level.	24.64	6.6
5346..	Lucky Cuss mine, 500 level.	25.09	8.2
5347..	Oregon mine, 100 level.....	29.07	2.8
5349..	Randolph mine, surface dump	17.12	17.3

Salvador mine

There are several open pits and two underground workings on the Salvador property. The underground workings consist of two stopes that are accessible from separate side-hill open cuts.

Two samples of the ore, in lots of 10 and 15 tons, were obtained from the property and shipped to Salt Lake City for metallurgical testing. The separate ore samples were obtained from the stopes in approximately equal portions.

Preliminary to mining the test samples of ore, three samples were taken as a check against nine samples obtained during examination of the property for manganese. The analyses of these samples and the general locations from which they were obtained are as follows:

Sample No.	Description	Mn, percent	Ag, oz./ton
1....	25-foot brecciated zone, stringers and bunches of Mn minerals in tunnel to most southerly stope..	11.70	13.90
2....	24-inch mineralized streak, same location as No. 1	21.30	35.00
3....	High-grade ore pocket, same location as Nos. 1 and 2.....	34.50	24.45
4....	Pillar in most northerly stope.....	15.90	12.85
5....	5-foot zone in open cut south of sample 1.....	18.50	12.80
6....	6-foot zone in open cut by natural cave northwest of sample 5.....	17.00	4.25
Check.	10-foot cut in same open cut as sample 6.....	12.10	3.10
7....	20-foot zone in open cut between samples 5 and 6.	12.10	11.95
Check.	12-foot cut in same open cut as sample 7.....	10.92	2.00
9....	15-foot zone, south end of most northerly stope..	16.17	18.55
10....	West face of deepened section of stone represented by sample 9.....	15.42	13.95
Check.	8-foot cut, same location as No. 10.....	16.67	21.80

Sheep Tanks Mine

A 10-ton sample of ore was obtained from the main stope of the Sheep Tanks mine. About 2½ tons of the sample was obtained by drilling and blasting material from several places in the roof. Similarly, 3½ tons of material was mined from the floor, and the remainder was obtained from pillars and humps.

As a guide to this operation, four samples were taken and analyzed. The analyses of these samples were as follows:

Sample No.	Description	Oz./ton Au	Oz./ton Ag	Mn, percent
5324..	5-foot vertical cut in roof of stope.....	0.12	2.9	4.45
5325..	8-foot vertical cut from an ore pillar.....	.14	4.6	9.24
5326..	9-foot vertical cut from an ore pillar.....	.23	11.6	5.94
5327..	9-foot vertical cut in floor of stope.....	.07	4.5	3.30

Reymert Mine

A 15-ton sample of ore taken from four places was obtained at the Reymert mine and shipped for testing purposes. Slightly over 90 percent of the ore was obtained in equal amounts from each of three underground locations. These were as follows: South side raise in footwall or west ore streak on 300-foot level; north drift in hanging wall or east ore streak on 250-foot level; and hanging-wall streak about 75 feet in from entrance to adit, which is about 200 feet south of Alaska shaft. The remainder of the large sample was taken from sample rejects that have accumulated over a period of 5 years.

As a guide to this operation, six samples were taken and analyzed. The general locations from which samples were obtained and the analysis of each sample are shown below:

Sample No.	Description	Mn, percent	Ag, oz./ton
9201..	Grab sample, 10 tons ore in bin.....	1.22	8.3
9202..	Composite of 6 channels across high-grade veinlet, handing wall 250-foot level.....	1.84	27.2
9203..	5-foot channel across face of north drift 300-foot level.....	2.40	2.45
9204..	30-foot channel across width of mineralized zone between high grade veinlets on 300-foot level...	1.68	1.3
9205..	Same as 9204.....	2.04	.5
9206..	Same as 9204.....	1.80	.3

METALLURGICAL DATA

The analyses of the 10- to 16-ton lots of the various ores shipped to the Salt Lake City laboratory of the Bureau for metallurgical testing are given in table 1. The Salvador, Tombstone, and Sheep Tanks ores were tested thoroughly on a semipilot-plant scale for the recovery of manganese by the dithionate process of sulfur dioxide leaching.[10/] Four or more continuous pilot-plant runs were made on each ore, the ore being treated at the rate of 16 to 30 pounds per hour for approximately 100 hours in each run. Cyanidation and flotation tests were made on the raw ores and on samples of the leach residues. Dithionate leaching tests on the Reymert ore were confined to laboratory tests.

Manganese Leaching

In the dithionate process, gas containing sulfur dioxide is passed through a suspension of the ore in calcium dithionate (CaS_2O_6) solution. The manganese is dissolved as manganese dithionate, and the SO_2 is oxidized mostly to sulfate ion, which precipitates out as calcium sulfate; part of the SO_2, however, is oxidized to dithionate ion. The leach residue, consisting of the insoluble portion of the ore and the precipitated calcium sulfate is filtered off and washed, and the filtrate is treated with milk of lime to precipitate manganese hydroxide and regenerate calcium dithionate.

10/ Ravitz, S. F., Wyman, W. F., Back, A. E., and Tame, K. E., The Dithionate Process for Recovery of Manganese from Low-Grade Ores: A.I.M.E. Tech Pub. 2064, Metals Technology, Sept. 1946, 10 pp.

The manganese hydroxide precipitate, after being filtered and washed, is sintered or nodulized to produce a manganese oxide product assaying more than 60 percent manganese. A large part of the zinc and copper in the ore is extracted in leaching, but, if necessary, such impurities can be eliminated or recovered in the process, so that a final product meeting ferrograde specifications can be produced. The quantities of lead, gold, or silver extracted are insignificant.

In most of the semipilot-plant and laboratory tests the ore was ground to minus 65 mesh and air containing about 3.3 percent SO_2 (to simulate waste smelter gas) was used for leaching. All four ores responded well to the dithionate process. Manganese recoveries of 90 percent or more were obtained readily, and ample dithionate could be formed under proper leaching conditions to make up for losses in washing the leach residue and the manganese hydroxide. The quantity of SO_2 introduced into the leaching cells was 2.5 to 3.5 pounds per pound of manganese extracted, of which 60 to 70 percent was consumed. Lime consumption usually ranged from 1.1 to 1.5 pounds per pound of manganese extracted. The weight of calcium sulfate precipitated during the leach was greater than the weight of manganese dioxide and impurities dissolved, so that the weight of dry residue was 6 to 20 percent greater than that of the ore and tended to increase as the manganese content of the ore increased.

TABLE 1. - Analyses of metallurgical test samples

Sample	Weight, tons	Analyses, percent								
		Mn	Cu	Pb	Zn	Fe	CaO	MgO	CO_2	BaO
Tombstone..	15	17.8	0.34	1.6	2.2	3.4	17.2	0.35	11.4	-
Salvador I.	10	13.5	0.12	1.1	1.3	1.9	0.4	0.05	-	-
Salvador II	15	15.2	0.12	1.5	1.3	1.6	0.2	0.2	-	-
Sheep Tanks	10	3.5	0.02	<0.1	<0.1	3.5	1.8	Tr.	-	-
Reymert....	15	4.75	<0.05	0.8	0.7	4.95	6.2	0.3	-	8.7

Sample	Weight, tons	Analyses, percent						Oz. per ton	
		Insol.	SiO_2	Al_2O_3	P	S	Co	Au	Ag
Tombstone..	15	26.1	22.1	3.8	0.1	0.2	0.01	0.01	7.5
Salvador I.	10	69.8	67.4	1.2	0.04	<0.01	-	Tr.	11.2
Salvador II	15	67.0	62.8	2.1	0.05	0.15	-	0.005	11.3
Sheep Tanks	10	83.5	64.9	10.5	0.12	0.07	0.02	0.25	8.0
Reymert....	15	60.8	51.3	-	0.7	1.25	-	<0.005	16.35

Cyanidation and Flotation

Typical results of cyanidation and flotation tests on the ores and on the leach residues are summarized in table 2, in which the minus 65-mesh residues refer to residues obtained by leaching minus 65-mesh ore; the minus 200-mesh residue listed under the Sheep Tanks tests was produced by regrinding minus 65-mesh residue. In the pilot-plant operations the leached slurry was usually neutralized to a pH of about 3.5 to minimize corrosion of the filter; extraction of silver and gold by cyanidation was approximately the same for residues from neutralized slurries as for those from unneutralized slurries, but the former consumed more cyanide and gave poorer results by flotation. Data are therefore given in table 2 only for unneutralized residues. In the flotation tests two stages of sulfidization were used.

TABLE 2. - Summary of cyanidation and flotation tests

	Size, mesh	Time, hours	Grade concentrate, ounces per ton		Extraction, percent 1/		NaCN consumed, pounds per ton of ore
			Ag	Au	Ag	Au	
			Salvador				
Cyanidation:							
Ore.....	-65	96	-	-	6.4	-	6.3
Residue.....	-65	24	-	-	89.6	-	0.9
Flotation:							
Ore.....	-65	-	12.6	-	3.3	-	-
Residue.....	-65	-	100.5	-	86.3	-	-
Cyanidation of residue flotation concentrate.....	-65	-	-	-	84.6	-	2.6
			Tombstone				
Cyanidation:							
Ore.....	-65	96	-	-	27.3	-	5.3
Residue.....	-65	24	-	-	84.4	-	4.9
Flotation:							
Ore.....	-100	-	84.8	-	10.1	-	-
Residue.....	-65	-	55.7	-	78.9	-	-
Cyanidation of residue flotation concentrate.....	-65	-	-	-	72.2	-	2.9
			Sheep Tanks				
Cyanidation:							
Ore.....	-65	48	-	-	14.1	97.4	0.25
Residue.....	-65	46	-	-	39.4	94.4	0.65
Residue.....	-200	47	-	-	43.3	99.0	0.54
Flotation:							
Ore.....	-200	-	12.5	1.5	20.0	90.5	-
Residue.....	-65	-	20.2	2.3	12.8	42.2	-
			Reymert				
Cyanidation:							
Ore.....	-65	96	-	-	17.2	-	2.5
Residue.....	-65	96	-	-	23.4	-	4.0
Flotation:							
Ore.....	-65	-	116.0	-	10.6	-	-
Residue.....	-65	-	77.1	-	36.7	-	-

1/ Based on total in ore.

Salvador Ore. - The results on the two lots of Salvador ore (see table 1) were substantially the same. Very poor results were obtained by cyanidation or flotation of raw ore. The leach residue, however, responded well, giving extractions of about 90 percent by cyanidation and recoveries of about 85 percent by flotation.

Tombstone Ore. - The results for the Tombstone ore were similar to those for the Salvador. Very little of the silver was recovered from the raw ore, but from the leach residue about 85 percent was extracted by cyanidation and nearly 80 percent by flotation.

Sheep Tanks Ore. - Excellent recovery of gold was obtained from both the raw Sheep Tanks ore and the leach residue by cyanidation and from the raw ore by flotation, although very fine grinding was necessary prior to flotation. Silver recovery, however, was very poor, even after 97 percent or more of the manganese had been extracted from the ore and the residue had been reground to minus 200 mesh. Only 77 percent of the silver was extracted under the extreme conditions of grinding the residue with cyanide solution in a pebble mill for 96 hours.

Reymert Ore. - As with the Sheep Tanks ore, the recovery of silver from the Reymert ore before or after leaching out the manganese was very poor.

Summary

The Salvador and Tombstone manganese-silver ores are not amenable to direct cyanidation or flotation for the recovery of silver. However, 90 percent or more of the manganese can readily be recovered as a ferrograde product by the dithionate process of sulfur dioxide leaching, and 80 to 90 percent of the silver can be recovered from the resulting residue by cyanidation or flotation.

The manganese ~~can be~~ recovered readily from the Sheep Tanks and Reymert ores by the dithionate process, and excellent extraction of gold can be obtained from the Sheep Tanks ore by cyanidation either before or after extraction of the manganese. Recovery of silver from either of these ores by cyanidation or flotation is poor, however, even after virtually all the manganese has been leached out. In view of their low manganese contents and the poor recovery of silver, it is doubtful whether treatment of these ores by the dithionate process, followed by cyanidation or flotation of the leach residues, would be feasible.

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deposits and lenses of chromite are elongated parallel to flatly plunging lineations in the foliated peridotites. The chromite contains 54 to 59 percent Cr_2O_3 with a chromium to iron ratio of 2.2 to 2.8.

In addition to the economically important nickel laterite at Riddle, Oreg., nickel laterites overlie fresh to moderately serpentinized Jurassic or Cretaceous peridotite elsewhere in scattered areas in Tertiary erosion surfaces in southwestern Oregon, northwestern California, and the western Sierra Nevada, Calif. It is estimated that these undeveloped deposits have a resource potential of 96,000,000 t of laterite and saprolite containing 0.7 to 1.2 percent nickel and 0.05 to 0.08 percent cobalt.

Arizona molybdenum mineral associations as keys to ore deposit metallogenic types

A comprehensive literature survey by J. C. Wilt and S. B. Keith (Arizona Bureau of Geology and Mineral Technology) has located some 300 occurrences of molydenum in Arizona, the world's third largest molybdenum producer. In Arizona, molybdenum occurs in four major geologic habitats: (1) as molybdenite (also as lindgrenite and ferrimolybdite oxidation products) in the potassic cores of lower Tertiary porphyry copper sulfide systems, (2) as wulfenite in the oxide zone of Upper Cretaceous and middle Tertiary lead-silver-zinc deposits, (3) as powellite and molybdenite associated with scheelite and wolframite in tungsten fissure vein deposits, and (4) as ilsemannite, umohoite, and jordisite associated with uranium and vanadium oxysalts in sandstone uranium deposits on the Colorado Plateau.

In Arizona's Basin and Range province, the first two occurrence types are almost mutually exclusive. Molybdenite usually occurs in the potassic cores of porphyry copper sulfide systems near the center of the district zoning. Little or no wulfenite is found anywhere in those sulfide systems. In contrast, much larger amounts of wulfenite are found in the oxidized portions of lead-silver-zinc districts. None of these districts has produced more copper than lead plus zinc. Also, wulfenite-bearing districts consistently lack molybdenite, contain more lead than zinc, and are associated with more potassic igneous rocks than those districts that contain porphyry copper mineralization. Thus, the occurrence of large amounts of wulfenite is a guide to lead-silver-zinc districts but not to porphyry copper districts.

The unoxidized zones of wulfenite-bearing lead-silver-zinc deposits contain no reported molybdenum minerals or anomalous molybdenum contents. This fact, combined with the late paragenetic occurrence of wulfenite (generally after cerussite crystallization), suggests that molybdenum in the oxide zones of lead-silver-zinc deposits is exotic in character and was transported to the sites of oxidizing lead-silver-zinc deposits by meteoric ground waters, where it reacted with the oxidized lead minerals to form wulfenite.

Greenstone in the Havallah Formation, Nevada

Geologic mapping by D. H. Whitebread and M. L. Sorensen in the southern East Humbolt Range, Nev., has disclosed several large units of greenstone in the Havallah Formation of late Paleozoic age. The greenstones are of particular interest because of their potential for the occurrence of massive sulfide deposits. Locally, the greenstones contain small siliceous manganese deposits and copper-bearing quartz veins, but no disseminated sulfides or their gossans have been found.

Initial strontium ratios of plutonic rocks along the "Uinta trend," northwestern Utah

W. J. Moore and R. A. Armin report that initial strontium ratios for Upper Cretaceous and Tertiary plutonic rocks increase systematically westward from the Park City area (~0.7060), through the Bingham mining district (~0.7085), to the Gold Hill district (~0.7010) on the Utah-Nevada border, a distance of over 200 km. These igneous centers lie along an inferred westward prolongation of the Uinta arch commonly termed the Uinta trend; emplacement of the plutons was apparently guided by a deep-seated zone of crustal instability.

More than one source or mechanism of generation is necessary to explain the westward increase. For instance, the magmas may have been derived from progressively shallower source regions westward from the Park City area or from a lower crustal source and differentially contaminated by sedimentary rocks enriched in radiogenic strontium. "Hot spots" in the belt of metamorphic core complexes along the Utah-Nevada border may have enabled a more efficient scavenging of radiogenic strontium during magma generation.

Massive copper sulfide deposit of syngenetic- epigenetic origin, north-central Nevada

Sulfur isotopes and textures in sulfide minerals at the Big Mike mine, Pershing County, north-central Nevada, have been investigated by R. O. Rye and R. J. Roberts. The sulfides are of two contrasting textural and isotopic types: early fine-grained laminated framboidal pyrite with a $\delta^{34}S$ value of -22.3 per mil and later coarse-grained pyrite and chalcopyrite with $\delta^{34}S$ values ranging from -6.36 to $+5.54$ per mil. Coarsely crystalline pyrite-chalcopyrite pairs in equilibrium apparently formed at temperatures between 250° and 310°C.

These data are compatible with the formation of the early framboidal pyrite syngenetically on the sea floor in

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Geologic development of the Cordilleran metamorphic core complexes

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PALEOZOIC METASEDIMENTARY ROCKS OF THE SOUTHEASTERN MOJAVE DESERT REGION, CALIFORNIA AND WESTERN ARIZONA

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Deformed, regionally metamorphosed Paleozoic strata occur as isolated outcrops throughout the southeastern Mojave Desert region of California and adjacent western Arizona (Figure 1). Paleozoic strata in the southeastern part of this region, including the Palen, Arica, Big Maria, Little Maria, Riverside, and Buckskin Mountains, are metamorphosed equivalents of the classic cratonal Paleozoic sequence of the western Grand Canyon, Arizona (Figure 2A). Farther northwest, in the Kilbeck and Fenner Hills and in the Old Woman, Piute, and Little Piute Mountains, metamorphosed Paleozoic strata are correlated with nonmetamorphosed Paleozoic sequences transitional between cratonal and miogeoclinal as exposed in the nearby Providence, Marble, and Ship Mountains (Figure 2B). Throughout the region, Precambrian crystalline rocks are commonly exposed unconformably beneath the metamorphosed Paleozoic sequence, and Mesozoic metasedimentary rocks commonly overlie it. Original lithologic features, fossils, and depositional thicknesses of the Paleozoic strata in the region generally have not been preserved because of metamorphism and severe ductile deformation. The strata are thus correlated solely on the basis of general lithology and stratigraphic sequence.

Paleozoic epicontinental strata once extended continuously from the southern Great Basin and Colorado Plateau provinces across the Mojave Desert region at least as far west and southwest as the Big Maria and Palen Mountains. Relict exposures of this sedimentary blanket and the underlying Precambrian continental basement in the southeastern Mojave Desert region define a terrane which has been disrupted by Mesozoic thrust faults and by Tertiary detachment faults but which otherwise appears to be structurally coherent. The Jurassic Mojave-Sonora megashear (Anderson and Silver, 1979), if this fault extends northwestward from the area where it has been mapped in Sonora, Mexico, into the Mojave Desert region, must pass somewhere southwest of the Paleozoic exposures in the Big Maria and Palen Mountains. Paleozoic epicontinental strata correlative with those of the southeastern Mojave Desert region occur 100 km to the west in the San Bernardino Mountains and in the Victorville area (Stewart and Poole, 1975; Miller, in press). Assuming that these western Paleozoic outcrops are autochthonous, Paleozoic paleogeographic trends which can be traced through the southeastern Mojave Desert apparently extend across the southwestern Mojave as well until finally terminating against the San Andreas Fault (Stewart and Poole, 1975). If this assumption is valid, it would appear improbable that any major fault passes between the southeastern and southwestern Mojave Desert regions, meaning that the Mojave-Sonora megashear would most likely pass south of the San Bernardino Mountains and come to an end against the San Andreas Fault.

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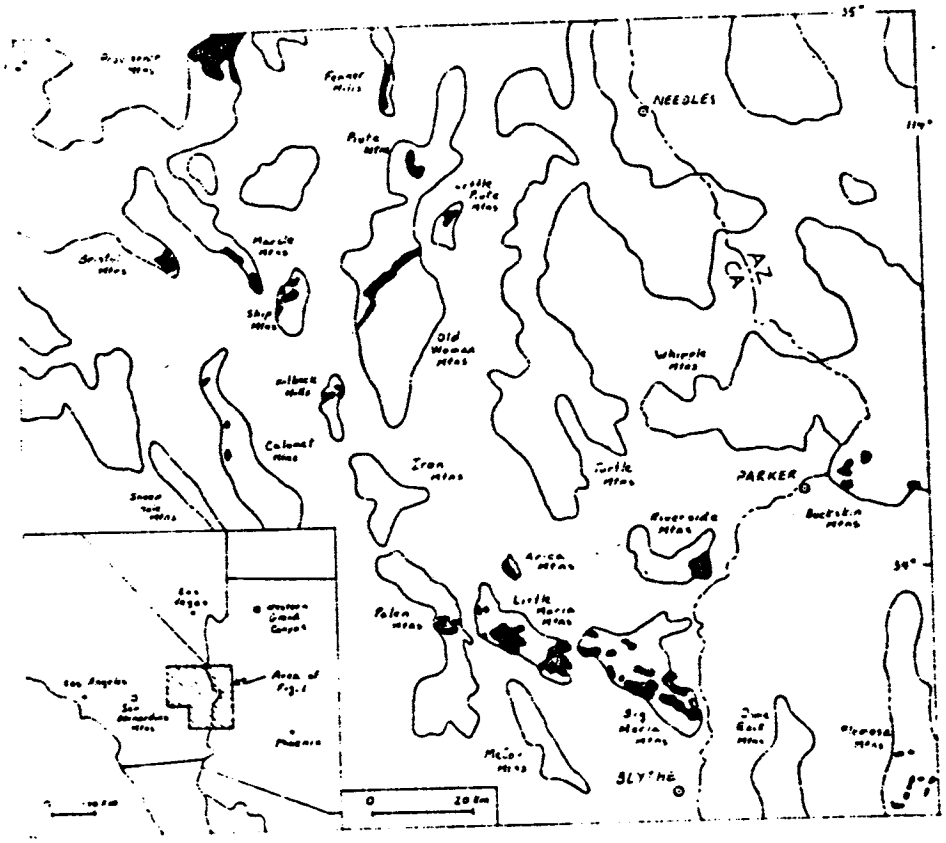

Figure 1. Map showing Paleozoic outcrop localities in the southeastern Mojave Desert region. Mountainous regions shaded; Paleozoic outcrops solid. The Paleozoic strata are metamorphosed and ductilely deformed at all localities except the Providence, Marble, and Ship Mountains.

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