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THE MINERAL HILL - DAISY MINES

General Geology

F. D. MacKenzie, Geologist, Banner Mining Co.
Tucson, Arizona

INTRODUCTION

The Mineral Hill-Daisy Mine area herein described is situated in the Pima Mining District, Pima County, Arizona, and entails Sections 35, T16S, R12E and Section 2, T17S, R12E. The topography is gentle with several small hills that are erosional remnants of past orogenic disturbances. The average elevation is about 3,300~~0~~ feet and the area has a gentle drainage to the east into the Santa Cruz river, an intermittent stream. The annual rainfall is approximately 11 inches. This property is owned by the Banner Mining Company, a Nevada corporation.

ACKNOWLEDGEMENTS:

Acknowledgement is hereby given to Mr. A. B. Bowman, General Manager & Vice President of Banner Mining Company for permission to publish this article and to the U.S. Bureau of Mines for the use of the cited references.

~~HISTORY~~

GENERAL GEOLOGY (1)

The Pima Mining District is on the eastern margin of the Sierrita Mountains to 30 road miles south-southwest of Tucson. It includes the subdistricts of Mineral Hill and Twin Buttes. A plain, ranging in altitude from 4,500 feet on the west to about 3,000 feet on the east, slopes gently eastward toward the Santa Cruz River. However, this plain is surmounted by Mineral Hill, Helmet Peak, and Twin Buttes, which rise prominently above the piedmont. Drainage is eastward to the Santa Cruz River.

In general, the Sierrita Mountains are composed of a granitic core with metamorphosed sedimentary rocks on the west slope and much less altered sediments on the east. Coarse-grained intrusive igneous rocks, ranging from granite and quartz monzonite to granodiorite, underlie much of the eastern piedmont. Some intrusive dikes cut the sediments and probably are related to the granitic intrusion.

The regional structure has been complicated by folding, overturning, low-angle thrust faulting, and steeply dipping faulting; howver, much of the complicated structure has not been worked out.

HISTORY (2)

The lode-mining claims at the Mineral Hill property originally were located about 1882. The Emperor Copper Mining Company developed the copper deposits from 1882 until 1884, when the decline in the copper market forced it to close. It is reported that Mineral Hill Mining Company was formed in 1889 and took over the property. In 1894 this company consolidated with the Copper King Company which operated the mine until 1897. In 1897 the consolidated company was reorganized as the Azurite Copper & Gold Mining Company.

In 1898 the Azurite Copper & Gold Mining Company constructed a small furnace at the Mineral Hill mine and produced copper for about a year. The mine then remained idle until 1904, when the company was taken over by the Mineral Hill Consolidated Copper Company which operated it until 1907. It then was closed because of the financial panic of that year. The mine was operated again in 1912 by this same company but was closed again in September 1913. In 1916 the old smelter was enlarged and production was resumed for a few years until the mine finally was closed in 1921. It remained shut down until 1951.

About 1951 the Barnsdall Corporation of New York City acquired control of the Mineral Hill Consolidated Copper Company. The last production evidently was done under the direction of this company. In 1929 the charter of the Mineral Hill Company expired, and the total assets were taken over the by Barnsdall Corporation.

(1) U.S. Bureau of Mines Information Circular #7786

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It is reported that 9000 tons of high-grade copper ore was produced before 1889. From 1889 to 1894, 4,000 tons, averaging 12.5 per cent copper, is said to have been shipped to El Paso; from 1895 to 1897, about 2,500 tons were shipped, reportedly ranging from 10.7 to 20.0 per cent copper. From 1898 to 1899, 9,600 tons of ore are said to have been smelted in the small furnace of the Azurite Copper & Gold Mining Company. This ore is supposed to have produced 800,000 pounds of copper matte, ranging from 65 to 70 per cent copper.

No production records are available from 1899 to 1915. It is said that from 1915 to 1917, about 46,000 tons of ore were mined, which averaged 3.8 per cent copper and 0.77 ounce of silver a ton. From 1917 to 1921 the lower levels of the mine were developed, but evidently little or no ore was produced.

The Mineral Hill mine remained closed from 1921 until 1951, when the Banner Mining Company obtained an option on the property and reopened it with Government exploration assistance under the Defense Production Act of 1950. From August 1951 to December 1952 this company pumped out the mine, rehabilitated most of the old underground workings, and thoroughly sampled them. With indication of enough ore, the company started to construct a 400-ton flotation plant in 1953 with the assistance of the Defense Materials Procurement Agency. It was completed and placed in operation in June 1954. The Mineral Hill mine began production early in 1953, the ore was stockpiled on the surface until the mill could be completed.

Meanwhile, the Banner Mining Company had located another orebody by geophysical means some 3,000 feet east of the Mineral Hill incline and had explored it by surface diamond drill holes. In 1953 a vertical shaft, the Daisy, was sunk in this orebody. A considerable amount ofoxidized copper ore was shipped to International Smelting & Refining Company Inspiration smelter. Sulfide ore from this shaft later was treated in the company flotation plant. The concentrates are shipped to the American Smelting & Refining Company, El Paso, Texas smelter.

GENERAL STATEMENT

The location of the ore bodies in the Mineral Hill-Daisy area was controlled primarily by faulting and favorable beds. The ore bodies are of the Pyrometasomatic and replacement types, of these two the first type is the more important as to size and grade.

SEQUENCE OF EVENTS

1. From the ~~pPre-Cambrian~~ to the Cretaceous time this general area witnessed sedimentation and erosion accompanied by various orogenic disturbances. Field evidence shows that several unconformities are present in the geologic column in this area occurring during the Ordovician, Silurian periods and again during the Triassic-Jurassic

2. During the Cretaceous period of time thrusting and faulting occurred with accompanying vulcanism.

3. Intrusions of granitoidal rocks followed with subsequent garnetization of the Permian-Pennsylvanian formations adjacent to the intrusions.

4. Mineralization followed the pyrometasomatism with chalcopyrite the chief primary ore mineral.

5. Overthrusting and shearing occurred with displacement of the various ore bodies.

6. Oxidation and secondary enrichment followed by a drop in the local water table.

7. Recent faulting has had some effect upon the erosion and topography in this area.

STRUCTURE

The structural conditions ~~at the Mineral Hill-D~~aisy area are very complex as well as very interesting. These conditions are interpreted through surface and underground mapping and the results of diamond drilling information.

Although structural features were very important factors in the mineralization of the area, they were not the sole determinants. Favorable beds played an important part as well in the control of ore localization.

The major portion of mineralization occurred along the Mineral Hill fault which extends in a general east-west direction for well over a mile. This fault is premineral and has various formations as footwall and hanging wall along its strike length. The orebodies along this fault are sporadic and very irregular in shape. The general dip of this thrust fault is about 35 degrees to the south. It is along this fault that several igneous intrusions occurred prior to and related to the mineralization of the district. These intrusions have a very low grade pyrite content.

Associated with the Mineral Hill thrust fault are several northerly striking shear zones which are post mineral in age. These shear zones are nearly vertical in most cases with a few having a steep easterly dip. Along some of these post mineral shear zones some transported or secondary mineralization has taken place to shallow depth. Field evidence indicates that some of these post-ore shears moved up to several hundreds of feet in a northerly direction.

An open breccia is encountered underground in the footwall of the ore bodies where the post-mineral thrusting brecciated the competent hornfels and deformed the more plastic overlying limestones.

GENERAL MINERALOGY

The chief primary ore came as chalcopyrite with minor bornite. The ore-bearing solutions followed various courses, some replacing the thin layers of limestone between the hornfels in the Naco formation, some replacing limestone at the contact of Permian and Cretaceous formation. In most cases, however, the chalcopyrite was injected into the garnetized limestones close to the igneous contacts.

SUPERGENE MINERALIZATION

In the Mineral Hill-Daisy area chrysocolla was the chief ore mineral in the oxidized zone with small amounts of Tenorite, Melaconite, Azurite, and Malachite. Several fine specimens of Azurite crystals up to the size of hens eggs were found in the oxide zone and have now become collectors items.

The enriched supergene sulfide zone in this area is relatively thin with chalcocite and cuprite being the main constituents in the Daisy area. This zone was deprived of extensive secondary sulfide enrichment by a limestone footwall which neutralized the descending copper-bearing acid solutions. These acid solutions descending along the dip formed a vein comprised chiefly of chrysocolla several feet thick and extending down to a depth of several hundreds of feet below the present surface. The general grade of this supergene ore is considerably greater that that of the primary hypogene sulfides below indicating that the vein had been somewhat enriched before erosion carried away the upper portion. The leached zone above the Mineral Hill-Daisy orebodies is virtually non-existant or only a few tens of feet in a few cases. The leached zone has been recently eroded away and was probably several hundreds of feet higher than the present surface as indicated by vein mineralogy and inferred structural conditions.

Native copper, silver and wulfenite are present in the secondary enrichment zone in very small proportions. The native copper is found mainly along slippage planes as very thin sheets. Wulfenite crystals up to $\frac{1}{4}$" across are fairly abundant in spots throughout this zone. Smithsonite is present only in small amounts in the present workings, but elsewhere on the property it was mined in small underhand ~~sti~~ stopes to shallow depths.

HYPOGENE MINERALIZATION

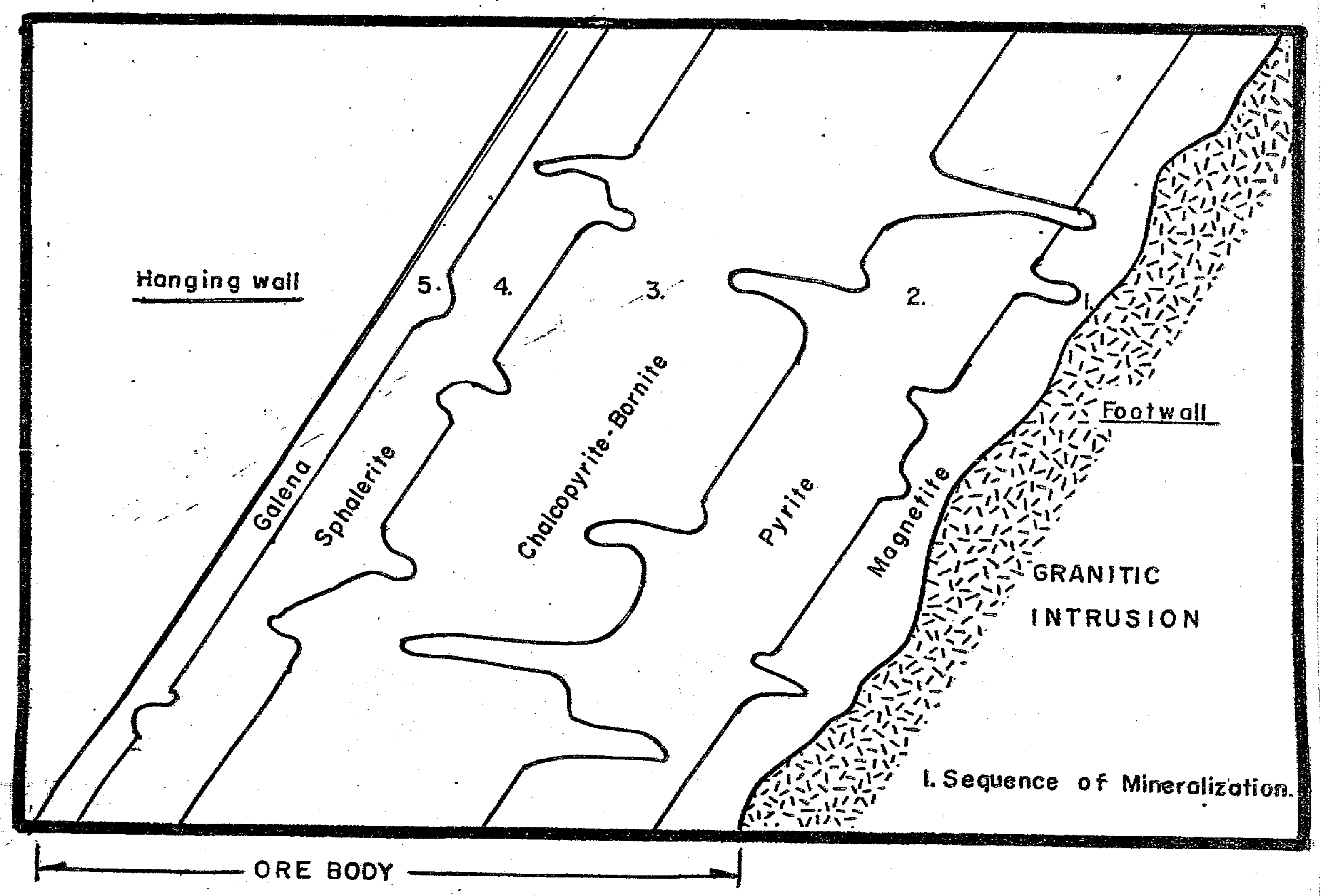
The primary ore minerals are comprised chiefly of chalcopyrite with some bornite and varying proportions of pyrite and sphalerite.

Magnetite is present in the hypogene zone and has been localized primarily in close proximity to the igneous intrusions. The magnetite was the first to form with pyrite next, then followed by chalcopyrite, bornite, sphalerite and galena.

Small amounts of scheelite and molybdenite are dispersed throughout the orebodies and are localized close to the footwall.

These latter two minerals are not of sufficient quantities to warrant separating in mills of small daily tonnage capacity.

There is a distinct zonal arrangement of the ore minerals that can be observed underground in the Mineral Hill Mine and even more pronoucedly in the Daisy Mine. In each case we have the igneous intrusive in the footwall which caused the mineralization. In order of formation and sequence going away from the igneous mass we have zones of magnetite, pyrite, chalcopyrite, bornite, sphalerite and galena. There is definite interfingering of the zones with each other as depicted in the generalized N-S vertical section (Fig. #1) of the ore bodies. As a result of these magnetite zones, several hidden orebodies were disclosed by geophysical means and by later diamond drilling.



DIAGRAMMATIC REPRESENTATION OF THE ZONAL ARRANGEMENT OF ORE AT THE MINERAL HILL-DAISY MINES AREA.

TIME			SEDIMENTS	IGNEOUS ROCKS	STRUCTURE	Degree of Permeability
CENOZOIC	QUATERNARY	Recent	Present Stream Alluvium	Mainly Basalt Flows	Minor Normal Faulting & Tilting UPLIFT	Generally High & Some Low
		Pleistocene: Late, Middle, Early	Terrace Deposits Basin Fill			
			Erosion			
	TERTIARY	Late: Pliocene	Gila Formation		Large Scale Normal Faulting UPLIFT Mountains Attenuated	High to Low
			Erosion			
		Middle: Oligocene	Helmet Fanglomerate Pantano	Superior Dacite Turkey Track And.	Thrust Faulting Present Mtn Chains forming	Medium to Low
		Early: Eocene	San Xavier Minetta White Tail Congl.	Andesite Flows & Dacite Tuffs		
			Erosion			
		Early: Paleocene	Claflin Ranch	Canelo Cat Mtn Rhyolite Silverbell & Equiv.	Thrust Faulting	Range of Normal Faulting
MESOZOIC	CRETACEOUS	Late	Erosion	Rhyolite, Tuff & Flows Quartz Monzonite, Copper Mineralization Epidotized & Chloritized Andesite		Range of Thrusting Generally very Low
		Early	Sonoita Group Amole Arkose Marine & Continental Dep. Bisbee Group			

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HYDRAYLIC SAND FILL AT MINERAL HILL MINE

General:

The Mineral Hill Mine is a copper mine owned and operated by the Banner Mining Company. It is located in the Mineral Hill Mining District, Pima County, 14 miles south of Tucson, Arizona.

It is an underground mine serviced by two shafts, one a compartment and a half 500 foot vertical shaft, the other a 900 foot incline hoisting shaft. It produces approximately 350 tons per day.

Hydraulic sand was first used to mine the 500 - 300 ore body. This orebody was of the clay-garnet type and contained approximately 100,000 tons. It measured 180 feet long and averaged 60 feet wide. The foot wall was granite and the hanging wall limestone. Their average dip being about 35°. Both walls were very irregular in dip, some places being almost flat and others almost vertical.

At first we tried mining the orebody by the shrinkage system. This proved unsuccessful because of its irregularity, but we found the optimum limits that the ore and hanging wall could be opened up along the strike and still be self supporting. This limit was 25 feet and was the basis of our stoping method. It was decided to run horizontal slot cut and fill stopes 25 feet wide perpendicular to the strike. Once we settled on the mining system, the next problem was transferring the usual mine fill down such a flat irregular dip. Testing was done on the mill tailings by Equipment Engineers Inc. of San Francisco and it was found that after desliming they would make a satisfactory fill material. We refer to this fill as hydraulic sand.

Hydraulic Sand Preparation Plant

The hydraulic sand preparation plant is located at the collar of the inclined shaft. Mill tailings are pumped by a 3 inch Wemco sand pump through a D10B Krebs cyclone located on top of a 14 foot diameter, 16 foot high steel tank. This tank will hold a 40 ton batch of hydraulic sand. While the tank is being filled the sand is agitated by a Wemco Devereaux type 4 blade propeller.

The hydraulic sand is fed into the stopes through 2 inch standard victraulic pipe. This pipe line has a 3" rubber pinch valve at the tank discharge and no other valves or quick bends. The sand will flow freely at 77% solids. You will notice from the screen analysis that the sand contains 10% -325 mesh. These slimes are very important from the standpoint of lubricating the pipe. They are held to a minimum because of their poor settling qualities.

Two men are required for the operation of filling. ne a sand plant operator on surface and the other a sand man underground. They communicate through two Signal Corps EE-8 telephones. The 2 inch line is flushed with water and compressed air before and after each pouring. The underground sand man is responsible for all sacking and sealing of the chutes and manways. To clarify the advantage of the Hydraulic Sand as a fill I will discuss two mining methods used at the Mineral Hill Mine.

Horizontal Cut and Fill Method

On the 500 level, chutes were cut in the footwall granite on 35 foot centers. Two compartment raises were driven on the 70° dip to the ore. The raises were then changed to a 45° - 6 x 8 raw raise and were driven to the 300 level. These raises were used for ventilation and service.

As soon as a raise was completed the actual stoping operation was started. A 7 x 8 slusher I-drift was started off the raise at the point where the ore was first contacted. These I-drifts were run horizontal and from footwall to hangwall. As soon as the I-drift was completed it was slabbed to a 25 foot width; this completed the first horizontal cut. The cribbed chute and manway were raise and the stope filled within two feet of the back with hydraulic sand. Once the stope was filled, a new 8' x 25' cut was started off the raise to start a new cycle.

In a fe instances the ground became too loose for safe mining. We would clean the stopes out, raise the chute and manway and fill them tight with sand. This meant we had to drive new I-drifts and start a new undercut. The original stoping method called for a 25 foot stope and 10 foot pillars. We found the sand so satisfactory that most stopes were mined against the sand of the adjoining stope

The most satisfactory slushing equipment proved to be a 15 H.P. electric slusher equipped with $\frac{1}{2}$" 6 x 19 IWRC VHS preformed wire rope and AB 36" Pacific slusher buckets.

All drilling was done with jack leg type drills and 8'-7/8" hex double diamond alloy steel fitted with a 1-3/8" threaded carset bit. All holes were drilled horizontal and blasted electrically with Millisecond Delay Electric Primers and Semi-Gelatin 40% dynamite. Considerable research was carried out to obtain the best fragmentation through hole spacing, loading and timing. Several patternrounds were established, but a lot of secondary blasting was necessary in this type of ground.

Manways were built of 3" x 12" x 4'6" wood cribbing and lined with 3" lagging. Chutes were built of 6" x 8" x 5' cribbing armored with $2\frac{1}{2}$" x $2\frac{1}{2}$" x $\frac{1}{4}$" angle iron. All chutes were covered with 14" square hole steel grizzlies.

Because of the loose and soft nature of the ore a suitable slusher pin for the "haul back" sheave produced quite a problem. In the softer ground a $6\frac{1}{2}$' x 1" C.F.&I. wedge type rock bolt was used; in the harder ground we used a special 2' rock bolt made in our shop. During the filling operation the slusher and bucket were hung from rock bolts placed in the back of the stope.

Timbered Slot and Fill Method

The other place that hydraulic sand is very successful is in mining the 300 orebody. This orebody is also very irregular in dip and strike and is of a chloritic nature. It is practically non-self supporting. Its width varied from 10' to 30'. Because of a horizontal fault at the 200 level which cuts the ore off completely, all stopes were run blind with only "up" service from the 300 level.

This method could probably be called a "Reverse Mitchell Slice." We drive timbered square set slot raises on 30 foot centers, after each floor is completed the pillar between raises is blasted out and the ore slushed in the chute. The raises are then gob lagged off and the pillar area filled tight with sand. By cutting the solids ratio, we have been able to run hydraulic sand up 145 feet vertically above the 300 level.

Conclusion

Hydraulic Sand is the most versatile fill you can use. You can fill any place that can be reached with a 2 inch pipe.

We had a raw pocket that started sloughing to the point of endangering the level above. We cribbed the pocket with 6 x 8 cribbing and poured sand around the cribbing.

Of course, any system has its faults and hydraulic sand has its share. Because of the particular nature of our fill the water always percolated through the sand and as a result we had no control of it. The water continually drained into the chutes causing wet muck and considerable trouble pulling the chutes and pockets.

Every so often we sould develop a hole in the seal during a pouring operation and run sand on the sill below filling the track and ditches. We have an occasional break in the sand line that will run on the sill or in the shaft, but any of these so called troubles are offset by the versatility and cheapness of hydraulic sand as a back fill.

SCREEN ANALYSIS OF HYDRAULIC SAND

Cyclone Feed - Sp. G. 3.20

77.15% Moisture
22.85% Solids

Mesh	%
+48	3.22
+65	1.31
+100	6.93
+150	10.26
+200	11.78
+325	17.00
-325	52.50
	100 .00

Cyclone Underflow or Hydraulic Sand Fill - Sp. G. 3.44

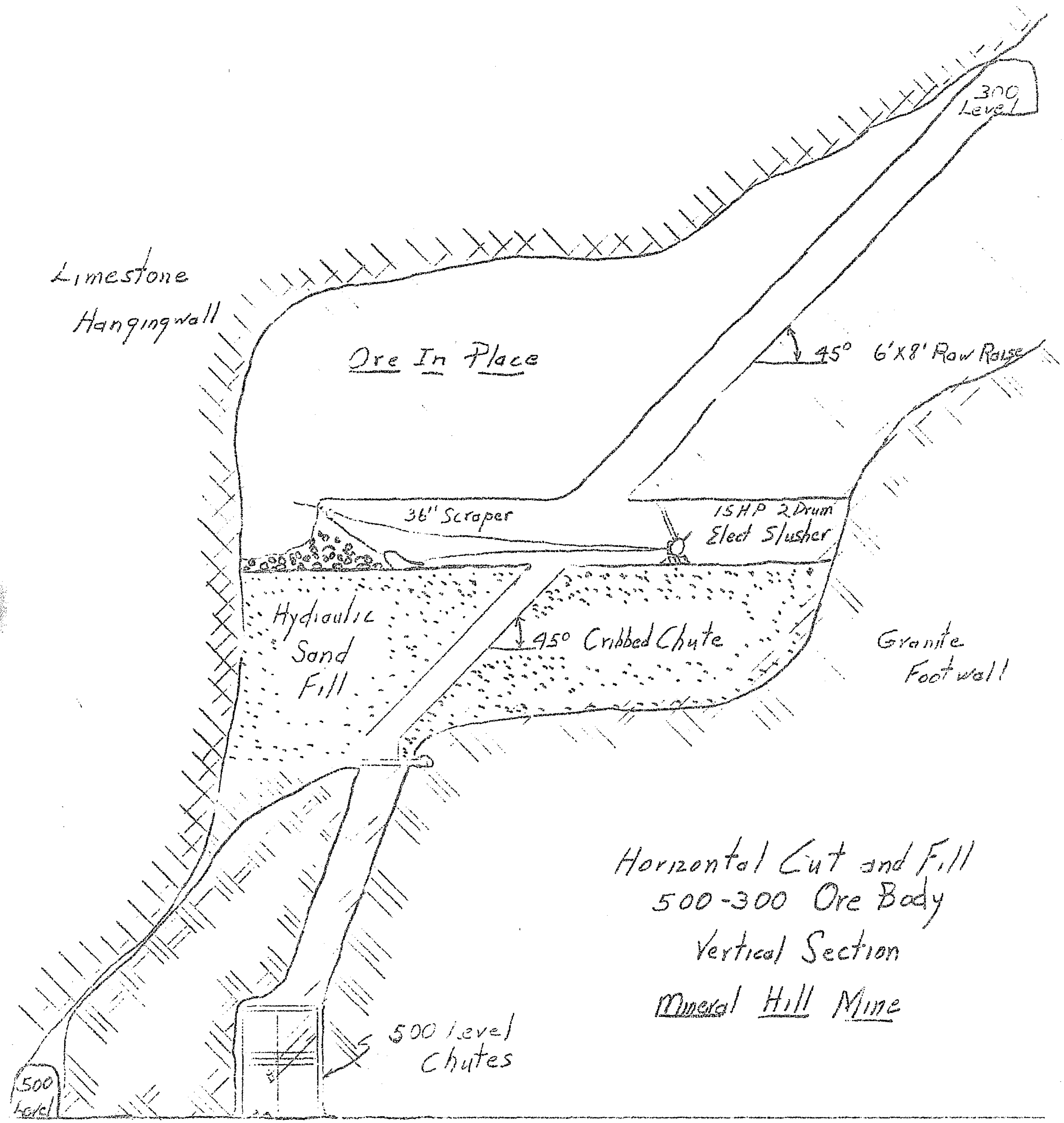
21.6% Moisture
78.4% Solids

Mesh	%
+48	.28
+65	5.70
+100	13.70
+150	20.30
+200	22.60
+325	27.10
-325	10.30
	100.00

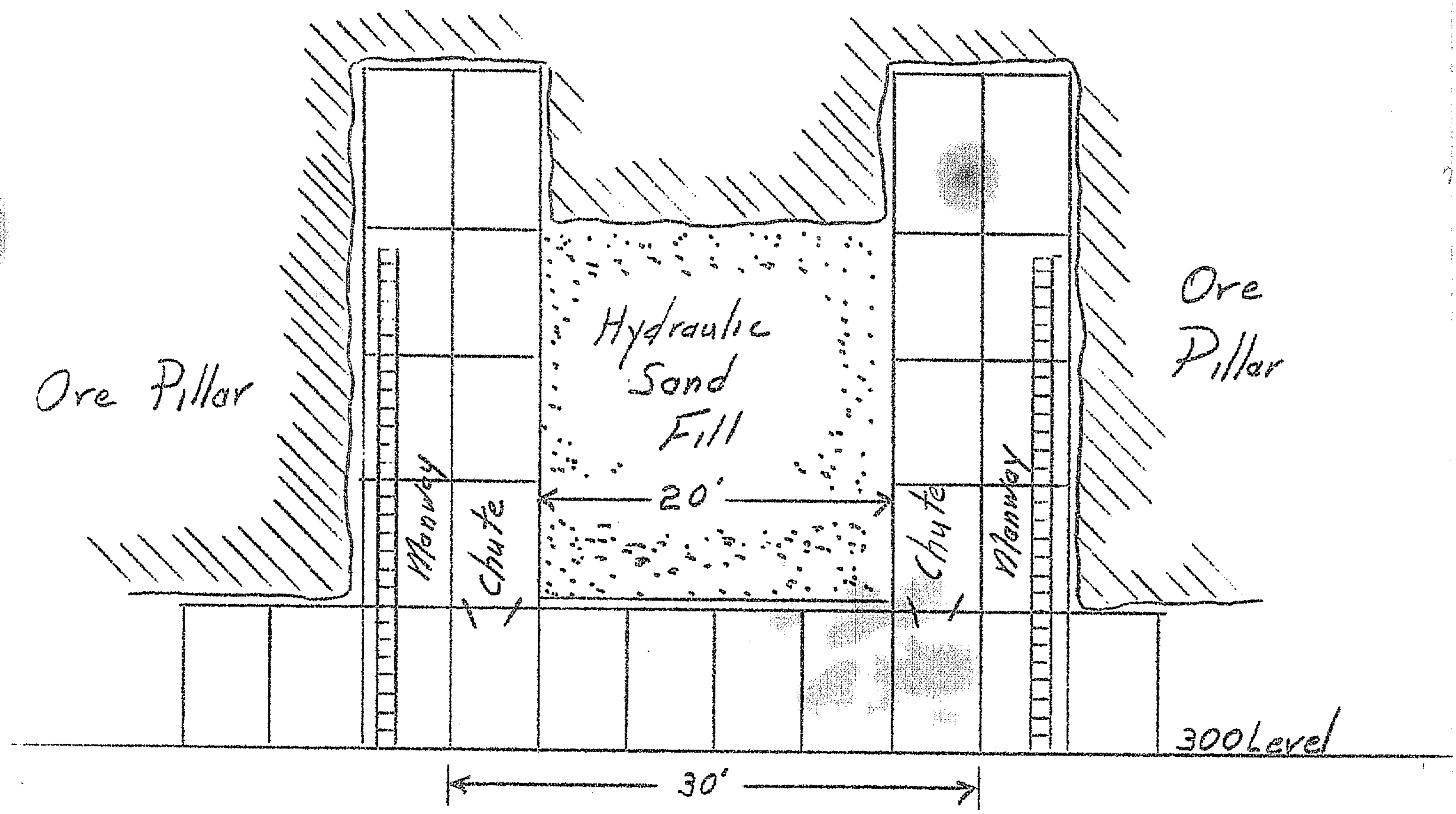
Cyclone Overflow - Sp. G. 2.29

73.2% Moisture
26.8% Solids

Mesh	%
+200	0.33
+325	6.35
-325	93.40
	100.08%



Horizontal Cut and Fill
500-300 Ore Body
Vertical Section
Mineral Hill Mine



Timbered Slot & Fill
300 Ore Body
Vertical Section
Mineral Hill Mine

Registered Geologist
CERTIFICATE EXPIRES
F. D.
MacKenzie
#2915
DEC. 31, 1958
ARIZONA, U. S. A.

Bureau of Mines
Information Circular 7786

MINING METHODS AND PRACTICES AT THE MINERAL HILL COPPER MINE BANNER MINING CO., PIMA COUNTY, ARIZ.

BY WALTER R. STORMS AND ALLAN B. BOWMAN

United States Department of the Interior — May 1957

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UNITED STATES DEPARTMENT OF THE INTERIOR
Fred A. Seaton, Secretary
BUREAU OF MINES
Marling J. Ankeny, Director

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by

Walter R. Storms[1] and Allan B. Bowman[2]

CONTENTS

1/ Supervising mining engineer, Bureau of Mines.
2/ Vice-president and general manager, Banner Mining Co.

CONTENTS (Con.)

ILLUSTRATIONS

SUMMARY AND INTRODUCTION

This paper, which describes mining methods and practices at the Mineral Hill copper mine, is one of a series being prepared by the Division of Minerals of the Bureau of Mines on mining methods, practices, and costs in various mining districts of the United States.

The Mineral Hill mine is situated on the northeastern piedmont of the Sierrita Mountains at an altitude of 3,650 feet in sec. 35, T. 16 S., R. 12 E., and sec. 2, T. 17 S., R. 12 E., Pima mining district, Pima County, Ariz. (fig. 1). The claims (figs. 2 and 3) are in a gently rolling area with only scant desert vegetation. The average annual precipitation is about 11 inches. The nearest surface water is the Santa Cruz River, an intermittent stream 8 miles east of the mine. The property is owned by the Banner Mining Co., a Nevada corporation.

This report presents a brief history of the mine, describes the geology of the area and the ore deposits, outlines methods of prospecting and exploration, and gives methods of sampling and the estimation of ore reserves and values. Development and stoping methods are explained, and methods of underground transportation, ventilation, mine drainage, and safety measures are described. The concluding section of the paper is a section on milling.

The Mineral Hill mine is an old mine that was reopened in 1951 after having been closed for 30 years.

ACKNOWLEDGMENTS

Acknowledgment is made to the executives and staff of the Banner Mining Co. for permission to publish this paper and for their valuable assistance. Special acknowledgment is due Boyd W. Venable, mine superintendent, and Wallace Boyd, mine geologist. The assistance of mining engineers of the Bureau of Mines Southwest Experiment Station in preparing this paper is also greatly appreciated. * FD MacKENZIE Chief Geologist

HISTORY[3] [4]

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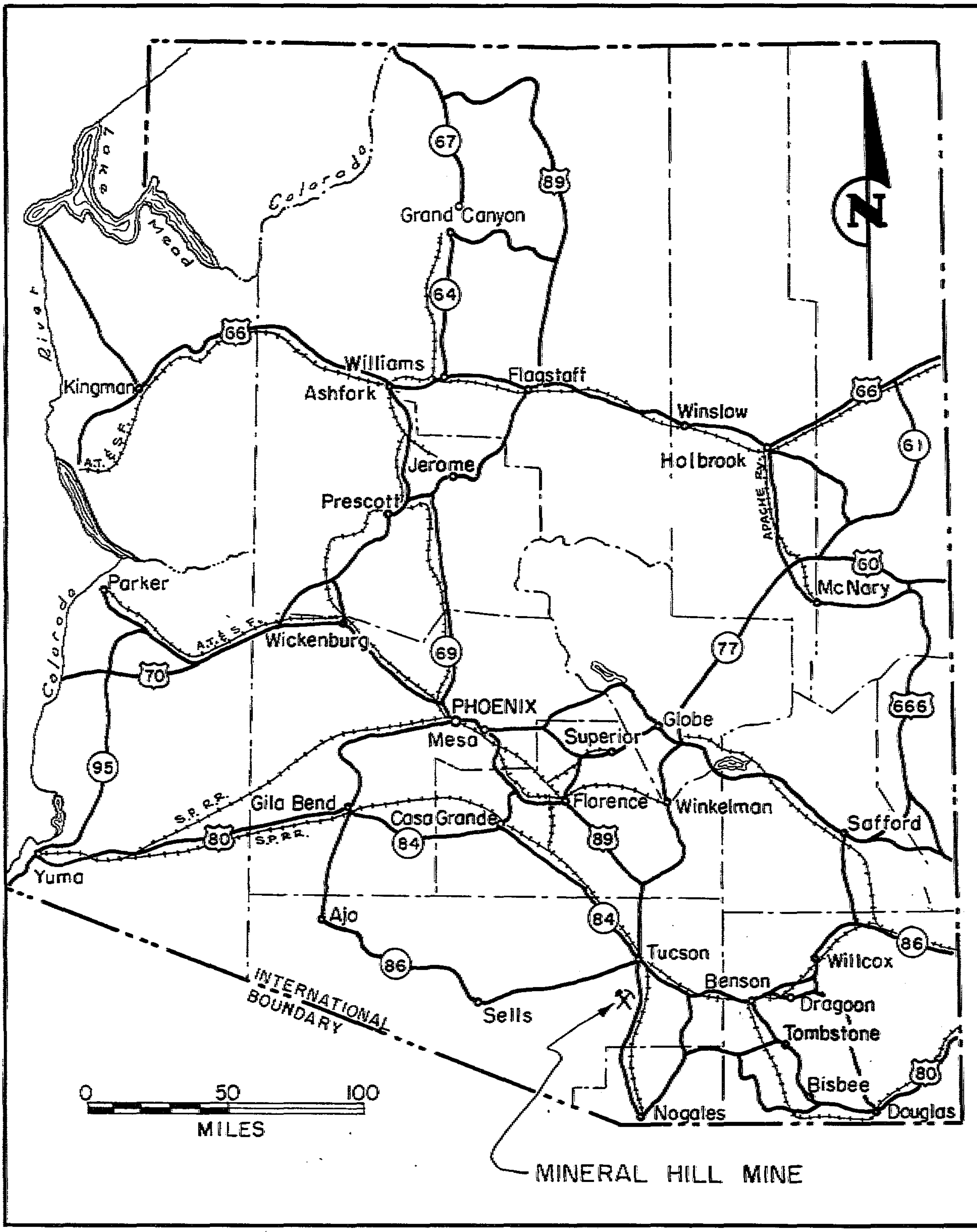

Figure 1. - Location map.

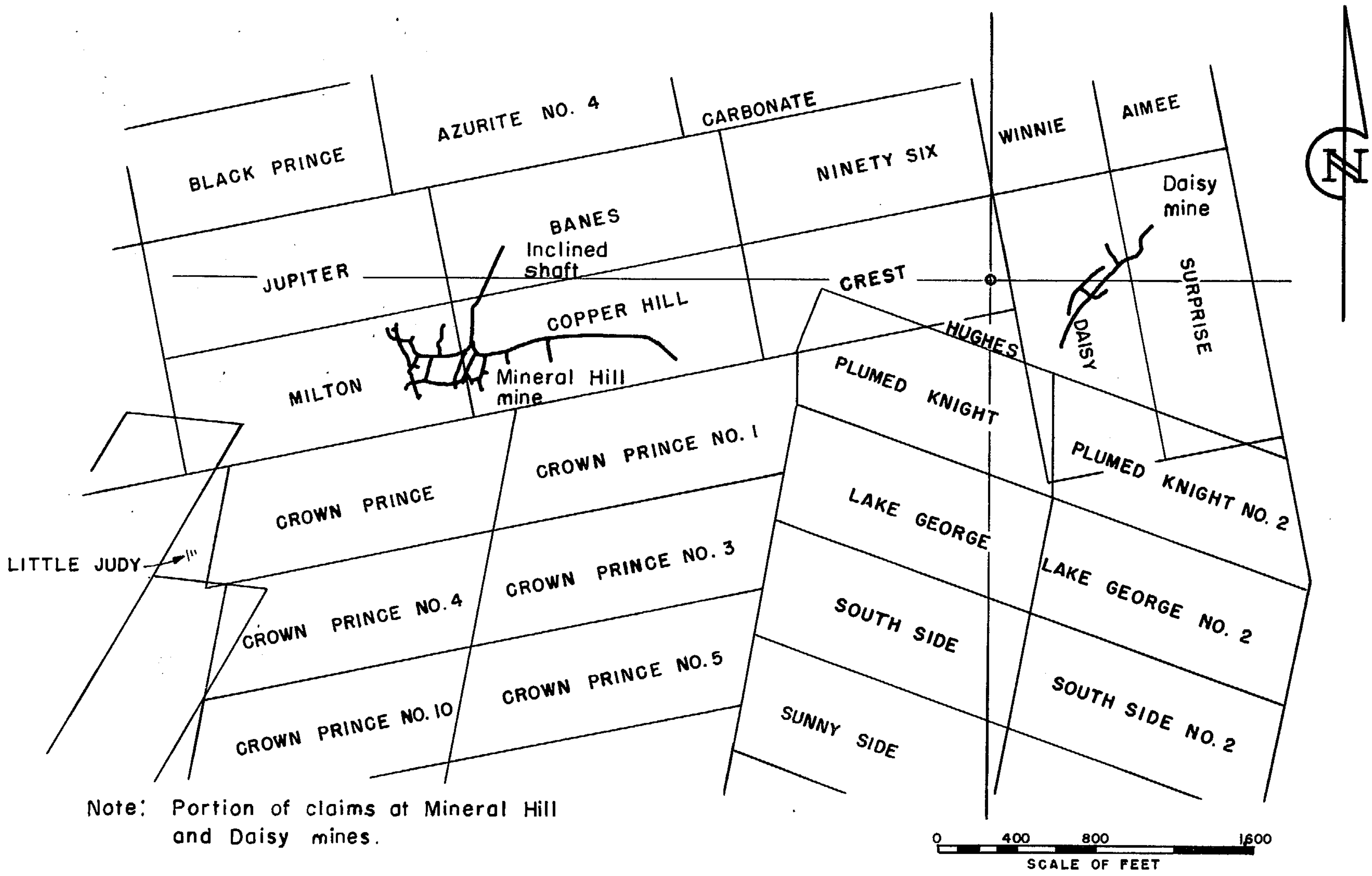

Figure 2. - Claim map.

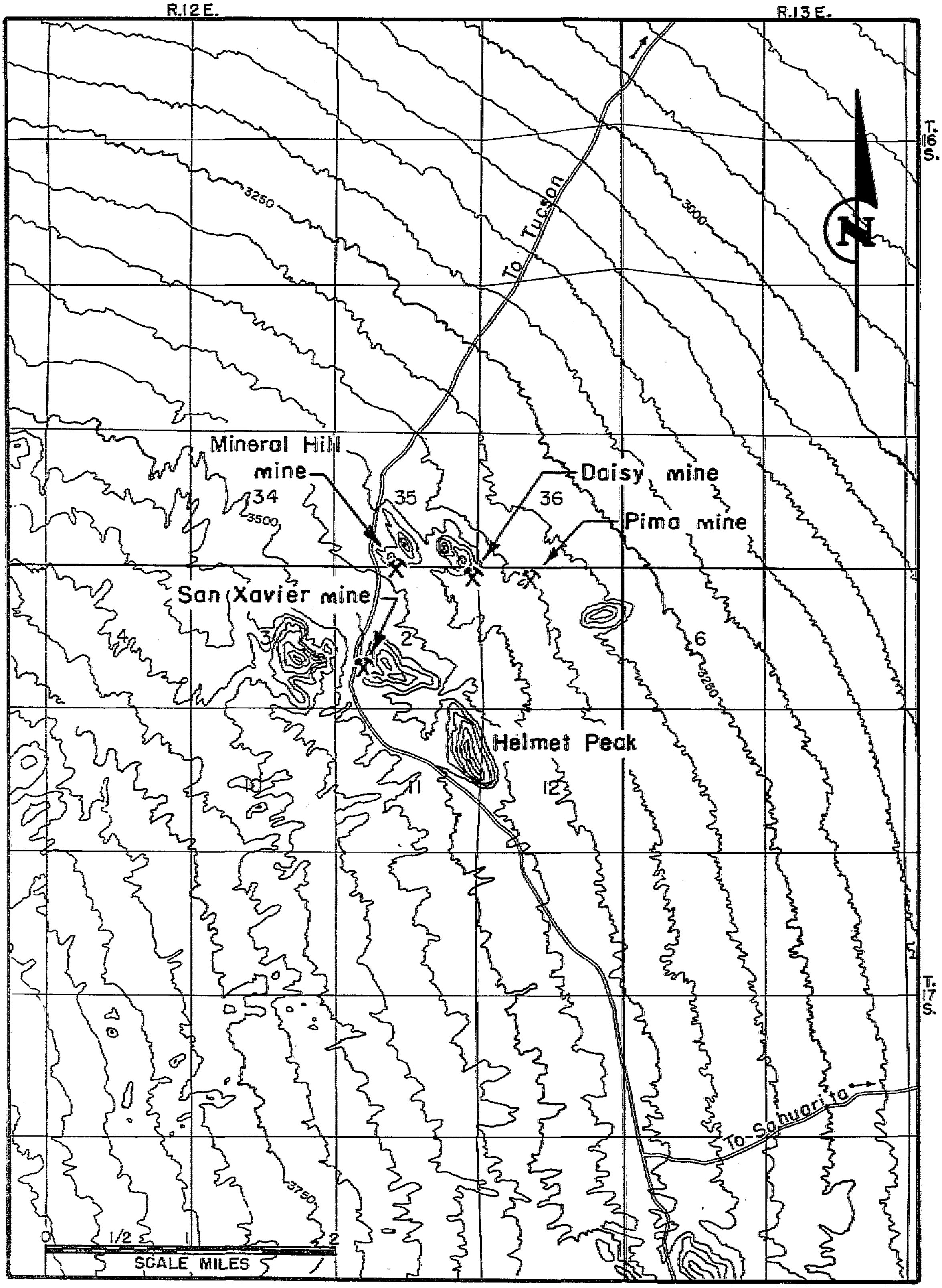

Figure 3. - Surface topography.

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GEOLOGY

General Geology[5]

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The regional structure has been complicated by folding, overturning, low-angle thrust faulting, and steeply dipping faulting; however, much of the complicated structure has not been worked out.

Ore Deposits

Sedimentary rocks, ranging from Cambrian to Cretaceous in age and consisting principally of limestones, shales, and quartzites, outcrop in the vicinity of the Mineral Hill mine (fig. 5). Farther eastward these rocks are covered by surface material, which is some 150 feet deep at the eastern property line. These sediments have been intruded by granite, which underlies much of the area, and cut by several porphyry dikes.

A large east-west preore thrust fault, the Mineral Hill fault, transverses the claims for almost 5,500 feet. At places this fault strikes almost northwest, but its general trend is east-west. It dips about 35° southward. Ore mineralization occurs along this large fault, usually at intersections with cross faults, or at or near intrusive contacts with limestone or quartzite.

Copper-ore deposits at the Mineral Hill mine are of the contact metamorphic type; the deposits usually occur sporadically along shear zones in the limestone and also disseminated through the contact silicates. Chalcopyrite is the principal ore mineral, although small amounts of chalcocite and bornite also occur. Some magnetite, pyrite, and small amounts of sphalerite, molybdenite, and scheelite are found. The gangue consists of limestone, quartz, pyrite, hematite, calcite, and contact silicates.

Two ore bodies are being mined at the Banner property, the Mineral Hill and the Daisy (some 3,000 feet east of the former).

At the Mineral Hill deposit some of the ore on and above the 300-foot level is very fractured and chloritic, and the ground is heavy. Below the 300- and above the 500-foot level the ground is better in some sections, but stope walls still require support. On the 600-foot level some of the ground is fairly strong, and some

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5/ Work cited in footnote 3.

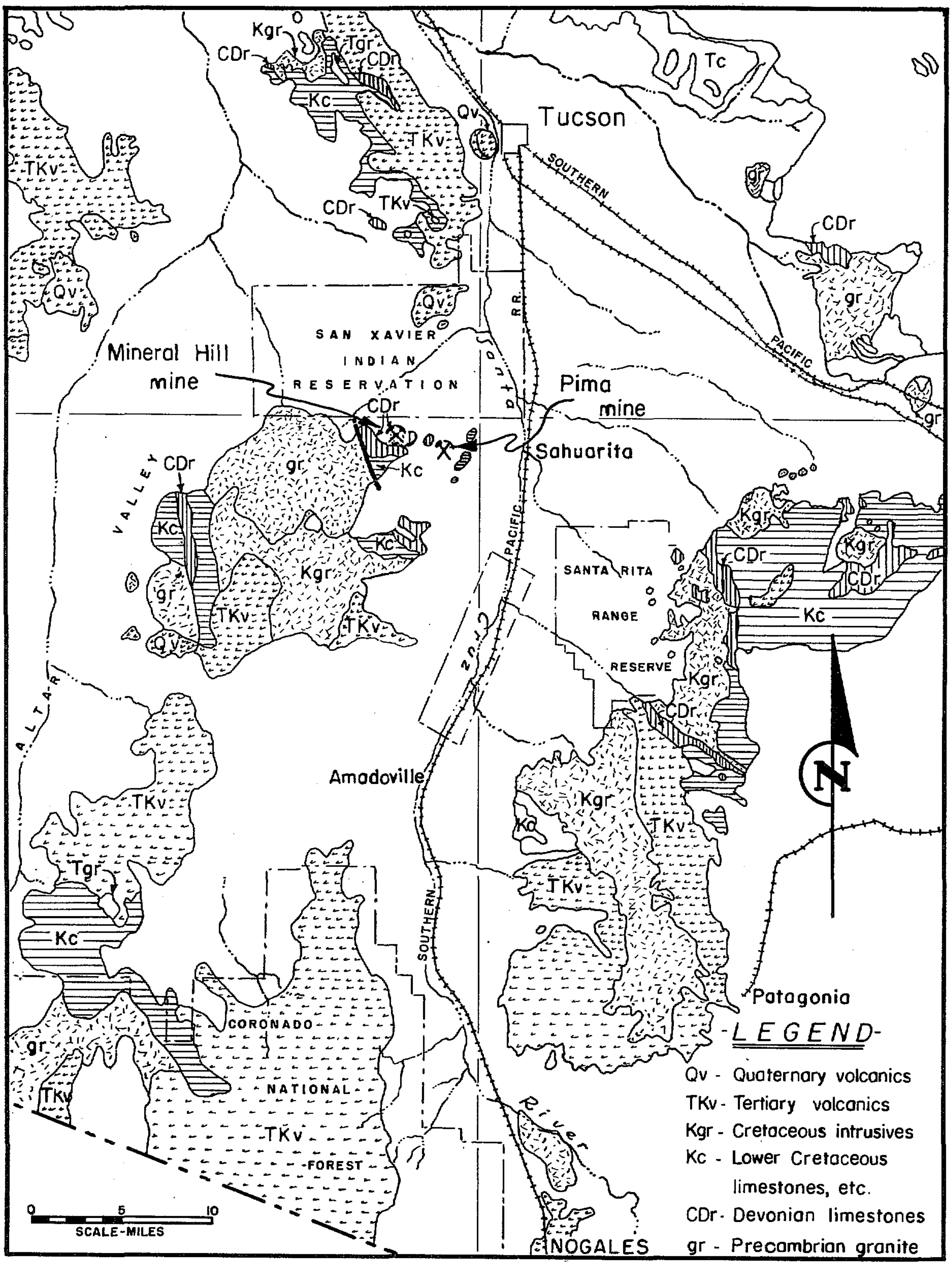


Figure 4. - Regional geology.

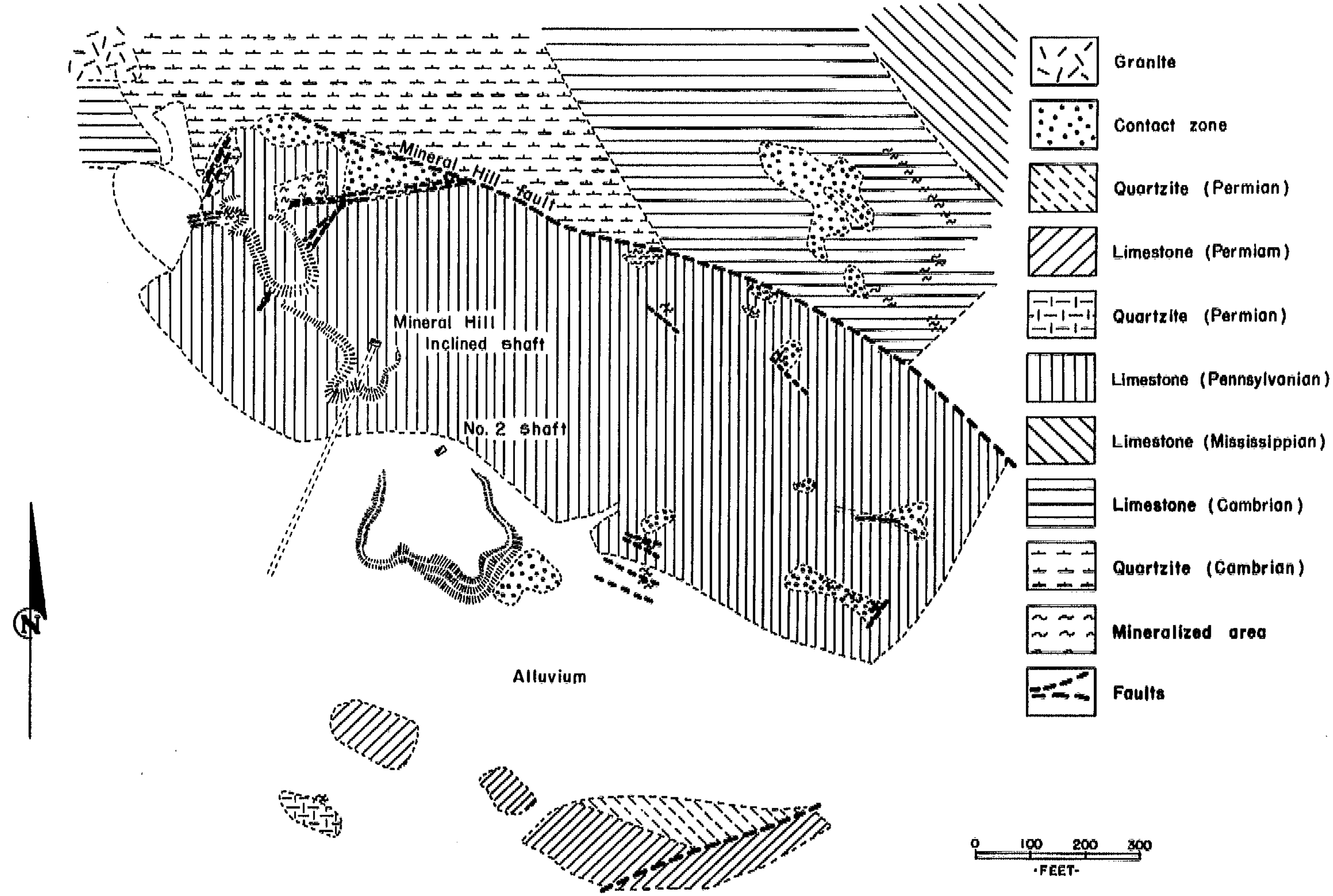


Figure 5. - Surface geology at Mineral Hill. *(Courtesy, Banner Mining Co.)*

stopes stand open with only chain pillars on 35-foot centers and roof bolts on a 5-foot pattern on the hanging wall to hold the back. The ground in chloritic areas on all levels is soft, weak, and heavy; in clay-garnet areas the ground is medium in strength but still requires sand fill to support the stope walls; in garnetite areas on part of the 600-foot level the ground is strong, and stopes may stand open after ore has been extracted.

Many ore shoots dip about 35° and are very erratic, both in dip and strike. Many shoots do not continue from one level to the next but pinch out, usually against a fault (see fig. 6 and 7).

The Daisy ore body was developed first by diamond-drill holes from the surface, then by a 450-foot vertical shaft. Bedrock was covered by 25 feet of overburden, mostly sand, gravel, and caliche. Ore came within 25 feet of the surface. It was localized along a northeast to east striking fault, which probably is a segment of the main Mineral Hill fault. Ore cccurs in sedimentary rocks in a zone near the contact between Permian limestone and quartzite; the best ore is in the limestone.

PROSPECTING AND EXPLORATION

The Mineral Hill mine originally was located in the 1880's and by 1921 had been developed by several shafts and several hundred feet of underground workings. It would seem that all prospecting and exploratory work before 1951 was done by actual shaft sinking, drifting, and crosscutting.

The mine was reopened in 1951 and 1952 by the Banner Mining Co. after it had been idle since 1921. The water was pumped out, and all principal underground workings were rehabilitated. Since that date considerable exploratory work has been done by drifting, crosscutting, and diamond drilling, chiefly on the 600-foot level (fig. 8).

The area east of the Mineral Hill mine also was explored by diamond-drill holes before and after a geophysical survey had indicated possible ore in that area. Ore was discovered by this drilling under 25 feet of surface alluvium, about 3,000 feet east of the Mineral Hill mine. This ore body then was developed by the Daisy shaft.

SAMPLING AND ESTIMATION OF ORE

When the Mineral Hill mine was reopened and rehabilitated in 1951-52, all underground mineralized areas on the several mine levels were carefully cleaned and sampled. The assays of these samples then were plotted on large-scale level maps. From these sampled areas a number of ore bodies were outlined and plans made to mine them.

After production from the Mineral Hill mine began, only mine cars and development workings were sampled. Samples from mine cars, as ore is pulled from stope chutes, are taken for stope control. No actual samples are taken in the stopes, as all ore areas merely are checked "by eye." Channel or chip samples are seldom taken. Drift or crosscut faces may be channel-sampled, although much reliance is placed on car samples from those workings.

In estimating ore: (1) Plans and sections are drawn on each ore body on each level; (2) the area of ore on each level is measured; and (3) the cubic feet and tonnage in the block between levels are calculated, using 10.5 cubic feet per ton of ore. Many ore bodies pinch out between levels, but company engineers and

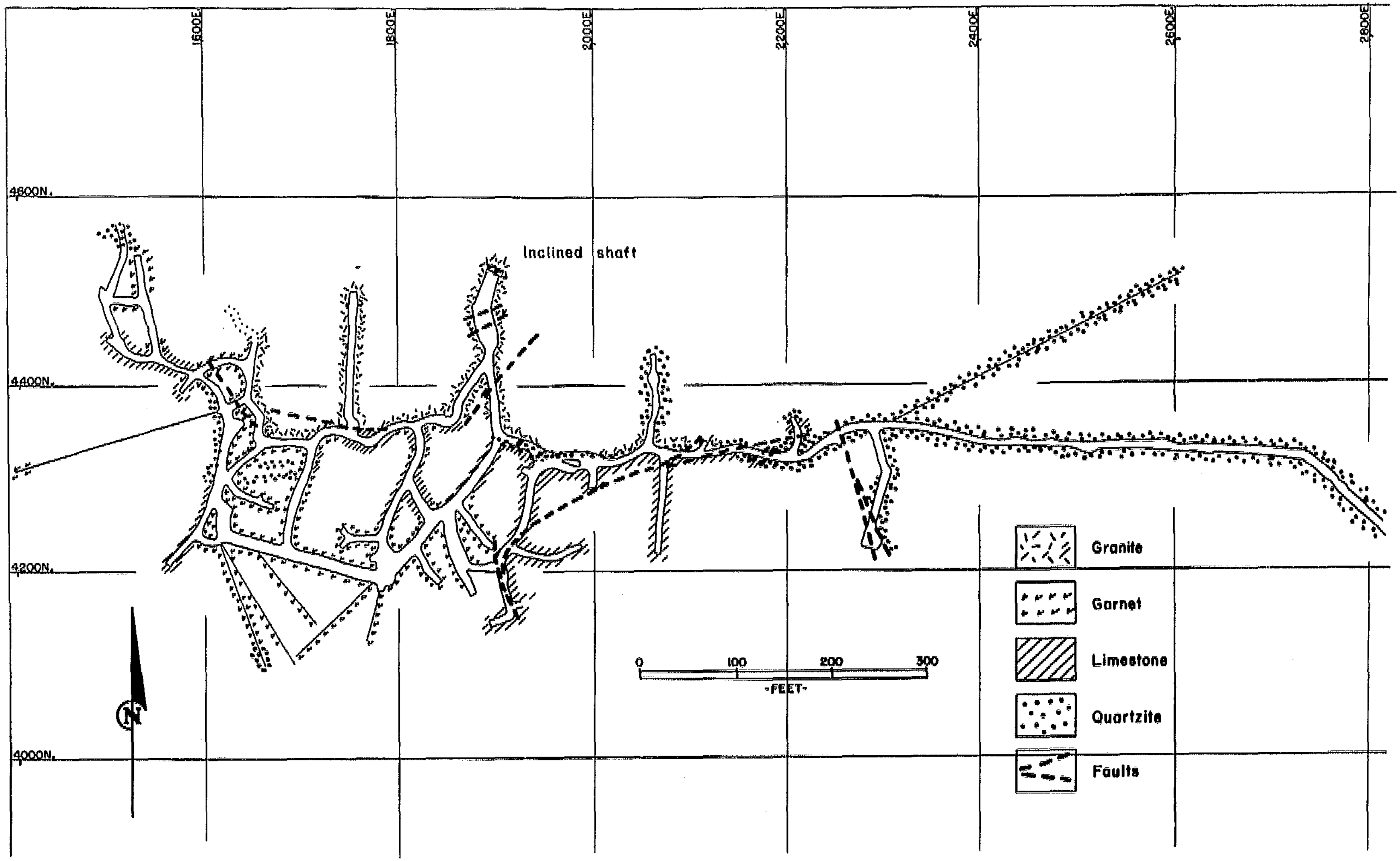


Figure 6. - 600-foot-level geology. *(Courtesy, Banner Mining Co.)*

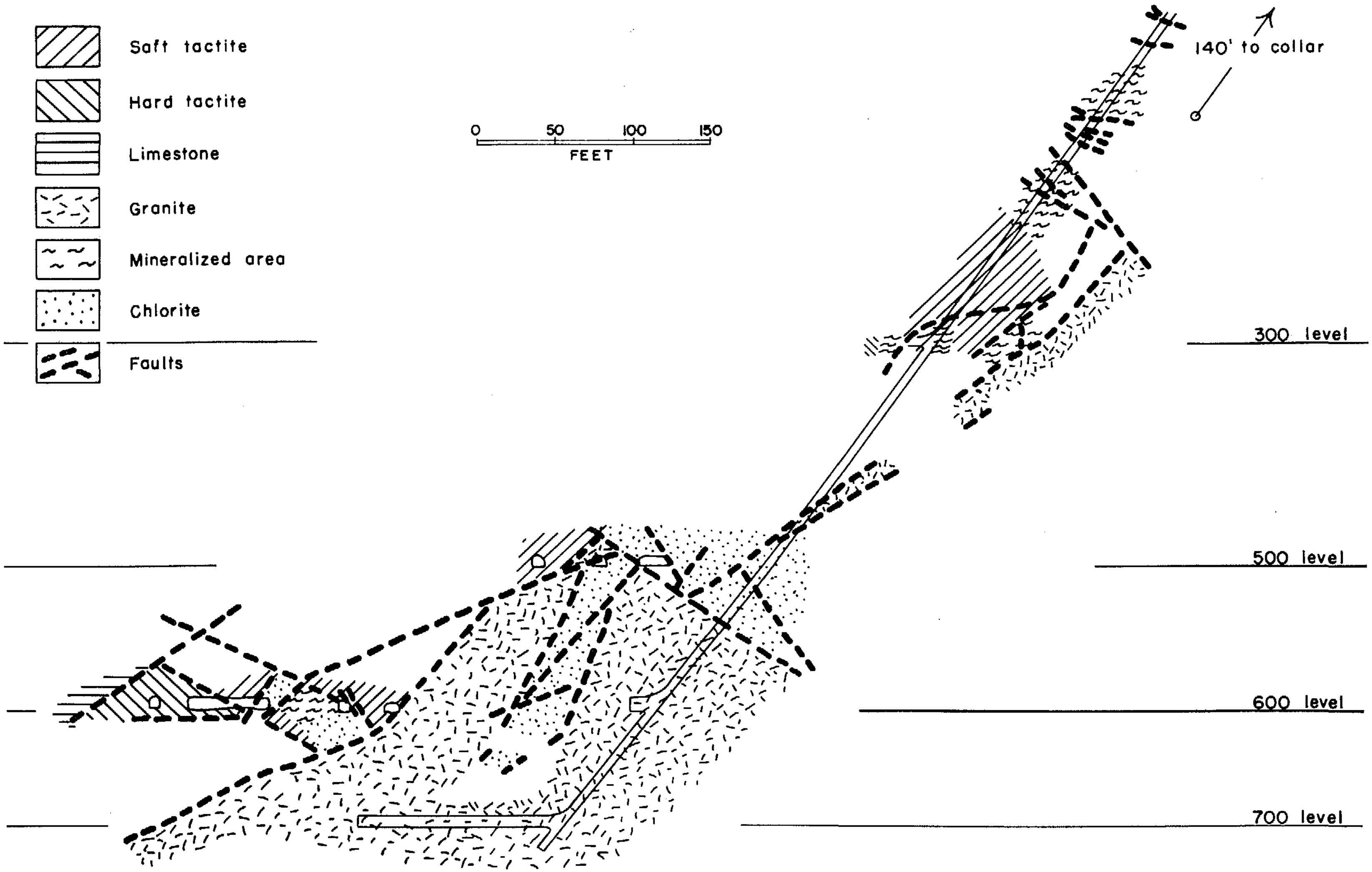


Figure 7. - Section through inclined shaft. *(Courtesy, Banner Mining Co.)*

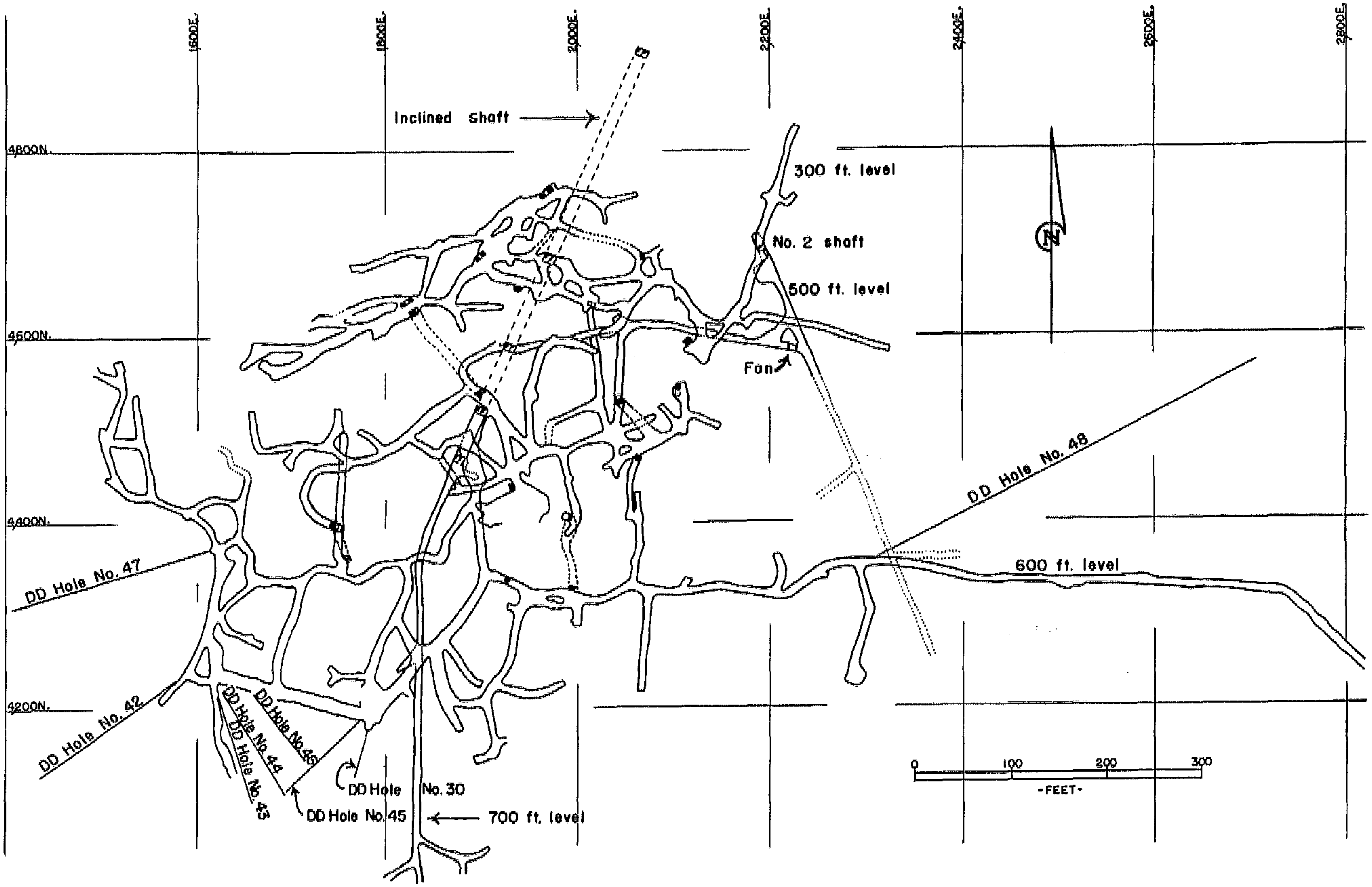


Figure 8. - Composite map of Mineral Hill mine.

geologists have found that enough new ore usually is discovered to make their calculations nearly correct.

DEVELOPMENT

Two separate ore bodies have been developed at the Banner Mining Co. property - the Mineral Hill and the Daisy deposits. The former was explored and developed before 1921 by at least 1 inclined and 4 vertical shafts, with many hundred feet of drifts and crosscuts; the latter was developed only recently by a 450-foot vertical shaft and some 2,500 feet of underground workings (see fig. 2).

Shafts

Shafts 1, 3, and 4 were sunk on 3 different mineralized outcrops at Mineral Hill for exploration purposes. Shaft 2 and the 54° inclined shaft were sunk to develop the main ore body. The former is a 2-compartment vertical shaft from the surface to the 500-foot level, a distance of 468 feet. The latter is a 2-compartment 54° inclined shaft from the surface to about the 800-foot level. Four levels have been developed from the inclined shaft - the 300, 500, 600, and 700. Only 2 of these levels, the 300 and 500, join No. 2 shaft. The 300-foot level is 348 feet vertically below the inclined shaft collar and 316 feet below the No. 2 shaft collar; the 500-foot level is 152 feet vertically below the 300; the 600-foot level is 100 feet vertically below the 500; and the 700 is about 90 feet vertically below the 600.

Both No. 2 and the inclined shaft have two compartments, the second compartment in each contains manway and pipes. The main compartment in the inclined shaft contains a 2-1/2-ton self-dumping skip running on 20-pound rails; the main compartment of No. 2 shaft contains a small cage used for men and supplies and sometimes for caging cars of muck to the surface. Both shafts were sunk before 1921 (the inclined shaft was sunk an additional 100 feet in 1955) and only recently were rehabilitated by the Banner Mining Co. Neither is completely timbered, the rock section in No. 2 being too small in places to hold anything except stulls for cage guides and for ladder and pipe supports. The inclined shaft is completely timbered only where the ground is heavy, otherwise track, ladder, and pipe are supported by stulls or sills across the incline bottom, or footwall.

The vertical Daisy shaft was sunk by the Banner Mining Co. after the ore deposit had been explored by surface diamond-drill holes.

Drifts and Crosscuts

All drifts and crosscuts are at least 5 by 7 feet in the clear. Haulageways usually are 7 by 8 feet. Timber is used only where necessary. Roof bolts are used where the ground is not too heavy but where some support is needed.

In developing the No. 1 ore body on the 600-foot level (fig. 6) a 12- by 12-foot haulageway was driven along the hanging wall of the ore shoot. Roof bolts, 1 inch in diameter and 6.5 feet long, were used to hold the back. They were spaced on the corners of a 5-foot square pattern, with 3- by 12- by 36-inch headboards and 8- by 8- by 3/8-inch washers. The bolts were of the slot-and-wedge type and were tightened by an impact wrench on the 1-inch nut. Roof bolts also are used in the smaller drifts and crosscuts where some support is necessary but where timber sets are not needed.

All drilling in drifts and crosscuts is done with medium-weight jackhammers on 3- and 4-foot feed legs. In both the Mineral Hill and Daisy mines, 7/8 inch, hexagonal, alloy-steel drill rods are standard and are used with 1 3/8-inch, detachable, tungsten carbide, 4-point star bits. Some drill steel has 1 9/16-inch tungsten carbide chisel bits formed directly on the end of the rod.

Drill rounds vary with the kind of ground encountered. Usually a burn cut is used, although a bottom or side wedge cut may be used in difficult rock. Forty-percent ammonia gelatin is used with 9-foot fuse and No. 6 blasting caps in dry headings. Where much water is encountered, regular-delay electric caps are used. Usually a 5-foot round is pulled in 7- by 8-foot drifts and crosscuts. All mucking is done by mechanical shoveling machines.

Raises

Raises at the Mineral Hill mine usually are driven at a very flat angle, so are stulled only. Manways and chutes through stope fill are cribbed, the inside of each being 4 by 4 feet in the clear on the inside.

MINING (STOPING)

At least four different methods of stoping are used by the Banner Mining Co. At the Mineral Hill mine both ore and country rock vary from soft and fractured to very hard and dense. On and above the 300-foot level much of the area is soft and badly brecciated and contains considerable soft gouge and chlorite. Between the 300- and 500-foot levels the ore and country rock are more firm outside of chlorite areas. On and above the 600-foot level much of the ore is hard garnetite-chalcopyrite.

In chlorite ore a system of slot mining is used; the clay-garnet ore is mined in long, narrow, cut-and-fill stopes; and on and above the 600-foot level in the No. 1 ore body a modified system of shrinkage stoping was used.

At the Daisy mine the ore is fairly hard, so it is mined chiefly by cut-and-fill stopes.

During December 1955, 12,800 tons of sulfide ore and 1,600 tons of oxide ore were mined. About two-thirds of this tonnage came from the Mineral Hill mine, the remainder from the Daisy. The average daily production is about 550 tons of sulfide-oxide ore.

Slot Mining Method

Much of the ore that remains above the 300-foot level is fractured and broken, with much chlorite and gouge. To mine this ore with least danger to miners, a slot system of mining was devised (see figs. 9 and 10).

First a 7- by 8-foot haulage drift was driven near the footwall side of the ore body. Next, square-set slots, 2 sets wide, were driven on 30-foot centers from the footwall for 35 feet, or to the hanging wall if the ore was not over 7 sets wide (it was seldom over 35 feet). The pillar between the two slots then was drilled and blasted out and the broken muck removed with a scraper attached to a double-drum slusher hoist. The slots were raised another set, a chute and manway were built into the first set off the haulage drift, then the haulageway was carefully lagged, and the two sill slots and the pillar were filled with sand prepared from mill tailings. No floor was used on this type of fill.

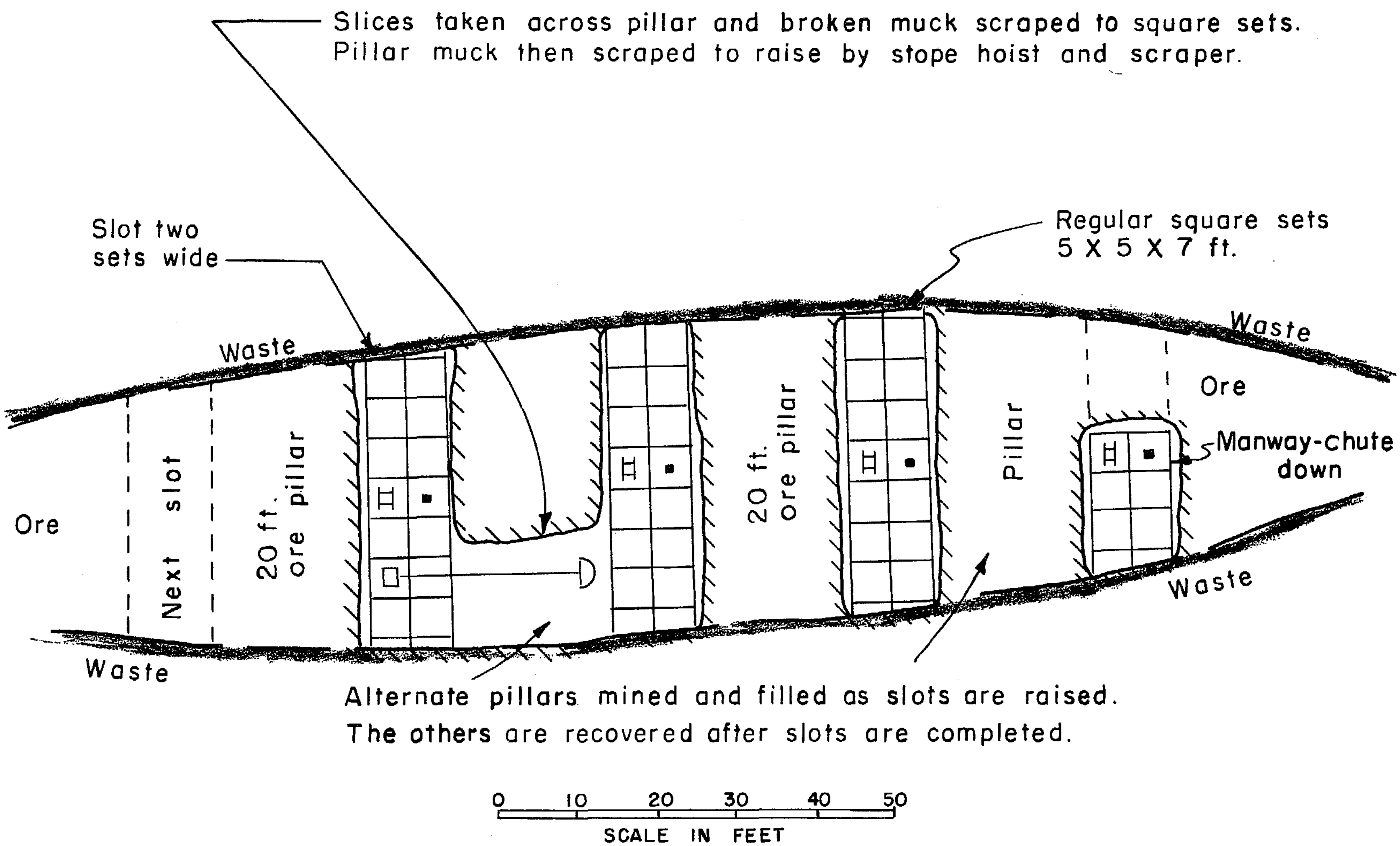


Figure 9. - Plan of slot-mining method.

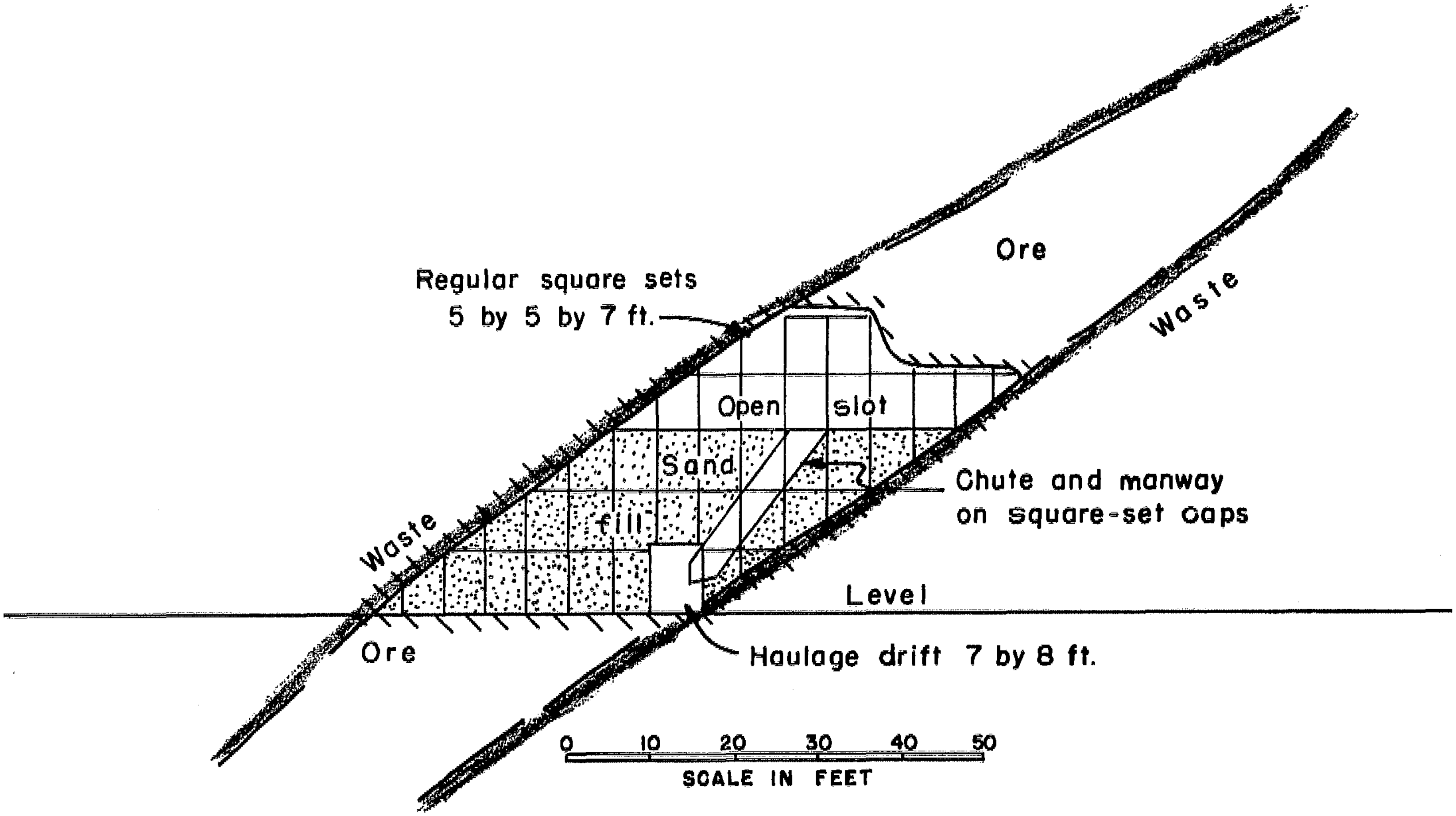


Figure 10. - Section through slot stope.

The slots now were advanced 1 set upward; then the pillar was drilled and blasted (see fig. 9) in successive vertical slices, the pillar face being kept about normal to the slots. The broken ore in the pillar was scraped to one of the slots, then moved to the chute by a second scraper, operating within the square sets. This cycle was repeated until the top of the ore body had been reached. Only alternate pillars were mined and filled as the slots were raised; the other pillars were recovered after the slots had been completed.

The chute and manway were carried up on an incline so the bottom usually rested on the square-set caps, as shown on figure 10. Figure 9 shows a plan of this type of stope, and figure 10 shows a cross section through one of the stopes.

Medium-size jackhammers with feedlegs were used for drilling, the same as in drifts and crosscuts. Hexagonal alloy-steel drill rods (7/8-inch) were used with detachable, 1-3/8-inch, tungsten carbide, 4-point star bits. Forty-percent ammonia gelatin was used with No. 6 caps and fuse for blasting. About 0.15 pound of powder was used per ton of ore broken. Production was 10 tons per man-shift, including mining, stope filling, and repairs.

All broken muck is scraped to the chute with scrapers pulled by double-drum hoists. When the distance for the muck to be moved is less than 40 feet, a 5-hp. double-drum air hoist with a 30-inch scraper is used. When this distance is over 40 feet, a 15-hp. double-drum electric hoist is used with a 36-inch scraper.

Cut-and-Fill Mining Method

Between the Mineral Hill 500- and 300-foot levels the ore and country rock stand better than in the area above the 300; but the wall rock still needs some support, as does the ore. In this area horizontal cut-and-fill stopes are used with roof bolts to temporarily hold up bad ground, and sands prepared from mill tailings to fill the stopes as the ore is being extracted.

On the 500-foot level a 7- by 8-foot, timbered haulage drift was driven lengthwise through the ore body; then raises were driven up on the approximate dip of the ore body to the 300-foot level. A 20-foot pillar was left above the haulage drift, then a stope was silled out from the raise, 20 feet wide, 8 feet high, and approximately 100 feet long across the ore body. A 15-hp., double-drum electric hoist with a 36-inch scraper was used to scrape the broken muck to the raise. Medium-weight jackhammers on feed legs were used to drill horizontal holes, first from the raise to start the stope and thereafter from the stope face. Drill steel and bits were similar to those used in drifting.

At first conventional detonators were used in the stope blast holes, but considerable trouble was encountered as the ore broke with many large boulders. These large pieces of ore caused trouble in slushing in the stope, in the chute pockets above the haulage level, and also at the grizzly over the shaft pocket. Millisecond electric blasting caps were tried and solved this problem. Much finer fragmentation resulted from the use of these millisecond caps, thus speeding loading at all points. Powder consumption in these stopes is about 0.65 pound per ton of ore broken. Ammonia gelatin, 40 percent strength, is used.

After the stope was silled out about 20 feet above the level, another 8- or 10-foot cut was taken, starting from the raise. The chute and manway then were raised to within 3 feet of the stope back (see figs. 11 and 12), and the stope was filled with sand from mill tails to this level. Chute and manway were cribbed, the chute

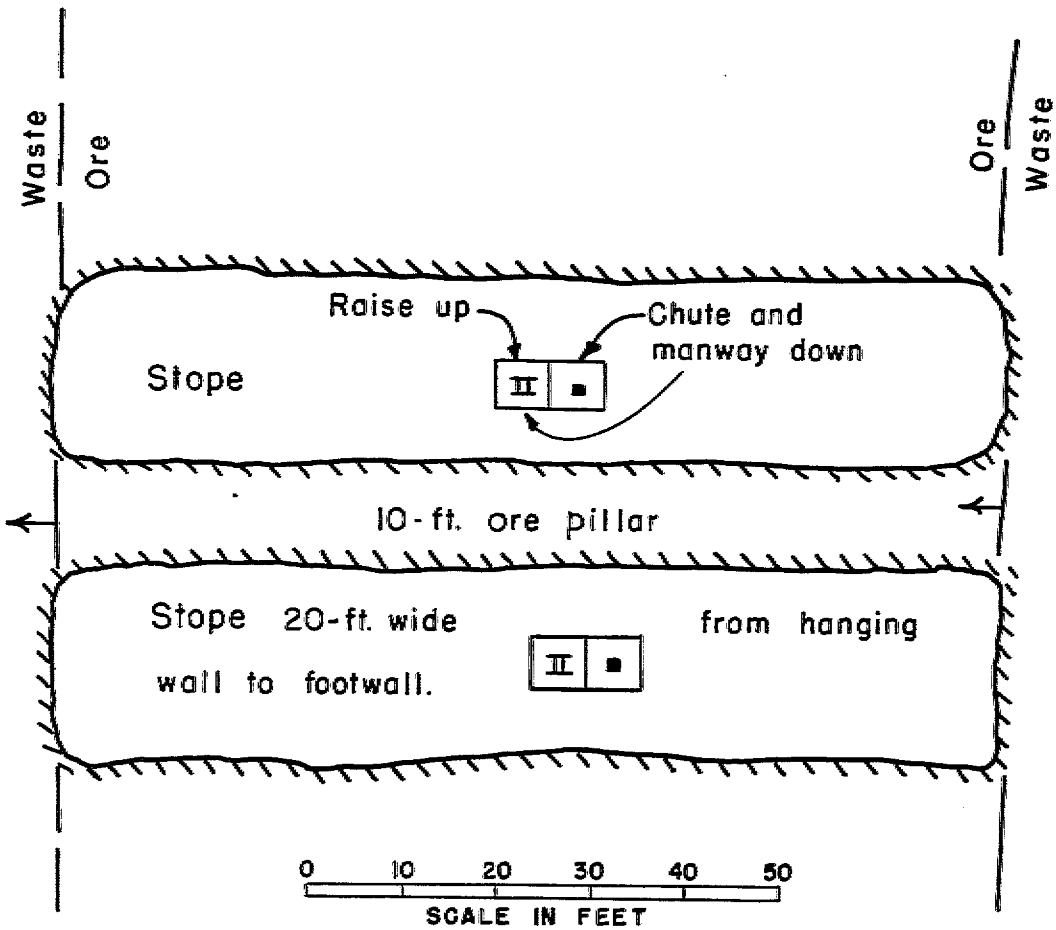


Figure 11. - Plan of cut-and-fill stopes.

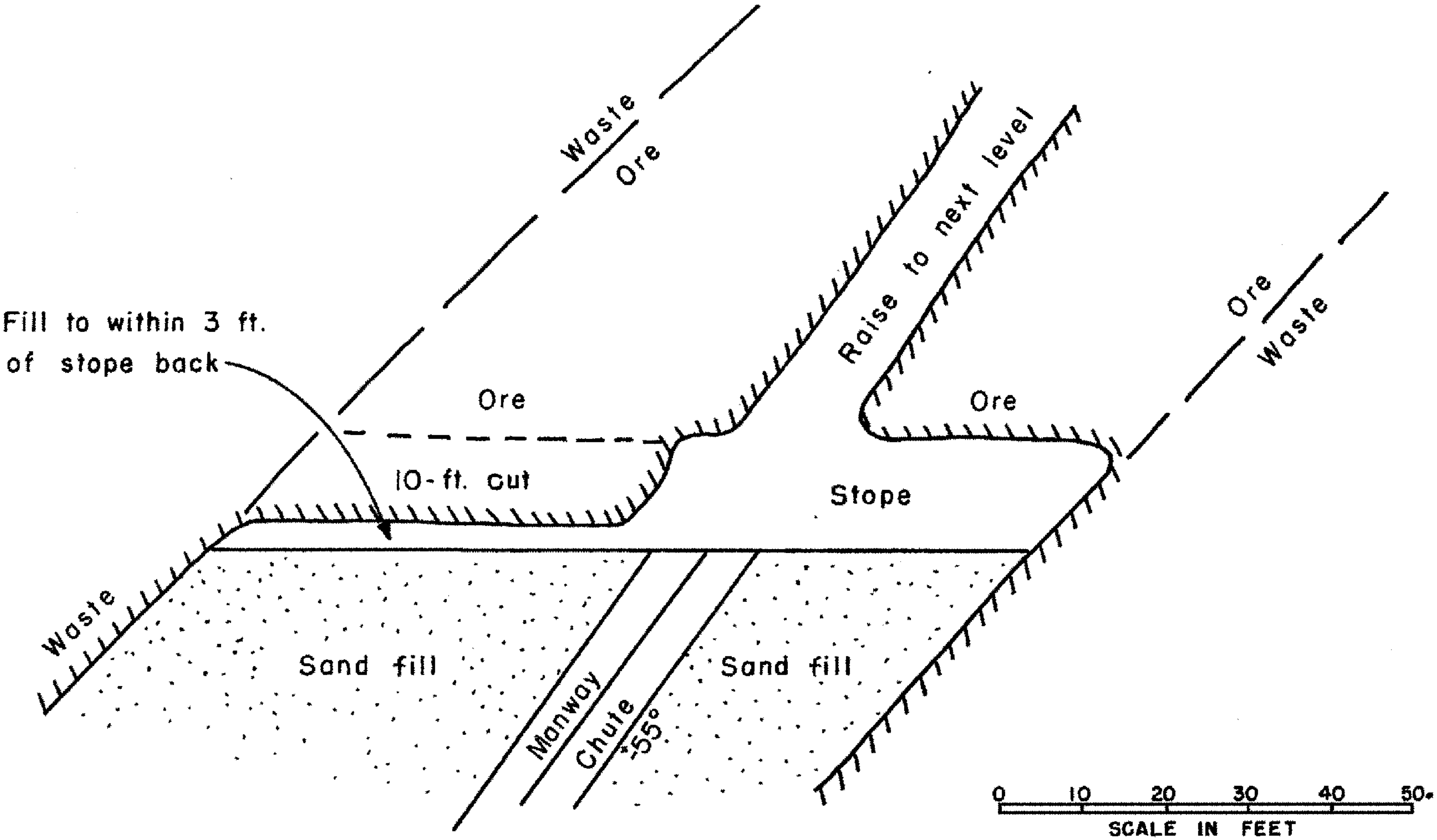


Figure 12. - Section on cut-and-fill stope.

being 4 by 4 feet on the inside, and lined with 2- by 12-inch boards. The chute-manway usually was inclined at about 55° with the manway above the chute. Production was 14 tons per man-shift, including mining, filling, and repairs.

Horizontal cut-and-fill stopes also are used at the Daisy shaft, although the hanging wall usually is very weak. Ordinary waste rock and alluvium are used for stope fill instead of sand from mill tails, as at the Mineral Hill mine. A floor of 2- by 12- or 3- by 12-inch boards, 5 feet in length, is laid on the waste fill. Production here was only 7 tons per man-shift.

Shrinkage Stopes

The No. 1 ore body on the 600-foot level of the Mineral Hill mine was mined by shrinkage-stoping methods, as the ore was a hard mixture of chalcopyrite and garnetite. The ore body was about 300 feet long and 80 feet wide and dipped at about 30°. It was developed by a 12- by 12-foot, double-track haulage drift along the hanging wall (see figs. 13 and 14), with raises near the ends of the ore body and sublevel drifts connecting these raises about halfway between the 600- and 500-foot levels. The main 12- by 12-foot haulage drift was rock-bolted and did not require timber.

At 30-foot intervals along the drift, as shown on figure 13, 8- by 8-foot stope openings were driven into the ore about 4 feet above the track level. These openings were widened to 25 feet and continued to the footwall of the ore. Broken muck was scraped from the stope with a 42-inch scraper pulled by a 3-drum, 25-hp. electric slusher hoist. This hoist was set up on the outer track in the 12- by 12-foot haulage drift and fastened temporarily to the drift wall by rock bolts. A portable, steel chute plate then was placed from the stope opening out over the inner track, so that muck could be scraped directly from the stope opening into 1-ton cars on this inner track.

After the stope had been silled out to a height of 8 feet, a second slice, about 6 feet thick, was taken from the stope back. Enough broken muck was left in the stope for miners to work upon. Jackhammers on feed legs were used for drilling; 8-foot horizontal holes were drilled after the cut had been started. As shown in figure 14, about 4 such 6-foot slices were taken from the stope back. Only enough broken ore was scraped out to allow working space above the muck pile. A 45° cut then was started a short distance from the stope opening and driven up to the hanging wall. This cut was enlarged the full width of the stope; then successive cuts were taken, as shown in figure 14, until the hanging wall had been reached. The hanging wall then was roof-bolted for safety. Only enough broken ore was pulled from the stope to allow space for miners to work. Access was either from an adjoining stope or from the inclined raise at the end of the ore body.

After this hanging-wall ore had been mined, slices again were taken from the back of the footwall section until the ore body had been mined out. The excess muck in this section was scraped down to the haulage-level opening, but difficulty was experienced with the hoist cable when broken ore was scraped from near the footwall. Because of this, some footwall ore was left in the stope and will be recovered later. Openings were broken through the pillars that separated the stopes for access and ventilation.

Forty-percent ammonia gelatin was used for blasting in these stopes with millisecond electric blasting caps. About 0.75 pound of powder was used per ton of ore broken.

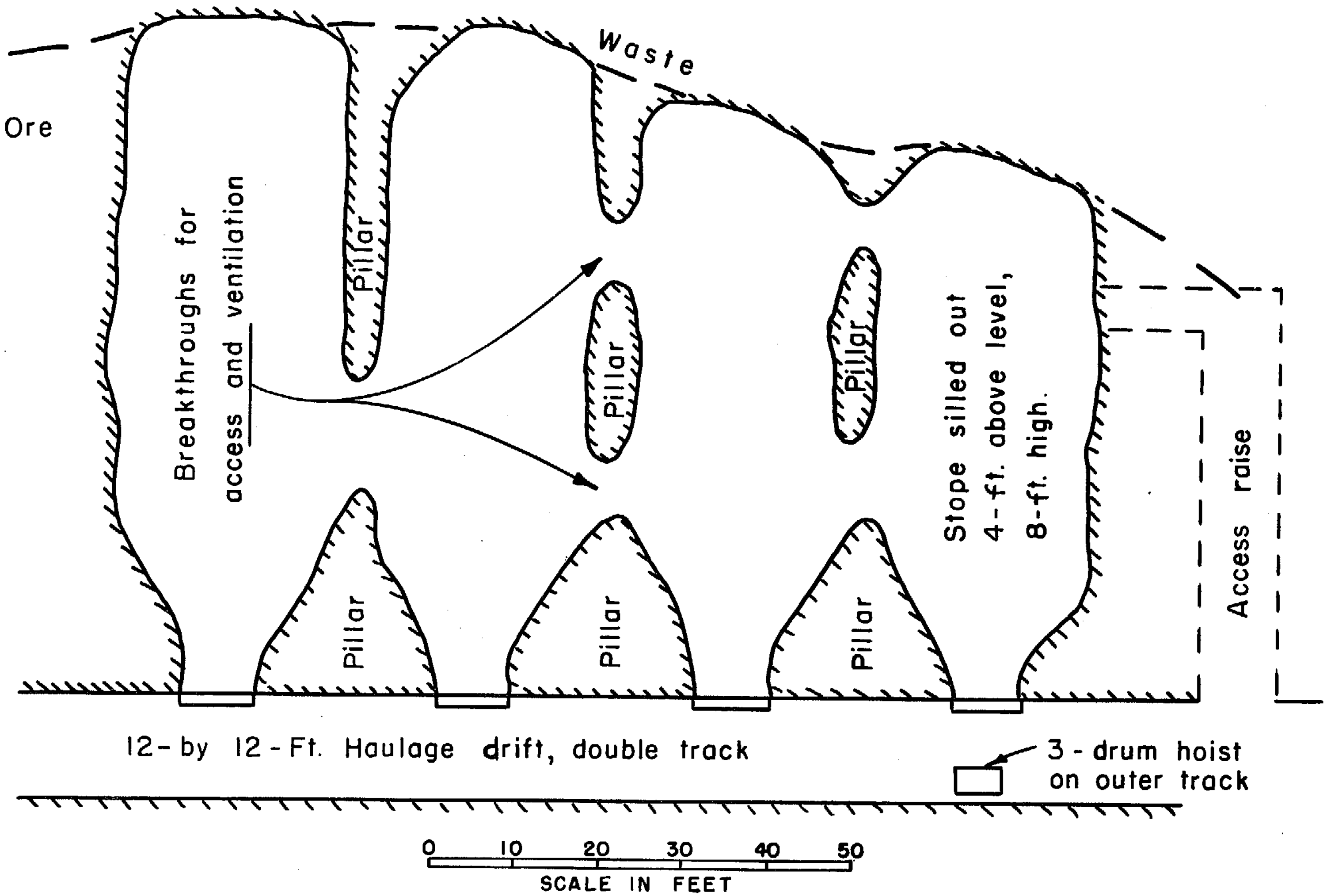


Figure 13. - Ideal plan of 600-level shrinkage stopes.

(1) Stope, 8 ft. high and 25-ft. wide driven to footwall.

(2)(5) 6-ft. slices taken from stope back as shown.

(6) Stope cut out to hanging wall.

(7)(11) Slices taken up to hanging wall.

(12) Slices now taken to footwall.

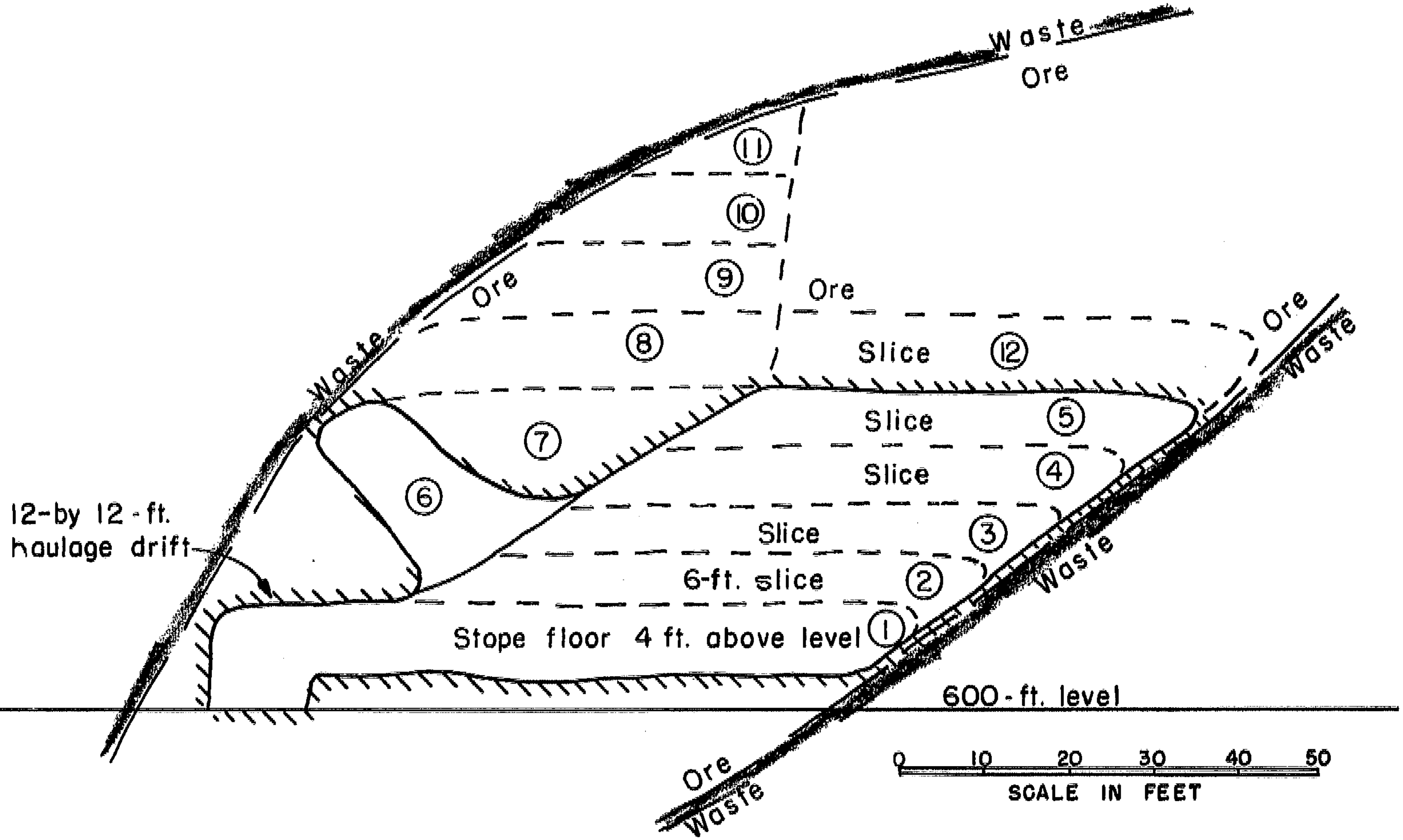


Figure 14. - Section through shrinkage stope.

Stope Fill

Horizontal cut-and-fill stopes at the Daisy mine are filled with waste from development openings and with alluvium. In the Mineral Hill mine stopes are filled with sand from mill tails.

On the surface at the Mineral Hill mine, mill tails to be used for stope fill are pumped to a 14- by 16-foot tank near the collar of the inclined shaft. The tails first go to a 10-inch, single-stage cyclone mounted on top of the tank and are pumped into this cyclone with a 3-inch sand pump at 30 pounds per square inch. The slime part of these mill tails, containing about 97 percent minus-325-mesh, is taken off in the cyclone and returned to the tailing thickener for transfer to the tailing pond. The sand part, or underflow of the cyclone, containing about 50 percent of the total tailing to the cyclone, falls into the 14- by 16-foot tank, which is equipped with a heavy-duty, propeller-type agitator. Sands are kept in agitation before a pour into the mine at about 78 percent solids.

A 2-inch, victaulic pipeline leads from the agitator tank down the inclined shaft to the several mine levels. Only one valve is in this line; this is a rubber pinch valve at the tank to control the sand flow. All pipe bends are of the sweep type to keep pipe friction at a minimum and lessen pipe wear. An independent telephone line leads from each level to the agitator tank. Underground portable, Army field-type telephones with long extension cords are used, so that they can be taken into stopes.

When a stope is ready to be filled (either one of the square-set slot stopes or a cut-and-fill stope), the 2-inch victaulic pipeline, which already has been run up a manway to the stope, is extended into the stope. The cribbed chute-and-manway, which has been raised to the proper level for the fill, is sealed thoroughly all around with burlap. Quick-setting cement is used for sealing difficult joints. The man in the stope then telephones the man at the agitator tank, and the fill is started. Water drains from the sand fill quite rapidly, so a man may walk out on the fill within an hour after it has been poured. Within 8 hours the miners can begin work again as the fill has solidified by that time.

Separate water and compressed-air connections have been installed in the sandline at the surface, so that more water may be added to the sand if needed and the line may be washed out; compressed air may be used to clear out obstructions in the line.

TRANSPORTATION

At the Mineral Hill mine ore is hoisted in a 2-1/2-ton skip in the inclined shaft. Men and supplies are hoisted and lowered in No. 2 vertical shaft, and occasionally some waste rock is caged to the surface there.

The inclined shaft is equipped with a 250-hp. single-drum hoist and a 2-1/2-ton self-dumping skip, which can hoist 50 tons per hour from the 500- and 600-foot levels. A 100-ton ore bin and a 75-ton waste bin are installed on the surface at the inclined shaft headframe. Material from these bins is loaded into 18-ton dump trucks and hauled either to the mill or to the waste dump.

No. 2 shaft is equipped with a 75-hp., gear-driven, double-drum hoist and a 1-car-capacity cage. A 45-foot wooden headframe has been constructed over this shaft.

Underground, all transportation on the levels is by trains running on 18-inch-gage tracks, with 20-pound rails. One-ton, 20-cubic foot, side-dump cars, pulled by 1-1/2-ton storage-battery locomotives haul the muck to the inclined-shaft loading pockets, which are below the 300-, 500- and 600-foot levels; one is now being constructed below the 700-foot level. Each such pocket contains a measuring pocket for loading the skip. Battery-charging stations are on each level near the No. 2 shaft.

A telephone on each level at No. 2 shaft connects directly with the hoistman. Electric signals also are used to signal the hoistman from each level.

VENTILATION

Forced ventilation is provided in the Mineral Hill mine by a 36-inch fan driven by a 30-hp. electric motor on the 500-foot level near the No. 2 shaft. This fan has a capacity of 25,000 cubic feet per minute. Air is drawn down No. 2 shaft and blown out through the 500-foot level and down to the 600-foot level through raises, then back to the surface up the inclined shaft. Dead-end workings and some stopes are ventilated by small blowers with vent tubing.

MINE DRAINAGE

All water in the Mineral Hill mine drains to a sump below the 600-foot level, then is pumped to the surface by either of 2 routes. One pump is installed so that water may be pumped directly to the surface. An alternate method is to pump from the sump below the 600-foot level to one at the 300-foot level, then from there to the surface. Average water pumped is about 140 gallons per minute although water pockets often are encountered by development workings, especially on the 600-foot level, which increase this amount to approximately 400 gallons per minute.

SAFETY MEASURES

At the Mineral Hill and Daisy mines a first-aid box is provided on each level and a stretcher at the collar of all shafts. The Banner Mining Co. owns an up-to-date ambulance, which is stationed at the company office a short distance from the Mineral Hill mine and about 1 mile from the Daisy shaft. This ambulance contains complete first-aid equipment, stretchers, etc.

All key personnel has taken first-aid training and ~~is~~ are qualified to give aid to the injured.

MILLING

As has been previously mentioned, a 400-ton flotation plant was constructed during 1953-54 at the Mineral Hill mine with the assistance of the Defense Minerals Procurement Agency. Recently the daily capacity of this mill has been increased to 500 tons by the addition of a middling regrind unit.

Ore is trucked from the Mineral Hill and Daisy mines to a 50-ton truck scale on the hillside above the mill. The ore is weighed and dumped into three 180-ton coarse-ore bins through grizzlies spaced 11 inches apart. From these bins, the ore is fed by three 36-inch apron feeders to a 30-inch conveyor belt feeding a 2-inch vibrating grizzly. The plus-2-inch material goes to a 30- by 18-inch jaw crusher. The minus-2-inch joins the crushed ore on a belt passing under both the vibrating grizzly and the crusher and is carried to a 4- by 8-foot, double-deck vibrating screen. The top deck carries a 3/4-inch scalping screen and the lower deck a 3/8-inch finishing screen. After passing an automatic sampler, the minus-3/8-inch material goes to the three 500-ton ore bins by means of a bucket elevator followed by a shuttle belt conveyor. The plus-3/8-inch material is returned to a 4-foot cone crusher discharging onto the belt passing under the vibrating grizzly and the jaw crusher.

Each fine-ore bin is equipped with a volumetric feeder, so that ore can be fed from any bin or combination of bins. The feeders discharge onto a collector belt, which in turn discharges onto the ball-mill feed belt. This belt passes over a weightometer and discharges into an 8 by 6 ball mill. A 5-foot classifier is used to close the mill circuit.

The classifier overflow is pumped to the flotation section, which consists of sixteen 44- by 44-inch flotation machines divided into the following subdivisions: Cleaners, 2 cells; first roughers, 4 cells; second roughers, 3 cells; and scavengers, 7 cells. The concentrate from the first roughers goes to the cleaners. The concentrate from the second roughers goes to the head of the first roughers. The concentrate from the last seven cells (the scavengers) goes to the regrind, as does the cleaner tailing.

The regrind unit is a 42-inch by 7-foot ball mill operating in closed circuit with a 6-inch Dorrclone. The reground middling is returned to the head of the first roughers.

Final concentrates go to a 30-foot thickener from which they are pumped to a 6-foot-diameter, 4-disk filter. The filter concentrate discharges into a storage bin.

The final tailing goes to a 60-foot thickener, then to the tailing pond.

Water from both thickeners is returned to the mill steady-head tank.

Automatic samples are taken of the classifier overflow, tailings, and final concentrate.

About 95 percent of the copper is recovered in a concentrate assaying 25.50 percent copper.

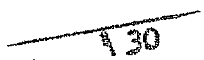
PREFACE

The purpose of a map is to give a rapid, if not nearly instantaneous, mental image of the geological and mine conditions. It should approach the effect of a picture or photograph as nearly as possible. Although many complex ideas cannot be represented on a map, in general, explanatory notes are out of place and suggest a weakness in the system of symbols and abbreviations.

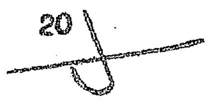
When notes must be used abbreviate the words by using consonants largely.

GENERAL LEGEND

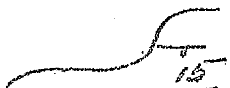
Structural Symbols



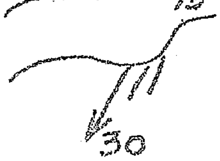
True, normal strike and dip



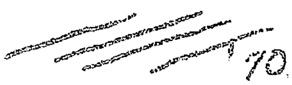
True, overturned strike and dip.



Trace of fault with true strike and dip



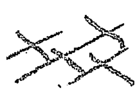
Strike or trace of fault with true strike and dip of striations or "flutings".

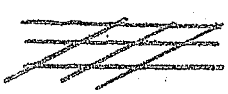


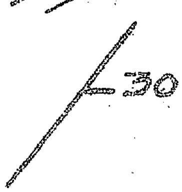
Joints (or "shear") with strike and dip.

Primary or pyrogenic planar element in igneous rock. See texts for additional related symbols.


Breccia, rubble type, fragments rotated.


Breccia, non-rotated type


Broken ground not classified as breccia



In vertical section. Contact or fault with acute angle of strike with section.


Contacts or faults inferred with spacing of slots increasing with inverse probability.

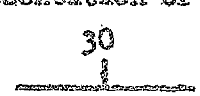
Key or "marker" beds

FA — Fault

GG — Gouge

BR — Breccia

N.B. On line representation of faults note thickness, character etc as:



3' GG, 2' BR

Age Classification of structure by color

Blue	undifferentiated
Red	pre-ore
Green	Post-ore
Violet	Intermineralization

Colors in general

Use red crayon or ink for ore areas. In general use other reds for igneous rocks, blues and greens for sedimentary rocks, browns for gossans, violets and purples for alteration and yellows and orange for mantle or other superficial rocks.

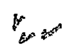
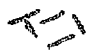
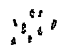
Primary rocks

AL	alluvium
AN	andesite
DI	diorite
GL	gravel
GR (+ +)	granite
IG	undifferentiated igneous
LS	limestone
ML	marble
MR	mantle rocks
PP (※)	undifferentiated porphyry
QT	quartzite
RY	rhyolite
SH	shale
SS	sandstone
TL	talus

N.B. Where rocks are mixtures use compound symbols with predominant composition first. Example: LS-SH. Or make more quantitative if possible. Example: 2/3 LS - 1/3 SH. Many variations are of course possible. A mantle rock predominately granite fragments is written MR-GR. If granite is known to occur below mantle rock write MR(GR). Capital letters are preferrable for all abbreviations.

Post primary (and post-secondary) changes in rocks .

MT	Metamorphosed. General term for the higher grades of metamorphism
AT	Altered. General term for the lower grades of metamorphism.
T	tactite (general term for contact metamorphism)
G	garnet
E	epidote
GE	skarn (garnet and epidote metamorphism)
H	hornfels, hornstone, porcellanite(preferred)
S	Silicified (fine-grained quartz)

Q	quartsified (coarse quartz)
SC	silication (high grade silicate metamorphism in places equivalent to tactite
Ca	calcite
CL	caliche
GS	gossan (high-iron represents massive sulphides)
CG	capping (low-iron represents disseminated ore)
SR	sericite
A	clay (argillite) undifferentiated
CH	chlorite
GA	"clay garnet"
	"ore" sulphide or other primary "valuable" mineralization. Includes secondary sulphides.
	low grade sulphides or other primary mineralization
	"ore" oxidized
	low-grade oxidized
PY PY	pyrite
GA GA	galena
SP SP	sphalerite
CC CC	Chalcocite
CP CP	Chalcopyrite
BN BN	bornite

N.B. The specific symbols may be used as a littered pattern to cover an area. Thus A A A A

Quantity of alterations is expressed by terms strong (ST), moderate (MD) and weak (WK). They can be combined with other symbols and abbreviations, thus: a granite strongly altered is written GR-ST or a shale weakly metamorphosed SH - WK - MT. A quantitative estimate of metamorphism may be written: LS-1/3G, 2/3E. Where the paragenesis is known, the youngest changes are placed successively to the right.

Local Formation Symbols

KA	Cretaceous arkose
KV	Cretaceous volcanic rocks
PSH	Permian, Snyder Hill limestone
PSA	Permian, San Andreas
PY	Yeso
PNN	Pennsylvania, Naco
ME	Mississippian, Escabrosa
DM	Devonian, Martin
ЄA	Cambrian, Abrigo
ЄB	Cambrian, Bolsa
PЄ	Pre-Cambrian