BUREAU OF ECONOMIC GEOLOGY
The University of Texas
Austin 12, Texas

JOHN T. LONSDALE, Director

Report of Investigations—No. 16

The Hazel Copper-Silver Mine, Culberson County, Texas

By
PETER T. FLAWN

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THE HAZEL COPPER-SILVER MINE, CULBERSON COUNTY, TEXAS[1]

Peter T. Flawn

INTRODUCTION

The Hazel mine is one of the oldest mines in Texas and has been the largest copper-producing property in the State. The mine has a recorded production of over 1 million pounds of copper and over ½ million ounces of silver, and there are a number of years in which the mine was active but for which no figures are available. True production is in the neighborhood of 4 to 5 million ounces of silver and 1½ million pounds of copper. The Hazel mine is the most important of a group of mines and prospects known as the Allamoore—Van Horn copper district (Sample and Gould, 1945). This district lies within Culberson and Hudspeth counties in an area of pre-Cambrian rocks exposed between the scarp of the Sierra Diablo to the north and Beach and Baylor Mountains to the southeast and east. The district is bounded on the east and west by the approximate longitudes of Van Horn and Allamoore. The altitude is about 4,500 to 5,000 feet, climate is arid or semi-arid (generally less than 10 inches rain per year), and mining operations can be conducted all year. Water is obtained from wells or mine seeps. Vegetation is of a desert type and consists of various cacti, yucca, and thorny shrubs without suitable mine timber. The present freight rate from Allamoore to the El Paso smelter is $3.77 per ton (plus 3 percent Federal tax) for ore valued at less than $75.00 per ton.

Location.—The Hazel mine, which is located about 15 miles northwest of Van Horn, can be reached by way of Van Horn or by way of Allamoore, although washouts on the latter route have made it impassable for conventional vehicles (fig. 1). From Van Horn one travels north on paved State highway No. 54 for 10.8 miles to a double earthern tank on the west side of the road, thence westward on an unimproved ranch road for 3.5 miles to the mine. From Allamoore the route is north for 5 miles on a good gravel county-maintained road and then northeast over an unimproved ranch road that is at present badly washed. On both routes, however, the ranch roads are on the Hazel sandstone, which makes an excellent hard-bottomed road.

The mine property is a patented section of 667 acres (section 14, block 66, T. 7., Texas & Pacific Railroad survey, Culberson County, Texas) owned by the Hazel Mining and Milling Company of Dallas, Texas. (This company is represented by R. B. Stichter, Jr., 2024 Ross Ave., Dallas 1, Texas.)

Previous work.—Von Streeruwitz (1890, 1891, 1892, 1893) described the Hazel mine during his early geologic reconnaissance of Trans-Pecos Texas, and was the only geologist, so far as is known, to examine the deeper workings of the mine. His report and accompanying map in the Third Annual Report of the Texas Geological Survey (1892) are reproduced as a part of this paper (pp. 7–8 and Pl. II). Richardson (1914, p. 8) briefly described the mine during his work in the Van Horn quadrangle. P. B. King visited the Hazel mine several times between 1928 and 1939 during the course of his work on the Sierra Diablo region for the U. S. Geological Survey. His most thorough examination was made in 1938, in company with S. J. Lasky of the Metals Section of the Survey. In 1944, as part of the war-time minerals explorations of the U. S. Geological Survey, the Hazel mine and others in the Allamoore—Van Horn district were studied by R. D. Sample and E. E. Gould. Much useful information on the various mines and prospects was obtained and is embodied in a report that has been available in open file since 1945. Evans (1943) made a preliminary survey of the mines and prospects in the Allamoore—Van Horn district prior to the work done by Sample and Gould, and some general observations on the area were published as a progress report.

Present work.—The writer was engaged in areal geologic mapping in the general

[1]Part of the work for this paper was performed in connection with a research project titled "Copper Deposits of the Allamoore—Van Horn District, Texas," which was undertaken by the writer as a reserve officer member of the 4000th Research and Development Unit, Organized Reserve Corps, Austin, Texas.

area in 1949 and 1950 and visited the property several times during that period. In 1951, assisted by S. M. Awalt, he spent two weeks on the property, mapped the surface area of the Hazel mine with telescopic alidade and plane table on a scale of 50 feet to the inch (Pl. I), and surveyed a network of stations for a gravity meter survey which was completed in January 1952 under the direction of Dr. V. E. Barnes, geologist, Bureau of Economic Geology. At the same time a gravity survey was made at the Marvin-Judson prospect about 1 mile due west of the Hazel mine where the Hazel fracture zone is intersected by a northwest-trending fault. Underground workings in both areas are inaccesible because of water. Most of the information herein is taken from a forthcoming report on the pre-Cambrian rocks of the Van Horn area by Dr. P. B. King, of the U. S. Geological Survey, and the writer. The present copper shortage makes it advisable to publish information on the Hazel mine as a separate report as an aid to further exploration in the area.

A great deal of the information in this paper came from local people who are familiar with the history of the mine. Particular thanks are due to Messrs. A. P. Williams and B. Melton of Van Horn. Mr. Williams was employed by the World Exploration Company during their period of operations as lessor and was himself a lessor during the late 1930's and early 1940's. He provided a great deal of information on workings, grade of ore, and history. Maps of the underground workings

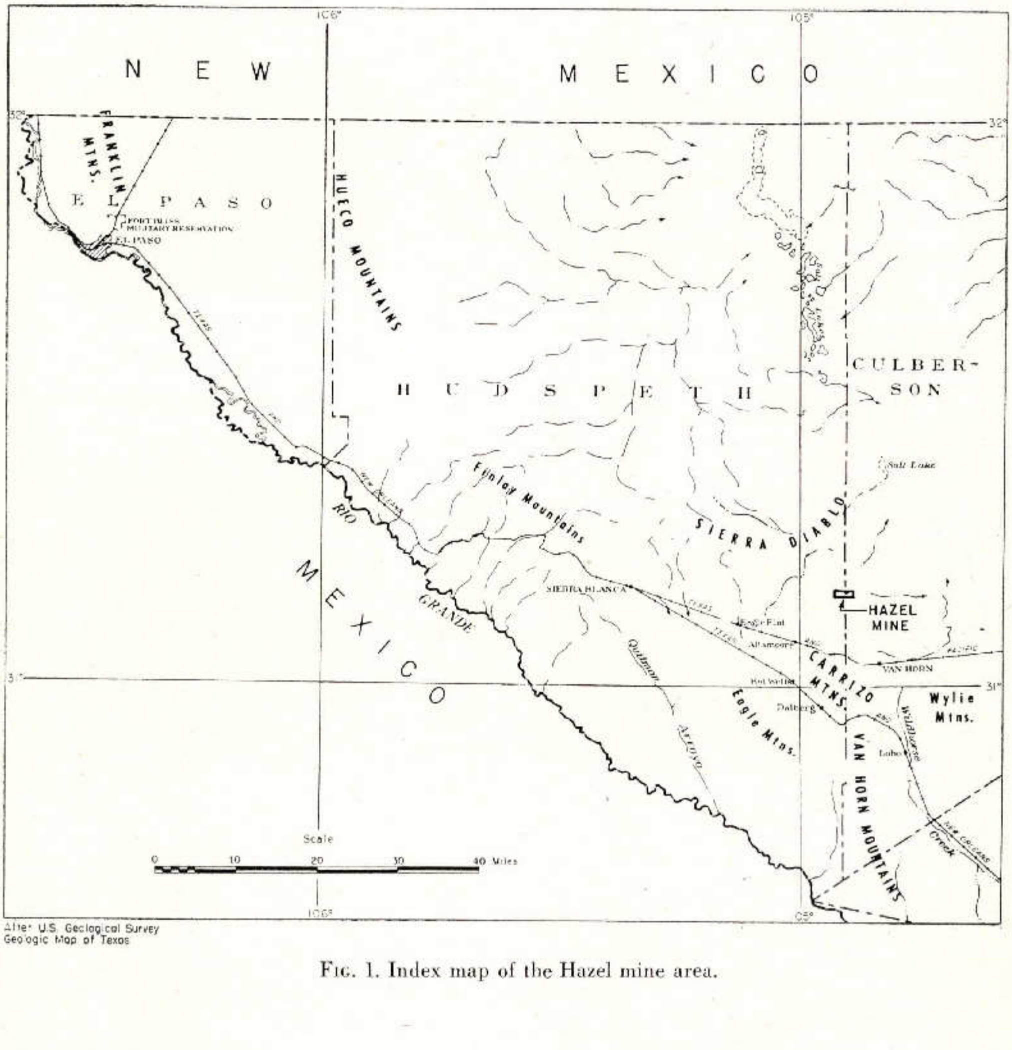


FIG. 1. Index map of the Hazel mine area.

made by the World Exploration Company are reproduced in Plates III, IV, and V. Permission to publish these maps was given by Mr. R. B. Stichter of the Hazel Mining and Milling Company. The writer is grateful to Dr. P. B. King for making available his notes on the mine in advance of his preparation of a general report on the area. Mr. G. L. Evans of the Texas Memorial Museum added much valuable information from his unpublished notes on the area. This paper has gained much by addition of the section on "gravimetric data" (pp. 16–18) contributed by Dr. V. E. Barnes. In this regard special thanks are due Mr. Frederick Romberg, Manager Southern Division, Geophysical Service, Inc., Houston, Texas, for aiding in interpretation of the gravity data.

HISTORY AND PRODUCTION

The history of the Hazel mine was pieced together from information obtained from residents of Van Horn and from volumes of *Mineral Resources of the United States* and the *Minerals Yearbook*. The mine was first located by T. R. Owens in 1856. Owens dug a shallow shaft about 20 feet deep (pit just north of Owens' house, Pl. I) and then was driven out of the country by hostile Apache Indians. Owens served as a Captain of Artillery in the Confederate Army during the Civil War and then returned to the Van Horn area, relocated the claim, and did some additional development work. According to Jim Bean of Van Horn, Texas, T. R. Owens and a man named Miller were located on the east end of the vein and W. H. Winn and C. S. Phinney were located on the west part of the vein in 1884, and only a few prospect pits had been made previous to this date. Shortly thereafter the property was sold to Messrs. Shriver and Andrews of San Antonio.

Shriver and Andrews operated the property until 1896 with H. J. Clifford as mine superintendent, and this period was the most profitable in the mine's history. During this period as many as 400 workers were employed at the mine. The ore was hoisted by steam power, hand sorted, sacked, hauled by wagon to Carrizo (a station, now abandoned, on the Texas and Pacific Railroad 2 miles east of Allamoore) and shipped to a smelter in Pueblo, Colorado. There is a report that wood was cut on the Diablo Plateau, north of and about 1,500 feet higher than the mine, for use as fuel to generate steam. Records are incomplete, but apparently a large tonnage of very high-grade ore was produced during the 1880's and early '90's. Sample and Gould (1945, p. 19) state that about 80,000 tons of high-grade silver-copper ore was produced between about 1880 and 1895. In 1889 Von Streeruwitz (1890, p. 224) reported that 10 carloads a week were shipped for ten consecutive weeks. In 1890 Von Streeruwitz (1891, p. 698) stated that over 200 carloads of ore had been shipped from the mine and "vast quantities of low grade ores are on dump." In 1892 Von Streeruwitz (1893, p. 151) stated:

> The Hazel mine, at the foot of the Sierra Diablo. . . . though not worked to its full capacity, *clears*, according to the statement of the owners, about $6,000 per month from the argentiferous copper ores shipped, besides dumping immense quantities of ores, which are regarded low grade and not fit for shipment up to twenty-three ounces of silver to the ton.

The writer has here reproduced Von Streeruwitz's complete description of the mine (1892, pp. 387–389) because it contains information on the deeper portions of the vein not to be found in more recent reports, is of historical interest, and provides an excellent introduction for the present paper.

> This mine is owned by Messrs. Shriver & Andrews, of San Antonio, and is located about ten miles north of Allamore station on the Texas and Pacific Railroad. The gangue is nearly perpendicular. Its width to a depth of about five hundred feet averages thirty-four feet, below this depth it widens to over forty feet. Its longitudinal extension may be traced for several miles, and its nearly uniform thickness is ascertained for eighteen hundred feet by the present workings shown in the accompanying sketch [Pl. III]. The gangue is in a fissure between a fine grained red sandstone of probable Devonian age, which also forms the walls, and which, in the vicinity of the gangue, is more or less metalliferous. The gangue has a whitish gray colored calcareous silicate, more or less impregnated through nearly its whole width with copper and silver sulphide and other metal combination, and numerous richer veinlets fill the space between the two principal veins known as the north and south veins.
>
> The north vein runs from the outcrop to the whole depth reached at the time I made the examination (June, 1891) down to five hundred and seventy-five feet practically perpendicularly. The south vein runs also perpendicularly to about one hundred and fifty feet, when it changes its dip slightly to the north and joins the north vein

at about four hundred and fifty-feet from the surface.

At about three hundred feet from the surface another vein was struck on the south side, which joins the north vein at about five hundred feet. A vein running in at three hundred and sixty feet through the south wall dips nearly parallel with the north vein to the full depth of the shaft, thus forming the south vein in the deeper parts of the mine. The strike of the gangue and the veins is nearly true east and west.

The east shaft, on which most of the work has been done, is sunk on the south vein, reaching (June, 1891) the depth of five hundred and seventy-five feet. From this shaft every fifty feet crosscuts are made to the north vein, determining the average width of the gangue from wall to wall to be about thirty-five feet. From these crosscuts as well as directly from the shaft, more or less extensive drifts are run in the north and south veins, as shown by the accompanying sketch [Pl. II] and the quantity and quality of ore struck by shafting and drifting in the veins and in pockets is highly promising to actual mining by stoping.

The west shaft is sunk on the north vein, eighteen hundred feet west of the east shaft, to a depth of three hundred and seventy-five feet and about three hundred and fifty feet of crosscuts and drifts worked from this shaft.

The middle shaft is three hundred feet west from the east shaft, on the north vein. It is forty-two feet deep, and was last June a drift of about forty feet in a material of the same character as the east shaft. The walls, as well as the gangue material in all the shafts and drifts, are sound and solid, and therefore very little timbering is required. Up to the time I made an examination of this mine no obnoxious gases were noticed, except those resulting from the blasts, and very little water was struck in the shafts and drifts.

The principal ores of the main veins, as well as the veinlets and pockets, are silver-bearing copper glance, gray copper, silver copper glance, silver glance, native silver, chlorides with more or less copper. Lead, antimony and arsenites are found in traces, and traces of gold are not infrequent, and strongly ferruginous specimens assayed ninety-five hundredths of an ounce in gold and thirteen ounces in silver. The gray copper yields very high assays up to two thousand ounces in silver, and assays of some of the copper glance exceed six hundred ounces to the ton.

These as well as the other combinations mentioned above are deposited through the vein material (calc-silicates, frequently heavy spar) widening out occasionally to pockets of considerable size, and resulting in those ores which stand shipping without concentration.

The whole gangue between the east and west shaft may be regarded as filled in with low grade ore through which the richer veins, pockets and veinlets are dispersed, and I regard it anything but an exaggeration to estimate the value of the ores in this mine as far as it is opened for work at twenty million ounces of silver.

There is no doubt that the greater part of the material on dump, not rich enough to be shipped without concentration, is a low grade ore worth being worked by lixiviation.

The red sandstone, in which the gangue runs to the depth of five hundred and seventy-five feet, will probably change into a crystalline schist or granitic rock at greater depth, and this change will in all probability favorably influence the ore-bearing.

There are numerous outcrops and prospects in the Sierra Carrizo, up to the cliffs of the Sierra Diablo, just as promising as those of the Hazel mine were. The same can be said of the outcrops and prospects of the Quitman and Chinatti [Chinati] mountains. To develop them requires only capital, energy and experience, as proved by assays made in the laboratory of the Geological Survey.

From 1896 to about 1912 the mine was operated spasmodically without any consistent production, and during this period the property was purchased by a group of Dallas men. In about 1912 Sutton, Steele & Steele began operations at the Hazel mine and built a 100-ton reduction mill using a dry-concentration process. Equipment consisted of a Blake crusher, 12 Sutton, Steele & Steele classifiers, 5 Sutton, Steele & Steele concentration tables, and a Sutton, Steele & Steele dielectric separator. Crude ore and concentrates were shipped until May 1914 when the mine closed. According to local sources, mill recovery was very poor. Sporadic shipments continued through 1917 when the mine fell idle.

In the early 1920's the mine was leased by M. F. Drunzer who did some work underground but did not make any large shipments until 1926. In 1926 and 1927 Drunzer shipped 13,000 tons from the old dumps; this material averaged 0.5 percent copper and 9 ounces in silver.

In 1928 the World Exploration Company began operations at the Hazel mine. They reconditioned the buildings, built a 65-foot headframe and a 150-ton ore bin, enlarged the old shaft to 4½ by 10½ feet in the clear, and timbered and lagged a three-compartment shaft to the 340-foot level of the old shaft. A 100-ton flotation mill was completed in January 1930. Equipment consisted of 2 Sturtevant crushers (still on the property), a Colorado Iron Works 6 by 6 ball mill, a Dorr duplex 5½ by 18-foot classifier, 3 MacIntosh flotation machines, an Oliver filter, and 2 Dorr thickening tanks. The mill operated for about 8 months at about 31 tons per day. From May to October 1930, 4,616 tons of ore were treated to yield 238 tons of concentrate carrying 23,260 ounces in silver and

102,587 pounds of copper. The mine and mill closed late in 1930, reportedly from lack of water.

In the early '30's the mine was leased by A. P. Williams of Van Horn. Williams made small but fairly regular shipments until 1945. In 1947 Drunzer again leased the property and shipped a small lot of ore (454 tons carrying 2,731 ounces of silver and 6,983 pounds of copper).

History of production from the Hazel mine is shown in Table 1, but these figures

TABLE 1. *Recorded production from the Hazel mine.*[a]

Year	Ore (short tons)	Copper (pounds)	Silver (fine ounces)
1855–1889*	?	?	?
1890	x	x	[38,000 dollars]
1891	600	42,000	353,370
1892–1905	?	?	?
1906	x	x	x
1907	0	0	0
1908	139	28,364	x
1909	0	0	0
1910	0	0	0
1911	x	x	x
1912	x	721	x
1913	x	34,665	x
1914	x	23,760	x
1915	x	x	x
1916	x	99,569	x
1917	x	x	x
1918	0	0	0
1919	0	0	0
1920	x	x	x
1921–1925	0	0	0
1926	x	10,000 approx.	x
1927	2,360†	19,676	27,365
1928	14,810‡	180,000 approx.	123,670 approx.
1929	6,813§	225,980	41,307
1930	4,616	102,587	23,260
1931	0	0	0
1932	x	x	x
1933	0	0	0
1934	941	28,800	13,359
1935	625	10,832	10,386
1936	223	7,079	3,251
1937	186	4,192	2,291
1938	373	7,217	8,214
1939	1,742	25,459	32,690
1940	1,055	33,000	18,093
1941	268	12,799	1,815
1942	469	28,242	2,081
1943	1,218	45,645	5,801
1944	326	4,909	3,579
1945	397	13,732	1,963
1946	0	0	0
1947	454	6,983	2,731
1948–1950	0	0	0
	37,615‖	1,016,211	674,991

[a]Data from U. S. Geol. Survey Mineral Resources of the United States, U. S. Bur. Mines Minerals Yearbook, and records of American Smelting and Refining Company.

*Mine located in 1850's but development halted by Indian wars. Relocated following Civil War. Von Streeruwitz reports over 200 cars shipped by 1890 with a 600-foot shaft and extensive drifts already existing.

? = nothing known about status of mine.

x = mine known to have shipped ore; figures lacking.

0 = mine known to have been idle.

†Dry silver ore with less than 0.5 percent copper from old dump.

‡10,000 tons from old dump carried 9 ounces silver and 0.24 percent copper; 4,810 tons siliceous ore from underground carried 7.63 ounces silver and 1.53 percent copper.

§Includes 238.5 tons of concentrates.

‖Does not include 80,000 tons estimated production from 1880 to 1896.

can be regarded as an absolute minimum because no records remain of the mine's most profitable years. Some estimate of the true production can be made by analysis of Table 1 in the light of other data, and this is facilitated by dividing the production into an early period (before 1895) of high-grade ores and a later period (subsequent to 1895) of mostly low-grade ores. Examination of the early period shows that in 1891, 600 tons of ore contained 42,000 pounds copper and 353,370 ounces silver, or 7 pounds copper and 588.9 ounces silver per ton. Sample and Gould (1945, p. 19) estimated that 80,000 tons of high-grade silver and copper ores were produced from 1880 to 1885, and Von Streeruwitz stated that the break between shipping ore and tailings during this period was 23 ounces silver per ton. Thus an assumption that this 80,000 tons of ore averaged 10 pounds copper and 50 ounces silver per ton does not seem unreasonable. This would give a total of 800,000 pounds copper and 4,000,000 ounces silver during the early period. The more complete records for the years subsequent to 1895 show a minimum production of 974,211 pounds copper and 321,621 ounces silver, and the total is about 1,774,000 pounds copper and 4,322,000 ounces silver.

WORKINGS

Hazel mine workings are by far the most extensive underground workings in the area. There are three main shafts with a considerable length of drifts and cross-cuts and two open stopes (Pls. II, III, IV). During the last two decades the deeper workings of the mine have been full of water, apparently as a result of seep and run-off rather than underground flow, but the water has been lowered by pumping during intermittent operations. The mine has not been worked below the 400-foot level since about 1900 and has been under water since that time. In 1938 the water level stood at 175 feet in the East shaft and at higher levels in some of the adjacent shafts; in 1944 the water level was 165 feet in the East shaft but was pumped out to 225 feet the following year; in 1952 the water stood within 30 feet of the surface. These high-water levels have prevented extensive underground examination, so that a considerable amount of the descriptions which follow have of necessity been taken from oral reports and early records. This is particularly unfortunate in the case of the Hazel mine because the vein on the outcrop is poorly developed compared to the vein at depth.

East shaft.—The East shaft has been the most important entry in the mine's history and had reached a depth of 575 feet at the time of Von Streeruwitz' examination in 1891. This shaft was deepened to 746 feet before 1900 and is at present the site of the headframe and hoist house. The mine has not been worked below a depth of about 400 feet (6th level) since the early 1900's, and the only information on the lower levels of the mine is given in Von Streeruwitz' early map (Pl. II). He shows drifting and cross-cutting on ten levels which are separated by intervals of some 60 or 70 feet. The upper six levels were included in the reconditioning work done by the World Exploration Company in 1928. According to Von Streeruwitz there was about 600 feet of drifts and cross-cuts on the 7th through 10th levels in 1891, and in all probability there was not a great deal of additional work done on these lower levels between 1891 and 1896 when continuous operations ceased. Most of the high-grade ore in the mine came from the first four levels—above 200 feet. Robbing of pillars and gouging operations have reportedly left the upper four levels of the mine in a dangerous condition. The collar and lagging at the top of this East shaft is rotted and weakened and would have to be repaired before there could be a renewal of operations from this entry.

Two stopes were worked through this shaft. The East stope is reported to be 200 feet deep and was "shrunk," at least in part, through the 4th level (200 feet). The West stope is connected to the East shaft on the 2nd level. Both of these stopes are shrinkage stopes that are open at the surface. The West stope is reported to have contained sporadic pockets of silver ore assaying as much as 1,800 to 2,000 ounces per ton, and most of the high-grade silver ore produced from the mine came from these two stopes.

Most of the dump that now surrounds the East shaft is the product of operations subsequent to 1928. The old dumps constituted low-grade ore and were shipped to the smelter prior to that date.

Inclined shaft.—About 600 feet west of the East shaft is a steeply inclined shaft about 200 feet deep. This shaft intersects drifts on the 3rd and 4th levels. The date of completion of this shaft is not known, but it was not in existence in the 1890's when Von Streeruwitz reported on the property.

West shaft.—The West shaft is 1,800 feet west of the East shaft. At the time of Von Streeruwitz' visit (1891) this vertical shaft had been sunk to a depth of 375 feet, and about 350 feet of drifts and cross-cuts were worked from it. There was never a great deal of additional work done on this shaft, although Evans[3] reports a 25-foot stope west of the entry. On the surface this shaft is a timbered double-compartment shaft, although it is not known to what depth the timbering extends. No head-frame is present, and the shaft is surrounded by its original dump. The shaft was not sunk in ore, and the values in the dump material are low.

There are many other pits and shallow shafts between the East and West shafts. About 150 feet east of the West shaft is the timbered Bonanza shaft with a concreted ventilation raise 50 feet farther east. This shaft was sunk on rich chalcocite ore, and the surrounding dump should be assayed. The workings from this shaft consist of small stopes extending east and west about 50 feet and reportedly connecting with the West shaft. (As shown on the World Exploration Company's map, Pl. III, this Bonanza shaft is erroneously shown to be 375 feet deep; this figure actually applies to the West shaft, about 150 feet to the west.) About 350 feet west of the East shaft is an old vertical shaft known as Middle shaft which Von Streeruwitz in 1891 reported as 42 feet deep with 40 feet of drift. This shaft is located on the southeast corner of the large open stope.

At the time of the writer's examination of the property the workings were filled with seep and run-off water to within about 30 feet of the surface. However, there is a noticeable difference in the water level in the separated workings, and this attests to the tight impermeable nature of the sandstone and vein. The workings are reportedly in a poor and even dangerous condition. The later operators robbed pillars and dumped waste in stopes, cross-cuts, and down the shaft.

[3]Personal communication from G. L. Evans, Texas Memorial Museum, 1951.

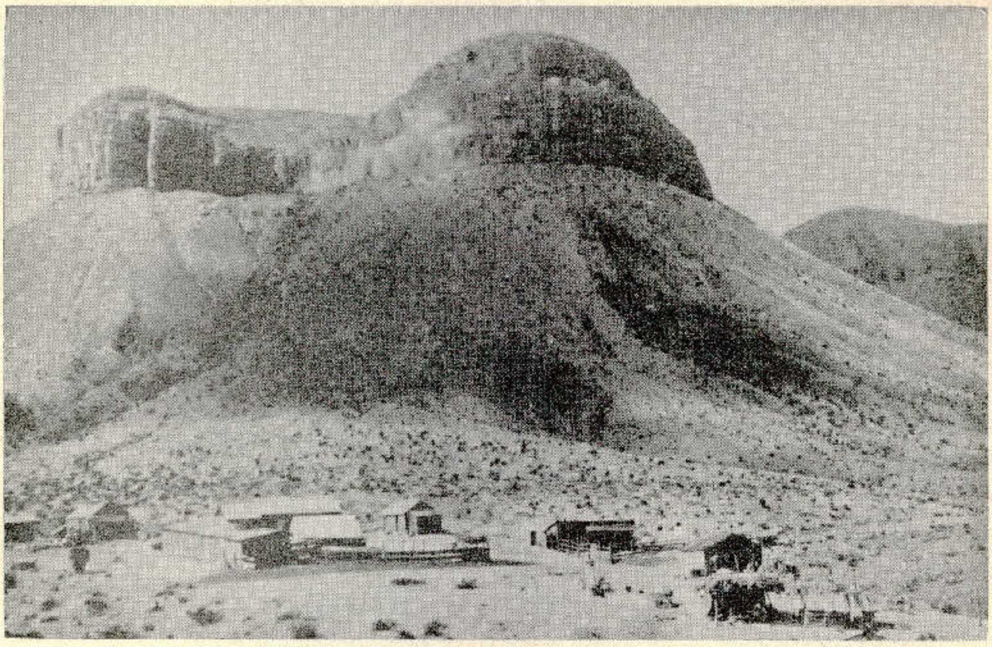
GEOLOGY

General geologic relations.—The Hazel mine is located on an east-west fracture zone in the late pre-Cambrian Hazel formation. The Hazel formation here is a very fine-grained, compact, closely jointed, minutely cross-bedded, homogeneous red sandstone and siltstone that strikes northwest and dips gently southwest on both sides of the fissure. The general geology of the area is shown in Plate VI, a geologic map made by P. B. King using an enlarged U. S. Geological Survey aerial photograph as a base. The Hazel vein stands out on the aerial photograph as a discolored zone that can be traced for over 3 miles west of the main workings, which are located on the approximate east end of the outcropping vein. Other attempts to exploit this vein were made at the Marvin-Judson prospect, 1 mile west of the Hazel mine, and at the Mohawk mine, 3 miles west of the Hazel mine.

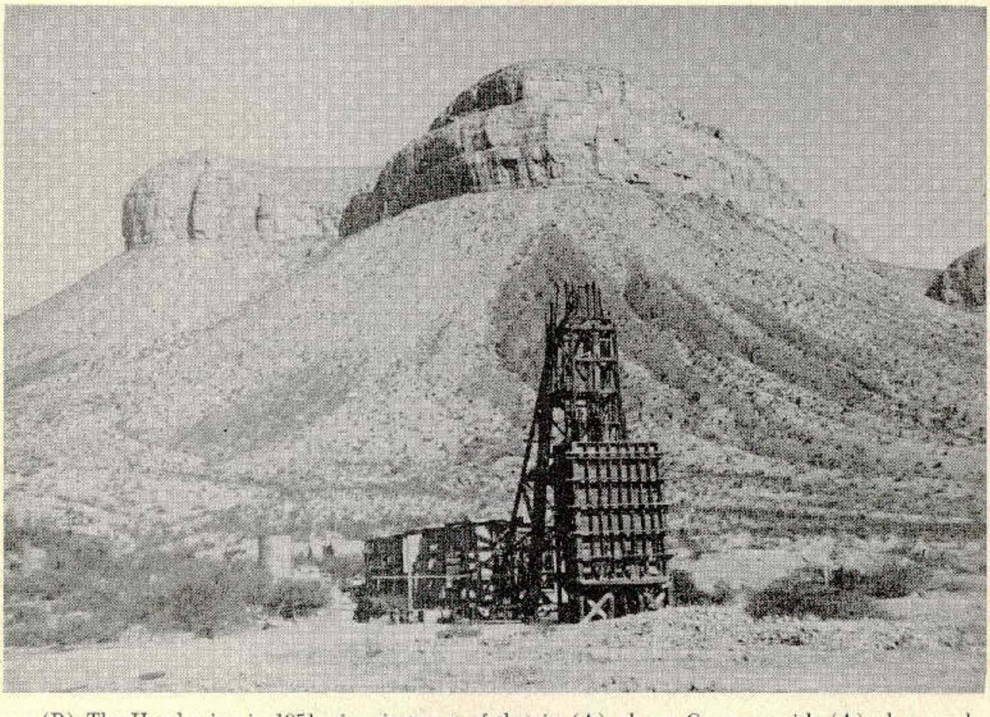
Immediately north of the mine the Hazel formation is unconformably overlain by the Hueco limestone (Permian Wolfcamp). The limestone forms a prominent cliff (Pl. VII) that marks the southern scarp of the Sierra Diablo. Southeast of the mine, in the Beach Mountains, the Hazel formation is unconformably overlain by the pre-Cambrian (?) Van Horn sandstone and a lower Paleozoic section. To the southwest the Hazel formation is thrown into complex folds with the Allamoore formation (pre-Cambrian) which lies stratigraphically beneath it. Boulders and cobbles of Allamoore limestone occur in conglomerate beds interbedded in the Hazel sandstone in the country a mile or two south of the mine, but no conglomerate is present near the mine itself. For references on the general geology of the area, see King (1935, 1940, 1944, 1945, 1949) and a forthcoming report by King and Flawn.

For exploration purposes it would be desirable to know the thickness of the Hazel formation at the Hazel mine, because

Report of Investigations 16 **Plate VII**



(A) The Hazel mine in 1889 (reproduced from a photograph by Rogers; Von Streeruwitz (1890), opposite p. 224).



(B) The Hazel mine in 1951, view just east of that in (A) above. Compare with (A) above and note the increase in creosote bush and decrease in grasses. Photograph taken by P. T. Flawn, 1951.

the lower contact of the formation, which where exposed to the south is a surface of movement, may have influenced ore deposition. Unfortunately there is only very tenuous evidence on this point. King (unpublished notes) has remarked that:

> The Hazel is clearly a very thick formation, but structural relations are such that only incomplete estimates of thickness can be made. Extending northward from the Allamoore formation in the central Streeruwitz Hills there appears to be a continuous, steeply dipping succession at least 5,000 feet thick; of this, more than half is conglomerate. On the eastern scarp of the Sierra Diablo near the Pecos prospect . . . . at least 2,250 feet of gently dipping sandstone is exposed.

At the Hazel mine there is no conglomerate exposed and the outcropping sandstone is apparently within the upper part of the Hazel formation. The East shaft of the Hazel mine reaches a depth of about 745 feet, and the sandstone wall rock apparently extends unchanged to the bottom of the shaft, which was reported to be in "granite." G. L. Evans (oral communication, March 1952) stated that as described to him by a local miner, this "granite" was plainly the conglomerate which occurs in the lower part of the Hazel formation. Concerning the thickness of the conglomerate King (unpublished notes) says:

> In the central Streeruwitz Hills, next to the southern outcrop belt of the Allamoore formation, conglomeratic beds are at least 3,000 feet thick, of which the lower half is solid conglomerate, and the upper half is interbedded conglomerate and sandstone. Conglomerate of similar structural relations in the southern Millican Hills is about 2,000 feet thick.

Thus, unless unrecognized structural relationships exist, the lower part of the Hazel formation, comprising 2,000 to 3,000 feet of conglomerate, must be penetrated before the bottom contact of the formation is reached.

Two definite structural trends marked by northwest-trending faults and east-west trending fractures are present in the general area (Pl. VI). The east-west Hazel fracture zone is intersected by a northwest-trending fault about 1 mile west of the Hazel mine at the Marvin-Judson prospect. The southwest side of the fault has apparently moved northwest, but there is no visible displacement of the Hazel fracture zone or the fault at the point of intersection, and the rock on either side of the Hazel fracture zone maintains a northwest strike and a gentle southwest dip. Evidently the nearly vertical Hazel fracture zone is younger than the northwest-trending fault or at least younger than the strike-slip movement along the northwest-trending fault. Tertiary normal faulting in the general region is characterized by similar northwest-trending and east-west trending faults, and it is possible that the Hazel fracture zone and the northwest-trending fault that intersects it are Tertiary structures, although the horizontal displacement in the northwest-trending fault is not characteristic of Tertiary faults in this area. King (personal communication, January 1952) states that the west-northwest fault system has had a long and complex history. He notes Tertiary vertical movements, several periods of pre-Tertiary vertical movements, and still older strike-slip movements that may be late-pre-Cambrian.

Hazel fracture zone.—In the vicinity of the Hazel mine the Hazel fracture zone shows up on aerial photographs of the area as a series of sub-parallel and *en échelon* fractures.

The fractured zone is marked by bleached, brecciated, and altered sandstone. The altered rock is yellow to gray and stands out clearly against the red sandstone that forms the walls. There is no evidence of large-scale displacement along this fracture zone, but the writer is informed that slickensides and mullion structures are visible underground. The main east-west fracture zone is intersected by a number of small northeast-trending fractures which have apparently been important in localization of the ore. At the surface the altered yellow sandstone that constitutes the gangue is generally less than 7 feet wide and occurs in discontinuous patches and feathery projections. Underground, however, the altered rock comes in solidly between distinct red sandstone walls and widens steadily downward until, according to Von Streeruwitz, it attains a thickness of over 40 feet at a depth of 500 feet. Evidently the present surface of the ground intersects the top of the fissure system.

MINERALIZATION

The ore.—The following copper and silver-bearing minerals from the Hazel mine were reported by Von Streeruwitz:

silver-bearing copper glance (chalcocite)
gray copper (tetrahedrite)
silver copper glance
silver glance (argentite)
native silver
chlorides with more or less copper
traces of lead
traces of antimony and arsenites
traces of gold

S. J. Lasky (letter to P. B. King, August 25, 1938; memorandum to P. B. King, October 28, 1938) reported that the steely mineral occurring as threads in the bleached rock is tennantite, and specimens given to him and said to have come from the upper levels of the mine were steely chalcocite. Lasky also noted pyrite, galena, chalcopyrite, and a trace of bornite. Massive sulfide specimens collected by the writer on a dump near the West shaft were steely chalcocite. Three polished sections of these dump samples from the West shaft were examined by the writer, and all consist largely of anisotropic chalcocite intimately penetrating and penetrated by barite. Fine brecciation and flowage structures are present in all three samples. Small irregular patches of bornite (0.02 mm) occur within the chalcocite and are commonly separted from the chalcocite by a very thin border of gray mineral that is probably tetrahedrite-tennantite. Small masses of covellite and tiny clusters of pyrite grains occur sporadically within the chalcocite and barite. Gangue minerals are calcite, barite, and quartz. The quartz is probably from the original sandstone.

Three polished sections of massive metallic fragments from the dump near the East shaft show a fine intergrowth (in part a microbreccia) of barite and a large number of metallic minerals. Chalcocite, tetrahedrite-tennantite (?), bornite, an unidentified strongly anisotropic brownish-gray mineral, chalcopyrite, native silver, pyrite, marcasite, covellite, and an unidentified pale silver-white mineral (antimony?) are present in approximately that order of abundance. The extremely fine grain size precludes microchemical analysis of the unknowns with the facilities available to the writer. Pyrite is apparently early and occurs in fractured grains which locally have been drawn out into lenses. Chalcopyrite is in part early in fractured grains and in part late in narrow veinlets parallel to the flowage structure. Bornite occurs in spongy intergrowths with tetrahedrite-tennantite (?) and in veinlets parallel to existing flow structure. Chalcocite and the unidentified brownish-gray mineral seem to have come in late and "healed" the microbreccia, but the relationship of the chalcocite and brownish-gray mineral to the bornite-tetrahedrite-tennantite (?) intergrowths is not apparent. Native silver was the last ore mineral deposited and occurs in fractures that crosscut the earlier structures and grain boundaries. Marcasite covellite, and the unidentified pale silver-white mineral (antimony?) are present in minute quantities. Possibly some argentite is included in what is here called tetrahedrite-tennantite (?) (see p. 8) because the two minerals, both gray, are not easily distinguished in such a fine-grained intergrowth. A thorough study of the relationship of mineral paragenesis and fracturing or brecciation would perhaps aid in the search for high-grade silver ore in this mine.

Assays of Hazel mine ores are erratic and characterized by sporadic high silver values. The bulk of the high-grade silver ore came from the open stope west of the main shaft (West stope) where assays as high as 1,800 to 2,000 ounces per ton were reported. As indicated by the polished section study, tetrahedrite-tennantite (?) and native silver were important ore minerals in this part of the vein. Silver values drop to the west, and in the vicinity of the West shaft the principal ore mineral is chalcocite. Most of the bleached altered sandstone gangue between the East and West shafts assays 1 to 5 ounces in silver. An unsubstantiated report handed down from one of the early miners in the Hazel mine states that work on the main shaft stopped at 746 feet because of a decrease in silver values downward. In the early days of the mine it was necessary to have a silver content above 23 ounces per ton to make shipping ore. The copper content of the ore supposedly remained fairly steady with increased depth.

Lasky (memorandum to P. B. King, October 28, 1938) reports on a black rock found in certain parts of the vein.

The black rock that accompanies the stronger parts of the vein and that the miners say they use as a guide to ore, seems to be crushed rock and vein matter that owes its color to comminuted sulphides. . . . . some of this black rock has a streaked structure resembling flowage and has about the texture and hardness of some slate. In it are breccia pieces of both vein matter and of wall rock, and the adjacent wall rock is also brecciated in some places. A thin section of the black rock shows breccia pieces of rock and calcite, and grains of quartz (presumably from the original sandstone), in a cryptocrystalline matrix made gray to black by opaque dust. Examination of a polished section cut from the same fragment as the thin section fails to give any clue as to the identity of the opaque dust, the only mineral identifiable being the irregular grains of pyrite that can be seen in the hand specimen, but I obtained a good microchemical test for arsenic. Though a test for copper is negative, the positive test for arsenic would seem to indicate that some of the opaque dust is tennantite, presumably powdered so fine as not to be apparent on polished surface, perhaps because of having been gouged out during polishing.

Localization of ore.—The copper and silver-bearing minerals occur in narrow veinlets and stringers in the yellow gangue. In the vicinity of the East shaft there are two main veins within the fractured zone, the north vein and the south vein. According to Von Streeruwitz (1892, p. 388), the north vein is essentially vertical throughout the depth of the shaft (575 feet in 1891). The south vein is perpendicular from the outcrop to a depth of about 150 feet, where it changes to a steep north dip and joins the north vein at a depth of about 450 feet. At a depth of about 300 feet a third vein comes in from the south, dips steeply north, and joins the two main veins at a depth of about 500 feet, just below the 8th level (Pl. II). The gangue between these veins is brecciated and filled with narrow anastomosing veinlets of silver and copper sulfides and sulpho-salts. A. P. Williams of Van Horn stated that in the drifts west of the East shaft the main metal-bearing veins averaged 2 to 3 inches wide with small pockets of rich ore where the east-west veins were intersected by cross fractures. In the open stope west of the main shaft there was a massive body of silver-copper minerals and barite 2 to 3 feet wide. In this area the east-west veins were intersected by a number of northeast-trending fractures that were also mineralized.

The interlacing ore veinlets pinch and swell along the strike, resulting in ore pockets and relatively barren areas, and it is this that has made it difficult to "stay in ore" or to calculate reserves at the Hazel mine. The ore is sharply contained within the massive sandstone walls bounding the fracture zone and is not disseminated within the country rock to any noticeable degree.

P. B. King (unpublished notes) describes a rather typical cross section of the fracture zone from an open cut 200 feet east of the East shaft.

The vein is nearly a vertical fracture about 7 feet wide, consisting of main fractures on each side, connected by diagonal, interlacing cross-fractures, enclosing moderately crushed country rock. Decolorization of the red sandstone extends 1 to 2 feet away from the vein on each side. Between the bordering fractures, decolorization is irregular. Mineralization consists of barite, with some chalcopyrite and tetrahedrite, which fill cracks 1 to 3 inches wide. The metallic minerals form only a small percent of the total volume.

Wall rock alteration.—Two types of altered Hazel sandstone are present in the fracture zone: a soft, crumbly yellow to buff rock and a hard gray rock carrying some metallic minerals visible as minute black spots. It is probable that alteration proceeded in that sequence; first a bleaching of the red iron oxide color and leaching of the cement of the red sandstone and then, in some places, an impregnation of metallic minerals. Both alteration types are veined by calcite and barite.

Sequence of mineralization.—The writer was unable to visit the mine underground and therefore unable to collect a suite of samples for a detailed paragenesis study. However, some general statements can be made. Brecciation and movement in the Hazel fracture zone occurred before and after the mineralization. This is demonstrated by brecciated ore made up of angular fragments of wall rock and ore minerals cemented by calcite (noted by King) and the finely comminuted opaque "dust" noted by Lasky in the black "slaty" rock that commonly accompanies the ore.

Barite is also a guide to ore in the mine, and the relationship of barite to the copper-silver minerals is worthy of study. Barite invariably occurs with ore, but the converse is not true. The writer has observed breccia fragments of gray sandstone surrounded by a thin coating of metallic minerals and the whole completely enveloped by barite. The space between the barite-coated fragments was then filled by metallic minerals. Apparently, the copper-silver mineralization both preceded and followed barite mineralization, although there may have been changes in the nature of the precipitated ore minerals over the period of deposition (perhaps a change from tennantite-tetrahedrite during early stages to chalcocite in the final stage).

Age of the mineralization.—The age of the mineralization at the Hazel mine or in the general area cannot be accurately determined. If the mineralized structures are Tertiary, which cannot be positively determined, the mineralization is also of a Tertiary age.

GRAVIMETRIC DATA

Observations of gravitational force in the vicinity of the Hazel mine and the Marvin-Judson prospect were made by V. E. Barnes and P. T. Flawn January 15–18, 1952. The observations were made with a LaCoste-Romberg gravity meter, and the writers wish to express their gratitude to Dr. L. J. LaCoste for the loan of the instrument. Frederick Romberg examined the data and helped make interpretations.

The observations were reduced in the usual manner for latitude and elevation. A combination Bouguer and free air elevation correction of 0.06 mg/ft was used, which corresponds to a density of 2.67 gms/cm^3. Terrain corrections were not made, even though for some stations the need for such corrections is apparent. These stations are mostly situated on the fringe of the area and have been disregarded. Tie-ins and check readings show that the probable error of any station with respect to any other station is less than 0.04 mg and that most of this error is due to insufficient accuracy in obtaining elevations. The elevations are least accurate in the areas of rough terrain which, as mentioned above, is mostly on the fringe of the surveyed area.

The locations of the stations, and the contour lines for the force are shown in figure 2 for the Hazel mine and in figure 3 for the Marvin-Judson prospect. North of the Hazel mine fracture (fig. 2), the gravity gradient changes, steepening northward. Such a change in the vicinity of a known fault might indicate a difference of density of the rocks on opposite sides of the fault. For such a feature, however, the classical interpretation is a level gravity field on one side and a level gravity field on the other side at a different level, with a gradient in between. More gravity data should have been obtained to the south in order to give information about the regional gradient in this direction. If the gradient steepens in this direction the classical interpretation would be fulfilled. If this interpretation is correct the density contrast should be situated at a depth of 300 or 400 feet and the denser material should be north of the fault. The implication of this interpretation is discussed later in "recommendations for exploration."

Another interpretation is possible because the Hazel sandstone in the vicinity of the vein is leached and less dense than normal. Density determinations made on nine specimens of the leached rock range from 2.32 to 2.60 gm/cm^3 and the average is 2.49 gm/cm^3, giving a density contrast of about 0.2 gm/cm^3 with the fresh rock. The leached zone averages about 34 feet thick, and the gravity anomaly (fig. 4) caused by such a zone will amount to about 0.1 mg. At least part of the flattening of the gravity gradient in the vicinity of the Hazel fracture zone could be caused by the presence of leached rock.

In the vicinity of the Marvin-Judson prospect (fig. 3) a negative gravity anomaly follows the main alluvium-filled valley. Removal of the regional gradient accentuates but does not change the position of the negative anomaly. Alluvium, being less dense than the Hazel sandstone, should cause a negative anomaly. The effect of 10 feet of alluvium can be estimated by assigning a density of 1.97 gm/cm^3 to the alluvium and comparing it to the Hazel sandstone which has a density of 2.67 gm/cm^3. This gives an anomalous density of 0.7 gm/cm^3. Therefore 15 feet of alluvium should cause a negative anomaly of the order of 0.15 mg., so that 15 feet of alluvial fill would be sufficient to produce all of the anomaly found.

However, a portion of the anomaly could be explained by a density contrast produced in some other manner. For example, the Hazel sandstone beneath the alluvium could be brecciated and porous and thus have a lower than normal bulk density. Because

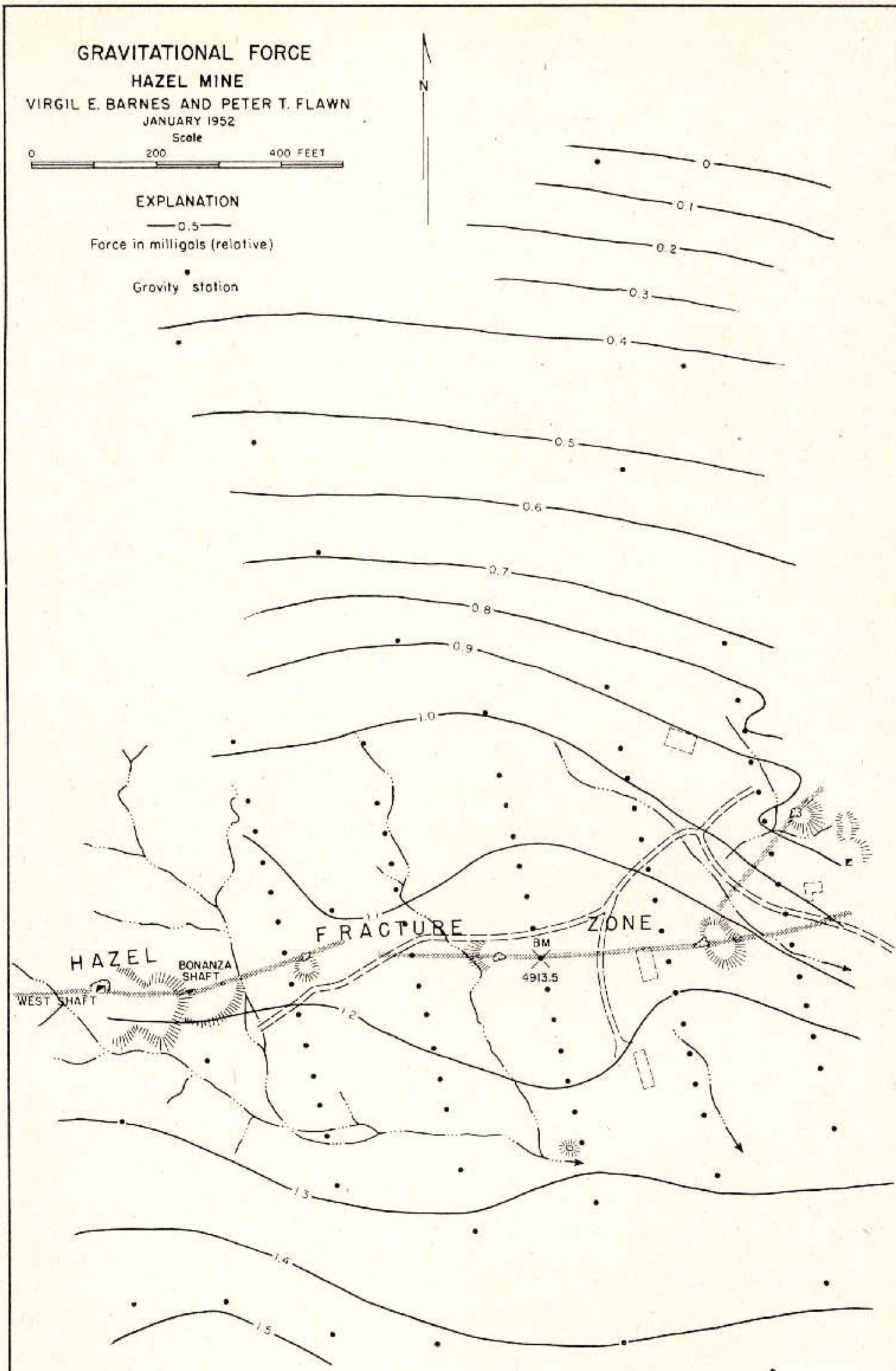


Fig. 2. Gravitational force map of Hazel mine.

the drain is following a fracture, this might be true. There is no evidence of a density contrast on opposite sides of the fracture, and also there is no evidence of a density contrast on the opposite sides of the Hazel mine fracture in this area.

The gravity survey failed to reveal any sharp positive anomaly indicative of a concentrated heavy mass (ore minerals plus heavy gangue) in the vicinity of the Hazel mine or the Marvin-Judson prospect. However, this is not positive evidence of the absence of concealed ore bodies in these areas because the effect of local concentrations of heavy metallic sulfides and barite might be compensated by general deficiency in density of the fracture zone itself. Moreover, concentrations of copper-silver minerals that might be worked profitably may not cause a sufficient density contrast to produce a gravity anomaly. The gravity meter survey was undertaken in hopes that a near-surface lens of barite and metallic sulfides, similar to those encountered in the stopes east and west of the East shaft, could be detected.

ORE RESERVES

Through the courtesy of A. P. Williams of Van Horn, the writer was permitted to examine assay maps made about 1929 or 1930 by the World Exploration Company. According to these maps, the World Exploration Company left 10,000 to 15,000 tons of broken low-grade ore (1 to 2 percent copper and 3 to 5 ounces in silver) in stopes between the 4th and 6th levels. This ore body apparently results from the convergence of the north and south veins and is about 25 feet wide (Sample and Gould, 1945, p. 19). Additional ore remains to be developed.

INVENTORY OF THE PROPERTY

The buildings and equipment at the Hazel mine, like the surface geology, are not prepossessing. There are three build-

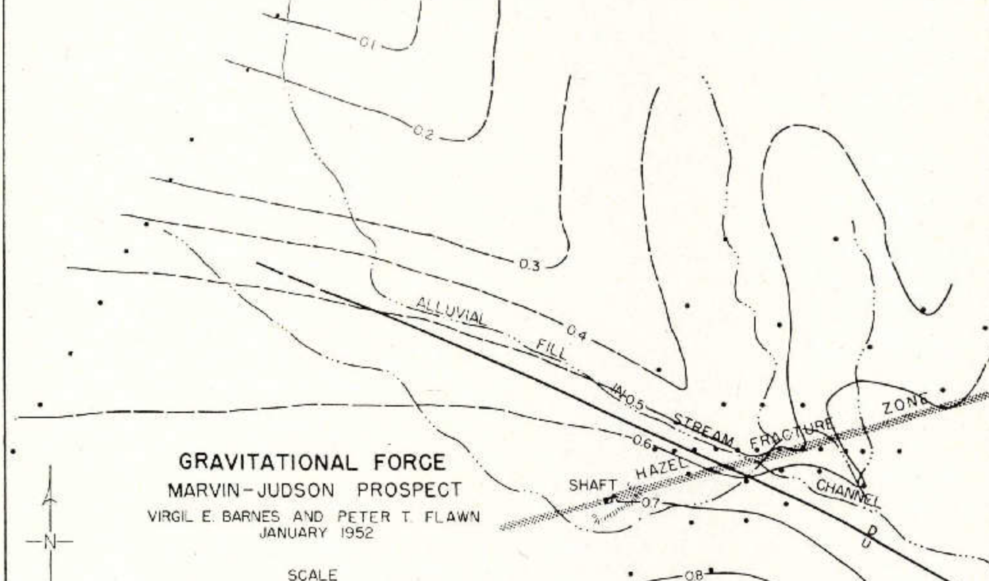


Fig. 3. Gravitational force map of Marvin-Judson prospect.

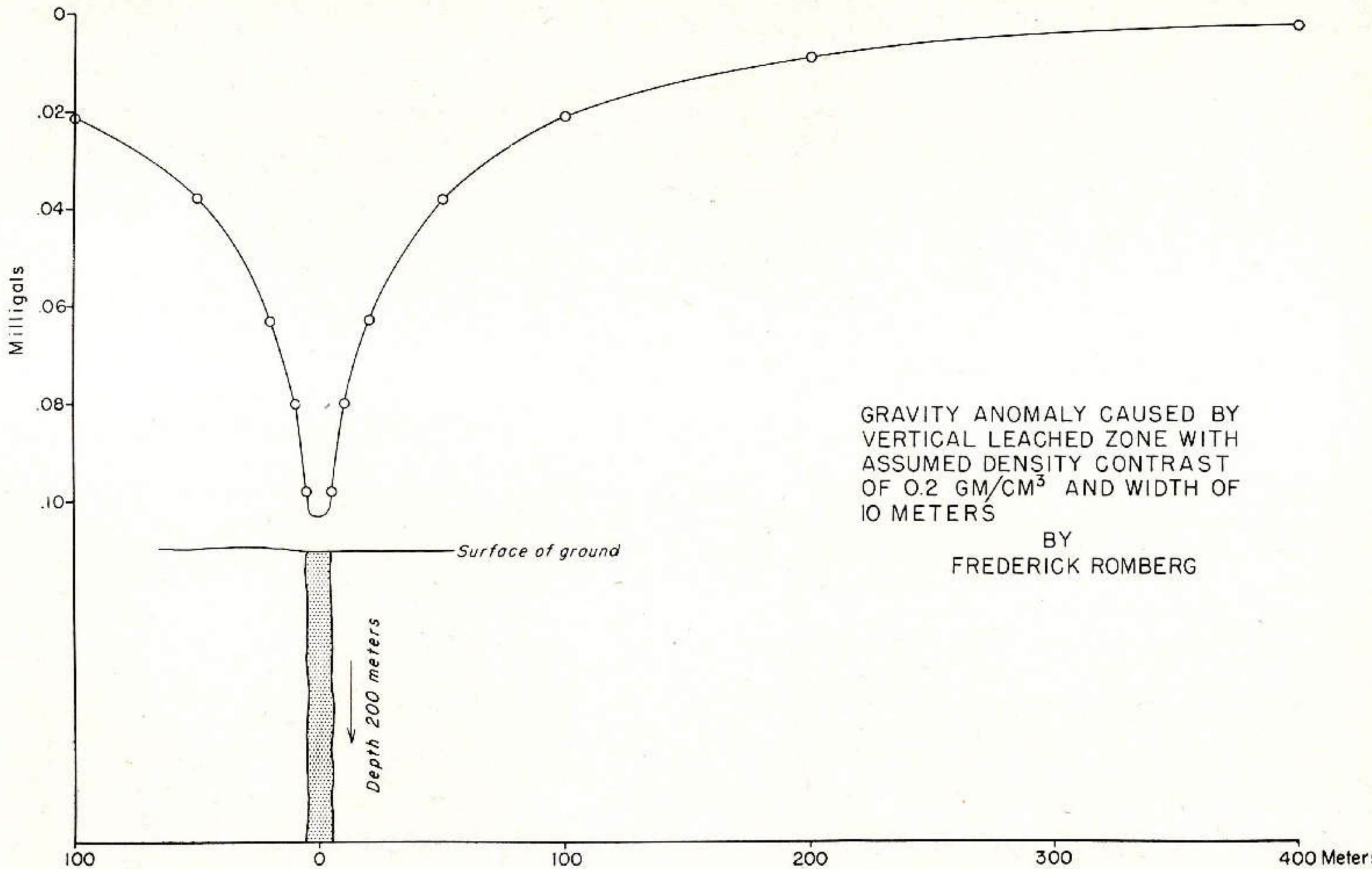


Fig. 4. Diagram of gravity anomaly caused by leached zone.

ings standing—the power house, hoist house, and a bunk house or office, but the hoist house has served as a source of corrugated tin roofing and siding and is partly demolished. The 65-foot headframe on the East shaft has suffered from woodpeckers and boring insects and needs repair. The ore bin (150-ton) is in good condition. The following equipment remains in the hoist house:

1 Fairbanks-Morse 60 HP gasoline hoisting engine, latest patent 1909, drum and cable (presumably there is an ore bucket at the end of the cable in the shaft)
1 85 HP Bessemer gasoline engine, latest patent 1899
1 Ingersoll Rand compressor, Imperial type 10
1 starting engine and compressor—8 HP Ziegler Schryer gasoline engine and size 45 Worthington compressor

The power house contains:

1 General Electric 2,300-volt, 45.3 ampere alternating-current generator
1 General Electric 125-volt direct-current generator (exciter for large generator)
Control panel

At the old mill site there are two Sturtevant Mill Co. 10 x 15 jaw crushers and a small gasoline engine.

It is doubtful if it would be economical to repair any of the equipment on the property.

RECOMMENDATIONS FOR EXPLORATION

Large-scale mining operations at the Hazel mine ceased in 1930 for the same reason that most mines close—lack of ore. Possibly the World Exploration Company could have continued operations for a time if they had had an adequate water supply for the mill, but there is no indication that they had successfully developed an ore supply. There is a possibility that an intelligent exploration program might develop new ore bodies at the Hazel mine. Such a program should take two possibilities into consideration: first, the possibility of discovering rich silver-copper "pods" or "pockets" such as were found at shallow depth east and west of the East shaft; and, second, the possibility of discovering a large tonnage of relatively low-grade copper ore at some depth where the vein is wide. The project should investigate (1) the undeveloped ground between the two shafts and (2) the lower levels of the mine. The mine is near both railroad and smelter, and the siliceous ore from this mine has been favorably received by the smelter in the past.

The undeveloped ground between the East and West shafts could be easily and cheaply explored by core drilling. In the area about 100 to 150 feet south of Owens' house (Pl. I) the sandstone is shattered, and, as projected from the surface evidence, a number of fractures intersect. On the surface this general area is perhaps the most favorable for prospecting, but it should be remembered that the fracture system widens underground and the vein west of this area to the West shaft should not be neglected. About a mile west of the Hazel mine is the intersection of the Hazel fracture with a northwest-trending fault (Pl. VI). The immediate vicinity of the intersection in concealed by a stream wash. West of the fault intersection is the Marvin-Judson prospect which consists of a vertical shaft cribbed with railroad ties. Bleached sandstone and barite can be seen on the dump. This area should be investigated.

The lower levels of the Hazel mine should be dewatered and examined to determine the nature of the fracture zone and the mineralization at depth. Von Streeruwitz reports a vein width of over 40 feet below a depth of 500 feet, and there is no reliable information on the nature of the mineralization at this depth. The unsubstantiated report that silver values decrease with depth while the copper values remain steady should be investigated in the light of the present world mineral situation. The lower levels of the mine were worked during the early period of the mine's history before the turn of the century when this part of Texas was little developed and costs were high. G. L. Evans (personal communication, March 1952) informed the writer that, according to a report he received, it was not economical to hoist ore valued at less than $30.00 per ton from the lower levels of the mine.

The sandstone is relatively flat-lying in the vicinity of the mine and, based on observations made to the south by King, is probably 3,000 to 4,000 feet thick. To the south the Hazel formation is stratigraphically above the Allamoore formation, a sequence of interbedded limestone, phyllite, and volcanic rocks, but complex structure makes it impossible to predict the subsurface relations in the Hazel mine area. If it is true that the East shaft bottoms in conglomerate, there is probably several thousand feet of it below the shaft; thus it would not be practicable to probe for the lower contact of the Hazel formation in hopes that it localized ore deposition. The conglomerate cannot be regarded as a more favorable host than the sandstone because it is a very hard compact rock. The unconfirmed reports on the geologic relations at the bottom of the shaft state that the vein in the conglomerate or "granite" is sharply walled and cuts cleanly through the country rock.

The interpretation of the gravity data indicates the presence of a heavy mass on the north side of the fracture at a depth of 300 to 400 feet. No such mass is mentioned in the previous reports. Possibly it is a conglomerate layer (the majority of fragments within the conglomerate are Allamoore limestone which would make a rock with higher density than the sandstone) that has been raised along the upthrown side of the fault. An exploration program should include investigation of this anomaly.

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