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QUICKSILVER DEPOSITS NEAR THE LITTLE MISSOURI RIVER PIKE COUNTY, ARKANSAS

BY
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CONTENTS

ILLUSTRATIONS

QUICKSILVER DEPOSITS NEAR THE LITTLE MISSOURI RIVER, PIKE COUNTY, ARKANSAS

By David Gallagher

ABSTRACT

The quicksilver district of Arkansas, where cinnabar was discovered in 1931, lies in the southwestern part of the State, in Clarke, Pike, and Howard Counties. During the Ouachita mountain-building period in Pennsylvanian time the Paleozoic rocks, including the Pennsylvanian Jackfork sandstone and the Stanley shale with its included sandstone members, were involved in a great overthrusting movement and now stand nearly vertical. The rocks in the overriding block were broken along northeast tear faults, north-south faults, and bedding-plane faults. The thrust movement, together with a subordinate east-west compression, caused local crumpling into Z-shaped and S-shaped bends. In the tensional parts of these bends, and at structural intersections, the permeability of the sandstones was increased, permitting the ingress of quicksilver-bearing solutions. The solutions were trapped beneath impermeable shales, where they formed tabular and pipelike deposits classifiable into six structural types: (1) Z-bends, (2) S-bends, (3) drag-folds, (4) fold-fault intersections, (5) fault-fault intersections, and (6) fault zones. Cinnabar is the only valuable mineral present, and the gangue is mainly quartz with some dickite. The tenor varies widely, but is commonly between 5 and 15 pounds of quicksilver to the ton. Since the discovery in 1931, Arkansas has produced about 8,000 flasks of quicksilver,[1] of which about half has come from the mines described in this report. The State has contributed annually about 1 to 3 percent of the total United States production, and under favorable price conditions can probably be counted on for between 1,000 and 2,000 flasks per year for at least one and perhaps two decades.

INTRODUCTION

The quicksilver deposits of Arkansas are chiefly in Pike County, in the southwestern part of the State, a few miles north of Murfreesboro. Cinnabar has been found at many places in the steeply dipping Carboniferous sedimentary rocks just north of

1/ A flask is the standard unit of quicksilver and contains 76 pounds net.

the Cretaceous overlap. The deposits lie within a narrow belt about 30 miles long, which extends east and west parallel to the regional strike. Only the deposits in the western part of the belt, near the Little Missouri River and about 6 miles west of State Highway 27, are considered in this report.

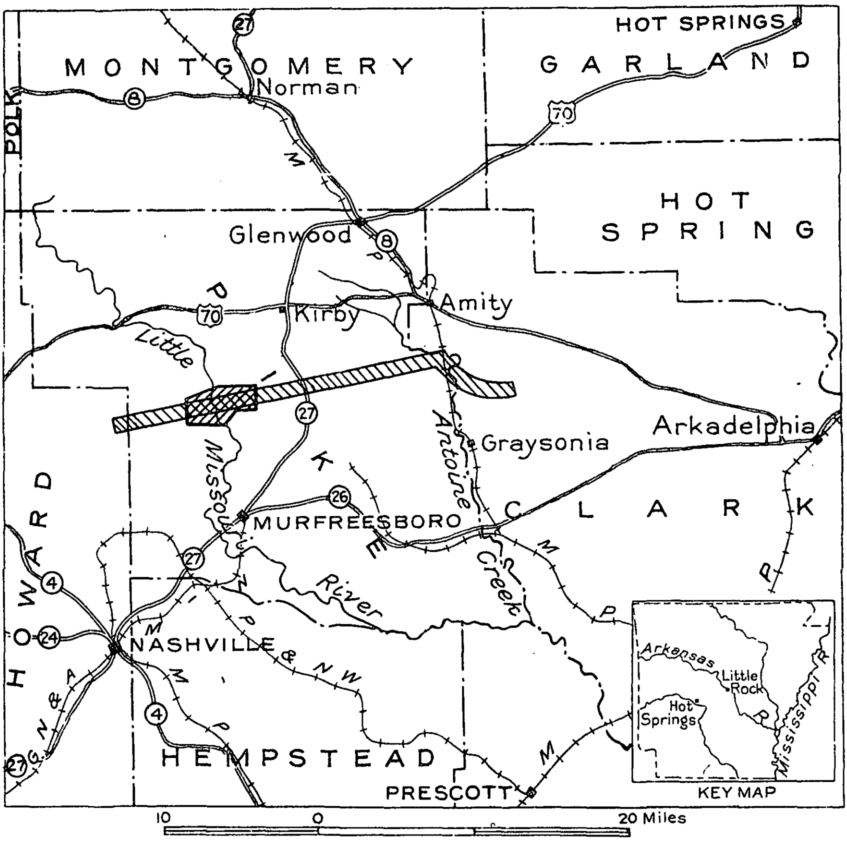

Figure 17.—Index map showing location and extent of the southwestern Arkansas quicksilver district (shaded area).

Cinnabar was first identified in this region in July 1931, and shortly thereafter detailed geologic mapping was done by N. H. Stearn and J. M. Hansell for one of the mining companies. The most recent and comprehensive publication on the district is a report by Reed and Wells.[2] Its maps and discussions of stra-

2/ Reed, J. C., and Wells, F. G., Geology and ore deposits of the southwestern Arkansas quicksilver district: U. S. Geol. Survey Bull. 886-C, pp. 15-90, 1938.

tigraphy, regional structure, and other factors of geologic setting were used as the background for the present investigation, whose objects were to study workings to determine more closely the factors that controlled ore deposition, and to estimate the potential value of the district as an emergency source of quicksilver.

In this study the Geological Survey and the Bureau of Mines, United States Department of the Interior, cooperated. The author prepared detailed geologic maps showing the surface topography, geology, and workings of 11 mines, and the underground workings and geology of 7 of these; the Bureau of Mines engineers directed diamond-drilling and bulldozer-trenching. The locations of the detailed maps are shown on plate 23, an index map overprinted on a segment of the map made by Reed and Wells.[3]

The writer wishes to acknowledge the cordiality and cooperation of the mining men of the district. Particular thanks are due to Messrs. J. D. Freeman, Leo Yount, R. B. McElwaine, and Ralph Cranston. The cooperation of Mr. M. C. Smith, who was in charge of the exploration project of the Bureau of Mines, United States Department of the Interior, is also appreciated. H. G. Ferguson, F. C. Calkins, T. A. Hendricks, J. C. Reed, and E. B. Eckel, of the Geological Survey, contributed many helpful suggestions and criticisms during the field work and the preparation of the manuscript.

GEOLOGY

As this report has a limited purpose, no attempt will be made to give a full account of the regional geology. In the following summary of the essential geologic features, the work

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3/ Reed, J. C., and Wells, F. G., op. cit., pl. 2.

of others is freely drawn upon.[4]

The northwestern part of the State of Arkansas is underlain by Paleozoic sedimentary rocks. These lie relatively flat in the northern part of the State, but are found to be progressively more and more deformed as they are traced southward into the Ouachita Mountains, which represent the eroded remains of what was formerly a great mountain range. The southeastern part of the State is covered by nearly flat-lying post-Paleozoic sediments, which overlap from the south onto the deformed Paleozoic rocks. The most southerly Paleozoic rocks to appear from under the northern edge of these overlapping younger sediments are Carboniferous shales and sandstones. These are tilted almost vertically and have a regional strike slightly north of due east. As the Pike County quicksilver belt extends along the strike of these rocks, it is long and narrow.

Differential erosion has carved strike valleys in the easily eroded shales, while the more resistant sandstones stand up as prominent ridges. The dominant topographic features are a southern sandstone ridge and a northern sandstone ridge, separated by a long, narrow, shale lowland, which consists essentially of two parallel valleys separated by a median ridge held up by a resistant sandstone member in the shale. The ridges are broken by gaps, which cross the regional strike at high angles and were probably eroded along fault zones.

Stratigraphy

The rock formations of the district are the Stanley shale, the Jackfork sandstone, and the Atoka formation, all of Pennsyl-

4/ Miser, H. D., and Purdue, A. H., Geology of the De Queen and Caddo Gap quadrangles, Ark.: U. S. Geol. Survey Bull. 808, pp. 1-195, 1929.
Hansell, J. M., and Reed, J. C., Quicksilver deposits near Little Missouri River, southwest Arkansas: Am. Inst. Min. Met. Eng. Trans. 115, pp. 229-244, 1935, with discussion by N. H. Stearn, pp. 244-246.
Stearn, N. H., Structure from sedimentation, Parnell Hill quicksilver mine, Ark.: Econ. Geology, vol. 29, pp. 146-156, 1934; The cinnabar deposits in southwestern Arkansas: Econ. Geology, vol. 31, pp. 1-28, 1936.
Reed, J. C., and Wells, F. G., op. cit.

vanian age. Only the first two are of concern in this report, for the Atoka occurs mainly outside the area. Observation must in the main be limited to the sandstones, because the soft shales are rarely exposed except in stream beds.

The Stanley shale is here generally less than 3,000 feet thick—less than half as thick as it is on the Athens Plateau.[5] It contains many thick beds of sandstone, and it has three thick sandstone members, which are ore-bearing. These are (1) a 100-foot sandstone about a thousand feet below the top of the Stanley, (2) below it, and separated from it by 150 feet of shale, a 300-foot sandstone, and (3), more than a thousand feet lower stratigraphically, a 160-foot sandstone. The 100-foot and 300-foot sandstones, together with the intervening 150 feet of shale, were named by Stearn [6] the Gap Ridge sandstone member of the Stanley shale. Reed and Wells, however, use the name in a more restricted sense, applying it to the 300-foot sandstone only, for the reason that "the upper 100-foot sandstone cannot be differentiated throughout the district * * *."[7] The 160-foot sandstone was named by Stearn [8] the Parker Hill sandstone member of the Stanley shale, but this name is not adopted by Reed and Wells.

The Jackfork sandstone is about 80 percent sandstone and 20 percent shale. The individual sandstone beds range in thickness from a few inches to as much as 20 feet, but commonly have a thickness of from 1 to 3 feet; the beds of laminated shale are generally thin, but may locally attain a thickness of more than 100 feet. The total thickness of the Jackfork is unknown because of the inadequate exposures and the complication due to thrust faulting, but it is estimated to be about 6,000 feet.

5/ Miser, H. D., and Purdue, A. H., op. cit., p. 60.
6/ Stearn, N. H., [Discussion of Am. Inst. Min. Met. Eng. Tech. Pub. 612]: Am. Inst. Min. Met. Eng. Trans., vol. 115, p. 245, 1935.
7/ Reed, J. C., and Wells, F. G., op. cit., p. 25.
8/ Stearn, N. H., op. cit. (Trans.), p. 245.

472020 O - 42 - 2

In the Stanley shale the sandstone beds have about the same range of thickness as in the Jackfork sandstone. The thickness of individual beds can commonly be seen to vary within distances of a few hundred feet along the strike. This variation in thickness may be original, but it has probably been caused in part, or at least accentuated, by the intensive deformation these rocks have suffered. Shale partings between sandstone beds have been thinned by compression and squeezed out laterally, so that in places one sandstone bed is separated from another by only a thin smear of gougy shale.

Except for the proportion of sandstone to shale within them, the two formations resemble each other so closely that they are not easily distinguished in the field. Both display the same set of lithologic peculiarities, and both are practically unfossiliferous.

Structure

The rocks of the region dip prevailingly southward at an average angle of about 80°, and have been deformed by four sets of fault movements with attendant crumpling. The duplication of the Jackfork sandstone, which lies with its top facing southward [9] in the ridges both north and south of the older Stanley shale of the lowland, is due to a major thrust fault movement from the south which pushed the rocks northward and upward. This fault has been named the Cowhide thrust by Reed and Wells, and although they indicate it diagrammatically on their map by a single line, it is more probably a zone of faulting, perhaps several hundred feet thick in places.

The other three sets of faults are subsidiary faults within the overthrust block and are attributed to east-west compression coupled with the thrusting from the south. These three sets are (1) northeast-striking tear faults on which the southeast side

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9/ Stearn, N. H., op. cit. (Econ. Geology, vol. 29).

moved relatively northeastward, (2) north-south faults on which the west side moved relatively northward, and (3) bedding-plane faults. These movements appear to have occurred in the general order named, but it is believed that all belong to one great period of deformation. The poor exposures and absence of definite distinguishing characteristics for individual beds limit the available evidence and make it difficult to coordinate the structural data.

The east-west compression also produced small folds of two patterns. Seen in plan these folds are Z-shaped and S-shaped (fig. 18). They resemble their alphabetic counterparts not only in form but also in bearing a right- and left-handed relation to

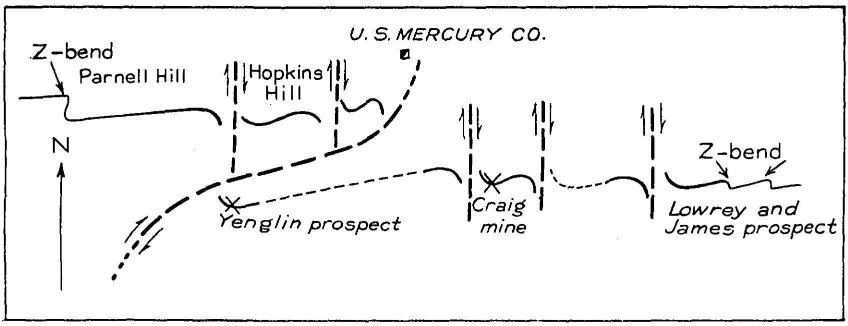


Figure 18.--Idealized sketch of Z-bends and a series of S-bends.

one another. The Z-bends are oriented so that they resemble a letter Z in its normal position when north is at the top of the map, but the S-bends resemble the letter S only when the map is rotated 90°. (This is properly described as a lazy S.) In addition to the S and Z folds there are simple drag folds adjacent to faults. As all these folds are important loci of ore deposition they deserve detailed description.

The noses of the Z-bends are remarkably sharp. A series of sandstone beds ranging in thickness from a few inches to 2 or 3 feet may be bent at right angles around a radius of curvature of no more than 3 or 4 feet, with a notable lack of secondary effects such as thickening or thinning. The best example in the district is the fold in No. 1 opening on Parnell Hill (pl. 30). At some places a bed in the nose of the fold is traversed by a single sharp break, while the adjacent beds pass unbroken around the bend.

These bends are developed in sandstones enclosed in shales that responded plastically to the deformation, and in the tensional portion of the bends multiple fractures were developed that are approximately normal to the bedding, nearly vertical, and about parallel to the axes of the folds. The individual fractures are en echelon and appear to die out within a few feet when traced vertically along a bedding plane surface. In the sharper bends offsets of an inch or two occurred on each of these fractures.

The S-bends, being sinuous and having a radius of curvature of several tens to a few hundreds of feet, show none of these features as distinctly as the sharp Z-bends. Cross fractures due to tension are common, but offsets on these fractures are not perceptible.

The Z-bends occur singly, but the S-bends tend to occur in linear series related to series of faults, as shown in figure 18, and each S-bend lies in a block that is bounded on both sides by faults. The Z-bends appear to have been formed principally by compression, but with the aid of a torque couple related to the forces that caused the northeasterly-striking tear faults. The S-bends are due partly to east-west compression but partly to drag along the north-south faults. The simple drag folds appear to be related to single faults.

ORE DEPOSITS

Quicksilver is the only mineral product of the district, and cinnabar the only abundant ore mineral. The deposits appear to be restricted to the sandstones. They include both pipelike and tabular bodies containing from a few hundred to a few thousand tons each. The ore has a wide range of tenor but generally averages between 5 and 15 pounds of quicksilver to the short ton. In the 30-mile length of the district there are about a dozen active mines, a dozen deposits that have been worked more or less, and at least a score of prospects. The annual quicksilver production of Arkansas has been about a thousand flasks.

Size and shape.--The ore bodies are divisible into two classes according to form: Pipelike bodies at structural intersections, and tabular bodies conformable to the bedding of the sedimentary rocks. The pipelike ore bodies range from a few inches to a dozen feet or so in diameter. Their vertical extent has not been fully explored, but some have been followed downward for as much as 100 feet. Some of the tabular ore bodies are as much as 150 feet long, but most of them are only a few tens of feet in length. They are generally from 1 to 5 feet thick, although a few are somewhat larger. The boundaries are in some cases economic, and in places where the total width of the mineralized zone is several feet the very high grade ore that is generally sought may be only a foot or so in thickness.

Distribution.--Throughout the portion of the district studied the deposits are restricted to the sandstones, and mostly to the Gap Ridge sandstone member of the Stanley shale as mapped by Reed and Wells,[10] although some occur in the other sandstones, including both the Jackfork and the Atoka. An outstanding example is the recent discovery of cinnabar on Lee Caroll's land in sec. 34, T. 7 S., R. 26 W., in the Atoka sandstone, at least 3½ miles south of the Stanley.

Mineralogy.--In addition to cinnabar (HgS), the deposits contain small quantities of native quicksilver (Hg), calomel (HgCl), eglestonite (Hg_4Cl_2O), and perhaps other, rarer quicksilver minerals. Sulfides other than cinnabar are rare, but pyrite (FeS_2) occurs in very subordinate quantity and a little stibnite (Sb_2S_3) has been observed. Small quantities of

10/ Reed, J. C., and Wells, F. G., op. cit., pp. 55-56.

stibiconite ($H_2Sb_2O_5$), goethite ($Fe_2O_3.H_2O$), hyalite ($SiO_2.nH_2O$), and metacinnabar (HgS) have been noted,[11/] and also siderite ($FeCO_3$), and livingstonite ($HgS.2Sb_2S_3$).[12/] The principal gangue constituents are quartz (SiO_2), dickite ($2H_2O.Al_2O_3.2SiO_2$), and shaly material. Most of the quartz is the original quartz of the sandstone, but some was deposited later, in part as minute, singly terminated crystals lining fractures, in part as anhedral quartz that was metasomatically introduced. There is some possibility that these quartz crystals are related to the widespread formation of quartz crystals in Arkansas, which may be entirely unrelated to the cinnabar mineralization. Dickite is generally very abundant in close association with the cinnabar, but it is distributed throughout a large part of Arkansas, and there is, moreover, nothing like a constant ratio between the percentage of cinnabar and the percentage of dickite at any given place. Much dickite is unaccompanied by cinnabar, and in some extremely rich ore dickite is almost absent, having perhaps been replaced by cinnabar.

Tenor.--As no systematic sampling and assaying have been done in the district, aside from that performed by the Bureau of Mines in restricted areas, there are no reliable figures on the tenor of the ore. A general idea of the tenor of most of the ore bodies is obtainable from the guesses of the individual operators; and some figures are available that are based on more or less accurate production statistics, which show that the tenor varies considerably from mine to mine but commonly ranges between 5 and 15 pounds of quicksilver to the ton of furnaced ore.

A composite of all available production figures in which both pounds of quicksilver produced and tons of ore treated are given, is shown on the following page.

11/ Sohlberg, R. G., Cinnabar and associated minerals from Pike County, Ark.: Am. Mineralogist, vol. 18, pp. 1-7, 1933.

12/ Stearn, N. H., op. cit. (Econ. Geology, vol. 31), p. 25.

Period	Hand-sorted ore treated (tons)	Hg produced (lb.)	Apparent tenor of ore (lb. Hg/ton)	Adjusted net tenor of rock mined
Up to Jan. 1, 1937......	11,322	169,793	15.0	3.0
Since Jan. 1, 1937......	29,264	187,125	6.4	1.3
Total..............	40,586	356,918	8.8	1.8

The decrease in grade of the ore is the result of the natural evolution of mining in the district, from the early operations which were little more than "high-grading" the rich, near-surface shoots, to larger-scale underground mining, which together with the increased price of mercury has permitted economic handling of lower-grade ore.

Origin and age.--Quicksilver deposits are generally regarded as being the result of epithermal emanations from igneous sources, and the mineral composition of these deposits indicates that they are no exception; but no igneous rocks crop out in the region, and the few known igneous rocks of Arkansas are too remote to be invoked as a possible source.

The available evidence, reviewed by Reed and Wells, indicates that the most probable age for the mineralization is middle Pennsylvanian, toward the end of the Ouachita period of mountain building.

Downward extent.--The Parker Hill ore body (see fig. 21) is the only one in the district that has been followed to any significant depth. It has now been mined through a vertical extent of about 520 feet, and, as about 200 feet of the upper part of the deposit appears to have been removed by erosion, its original vertical extent was at least 700 feet. It does not necessarily follow that any other ore shoot goes as deep, nor, on the other hand, that none goes deeper. The vertical extent of most of the ore shoots appears to be several times the strike length; but the Bloody Cut (see pl. 30) is an outstanding exception, for although it was about 150 feet long it gave out at a depth of only 30 feet.

Localization of the ore bodies.--Because the shales were impermeable to the mineralizing solutions, the ore bodies are restricted to the sandstones. The ore deposits were further localized, within the sandstones, in the zones of greatest permeability—at structural intersections and in the tensional parts of the folds. The mineralizing solutions had a marked tendency to move upward as indicated by the fact that much of the ore lies beneath hanging-wall shales. These shales were effective diversion dams even at the very steep dips characteristic of the region. Hence the best ore shoots that have been found occur in the anticlinal portions of the bends, generally along the east limbs, where, since the regional dip is to the south, the hanging-wall shales overlie the tensional parts of the bends. Conversely, the tensional parts of the synclines are not so favorable for ore deposition, because the adjoining shales lie beneath and the mineralizing solutions tended to dissipate their load by their upward movement away from the contact. As this was low-temperature mineralization, the solutions reacted very delicately to minor variations of environment.

The zones of advantageous permeability were structurally controlled, and the deposits may be classified into the following structural types: (1) Z-bends, (2) S-bends, (3) drag-folds, (4) fold-fault intersections, (5) fault-fault intersections, and (6) fault zones.

Ore reserves and future of the district.--Cinnabar deposits are notoriously difficult to evaluate, and in this district no sampling or assaying has been attempted. Calculations based on all the available information with regard to each ore shoot and dump, including such factors as mining history, past production, and structural habit, indicate that the western part of the Arkansas quicksilver district may reasonably be expected to yield about six or seven thousand flasks of quicksilver from an estimated reserve of about 35,000 tons of ore in the deposits already discovered, provided an attractive market price is maintained. These reserves indicate a fairly assured life, under present economic conditions, of about 10 years. This estimate takes account of the fact that the productivity of the district is on the increase, and makes no allowance for new discoveries, although these are being made continually. If high prices continue, the entire Arkansas quicksilver district can probably be counted on for at least 1,000 flasks, and possibly 2,000 flasks or more, per year for at least one and perhaps two decades.

MINING AND PROSPECTING

Partly because of world metal-market conditions, large capital has not been attracted to the district, and the enterprises have been small, undercapitalized, and short-lived. A dozen companies made 98 percent of the total recorded production, and half of these accounted for 75 percent, although over 50 company names may be found in the records of the district.

Production statistics, which cannot be published, reflect two distinct periods of mining activity; the first period was one of "high-grading" at the surface, and the second period one of underground mining.

During the early period, the rich ore in the outcrops was removed by unsystematic open-cut mining to very shallow depths, generally much less than 100 feet, although the main opening at Gap Ridge (see pl. 33) reached a depth of 230 feet. Only the richest ore was taken, and a slight diminution in grade was sufficient to force abandonment of a project.

The beginning of the recovery in market price attendant upon the outbreak of the Second World War stimulated a renewal of activity; many of the ore shoots beneath the older surface workings were reopened by shafts and underground mining, and a few new reduction plants were installed.

472020 O - 42 - 3

The region has been extensively prospected by men, known locally as "high-graders," who are remarkably astute at finding ore, and the future life of the district depends to a large extent on their skill and luck. Prospectors in their search for ore would do well to consider the relation of ore to structure. The ore is confined to sandstone, and within the sandstone beds the most favorable locations are directly beneath the shales along the outer sides of the bends, where the sandstone has been stretched or broken, particularly where the pitch of the stretched mass is to the south, so that the adjoining shale forms a hanging wall.

MINES AND PROSPECTS

Lowrey and James prospect

Cinnabar has been found at several places on the ridge in the central part of sec. 5, T. 7 S., R. 25 W., in property owned by the Ozan-Graysonia Lumber Co. The SE¼NW¼ and the SW¼NE¼ of the section are under lease to Mr. J. M. Lowrey of Hot Springs, Ark., and are being worked for him by Mr. W. M. James of Murfreesboro.

At the eastern end of the ridge is a small Z-bend. (See pl. 24.) Cinnabar has been found at several places here, and a small pit in the synclinal part of the bend contains material that is reported to be of good tenor.

The main opening, near the center of the ridge, is on an unusually open and sinuous Z-bend. The best ore occurs in the anticlinal part of the bend, in a thick bed of sandstone beneath a steep hanging wall of shale. The localization of the ore may have been influenced by the three sets of joints which are present. Nothing is known about the average grade of the ore, but selected specimens appear to be rich.

The openings near the west end of the ridge were made by Mr. Max Crockett early in 1940 for Mr. George Hales. The shaft is probably about 20 feet deep, and was sunk in the thick sandstone bed which appears to contain most of the ore. It is reported that only small showings of cinnabar were found here. Subsequent prospecting by Mr. James has revealed cinnabar at a number of new places where structural relations are obscured by soil cover.

Craig mine

Mr. Shelby L. Craig leased the property at the site of the old Isbell Hill mine, and began operations under the name Jack Fork Mining Co. Under the new name of Craig Mining Co., the company was incorporated in Arkansas on October 3, 1940, as a subsidiary of the Southern Mining & Reduction Co. The company controls the NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 6, T. 7 S., R. 25 W., owned by Lulu Bell, and the NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 5, T. 7 S., R. 25 W., owned by the Ozan-Graysonia Lumber Co. The new shaft is only 40 feet west of the boundary line between these two properties (see pl. 25), and the underground workings extend into both. Erection of a 15-ton Gould furnace was commenced on April 10, 1941, and milling was begun on May 20, 1941.

The first level, at a depth of 78$\frac{1}{2}$ feet, extends 65 feet northwest and 50 feet east of the shaft station (pl. 26). It is driven in a single thick bed of sandstone throughout most of its length. Only low-grade material has been found in the east drift, but the west drift contains two ore bodies, one about 12 feet wide with a strike length of about 8 feet and the other about 10 feet wide and 24 feet long.

The mine is located in the anticlinal part of an S-bend, and the richer ore shoot occurs in the most sharply bent part of the sandstone. A small quantity of high-grade ore was found in the pits in the synclinal part of the S-bend to the east, near the crest of the hill.

In the old 85-foot shaft, northeast of the new shaft, the ore occurred in a thick bed of sandstone overlain by a thin bed of shale. Three low-angle cross fractures were encountered in this shaft, and below each the ore was exceptionally rich. At the bottom of the shaft the mineralized zone passed into the next lower sandstone bed. This shaft is in a different mineralized horizon than the one in which the new shaft has been located, so that more than one bed of shale here acted as an effective trap during the mineralization.

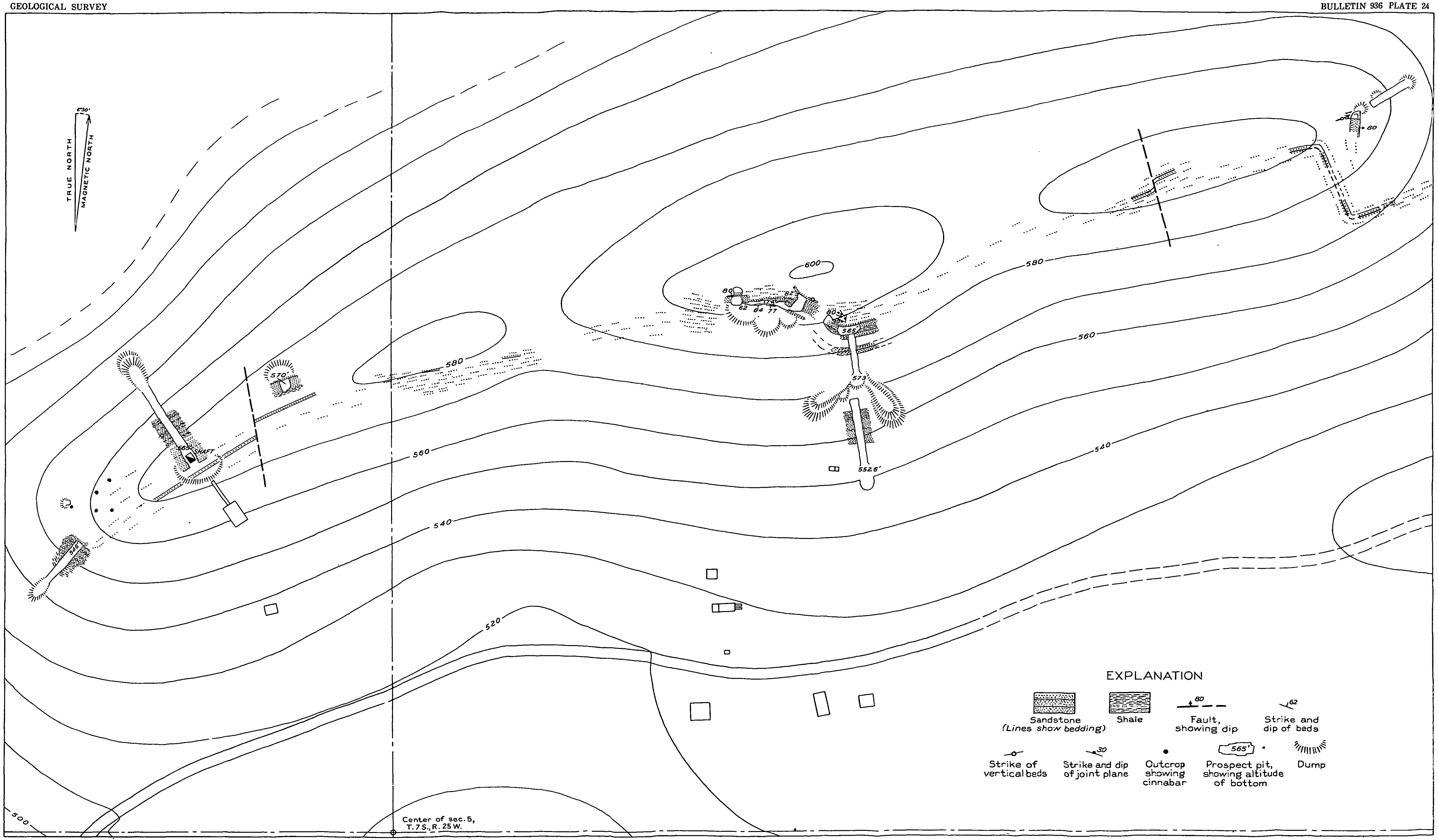
Yenglin prospect

The Yenglin prospect has a shaft in the SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 6, T. 7 S., R. 25 W. The shaft is just west of a slight synclinal bend, is inclined 82° S. down the dip of the sandstone, and is about 70 feet deep. Forty feet north and northwest of it are two shallow openings, and on the west end of the hill the beds apparently bend northward in an S-bend, but the exposures are too poor to afford conclusive evidence. The work was done by Yenglin and Johnson in mid-1934 and the small production was not recorded.

Hopkins Hill

The small hill in the NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 6, T. 7 S., R. 25 W., on land held by the U. S. Mercury Co., and the SE$\frac{1}{4}$SW$\frac{1}{4}$ of the same section, owned by Dr. J. S. Hopkins, consists of a well-defined but only gently sinuous S-bend. An open cut in the synclinal part of the bend on the northeast part of the hill was made by S. L. Craig. A single large sandstone bed was mined out to a depth of 25 feet, and is said to have yielded 47 tons of good ore, which occurred in layers.

Bureau of Mines diamond-drill hole No. 12 was put in from the north at an inclination of 49° to explore the possible downward extension of this ore body, which, according to the pro-



SURFACE MAP OF LOWREY AND JAMES PROSPECT

50 0 200 Feet

Contour interval 10 feet

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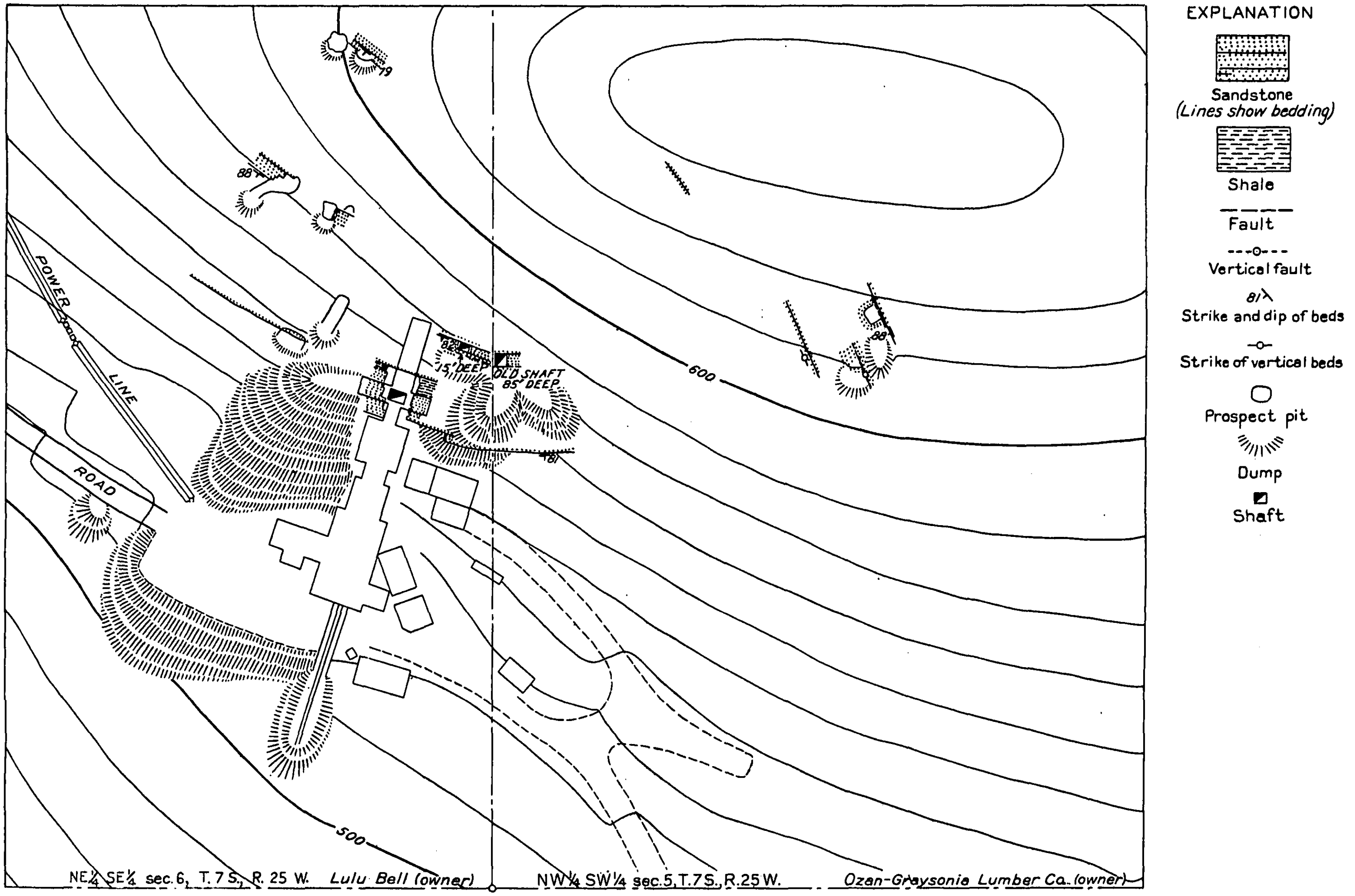

SURFACE MAP OF CRAIG MINE

50 0 150 FEET

Contour interval 10 feet

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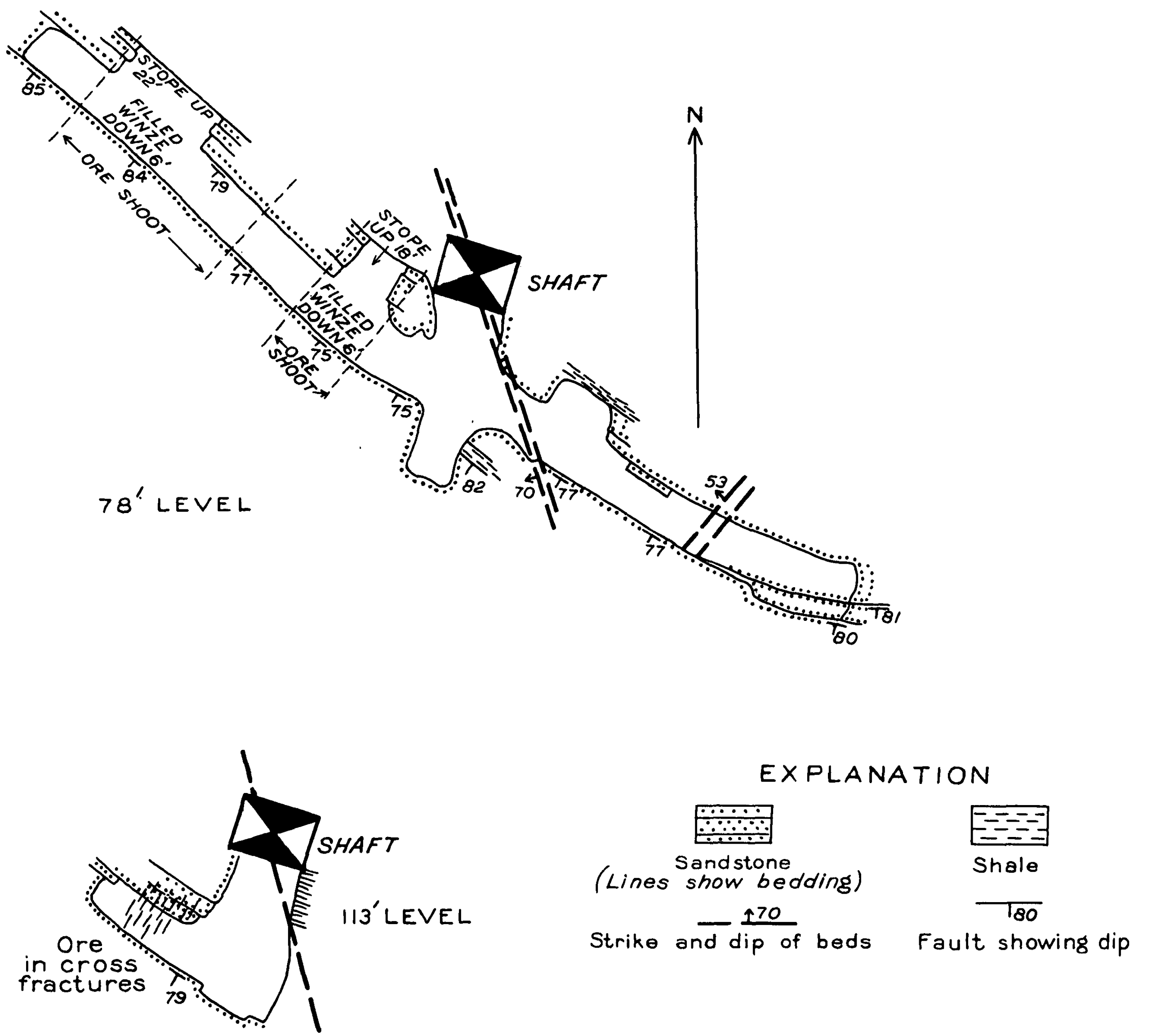

UNDERGROUND MAP OF CRAIG MINE

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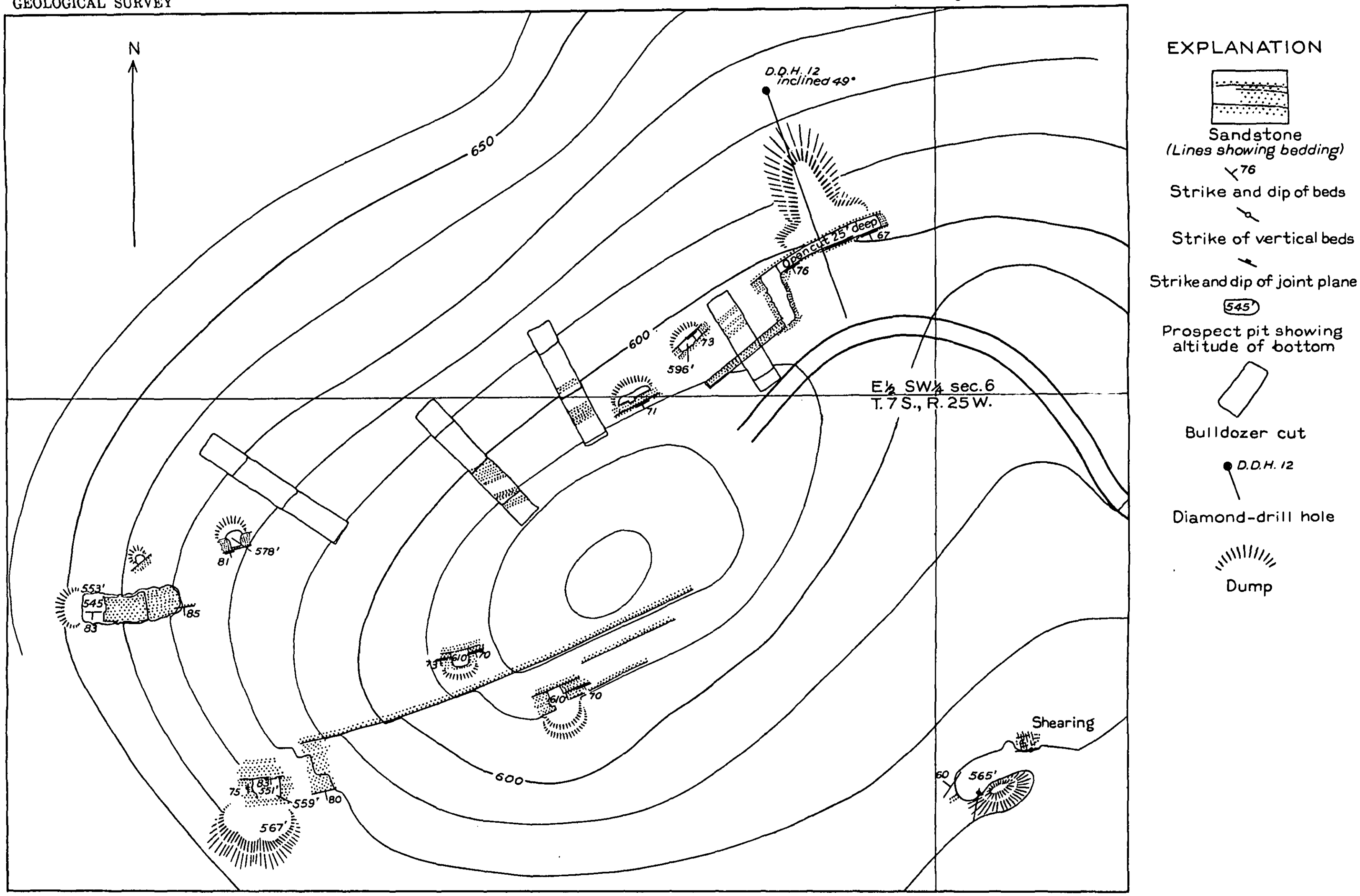


SURFACE MAP OF HOPKINS HILL

50 0 200 Feet

Contour interval 10 feet

U. S. GOVERNMENT PRINTING OFFICE: 1942 O - 472020 (faces p. 204)

jected surface dips, should have been reached at a drilling depth of 185 feet. Only a small showing of cinnabar was encountered at 147 feet, and none deeper, indicating that the mineralized horizon is steeper than the surface dips suggest, because the surface rocks have slumped down hill a few degrees. This small ore body is the best that has so far been worked in the synclinal portion of an S-bend.

Many small openings have been made at other places on the hill, but apparently only those in the southwestern part, on the anticlinal portion of the S-bend, yielded any quantity of cinnabar. These are said to have been worked by Otto Yenglin in the early days of the district, but there is no record of the production from them.

U. S. Mercury Co. property

The U. S. Mercury Co. has a lease on the N$\frac{1}{2}$SW$\frac{1}{4}$ and the SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 6, T. 7 S., R. 25 W., owned by the Ozan-Graysonia Lumber Co., and it has recently acquired the NW$\frac{1}{4}$SE$\frac{1}{4}$, owned by Lulu Bell.

The property (see pls. 28 and 29) was prospected without success until W. F. Hintze found excellent ore near the site of the present mine. He began working the prospect, and, in association with Otto E. Hirsche, Irving Hirsche, and Clarence A. Hirsche of Kansas City, he organized the U. S. Mercury Co., under the laws of Missouri. The upper part of the ore body was incompletely mined by unsystematic gophering operations. The shaft was deepened to the 160-foot level and two small raises were put up in the ore, but again operations were defeated by bad ground. The Hirsches bought Hintze out early in 1941 and installed J. D. Freeman as superintendent. Under his direction a crosscut was driven by the shortest route from the shaft to the ore on the 160-foot level, and the deposit was reclaimed by means of forepoling and heavy timbering. During the summer of

1941 a half interest in the property was acquired by H. C. Orton of Chicago for Mid-American Resources, Inc., and the company was reorganized as the U. S. Mercury Co., under the laws of Illinois. An ambitious program is now planned under new management, and, as a result of successful tests, mechanical concentration of the ore is to be tried on a commercial scale for the first time in this district.

This deposit, lying in a wide mineralized fault zone, is the only one of its type so far known in the western part of the district. The fault zone, which may be a branch of the Cowhide thrust, has a general east-west strike, dips southward about 47°, and appears to be at least 30 feet thick. The footwall consists largely of thick beds of sandstone. The fault zone, which appears to conform approximately to the bedding, consists largely of shale gouge and sheared shale fragments with slickensided surfaces of diverse orientation. Scattered through this are abundant sandstone fragments ranging from minute specks to blocks many feet in length. Some are composed of alternate beds of shale and sandstone from $\frac{1}{4}$ to 2 inches in thickness, broken into small, roughly cubic blocks by several sets of joints normal to the bedding. These joints are generally filled with white dickite, and some of them also carry cinnabar. The sandstone fragments in the fault breccia have been preferentially mineralized because of their greater porosity. In the larger sandstone fragments the ore is richest below hanging-wall shale cappings, and mineralization is more intense in the higher parts of local sinuosities. There is little mineralization of the shale, the cinnabar being mainly in the sandstone fragments.

Bureau of Mines diamond-drill hole No. 8 reached the mineralized zone at a slightly greater depth than was expected as the dip apparently had steepened downward, but only traces of cinnabar were found. Diamond-drill hole No. 9, which was expected to intersect the ore at a depth of about 200 feet, was abandoned at

166 feet because of bad ground. Inclined diamond-drill hole No. 7 was drilled to explore the possible westward extension of the ore zone, but it encountered no cinnabar. These drill holes show that the ore zone is not overlain by a thick series of shales, as the low topography suggests, but by a series of alternating sandstones and shales.

Cinnabar has also been found in trenches in both the southwest and southeast corners of the U. S. Mercury Co.'s west forty, and a small shaft, now filled with water, was sunk in a small open cut in the northwest corner of the NE¼SW¼ sec. 6. Good ore is said to have been found, but nothing is known as to its grade or amount.

Hales mine

The Hales Mining & Development Co. has a lease on the SE¼NW¼ sec. 6, T. 7 S., R. 25 W., owned by the Ozan-Graysonia Lumber Co. Mr. Max A. Crockett, acting for Mr. George A. Hales of Oklahoma City, Okla., discovered ore here on January 22, 1940, and the company was organized about April of that year, with Mr. Hales as president and Mr. Crockett as resident manager. On October 1, 1940, the property and equipment were leased from the Hales Mining & Development Co. by the Crockett Mining Co.

A shallow shaft, which was sunk on the original discovery about 100 feet east-southeast of the present shaft (see pl. 28), caved in and was later obliterated by the bulldozing done by the Bureau of Mines. The bulldozing revealed a large east-west fault zone, which may be a branch of the Cowhide thrust, passing approximately through this old shaft, and it also uncovered a small pocket of very high grade ore east of the old shaft site.

The present shaft is in the footwall sandstones below this main fault. An upper level was stoped out during 1940, and the shaft was deepened to the 72-foot level late in the year. The mineralized zone was encountered about 12 feet south of the shaft and was drifted on in both directions (fig. 19). No ore was encountered in drifting westward, but rich ore was found about 20 feet east of the crosscut, just beyond the junction of several small gouge-covered slips which form a cylindrical receptacle in which the ore solutions were apparently trapped. East of this rich zone, along the strike toward the old shaft, ore of lower grade continues for an unknown distance.

In the spring of 1941, after the installation of a new headframe, hoist, and compressor and the complete electrification of the plant, the shaft was deepened again and a new level driven

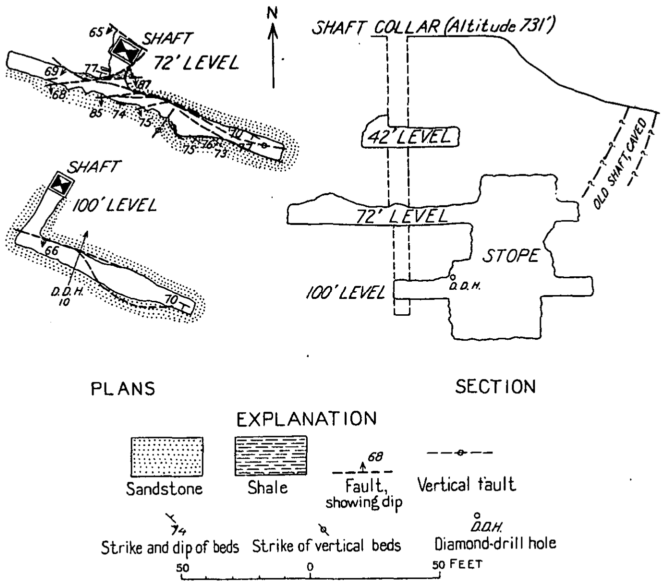
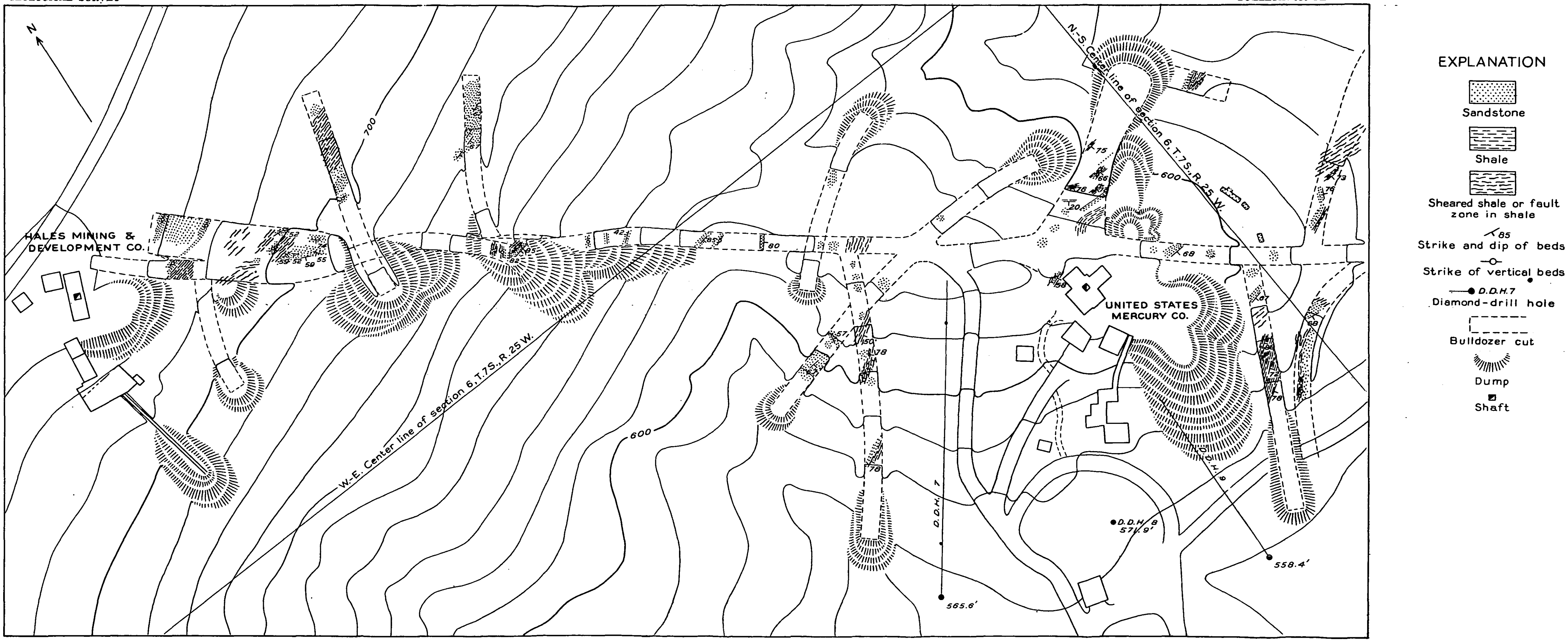


Figure 19.—Underground map and section of Hales mine.

at a depth of 100 feet. Bureau of Mines diamond-drill hole No. 10 encountered the mineralized bed within a foot of the anticipated depth, but showed only a trace of cinnabar. The 100-foot level found this drill hole and revealed that it had missed high-grade ore by only a few inches. This was the same rich shoot that had been encountered on the 72-foot level, and by the end of June it had been stoped up to that level.

The localization of the ore here appears to have been controlled by the fault zone and the subsidiary slips near it. The major fault zone may have been the chief channelway for the



SURFACE MAP OF U. S. MERCURY CO. AND HALES MINING & DEVELOPMENT CO. PROPERTY

50 0 250 Feet

Contour interval 10 feet

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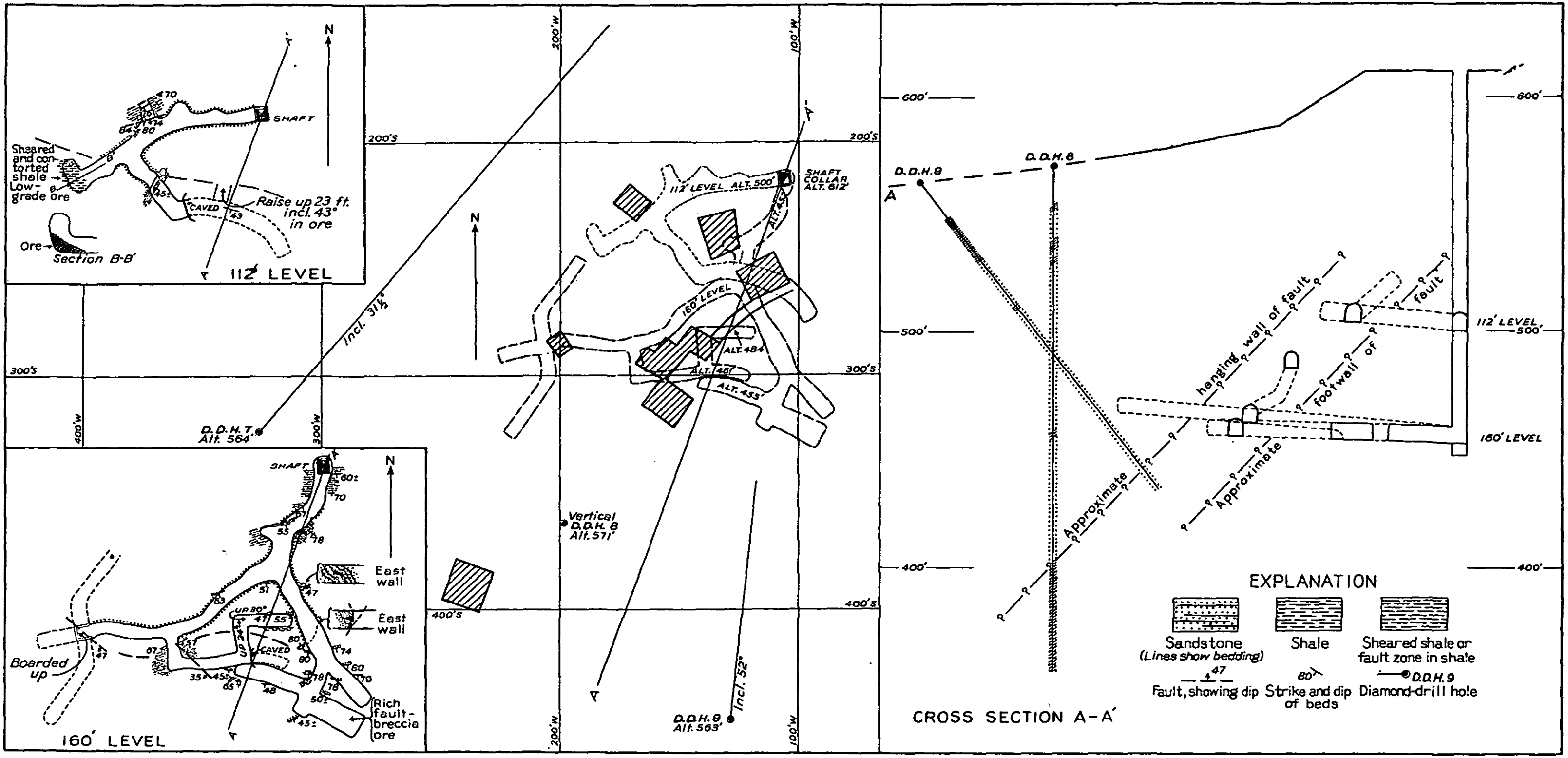


UNDERGROUND MAP AND SECTIONS OF U. S. MERCURY CO. MINE

50 0 150 Feet

U. S. GOVERNMENT PRINTING OFFICE : 1942 O - 472020 (faces p. 208)

rising solutions, but the location of the ore beneath it suggests that perhaps it was influential in confining the solutions to the upper part of the underlying sandstones. The detailed control was provided by the thin gouge films on the subsidiary slips.

It was recently reported that new ore has been found about 700 feet west of the shaft.

Parnell Hill

Most of Parnell Hill, which has been one of the most productive localities in the district, lies in the SW¼SW¼ sec. 6, T. 7 S., R. 25 W., controlled by Mr. Leo Yount and his partners. Ore was first found here by Mr. Yount in July 1931 at the Bloody Cut, so called because the mine water was red from cinnabar. The ore body was the longest that has yet been found, and one of the richest. Mr. Yount bought the property, and also Parker Hill, from G. J. Parker and began to mine the Bloody Cut and No. 1 open cut in September. In 1932 he organized the Southwestern Quicksilver Co., which took over both the Parnell Hill and Parker Hill properties, and worked them until the low metal price of 1934 forced a shut down. The property was then optioned to Mercury Producers, Inc., and under the direction of M. J. Eunson a long adit was driven into the hill and many surface prospect openings were made, but little quicksilver was produced. The option was dropped early in 1936, and the properties remained idle, except for some prospecting, until bought out by Mr. Yount in October 1939 and reorganized as the Arkansas Quicksilver Corporation, which started production in February 1940.

Showings of cinnabar have been found in many of the prospect pits on Parnell Hill, indicating that mineralization of subcommercial grade is very widespread here.

The Parnell Hill adit was reopened in the spring of 1941 (fig. 20). It crosscuts the shale for about 120 feet to the sandstone, and here a drift runs westward parallel to but below the contact. The crosscut continues on and then turns northward at right angles to the strike of the rocks. This crosscut

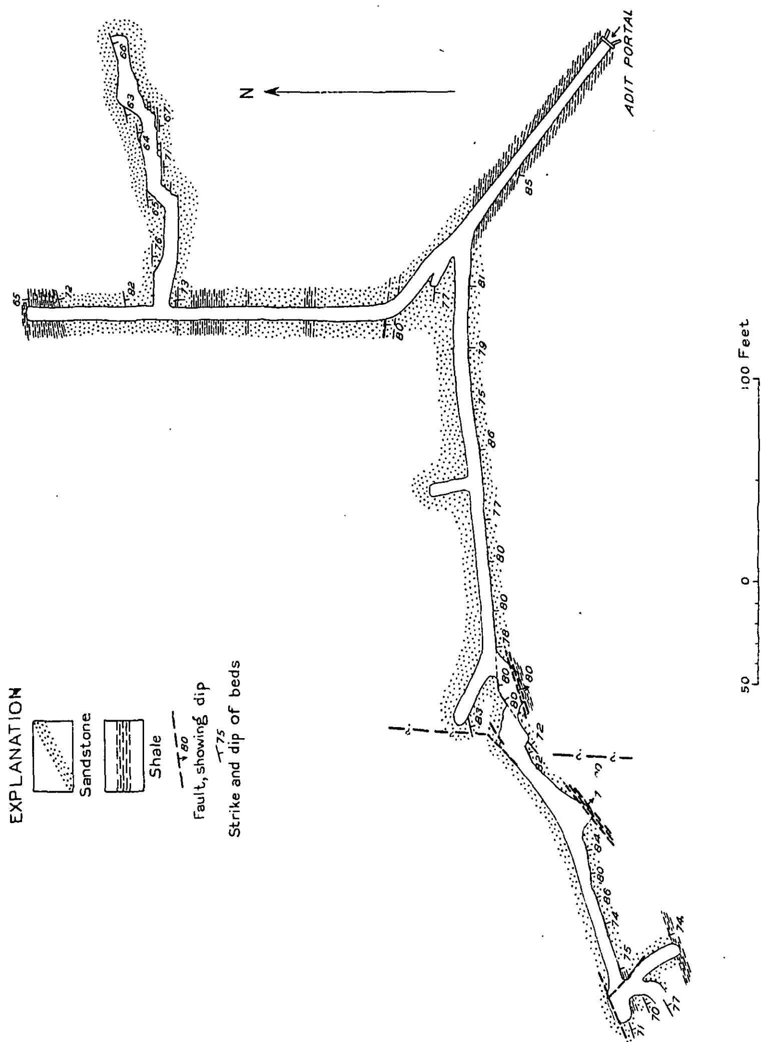


Figure 20.--Underground map of Parnell Hill adit.

passed through about 220 feet of sandstone, with a little interbedded shale, to the footwall shalé on the north. About 60 feet stratigraphically above this north contact a small fault was followed eastward, and on it a small quantity of low-grade ore was found. This is probably the downward extension of some small ore showings on the surface.

The west drift of the adit reveals a long gradual synclinal curve, and although the hanging-wall rocks have not been explored there is little probability of finding good ore in them because they are in a zone of compression. Two short crosscuts were driven north but did not encounter any ore. The first ore found in this drift is in the downward extension of the faulted and mineralized zone seen on the surface in the No. 15 open cut (pl. 30). As the bend of the sandstone is here slightly synclinal, the mineralization is probably due to the permeability of the fault zone itself.

Bureau of Mines diamond-drill hole No. 5 explored this ore zone, and encountered cinnabar in five places. The first 34 feet of sandstone beneath the main shale hanging-wall contact is mineralized, but a crosscut driven south to explore this discovery reached the contact about 13 feet west of the drill hole without finding ore, and exploration was then abandoned.

Eunson's shaft is said to have followed a rich pipelike ore body, and it lies in the junction of a northwest-southeast fault with a bedding-plane fault. At the bottom of the shaft an anomalous disposition of small drag-folds indicates a recurrence of fault movement in the reverse direction. A small drift westward from the bottom of the shaft is said to have revealed considerable ore of moderate grade, and it connects with some old workings that are now caved, including the caved adit in No. 12 opening.

The Bloody Cut lies in the beginning of the anticlinal flexure east of the major Z-bend in No. 1 open cut of Parnell Hill. The ore body was exceedingly rich, long, and wide, but the values gave out at a depth of less than 30 feet, and mining was then discontinued. Bureau of Mines diamond-drill hole No. 6 explored the possible downward extension of this ore body but revealed only low-grade material.

Diamond-drill hole No. 11 investigated the possible extension of ore between the Bloody Cut and the Z-bend in No. 1 open cut, but showed only traces of cinnabar.

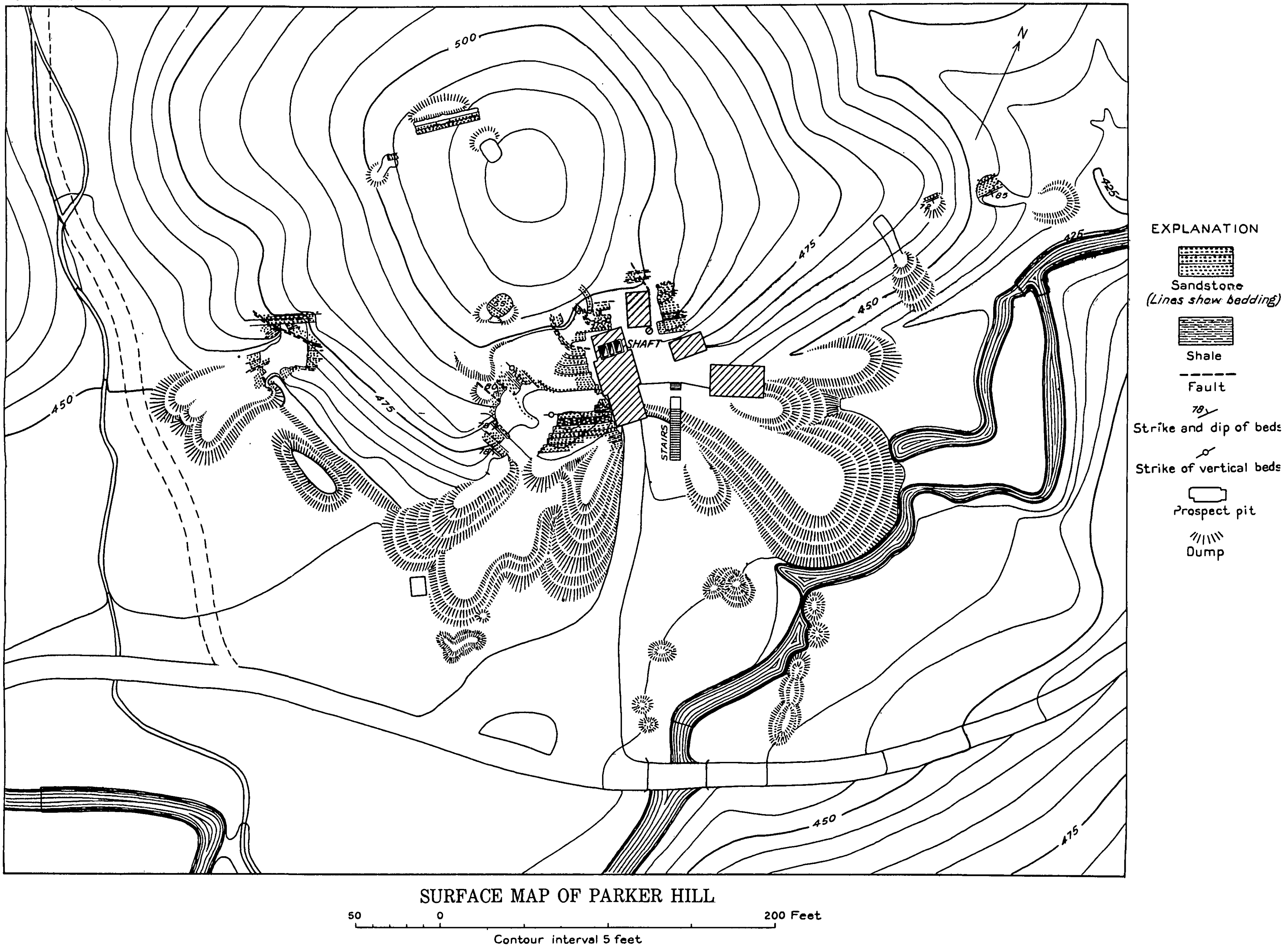
In the small openings west of the Bloody Cut, the anticlinal flexure is seen to become more pronounced, and in No. 1 open cut the beds curve abruptly around and strike due north. Some low-grade ore is said to occur here, but being in a zone of compression it holds little promise. A short adit driven northward along one of the sandstone beds encountered a small pipelike ore body, in the synclinal bend, which has been stoped out to the surface. This syncline is so sharply folded that the broken ends of some of the beds now abut against the bedding planes of other beds, giving rise to a permeable zone which determined the localization of this ore body.

Traces of cinnabar have been found west of No. 1 open cut, and although there is a slight suggestion of an anticlinal flexure here the zone was probably under considerable compression and is not likely to contain an ore body. A little ore has been found on the north side of the hill, on the northeastward extension of the anticlinal axis of the main Z-bend.

Mineralization has been widespread on Parnell Hill, which contains so many favorable structures as to merit further exploration.

Parker Hill mine

West of the Little Missouri River in the SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 1, T. 7 S., R. 26 W., is a small sandstone knoll, called Parker Hill, on which the first cinnabar discovered in the district was found by Crown Cox in June 1931 (pl. 31). The early history of the property under Mr. Yount parallels that of Parnell Hill, but with the reorganization and reopening under the Arkansas Quicksilver Corporation the Parker Hill mine, now by far the deepest quicksilver mine in Arkansas, became the chief site of activity.



SURFACE MAP OF PARKER HILL

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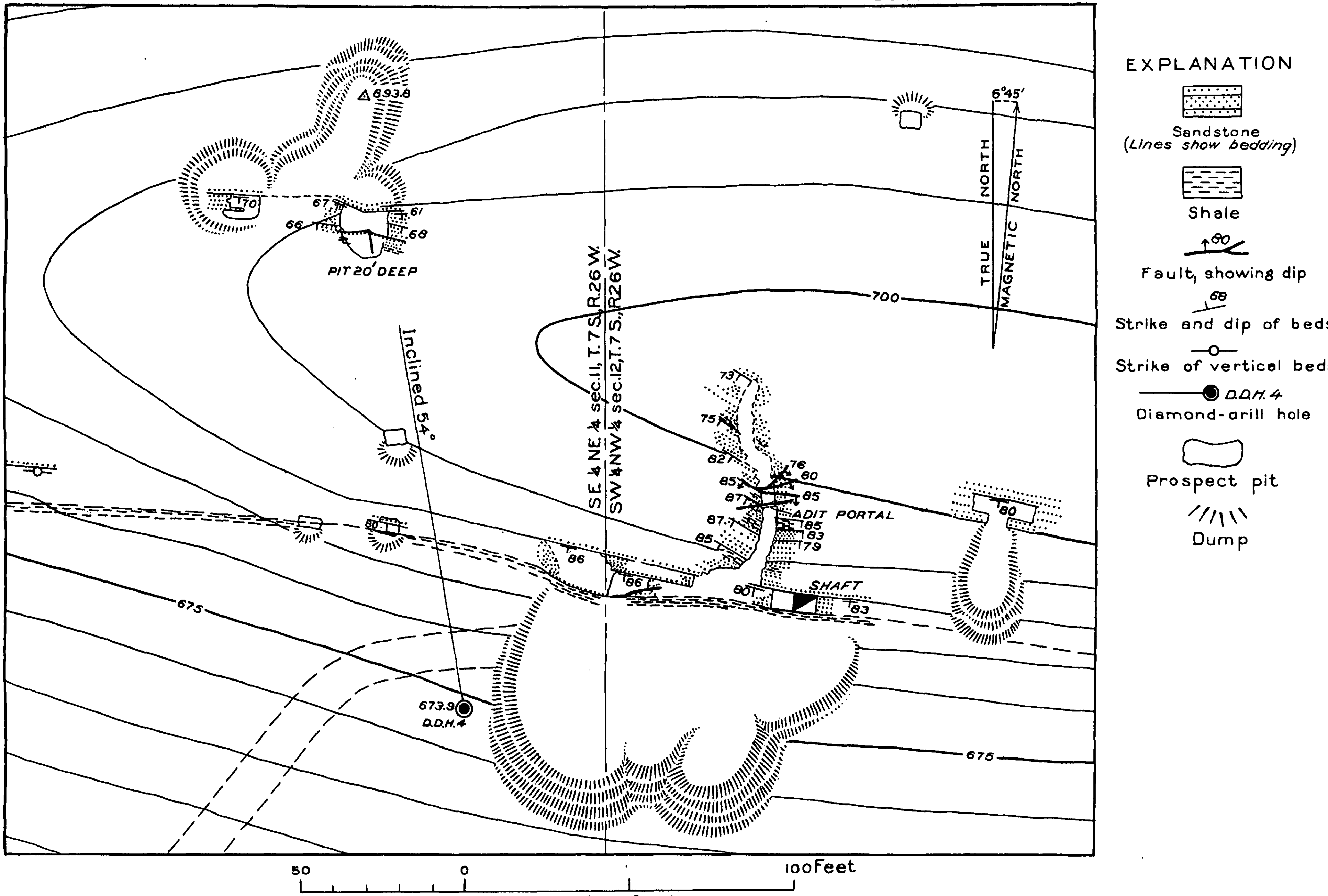

SURFACE MAP OF EAST GAP RIDGE

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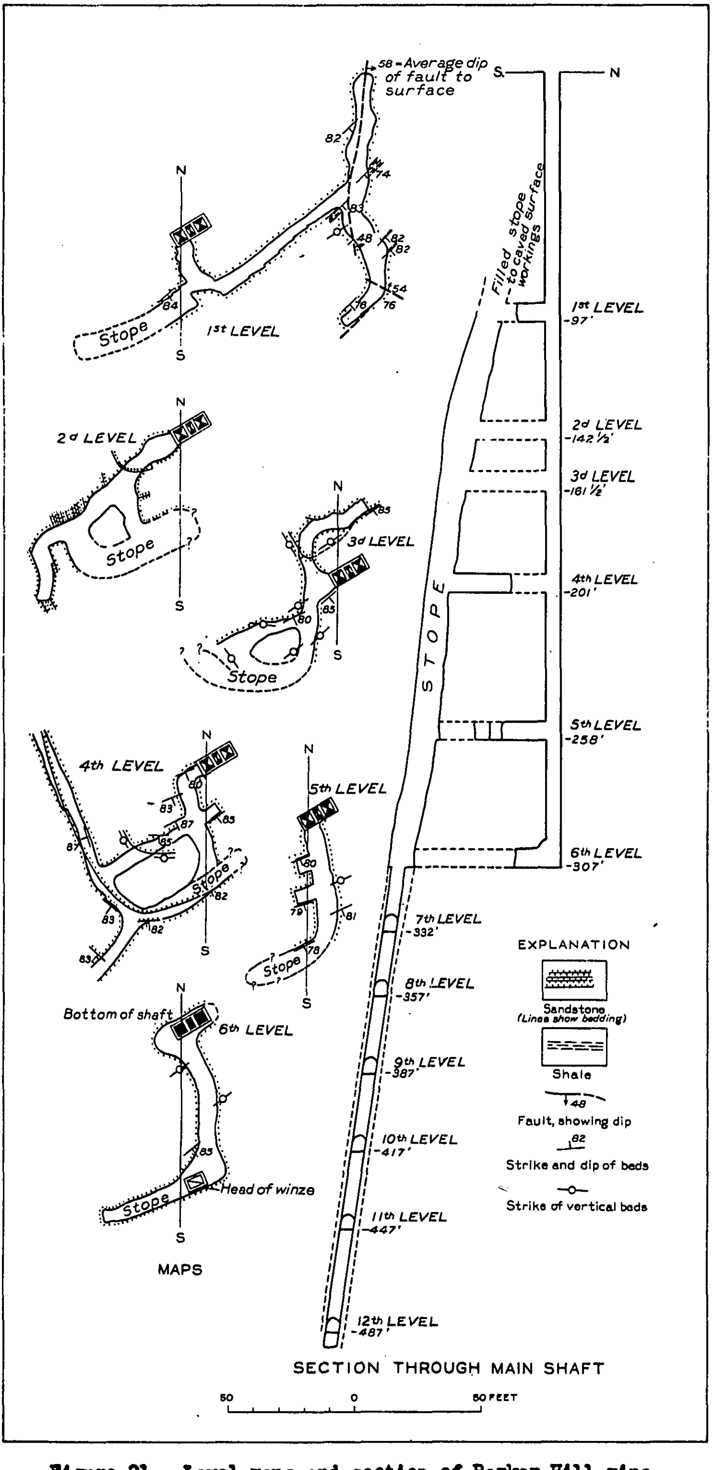


Figure 21.--Level maps and section of Parker Hill mine.

Six levels were driven from the vertical shaft sunk on the outcrop, the lowest being at a depth of 307 feet (fig. 21). As the ore dips 82° S., it became expedient to sink an inclined winze from the sixth level in the mineralized bed, and from this winze another six levels were driven. All 12 levels have now been stoped out to a depth of 487 feet below the shaft collar.

The ore shoot had a strike length of about 50 feet, though its length varied considerably from level to level. The shoot lay east of the anticlinal nose of a pronounced Z-bend, and in places the mineralization was traced for a short distance around the nose. The ore appears to have been trapped beneath a shale that is interbedded with the sandstone, and the location of the main sandstone-shale contact to the south has never been ascertained, although it is a place that seems favorable to ore deposition. The tenor of the ore was remarkably uniform down to the 487-foot level.

The valley west of Parker Hill, and its counterpart west of Mill Mountain, may indicate a fault. If the southward bend of the sandstone beds in the surface pit west of the mine is due to drag on this fault, the east side moved relatively northward, and it is therefore possible that the sandstone of Parker Hill, the type locality of the Parker Hill member, is actually a faulted segment of the Gap Ridge sandstone member.

East Gap Ridge

On the eastern part of Gap Ridge, near the boundary line between the SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 11, T. 7 S., R. 26 W., owned by the Southern Kraft Paper Co., and the SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 12, owned by the Arkansas Power & Light Co., are several small abandoned openings (pl. 32). A shaft said to be about 85 feet deep, was sunk in the sandstone at the main sandstone-shale contact. A trench has been cut that extends northward from a point near the shaft to a short adit only 7 feet below the top of the hill. The main sandstone-shale contact appears to be uninterrupted, but the beds on the two walls of the trench do not match. At the entrance of the adit there is a small bend with a radius of curvature of about 2 feet, and a bedding-plane fault that splits into three branches inclined to the bedding. Inside the adit, north of these features, the beds are continuous across the adit.

About 100 feet northwest of the adit is a pit about 10 feet in diameter and 20 feet deep, from which high-grade ore is said to have been taken. The axis of a small anticline dips with the footwall sandstone, and only a few feet away, facing it and parallel to it, is the axis of a syncline in the hanging-wall sandstone. The syncline is broken by a small fault parallel to the axis but inclined to the axial plane. This peculiar arrangement of structural features appears to have provided a permeable zone that determined the location of a small pipelike ore body. Bureau of Mines diamond-drill hole No. 4 explored the downward extension of this ore, but it showed only low-grade material.

Cinnabar has been found in small quantities at many places along the main sandstone-shale contact throughout the length of Gap Ridge.

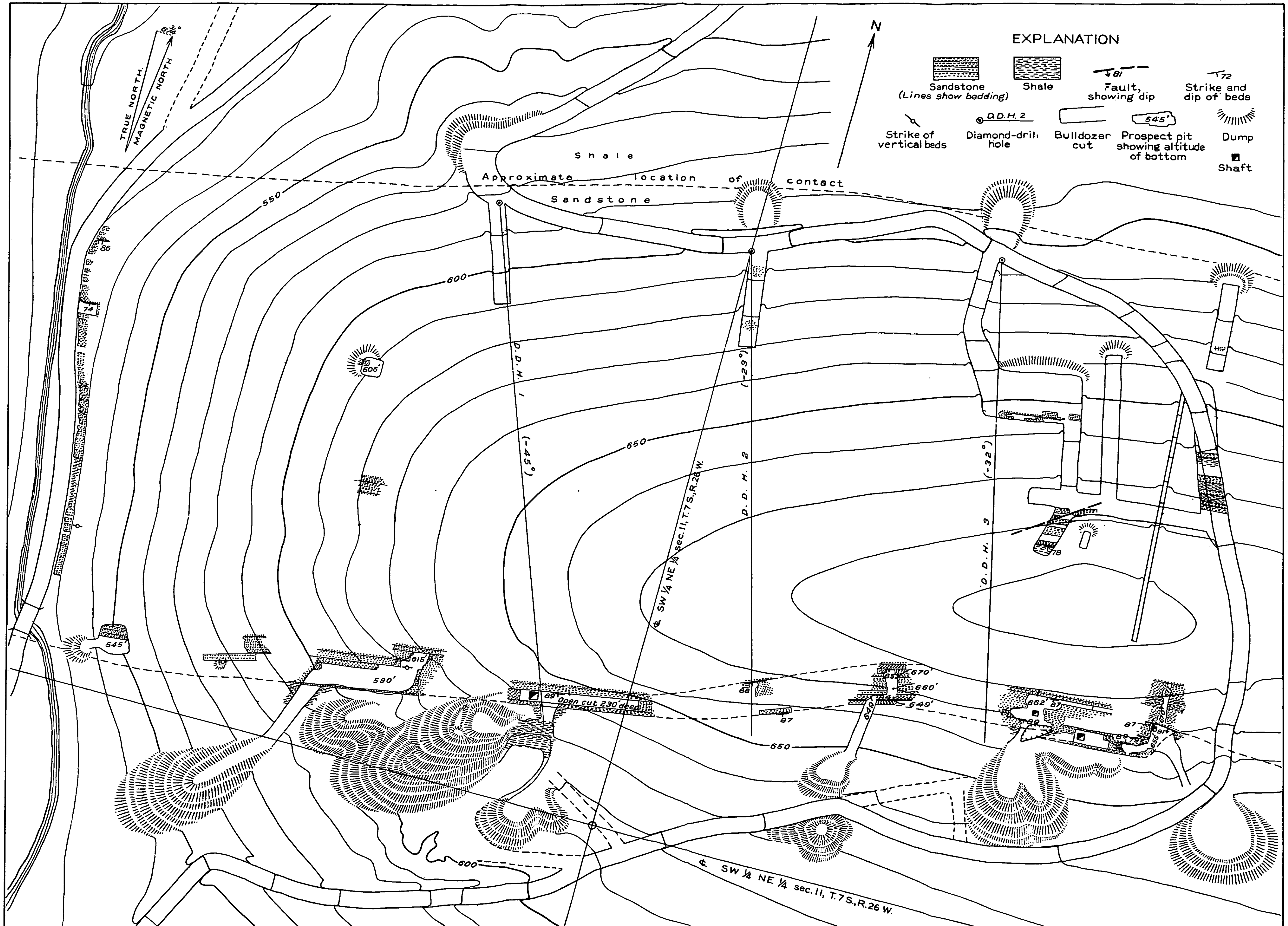
Gap Ridge

The third important property of the Arkansas Quicksilver Corporation is at the west end of Gap Ridge, in the SW¼NE¼ sec. 11, T. 7 S., R. 26 W. Its history under Mr. Yount and his associates parallels that of Parnell Hill except that the property was not reopened until early in the summer of 1941. There are nine openings in the sandstone just below the main sandstone-shale contact, which here is nearly vertical (pl. 33). The main opening, which was one of the largest and richest mines of the district, was worked as an open cut to a depth of 230 feet. A width of 8 feet of sandstone was thus mined out, but one highly mineralized hanging-wall bed was left to support the hanging-wall shale. At the eastern end of the property are two shafts, the western one 70 feet and the eastern one 130 feet in depth. These were connected by a level at a depth of 50 feet, and a drift was run westward for 95 feet from the bottom of the deeper shaft. These workings were full of water when visited. The eastern shaft is said to have encountered a fault seen at the surface and to have followed it down on the incline. The main open cut was dewatered in the summer of 1941 and the mineralized hanging-wall bed salvaged, but the ore was found to be cut off by a horizontal fault a few feet below the bottom of the open cut.

Traces of cinnabar have been found at a number of other places on the ridge, and several of these appear to lie at a horizon that is about the same distance above the footwall shale as the ore in the northeastern part of Parnell Hill.

No major structural control of the ore is evident. Among the detailed controls are the trapping effects of the shales and faults, particularly the main hanging-wall shale, and the small crenulations still visible in the hanging wall of the main opening, to which the distribution of rich ore is said to have been related. An apparent small offset between Gap Ridge and its westward continuation suggests the presence of a fault, which would seem to be the likeliest reason that the ridge was cut across by a stream at this point; the exposures here are too poor, however, to afford direct proof of faulting.

Bureau of Mines diamond-drill hole No. 1 was intended to determine whether the ore extended below the main open cut. It was so directed that it would cut the ore zone about 200 feet below the bottom of the cut and pass out into the hanging-wall shale at a drilling depth of 535 feet. It continued in barren sandstone, however, to a drilling depth of 647 feet before encountering the shale, and no ore was found. This is evidently



SURFACE MAP OF GAP RIDGE

50 0 200 Feet

Contour interval 10 feet

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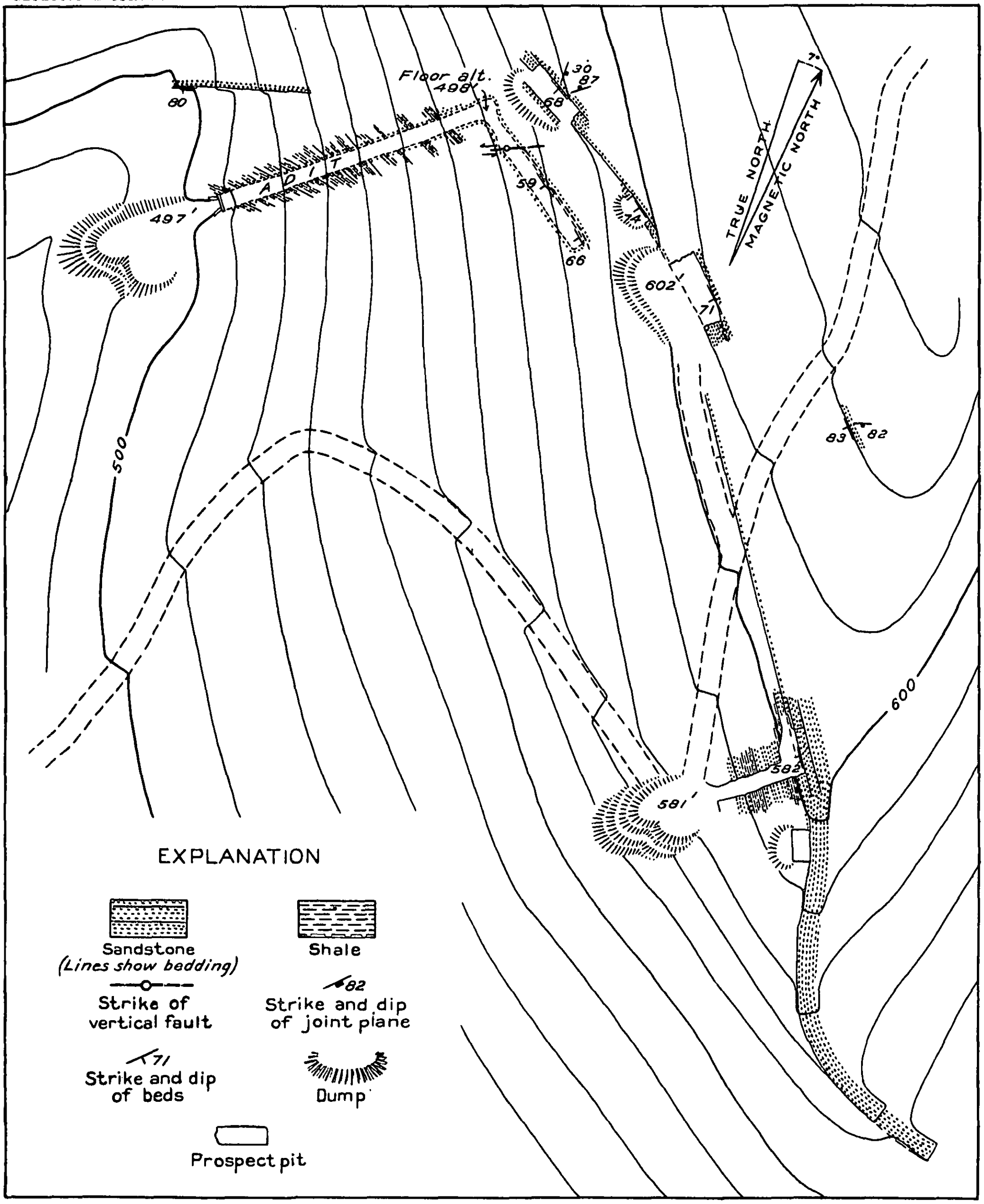

SURFACE AND UNDERGROUND MAP OF SOUTH MILL MOUNTAIN

50 0 150 Feet

Contour interval 10 feet

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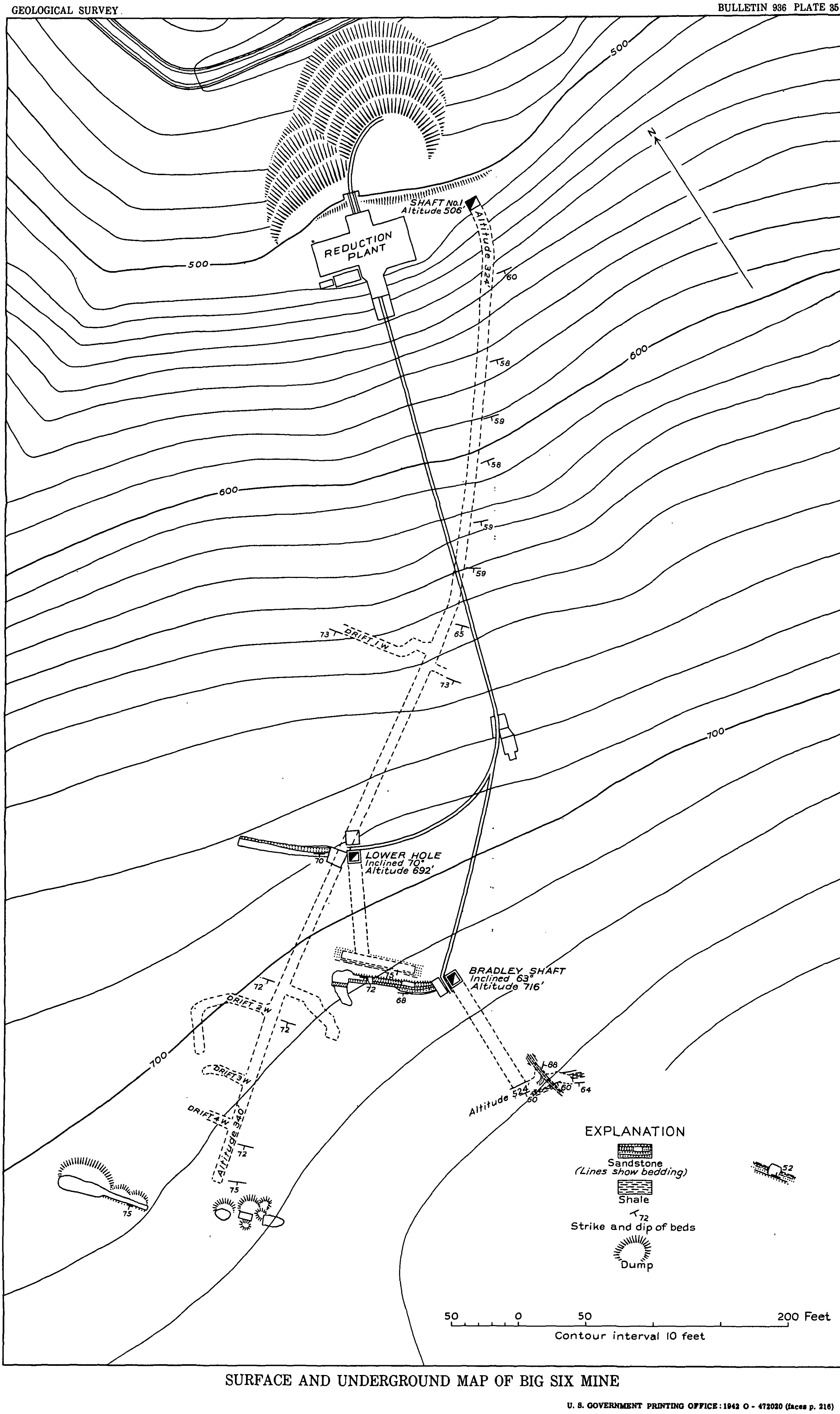

SURFACE AND UNDERGROUND MAP OF BIG SIX MINE

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accounted for by the horizontal fault below the ore that was exposed when the mine was reopened in the summer of 1941.

Bureau of Mines diamond-drill hole No. 3 was designed to test the possible downward extension of the ore in the eastern shafts. Cinnabar was encountered between 166 feet and 170 feet, in the zone corresponding to that already known on the surface; and between 375 feet and 403 feet some low-grade material was found that may correspond with the main ore horizon, although it is overlain by 50 feet of barren sandstone.

Diamond-drill hole No. 2, midway between the others, encountered no ore.

South Mill Mountain

On the south end of Mill Mountain, in the SW¼NE¼ sec. 12, T. 7 S., R. 26 W., a sinuous Z-bend, on which several prospect openings have been made, is well exposed (pl. 34). So much rock has been removed here as to indicate that cinnabar was present or was thought to be present. The prospecting seems to have been done in sandstone beneath a 3-foot bed of shale. Little cinnabar is now visible, however, and it seems probable that bright-red hematite, which is abundant along joints and bedding planes, was mistaken for cinnabar.

An adit was driven 85 feet lower down the hill for 125 feet through alternating shales and sandstones showing a progressive change of strike. A little ore was encountered, and a drift was started eastward along the strike of the ore-bearing bed. At about 15 feet the ore is cut off by a fault that strikes northeast and offset into the footwall, as indicated by the drag folding in the shale, but the drift was continued for 50 feet more. The displacement is probably slight, as the fault cannot be found on the surface.

Big Six mine

The $SE\frac{1}{4}SW\frac{1}{4}$ sec. 12, T. 7 S., R. 26 W., was acquired in August 1937 by the Big Six Mining Co., Inc. They sank a shaft 192 feet deep, near the base of the hill on which the old Parker prospect was located and just east of the present plant (pl. 35). From the bottom of the shaft a crosscut was driven southward for 760 feet into the hill, under the Parker prospect and Bradley shaft. On December 1, 1939, the property was acquired by The Big Six Mining Co. (not to be confused with the previous company). A 25-ton rotary reduction plant was installed, and production was begun in June 1940. The old Bradley shaft, now called the Upper Hole, was deepened to 215 feet, and the Lower Hole, about 110 feet north of it, was sunk to 230 feet. These shafts are, in effect, stopes, for they were made 20 or 30 feet wide in the direction of the strike and the rock mined from them was treated in the reduction plant. In June 1941 a short drift extending eastward from the bottom of the Bradley shaft found a mineralized fault, striking a little east of north, on which the drag folds indicate that the east side moved relatively northward, so that this fault is probably related to the tear faults of the region. The discovery of this fault explained the general convex southward bend of the rocks seen in both the Upper and Lower Holes and in the surface openings west of them.

In the Bradley shaft, or Upper Hole, a thickness of about 8 feet of sandstone has been mined out beneath a hanging wall of shale. West of the fault, which passes about 6 feet east of the shaft, the beds are slightly convex southward, the bend becoming more pronounced near the fault, while east of the fault the beds are slightly convex northward. Cinnabar occurs in the fault and in the sandstones on both sides of it. Ore of higher than average grade occurs below small rolls in the shale hanging wall, three or four of which were encountered in sinking this 215-foot shaft.

In the Lower Hole a similar amount of rock has been removed. The upper surface of the footwall sandstone shows a set of peculiar ridges spaced at intervals of about 10 feet. These ridges are flat-topped, about 3 inches high, and a foot or two broad, and they run diagonally across the footwall surface at an angle of about 30° from the horizontal. It is said that the ore was better below each of these than elsewhere.

The cinnabar occurs in joint fractures approximately normal to the bedding. The principal set of mineralized joints strikes about N. 60° E. and dips about 35° NW. Neither these joints nor the footwall ridges are visible in the hanging-wall shale, which is almost mirror-smooth. The jointing is evidently due to tension caused by the drag folding on the fault.

It seems reasonable to expect that cinnabar may be found both along the fault and extending into the adjoining sandstones at places where they have undergone tension that was due to drag folding and are overlain by impervious shales. As the regional dip is to the south, better ore will presumably be found in the drag folds west of the fault than in those to the east.

O