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March 13, 1992

Mr. John Peterson
Arimetco
6245 E. Broadway, Suite 350
Tucson, Arizona 85711

Dear Mr. Peterson:

Enclosed is a copy of our land map and schedule of work and payment obligations for our Courtland-Gleeson (Maud Hill) project.

I understand that you have looked at the geologic data but that there is still some geologic information and data that you want sent. I will check with Fred Jenkins and get this information to you soon.

If you are interested in discussing a possible Joint Venture after you complete your review, please call me.

Sincerely,

Dale B. Trubey

D. B. Trubey
Director - Land

DBT:efo

Enclosure

cc: F. J. Jenkins

GEOLOGY
OF THE
STAR HILL CARBONATE REPLACEMENT DEPOSIT

ANNUAL PROGRESS REPORT
ON THE
COURTLAND-GLEESON PROJECT
COCHISE COUNTY, ARIZONA

DECEMBER 1, 1989

W. D. RIESMEYER
SANTA FE PACIFIC MINING, INC.
ALBUQUERQUE

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SUMMARY

The 1988-89 Courtland-Gleeson drilling project resulted in the discovery and partial delineation of the Star Hill carbonate replacement deposit. A total of 44 core holes, with an aggregate footage of 43,286 feet, were drilled, which outlined a mineral resource of approximately 2.8 MMT grading 0.85-0.90% Cu. This resource includes disseminated porphyry copper-style mineralization and a weak chalcocite blanket, in addition to the CRD. The thickest and highest grade part of the CRD contains a potentially economic orebody containing about 700 MT grading 3.1% Cu, 0.24 opt Ag, and 0.051 opt Au.

While the geology of the Courtland-Gleeson district is extremely complex, close-spaced drilling has allowed a good understanding of the geometry and ore controls of the Star Hill deposit, and the broad geologic features of the project area. During the Jurassic, the relatively undeformed Paleozoic section was intruded by a series of igneous rocks probably related to the Gleeson quartz monzonite stock. The first intrusives were the Star Hill and Copper Belle porphyries which invaded the bedding of the upper Cambrian Abrigo formation to form a thick sill complex. The intrusion of the Sniveler and Courtland breccias followed. It is believed that their intrusion was controlled by a fault intersection which resulted in the emplacement of a pipe-like breccia mass. CRD mineralization is thought to have occurred concurrently with breccia intrusion. During the Cordilleran orogeny the entire mineralized package of rock was subjected to strong compression resulting in recumbent folding, and finally thrust faulting. The now allochthonous mineralization was transported over the Courtland thrust for a distance of several miles, ultimately resulting in the juxtaposition of the Abrigo and CRD over the Cretaceous Bisbee formation. Subsequent basin-range faulting did little to dismember the major part of the Star Hill deposit.

The CRD is believed to have been formed by mineralizing fluids channelled upwards through and along the margins of the Sniveler-Courtland breccia pipe. These selectively replaced two stratigraphic zones in the Abrigo formation. Fluid ponding directly beneath the Star Hill-Copper Belle sill complex may also have influenced the site of mineral deposition. The resulting CRD is well zoned away from the breccia mass in the sequence magnetite-pyrite-chalcopyrite-gold to pyrite-chalcopyrite ± gold to sphalerite-pyrite-silver ± chalcopyrite ± gold. The thickness and intensity of CRD mineralization also decreases away from the breccia mass.

Post-mineral recumbent folding greatly increased the thickness of the CRD in the nose of the Star Hill anticline where ore is thought to be folded directly upon itself. Thus, CRD thicknesses near the fold nose may exceed 150 feet whereas thicknesses on the limbs rarely exceed 50 to 75 feet. Ore grades

vary widely among the different mineral zones and within the zones themselves. Typical grades over tens of feet in the magnetite-pyrite-chalcopyrite zone are 0.5 to 3.5% Cu and 0.0X opt Au, in the pyrite-chalcopyrite zone: <0.5% to 1.5% Cu and 0.01 to 0.03 opt Au, and in the sphalerite-pyrite zone: 0% to 1% Cu, 1-2% Zn, and <1 to 2.8 opt Ag. Many shorter intervals in all zones contain considerably higher grades.

Three areas are recommended for additional drill exploration. The first may contain a CRD which is the "mirror image" of the Star Hill deposit, lying on the opposite flank of the Sniveler-Courtland breccia pipe. The second area lies in sparsely drilled terrain on the southeastern strike extension of the Star Hill CRD. The final area encompasses ground which may contain ore-grade mineralization hosted by carbonates stratigraphically above the Abrigo formation. A total of 15,700 feet of core and reverse circulation drilling are recommended for these three potential areas.

INTRODUCTION

Location and Access. The Star Hill deposit is located in the eastern foothills of the southern Dragoon Mountains, at a mean elevation of 4,600 feet, in central Cochise County, Arizona. The project area lies approximately 75 miles east-southeast of Tucson and 22 miles north of Bisbee and the Warren mining district (fig. 1). Tombstone, the site of core logging and storage facilities, is 15 miles east of the project. Access to the Star Hill area is easily obtained from Tombstone, Elfrida, and Pearce via county-maintained graded roads, which, however, are subject to flooding and washouts during the summer monsoon.

Land Holdings. The Star Hill deposit lies in the north central part of an extensive claim block controlled by Santa Fe Pacific Mining, Inc. (Plate I). The block consists of leased patented and unpatented lode claims, company-staked claims, and state prospecting permits which occupy a strip of land in the eastern foothills of the Dragoons between the ghost town of Courtland on the north, and Outlaw Mountain on the south. State prospecting permits extend the block about three miles eastward into the gravel-covered pediment.

History. The Star Hill deposit is located in the Courtland-Gleeson mining district which has a long but erratic history of mineral production. The first mining in the district was probably carried out by pre-Columbian Indians who exploited shallow turquoise deposits in the area of Turquoise Ridge. The first mining claims in the district were staked in 1877 in the vicinity of Gleeson, and mining activity slowly advanced northward towards Courtland. Prior to 1907, significant, but unrecorded amounts of silver, lead, copper, and gold were recovered in the area. Between 1907 and 1912, the district boomed, due in part to the arrival of the railroads in 1909. Copper production reached a peak in 1912, after which production steadily declined. By 1920 most of the major mines were idle (Wilson, 1927). Since that time, leasees have contributed only minor, sporadic production. Between 1907 and 1924, 45.75 MM pounds of copper and 2.12 MM pounds of lead were produced in the district; gold and silver production was not recorded. Renewed interest in the Courtland-Gleeson area resulted in a substantial drilling program by Minerals Exploration Company (Union Oil) in the Star Hill area between 1957 and 1972, one purpose of which was to explore for a supergene chalcocite orebody. In the early 1960s, Bear Creek Mining undertook a large, but unsuccessful porphyry copper exploration and drilling program. The area immediately north of Star Hill was drilled by Newmont in 1987-88 in search for Tertiary copper-gold mineralization. Presently, Placer-Dome is drilling on Mexican Hat Mountain, and have announced a gold reserve of 9.1 MMT grading 0.035 opt.

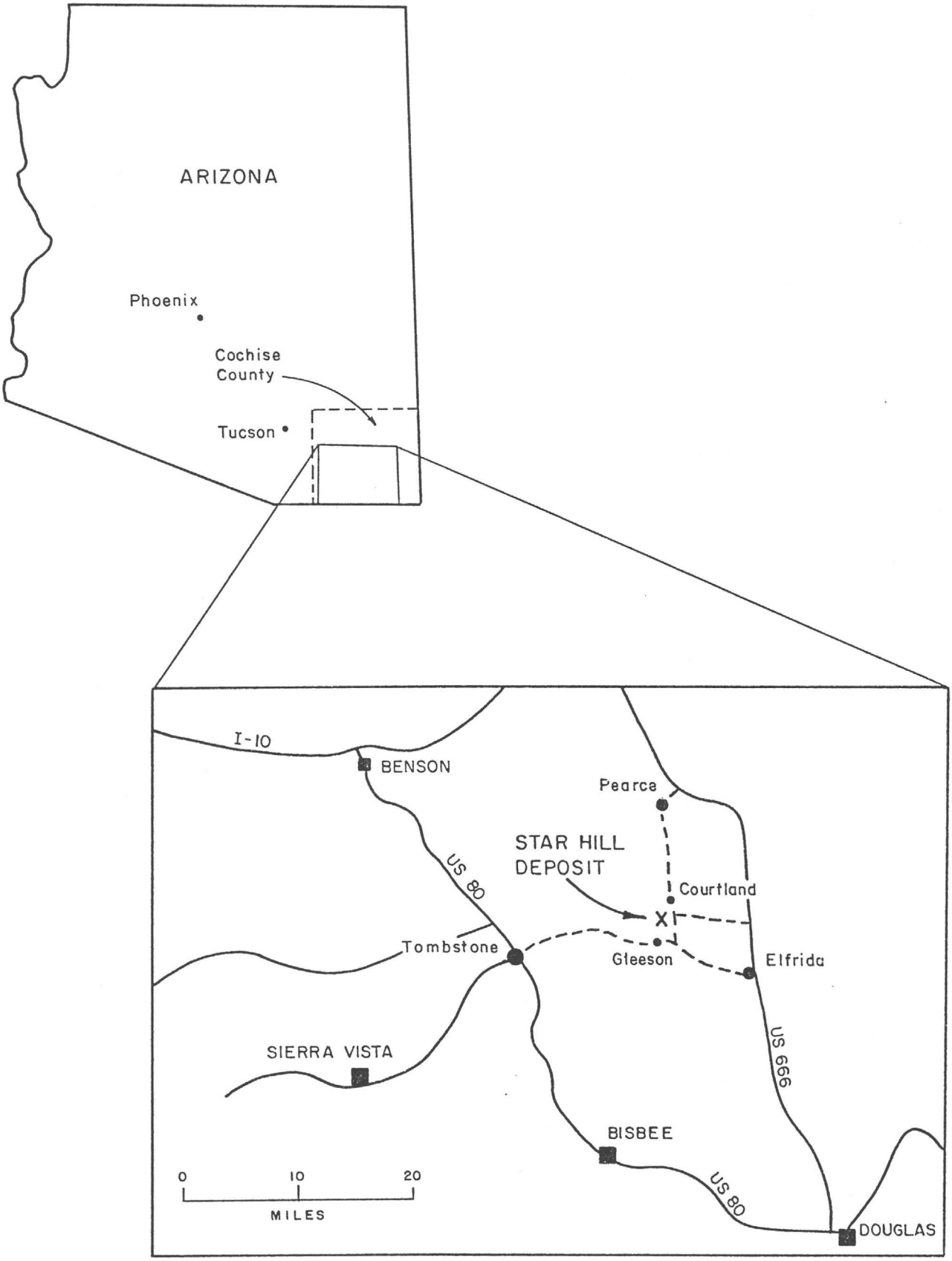


Figure 1.

Maps showing the location of the Courtland-Gleeson area, and the Star Hill carbonate replacement deposit.

The Courtland-Gleeson Project. The Courtland-Gleeson project is an outgrowth of a major CRD exploration program begun by Santa Fe Pacific Mining, Inc. in 1984. The program's target was the discovery of precious metals-rich carbonate replacement deposit similar to those at Bisbee or those in northern Sonora, Mexico. The effort was concentrated in Cochise County and resulted in the generation of several targets and drilling programs in the northern and southern Dragoons, the Tombstone Hills, the Swisshelms, and the eastern edge of the Sulfur Springs Valley. Drilling began in the Maud Hill area, in the southern Dragoons in 1985, and continued for three years. In 1988, the focus of exploratory drilling shifted north to the Star Hill area. In August, 1988, hole 28-3, generally regarded as the discovery hole, was drilled into the Star Hill CRD. Subsequent drilling (through hole 28-13) outlined a mineral resource of approximately 2.8 MMT, grading 0.85-0.90% copper, which included supergene chalcocite mineralization, disseminated porphyry-hosted chalcopyrite mineralization, and massive carbonate replacement deposits. Within this resource block, a potentially economic CRD has been delineated which contains a very conservatively estimated reserve of 694,406 tons grading 3.08% copper, 0.24 opt silver, and 0.051 opt gold. Additional drilling may significantly enlarge this reserve.

Between August, 1988 and August, 1989, 44 28-series NC/NX core holes were completed in the Star Hill area (Plate II). A total of 43,285.8 feet were drilled, with TDs ranging from 634.5 to 1665 feet; the average TD was 984 feet. Most holes were drilled to penetrate the Courtland thrust. The core was transported to Tombstone where it was logged in detail, photographed, split, and sent for assay.

A summary listing of significant assay intervals obtained during the 1988-89 drilling program is included as Appendix I, and simplified graphic drill logs for all 28- series holes, except 28-6 and -7, appear in Appendix II. Detailed drill logs, complete assay results, core photographs, and other supporting data are contained in a 15 volume set of compiled data on file in the Albuquerque office, to which the reader is also referred.

The following report summarizes the data derived from the Star Hill drilling program and presents interpretations regarding the origin, mineralization controls, and structure of the CRD. Included are sections on stratigraphy, structure, and mineralization, as well as a proposal for additional exploration in the Star Hill area.

STRATIGRAPHY

General Outline. Rocks in the Star Hill project area include clastic and carbonate sedimentary units of lower-most Paleozoic age, intrusive rocks of probable Jurassic age, Cretaceous volcanic and sedimentary units, and minor Tertiary felsites. The Paleozoic section consists of the Cambrian Bolsa quartzite, Pima sandstone, and Abrigo limestone. These units have been invaded by a complex series of Jurassic intrusive rocks and breccias which, in places, strongly altered and mineralized the Abrigo section. This entire rock package was subsequently folded and thrust over a thick, overturned sequence of Cretaceous Bisbee volcanics and sediments. Minor amounts of felsite intrude structures of early Tertiary age. Because of severe alteration and complex structure in the project area, many stratigraphic and lithologic details have been obliterated, leaving several issues of exploration significance unresolved.

PALEOZOIC SEDIMENTARY ROCKS

Bolsa Quartzite

In the project area, the middle Cambrian Bolsa quartzite is a gray to light gray, medium- to coarse-grained, moderately recrystallized sandstone. It is composed primarily of quartz grains, with only very minor feldspar and clay, set in a silica matrix. Laminations of heavy minerals locally define bedding, but cross and graded bedding have not been observed in the core. Thin interbeds of calcareous siltstone are present, especially towards the top of the unit. A minimum thickness of 200 feet is present in the drilling area.

Mineralization. Minor disseminated and veinlet-controlled sulfides are present throughout the Bolsa section. Generally these consist of $\leq$ 2% py>>cpy>>sl, although local concentrations of up to 5% sulfides have been observed. No mineralization of economic interest has been encountered in the Bolsa.

Stratigraphic Relationships. In the Dragoon Range, the Bolsa unconformably overlies the Precambrian Pinal schist. This contact was not encountered in any of the drill holes. The Bolsa is conformably overlain by the middle-Cambrian Pima sandstone, an informal unit described from the nearby Whetstone Mountains. In core, this contact appears gradational and was set arbitrarily during logging.

Pima Sandstone

The middle Cambrian Pima sandstone is a transitional unit lying between the Bolsa quartzite and the Abrigo limestone. It consists of an interbedded sequence of calcareous siltstones,

limestones, dolomites, and sandstones. Sandstones are recrystallized, fine- to medium-grained, and composed of clear quartz grains and very sparse feldspar, set in a gray silica matrix containing minor clay. Calcareous siltstones are white to green, finely laminated rocks containing a mixed calcite-dolomite component.

Many sections are clay-altered, weakly hornfelsed, or lightly skarned. Limestones are light gray and finely laminated, but commonly clay-altered or, more rarely recrystallized. Dolomitic interbeds appear most commonly as recrystallized fine- to medium-grained marbles.

Mineralization. Carbonate beds in the Pima locally contain disseminated to semi-massive pyrite replacements. Trace to minor amounts of chalcopyrite and sphalerite commonly accompany the pyrite replacements.

Stratigraphic Relationships. The Pima conformably overlies, and is gradational into the underlying Bolsa. The lower-most calcareous unit in the Pima generally marks its lower contact. In a similar fashion, the Pima grades upward into the conformably overlying Abrigo. The upper Pima contact is arbitrarily defined as the top of the upper-most sandstone unit.

Abrigo Limestone

In the project area, the Cambrian Abrigo limestone consists predominantly of thick limestone and dolomite units, along with subordinate interbedded and interlaminated silty limestones and limey siltstones and shales. The major carbonate units range from 10 to 50 feet thick, while the interlayered clastics range from 1/4" to two or three feet in thickness. Clastic laminae in the carbonates typically have a wavy or crenulated appearance and define the generally thin-bedded nature of the units. Recrystallization of the carbonates to tan, gray, or locally white, medium-grained marbles is common. Large volumes of the Abrigo, especially the upper parts, have been severely altered.

Mineralization-related alteration includes strong clay development, commonly attended by vuggy to massive jasperoid, as well as by less widespread dolomitization, chloritization, and talc alteration. The latter are frequently accompanied by calcite and gypsum veining. In the skarn environment, chlorite, epidote, garnet, diopside, potassium feldspar, and quartz constitute the alteration assemblage.

Mineralization. The Abrigo hosts abundant sulfide replacements. These range from minor disseminations containing less than 2% sulfides, to semi-massive and massive replacements containing greater than 60% pyrite, chalcopyrite, sphalerite, minor galena, trace native gold, and possible traces of

sulfosalts, as well as local, major amounts of specularite, hematite, and magnetite. Chalcocite and native copper occur in clay-altered Abrigo in the supergene zone.

Stratigraphic Relationships. The Abrigo conformably overlies the Pima, as discussed above, and is unconformably overlain by the upper Devonian Martin limestone. The Martin, however, was nowhere drilled in the project area. Rather, the upper Abrigo (or Abrigo-hosted CRD) is found in contact with various intrusive rocks or breccias. At the contact, the Abrigo is usually (but not universally) altered to some degree, and the contact generally shows evidence of fault movement. In the Star Hill area, it is inferred that the Abrigo hanging wall is everywhere marked by a generally sheared intrusive contact between limestone and sills of Copper Belle or Star Hill porphyry.

JURASSIC INTRUSIVE ROCKS

Star Hill Monzonite Porphyry

In composition, the Star Hill ranges from monzonite, to quartz monzonite, to granite; monzonite is decidedly the most common, granite the rarest. Typically the rock is a light pinkish to greenish gray, fine- to medium-grained porphyry consisting of 30-40% equant phenocrysts of plagioclase and K-feldspar, set in a 60/40 to 10/90 quartzo-feldspathic matrix. Phenocrysts are generally less than 1/4" in maximum dimension; plagioclase is commonly twinned, and quartz (when present as phenocrysts) is sharply angular due to advanced embayment. Occasional K-feldspar megacrysts, up to 1/2" in diameter, are present, but are nowhere as common as in the Copper Belle.

Alteration of the Star Hill is almost pervasive, ranging in intensity from weak to very strong. Most common is argillization and silicification. Also present, and locally significant, is K-feldspar flooding, sericitization, chloritization, and calcite veining.

Mineralization. Typically, the Star Hill contains a couple of percent finely disseminated py>cpy. Locally, the unit hosts veinlet-controlled stockworks of py>cpy>>sl which contain several percent sulfides. No economic concentrations of such mineralization have yet been found. In the supergene zone, the Star Hill hosts a weak chalcocite blanket containing up to 2-4% copper.

Intrusive Relationships. In core, the Star Hill is seen to be intruded by all other igneous rocks identified in the course of the project. Many of the observed relationships, however, are equivocal, and one surface outcrop clearly shows a Star Hill-like dike intruding the Copper Belle. However, the preponderance of evidence indicates the Star Hill is the earliest intrusive in

the project area. The overall geometry of the Star Hill suggests the bulk of the unit was intruded as a sill along bedding in the upper Abrigo, and is perhaps 250-300 feet thick. Thinner intercepts of Star Hill indicate the presence of smaller sills and dikes of the intrusive, isolated from the large sill, lying deeper in the Abrigo section.

Copper Belle Monzonite Porphyry

The Copper Belle ranges in composition from monzonite to quartz monzonite. The former is most widespread. The rock is a gray to greenish gray, medium- to coarse-grained porphyry. White plagioclase phenocrysts range from 3/16" to 5/8" in size; quartz phenocrysts, when present, are deeply embayed and range from 3/16" to 5/16" across. The unit is characterized by the presence, especially near contacts, of large (1"-2"), pink, unaltered K-feldspar megacrysts. Phenocrysts comprise 10-30% of the rock. The fine-grained matrix consists of quartz and K-feldspar, nearly always altered to clay and sericite. Biotite and sphene occur as common accessory minerals.

The Copper Belle is generally less altered, over all, than the Star Hill. The typical alteration suite is clay-sericite-quartz ± chlorite. Calcite stockworks are present, but not common.

Mineralization. The Copper Belle contains intervals of 5-10% disseminate pyrite ± chalcopyrite ± sphalerite. Sphalerite is more abundant in the Copper Belle than in any other intrusive unit in the project area. As does the Star Hill, the Copper Belle hosts chalcocite mineralization in the supergene zone.

Intrusive Relationships. Relationships observed in core, as well as crosscutting relationships implied by cross sections indicate the Copper Belle intrudes the Star Hill, but is itself cut by all other recognized intrusives in the project area. Three dimensional modeling shows the bulk of the Copper Belle to be a thick (locally to 300′) sill intruded between the Abrigo and the overlying Star Hill sill. "Fingers" of Copper Belle invade the Star Hill sill and the lower Abrigo as thin sills and dikes. Copper Belle-Abrigo contacts are invariably clay-altered to some degree, and are commonly sheared.

Sniveler Quartz Monzonite Porphyry

The Sniveler shows little variation from a quartz monzonite composition. The rock is a medium gray, fine- to medium-grained porphyry consisting 1% to 15% equant to lath-shaped untwinned plagioclase and rounded quartz phenocrysts, set in a fine-grained matrix of quartz > sericite. Quartz phenocrysts, which characterize the Sniveler, are 1/8" to 3/16" across, cloudy

white, and generally spherical due to secondary overgrowths of silica. Altered biotite is the only important accessory mineral. Visible K-feldspar is absent.

Locally, the Sniveler has been strongly silicified; silica flooding predominates over veining. In extreme cases, silica flooding renders the Sniveler unidentifiable, yielding (possibly) the "Unknown porphyry", discussed below. Total sericitization of matrix feldspar apparently preceded silica flooding in the Sniveler. Only local, minor chlorite alteration has been observed in the unit.

Mineralization. One to five percent disseminated pyrite-chalcopyrite, accompanied by rare sphalerite, is common throughout the unit. Of possible economic interest, however, is the presence of locally strong stockworks of pyrite and pyrite-chalcopyrite which, in places, coalesce to form bodies of nearly massive sulfide containing 3-4% copper and up to 0.05 to 0.30 opt gold. Sphalerite is notably absent in stockwork mineralization. Where present in the supergene zone, the Sniveler, like the other intrusives, hosts chalcocite mineralization.

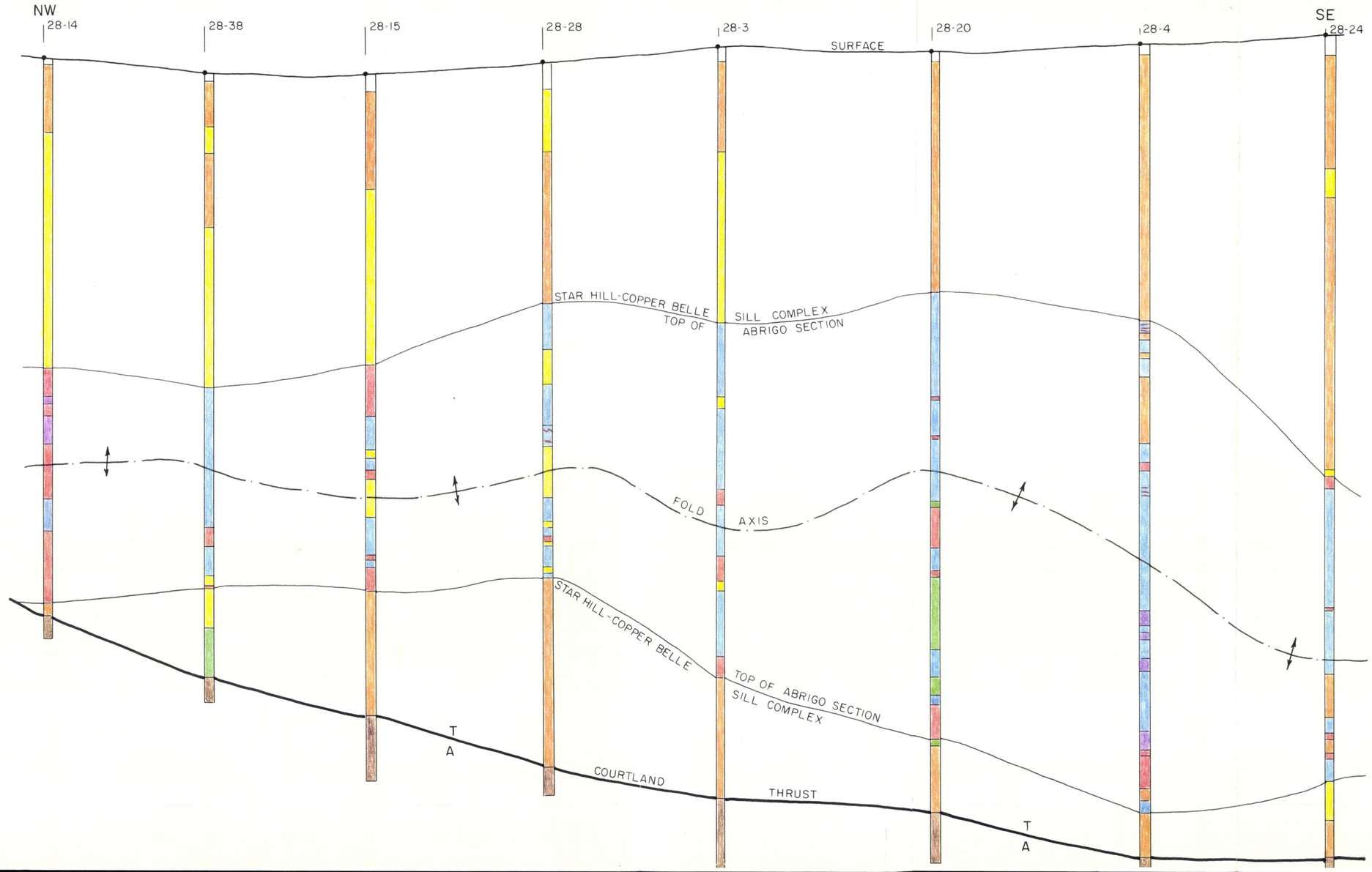
Intrusive Relationships. The Sniveler porphyry intrudes all Paleozoic sedimentary rocks, as well as the Star Hill and Copper Belle porphyries, but is, in turn, cut by the Sniveler and Courtland breccias. Isopachs on the porphyry define narrow northeast and northwest linear trends, suggesting the porphyry was intruded as dikes along similarly trending faults.

"Unknown Porphyry"

In most intercepts, this unit is probably a highly silicified phase of the Sniveler porphyry. In other areas, it may represent silicified Star Hill or Copper Belle porphyry. Inferred to have originally been a quartz monzonite like its spatially related intrusives, the "Unknown porphyry" presently presents an almost featureless appearance. The rock is medium to dark gray in color, and consists of +95% fine-grained to aphanitic quartz. Rarely, ghost phenocrysts of plagioclase (?) are present, consisting of 85% quartz and 15% clay and sericite. Small relict spherical quartz phenocrysts (?) are sparingly present.

Mineralization. Disseminated pyrite $\pm$ chalcopyrite comprising 3-5% of the rock is locally present in the "Unknown Porphyry". Nowhere is mineralization of economic interest in evidence.

Intrusive Relationships. The "Unknown Porphyry" is not of sufficiently widespread occurrence to allow determination of either its geometry or various intrusive relationships.



LONGITUDINAL SECTION
BETWEEN DRILL HOLES 28-14 & 28-24
SHOWING DISTRIBUTION OF
ABRIGO LIMESTONE
IN THE NOSE OF THE
STAR HILL ANTICLINE

VIEW: SOUTHWEST
VERTICAL & HORIZONTAL SCALE: 1" = 100'

EXPLANATION

- Bisbee Formation
- CRD
- Courtland Breccia
- Sniveler Breccia
- Sniveler Porphyry
- Copper Belle Porphyry
- Star Hill Porphyry
- Abrigo Limestone

Intrusive Contact

T/A Thrust Fault Showing Movement

Fold Axis

Note: Intrusive rocks within Abrigo section not shown

Figure 3.

Sniveler Breccia

The Sniveler is an intrusive polylithic breccia probably comagmatic with the Sniveler porphyry. The breccia consists of angular to subrounded fragments averaging 1/4" to 2", but also includes blocks up to 1 foot across, set in a matrix of Sniveler porphyry. Fragments of Bolsa quartzite are the most common, but clasts of Abrigo limestone, Star Hill and Copper Belle monzonite and quartz monzonite porphyries, and Sniveler porphyry are also abundantly present. Rare fragments of pyrite-rich massive sulfide and jasperoid have also been identified. Flow laminations are absent in the matrix, as is rock flour, suggesting non-explosive emplacement. The unit is pervasively silicified, locally very strongly. Weak to moderate sericite and chlorite alteration are also locally important.

Mineralization. The Sniveler breccia contains both disseminated and stockwork py>cpy mineralization. Only very minor sphalerite has been observed in the unit. Stockworks range from horsetailing and anastomosing veins comprising 2 to 10% of the core, to solid intervals of massive sulfides. In the latter, chalcopyrite locally equals or exceeds the amount of pyrite, producing copper assays of 2-4%. Significant gold (0.0X opt) also accompanies such mineralization.

Intrusive Relationships. As evidenced by clast composition, the Sniveler breccia intrudes all rock units previously described, including the Sniveler porphyry. As shown by isopach mapping, the breccia forms two pronounced pods along a northeast-trending mass of Sniveler porphyry, suggesting it forms a breccia pipe rooted in the "parent" porphyry dike.

Courtland Breccia

Like the Sniveler, the Courtland is an intrusive polylithic breccia. It consists of angular to subrounded fragments suspended in either a rock flour or igneous matrix. Deeper breccia intercepts, as a rule, contain more igneous matrix than rock flour, the former having a hornblende granite composition. In shallower intercepts, rock flour is present to the exclusion of igneous matrix. Clasts range in size from a fraction of an inch to well over five feet across, and consist of all lithologies previously described. Several types of CRD are represented in the clast population: py-cpy, py, and py-mag-cpy. Jasperoid fragments are also present.

Moderate to strong chloritization is the most characteristic alteration of the Courtland breccia, being most pronounced in the rock flour matrix. Igneous matrix, as well as all fragment types are also chloritized to varying degrees. Weak calcite, sericite, and K-feldspar alteration is locally present.

Mineralization. Mineralization in the Courtland is very similar, in both type and grade, to that in the Sniveler breccia. Chalcopyrite is most abundant in the igneous matrix parts of the unit where it, along with pyrite forms stockworks which cut earlier disseminated pyrite mineralization. Locally, large exotic blocks of CRD, entrained in the breccia, generate significant assay intervals.

Intrusive Relationships. The Courtland breccia is the youngest of all the Jurassic intrusive rocks in the Star Hill area as it contains clasts of all rock units previously described. In addition, several types of deep-seated granite (possibly including the Turquoise) have been found among the clast population. The presence of these subrounded fragments derived from great depths, set in a rock flour matrix, as well as vague clast alignment and flow laminations indicate explosive emplacement, strong upward transport and milling, and possible surface venting of the Courtland breccia in pre-Bisbee time (no Bisbee fragments are incorporated in the breccia). While relatively thin core intercepts of Courtland breccia have a sill-like aspect, isopach mapping suggests the bulk of the unit is cross-cutting. The largest pod of Courtland breccia appears nested within the Sniveler breccia in a pipe-like configuration.

CRETACEOUS SEDIMENTARY ROCKS

Bisbee Formation

The lower Cretaceous Bisbee formation, in the Star Hill area, forms the footwall of the Courtland thrust. It consists of maroon mudstones, siltstones, sandy siltstones, and sandstones. In addition, felsic and intermediate volcanic flow breccias and debris flows are locally present. Thin- to medium-bedded mudstone is the most common lithology, typically containing interbedded silty units. Sandstones are arkosic to sub-arkosic with calcite and clay cement. Graded bedding is locally present in these units, and where clearly developed always shows overturning.

Volcanic rocks are typically polylithic flow breccias and debris flows with a felsic to intermediate matrix. Flow banding is developed in some units. This package of volcanic rocks may belong to the late Cretaceous Salero formation, rather than the Bisbee (Drewes, 1981).

Weak to moderate bleaching, argillization, carbonatization, and chloritization are developed in both the clastic and volcanic rocks described above. These types of alteration are best developed proximal to the Courtland thrust, and decrease rapidly in intensity away from the fault zone.

Mineralization. Mineralization in the Bisbee formation consists exclusively of <1% finely disseminated pyrite, which is probably diagenetic.

Stratigraphic Relationships. In the Star Hill project area, the Bisbee is found only beneath the Courtland thrust; it is absent in the upper plate and does not crop out anywhere near the drilled area. Thus, the upper plate Martin, Escabrosa, Naco group, and Bisbee, if originally present, have either been eroded away, or lie buried under pediment gravels.

TERTIARY IGNEOUS ROCKS

Felsite

In the project area, a felsite sill occurs within the Courtland thrust zone. The felsite is white to pink, aphanitic to fine-grained, and phenocryst-poor, except along its margins. The margins show flow laminations in addition to scattered small quartz and muscovite phenocrysts, and 1-2% tiny disseminated euhedral pyrite cubes. Brecciated sill margins are locally present, as is weak clay and chlorite alteration. Adjacent thrust mylonites are weakly bleached.

Mineralization. The aforementioned pyrite disseminations are the only manifestations of mineralization in the felsite. Assays show no anomalous Cu, Pb, Zn, Au or Ag.

Intrusive Relationships. The felsite is strictly confined to the Courtland thrust zone, generally enclosed in mylonites and only rarely invading relatively undeformed Bisbee sediments. In all cases, it clearly dilated the invaded lithology. In plan, the sill is probably very irregular as it is present in some drill holes, but not in others. The restriction of the sill to the thrust zone, along with its lack of tectonic fabric, indicate a post-early Tertiary age of the felsite. While it bears a superficial resemblance to the felsites north of Star Hill which are closely related to mineralization near Courtland, this sill is clearly younger, as the Courtland felsites are cut by early Tertiary thrust faults.

STRUCTURAL GEOLOGY

General Outline. The rocks of the southern Dragoon Range have undergone a number of episodes of structural deformation and intrusive activity. The result has been a seemingly chaotic jumble of igneous and sedimentary rocks, especially in the area between Courtland and Gleeson. Gilluly (1956) termed this terrane a large scale thrust breccia, Drewes (1981) called it an extraordinarily complex volcanotectonic breccia, and several workers have lumped all the lithologies in the area into one map unit - "the Courtland Complex".

The close-spaced in the Star Hill area has allowed a detailed examination of a small part of the Courtland-Gleeson terrane, and the abundant sub-surface date has facilitated the assembly of a coherent structural interpretation of the area. The picture which emerges is one of early faulting, complex intrusive activity, mineralization, recumbent folding and thrust faulting, and finally basin-range faulting.

FOLDS

While Wilson (1927) documented small folds near Gleeson, and Gilluly (1956) suggested the presence of a large scale overturned fold in the Bisbee near South Pass, large scale folding in the Courtland-Gleeson area has heretofore been unrecognized. Star Hill drilling data and surface mapping has, however, revealed several evidences of a large, recumbent anticline in the project area. These include:

1) the presence of an abnormally thick Abrigo section in the Star Hill valley (2,700′ apparent thickness, assuming a 60° monoclinal dip between Abrigo outcrops west of the North Star shaft and Abrigo intercepts in DDH 28-8, versus a true thickness of 770′ measured at the type section).

2) the presence of the Star Hill-Copper Belle sill complex both above and beneath the Abrigo section.

3) the wedge shape of the mass of Abrigo in the project area as shown by a drill hole model.

4) a fairly consistent pattern, where preserved, of steepening Abrigo bedding dips down hole, which turn vertical, and then progressively flatten towards the bottom of the hole.

4) the possible repetition of mineralized beds down hole.

5) the existence of overturned bedding in the Bisbee formation.

The geometry of the proposed Star Hill anticline is shown on the accompanying cross and longitudinal sections (figs. 2 and 3), as well as by the three dimensional drill hole model. The sections show a tight, or nearly closed anticline in a strongly recumbent position with an axial plane striking N30^{o}W and dipping 15°-20° SW. The hinge line, defined by the top of the Abrigo, lies between holes 28-8 and 28-10, while the crest line lies an unknown distance to the southwest. The longitudinal section (fig. 3), while showing warps in the axial plane, only weakly suggests a plunge to the southeast. Wave length and amplitude can not be determined, but both probably exceed 1000 feet. Fold digitation, as shown on the cross section, while suggested by drill data, can not be proven with the existing drill hole spacing.

Because bedding and bedding orientations in the Abrigo have been nearly destroyed by structure, alteration, and mineralization, the shape, and even the existence of the Star Hill anticline is largely defined by the contact between the Abrigo and the Star Hill-Copper Belle sill complex. A major presumption in the fold model idea is that these intrusive rocks form a sill, and are not simply an irregular intrusive mass or fault-emplaced blocks that merely present the illusion of a fold form. The numerous examples of unfaulted intrusive contacts between Abrigo and Star Hill-Copper Belle observed in core eliminate the possibility that the contact geometry shown in figure 2 was fault generated. That the geometry shown is simply a highly irregular intrusive boundary begs the existence of major, relatively flat-lying pre-porphyry faults which would have guided the intrusion along the lobes shown in the cross section. No pre-intrusive (and pre-Courtland thrust) structures of the required orientation have been found elsewhere in the area. It is therefore likely, and supported by evidence of concordancy in the core, that the porphyries were intruded along Abrigo bedding, the only known, then existing structural fabric. Both the Abrigo and the porphyry sills were then subsequently folded. Accordingly, the Abrigo - Star Hill-Copper Belle contact is thought to very nearly mimic a normal stratigraphic contact for the purpose of outlining major structures.

Preserved evidences of folding within the Abrigo section are sparse. Where not destroyed by subsequent alteration, the dip angle of bedding can be determined, but because the vertical core is unoriented, the <u>direction</u> of dip cannot; dip reversals, then, cannot be proven. A down hole pattern of steepening dips, turning vertical, and then flattening (as seen best in hole 28-6 but present in many others) can be interpreted as either 1) local steepening in an otherwise monoclinal dip, or 2) dips steepening towards the axial plane of a fold in the upper limb, turning vertical at the hinge line, and reversing direction and flattening away from the axial plane in the opposing limb of the fold. The latter hypothesis is preferred. A few minor folds have been documented in the core. These have a wave length of three feet or less, and are recognized by the repetition of thin

distinctive beds in the Abrigo. Their apparent paucity is surprising, given the severity of the major folding, but is perhaps explained by the obliteration of bedding by alteration and mineralization in crucial areas, especially near the axial plane. Repetition of bedding-controlled CRDs, as evidence for folding, will be discussed in a subsequent section.

The presence of a large recumbent fold in the Star Hill area readily accounts for the "Abrigo thickness problem" alluded to earlier. The 2,700 foot apparent thickness may really be only the linear measure of the Abrigo in the upper limb of the fold (fig. 2). In reality, an abnormally thin Abrigo section is probably present in the project area. The true thickness of the Abrigo in the apressed part of the fold (e.g. in 28-8 or 28-38) is only 100 to 125 feet. A true measure of the thickness of the Abrigo in the less distorted limbs of the fold (i.e. to the west of 28-16) cannot be obtained because of extensive intrusion by Sniveler and Courtland breccias. If would be expected, however, that the limbs have experienced significant tectonic thinning. Whether additional Abrigo occurs in the axial region of the fold to the east of 28-10, and stratigraphically above an undetermined thickness of the Star Hill-Copper Belle sill, remains an open question.

The existence of the Star Hill anticline implies the presence of overturned synclines. Overturned bedding in the Bisbee formation suggests the existence of one such fold. Several drill holes show examples of overturned graded bedding in the coarser clastic members of the Bisbee, the best, perhaps, being in hole 28-23. Once dismissed as a local phenomenon caused by thrusting along the Courtland fault, overturning in the Bisbee is now thought to reflect the presence of a large, pre-thrust, overturned syncline, similar in scale to that proposed by Gilluly to explain a large area of overturned Bisbee exposed in the South Pass area (Gilluly, 1956, Plates V and V1, but see also Drewes (1981), p. 52-53 for opposing views). In the Star Hill area, Abrigo rests directly on the Bisbee, separated by the Courtland thrust, as, for example, in hole 28-16 (fig. 2). Here, a minimum of 1,000 to 5,000 feet of stratigraphy (Martin through middle Bisbee) may have been cut out by the thrust. This requires the over-riding Abrigo fold to have travelled an unknown, but probably great distance to become juxtaposed atop the Bisbee syncline. Thus, the Star Hill anticline and Bisbee syncline are not adjacent paired folds, rather the Star Hill anticline has ridden over a series of decapitated folds to reach its present position, as will be further discussed in the section on tectonics.

The Star Hill anticline has been traced laterally for only a short distance within the drilling area; its north and south limits are unknown. To the south of Solo Ridge there is a suggestion of the existence of the anticline in hole 28-6, but re-logging will be necessary to confirm it. Further south, the geology of Maud Hill (Lawrence, 1989) is entirely different than

that of the Star Hill area, suggesting a major structural discontinuity between the two. In addition, regional magnetic data (fig. 4) shows a major embayment in the so-called "Abrigo trend" between Solo Ridge and Maud Hill, in Rat Canyon. Previous workers (McRae, 1966; et. al) have proposed the "Rat Canyon thrust" occupies the valley. It is here proposed that the Rat Canyon is a tear rather than a thrust fault which forms the southern edge of the Star Hill fold salient. Regional magnetics also show a sharp westward bend in the "Abrigo trend" immediately north of Star Hill. This, combined with the obvious differences between the geology of the southern Courtland district and the Star Hill area, suggest another tear fault may separate these two terranes. Lawrence (1989, Plate III) has mapped minor tear faults in the southern-most Courtland district which may parallel a major tear concealed by colluvium immediately north of Star Hill. Drilling will be necessary to determine whether the Star Hill salient is terminated by a tear fault on the north, or if the fold structure merely bends to the west and continues into the Courtland area.

FAULTS

Three major periods of faulting can be recognized in the Star Hill project area. The first is a series of pre-folding, probably syn-plutonic normal (?) faults. The second grouping includes syn-folding thrust and tear faults (as well as thrust-related imbricate and reverse faults in the allochthon), the most important of which is the Courtland thrust. The final period of faulting is represented by basin-range faults. Each group is described below.

Pre-Fold Faults

The earliest set of faults recognized in the project area formed prior to folding and have normal displacements. Included in this set are faults striking northeast, east, and west-northwest, which have been mapped on the surface, and faults of northeast and northwest orientations, which have been delineated by drilling in the subsurface.

Surface mapping (Lawrence, 1989; Plate I) shows a strongly developed and closely spaced set of northeast-striking faults on the western part of Solo Ridge. These cut the Star Hill porphyry and have been intruded by Sniveler-like porphyry and minor breccias. Their trace over topography is very straight, indicating nearly vertical dips. On the east end of Solo Ridge, and on the east side of Star Hill, porphyry-intruded faults have a west-northwest orientation and indications of nearly vertical dips. While the preferred interpretation of this fault pattern is that there are two distinct sets of steeply dipping faults, one with a northeast strike and another with a northwest trend, it is possible that this configuration may be attributed to one

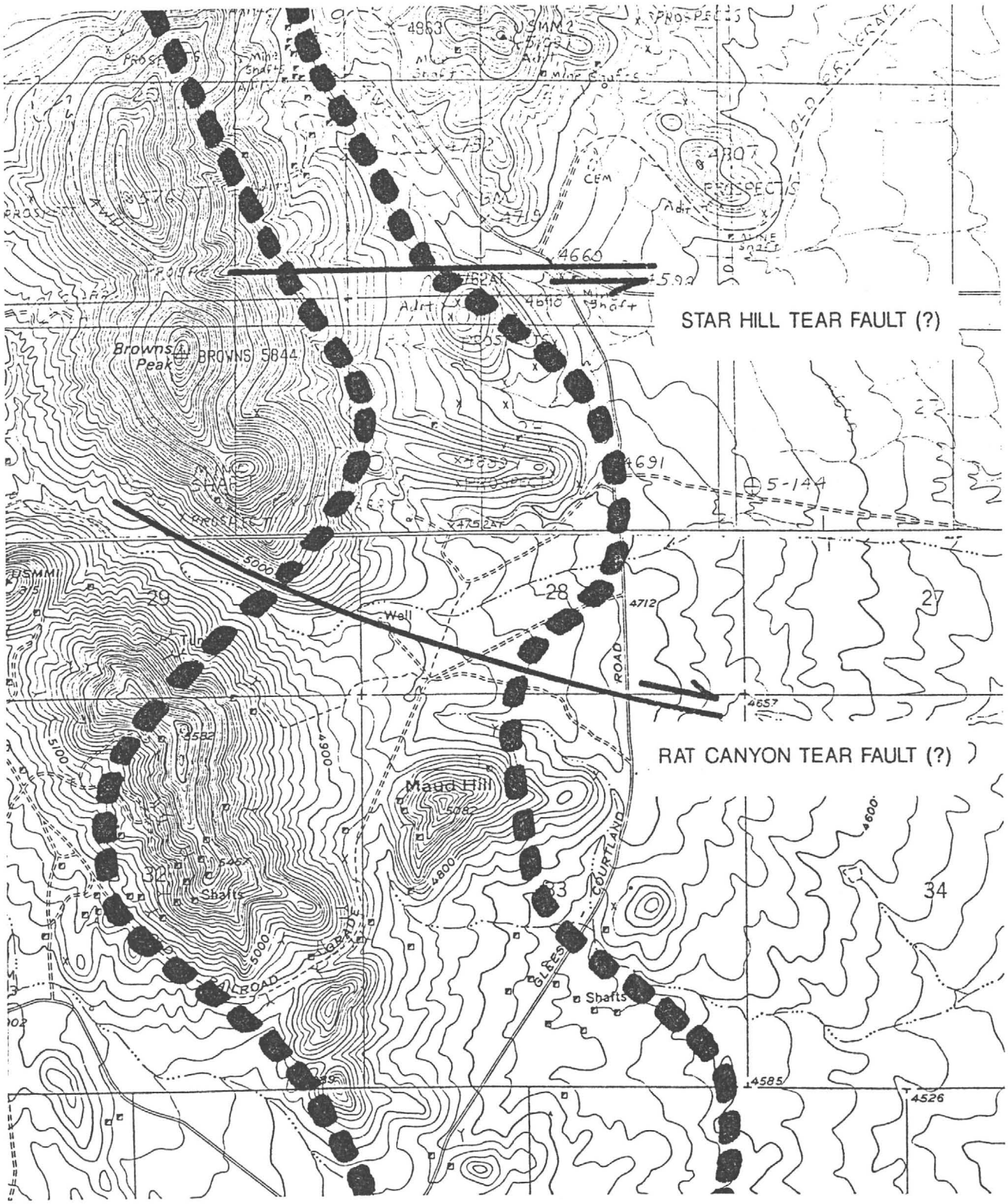


Figure 4.

Trend of the "Abrigo Belt" (dashed outline), as expressed by regional magnetic data, broken by possible tear faults on the margins of the Star Hill structural salient.

set of east-west faults which dip very gently to the south, creating the arching pattern of dikes over the topography of Solo Ridge. Drilling has not resolved this issue. An east-trending set of faults cutting the Bolsa is present near the Gilbert Flux Pit. Here, however, the faults' traces over rugged topography clearly indicate nearly vertical dips.

Drilling has revealed the presence of northeast- and northwest-trending faults in the subsurface. The northeastern trend may be related to similarly trending faults mapped on the surface, but the northwest trend is apparently not manifested in outcrop. Like those mapped on the surface, the subsurface faults are defined by dikes of Sniveler breccia and porphyry, as well as by the Courtland breccia. Isopach maps of these three lithologies (figs. 5, 6, and 7) show strongly developed northeast trends. The major northeast trend lies along drill line 28-29 - 28-17, while two less well developed trends lie along lines 28-32 - 28-10 and 28-39 - 28-40. Drilling has not been sufficiently close-spaced to accurately determine the dip of these dikes (faults), but they are assumed to be nearly vertical. Because of their assumed vertical dip, and because they strike nearly at right angles to the hinge line of the subsequently formed recumbent fold, the post-folding geometry shown on the isopach maps is similar to the pre-fold geometry.

Figure 5 also shows a northwest-trending dike of Sniveler porphyry along the 28-30 - 28-5 drill line. It is presumed to have a steep southerly dip, but because of the lack of drill holes southwest of the dike, its exact pre- and post-folding orientation and geometry cannot be determined. Overlying the Sniveler, Sniveler breccia, Courtland breccia, and CRD (fig. 11) isopachs reveals a northwest-trending line running between holes 28-24 and 28-44, which is parallel to the 28-30 - 28-5 dike, and which is marked by a number of structural anomalies. These include northwest embayments in all three northeast Sniveler and Sniveler breccia trends, bulges in the isopachs of Sniveler porphyry and Sniveler and Courtland breccias immediately adjacent to the line, and linear distortions in the CRD isopachs. It is proposed that this line of structural disruption is a fault parallel to that along which the 28-30 - 28-5 dike was emplaced.

The intersection of this fault and the northeast-trending Sniveler porphyry dike is the site of anomalous concentrations of Sniveler and Courtland breccias (figs. 6 and 7). It is tentatively proposed that these concentrations mark the location of a nested breccia pipe. The dike-fault intersection appears to have been intruded first by an elliptically shaped pipe of Sniveler breccia which contains abundant fragments of the host Sniveler porphyry. This pipe was then centrally intruded by a pipe of Courtland breccia which contains fragments of both Sniveler porphyry and breccia. The resulting compound pipe thus shows Courtland breccia nested within Sniveler breccia. Folding this proposed pipe would result in the presently observed distortions of the originally circular or elliptical shape.

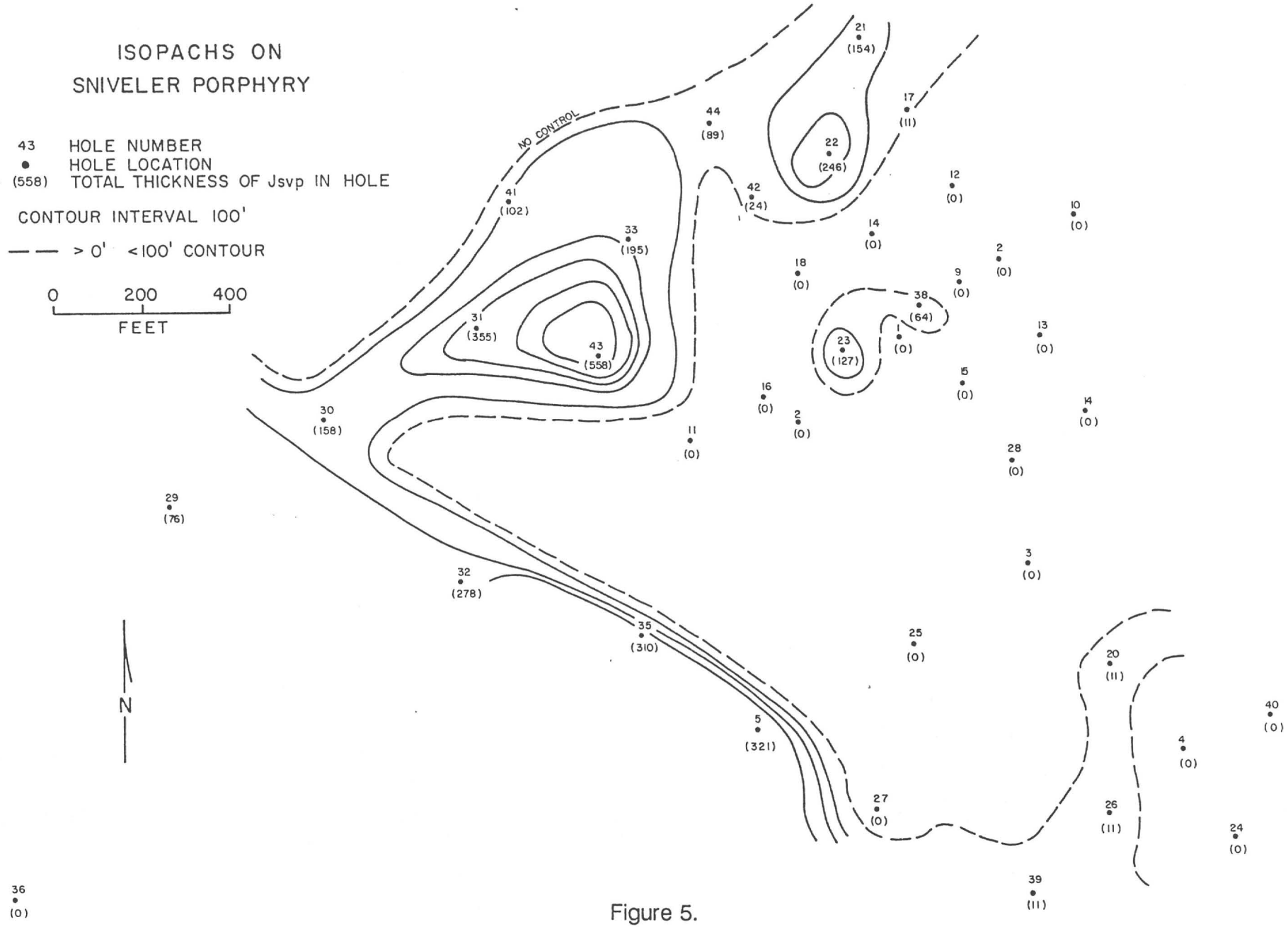

ISOPACHS ON
SNIVELER PORPHYRY
43 HOLE NUMBER
HOLE LOCATION
(558) TOTAL THICKNESS OF Jsvp IN HOLE
CONTOUR INTERVAL 100'
> 0' <100' CONTOUR
0 200 400
FEET
N
NO CONTROL
21 (154)
17 (11)
44 (89)
22 (246)
12 (0)
10 (0)
41 (102)
42 (24)
14 (0)
33 (195)
2 (0)
18 (0)
9 (0)
38 (64)
31 (355)
13 (0)
1 (0)
23 (127)
43 (558)
15 (0)
16 (0)
14 (0)
30 (158)
2 (0)
11 (0)
28 (0)
29 (76)
3 (0)
32 (278)
35 (310)
25 (0)
20 (11)
40 (0)
5 (321)
4 (0)
27 (0)
26 (11)
24 (0)
39 (11)
36 (0)

Figure 5.

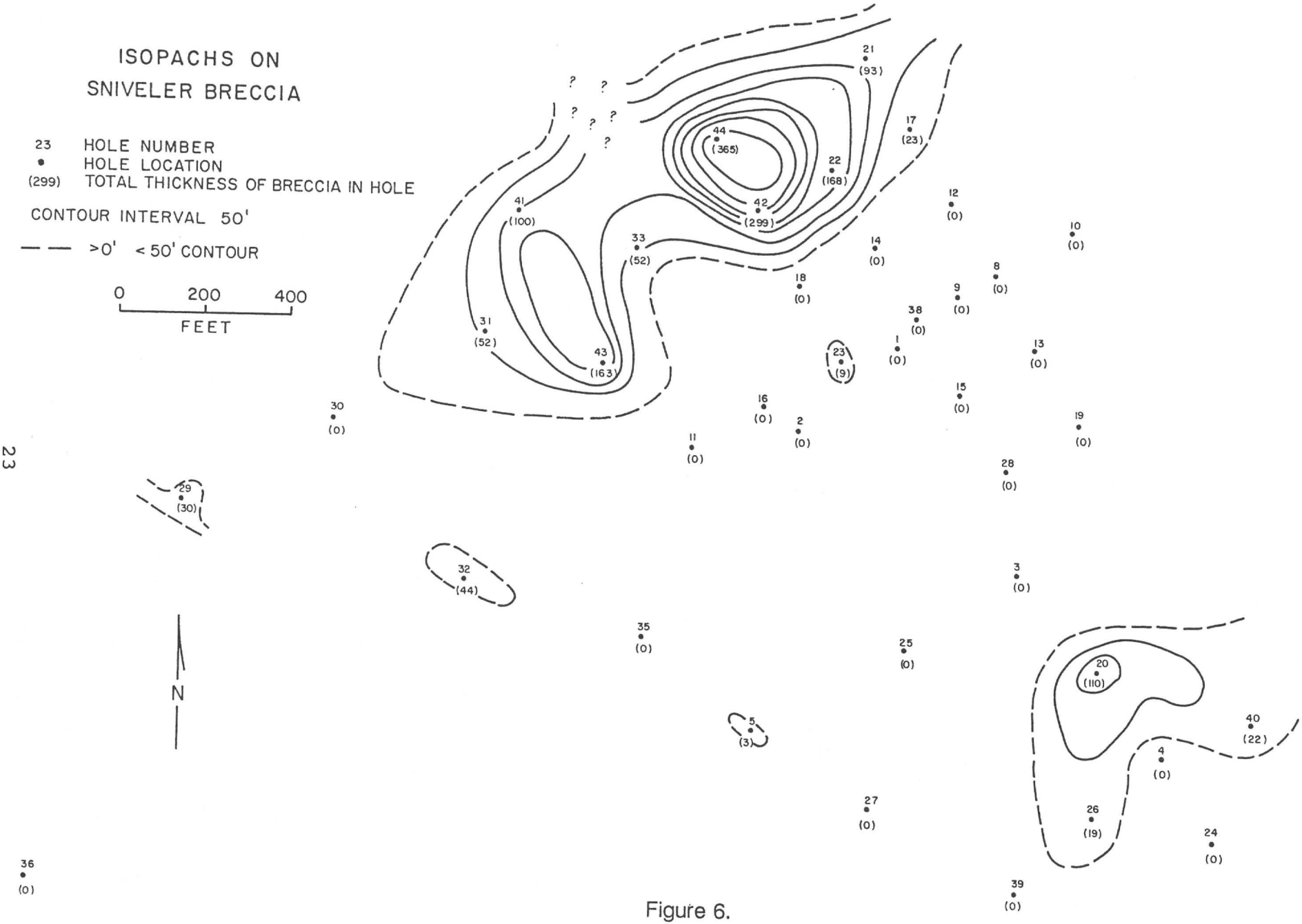

ISOPACHS ON
SNIVELER BRECCIA
23 HOLE NUMBER
HOLE LOCATION
(299) TOTAL THICKNESS OF BRECCIA IN HOLE
CONTOUR INTERVAL 50'
>0' <50' CONTOUR
0 200 400
FEET
N
21 (93)
17 (23)
44 (365)
22 (168)
42 (299)
12 (0)
10 (0)
41 (100)
33 (52)
14 (0)
8 (0)
18 (0)
9 (0)
38 (0)
31 (52)
43 (163)
23 (9)
1 (0)
13 (0)
15 (0)
30 (0)
16 (0)
2 (0)
19 (0)
11 (0)
28 (0)
29 (30)
32 (44)
3 (0)
35 (0)
25 (0)
20 (110)
40 (22)
5 (3)
4 (0)
27 (0)
26 (19)
24 (0)
36 (0)
39 (0)

Figure 6.

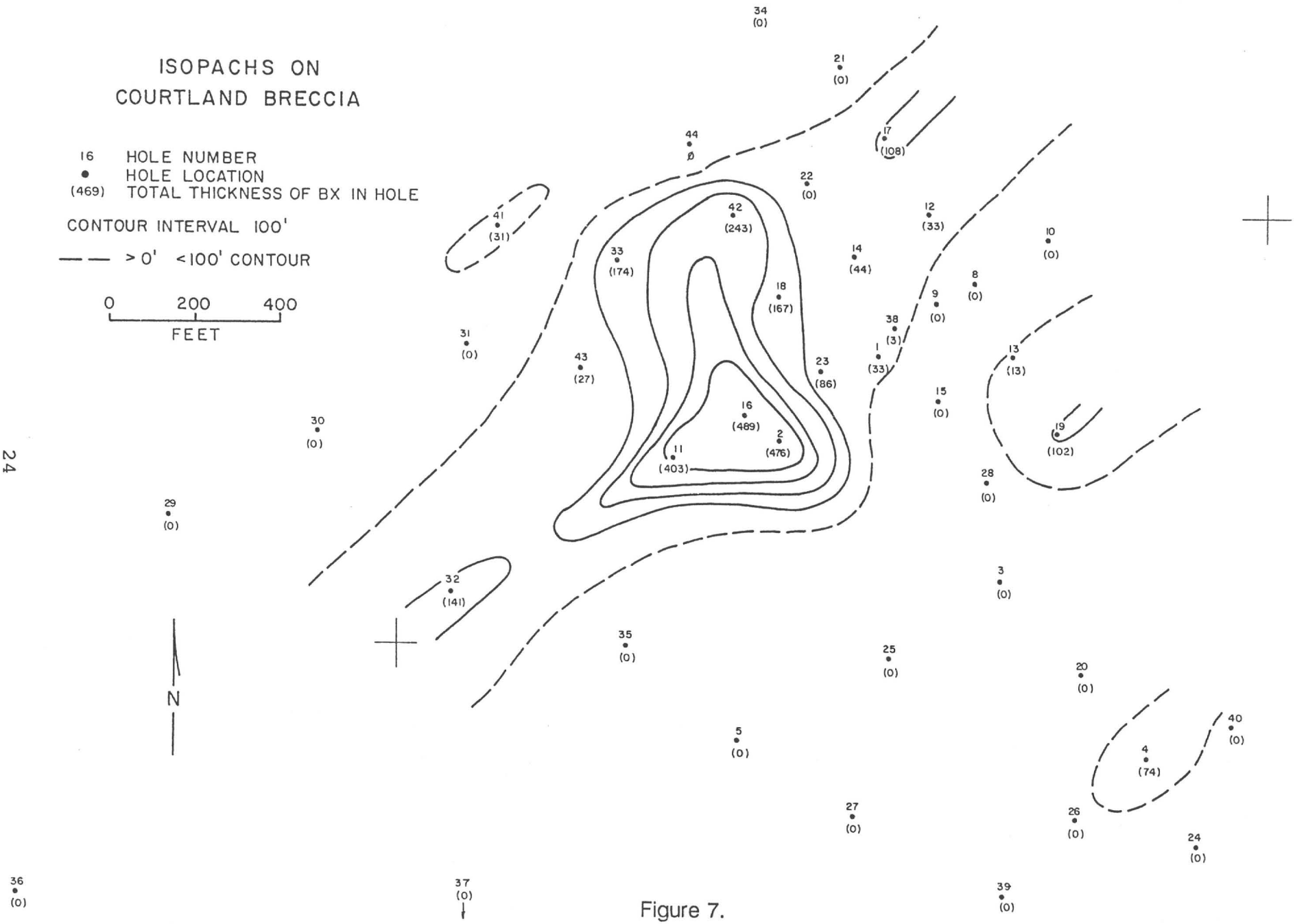

ISOPACHS ON
COURTLAND BRECCIA
16 HOLE NUMBER
HOLE LOCATION
(469) TOTAL THICKNESS OF BX IN HOLE
CONTOUR INTERVAL 100'
> 0' < 100' CONTOUR
0 200 400
FEET
N
34 (0)
21 (0)
44 Ø
17 (108)
22 (0)
42 (243)
12 (33)
10 (0)
41 (31)
33 (174)
14 (44)
18 (167)
8 (0)
9 (0)
38 (3)
31 (0)
43 (27)
1 (33)
23 (86)
13 (13)
15 (0)
16 (489)
2 (476)
19 (102)
30 (0)
11 (403)
28 (0)
29 (0)
32 (141)
3 (0)
35 (0)
25 (0)
20 (0)
40 (0)
5 (0)
4 (74)
27 (0)
26 (0)
24 (0)
36 (0)
37 (0)
39 (0)

Figure 7.

Thrust Faults

Aside from the Star Hill anticline, the Courtland thrust is the predominate structural feature in the project area. In the southern Dragoon Range, the Courtland is the structurally lowest of a group of imbricate thrusts which include (in ascending order) the Gleeson, Turquoise Ridge, and Dragoon thrusts (Gilluly, 1956; McRae, 1966). Insofar as it is the lowest thrust known in the area, the Courtland probably is the sole of the regional Cochise thrust of Drewes (1980, 1981).

Near Star Hill, the Courtland thrust strikes generally northwest, dips gently to the southwest, and lies between 590 and 1,355 feet below the surface (in holes 28-34 and 28-5, respectively). The fault surface, shown on figure 8, is an unremarkable, gently undulating one, broken, in places, by basin-range faults of relatively minor displacement (e.g. the trough extending south from DDH 28-44, and the "hole" around 28-40). The overall dip of the fault plane in the project area is 14° SW (between holes 28-32 and 28-10), a figure in agreement with a 15° SW dip measured by McRae (1966) in the Courtland area. Immediately below the Star Hill CRD, the Courtland thrust dips more gently; 11.5^{o} SW between holes 28-16 and 28-10.

In the Star Hill area, the Courtland thrust separates the allochthonous plate composed of Paleozoic sedimentary and Jurassic plutonic rocks, from what is probably true foreland, everywhere consisting of Cretaceous Bisbee sediments and volcanics. The fault zone ranges from a few inches up to 32 feet in thickness, the latter being exceptional. In most instances, the fault consists of well developed mylonite, although occasional rubbly zones have been recorded, in which locally derived, sheared fragments of CRD are found. Proto-mylonitic fabric has been developed several tens of feet into the hanging wall in some areas. The thrust has been intruded, in many places, by a highly irregular Tertiary felsite sill which has locally consumed the mylonite zone.

A number of minor reverse fault sets of various orientations were developed in the allochthonous plate in conjunction with the formation of the Courtland thrust. These probably developed during two periods of differing strain orientation: viz. a horizontally oriented strain field existing before rupture and movement on the Courtland thrust (strain ellipsoid I in figure 9), and an inclined field existing during transport of the allochthon over the thrust (fig. 9, II). In the horizontally oriented strain field, the Courtland (A-A′) and minor, parallel thrusts (a-a′) developed, along with high angle reverse faults (b-b′). After rupture along the thrust, the strain field in the upper plate rotated to a position parallel with the thrust plane. In this field, high angle (c-c′) and low angle (d-d′) reverse faults formed, with a dips opposing those formed in the horizontal field. While faults with all these orientations and movements have been documented in core, detailed cross sections

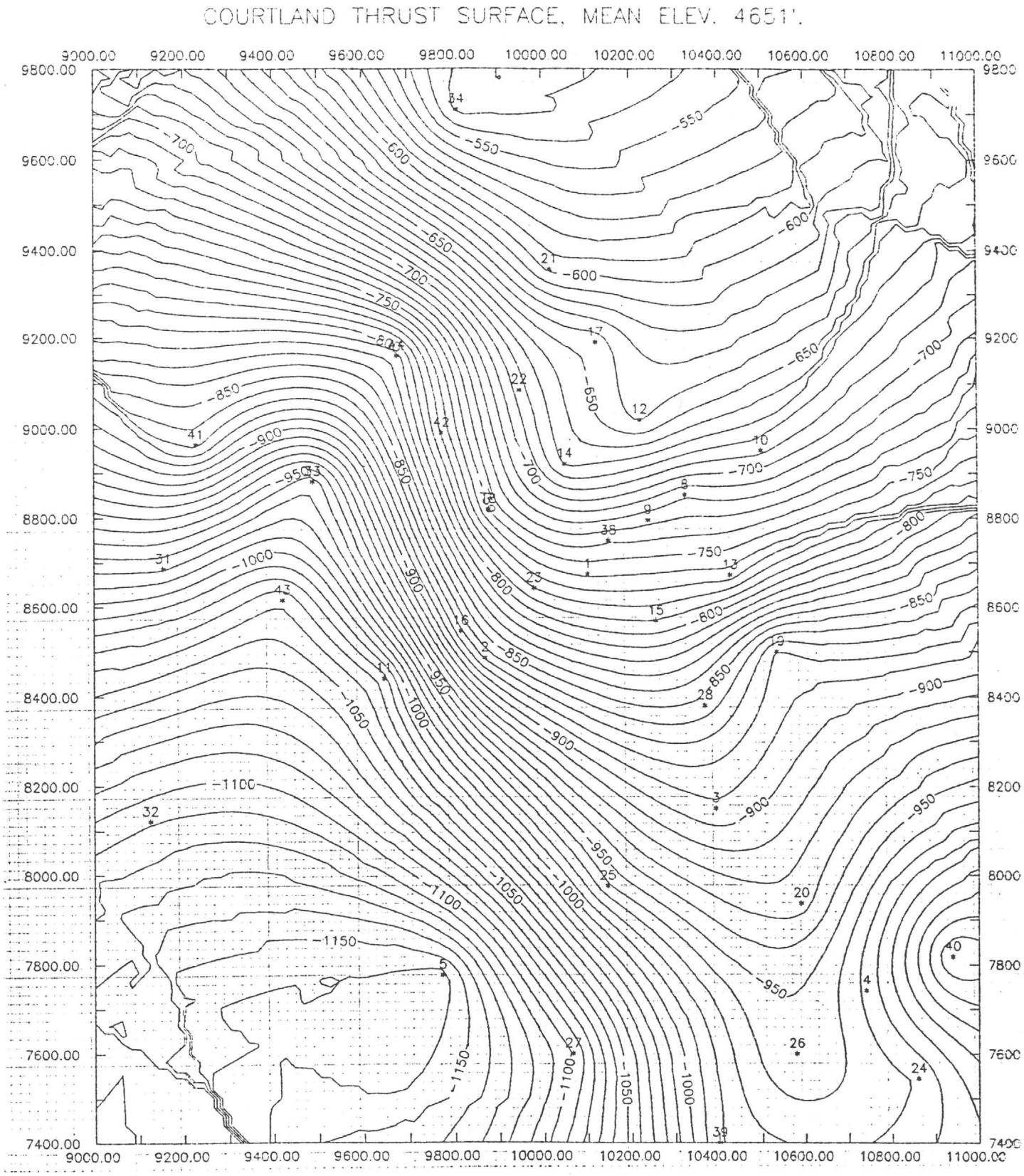


Figure 8.

Contour map of the Courtland thrust surface. Contour interval: 10'.

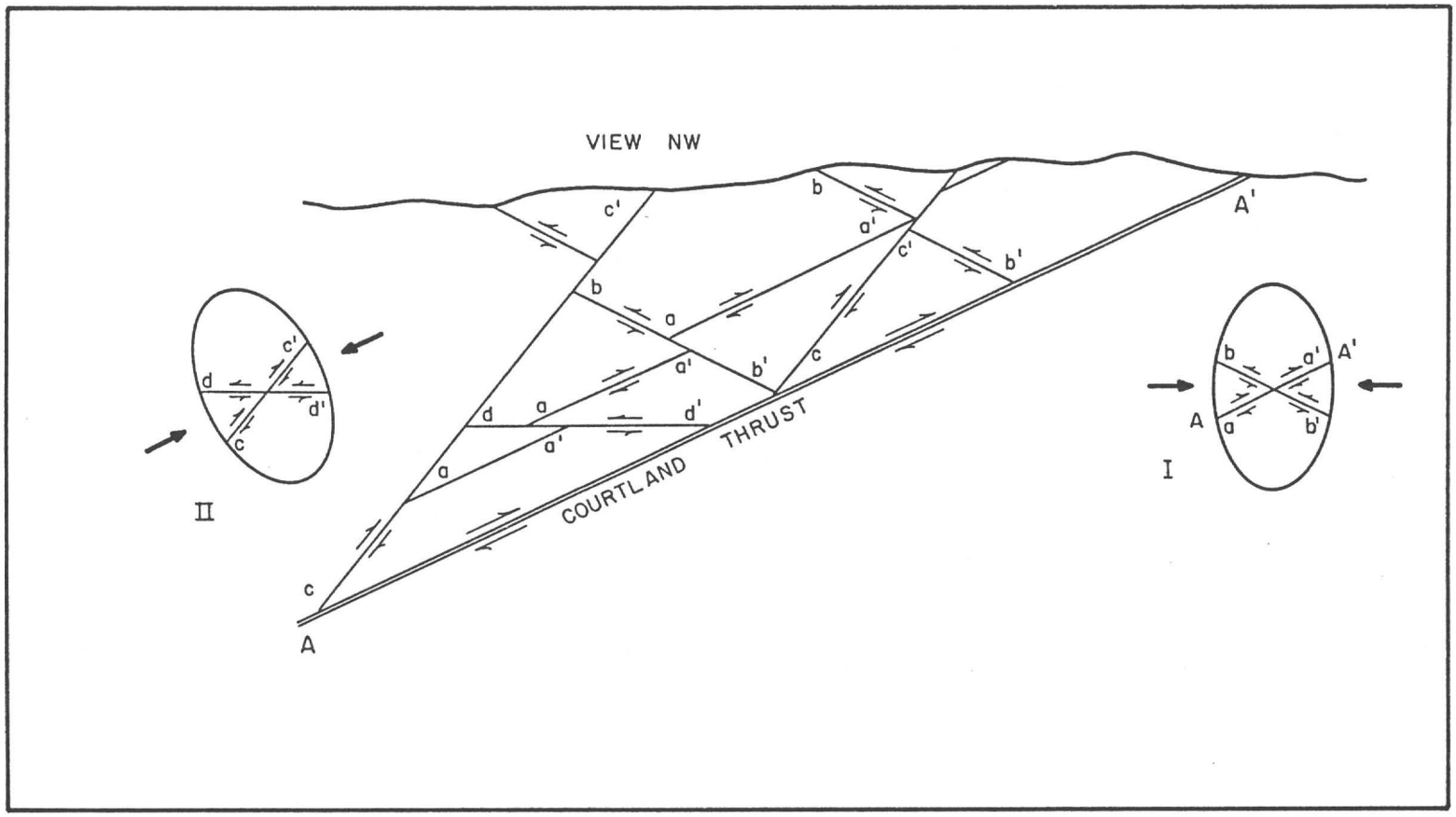


Figure 9.

Minor faults developed in the Star Hill allochthon during pre-thrust compression (strain ellipsoid I), and syn-thrust movement (strain ellipsoid II).

show the amount of movement on all but the master Courtland thrust have been very minor; a few to a few tens of feet.

The direction of movement of the allochthon along the Courtland thrust is clearly to the northeast, and is based on abundant physical evidence such as direction of overturning, slickensides, etc. The magnitude of movement is very much less certain. Drewes (1981) suggests, based on equivocal evidence, that the entire Cochise allochthon has moved between 60 and 125 miles northeast. Gilluly (1956) is more noncommittal, suggesting the allochthon moved "several miles". A simple construction involving ramping the Abrigo up a 14° thrust incline over the $\pm$ 5000 feet of missing stratigraphy in the Star Hill area, to place it atop upper Bisbee, involves a lateral transport distance of 3.8 miles.

The age of the Courtland thrust may be fairly closely bracketed. The thrust cuts all Paleozoic sedimentary rocks, Jurassic intrusive rocks and mineralization, as well as clastic and volcanoclastic units, here assigned to the Bisbee, but possibly belonging to the late Cretaceous Salero formation (see p. 12). The thrust, in turn, is cut by Basin and Range faults which may date as early as the Oligocene. Thus, the probable age of thrusting lies between latest Cretaceous and early Tertiary.

Basin and Range Faults

The Star Hill project area lies between the range front of the Dragoon Mountains and the Sulfur Springs basin to the east, and is cut by a multitude of generally north-striking basin-range faults.

On the surface, Lawrence (1989, Plate I) has mapped numerous faults cutting Solo Ridge and Star Hill, which strike north to slightly west of north and dip vertically. Their recognition is based largely on offsets of Sniveler dikes in the otherwise monotonous Star Hill porphyry terrane. Topographic expression of the more major faults is found in the north-trending valley immediately west of Star Hill, in the linear connecting the valley on the south side of Star Hill and the notch on eastern Solo Ridge, and possibly by the linear marking the eastern edges of Solo Ridge and Star Hill.

Basin-range faults were not cut in any drill hole, however cross sections of the subsurface clearly indicate their presence. A cross section along line 28-29 - 28-17 shows the Courtland thrust displaced 150 feet, west side down, between holes 28-33 and 28-42. This fault corresponds to a north-striking vertical fault mapped on the surface in the valley on the south side of Star Hill. A similarly oriented cross section reveals the Courtland thrust in hole 28-40 has been down-dropped about 100 feet relative to its unfaulted projection. It is probable that this east side down displacement was caused by a basin-range

fault trending north between holes 28-4 and 28-40 (fig. 8). These two faults, which show a greater displacement then all others in the drilled area, thus define a north-trending horst, approximately 1200 feet wide, which contains the bulk of the Star Hill CRD mineralization. It is suspected that several basin-range faults cut the horst but that their displacement is minor; a few tens of feet. The complex fold structure and normal undulations in the Courtland thrust make exact offset determinations difficult.

Drilling has not proceeded far enough to the east to determine the location of the major basin-range fault which forms the principal western boundary of the Sulfur Springs Valley, if indeed one exists. Multiple horst and graben structures may extend potentially mineralized upper Abrigo or Martin rocks a considerable distance east of Star Hill-Solo Ridge under only rather shallow alluvium.

TECTONICS SUMMARY

The earliest period of tectonism which can be discerned in the project area is expressed by east-, northeast-, and northwest-trending normal (?) faults. In most cases, these have been intruded by various kinds of Jurassic intrusive rocks, suggesting their development may be related to plutonism; there is no regional evidence suggesting the existence of ancient pre-plutonic faults of these orientations (Drewes, 1981; Gilluly, 1956; McRae, 1966). Accordingly, it is proposed that these faults formed in response to a tensional environment created in the roof zone above large, rising bodies of magma which eventually crystallized as the Gleeson-Turquoise pluton. These tensional faults were probably long lived, preceding the rising magmas, cutting early emplaced sills of Star Hill and Copper Belle porphyry, and remaining open to provide channelways for the intrusion of late-stage dikes, breccia pipes and the mineralizing solutions which created the Star Hill CRD.

The major tectonic event to affect the Star Hill CRD was the late Cretaceous-Paleocene Cordilleran orogeny. During this period, a large part of southeastern Arizona experienced a strong northeast-southwest compression, probably resulting from a major plate collision. This compression resulted in the formation of the Cochise thrust sheet which was transported perhaps 60 to 125 miles to the northeast (Drewes, 1981). In the local project area, it is proposed that open folding occurred early in the compressional event and involved the entire Precambrian through late Cretaceous sedimentary and igneous package. Continued northeast-directed compression tightened the open folding which was subsequently overturned and eventually carried to recumbency. Unable to accommodate additional strain through folding, tear faults developed, allowing certain segments of the recumbently folded terrane, such as the Star Hill area, to be shoved even further to the northeast, forming structural salients. Simultaneously, or immediately preceding tear faulting, the entire horizontally strained package ruptured with the formation of the Courtland thrust. The newly created, intruded, mineralized, and folded allochthon then travelled northeastward a minimum of 3.8 miles; actual transport distance was probably much greater.

The final tectonic event in the Star Hill area occurred perhaps as early as Oligocene time and resulted in the formation of basin-range faults and the creation of a semblance of the present topography. While the regionally extensive, east-west directed Basin and Range tensional event generated the usual north-trending faults of normal displacement, in the Star Hill area it did not, however, produce the normal pattern of blocks successively down-dropped from the range to the adjacent basin. Rather, one or a series of horsts and grabens were formed in the terrane between the Dragoon Range and the Sulfur Springs Valley.

MINERALIZATION

General Outline. A variety of types of mineralization occur in the Star Hill project area which are typical of those occurring on the periphery of a porphyry copper system. While porphyry-hosted disseminated copper mineralization, skarns, and breccia-hosted stockworks are present, it is the carbonate replacement deposits (CRD) and, to a lesser extent, the supergene chalcocite mineralization which presently appear to be of economic interest. The following sections present a classification scheme and description of the various types of mineralization, as well as a discussion of mineral zoning, ore controls, and the effects of post-mineral structure on the ore deposit. Finally, a model of CRD genesis is outlined.

Mineralization Classification and Description

The following types of mineralization are recognized in the Star Hill project area: 1) porphyry-style disseminated copper mineralization, 1a) porphyry-derived supergene chalcocite mineralization, 2) skarn-related sulfides, 3) CRDs, and 3a) CRD-related, breccia-hosted stockworks. Each is briefly described below.

Porphyry Copper-Style Mineralization

Porphyry copper-like mineralization is found hosted by both Copper Belle and Star Hill monzonite and quartz monzonite porphyries, and is of nearly ubiquitous occurrence in these host rocks. While this type of mineralization is widespread in the project area, it is of little economic interest because of its consistently low grade. The early phase of this mineralization consists of finely disseminated 1-3 mm anhedral to subhedral grains of pyrite and chalcopyrite which appear to have crystallized as accessory minerals in the host monzonites. Disseminated accessory sphalerite occurs along with early pyrite-chalcopyrite in the Copper Belle. Superimposed upon this early phase is a latter stage of pyrite-chalcopyrite which occurs in quartz veinlets, typically $\leq$ 1/8" wide, and exceptionally as veinlet stockworks. This veinlet-controlled mineralization was probably introduced during the main stage of alteration of the porphyries, which affected virtually the entire mass of both the Copper Belle and Star Hill, and resulted in widespread silicification, sericitization, and argillization, as well as more localized K-feldspar flooding. Mineralized veinlets, themselves, are often accompanied by thin quartz-sericite $\pm$ K-feldspar selvages.

Typically, the porphyries contain 1% to 3% combined disseminated and/or veinlet-controlled pyrite-chalcopyrite, and return assays of <0.2% Cu. Exceptionally, total sulfides may comprise up to 10% of the porphyries, returning assays of up to 0.4% Cu over intervals exceeding 100 feet. Zinc assays are usually negligible, with the exception of one 24 foot interval of Copper Belle in hole 28-26 which ran 1.23% Zn.

Supergene Chalcocite Mineralization

The presence of chalcocite mineralization in the vicinity of Star Hill prompted the first serious drill exploration of the project area in the 1950's. Targeted as a thick, high grade blanket deposit lying in the Star Hill valley, close-spaced drilling has since proven that such does not exist. The delineated sparse mineralization may still prove to be of economic interest if an open pit can ever be developed on the underlying CRDs. Metallurgical work (Dawson Metallurgical Laboratories, Inc., 1989) indicates, however, that the Star Hill chalcocite "ore" has poor heap leach copper recoveries (20-35%), poor percolation characteristics, and high acid consumption.

The blanket mineralization consists primarily of sooty chalcocite rimming and/or veining, but only partially replacing hypogene pyrite, chalcopyrite, and sphalerite. Finely divided native copper is also relatively common in the supergene zone; rarely thumbnail-sized masses of native copper occur, as in hole 28-20. Minor secondary copper minerals identified in core include covellite, cuprite, bornite, turquoise, malachite, and digenite. Metallurgical work has revealed the rare presence of fine, liberated native gold in chalcocite-rich composites. Chalcocite mineralization is generally accompanied by clay alteration; the strongest mineralization occurring in almost totally argillized porphyry or Abrigo limestone. It is unknown if this clay alteration is of acid-generated supergene origin, or if it was developed during hypogene mineralization. In either case, chalcocite precipitation appears to have been strongly influenced by the charged surfaces of clay particles.

At a 0.2% Cu cutoff, the thickness of the chalcocite blanket ranges between 15 and 150 feet, perhaps averaging 40 feet. Copper grades over these widths generally average between 0.5 and 0.6% Cu, but locally may exceed 1% over scores of feet, and approach 2% over intervals of a few tens of feet. The grade-thickness of the Star Hill chalcocite blanket is shown on figure 10. Far from the anticipated uniform distribution, the mineralization shows a high degree of structural control, being strongly localized by NNW-trending basin-range faults which apparently influenced groundwater movement during the supergene event.

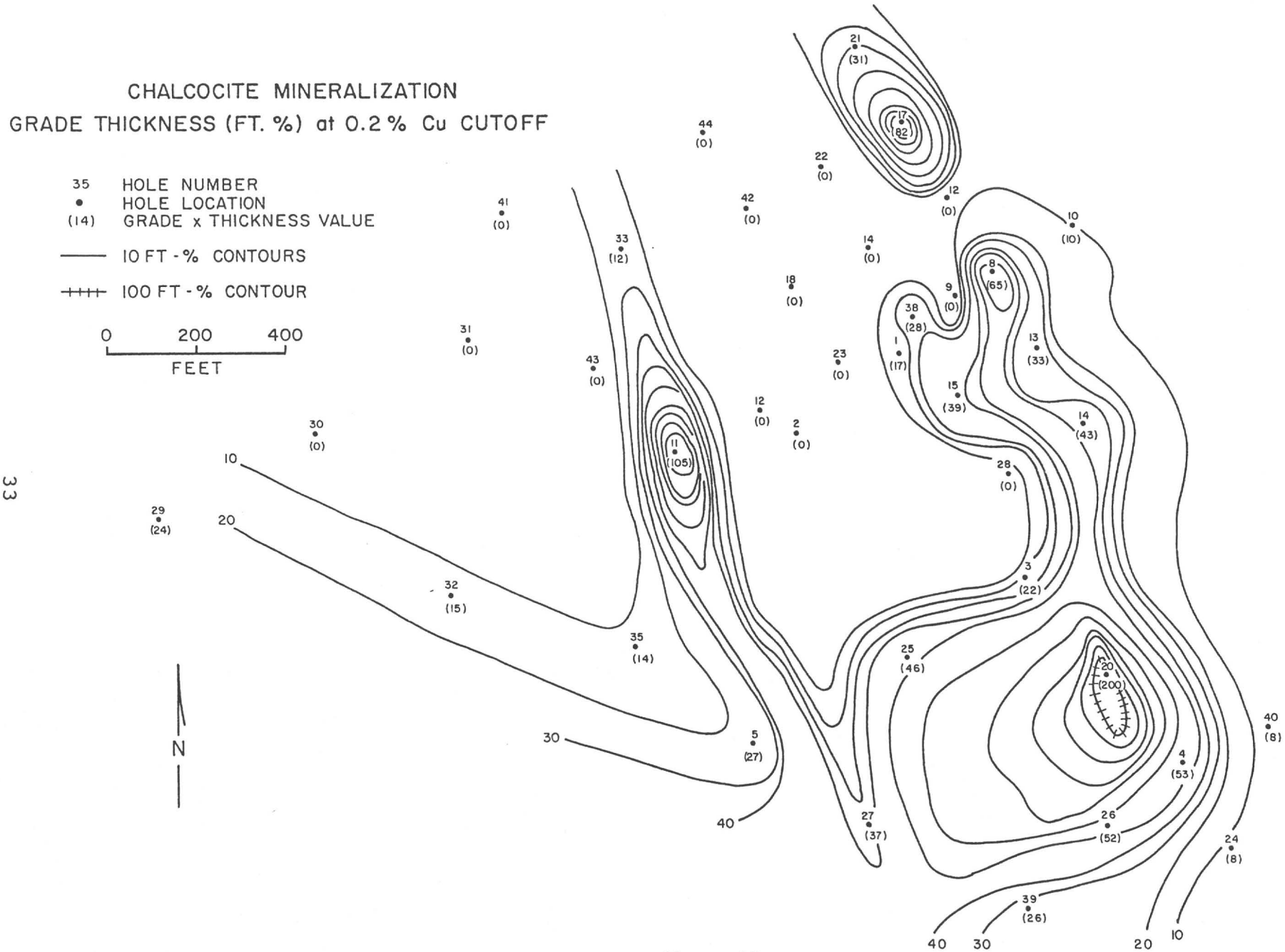

CHALCOCITE MINERALIZATION
GRADE THICKNESS (FT. %) at 0.2 % Cu CUTOFF
35 HOLE NUMBER
HOLE LOCATION
(14) GRADE x THICKNESS VALUE
10 FT - % CONTOURS
100 FT - % CONTOUR
0 200 400
FEET
N

Figure 10.

The source of the mineralization in the supergene blanket is thought to be the hypogene chalcopyrite contained in the host Star Hill and Copper Belle porphyries. While a now eroded, high grade CRD source cannot be disproven, a widespread, low grade porphyry source is clearly at hand, and stands as the most expedient source for a similarly widespread and low grade chalcocite blanket.

Skarn Mineralization

Several intervals of calc-silicate skarn have been drilled in the Star Hill project area, but, to date, none of possible economic significance have been found. Skarning is best developed in the Abrigo, but has also developed in a few calcareous beds of the Pima; only minor skarn has been observed in the Bolsa. In most instances, skarn has developed on or near contacts with either Star Hill or Copper Belle porphyry, to which they probably owe their development. In only a few instances (e.g in hole 28-4) does skarn occur isolated in the sedimentary sequence, remote from an intrusive contact.

Where best developed in the Abrigo, skarn consists of massive, medium- to coarse-grained, brown and green aggregates of calcite > brown and green garnet > epidote $\geq$ chlorite > quartz $\pm$ diopside $\pm$ K-feldspar. Commonly, skarn is cut by a multitude of calcite-filled fractures. Sulfide content is generally low, averaging 1-2%, and consists of disseminated or veinlet-controlled py$\geq$sl>gl$\geq$cpy. Very locally, sulfide content may range up to 40%, one half of which may be composed of base metal sulfides. Only one hole (28-6), however, produced mineralized skarn intervals of significant thickness (Appendix I). In addition to copper and zinc, the 28-6 intercepts are among only a few to contain over 0.5 opt Ag. Skarn in Pima sandstone is similar in character to that in Abrigo, but is commonly distinctly banded, a fabric inherited from the distinct thin bedding in this unit. In both the Abrigo and Pima, skarned intervals range from a few up to 50 feet in thickness. Peripheral alteration, where present, includes marblization, dolomitization, and/or extensive development of chlorite.

While intervals of skarn are present in or near the guts of the Star Hill CRD, in holes 28-2, -4, and -24, most skarn is found in areas remote from the focus of sulfide mineralization, i.e. in holes 28-6, -7, -29, -32, and -37. The reason for this apparent zonal arrangement is not presently understood.

Mineralization Hosted by Sniveler and Courtland Breccias and Porphyries

The Sniveler porphyry, Sniveler breccia, and Courtland breccia host significant copper-gold mineralization in the form of disseminations, stockworks, and mineralized breccia clasts.

The Sniveler porphyry (fig. 5) typically contains fine disseminations of subhedral to anhedral grains of pyrite >> chalcopyrite which together comprise 3-6% of the rock; very locally more than 10% disseminated sulfides may be present. Intervals containing exceptionally heavy pyrite-chalcopyrite disseminations assay up to 0.4% Cu over as much as 15 feet (e.g. hole 28-21). Pyrite-chalcopyrite stockworks are sparingly developed in the Sniveler porphyry, but where present contain significant amounts of copper and gold (e.g. 28-31: 59 feet of 1.66% Cu and .04 opt Au, with 5 feet running .29 opt Au). Alteration accompanying both disseminated and stockwork mineralization is generally characterized by moderate silicification and patchy, weak to moderate sericite, clay, and chlorite development.

Mineralization in the Courtland and Sniveler breccias consists of both pyrite-chalcopyrite disseminations and stockworks. Disseminated mineralization is similar in character to that in the Sniveler porphyry. Several intervals of substantial thickness and grade have been drilled (Appendix I), some recording in excess of 1% Cu and 0.1 opt Au. Stockwork mineralization is prominent in both the Courtland and Sniveler breccias, far more so than in the Sniveler porphyry, and is especially well developed in the area of the proposed compound breccia pipe. Here, mineralization ranges in intensity from open stockworks, containing relatively few veins per foot of core, to dense stockworking, characterized by several veins per inch of core, to coalescing stockworks, consisting of nearly massive sulfides over more than 10 feet of core. Mineralogy of the veins is simple, consisting of medium- to coarse-grained aggregates of pyrite and chalcopyrite with ratios typically ranging from 85:15 to 95:5. Trace amounts of sphalerite and galena are locally present. Typical copper grades are 0.5%, but range up to 2.34% over short intervals (Appendix I), and locally up to + 5% over three feet. Gold grades are usually low (0.01 opt), but selected intervals in hole 28-42 ran as high as .045 opt over 10 feet. Quartz is the most common gangue mineral in the veins, and silicification of the surrounding host rock is typical. In the Courtland breccia, moderate to very strong chlorite alteration characteristically accompanies mineralization.

CRD clasts are present in both breccias, but are more common in the Courtland. The most prominent example is in hole 28-11 where angular to subrounded blocks of early-formed magnetite-specularite-pyrite-chalcopyrite CRD, up to five feet across, are found suspended in a strongly chloritized, but unmineralized rock flour matrix. The 124 foot interval containing these blocks assayed 0.43% Cu. In several other drill holes, occasional smaller clasts (± 1") of CRD occur in both Sniveler and Courtland breccia. These consist of py>>cpy and are thought to be true CRD fragments; they may, however, represent Abrigo limestone clasts which were replaced by sulfides after their incorporation into the breccia.

CARBONATE REPLACEMENT DEPOSITS

The 1988-89 drilling program resulted in the discovery and partial delineation of a carbonate replacement deposit in the Star Hill-Solo Ridge area. A part of the deposit may be of adequate grade and thickness to constitute an economic orebody of modest size, if exploited by underground mining methods. The following sections describe the distribution and geometry of the CRD, the types of ore present and their zonal arrangement, accompanying alteration, and the probable ore controls. A concluding section discusses the genesis of the deposit.

Distribution and Geometry of CRD Mineralization

The Star Hill CRD consists of two distinct, highly elliptical mantos which have been recumbently folded. In plan, mineralization has been traced along strike, by close-spaced drilling, for a distance of 1,700 feet from its breccia contact, immediately northwest of hole 28-14, southeastward to hole 28-24. If future drilling shows continuity of mineralization further southeastward to the area of holes 28-6 and -7, a total strike length of 3,250 feet is indicated. CRD mineralization has been traced down the limbs of the fold continuously for a distance of 850 feet, from a point near hole 28-8, southwestward to an area immediately northeast of 28-11, and for about 1,100 feet between holes 28-19 and 28-35 (fig. 11). The limits of the CRD are apparently defined by the Abrigo hinge line on the northeast side, by Sniveler porphyry and a compound breccia pipe along the northwest side, and by an irregular mass of porphyry and breccia on the southwest side. The CRD is open along strike to the southeast.

Figures 12 and 13 show the proposed geometry of the folded CRD in cross and longitudinal section. The sections show two CRD zones. As used here, a "zone" includes massive and semi-massive CRD mineralization, as well as peripheral and internal jasperoid and very thin intervals of internal, unmineralized carbonate or intrusive rock. The upper manto, comprising most of Zone I, occurs in the upper-most beds of the existing Abrigo section, immediately below the Star Hill-Copper Belle sill. In the fold nose, Zone I attains a maximum pre-fold thickness of approximately 100 feet and a maximum folded thickness of 180 feet. The thickness of the Zone I diminishes along the limbs to about 30 feet in the vicinity of hole 28-23, due, in part, perhaps to tectonic thinning. In long section, Zone I is apparently discontinuous along the upper limb, varying in thickness from 0 to 60 feet. Zone I in the lower limb shows much greater continuity and a thickness varying between 5 and 85 feet. Because of the inherent irregularities of CRDs in both plan and section, the above figures will vary from section to section, but they are, nonetheless, thought to be generally representative of the deposit as a whole. The Zone II manto is considerably smaller than that in Zone I, and occurs about 85-115 feet deeper

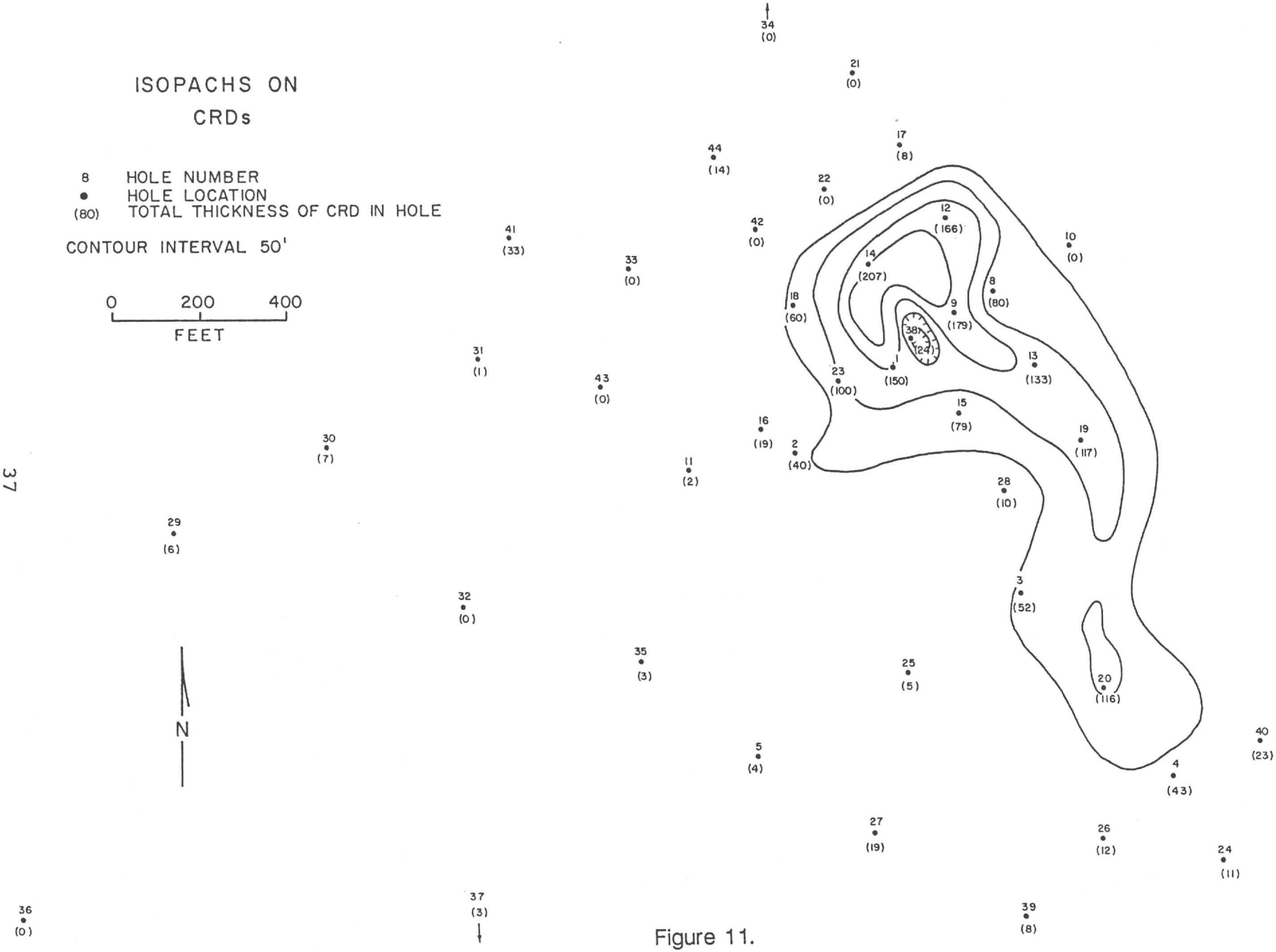

ISOPACHS ON
CRDs
8 HOLE NUMBER
● HOLE LOCATION
(80) TOTAL THICKNESS OF CRD IN HOLE
CONTOUR INTERVAL 50'
0 200 400
FEET
N
34 (0)
21 (0)
17 (8)
44 (14)
22 (0)
42 (0)
12 (166)
10 (0)
41 (33)
33 (0)
14 (207)
8 (80)
18 (60)
9 (179)
38 (24)
31 (1)
1 (150)
13 (133)
43 (0)
23 (100)
15 (79)
16 (19)
19 (117)
30 (7)
2 (40)
11 (2)
28 (10)
29 (6)
3 (52)
32 (0)
35 (3)
25 (5)
20 (116)
40 (23)
5 (4)
4 (43)
27 (19)
26 (12)
24 (11)
36 (0)
37 (3)
39 (8)

Figure 11.

in the Abrigo section. In the cross section it is represented only in holes 28-16 and 28-23 where it is less than 10 feet thick. It is better represented in long section where it obtains a maximum thickness of 80 feet (hole 28-20) in the lower limb.

Classification of CRD Ores

Based upon mineralogy, three major and distinct types of "ore" are present in the Star Hill CRD. These are: 1) magnetite-specularite-pyrite-chalcopyrite, 2) pyrite-chalcopyrite, and 3) sphalerite-pyrite-chalcopyrite ± galena ores. While distinct in isolated drill intercepts, these three probably represent "end members" in a continuum containing mixtures of the various mineralogical types.

Magnetite-Specularite-Pyrite-Chalcopyrite Ores. This type of ore consists of generally medium- to coarse-grained aggregates of magnetite ± specularite accompanied by distinctly subordinate amounts of pyrite and chalcopyrite. While the relative amounts of the various minerals varies widely, the iron oxides usually constitute >60% of the metallics, the sulfides <40%. In many intercepts specularite exceeds magnetite, and locally, sulfides may exceed oxide content. Pyrite-chalcopyrite ratios are typically in the 80:20 to 90:10 range. While the ore may be compact and well indurated, more typically it is loosely granular, friable, or vuggy, and contains significant amounts of iron-stained white or green clays and jasperoid.

While the details of the paragenesis of this ore type have not been established by polished section study, megascopic observations clearly show that the magnetite-specularite formed earliest, and was both cross-cut and replaced by later pyrite-chalcopyrite. Locally, as illustrated in figure 14, delicate pyrite-magnetite replacement textures have been preserved.

Metal content of magnetite-bearing ores varies widely. While copper assays of up to 9% have been obtained over five foot intervals, grades of 0.5 to 3.5% over tens of feet are more representative. Gold is widespread in magnetite-pyrite-chalcopyrite ores, but is very erratically distributed. Values exceeding 0.1 opt Au over five foot intervals are not uncommon, but values in the 0.0X opt range over longer intervals are more typical. No significant amounts of zinc, lead, or silver have been found in this type of ore.

While the iron oxide content of this class of ore is typically ±60%, short intervals may consist exclusively of solid magnetite and contain less than 1-2% gangue minerals. This remarkable concentration of magnetite in the core zone of the CRD generates a sharp airborne magnetic anomaly (fig. 15), a characteristic which may be of value in the search for CRDs elsewhere in the district.

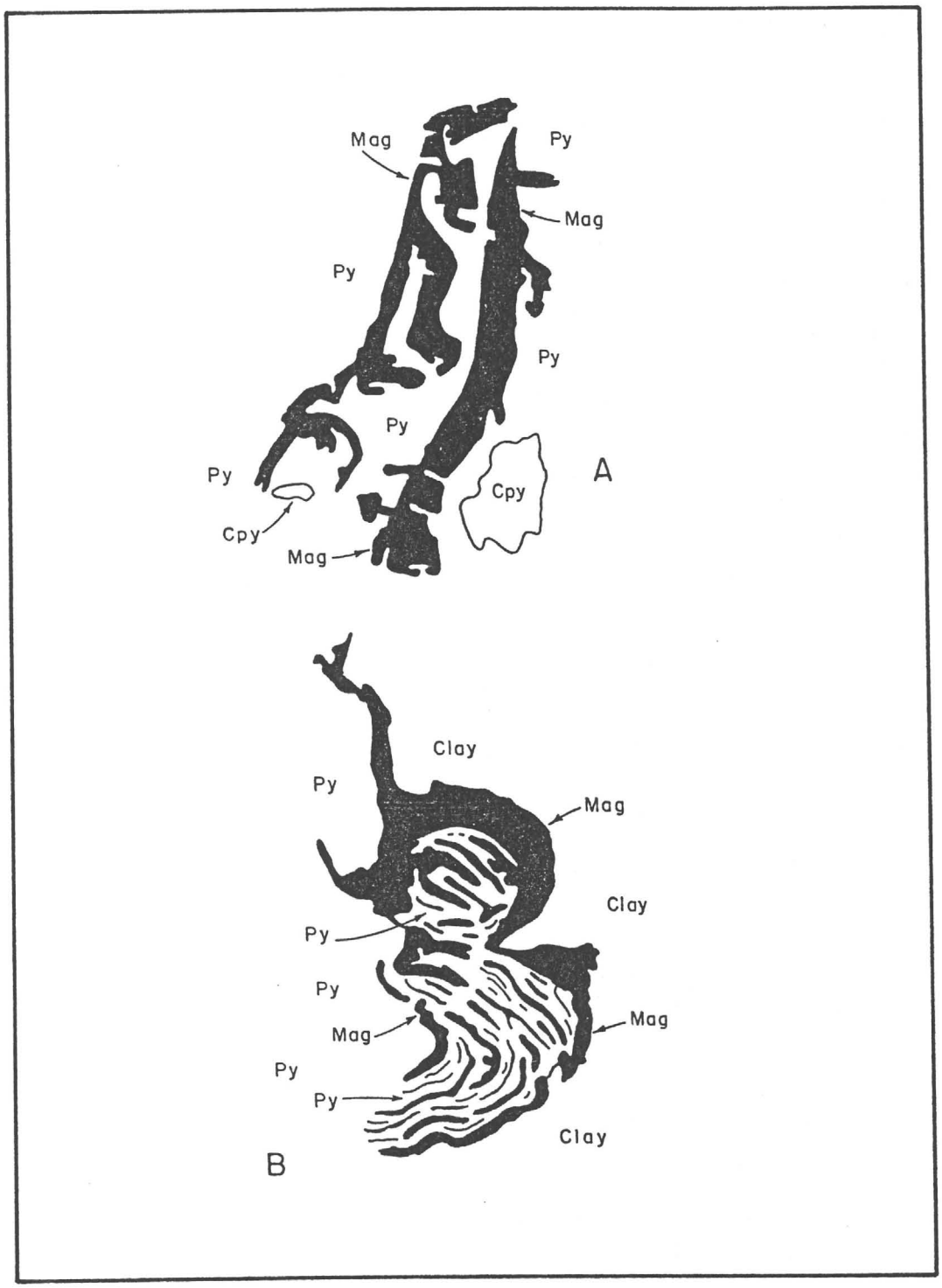


Figure 14.

Replacement textures in core from DDH 28-9. A: magnetite engulfed and replaced by pyrite, possibly along skeletal crystal boundaries. B: fine rhythmic pyrite replacement fronts in magnetite. Scale approximately 1.5X actual size.

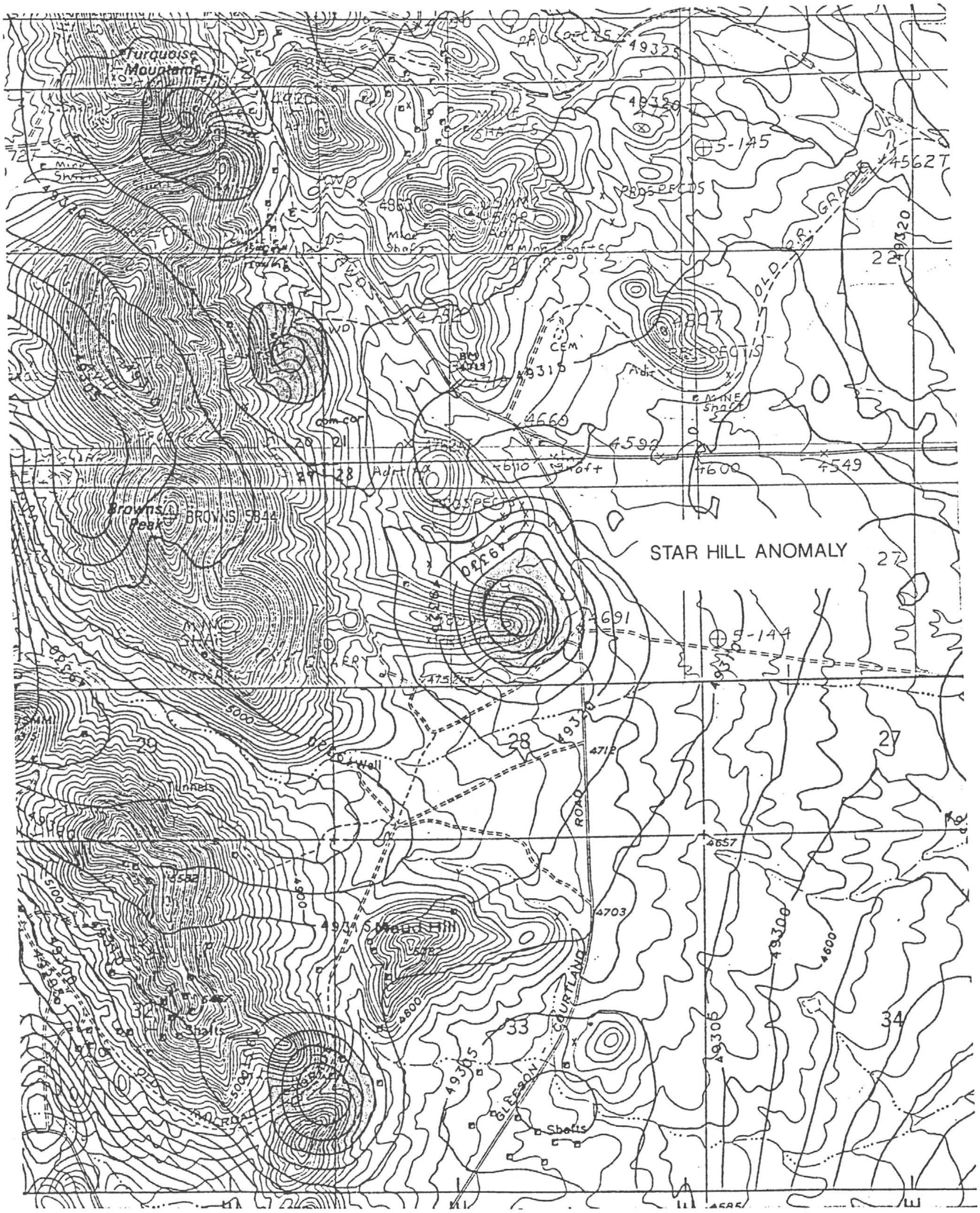


Figure 15.

Total field magnetic anomalies in the Courtland-Gleeson district. Flight altitude 500 feet, line spacing 200 meters, contour interval 5 gammas.

Pyrite-Chalcopyrite Ores. This type of ore is perhaps the most common and widespread in the Star Hill CRD. It consists of semi-massive to massive fine- to coarse-grained pyrite (25-75%), with intergranular chalcopyrite, and calcite, chlorite, clay, and/or silica gangue. Rarely, long intervals consist exclusively of massive pyrite. Pyrite to chalcopyrite ratios are characteristically in the 80:20 to 90:10 range, although chalcopyrite may exceed 30% over short intervals. In fresh core, the chalcopyrite content is difficult to ascertain, but left to oxidize for a few days, it becomes readily apparent. Even so, copper assays frequently exceed that indicated by chalcopyrite percentages, suggesting the presence of cupriferous pyrite. The ore is usually dense, compact, and well indurated, although locally crumbly or vuggy. Faint banding, inherited from Abrigo bedding, is occasionally present. Cataclastic texture is common.

The copper content of pyrite-chalcopyrite ores ranges from <0.5% to slightly greater than 1.5% over long intervals; values exceeding 2.5% over five foot intervals are rare. Significant lead, zinc, or silver values are absent; the only exception being 56 feet of pyrite-chalcopyrite CRD in hole 28-26 which ran 0.24 opt Ag, and 40 feet in hole 28-7 which ran 0.64 opt. Gold values are generally low - in the 0.01 - 0.03 opt range - and erratically distributed. An apparent exception is found in hole 28-8 where one foot of pyrite-chalcopyrite CRD ran 1.620 opt Au; small flakes of native gold were visible in the interval. A 64 foot run of mixed magnetite- and pyrite-dominant CRD types, which included this one foot interval, assayed 0.116 opt Au.

Sphalerite-Pyrite-Chalcopyrite ± Galena Ores. This type of ore consists of fine- to coarse-grained granular aggregates of sphalerite and pyrite with subordinate amounts of chalcopyrite and galena. Sphalerite typically exceeds pyrite in abundance, although the reverse have been observed. The most characteristic composition is sl>py>>cpy≥gl, in a typical ratio of 60:30:5:5; extremely different ratios are locally present. Sulfide content of sphalerite-rich CRD ranges from semi-massive (30% sulfides) to massive (>60%); the remainder of the rock is composed of carbonate, clay, and/or siliceous gangue. The ore is generally moderately indurated, but punky, friable, vuggy, or cavernous intervals are also common. Sphalerite-rich mineralization is also found replacing matrix or filling interstices between clasts in cavern-related solution collapse breccias which are erratically distributed in the footwall of zinc-rich CRDs. Another type of zinc mineralization, present either in the immediate foot or hanging wall of the CRDs, occurs in tan, strongly silicified and dolomitized Abrigo with a distinctive honeycomb structure. The rock is remarkably heavy and commonly assays several percent zinc. The mineralogy of the zinc in this rock is unknown.

The paragenesis of sphalerite-rich ore has not been studied in detail. Megascopic observations suggest the sequence pyrite-amberjack - blackjack - chalcopyrite - galena. Blackjack

sphalerite commonly rims amberjack grains and is cut by chalcopyrite veinlets, while galena is seen to vein sphalerite grains. Polished section study will be required to verify this proposed paragenesis.

As the mineralogical composition of these ores suggest, zinc assay values always exceed copper values over mining widths. Short intervals exceeding 10% zinc have been cored, but more typically, grades of 1-2% Zn over widths of 10 to 80 feet characterize this ore type. Copper values, over similar widths range from 0 to 1%. Lead values are generally less than 1% (Appendix I); the richest interval cored (hole 28-35) ran 3.36% Pb over six feet. Silver values are erratically distributed and generally less than 1 opt (Appendix I). Hole 28-24 contained the highest grade interval: 2.84 opt over 10 feet. Gold values in most sphalerite ores are less than 0.01 opt; where present at all, grades do not exceed 0.02 opt, except for one 9 foot interval in hole 28-7 which graded 0.116 opt.

Mineral Zoning

The Star Hill CRD displays a distinct zonation of the ores discussed above. Figure 16 shows the areal distribution of the various ore types based on the generalized data from Appendix I. The plot shows that base-metals zone outward from a copper-rich core zone, centered approximately on hole 28-38, to zinc-rich margins both along strike and down the limbs of the folded mantos. In a similar fashion, precious metals zone from a gold-enriched core zone of magnetite-specularite-pyrite-chalcopyrite and pyrite-chalcopyrite ore types, to a gold-poor, silver-rich marginal zone of sphalerite-pyrite-chalcopyrite ore which may extend as far south as drill holes 28-6 and -7.

A similar zoning pattern is also seen in section. Data plotted in longitudinal section (fig. 13) shows a copper-rich zone near the CRD - breccia contact (hole 28-14), grading southeastward along strike into a zinc-rich marginal zone. Local reversals are present, however, along the lower limb of the Zone I and II mantos where isolated magnetite-rich ores are found further from the "core zone" than in the upper limbs. In general, however, the following metal zoning is apparent in both plan and section:

Magnetite-Chalcopyrite → Pyrite-Chalcopyrite → Sphalerite-Pyrite

Gold → Silver — Precious Metals

Copper → Zinc — Base Metals

"Core Zone" → "Marginal Zone"

An apparent complication in this simple zoning pattern is that magnetite ± specularite-pyrite-chalcopyrite and pyrite-chalcopyrite ore types occur together, interlayered in the "core zone". In hole 28-38, for example, the lower limb Zone I CRD shows the following pattern:

561-566': pyrite-chalcopyrite CRD
566-576': magnetite-specularite-pyrite-chalcopyrite CRD
576-580': pyrite-chalcopyrite CRD

Drill holes further towards the northeast show a more complex down hole pattern, generally as follows:

pyrite-chalcopyrite CRD
magnetite-specularite-pyrite-chalcopyrite CRD
pyrite-chalcopyrite CRD
magnetite-specularite-pyrite-chalcopyrite CRD
pyrite-chalcopyrite CRD

It is proposed that these patterns are the result of a combination of alteration and folding. In the simple, unfolded case of the 28-38 intercept, a magnetite-rich core is surrounded by a pyrite-rich shell. As discussed previously (p. 40) there is evidence that magnetite has been replaced by pyrite in the CRD. It is suggested then, in this example, that an early magnetite-rich CRD was replaced along its outer margins by pyrite to yield the existing pyrite-magnetite-pyrite layering. The more complex pattern of alternating ore types, outlined above, is found in holes in the hinge zone of the fold (e.g. in holes 28-8, -9, -12, -13, and -14), and therefore represents a fold repetition of the 28-38 pattern as shown in figure 17. Thus, ore types zone outward from a magnetite-specularite-pyrite-chalcopyrite core to a pyrite-chalcopyrite shell in the "core zone", and then zone laterally into a sphalerite-pyrite-chalcopyrite "marginal zone" as shown on figure 16.

Alteration

Numerous kinds of alteration are associated with the Star Hill CRD; the following section describes only the most important types and their zonal distribution.

Strong clay alteration of the host Abrigo limestone is the most widespread and characteristic type of alteration accompanying the CRD in all mineral zones. White to tan, non-swelling clay occurs in either or both the footwall or hanging wall of the mantos; more rarely it is interlayered in the CRD itself. This alteration, which in most instances represents the complete destruction of the Abrigo protolith, extends a few feet to over 20 feet away from the massive sulfides. It is commonly accompanied by chlorite development, silicification, and minor finely disseminated sulfides.

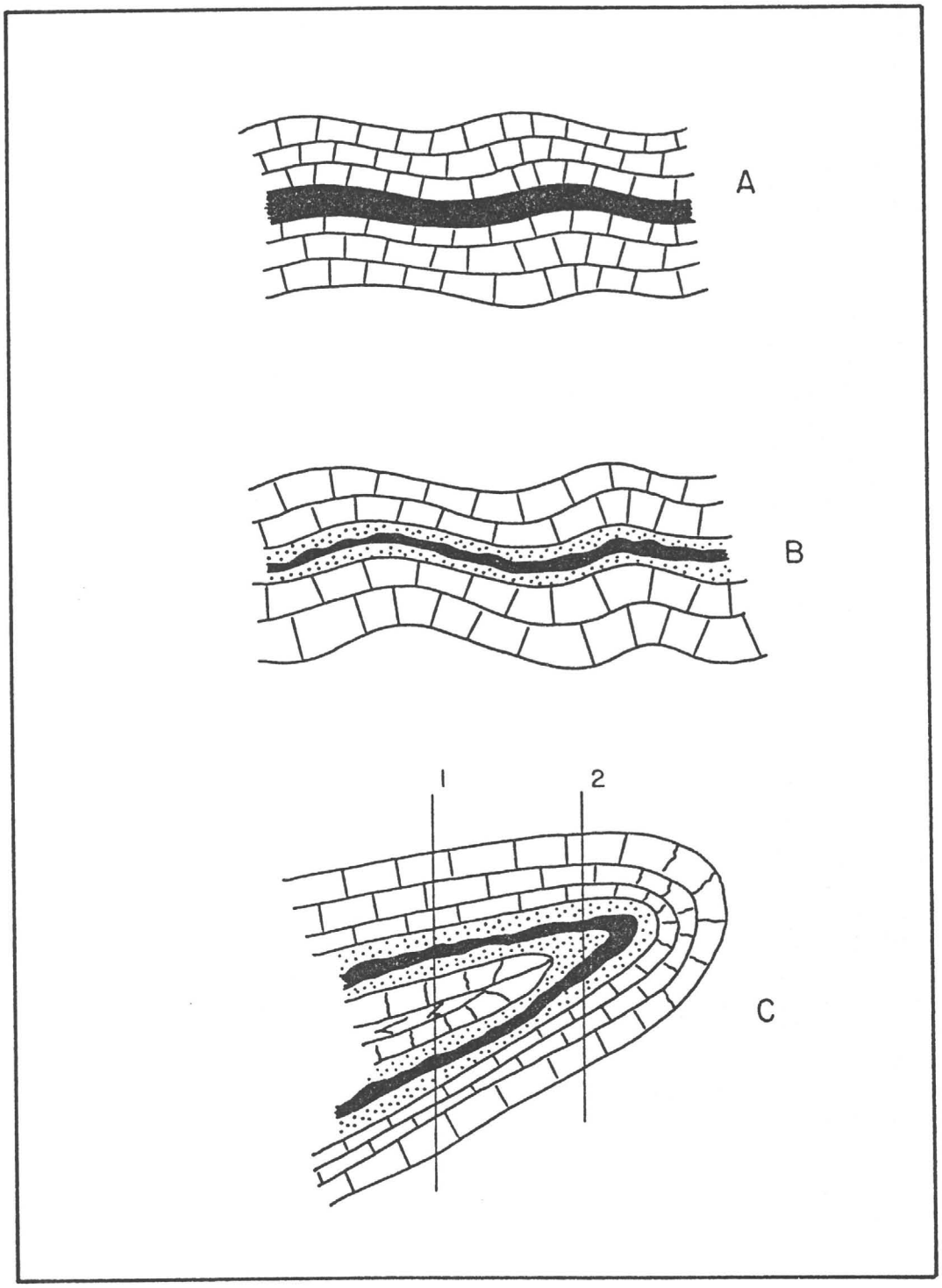


Figure 17.

Development of simple and apparently complex zoning between magnetite-specularite-pyrite-chalcopyrite ore (solid) and pyrite-chalcopyrite ore (stippled). A: early magnetite-specularite manto development. B: marginal replacement by pyrite-chalcopyrite. C: folding of compound manto. Two simply zoned CRD intercepts appear in drill hole 1, while one "complexly" zoned intercept appears in drill hole 2.

Jasperoid is also widely associated with CRD mineralization in all ore zones, but is more erratically distributed then clay alteration. The jasperoid ranges from gray to maroon in color, is typically vuggy or cavernous, but in places dense and massive, and commonly is strongly pyritic (± chalcopyrite). Like clay alteration, jasperoid is developed in either or both the hanging or footwall, but shows a slight preference for the latter. It also occurs as irregular patches within the mantos. While it may comprise the only alteration shell, jasperoid most typically occurs interlayered or otherwise associated with clay alteration. Generally, jasperoid extends only a few feet from the CRD; exceptionally, thicknesses exceeding 20 feet have been cored.

Magnesium alteration is of more restricted distribution than clay or jasperoid, occurring primarily with the sphalerite-pyrite-chalcopyrite ore type. A typical envelope, which may extend several tens of feet away from the CRD is: 1) CRD, 2) talc ± chlorite ± dolomite, 3) dolomite ± talc, 4) dolomite ± clay, and most distal 5) recrystallization and bleaching ± clay. The recrystallized zone is commonly represented by massive, coarse-grained calcite marble.

Minor, weak manganese oxide alteration is also apparently restricted to the zinc zone, and is evidenced by the presence of pink carbonate proximal to massive sulfide mineralization. The pervasive and widespread MnO alteration which accompanies the large Mexican CRDs is lacking in the Star Hill deposit.

The development of karst features proximal to the Star Hill mantos may represent an alteration phenomenon. Open caves have been found in four drill holes in the immediate stratigraphic footwall of massive sulfide bodies. Solution collapse breccias have also been found in these, and several other holes, in similar positions. The honeycomb-structured alteration, discussed above, may be a related phenomenon. Cave floor rubble, collapse breccias, and honeycomb altered areas all have been strongly silicified and/or dolomitized, and some host weak sulfide mineralization. These karst features are thus either pre- or syn-mineral; they are clearly not post-mineral oxidation cavities. The lack of caves or solution breccias remote from the mantos suggests (but does not prove) that karst formation was related to the mineralizing event. Further, there is no evidence that Star Hill sulfides filled pre-existing caves (see Landis and Tschauder, 1988 for a description of this type of mineralization). It is therefore possible that the caves and solution breccias in the Star Hill area formed as a result of hydrothermal karsting.

GENESIS OF MINERALIZATION IN THE STAR HILL AREA

The following paragraphs place the data and ideas of the preceding sections into a chronology which outlines the genesis of the various types of mineralization in the Star Hill project area. Emphasis is placed on the development of the carbonate replacement deposit, the source of the fluids responsible for its formation, and possible structural and stratigraphic ore controls.

Jurassic magmatism was first manifested in the Star Hill area by the intrusion of the Star Hill and Copper Belle porphyries. It is believed that these were sequentially emplaced at a relatively high crustal level in advance of the rising magma of the Gleeson quartz monzonite stock, from which the porphyries were derived. The magma taps for the Star Hill and Copper Belle are envisioned as normal faults formed in the tensional environment in the expanding roof zone over the rising magma chamber. Upon reaching the Abrigo section the Star Hill, and later the Copper Belle magmas spread laterally along bedding planes to form a thick compound sill.

Sill emplacement was both accompanied and succeeded by porphyry copper-style mineralization in both the Copper Belle and the earlier Star Hill porphyry. Small amounts of disseminated chalcopyrite apparently crystallized along with the intrusives as an accessory mineral. With the establishment of convecting cells of ground water heated by the invading porphyries, the Star Hill - Copper Belle sill experienced pervasive silica and clay alteration which was accompanied by veinlet-controlled chalcopyrite-pyrite mineralization. It is believed that this copper mineralization was derived from the early "accessory" chalcopyrite which was leached, concentrated, and re-deposited in veinlets by locally circulating hydrothermal fluids.

The continued upward movement of the Gleeson stock magma resulted in the formation of additional normal faults in the roof zone. These northeast- and northwest-trending faults tapped additional magma, resulting in the emplacement of the Sniveler porphyry. With continued upward movement and increasing volatile content, subsequent intrusions derived from the Gleeson stock magma were emplaced more forcefully along the actively evolving faults in the roof zone. Two such intrusions were the Sniveler and Courtland breccias.

The focus of Sniveler breccia intrusion appears to have been at the intersection of a re-opened northeast-trending fault, previously intruded by the Sniveler porphyry, and a northwest trending fault. The geometry of the intrusion is believed to have been a vertically standing, ellipsoidal pipe. Repeated movement on the two faults re-opened the structural intersection and allowed the subsequent intrusion of the Courtland breccia.

Its rock flour matrix suggests a violent, even explosive penetration which entrained fragments of deep-seated (?) granites, Paleozoic rocks, and clasts of earlier mineralized Star Hill and Copper Belle porphyries.

Continued fault movement and repeated episodes of breccia injection in the Sniveler-Courtland pipe provided numerous channelways for the upward movement of magmatically derived mineralizing fluids. These fluids are believed responsible for the formation of both disseminated and stockwork copper-gold (and very minor zinc, lead, and silver) mineralization hosted within and along the margins of the breccias. Mineralization in the breccias is of higher grade than that in the early porphyries, probably reflecting the increasing concentration of metals and volatiles in the rest melt of the crystallizing Gleeson stock.

The same fluids responsible for mineralization and alteration within the breccia pipe are believed to have been the source of the Star Hill CRD. Three lines of evidence support this idea: 1) the close spatial relationship between the breccia and the CRD, 2) mineral and metal zoning in the CRD which appears centered on the breccia pipe, and 3) the similarity of mineralization in the breccia pipe and that in the "core zone" of the CRD.

The spatial relationship between the breccia and the Star Hill CRD is shown on figure 18. The important features of the diagram are: 1) the Star Hill deposit directly abuts the breccia pipe, 2) the CRD is thickest near the breccia and thins away from the pipe, and 3) CRDs do not occur in areas where breccias do not occur. These relationships strongly suggest that the CRD-generating fluids emanated from the breccia pipe.

Further evidence that the breccia was the source of the mineralizing fluids lies in the pattern of metal zoning in the CRD. The mineral and metal zoning of the Star Hill CRD, discussed in a preceding section and illustrated in figure 16, is typical of those documented in many of the classic CRD districts which show a magnetite-chalcopyrite-gold zone to lie closest to the source intrusive, while zinc-silver (-lead) mineralization forms a distal zone, peripheral to the source. Excellent examples of this may be observed in the metal-mineral zonation around the Breece Hill intrusive center in the Leadville district (Emmons, et.al, 1927; Thompson, 1988). That the high magnetite-chalcopyrite-gold zone at Star Hill lies adjacent to the breccia and grades outward into a sphalerite-silver zone away from the pipe suggests that the mineralizing fluids emanated from the breccia - a situation entirely analogous to similarly zoned mineralization around the Condesa breccia in the Potosi Mine at Santa Eulalia.

A final line of evidence supporting a breccia pipe source for the CRD mineralizing fluids is the similarity of the mineralization in the breccia and that in the "core zone" of the

replacement deposit. Save for the magnetite-specularite component (discussed below) the mineralogy, as well as the base and precious metal content of the proximal part of the CRD is very similar to that of the pyrite-chalcopyrite-gold stockworks and disseminations in the breccia (Appendix I). Further, the presence of minor amounts of sphalerite, galena, and silver in the breccia shows that these metals, too, were transported in solution through the pipe, the bulk of which were subsequently deposited in the more "distal" parts of the CRD. Additional metal ratio and trace element analyses are clearly needed, however, to support these speculations.

It is concluded, based on the evidence above, that the mineralizing solutions responsible for the development of the Star Hill CRD were channelled upward through the Courtland-Sniveler breccia pipe. Upon reaching two specific "favorable" horizons in the enclosing Abrigo formation, these fluids reacted with the carbonate rocks, spreading laterally to form the two Star Hill mantos.

As argued earlier, it is believed the first phase of CRD mineralization was the deposition of magnetite-specularite. The focus of magnetite deposition was immediately adjacent to the breccia (fig. 16) in two "favorable" Abrigo beds (Zones I and II, fig. 13). The mineralogy and proximity to an igneous contact of this early mineralization suggests the resulting deposit may have been pyro-metasomatic. Only small, possibly isolated pods of magnetite formed more remote from the breccia (fig. 13). A drop in the temperature of the mineralizing solutions into the pyrite stability field allowed the deposition of pyrite-chalcopyrite ± gold ores. This allowed not only ore deposition in the more distal pyrite-chalcopyrite mineral zone (fig. 16), but also resulted in the marginal replacement of the proximal magnetite-specularite zone by iron and copper sulfides (fig. 17). An analogous situation is found in the ore deposits of the Penn and Ibex mines in the Leadville district (Emmons, et. al., 1927). Further cooling of the fluids, as they moved away from the breccia along the two "favorable" Abrigo beds, resulted in the sequential deposition of sphalerite ± galena ± silver ± gold in the most distal parts of the Star Hill mantos (fig. 16).

That the deposition of the Zone II manto was stratigraphically controlled by a "favorable" bed of limestone in the Abrigo is reasonably clear (figs. 12 and 13). The depositional control of the Zone I manto is less certain. Figure 12 shows Zone I mineralization to occur directly below or a very short distance beneath the Star Hill-Copper Belle sill. The occurrence of CRDs beneath the Pando porphyry sill in the Gilman district, and beneath the White and Gray porphyry sills in the Leadville district has been interpreted by numerous investigators as having been caused by the ponding of mineralizing fluids beneath an impermeable capping sill; the "favorability" of the replaced rock being of secondary importance. Figure 13 shows the upper limb Zone I manto is lacking in holes 28-38, -3 and -20

despite the presence of the Star Hill-Copper Belle sill in contact with Abrigo limestone. It is possible that at these locations the sill complex cut slightly down bedding, eliminating the "favorable bed". It is equally likely, however, that the "favorable bed" exists in this area but simply was not replaced (fig. 12: hole 28-8). The second possibility is favored. It is nonetheless believed that the sill complex served, in some degree, in confining fluids to this bed, preventing their escape upward to other possibly "favorable beds" higher in the section.

The presence of CRD clasts in the breccia pipe presents an apparent difficulty with the timing of mineralization in this model. Two possibilities exist: 1) the formation of the pipe occurred in multiple stages of pre-, syn-, and post-mineral timing, or 2) the pipe is entirely of post-mineral age. While the first case is clearly favored, and is supported by well studied examples in some Mexican CRDs (Miranda and Megaw, 1986), and by the several local lines of evidence outline above, there is insufficient data to disprove the second case. In either case, the geometry and mineral zoning of the CRD indicate the mineralization was derived, if not from fluids emanating of from the breccia itself, then from a structural conduit subsequently intruded by the breccia. Lacking persuasive evidence, it is suggested that the pipe was the fluid conduit, and that intrusive activity in the pipe continued after the formation of the CRD which resulted in the incorporation of proximal parts of the orebody into the breccia.

The structural events of the Laramide and the Basin and Range periods had important economic results for the Star Hill deposit both in terms of what did and what did not happen to the orebody. Recumbent folding during the Laramide doubled the thickness of a major part of the copper-rich zone of the CRD, rendering a potentially economic ore deposit from what otherwise would be an uneconomically thin zone of mineralization. Thrust faulting, which immediately followed, neatly scraped the folded orebody, intact, off of the autochthon, and carried it to its present position without important imbricate smearing. Basin and Range faulting fortuitously left the orebody intact in an isolated and only weakly faulted horst, surrounded east and west by much more profound faults which would have thoroughly dismembered the Star Hill deposit. Those basin-range faults which are present in the deposit area, while not seriously disrupting the continuity of the CRD, served instead to localize supergene chalcocite derived from disseminated chalcopyrite mineralization in the Copper Belle and Star Hill porphyries.

SUMMARY

The following is a listing of the geologic features of, or associated with the Star Hill CRD which are believed to form important criteria for further exploration in the Courtland-Gleeson district.

1. Reactive Paleozoic Carbonate Stratigraphy. Two stratigraphic zones, thought to lie in the upper part of the Abrigo formation, host the manto deposits of the Star Hill CRD. The lower Abrigo, Pima sandstone, and Bolsa quartzite have been found to be unfavorable hosts. Carbonates higher in the section, such as the Martin, are mineralized in the Warren district, and may be CRD hosts elsewhere in the Courtland-Gleeson area.

2. Structural Intersections as Channelways for Mineralizing Fluids. In the Star Hill area, the intersection of pre- or syn-magmatic, northeast- and northwest-trending faults is believed to have created a nearly vertical, open channelway (occupied by a breccia pipe) for rising mineralizing fluids which were responsible for the formation of the CRD. Intersections of faults of similar age but differing orientations may have been important in localizing ore elsewhere in the Courtland-Gleeson district.

   2a. Late Stage Dikes. Late stage intrusives, such as the Sniveler porphyry, while not directly related to mineralization, serve to delineate otherwise obscure pre-mineral faults.

   2b. Breccia Pipes. Breccia pipes serve to pin point profound pre-mineral structural intersections, and may have served as taps for magmatically derived mineralizing solutions. At Star Hill, it is believed that the compound Sniveler-Courtland pipe served both as a fluid tap and conduit through which mineralizing solutions rose into reactive carbonate stratigraphy.

3. Thick Sills of Igneous Rock. Sills of Star Hill and Copper Belle porphyry may have served as impermeable barriers, trapping mineralizing solutions in reactive carbonate stratigraphy. While their importance, relative to the "favorability" of certain limestone beds, in localizing manto-style replacements is uncertain, the presence of igneous sills within a carbonate stratigraphy cannot be regarded as unfavorable with regard to CRD development.

4. Mineral and Metal Zoning. The Star Hill mantos show a fairly well developed mineral and metal zoning. The zoning patterns established at Star Hill may serve to establish vectors towards copper-gold "core zones" in CRD systems which may be discovered in other parts of the Courtland-Gleeson district.

5. Magnetic Anomalies. The remnant magnetite "core" of the Star Hill CRD is clearly reflected as an airborne magnetic anomaly. Other anomalies in the district may reflect similar mineralization. It should be noted, however, that in other CRDs, replacement of the magnetite "core" by pyrite may have been more extensive than at Star Hill, or may have proceeded to completion. In these instances, the magnetic expression of CRD mineralization may be diminishingly small or altogether absent.

6. Folds. While not related to the process of mineralization, the Star Hill anticline served to double the thickness of the "core zone" of the CRD, increasing its economic potential. Folded terrane undoubtedly exists elsewhere in the Courtland-Gleeson district. The identification of such terrane, in conjunction with the presence of other important geologic features discussed above, would outline an area of unusually high exploration and economic potential.

EXPLORATION RECOMMENDATIONS

Potential extensions of the Star Hill CRD lie in three areas. The first lies northwest of the crest of Star Hill where the northwest-trending strike extension of known mineralization may occur. The second area lies between drill hole 28-24 and holes 28-6 and -7, where the southeastern part of the CRD system has been inadequately explored. The final area, located east of the Star Hill deposit, may host mineralization in carbonates stratigraphically above the Abrigo. These three areas are outlined on figure 19.

Area I outlines ground having the highest potential for hosting copper-gold CRD mineralization, and should be drilled on a priority basis. It is believed that this area may contain mineralization which is the "mirror image" of the Star Hill CRD, lying on the northwest side of the Sniveler-Courtland breccia pipe and hosted by the continuation of the "Abrigo trend" (fig. 4). Potential copper-gold mineralization developed proximal to the northwest edge of the breccia pipe (fig. 16) may grade northward into the zinc-rich mineralization drilled by Newmont near the Highland shaft, immediately north of Area I, in a zoning pattern similar to that shown by the Star Hill deposit.

A potential problem in Area I involves the depth to the Courtland thrust. Hole 28-34 (Appendix II) showed the thrust to be rising rather abruptly to the north from the Star Hill valley (fig. 8). If this trend continues or steepens north of Star Hill, a significant part of the Abrigo and any CRD mineralization may have been cut out by the thrust.

Placement of the first drill hole in Area I involves several difficulties. Because the area is totally covered by Bolsa talus, and because the "Abrigo trend" bends to the northwest or is broken by a tear fault, the fold nose of Abrigo cannot be located by simple projection from the Star Hill deposit. In addition, there is no reliable estimate of the width of the breccia pipe, thus the Abrigo-breccia contact northwest of Star Hill cannot be accurately placed. The hole should be placed southwest of the Abrigo - sill complex hinge contact, and northwest of the Abrigo-breccia contact, but neither contact can be seen on the surface or located by projection. Initial hole placement, then, will be on a "best guess" basis. Five follow-up holes should be budgeted to allow for: 1) off-sets of the initial hole to locate the Abrigo/CRD if the first fails to do so, and/or 2) tracing the Abrigo/CRD trend relative to the first hole. The average TD of these holes will have to be slightly deeper than in the Star Hill area because of topography: approximately 1,100 feet, for a total of 6,600 feet. Because of the sensitivity of the target to structure and subtle differences in lithologies, it is recommended that this footage be cored.

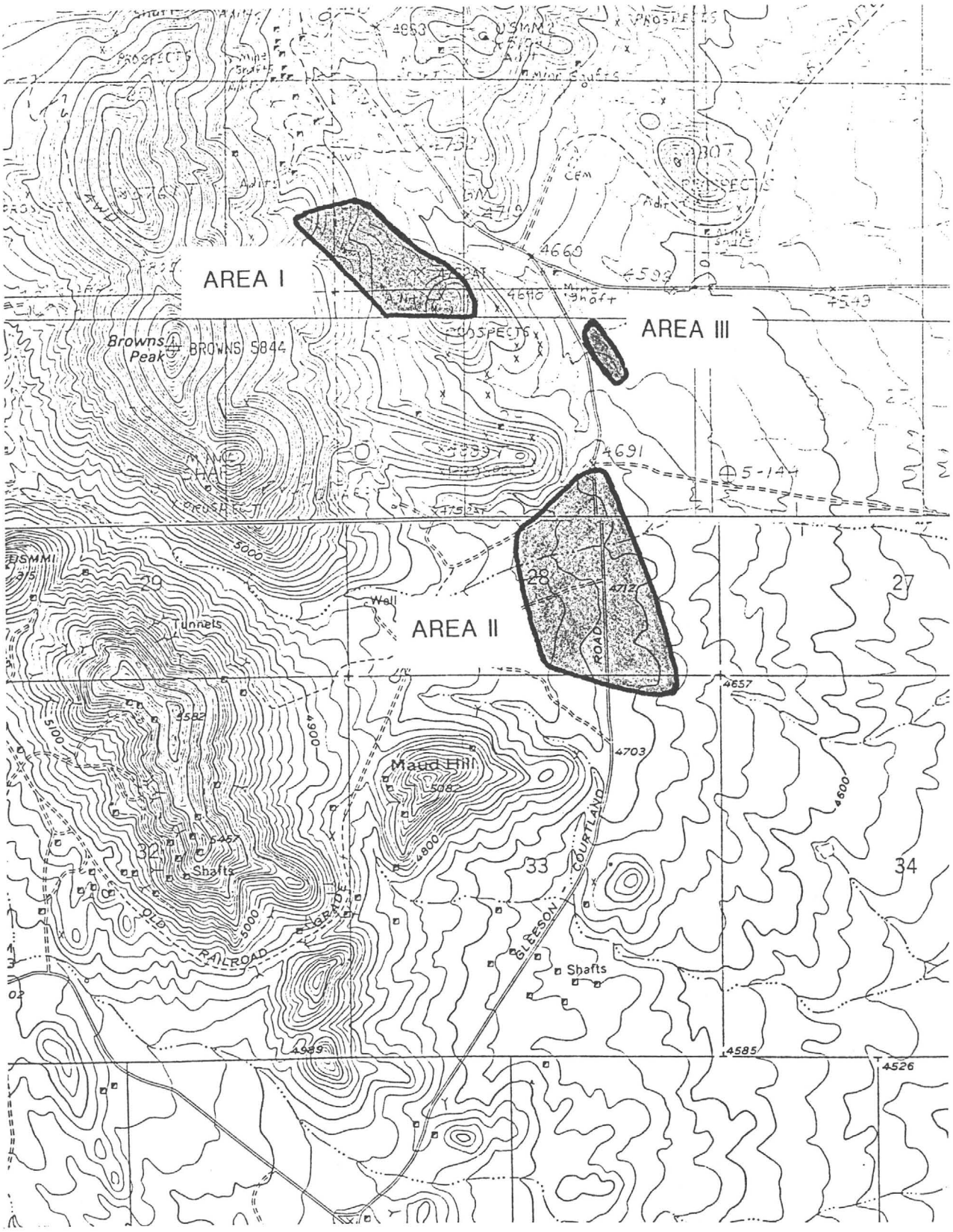


Figure 19.

Areas recommended for additional exploratory drilling.

Area II encompasses the southeastern strike extension of the Star Hill CRD which has been inadequately explored by drill holes 28-6 and -7. The area is limited on the northeast by a simple projection of the Abrigo-sill complex hinge contact (fig. 11), on the northwest by completed drilling (Plate II), and on the south by the probable existence of a major structure in Rat Canyon (fig. 4). Mineral zoning patterns indicate that CRD mineralization in Area II will be of the sphalerite-pyrite type which may host economic amounts of silver ± gold (Appendix I); the occurrence of significant copper-gold mineralization in this area is unlikely. Six initial reverse circulation-piloted core holes, with an average TD of 1400 feet, are recommended: four holes at 200 foot spacings between holes 28-24 and 28-6, with two holes off-set 100 to 200 feet east or west of the line, as dictated by drill results.

Area III, is recommended as the site for one wildcat core hole. The purpose of this hole would be to investigate the potential for the occurrence of a CRD hosted by upper-most Abrigo or Martin carbonates which may occur stratigraphically above the Star Hill-Copper Belle sill complex. If the feeder breccia pipe pierced the sill complex and extended upward through the Martin, and if the sill did not trap the bulk of the mineralizing fluids beneath it, there is a reasonable possibility that CRD development occurred above the sill in lithologies which host important ore at Bisbee.

Completed drilling shows the sill complex to have an absolute minimum thickness of about 350 feet; it may be considerably thicker. Assuming a true thickness of twice this number, the proposed hole would have to be located 700 to 1000 feet to the northeast of the Abrigo-sill hinge line contact to drill rock lying stratigraphically above the sill. If ore occurs in this area, it may lie immediately under 100 to 200 feet of gravel and may be supergene enriched. Potential problems include: 1) severe basin-range faulting which may have dropped the target to unacceptable depths, and 2) the Courtland thrust which may be close to "skying out" in the target area. Despite these potentialities, a drill hole, to be sited near the center of Area III, is recommended - to be piloted by reverse circulation drilling to the gravel-Paleozoic contact (±200 feet), and then cored to the Courtland thrust (±500 feet).

Clearly, drilling in Area I has the greatest potential for the discovery of an economic copper-gold deposit, and should receive priority over the other two areas. As this area is believed to contain "the other half" of the Star Hill deposit, it may host a copper-gold orebody of equal or greater size and grade than that already delineated south of Star Hill. In addition, if

this "mirror image" orebody exists, tracing it northward along strike and zoning should reveal an area of potentially economic zinc-silver ± gold mineralization similar to that already found in the area of holes 28-24 and -4.

The type of mineralization likely to be found in Area II (Zn-Ag ± Au), as well as the trend of increasingly thin CRD development away from the breccia (fig. 11), suggest that the potential for the discovery of an economic deposit here is less than in Area I. However, intercepts of +1.0 opt Ag and + 2% Zn, as well as the more scattered high gold intercepts already drilled (Appendix I), definitely warrant additional exploratory drilling in this area.

While exploration in Area III is of the lowest priority, the potential occurrence of reactive carbonate stratigraphy in close proximity to a known mineralized system demands eventual investigation. It is believed that the one recommended drill hole can resolve many of the structural uncertainties in this gravel-concealed area, and may offer sufficient encouragement to further explore this section of stratigraphy, if present, which hosts many of the important CRDs at Bisbee.

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Appendix I
Significant Assay Intervals
Star Hill Project, 28-Series Drill Holes

Hole No.	Interval (')	Thickness (')	Au OPT	Ag OPT	Cu %	Pb %	Zn %	Type Mineralization
28-01	249-395	146	0.014		1.20			Cc blanket in Jcmp + FeOx-py-cpy CRD
	(249-364)	115	0.016		1.41			FeOx-py-cpy CRD
28-02	330-445	115			0.40			Diss cpy in Jcbx
	520-555	35			0.27			Diss cpy in Jcbx
	625-744	119			0.32			Diss cpy in Jcbx + ca!
	785-802	17			0.96			FeOx-py-cpy CRD
	845-868	23			0.87			FeOx-py-cpy CRD
28-03	385-400	15			1.45			Cc blanket in Ca
	633-656	23			1.13			FeOx-py-cpy CRD
	763-798	35			1.65			Py-cpy CRD
28-04	207-282	75			0.21			Cc blanket in Jsmp
	312-370	58			0.64			Cc + cpy in Jsmp + jasp + ca
	492-516	24			0.19			Diss cpy in jasp
	515-561	46					6.09	Py-sl CRD + jasp
	867-879	12			0.33			FeOx-py-cpy CRD
	894-918	24			0.70			Py-cpy CRD
28-05	160-190	30	0.040		1.02			Py-cpy CRD + cc in Ca (minimal)
	1255-1270	15			0.43			Diss cpy in Jsmp
28-06	503-534	31		0.48	0.61			Skarn in Ca
	692-698	6		1.01			3.11	Skarn in Ca
	772-801	29		1.79	0.20		2.55	Py-sl CRD
28-07	1350-1385	35	0.033	1.13	1.03		2.78	Py-cpy-sl CRD
	(1350-1359)	9	0.116	1.79				Py-cpy-sl CRD
	1405-1445	40		0.64	1.38			Py-cpy CRD
28-08	406-524	118	0.069		2.33			FeOx-py-cpy CRD
	(411-491)	80	0.095		3.08			FeOx-py-cpy CRD
	(427-491)	64	0.116		3.27			FeOx-py-cpy CRD
	(434-435)	1	1.620		3.44			Fe-cpy CRD w/VG
28-09	369-429	60	0.02		1.78			FeOx-py-cpy CRD
	480-602	122	0.02		0.88			FeOx-py-cpy CRD + Jasp + Jsmp
28-10	115-140	25			0.41			Diss cpy in Jsmp
	305-360	55			0.28			Diss cpy in Jcmp
	430-500	70			0.37			Diss cpy in Jcmp (?) unknown purple

Hole No.	Interval (')	Thickness (')	Au OPT	Ag OPT	Cu %	Pb %	Zn %	Type Mineralization
28-11	110-140	30			2.43		2.80	Cc blanket in Ca
155	115-218	63			0.51		0.12	Cc blanket in Ca & Jsmp
	604-619	15			0.25			Py-cpy CRD – 1 ft in Ca
	652-776	124			0.43			Diss cpy + CRD clasts in Jcbx
	886-1051	165	0.01		0.32			Diss cpy in Jcbx
28-12	367-382	15			0.31			Diss cpy in fault gouge – poly lithic bx
	445-507	62			0.72			FeOx-py-cpy CRD
	538-595	57	0.03		1.31			FeOx-py-cpy CRD
	592-663	71			0.20			Diss cpy in Jcbx & Jcmp
28-13	149-189	40			0.54			Cc blanket in Jcmp
	209-249	40			0.29			Cc blanket in Jcmp / Shear zones
	393-423	30	0.03		0.50			Py-cpy CRD + Ca at top
	458-485	27	0.01		0.40			Py-cpy CRD
	528-581	53	0.02		2.61			FeOx-py-cpy CRD
28-14	378-450	72	0.11		1.11			Py-cpy CRD + cc
	595-675	80			1.12			FeOx-py-cpy CRD
28-15	260-385	125			0.35			Cc blanket in Jcmp + Py-cpy CRD fault between
	385-426	41			1.62	0.03		Py-cpy CRD
	479-505	26			0.94	0.01		Py-cpy CRD + Ca at top
	606-641	31			0.63	0.01		FeOx-py-cpy CRD
28-16	430-570	140			0.58			Diss cpy in Jcbx
	(465-495)	30			1.31			Diss cpy in Jcbx
	770-825	55			0.39			Diss cpy in Jcbx w/CRD blocks
	878-896	18	0.02		1.98			FeOx-py-cpy CRD + fault zone
28-17	60-97	37			0.82			Cc blanket in Jsmp
	120-152	32			0.43			Cc blanket in Jsvp
	(60-330)	270			0.24			Cc + cpy in Jsmp & Jsvp
	525-575	50			0.49			Diss cpy Jcbx & Jsvp
	617-639	22	0.01		0.45			Diss cpy in Jsvp
28-18	322-370	48			0.55			FeOx-py-cpy CRD – mostly bx
	462-485	23			0.30			FeOx-py-cpy CRD + Shear below
	535-575	40			0.26			Diss cpy in Jcbx
	727-763	36	0.01		0.45			FeOx-py-cpy CRD – mudelite Ca
	(750-763)	13			1.21			FeOx-py-cpy CRD
28-19	160-253	93			0.46			Cc blanket in Jcmp + 87' FZ + Star Hill at bttm
	335-355	20	0.01		0.16			Py-cpy CRD + Star Hill
	605-642	37	0.01		1.11			FeOx-py-cpy CRD

Hole No.	Interval (')	Thickness (')	Au OPT	Ag OPT	Cu %	Pb %	Zn %	Type Mineralization
28-20	250-391	141			1.42			Cc blanket in Jsmp & Ca
	(370-391)	21			1.93			Cc blanket in Ca: native Cu
	387-488	101					2.27	Py-sl-cpy CRD – mostly Ca only 9' CRD
	577-613	36	0.01		0.23		2.75	Py-sl-cpy CRD
	639-675	36	0.01		0.85			Py-cpy CRD + Jsvp bx
	807-860	53	0.04		0.69			Py-cpy CRD + Jsvp bx
28-21	85-140	55			0.57			Cc blanket in Jsmp
	505-545	40	0.01		0.27			Diss cpy in Jsbx
	630-645	15			0.41			Diss cpy in Jsvp
28-22	640-695	55			0.32			Diss cpy in Jsvp & Ca
28-23	(284-297)	13	0.01		0.49			Py-cpy CRD
	435-485	50	0.01		0.55			FeOx-py-cpy CRD + Jcbx
	730-767	47			0.64			FeOx-py-cpy CRD + Jcbx
28-24	160-200	40			0.21			Cd blanket in Jsmp & Jcmp
	540-563	23					2.13	Py-sl CRD
	620-635	15					1.45	Py-sl CRD
	795-805	10	0.01					Diss py in Jsmp
	840-869	29	0.02		0.46		0.91	Py-cpy-sl CRD + diss + Ca above
	(859-869)	10		2.84				Py-cpy-sl CRD
	889-913	24	0.02	1.09			2.43	Py-sl CRD + diss + Ca + Jsmp
28-25	125-140	15			0.61			Cc blanket in Jsmp
	195-290	95			0.39			Cc blanket in Jsmp & Ca
	510-570	60					1.00	Diss sl in Ca
	745-790	45					1.10	Diss sl in Ca
	969-1045	76					1.32	Diss sl in Ca
28-26	80-100	20			0.92			Cd blanket in Jcmp unknown peak
	353-380	27	0.01		1.27			Cc blanket in Jcmp
	375-399	24					1.23	Diss sl in Jcmp
	523-572	49					1.21	Py-sl CRD + diss 6' CRD in Ca
	910-966	56	0.02	0.24	1.45			Py-cpy CRD + jasp + Jsmp
28-27	195-230	35			0.36			Cc blanket in Jsmp
	265-290	25			0.61			Cc blanket in Jsmp
	305-320	15			0.59			Cc blanket in Jsmp & Ca
	595-623	33					1.35	Diss sl in Ca
	628-645	17			0.58			Py-cpy CRD 10' CRD 5' Ca
	645-715	80					1.08	Py-sl CRD + diss NO CRD logged!
	(690-745)	55			0.30			Py-sl-cpy CRD 4' CRD mostly Ca

Hole No.	Interval (')	Thickness (')	Au OPT	Ag OPT	Cu %	Pb %	Zn %	Type Mineralization
28-28	150-235	85			0.32			Diss cpy in Jsmp
	270-290	20			0.31			Diss cpy in Jsmp
	298-354	55				0.50	2.17	Py-sl-gl CRD – intermittent in Ca
	(314-354)	40		0.50				Py-sl-gl CRD "
	397-467	70					1.38	Py-sl CRD + diss only 2' CRD Ca + F3
	561-568	7	0.04		0.26		3.12	Fault gouge - Ca & Jcmp
	584-590	6			0.33		8.53	Py-cpy-sl CRD ~~4' CRD + Ca + Eap~~
28-29	110-148	38			0.64		0.30	Cc blanket in Ca
	236-260	23			0.46		0.69	Py-cpy-sl CRD + diss 4' CRD + Ca + Eap
28-30	728-772	44			0.21			Diss cpy in unkn porp
	1030-1040	10			0.35			Diss cpy in Pima
28-31	331-420	89					1.22	FeOx-py-sl CRD – no CRD logged!
	425-439	14	0.01					Diss cpy in Ca at ctct unknown porph.
	822-881	59	0.04	0.33	1.66			Stwk py-cpy in Jsvp + massive sulfide
	(837-842)	5	0.290	0.22	1.50			Stwk py-cpy in Jsvp
	911-945	34	0.01		0.43			Stwk py-cpy in Jsbx
28-32	160-190	30			0.29			Cc blanket in unkn porp
	245-275	30			0.21			Cc blanket in Jsvp & Jsbx
	334-360	26			0.24			Diss cpy in Jsvp + Turquoise Cr
	605-655	50					4.39	Py-sl skarn
	1072-1120	48	0.01		0.47			Diss cpy-py in Jcbx
	1135-1219	84	0.011		0.64			Diss cpy-py in Jcbx
28-33	130-170	40			0.31			Cc blanket in Jsmp
	592-605	13			0.39			Diss cpy in Jsvp
	725-955	230			0.50			Stwk cpy in Jsvp, Jsbx & Jcbx
	(765-805)	40	0.011		1.22			Stwk cpy, as above
	965-1021	56	0.016		0.60			Diss cpy in Jsbx & Jsvp
	(1000-1005)	5	0.110		1.69			Diss cpy in Jsbx & Jsvp
28-34	No significant assay intervals							
28-35	129-150	21			0.41	0.43		Diss cpy-gl in Jsmp & Jcmp not on log
	170-185	15			0.35			Diss cpy in Jsmp
	262-268	6	0.01	0.25	0.37	3.36	9.61	Py-sl-gl CRD
28-36	No significant assay intervals							
28-37	No significant assay intervals							

Hole No.	Interval (')	Thickness (')	Au OPT	Ag OPT	Cu %	Pb %	Zn %	Type Mineralization
28-38	170-197	27			0.43			Cc blanket in Jsmp & Jcmp
	235-280	45			0.36			Cc blanket in Jcmp
	375-420	45	0.021		0.68			Diss cc-cpy in Ca + Jcmp above
	561-589	28	0.014		0.57			FeOx-py-cpy CRD + minor Ca
	634-650	16	0.009		0.42			FeOx-py-cpy CRD 5' CRD + Jcmp
28-39	225-255	30			0.44			Cc blanket in Jsmp – Jsbx
	270-280	10			0.41			Cc blanket in Jsmp
	299-323	24			0.34			Cc blanket in unkn porp
	354-383	29	0.016		0.99			Py-cpy CRD + diss – only 3' CRD Jcmp + Ca
	702-715	13					4.44	Diss sl in Ca
28-40*	195-215	20			0.39			Cc blanket in Jsmp
	597-629	32	0.020	0.80				Py-sl CRD + jasp
	720-735	15	0.029	2.41	0.44			Diss py-cpy-sl in Ca & Jcmp
	795-880	85	0.015		0.61			Py-sl-cpy CRD + jasp only 15' CRD + Jsbx + Fz
28-41*	759-762	3			0.82			Py-cpy CRD
	850-948	98			0.42			Stwk cpy in Jsbx & Jcbx
28-42*	660-670	10	0.045		0.42			Stwk cpy in Jcbx
	765-770	5	0.022	0.90	2.34			Stwk cpy in Jcbx
28-43*	850-870	20	0.019		1.98			Stwk in Jsbx
28-44*	799-809	10	0.014		0.59			Stwk in Jsbx

*Only visually selected "high grade" intervals from these holes sent for assay

APPENDIX II

MAUD HILL PROJECT
PAYMENT/WORK OBLIGATIONS
01-01-92 to 12-31-96

OWNER	ACQUIRED BY	PROPERTY TYPE	FILE #	ROYALTY	DATE	ANNUAL PAYMENT	WORK OBLIGATIONS TYPE	WORK OBLIGATIONS AMOUNT
AZ STATE LAND DEPT.	PROSPECTING PERMIT #98452	STATE LANDS	3-024-0001	N/A	09-25-92	114.55	ANNUAL	1,145.50
					09-25-93	114.55		2,291.00
					09-25-94	114.55		2,291.00
					09-25-95	0.00		2,291.00
	PROSPECTING PERMIT #99313	STATE LANDS	3-024-0003	N/A	06-11-92	0.00	ANNUAL	799.90
					06-11-93	79.99		799.90
					06-11-94	79.99		1,599.80
					06-11-95	79.99		1,599.80
					06-11-96	0.00		1,599.80
	PROSPECTING PERMIT #96033	STATE LANDS	3-024-0022	N/A	07-19-92	129.15	ANNUAL	2,583.00
					07-19-93	0.00		2,583.00
1) BERTRAND, BERNARD & NELLIE J. 2) BERTRAND, RUTH ELIZABETH	LEASE & OPTION TO PURCHASE	PATENTED CLAIM	3-024-0015	5% NET RETURNS	06-20-92	4,000.00	N/A	N/A
					06-20-93	5,000.00		
					06-20-94	7,000.00		
					06-20-95	9,000.00		
					06-20-96	30,000.00		
CHRISTIANSEN, DAN & BARBARA	MINING LEASE	PATENTED & UNPATENTED LODE CLAIMS	3-024-0002-02	5% NET RETURNS	06-19-92	8,000.00	ASSESSMENT	2,600.00
					06-19-93	8,000.00		2,600.00
					06-19-94	10,000.00		2,600.00
					06-19-95	10,000.00		2,600.00

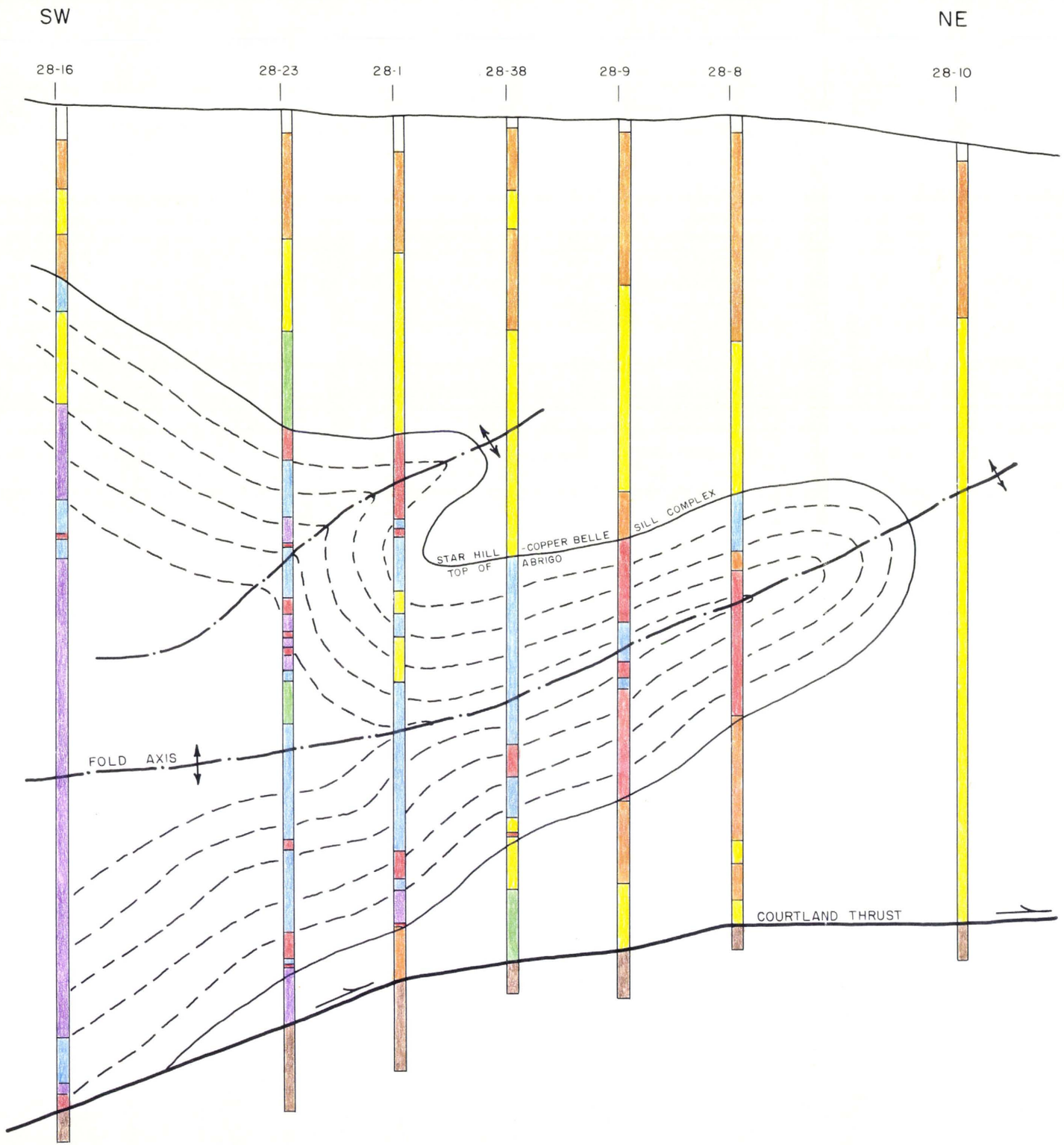
OWNER	ACQUIRED BY	PROPERTY TYPE	FILE #	ROYALTY	DATE	ANNUAL PAYMENT	WORK OBLIGATIONS TYPE	WORK OBLIGATIONS AMOUNT
CHRISTIANSEN, DAN & BARBARA (cont.)	MINING LEASE	UNPATENTED LODE CLAIMS	3-024-0013	4% NET RETURNS	04-13-92	7,000.00	ASSESSMENT	4,100.00
					04-13-93	7,000.00		4,100.00
					04-13-94	9,000.00		4,100.00
					04-13-95	9,000.00		4,100.00
					04-13-96	11,000.00		4,100.00
COSTELLO INVESTMENTS	MINING LEASE	PATENTED CLAIMS	3-024-0002-01	5% NET RETURNS	01-14-92	10,301.28	N/A	N/A
					01-14-93	17,168.80		
					01-14-94	17,168.80		
					01-14-95	17,168.80		
1) COWAN, R.C., RANCH LTD. 2) WALLER, EVELYN	MINING LEASE & PURCHASE OPTION	PATENTED CLAIMS	3-024-0012-01	4% NET RETURNS	07-08-92	1,700.00	N/A	N/A
					07-08-93	1,900.00		
					07-08-94	1,900.00		
					07-08-95	1,900.00		
					07-08-96	2,000.00		
DALKOFF, LEONARD	MINING LEASE & PURCHASE OPTION	PATENTED CLAIM	3-024-0012-03	4% NET RETURNS	04-20-92	1,500.00	N/A	N/A
					04-20-93	2,750.00		
					04-20-94	2,750.00		
GILBERT, A.J., CONSTRUCTION	MINING LEASE	UNPATENTED LODE CLAIMS	3-024-0010	4% NET RETURNS	03-19-92	5,000.00	ASSESSMENT	1,300.00
					03-19-93	6,000.00		1,300.00
					03-19-94	6,000.00		1,300.00
					03-19-95	6,000.00		1,300.00
					03-19-96	6,000.00		1,300.00

OWNER	ACQUIRED BY	PROPERTY TYPE	FILE #	ROYALTY	DATE	ANNUAL PAYMENT	WORK OBLIGATIONS TYPE	WORK OBLIGATIONS AMOUNT
RAE, KATHRYN AUCOIN	MINING LEASE & PURCHASE OPTION	FEE & PATENTED CLAIMS	3-024-0012-02	4% NET RETURNS	06-16-92	40,000.00	N/A	N/A
					06-16-93	40,000.00		
					06-16-94	40,000.00		
					06-16-95	50,000.00		
					06-16-96	50,000.00		
SFPM	LOCATION	UNPATENTED LODE CLAIMS	3-024-0005	1.5% NET RETURNS SEE FILE: 32-024-0002-01	09-01-92	N/A	ASSESSMENT	3,500.00
					09-01-93			3,500.00
					09-01-94			3,500.00
					09-01-95			3,500.00
					09-01-96			3,500.00
	LOCATION	UNPATENTED LODE CLAIMS	3-024-0008	N/A	09-01-92	N/A	ASSESSMENT	1,600.00
					09-01-93			1,600.00
					09-01-94			1,600.00
					09-01-95			1,600.00
					09-01-96			1,600.00
	LOCATION	UNPATENTED LODE CLAIMS	3-024-0011	N/A	09-01-92	N/A	ASSESSMENT	10,100.00
					09-01-93			10,100.00
					09-01-94			10,100.00
					09-01-95			10,100.00
					09-01-96			10,100.00
	LOCATION	UNPATENTED LODE CLAIMS	3-024-0014	1.5% NET RETURNS SEE FILE: 32-024-0002-01	09-01-92	N/A	ASSESSMENT	1,000.00
					09-01-93			1,000.00
					09-01-94			1,000.00
					09-01-95			1,000.00
					09-01-96			1,000.00

OWNER	ACQUIRED BY	PROPERTY TYPE	FILE #	ROYALTY	DATE	ANNUAL PAYMENT	WORK OBLIGATIONS TYPE	WORK OBLIGATIONS AMOUNT
SFPM (cont.)	LOCATION	UNPATENTED LODE CLAIMS	3-024-0024	1.5% NET RETURNS SEE FILE: 32-024-0002-01	09-01-92	N/A	ASSESSMENT	300.00
					09-01-93			300.00
					09-01-94			300.00
					09-01-95			300.00
					09-01-96			300.00
	LOCATION	UNPATENTED LODE CLAIMS	3-024-0039	1.5% NET RETURNS SEE FILE: 32-024-0002-01	09-01-92	N/A	ASSESSMENT	400.00
					09-01-93			400.00
					09-01-94			400.00
					09-01-95			400.00
					09-01-96			400.00
	LOCATION	UNPATENTED LODE CLAIMS	3-024-0040	1.5% NET RETURNS SEE FILE: 32-024-0002-01	09-01-92	N/A	ASSESSMENT	300.00
					09-01-93			300.00
					09-01-94			300.00
					09-01-95			300.00
					09-01-96			300.00

TOTAL ANNUAL PAYMENT AND WORK OBLIGATIONS:

1992	107,473.38
1993	118,887.24
1994	123,104.14
1995	132,239.59
1996	123,199.80



CROSS SECTION
BETWEEN DRILL HOLES 28-16 & 28-10
SHOWING DISTRIBUTION OF
ABRIGO LIMESTONE
IN THE NOSE OF THE
STAR HILL ANTICLINE

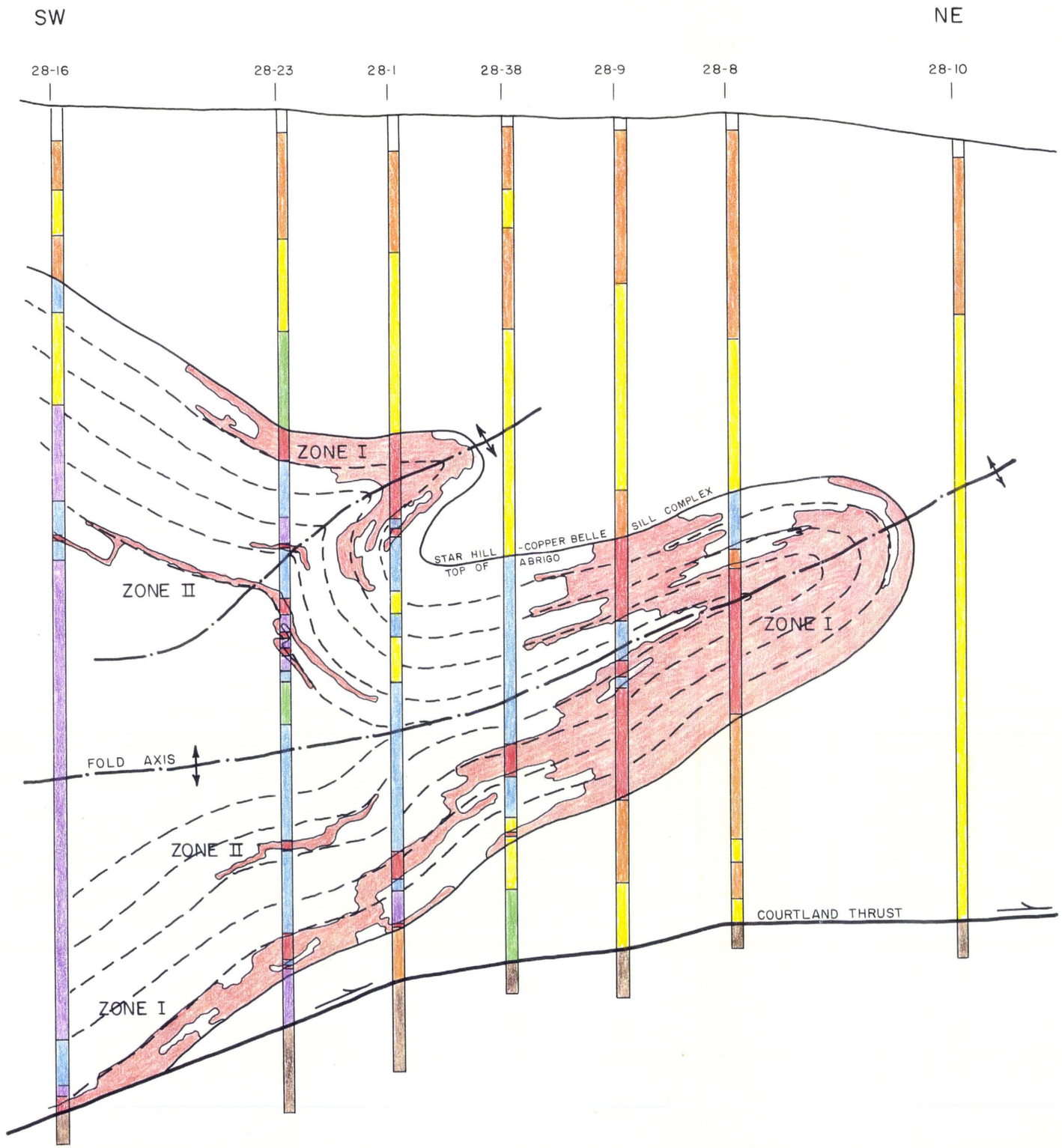
VIEW: NORTHWEST
VERTICAL & HORIZONTAL SCALE: 1" = 100'

EXPLANATION

- Bisbee Formation
- CRD
- Courtland Breccia
- Sniveler Breccia
- Sniveler Porphyry
- Copper Belle Porphyry
- Star Hill Porphyry
- Abrigo Limestone
- Intrusive Contact
- Trend Line of Abrigo Bedding
- Thrust Fault Showing Movement
- Fold Axis

Note: Intrusive rocks within Abrigo section not shown.

Figure 2.



CROSS SECTION
BETWEEN DRILL HOLES 28-16 & 28-10
SHOWING DISTRIBUTION OF
ZONE I & ZONE II CRDs
IN THE NOSE OF THE
STAR HILL ANTICLINE

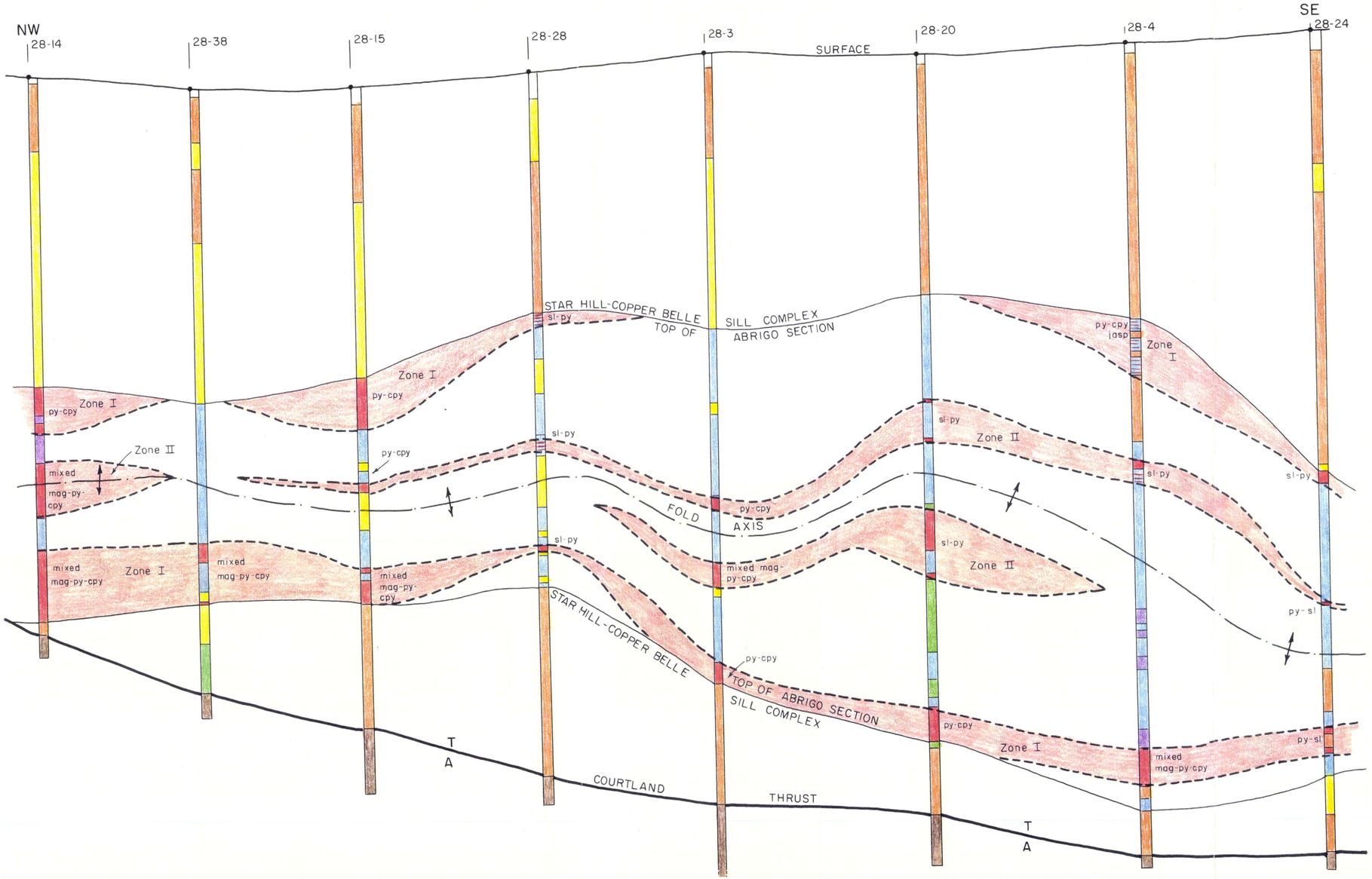
VIEW: NORTHWEST
VERTICAL & HORIZONTAL SCALE: 1" = 100'

EXPLANATION

- Bisbee Formation
- CRD
- Courtland Breccia
- Sniveler Breccia
- Sniveler Porphyry
- Copper Belle Porphyry
- Star Hill Porphyry
- Abrigo Limestone
- Intrusive Contact
- Trend Line of Abrigo Bedding
- Thrust Fault Showing Movement
- Fold Axis

Note: Intrusive rocks within Abrigo section not shown.

Figure 12.



LONGITUDINAL SECTION
BETWEEN DRILL HOLES 28-14 & 28-24
SHOWING DISTRIBUTION OF
ZONE I & ZONE II CRDs
IN THE NOSE OF THE
STAR HILL ANTICLINE

VIEW: SOUTHWEST
VERTICAL & HORIZONTAL SCALE: 1" = 100'

EXPLANATION

- Bisbee Formation
- CRD
- Courtland Breccia
- Sniveler Breccia
- Sniveler Porphyry
- Copper Belle Porphyry
- Star Hill Porphyry
- Abrigo Limestone

Intrusive Contact

T/A Thrust Fault Showing Movement

Fold Axis

Note: Intrusive rocks within Abrigo section not shown

Figure 13.

DISTRIBUTION OF CRD MINERAL ZONES
SHOWING RELATIONSHIP TO BRECCIA MASSES

SCALE: 1" = 200'

14 DRILL DRILL HOLE NUMBER

• DRILL HOLE LOCATION

(207) TOTAL THICKNESS OF CRD IN HOLE

50 ISOPACHS ON CRD; Contour Interval 50'

50 ISOPACHS ON COMBINED THICKNESS OF SNIVELER & COURTLAND BRECCIAS; Contour Interval 100'

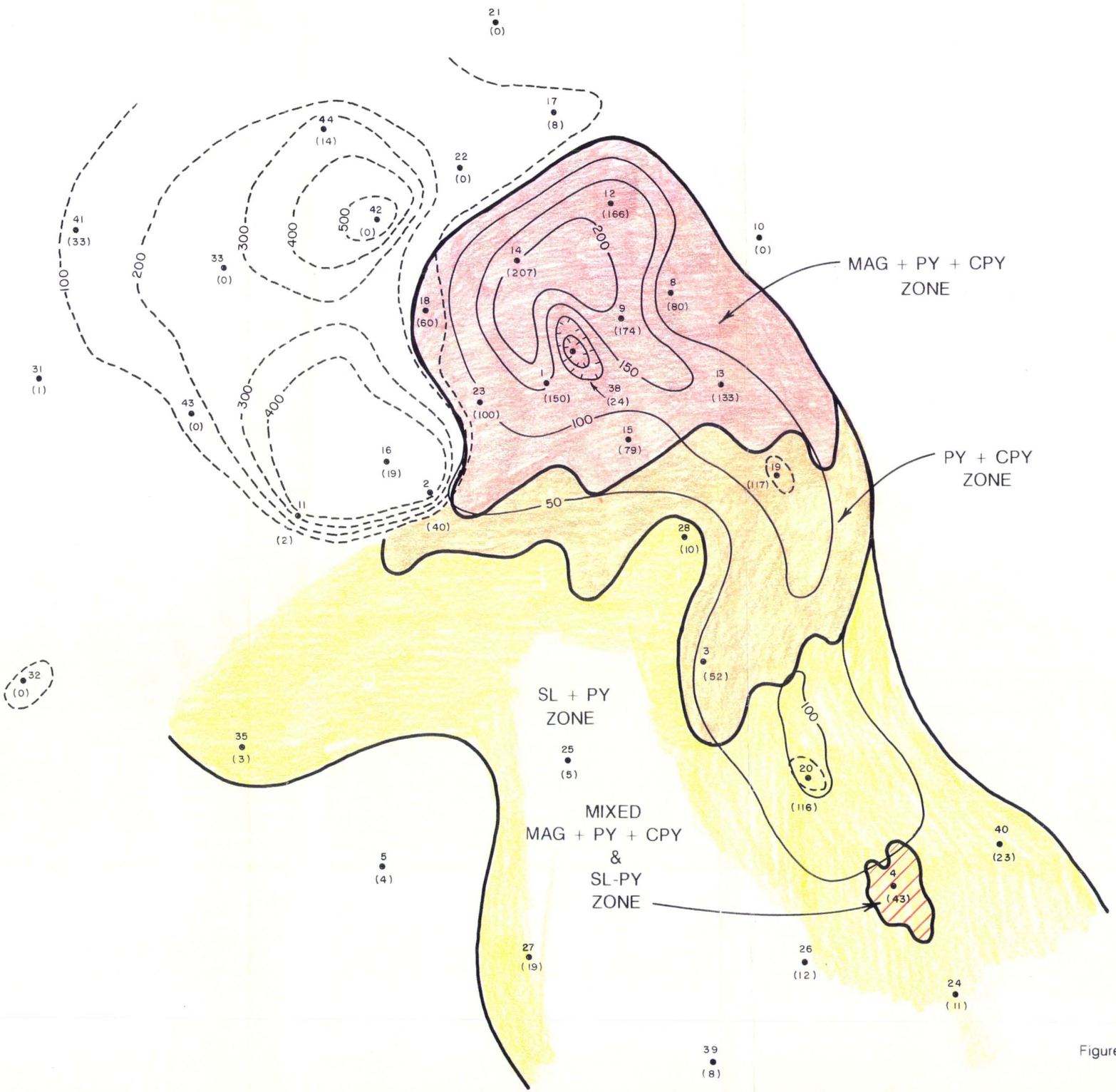


Figure 16.

DISTRIBUTION OF CRD MINERALIZATION
SHOWING RELATIONSHIP TO BRECCIA MASSES

SCALE: 1" = 200'

14 DRILL DRILL HOLE NUMBER

• DRILL HOLE LOCATION

(207) TOTAL THICKNESS OF CRD IN HOLE

50 ISOPACHS ON CRD:
Contour Interval 50'

50 ISOPACHS ON COMBINED THICKNESS
OF SNIVELER & COURTLAND BRECCIAS:
Contour Interval 100

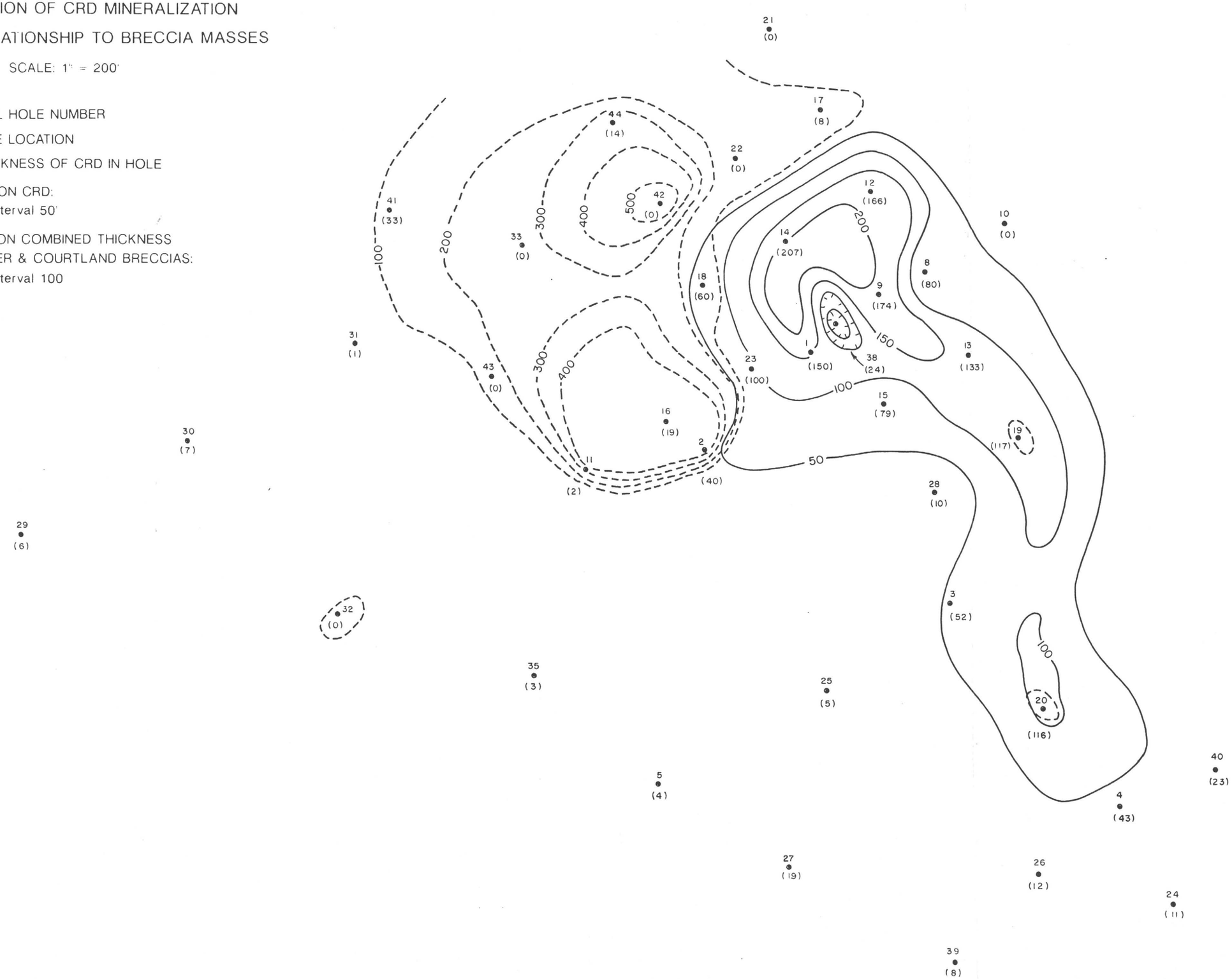


Figure 18.