CIRCULAR 34

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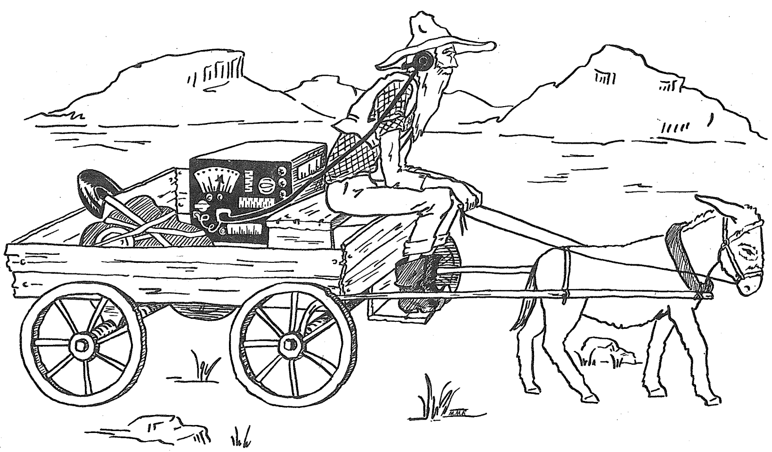
by
Frederick J. Kuellmer



NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

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STATE BUREAU OF MINES AND MINERAL RESOURCES

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Socorro, August 1955

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ABSTRACT

A funnel-shaped intrusive mass of quartz monzonite porphyry with an outcrop area of one-half square mile and a copper content of 0.35 weight percent occurs in the Animas Hills near Hillsboro, Sierra County, New Mexico. The intruded rocks are early Tertiary (?) dark-colored andesitic flows, tuffs, and agglomerates with small feldspar and hornblende phenocrysts which, together with the matrix, have been altered variably to aggregates of chlorite, sericite, calcite, and epidote. The quartz monzonite porphyry is light-colored and ranges in grain size from very fine to coarse, with large orthoclase cryptoperthite phenocrysts. Many monzonitic dikes, roughly radial to the main intrusive mass, occur throughout the Animas Hills. A biotite latite dike and basalt dikes are younger than the monzonitic rocks. Thin accumulations of alluvium cover parts of the area.

Jointing and fracturing throughout the area trend predominantly in directions ranging from N. 30° E. to N. 65° E. and from N. 40° W. to N. 65° W. Veins of sulfides and disseminated sulfides are found in both the porphyry and the intruded rocks. Sulfide minerals appear to be most abundant in quartzose and brecciated areas.

As the shape of the intrusive body is a dominant factor in an evaluation of the amount of possible ore it may contain, or of the possibilities for ore in older

rocks underlying the volcanics, the configuration of the intrusive quartz monzonite porphyry was investigated not only by field geologic methods but by five magnetometer profiles. These investigations suggest strongly that the intrusive rock decreases in diameter with depth.

Published descriptions of copper-porphyry-type intrusives show that inward-dipping contacts, funnel shapes, or even floors are common. Intrusives of this type owe their shape to the excess of magmatic pressures over the confining pressures of the host rocks, with approach toward the surface. Lateral as well as upward expansion of such hypabyssal magmas appears to be best attributed to their gaseous phase.

INTRODUCTION

Purpose and Scope

The purpose of this study is to provide the most recent geologic and assay data on the Copper Flat area, near Hillsboro, New Mexico, in the hope that additional exploration may be encouraged. The area was mapped by the writer on Soil Conservation Service photographs on a scale of about 1:31,680. Figure 2 is an enlargement of this geologic map and probably shows distortions normally found in such a magnification. However, a comparison of this geologic map (fig 2) with mining maps on a much larger scale shows that the distortions are quite insignificant. Five magnetometer profiles were run using the Ruska Scout Magnetometer, which has a sensitivity of 25 gammas. In addition, all mining reports in the possession of the major property owner were made available to the author, and from these all assay data were obtained.

Acknowledgments

The author is indebted to Mr. Max Hiltscher, owner of the properties, for full cooperation and assistance, and especially for permission to make public all assay and drill-hole data which he had available. Dr. Eugene Callaghan has assisted immeasurably in many discussions; indeed, the idea that gaseous expansion is significant in the emplacement of igneous masses is directly attributable to him. The entire staff of the New Mexico Bureau of Mines and Mineral Resources has been most helpful. Mr. W. E. Arnold and Mrs. M. M. Frische prepared the illustrations.

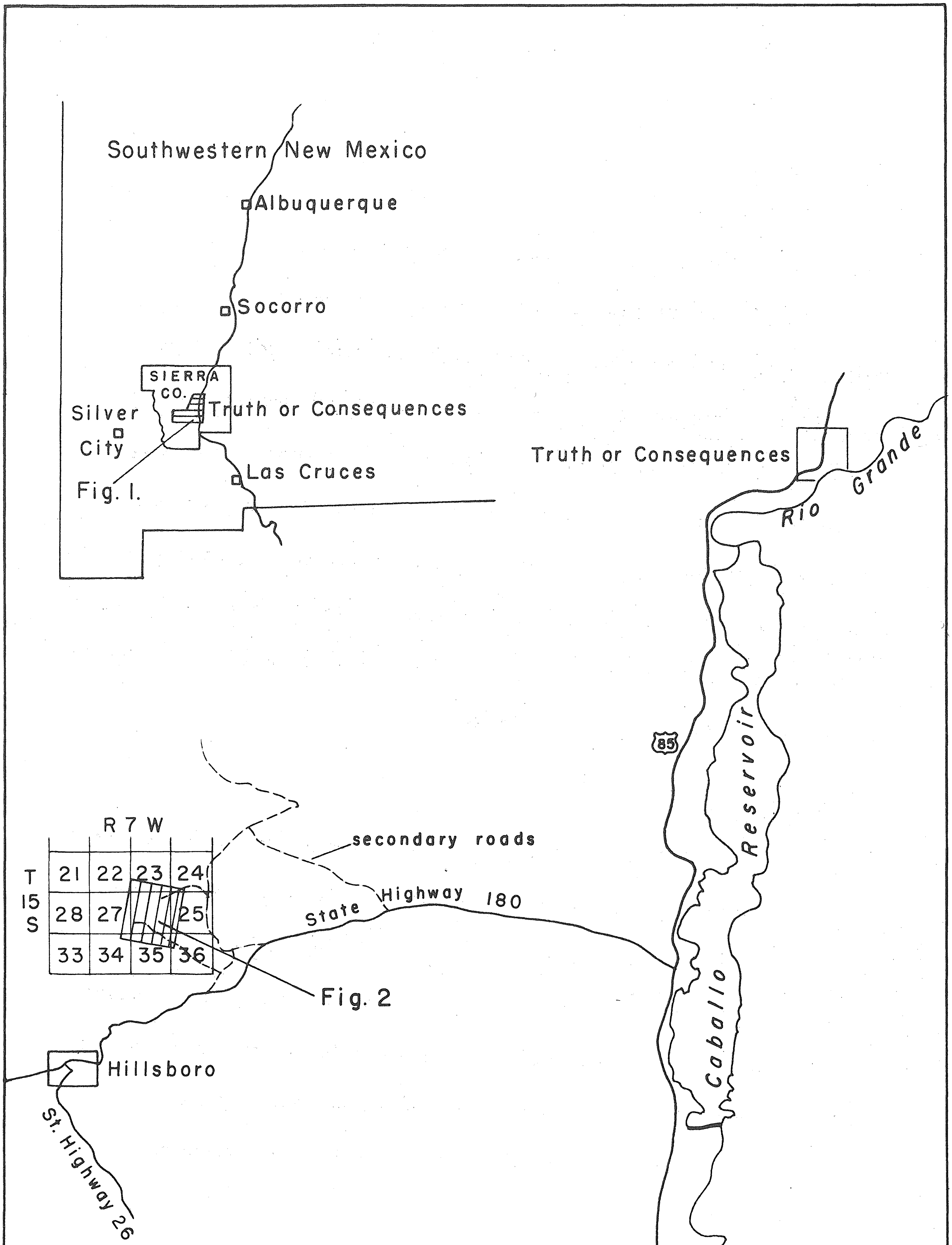

Figure I. Index Maps. Copper Flat Area, Hillsboro, New Mexico

The Research and Development Division of the New Mexico Institute of Mining and Technology loaned the author its Ruska Scout Magnetometer. Mr. V. Vacquier and Mr. C. R. Holmes, of the above division, generously provided guidance for the magnetometry.

<u>Location</u>

The Copper Flat area is in Sierra County, New Mexico, about 20 miles southwest from the city of Truth or Consequences. The area may be reached by driving 10.5 miles west from the junction of U. S. Highway 85 and State Highway 180, and turning onto a graded road leading to the almost deserted settlement of Gold Dust. From 1,000 yards north of Gold Dust, an unimproved road leads westward to the Hiltscher residence and beyond to the Copper Flat area. The survey location may be seen in Figures 1 and 2.

The name "Copper Flat" used in this report is taken from the name used on the topographic map of the Hillsboro, New Mexico, quadrangle issued by the U. S . Geological Survey. Unfortunately, within the Central Mining District, on the Silver City, New Mexico, quadrangle another area has been designated as "Copper Flat," and there may still be others. This is mentioned here in the hope of eliminating confusion.

<u>Physical Features</u>

The Animas Hills surrounding Copper Flat have a maximum relief of about 800 feet and are part of a north-south line of dissected hills extending from the Sierra Cuchillo southward to the Lake Valley Hills. This block is probably an eastward tilted uplifted block or horst, although the east-bounding fault is not exposed in most places. The Animas Hills are bounded on the east by the alluvial sediments of the Rio Grande depression. To the west the Animas Hills are terminated abruptly by a fault contact with alluvial sediments on the west side.

History

According to Harley (1934, p 139), gold was reported to have been discovered in the Hillsboro district in 1877. Both placers and lodes were mined from the very first. Work in the mining district has been very intermittent with most activity in the years 1877-1893, 1906, 1918-1921, and 1931-1933. The total estimated value of production from both placers and lode mines is given by Harley (1934) as $6,900,000. Only a small part of this value was produced within the mapped area (fig 2). Primary value has come from gold, with minor silver and copper.

Previous geologic work has included part of Harley's (1934) study of the geology of Sierra County and a part of the professional paper of Lindgren, Graton, and Gordon (1910) on the ore deposits of New Mexico. At least one recent unpublished mining report deals specifically with the Copper Flat area. No other geologic or mining investigation has been made, so far as the author is aware.

GEOLOGY

Introduction

Rocks exposed in the mapped area (see fig 2) may be tabulated as follows, from oldest to youngest:

1. Andesite and latite flows, tuffs, and agglomerates
2. Intrusive quartz monzonite porphyry
3. Biotite latite dike and basalt dikes

In addition to the foregoing igneous rocks there are local accumulations of unconsolidated alluvium and terrace gravels of very limited thickness and occurrence. Such Quaternary alluvial deposits, because of their limited nature and relative unimportance, have been omitted from the geologic map (fig 2) in order to simplify the presentation.

All of the above rock units are presumably Tertiary in age, except for the basalt dikes, which may be either Tertiary or Quaternary.

Rocks ranging in age from Precambrian to Pennsylvanian occur a short distance to the north along Tank Canyon and Dutch Gulch, and to the south near State Highway 180. Throughout the Hillsboro quadrangle, which includes the mapped area, extrusive andesitic rocks, similar to those of item 1 (above), overlie no sediments older than the Mississippian Lake Valley formation. This suggests that Paleozoic strata may be concealed under the oldest andesitic volcanic rocks in the mapped area. Table 1 describes the strata which may be concealed as well as the rocks which are

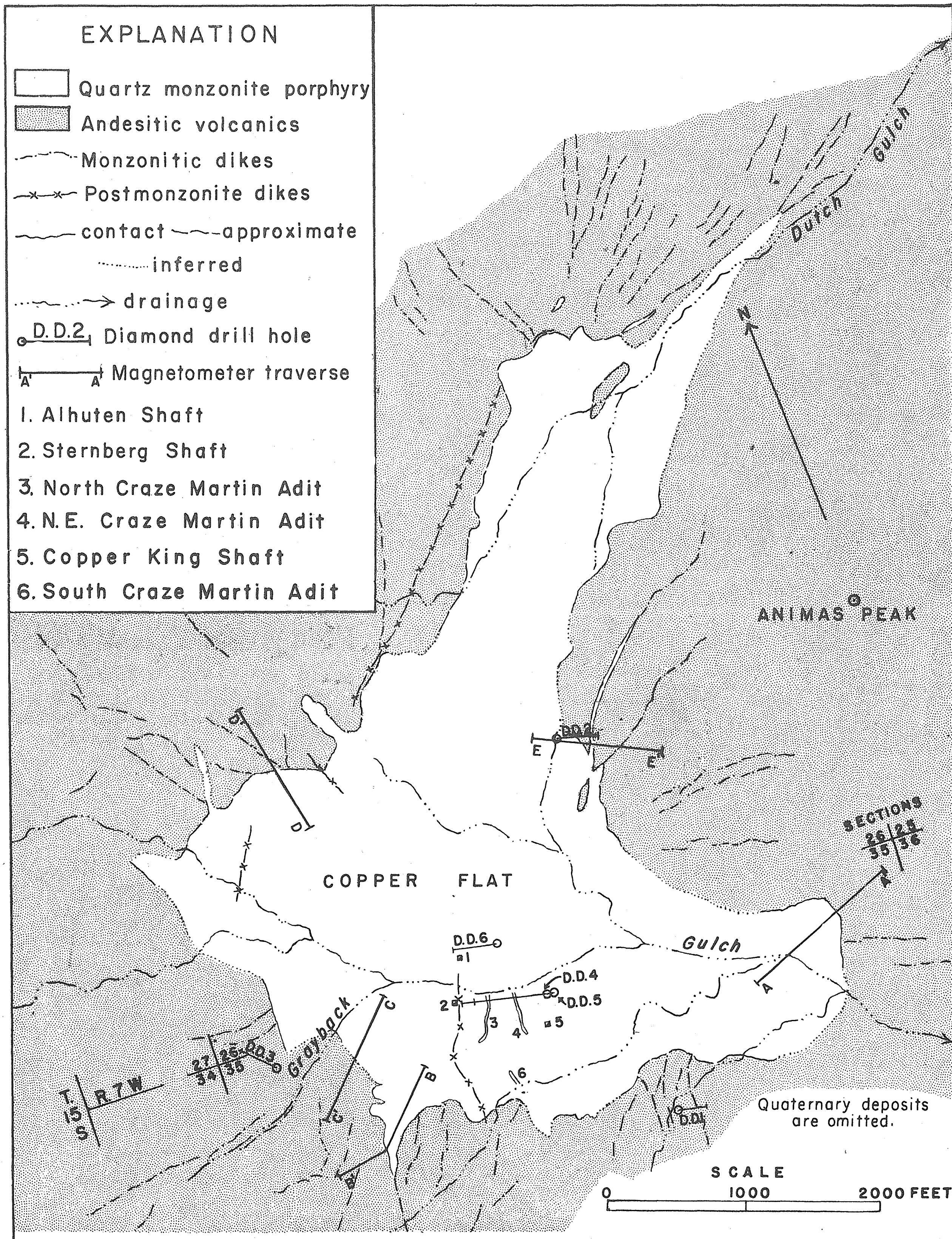

Figure 2. Geologic Map of the Copper Flat Area, Hillsboro, New Mexico

Table 1

ROCK SEQUENCE OF THE COPPER FLAT AREA

Present in area	Rock Unit	Remarks
Exposed	Postmonzonite dikes A. Basalt dikes	Black, scoriaceous, may be Quaternary. Away from Copper Flat similar basalt truncates and is interbedded with alluvial sediments (Santa Fe group ?).
Exposed	B. Biotite latite dike	Grayish-blue aphanitic porphyry, probably younger than the quartz monzonite porphyry.
Exposed	Intrusive quartz monzonite porphyry and related dikes	Aphanitic to coarse-grained porphyry with large orthoclase phenocrysts. Ore deposits were formed after the intrusive porphyry was emplaced.
Exposed	Andesite, latite, flows, tuffs, and agglomerates	Rocks are highly altered and replaced by chlorite, sericite, calcite, and epidote. Forms a large volcanic pile with a maximum height (thickness) of about 2,000 feet.
Concealed	Pennsylvanian limestones and shales	Originally probably more than 650 feet thick; as a result of prevolcanic erosion, it now may be absent or very thin.
Concealed	Mississippian Lake Valley limestone	Originally 140 feet thick, but now may be partly or completely removed by erosion.
Concealed	Devonian Percha shale	About 148 feet thick.
Concealed	Silurian Fusselman dolomite	About 80 feet thick, or may be absent. An important ore horizon in the Kingston mining district.
Concealed	Ordovician Montoya formation	Approximately 200 feet thick. An important ore horizon in the Kingston mining district.
Concealed	Ordivician El Paso limestone	About 300 feet thick. An important ore horizon in the Kingston mining district.
Concealed	Cambrian Bliss formation	About 100 feet thick.
Concealed	Precambrian rocks	Basement complex of granite, quartzite, metadiabase, and schistose quartzite.

Note: The presence of the concealed rocks is inferred on the basis of their presence in areas immediately to the north and south of the Copper Flat area. Their thicknesses are based on measurements made in the vicinity of Kingston (Kuellmer, 1954). The oldest rocks are at the bottom and the youngest at the top of the table.

known to be present. "In a drill hole from the bottom level of the Rattlesnake mine, limestone underlying the extrusives was encountered at a depth from the surface of approximately 1,150 feet, and these extrusive rocks may be underlain by limestone in most of the district," (Harley, 1934, p 131). Both the Copper Flat area and the Rattlesnake mine are part of the Hillsboro (Las Animas) mining district; the Rattlesnake mine is located about 2¼ miles southwest of Copper Flat. The andesitic and latitic volcanic rocks described above are part of the same rock mass as the extrusive rocks mentioned in the above quotation. Mr. Max Hiltscher has kindly presented to the author a drill-core sample purporting to be from the bottom of the Rattlesnake mine drill hole. After examination of the limestone core sample, both Dr. Rousseau Flower, of the New Mexico Bureau of Mines and Mineral Resources, and the author concurred in the opinion that the specimen most likely came from upper Paleozoic limestones; this would suggest that the andesitic volcanic rocks are floored by Mississippian or Pennsylvanian sediments. It is worth noting that limestones and dolomites, namely the El Paso, Montoya, and Fusselman formations, of the same age as those in which the greatest ore deposits of the nearby Kingston district were found, should also underlie the andesitic volcanic rocks.

Andesitic Volcanic Rocks

Most of the Animas Hills consist of andesitic volcanic rocks. It has not been possible to date these earliest volcanics, except in a general way by comparison with the volcanic sequence in nearby regions. On the basis of their stratigraphic position, texture, and extensive alteration these rocks are very similar to the earliest volcanic rocks in the vicinities of nearby Kingston (Kuellmer, 1954), Santa Rita (Hernon, Jones, and Moore, 1953), and Lake Valley (Jicha, 1954). Such andesitic volcanic rocks in the vicinity of Kingston previously (Kuellmer, 1954, p 29) have been regarded as Tertiary in age, and older than early Miocene. As discussed above, it seems reasonably certain that the andesitic rocks unconformably overlie concealed sediments (table 1).

The andesitic flows, tuffs, and agglomerates are green, gray, blue, black, or violet porphyritic aphanites. Rocks of this unit weather a dark brown. The phenocrysts, which show considerable variation in relative abundance and distribution, consist primarily of altered and weathered white lath- and tabular-shaped feldspar (about 0.5 cm and less in length). Chloritized hornblende or hornblende-shaped cavities, 2 mm and less long, are locally abundant.

Some of the andesitic rocks show a flow banding, and in a few localities the fragmental pyroclastic rocks are well bedded. Closely spaced subparallel joints are common and trend predominantly in the same direction as the elongation of the quartz monzonite porphyry, and the monzonitic dikes (see fig 2).

Microscopic examination reveals that the primary matrix is an interlocking mosaic of lath-shaped feldspar. Most of the andesine feldspar phenocrysts and a large part of the matrix are replaced by calcite, chlorite, sericite, and epidote.

Close to the quartz monzonite porphyry intrusion, the andesitic rocks are more massive and show less planar structure. One rock variety, very common near the intrusion, is dark green, bulish-violet, or black and contains abundant green augite-shaped phenocrysts (1 cm and less in length). Locally this rock contains small pink feldspar laths (1 mm and less) and sparse small sulfide specks. Microscopic study has shown that the stubby green phenocrysts are hornblende. The habit of the hornblende suggests that it is a pseudomorph after augite. Epidote, chlorite, and sericite are also common constituents of this rock. The presence of pseudomorphs after augite in the vicinity of the quartz monzonite porphyry, when they are absent a considerable distance away from the quartz monzonite, may be an indication of a contact-metamorphic effect. No prominent hornfels facies occurs near the quartz monzonite porphyry.

Quartz Monzonite Porphyry

Exposures of quartz monzonite porphyry are found in the central part of the Animas Hills over an area of about one-half square mile (fig 2). Quartz monzonite porphyry dikes can be traced almost continuously from the main mass outward to where they clearly truncate the surrounding andesitic volcanics. Thus, the quartz monzonite porphyry is younger than, and intrusive into the andesitic volcanic rocks.

Although in several locations one part of a rock slab might show a slight alignment of lath-shaped feldspars, most of the outcrops show no preferred feldspar orientation. Diligent search was made for any orientation or structural features. The quartz monzonite is massive and generally broken by one set of closely spaced subparallel joints. These joints trend predominantly in two directions, as do the monzonitic dikes in the surrounding country rocks (see fig 2).

Weathering of the quartz monzonite porphyry produces flattened slabs and angular blocks or even large spheroidal masses. At a distance the weathered rock slopes are a light orange-brown.

Three textural and compositional phases of the quartz monzonite porphyry may be distinguished, namely, (a) the porphyritic facies, (b) the contact facies, and (c) the aphanitic dike facies. All three varieties are closely associated in space and time, and therefore are presumably consanguinous. The porphyritic facies consists of gray, cream, tan, or brown porphyries containing abundant euhedral to subhedral, lath- or tabular-shaped feldspar phenocrysts. The gray to pink potash-feldspar phenocrysts, ranging from 1 cm or less up to 5 cm in length, with an average length of about 1.5 cm, are a diagnostic feature of this rock type. Within the quartz monzonite porphyry the matrix ranges from coarse-grained (5 mm) to aphanitic, whereas the porphyritic dikes have an invariant aphanitic matrix. Where the matrix is coarse enough, one can see white to gray, elongated, anhedral plagioclase grains, and subhedral pink potash feldspar laths. In addition, fresh or chloritized hornblende and/or biotite, of a small grain size (1 mm), are present locally. No quartz is visible in hand specimen except in brecciated and silicified zones. Study of the drill cores from the quartz monzonite porphyry mass revealed at depth coarse-grained nonporphyritic parts, which locally are even pegmatitic. However, there does not appear to be any systematic change in grain size with depth.

Two estimated modes determined in thinsection are presented in Table 2. A point-counting system on a rectangular network was used to estimate the modal proportions. As only about 300 points were counted, all percentages less than 2 were listed only as present, except for chalcopyrite in one specimen. Microscopic study reveals that the rock is a network of anhedral feldspar laths (large potash feldspar and small plagioclase) with a very fine matrix of anhedral quartz and dark-colored minerals. The feldspars have sutured or granophyric-type contacts. The potash feldspars are orthoclase crypotoperthites with a total approximate composition of Or_{75} Ab_{25} ($\pm$ 5 mol percent), based on X-ray determination of $\bar{2}01$ spacing. Quartz occurs only as small anhedra interstitial to the feldspar and granophyrically intergrown with the feldspar. Biotite aggregates of small anhedral shreds occur in close association with quartz. Sulfide minerals were found filling cracks and preferentially replaced quartz and chloritized biotite.

The contact facies is a dark-gray nonporphyritic rock found at or near the andesite-quartz monzonite contact in only four localities. It cannot be demonstrated that the gray nonporphyritic rock is exactly at the contact, nor is the rock exposed sufficiently to be mapped as a separate unit. This facies crops out (see fig 2) along the contact southwest from the southwest corner of Sec 25, in the draw about 1,000 feet north from the northwest corner of Sec 35, near the contact southwest of the South Craze Martin adit, and near the contact about 1,000 feet northeast from where the "O" in Copper Flat appears on the map (fig 2).

Table 2

MODES OF THE QUARTZ MONZONITE PORPHYRY

Primary Minerals	390A-43	390A-44
potash feldspar (Or_{75})	49%	38%
plagioclase (Ab_{72})	21	20
quartz	22	27
biotite	7	2
apatite	x	x
zircon	x	x
magnetite and ilmenite	x	x
sphene	x	x
Secondary Minerals*		
sericite	x	x
chlorite	x	2
calcite		x
hematite and leucoxene	x	x
chalcopyrite	x	1
pyrite	x	5
quartz		x
Totals	99%	95%

* Includes both alteration and introduced minerals. See text.

x Indicates present.

Brown weathering, an overall gray color on a fresh surface, and a black and pink coarse salt-and pepper texture characterize the fine- to coarse-grained non-porphyritic contact facies. The parts which have an overall gray color are penetrated by thin zones and veinlets of pinker and more feldspathic material. The veinlet boundaries are gradational and divide the darker rock into pebble- and cobble-shaped masses. The entire rock has the appearance of a resorbed autolithic breccia in which an early crystallized mafic phase has been brecciated and subsequently reacted with a later more feldspathic phase of the same intrusive melt.

The microscopic texture is xenomorphic-granular, although locally a granophyric texture fringes feldspars or occurs interstitially to the larger grains. Green-black hornblende comprises about 30 volume percent, magnetite 3 percent, and quartz only about 5 percent of the contact facies. Quartz is found only as very small anhedra or in the granophyric intergrowths. Potash feldspar and plagioclase are very similar in kind and abundance to those of the porphyritic facies.

Monzonitic dikes are of two varieties, (1) aphanitic porphyries, described above, and (2) aphanitic dikes. The aphanitic-dike facies was also found within the main mass of quartz monzonite porphyry in minor amounts, and is gradational to some of the coarser phases, although it occurs principally as dikes in the surrounding country rocks. The aphanitic dikes are white to brown, nonporphyritic rhyolites, which weather yellowish-brown or brown. Locally they contain sparse small (1 mm) biotite or feldspar phenocrysts. Such dikes have the appearance of unglazed porcelain and are very hard, possibly even silicified. A microscopic examination shows that the rock is an interlocking network of very fine feldspar laths with anhedral interstitial quartz, and sparse altered biotite and feldspar phenocrysts.

All of the above textural varieties are considered as part of the quartz monzonite porphyry intrusion because of their intimate interspersion and similar compositions. It is not possible to establish a simple sequence for the various rock types on the basis of field relations. The range of grain sizes, from aphanitic to pegmatitic, and the irregular distribution of grain size within an outcrop or a single drill core, suggest that the intrusion was emplaced at a shallow level such that local conditions determined whether volcanic or plutonic textures would be formed.

Postmonzonite Dikes

In order to simplify the geologic map (fig 2), two species of postmonzonite dikes have been indicated by one map symbol. These dikes are a biotite latite and basalts.

The biotite latite dike, with the longest extent of any postmonzonite dike, is found near and approximately parallel to the northwesterly contact of the quartz monzonite porphyry. Exposures of the dike are moderately continuous throughout its length except for the northeasternmost 800 feet, where they are very sparse. It cannot be clearly demonstrated that the biotite latite truncates its surroundings, hence the interpretation as a dike is based only on the linear distribution of material.

Estimates of the relative age of the biotite latite are based on the following facts:

1. The dike probably truncates the andesitic volcanic sequence.
2. No sulfide mineralization occurs in the dike.
3. Lithologically similar latitic flows are found nearby in the Black Range and south of the Animas Hills. In the adjacent areas such latitic rocks were deposited much more recently than the rocks roughly comparable to the andesites and the quartz monzonite porphyry of the Copper Flat area.

For the above reasons the biotite latite is believed to be younger than the andesitic volcanic rocks, the quartz monzonite porphyry, and the sulfide ore deposits.

The biotite latite is a purplish-blue to grayish-blue aphanitic porphyry, which outcrops as brown rounded boulders. Locally, it shows a planar parting parallel to the dike trend and sparse elongated gas cavities up to $1\frac{1}{2}$ inches long. The gas cavities have a bearing parallel to the parting and dike trend, and a high-angle plunge. White to colorless equant feldspars, up to 1 cm in diameter, are abundant. Quartz phenocrysts (1 cm and less) are sparse. Biotite is abundant and attains a maximum size of 4 mm, although most grains are about 1 mm long.

All the other postmonzonitic rocks indicated in Figure 2 are basalt. Basaltic dikes and lava flows are quite common in the vicinity of the Copper Flat area. Such dikes truncate all rock types in the Copper Flat area, and a few miles to the southeast a basaltic dike truncates even the alluvial deposits (Santa Fe group ?) of the Rio Grande trough. This demonstrates the comparatively recent age of the basaltic rocks.

In the Copper Flat area the basalts are black or bluish-black, aphanitic, and locally scoriaceous with elongated gas cavities (2 inches and less in length). Near some of the areas most stained with copper minerals, amygdules of azurite and malachite are common in the basalt dikes. No sulfide minerals were noted in the basalts.

Structure

Andesitic volcanic rocks show bedding or a flow banding in many parts of the Animas Hills. However, most of the measured structural attitudes are beyond the present map limits and, so far, are sparse enough so that little can be stated definitely concerning the shape of the andesitic volcanic pile. The topography, namely, a central mass of volcanic rock hills rising abruptly from adjacent areas in which no andesitic volcanic rocks are found, suggests a single volcanic pile. Such an appearance may be fortuitous, however, inasmuch as the Animas Hills are bounded on three sides by known faults and on a fourth by contact with the alluvial deposits of the Rio Grande trough.

As jointing is the only common structure within the quartz monzonite porphyry, the andesite-quartz monzonite porphyry contact was carefully studied in an attempt to ascertain properly the shape of the intrusive rocks. Four localities are most significant in this regard, namely:

1. In the area in the vicinity of the "b" in Grayback Gulch (see fig 2), where the contact exposed in the arroyo bed is downstream from that on adjacent hillslopes and considerably closer to the center of the intrusive quartz monzonite porphyry. The distribution of the contacts in this gulch and adjacent hillslopes indicates that the contact surface has a calculated strike of N. 42° W., and a dip of 11° N. E. Significant here is the fact that the dip is toward the center of the intrusive rock, and not the actual value of the dip and strike.

2. Approximately 1000 feet east of the word "Gulch" in Grayback Gulch (see fig 2), the exposed contact has a calculated (three-point) dip of 14° S. W., and a strike N. 56° W. In the field it is also quite apparent from nearby high points that the quartz monzonite porphyry laps up onto the andesitic volcanic rocks, and that the contact surface slopes gently southwestward toward the center of the intrusion.

3. Along Dutch Gulch (see fig 2) to the southwest, the quartz monzonite porphyry has a greater areal extent than to the northeast in the topographically lower parts of Dutch Gulch. This suggests that the contacts of the quartz monzonite slope inward toward the center of the rock mass.

4. In the wash, approximately 250 feet southwest of the entrance to the South Craze Martin tunnel (see fig 2), the contact of the porphyry and the andesitic rocks dips southward or away from the center of the quartz monzonite porphyry at a high angle. Brecciation is considerable near the contact, and the exposures are poor, so that this might actually represent a fault zone and thus not contribute to an understanding of the original shape of the intrusive porphyry.

From the foregoing tabulation, it seems most probable that the quartz monzonite porphyry is funnel-shaped. It does not imply that all contacts must dip inward, inasmuch as faulting might easily have modified the original intrusive shape locally. Such an interpretation differs from that of previous workers who have called the porphyry a stock. Magnetometer profiles, presented in detail in a later section, greatly strengthen this interpretation and eliminate other hypotheses.

One set of subparallel joints is prominent in almost every outcrop. Such joints trend for the most part in two directions, one direction ranging from N. 30° E. to N. 65° E., and the other from N. 40° W. to N. 65° W. These joint directions are common in both the andesites and the monzonite. Furthermore, the irregular elongations of the main monzonite mass and the trends of the monzonitic dikes suggest that these directions of weakness were influential in determining the distribution of the quartz monzonite porphyry. Xenoliths of the andesitic rocks ranging from pebble size upward and showing different degrees of resorption are to be found locally. Many of the larger enclosed andesitic masses have an elongation parallel to the joint trends, such as those large enough to be shown on the map (fig 2). The joint directions, the monzonite elongations, the dike trends, and the country-rock enclosures all suggest that the intrusion is a coalescing dike system emplaced in a highly fractured upper level of the earth's crust. Inasmuch as the confining stresses must be less at a higher level, such a coalescing dike system could easily have an overall funnel shape.

ORE DEPOSITS

Two varieties of ore mineralization may be differentiated in the Copper Flat area, namely: (1) veins in the andesitic volcanic rocks and in the quartz monzonite porphyry, and (2) finely disseminated ore minerals in the quartz monzonite porphyry and to a lesser extent in the andesites. Actually, there is every gradation from veins to disseminated ore minerals, in distribution, size, and minerals. Ore minerals observed by the author include chalcopyrite, pyrite, molybdenite, chalcocite, chalcanthite, azurite, and malachite. Additional minerals reported by Harley (1934, pp 134-136, 163-165) include bornite, tetradymite, gold, silver, and copper. Secondary enrichment is minor; primary sulfides occur even in the most altered parts of the porphyry.

The disseminated sulfides commonly are found where the quartz, biotite, and/or chlorite are most abundant. It appears that these minerals were favored hosts for sulfide replacement. A considerable portion of the disseminated sulfides on close inspection are seen to be very small veins with varying degrees of continuity. Such a sulfide distribution will affect many rock properties which might be measured in a geophysical exploration. Joints and brecciated zones in the quartz monzonite porphyry have been cemented by vein quartz in several localities. It is quite apparent that the quartz and breccia zones are richer in sulfide minerals than massive unbrecciated rock, as Harley has reported (1934, p 134, fig 10).

All the assay data contained in this report have been taken from mining reports which are the property of Mr. Max Hiltscher. Assay data for the drill holes,

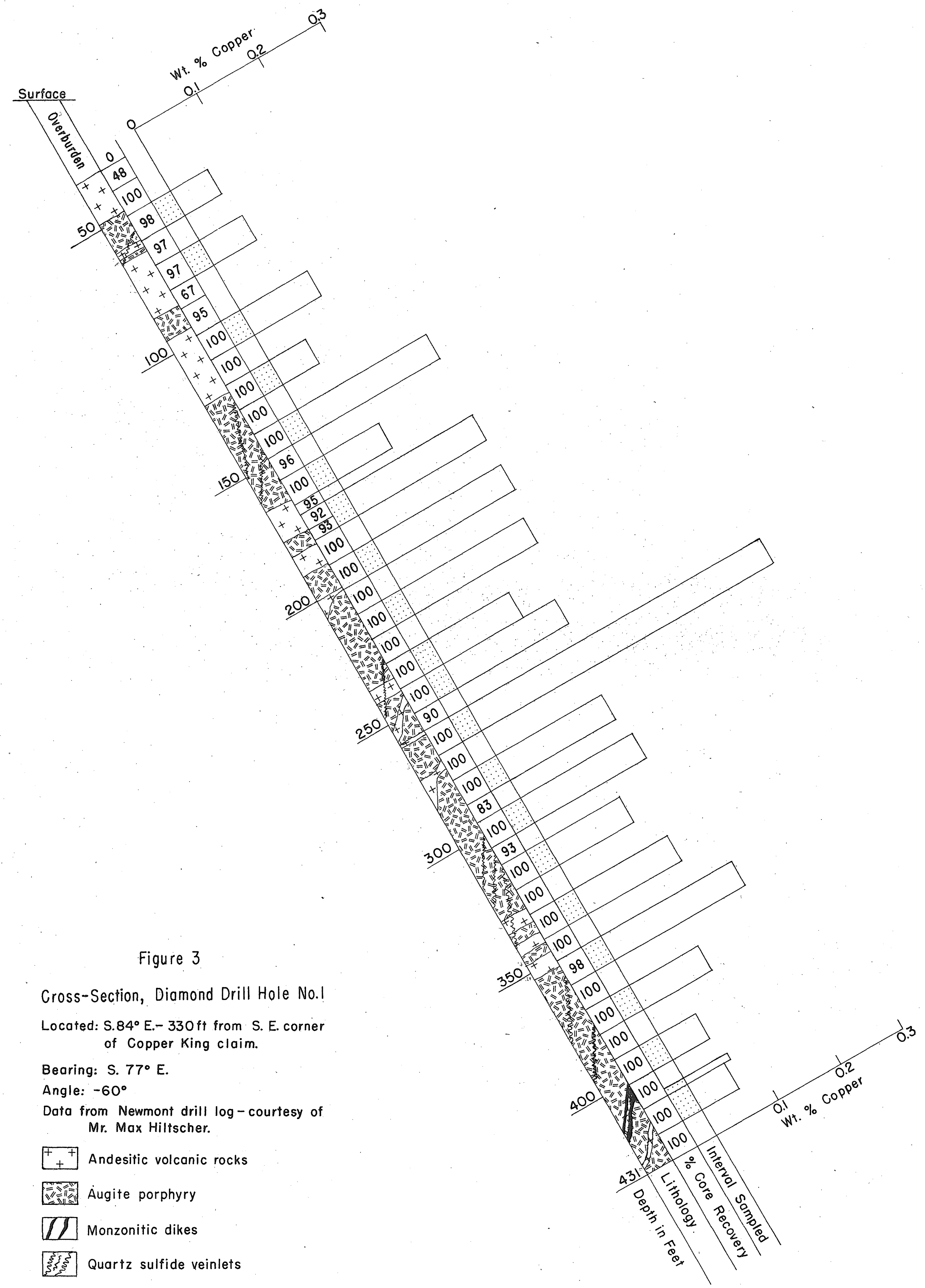

Figure 3

Cross-Section, Diamond Drill Hole No.1

Located: S.84° E.– 330 ft from S. E. corner of Copper King claim.

Bearing: S. 77° E.

Angle: -60°

Data from Newmont drill log – courtesy of Mr. Max Hiltscher.

- Andesitic volcanic rocks
- Augite porphyry
- Monzonitic dikes
- Quartz sulfide veinlets

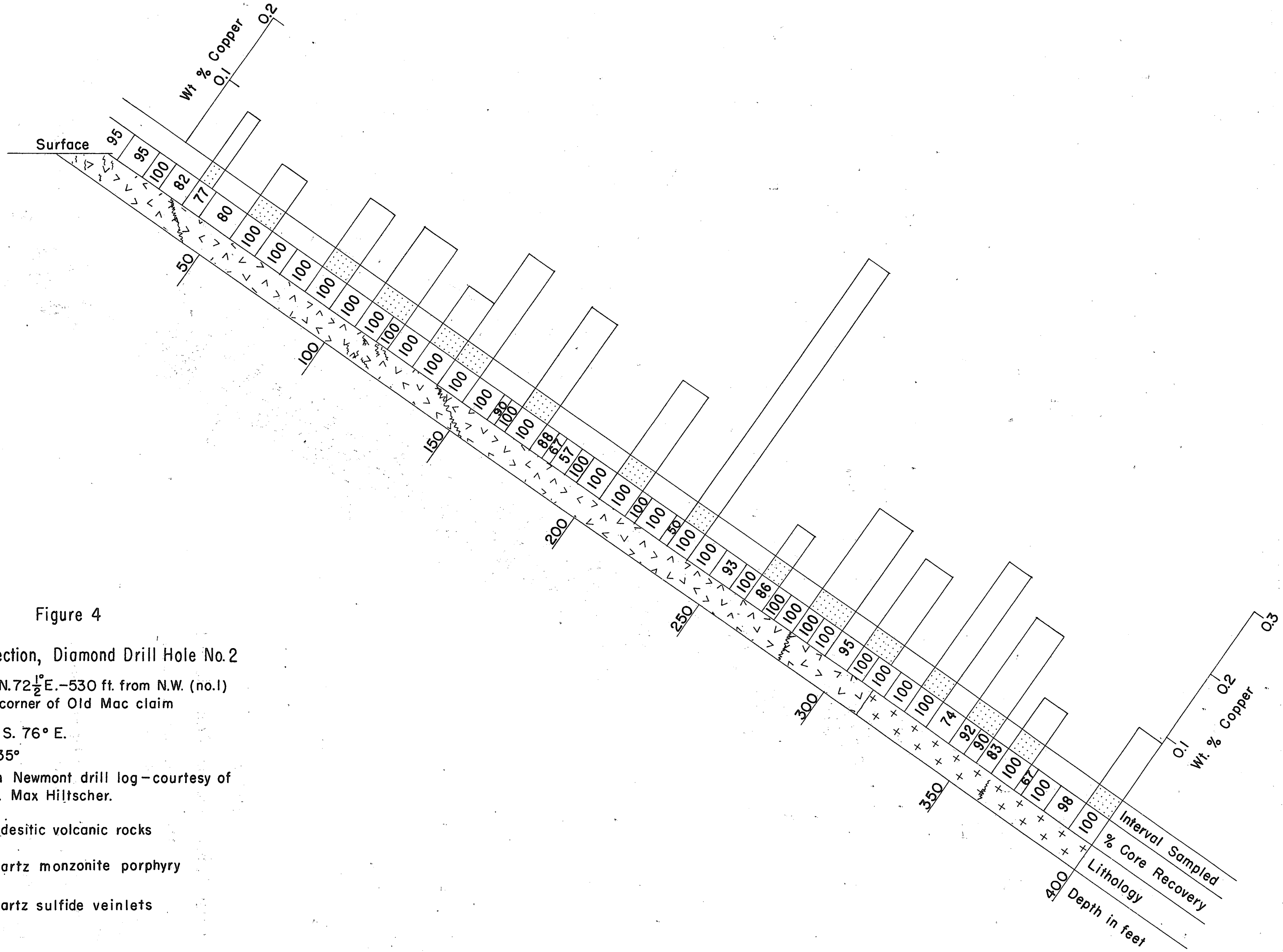

Figure 4

Cross-Section, Diamond Drill Hole No. 2

Located: N.72½°E.–530 ft. from N.W. (no.1) corner of Old Mac claim

Bearing: S. 76° E.

Angle: -35°

Data from Newmont drill log – courtesy of Mr. Max Hiltscher.

Andesitic volcanic rocks

Quartz monzonite porphyry

Quartz sulfide veinlets

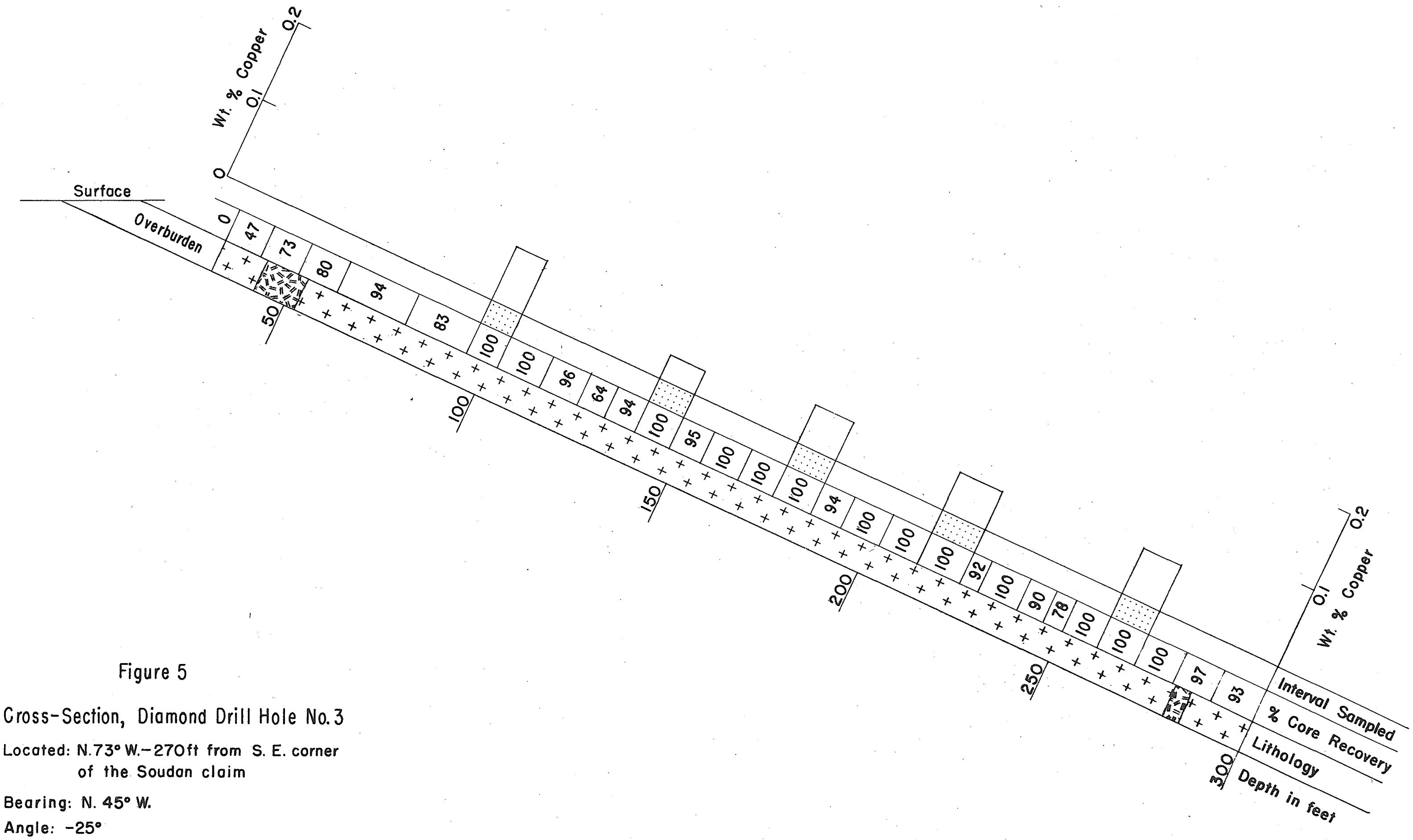

Figure 5

Cross-Section, Diamond Drill Hole No. 3

Located: N.73° W.–270ft from S. E. corner of the Soudan claim

Bearing: N. 45° W.

Angle: –25°

Data from Newmont drill log – courtesy of Mr. Max Hiltscher.

Andesitic volcanic rocks

Augite porphyry

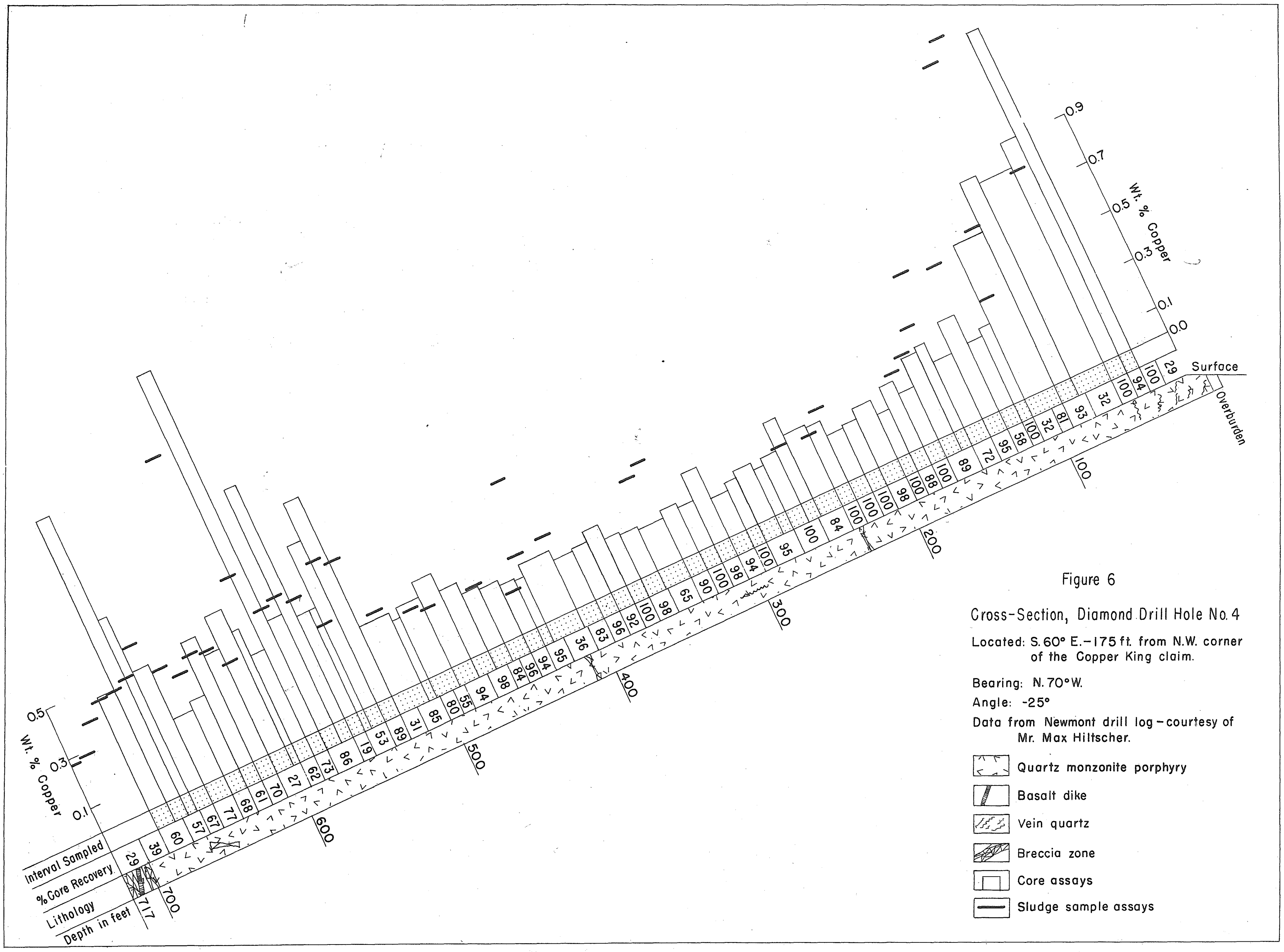

Figure 6

Cross-Section, Diamond Drill Hole No. 4

Located: S. 60° E. – 175 ft. from N.W. corner of the Copper King claim.

Bearing: N. 70° W.

Angle: -25°

Data from Newmont drill log – courtesy of Mr. Max Hiltscher.

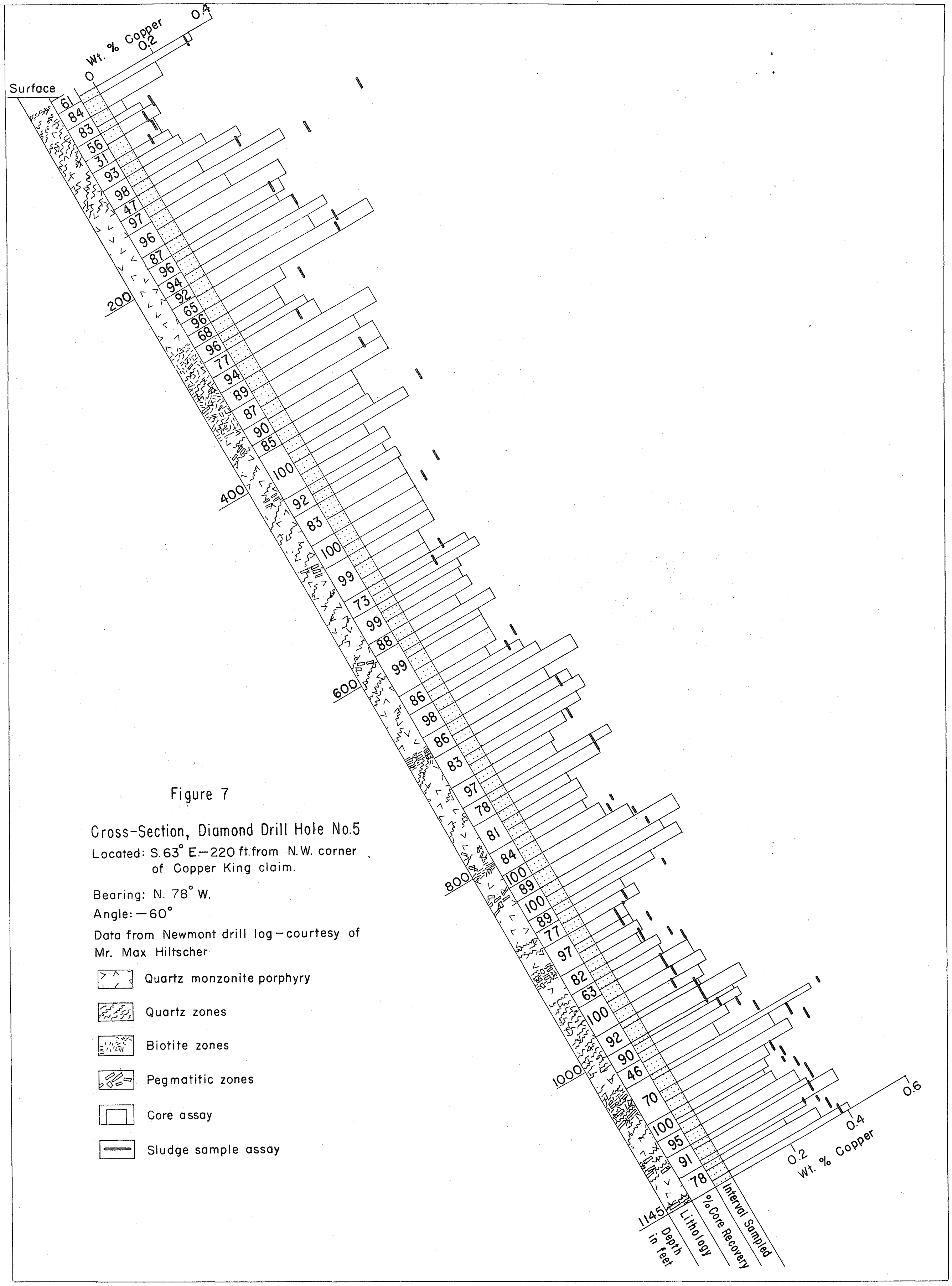

Figure 7

Cross-Section, Diamond Drill Hole No.5

Located: S. 63° E.–220 ft. from N.W. corner of Copper King claim.

Bearing: N. 78° W.

Angle: –60°

Data from Newmont drill log – courtesy of Mr. Max Hiltscher

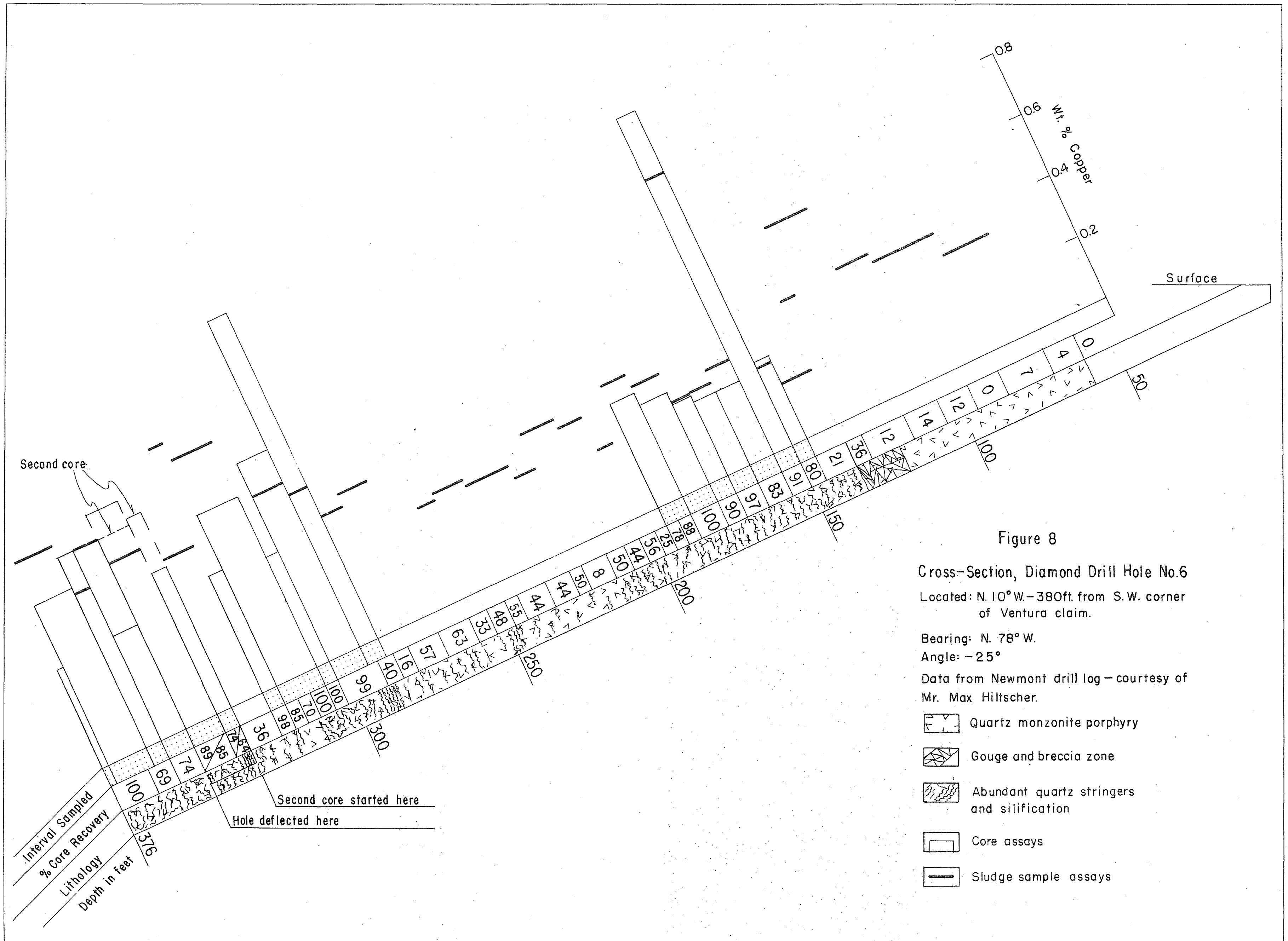

Figure 8

Cross-Section, Diamond Drill Hole No.6

Located: N. 10° W.–380ft. from S.W. corner of Ventura claim.

Bearing: N. 78° W.

Angle: –25°

Data from Newmont drill log – courtesy of Mr. Max Hiltscher.

adit, and dump samples are presented in Figures 3-9 inclusive, and Table 3. The drill log and any given angular relationships were plotted to scale along the center of the illustrated core.

Table 3

COPPER ASSAYS FOR ADIT AND DUMP SAMPLES

Locality	Percent Copper	
Dump of Alhuten Shaft	0.20	Unoxidized part
Dump of Sternberg Shaft	0.27	Unoxidized part
North Craze Martin Adit	0.29	Average of 21 wall samples
North Craze Martin Adit	0.42	Average of 7 back samples
N. E. Craze Martin Adit	0.42	Eight-foot samples from a cross-cut at 40 feet from portal
Dump of Copper King Shaft	0.34	Unoxidized part
South Craze Martin Adit	0.30	Four-foot back sample

In the drill-hole figures, the angle of contact or trend closest to vertical was illustrated arbitrarily. Where contact angles were not given in the drill log, they were plotted at right angles to the core. In Figures 3-8 inclusive, the drill holes have been located by reference to patented claim corners, which are not illustrated on the map.

In Figure 9, the assay data have been plotted against vertical depth, using as a datum plane the collar of diamond drill hole no. 3. Except for a slightly higher copper content above 400 feet depth (fig 9), the assay data appear to be independent of depth. While studying the drill-hole assays, the author noticed that the tenor of sulfides in the peripheral holes (numbers 1-3 inc.) was quite

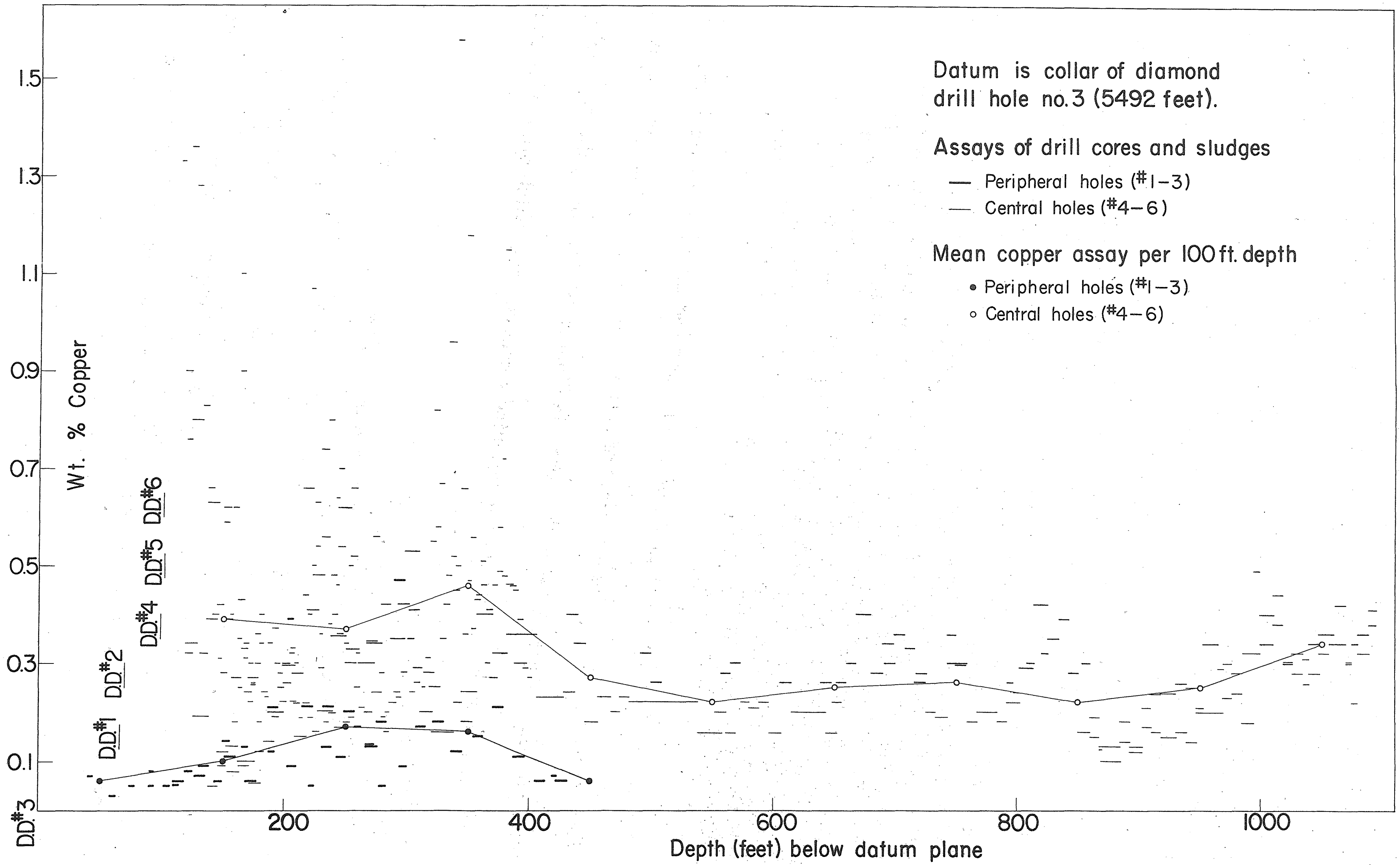

Figure 9. Relationship between copper assays and depth.

different from that in the central drill holes (numbers 4-6 inc.). Accordingly, the assay data were averaged into two groups per 100-foot depth. A pronounced difference in the copper content of the two groups is immediately apparent (see fig 9). No statistical verification of this difference was attempted, inasmuch as one could not assume random sampling. It seems reasonable that there must be a continuous gradation from high sulfide volumes to low sulfide volumes. For this report it is sufficient to note that the central part of the quartz monzonite porphyry, where the outcrops indicate the greatest sulfide content on the basis of leached sulfide estimates, actually contains the highest average copper content. Furthermore, the peripheral areas, which show almost no evidences of sulfide on the outcrop, contain a very low copper content.

MAGNETOMETER SURVEY

Five magnetometer profiles (see figs 2, 10, and 11) were measured approximately at right angles to the geological contacts. The instrument used was a Ruska Scout Magnetometer with a sensitivity of 25 gammas, generously loaned by the Research and Development Division of the New Mexico Institute of Mining and Technology. The author was assisted in the interpretation by Messrs. Victor Vacquier and C. R. Holmes, although full responsibility for the interpretation rests on the author. Table 4 presents the base reading of the various magnetic profiles, so that comparison may be made among the profiles.

Table 4

COMPARISON OF MAGNETOMETER PROFILES

Profiles	Base Reading*
A-A'	-8.1
B-B'	-48.3
C-C'	-55.4
D-D'	-19.1
E-E'	-17.6

* The base reading is the lowest value in a profile. The units are scale divisions of the Ruska Scout Magnetometer; one scale division equals 25 gammas.

Profile A-A' (fig 10) was determined across a contact which was known to dip gently toward the center of the rock mass. The contact in this area was described under item (2) in the section on "Structure." It was intended that profile A-A' should serve as one of the standard references with which to compare the other

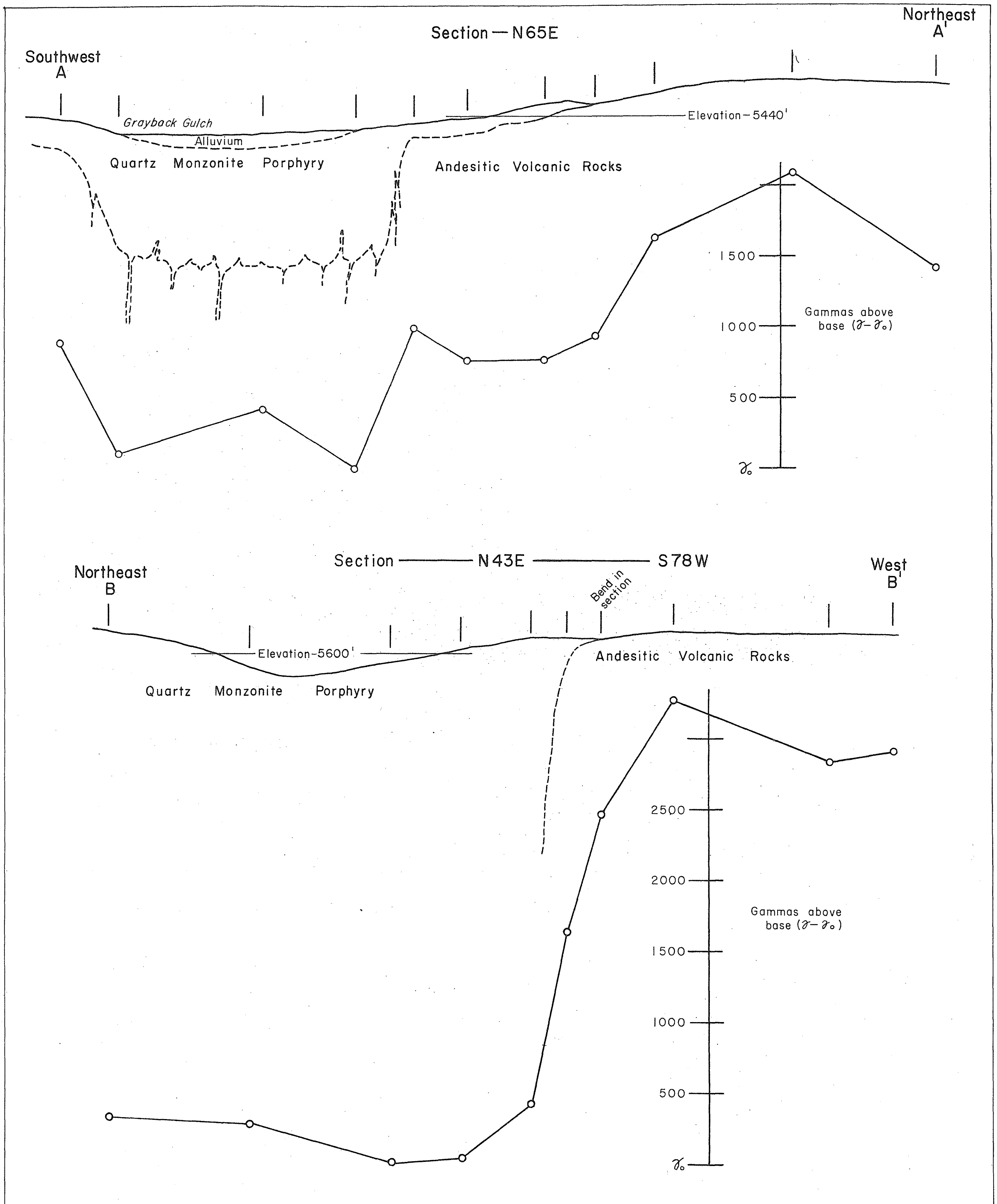

Figure 10. Magnetometer profiles and inferred geologic cross-sections.

Horizontal Scale and Vertical Scale for geologic cross-section.

0 100 200 feet

Inferred contacts are dashed

traverses. The magnetic anomaly strongly suggests that the quartz monzonite is floored at a shallow depth, which reinforces the geological evidence of an inward sloping contact. Some artistic license was taken in drawing this profile; no quantitative data are available to enable one to draw the actual depth to the shallow floor of the quartz monzonite porphyry.

Profile B-B' (fig 10) was determined across the andesite-quartz monzonite porphyry contact following a ridge line. The contact in this area is about 250 feet south of that described under item (1) in the section on "Structure," and about 750 feet west of that described under item (4). The magnetic anomaly indicates a high-angle inward sloping contact between the quartz monzonite porphyry and the country rocks.

Profile C-C' (fig 11) crosses the contact within the area described under item (1) in the section on "Structure," and near the south edge of a stream terrace and across a small alluvial fan. It was intended that this profile should also be a standard reference for the other profiles. Here too the magnetic anomaly reinforces the geological evidence of an inward sloping contact between the andesitic volcanic rocks and the quartz monzonite porphyry.

The magnetic anomaly along profile D-D' (fig 11) indicates a gentle inward-sloping contact between the two rock units.

Profile E-E' was chosen in order to provide additional data concerning the contact in the vicinity of diamond drill hole no. 2. The inferred contact on the

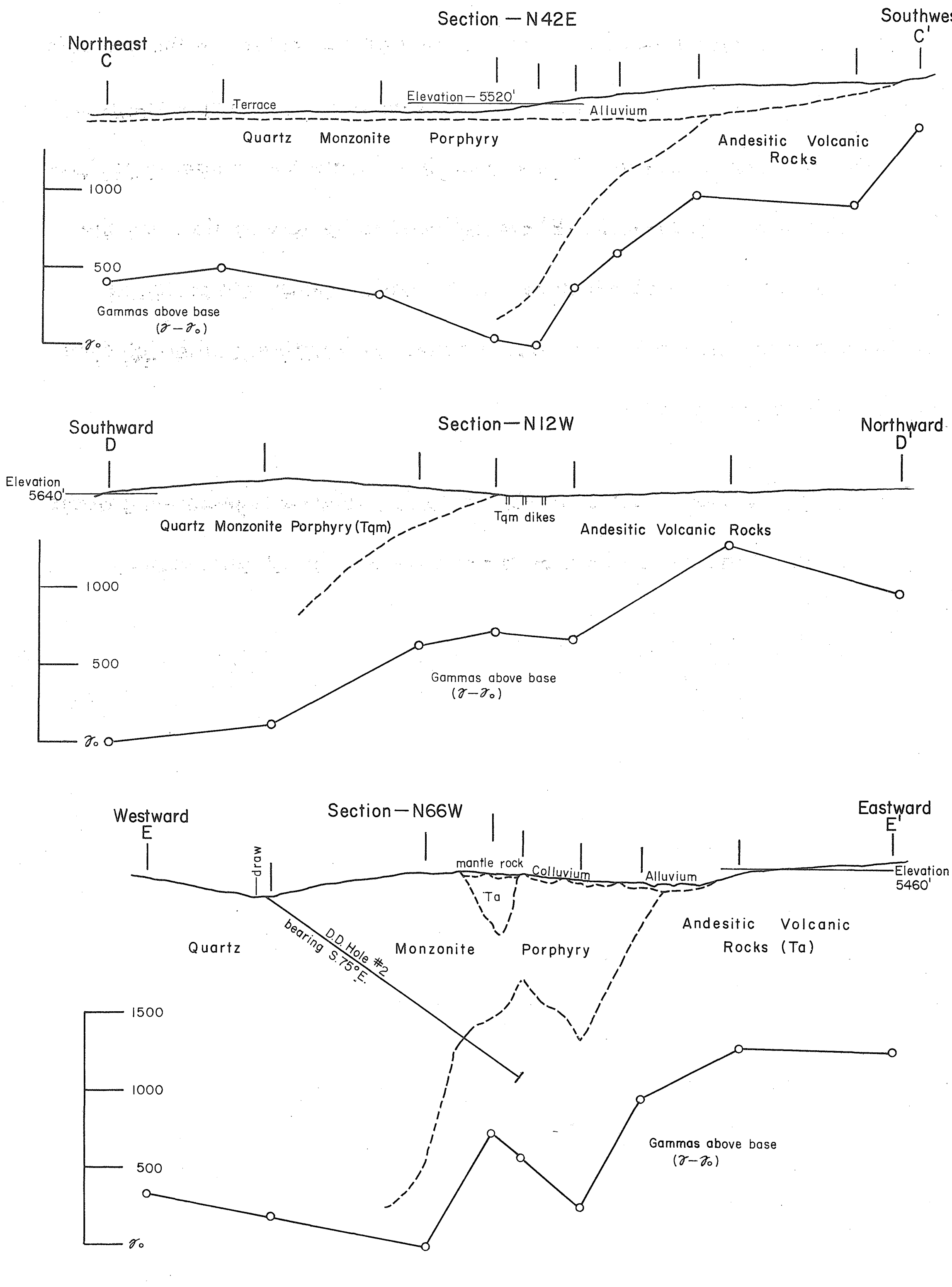

Figure 11. Magnetometer profiles and inferred geologic cross-sections.

Horizontal Scale and Vertical Scale for geologic cross-sections.

0 100 200 feet

Inferred contacts are dashed

profile E-E' (fig 11) was drawn about 150 feet east of the contact on the geologic map (fig 2). This discrepancy results from a difference in the two map scales and from the fact that exposures are not good enough to locate the contact unequivocally. Profiles A-A' (fig 10) and E-E' are believed to be very similar, and the inferred geologic section has been drawn on this basis. Other interpretations which the author has been able to visualize appear very unlikely, although they cannot be definitely eliminated.

The magnetometer profiles and the geologic evidence together necessitate the interpretation of the quartz monzonite porphyry as a funnel-shaped mass.

FUTURE POSSIBILITIES

Over 360 copper assays of the drill-core, sludge, dump, and adit samples from the central part of the quartz monzonite porphyry average 0.35 weight percent copper. The average copper content of the peripheral areas, on the basis of 42 drill-core assays, is 0.12 weight percent. According to Harrison Schmitt (1954, personal communication to Dr. E. Callaghan), an average of about 0.55 percent copper is the lower limit of current profitable mining. In addition, he states, "The possibility that we will mine some of the better protores, say, down to an average of 0.35 percent copper, within a decade of so does not appear to be too speculative, especially if most of the stripping has already been done . . . and some of the old equipment, plant, and housing is available, and further assuming that the demand for copper does not decrease materially." Utilizing the above data, a discussion of future possibilities necessitates one of two assumptions.

First, one might assume that the previous explorations have provided an adequate and reliable sample of the ore content. Then the peripheral areas and the central part of the quartz monzonite porphyry have no mining future except for local high-grade lode deposits. If technology improves and market conditions are favorable, there is a possibility that within about twenty years the central part of the quartz monzonite porphyry will have value as a low-grade copper deposit.

Second, and perhaps more important, one might assume that previous explorations have not revealed the structure and regional geology in detail, so that much of the sampling may be regarded as random. Previous reports, including unpublished mining reports, assumed that the quartz monzonite porphyry had the shape of a stock or cupola, and/or that it might flatten out under the volcanic rocks of the Animas Hills. This report shows that the quartz monzonite porphyry most likely is funnel-shaped. Furthermore, the general parallelism of the dikes, joints, and quartz monzonite porphyry elongations suggests a localization of intrusion along fractures. It is believed that such a difference in geologic interpretation might considerably modify any conclusions based on geophysical data. In addition, the drill-hole data from the bottom level of the Rattlesnake mine, which were discussed above, indicate to the author that the lower part of the funnel-shaped quartz monzonite porphyry probably truncates sedimentary rocks at a minimum depth of about 1,000 feet, and that these sedimentary rocks probably include horizons favorable to ore deposition. To the author, the above items suggest that the previous explorations have not been conclusive. Whether or not future mining explorations will be successful is, of course, speculative. At any rate, if the second assumption is valid, as it appears to be, then a thorough exploration must be undertaken before the future possibilities can be properly assayed.

GEOLOGICAL SIGNIFICANCE

Is it unusual for a copper porphyry intrusive to have a funnel shape, inward sloping contacts, or to be floored by the host rocks? A cursory search of pertinent geologic reports suggests that it is quite a common occurrence (see table 5). Unfortunately, geologists are extremely reluctant to suggest that large masses of igneous rock might be floored. If a large intrusive mass has an outward sloping contact in an outcrop, it is regarded as prima facie evidence that the rock is a subjacent body (see Daly for definitions, 1912, p 720-722). However, if a large intrusive igneous mass has inward sloping contacts in the field, then all too often the geologic interpretation disregards the contact evidence and insists that the igneous mass be a subjacent body (stock or batholith). There is apparently some a priori reason for preferring that igneous intrusive masses increase with depth, which reason, however, escapes the author. On the basis of Table 5 and this study, it is apparent that each large coarse-grained intrusive rock mass is not a subjacent body (stock or batholith), and that such rock masses must be studied closely in order to glean any evidence as to their depth projection.

If it is accepted that large igneous masses can be floored, funnel-shaped, or have inward sloping contacts, as indeed the evidence warrants, then our next question might be, "How does the igneous magma expand upward and outward?" Without discussing the detailed mechanics of emplacement, it is almost a truism to say that the pressure of the magma was greater than that of the enclosing country rocks, so that the magma thrust aside the host rocks. Stoping could not produce a

Table 5

PORPHYRY-TYPE INTRUSIVES WHICH MAY BECOME SMALLER WITH DEPTH

Locality	Intrusive Rock	Shape, Floor, or Contact	Remarks	Reference
Robinson Mining District, Nevada	Monzonite porphyry	Overall funnel shape	Bottomed at less than 1,000 feet, except for narrow conduits.	Pennebaker, 1942
San Manuel, Arizona	Quartz monzonite porphyry	A tabular body, in part	Pl 1 shows the porphyry in outcrop laps up over the Oracle granite. Pls 10-17 show most drill holes bottom in the Pre-cambrian, although the contact is very irregular.	Schwartz, 1953
Ajo, Arizona	Cornelia quartz monzonite	In the mining area, floored, or decreases in area with depth	Cross-section on pl 20, pl 22, pl 23, and pl 25. Most of Cornelia quartz monzonite west of Gibson fault is regarded as a sub-jacent body.	Gilluly, 1946
Santa Rita quadrangle, New Mexico	Fierro-Hanover quartz monzonite	South lobe is floored, ethmolithoid (funnel-shaped) sheet	Country rock thrust aside laterally by magma.	Schmitt, 1939
Tombstone district, Arizona	Uncle Sam porphyry	Laccolithic	Intruded along thrust or erosional surface.	Gilluly, 1945
Santa Rita quadrangle, New Mexico	Copper Flat intrusive	Contracts with depth and downward breaks into dikelike and chimneylike roots	Host rocks pushed aside forcibly by out-ward and upward expansion of igneous rock.	Hernon, Jones, and Moore, 1953

Table 5 (cont.)

PORPHYRY-TYPE INTRUSIVES WHICH MAY BECOME SMALLER WITH DEPTH

Locality	Intrusive Rock	Shape, Floor, or Contact	Remarks	Reference
Bisbee district, Arizona	Sacramento Hill granite porphyry	Sill-like apophyses, and funnel-shaped cross-section	Fig 3 shows a funnel-shaped cross-section.	Rove, 1942 Tenney, 1933
Goldfield, Nevada	Dacite	Intrusive sheet	Pl VIII shows floored or funnel-shaped cross-sections.	Ransome, 1909
Tyrone district, New Mexico	Quartz monzonite porphyry	North contact probably dips inward	"There is some evidence that on its northern border it dips to the south." No evidence in the other directions.	Paige, 1922
Llallagua, Bolivia	Quartz porphyry	Becomes smaller and more irregular with depth		Turneaure, 1942
Miami-Inspiration, Arizona	Quartz monzonite porphyry	North of Live Oak Gulch, prophyry floored by schist	Ore found in schist. Floor located by drilling.	Ransome, 1919
Iron Springs district, Utah	Quartz monzonite porphyry	Laccolith (Three Peaks intrusion), floored	Indirect evidence, floored by Navajo sandstone.	Mackin, 1947
Yellow Pine-Prairie Flower area, Goodsprings, Nevada	Granite porphyry	Sill-like masses	Intruded along thrust zones. Also forms dikes.	Albritton, et al., 1954

predominant lateral expansion of an intrusive body, although marginal stoping effects might be evident. Where the country rocks are layers of varying composition, the lateral magmatic expansion might be directed into certain favorable horizons as a consequence of differences in physical behavior.

Consider briefly the nature of the matter which would be most likely to produce a laterally expanding intrusive igneous body. An igneous intrusive will, of course, contain differing proportions of material in the solid, liquid, and gaseous states. Here the only concern, however, is to ascertain that state which contributes most to producing a lateral expansion of an intrusive magma.

As any igneous melt moves upward in the earth's crust, two phenomena must occur if the melt approaches the surface, namely, (a) the confining pressure decreases, and (b) the igneous material must cool and eventually crystallize. What effect would these phenomena have on the states of matter in the magma? Both the solid and liquid phases would show a minimum contraction or expansion as a result of the decrease in pressure and temperature during igneous intrusion, although some of the solid phase may be resorbed temporarily immediately after a pressure decrease, in accordance with the Clausius-Claperyron equation (see Barth, 1952, p 91).

Gases, however, as well-described by the gas law and its various modifications, would expand as the confining pressure decreases. On the basis of Goranson's data (1938), a liquid silicate phase with a large content of dissolved gases should exsolve gas as the confining pressure decreases. Also, as the temperature decreases during crystallization, the gaseous phase should increase as a result of exsolution from the liquid phase (Goranson, 1938). It is thus likely that the increased amount of the gaseous phase and reduced confining pressure on the gaseous phase would promote greatly the lateral as well as upward emplacement of an igneous body. Explosive volcanic activity is evidence that such a process occurs, and that gases do not expend their energy diffusing quiescently into the country rock in every case. Cryptovolcanic structures, and extremely brecciated and intricately intruded areas (Callaghan, 1937, 1938; Albritton, 1954; Kuellmer, 1954) are probably best explained by this mechanism. Explosive gaseous activity is advanced as a tenable mechanism capable of providing the space necessary for emplacement of hypabyssal floored or funnel-shaped igneous masses.

The idea that magmatic pressures caused a lateral and upward expansion of an igneous melt ties in very well with an additional phenomenon commonly observed in association with copper porphyries. Brecciation, jointing, and intricate faulting are abundant in copper porphyry areas. In most cases such examples of broken rock are attributed to regional tectonism. However, if a magma can thrust aside the country rocks, as is required by the existence of a funnel-shaped igneous rock, then it follows that magmatic pulsations, whether gaseous or otherwise, can produce brecciation, jointing, and faulting. Furthermore, it is not too far afield to say that the igneous rock itself might be brecciated by a late-stage magmatic pulsation.

The above discussion, at the very least, should weaken some of our preconceived notions as to the distribution of igneous rocks and their emplacement, and emphasize the necessity of careful and objective study, with consideration of all possibilities.

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