# Geochemical and Geologic Relations Of Gold and Other Elements at the Gold Acres Open-Pit Mine, Lander County, Nevada

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# GEOCHEMICAL AND GEOLOGIC RELATIONS OF GOLD AND OTHER ELEMENTS AT THE GOLD ACRES OPEN-PIT MINE, LANDER COUNTY, NEVADA

By Chester T. Wrucke and Theodore J. Armbrustmacher

ABSTRACT

The distribution and association of gold and other elements at the Gold Acres open-pit mine was studied to determine the suites of elements introduced during mineralization and their bearing on the origin of this disseminated gold deposit. The mine lies on the east flank of the northern Shoshone Range in rocks of Ordovician, Silurian and Silurian(?), and Devonian age in the southernmost of three closely spaced belts defined by anomalous concentrations of many metals. These rocks occur in the upper plate of the Roberts Mountains thrust fault of Mississippian age. Rocks of Devonian and Mississippian age in the lower plate of the thrust crop out in a window adjacent to the mine; a few tabular blocks of rocks of lower-plate lithology now occur interleaved with typical upper-plate rocks in the mine workings.The thrust fault may lie at shallow depth beneath the workings. Contact metamorphism resulting from intrusion of a buried granitic pluton in Cretaceous time transformed some of the rocks of the mine to hornfels and tactite.

Unmineralized samples collected from outcrops in the Cortez Range and from a drill core in upper-plate rocks 5.3 miles north of the open-pit mine provide a measure of background values for 31 elements; samples collected in an area of weak mineralization near Gold Acres were used to determine threshold concentrations. Median values used as a basis for comparing data on background and threshold concentrations with data from samples collected in the mine offer a means of establishing objective definitions of anomalies at the mine.

Within the mine, gold, arsenic, boron, mercury, and tungsten occur in anomalous concentrations in mineralized fault zones and in carbonate rocks. These elements, concentrated in the lower part of the mine, have similar distribution patterns. Copper, arsenic, bismuth, cadmium, manganese, and zinc occur in anomalous concentrations in the southern part of the mine in hornfels, tactite, and metagreenstone. These elements are associated with iron, lead, and molybdenum, which do not occur in anomalous amounts. Fault zones contain anomalous concentrations of elements that occur with gold, anomalous concentrations of chromium, cobalt, lead, manganese, nickel, silver, titanium, vanadium, yttrium, zinc, and zirconium, and strong but not anomalous concentrations of iron. Geologic considerations and data on correlations indicate that the mine contains a gold suite consisting of gold, arsenic, boron, mercury, and tungsten; a base-metal suite containing copper, lead, zinc, arsenic, bismuth, cadmium, iron, manganese, and molybdenum; and an iron-manganese suite of elements consisting of iron, manganese, arsenic, boron, chromium, cobalt, copper, nickel, scandium, titanium, yttrium, and zirconium. Silver may occur in the gold and base-metal suites.

Field relations of these suites of elements and data from fluid-inclusion studies indicate that mineralization began after contact metamorphism with the deposition of molybdenite in tactite at a temperature of 380°±50°C. Base metals were introduced during deposition of sphalerite, pyrite, and lesser amounts of other sulfide minerals at temperatures of 160°–235°C. Gold, arsenic, boron, mercury, and tungsten were deposited last, at 160°–195°C. Mineralization probably occurred at a depth of about 5,000 feet during hydrothermal activity following emplacement of the Cretaceous pluton beneath the open-pit mine. The iron-manganese suite is interpreted to have formed by supergene processes after hypogene mineralization.

## INTRODUCTION

A study of the relation of gold and other elements of the Gold Acres mine was undertaken as part of an investigation of the geochemistry and geology of the mineral deposits on the east flank of the northern Shoshone Range. An earlier study of the geochemical setting of the deposits (Wrucke and others, 1968), an investigation concerned mainly with the nearby Cortez district (Erickson and others, 1966), and a study of the Carlin mine (Radtke and others, 1972) had shown that the same minor elements occur at Gold Acres as at other disseminated gold deposits in north-central Nevada. Our investigations have refined these observations by establishing background and threshold concentrations for 31 elements resulting in objective definitions of anomalies at the open-pit mine. This paper further presents evidence that three suites of elements, of distinctive distribution and geologic associations, occur at Gold Acres and that deposition of gold began late in the history of mineralization.

The open-pit mine at Gold Acres, one of the largest producers of gold in Nevada in the 1950's, is 29 miles southeast of Battle Mountain, in north-central Nevada (fig. 1). Other disseminated gold deposits occur at Cortez, 9 miles to the east; Carlin, 50 miles to the northeast; and Getchell, 68 miles to the northwest. The Gold Acres mine, operating in 1942, was the second to achieve production (see Merrill and Gaylord, 1943); it remained in operation until 1961. The mine produced gold and silver worth nearly $10 million.

The open-pit mine of this study has been referred to as the Goldacres mine (Merrill and Gaylord, 1943), but published reports generally do not distinguish it from another property 2,000 feet to the southeast known by

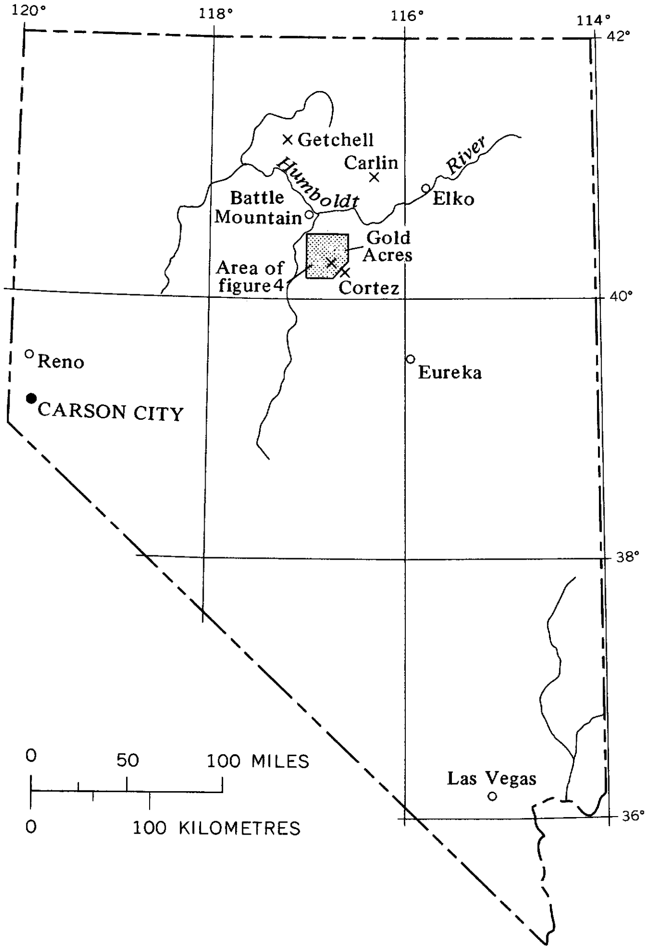



FIGURE 1.—Location of the Gold Acres, Carlin, Cortez, and Getchell disseminated gold deposits.

the same name. The name was first applied to the more southeasterly mine, known locally as the Little Gold Acres mine, an underground operation that produced gold during 1935–42 (Harry Treweek, oral commun., 1968) and was converted to open-pit mining in 1973. The northwesternmost open-pit mine, centered 0.7 mile southwest of the now-abandoned town of Gold Acres, was in production mainly after 1942 and can be identified in the literature by the companies that operated it—Willow Creek Mines, Inc. (Merrill and Gaylord, 1943), the Consolidated Goldacres Co., and the London Extension Mining Co. (Maurer, 1950). To avoid repetitious qualification, the mine or the Gold Acres mine referred to in this report is understood to be the northwestern of the two open-pit properties.

During the investigation, we were extended numerous courtesies by personnel of the American Mining and Exploration Co. (now Placer Amex, Inc.), in particular C. J. Purdy, J. E. Doherty, R. C. Banghart, and J. B. Bush, and Quail Lusty and D. M. Duncan of Cortez Gold Mines. It is a pleasure to acknowledge the helpful cooperation of Ralph Anctil, formerly of the Natural Resources Division, Union Pacific Railroad Co. The late Harry C. Bishop, former manager of the mine for the London Extension Mining Co., and Harry Treweek, former manager of the nearby Little Gold Acres mine, related to us interesting incidents in the history of mining in the Gold Acres area. We have benefited from numerous discussions with R. P. Ashley, W. J. Moore, J. T. Nash, M. L. Silberman, and T. G. Theodore, of the U.S. Geological Survey. T. E. Mullens, of the Geological Survey, generously provided us with analyses of the Roberts Mountains Formation in Rattlesnake Canyon. S. P. Gariepy, W. R. Jones, Jr., and M. J. Maxson assisted in the field; R. A. Koski and W. S. Snyder helped in the office.

## GEOLOGIC SETTING

The Gold Acres mine lies near the east margin of the northern Shoshone Range (fig. 4), an eastward-tilted fault block in the Basin and Range province. One of the prominent geologic features of the eastern part of the range is a window exposed in an area 1 mile wide and 3½ miles long, overlapped on the east by valley fill and bounded on the west by the upper plate of the Roberts Mountains thrust. This thrust, which originated during the Antler orogeny of Mississippian age, is one of the main structural elements of north-central Nevada. In the Gold Acres area, it forms the southwest margin of the window, but it has been dropped down along steep faults that bound the window on the northwest and northeast (fig. 2). The mine lies in the upper plate of the thrust a few hundred feet southwest of the window and west of one of the steep faults. Possibly the Roberts Mountains thrust occurs at shallow depth beneath the mine, as discussed under "General Geology of the Open-Pit Mine" following. The geology of the area is discussed in Gilluly and Gates (1965), Gilluly and Masursky (1965), and Wrucke and Armbrustmacher (1969).

Rocks exposed in the Gold Acres window are part of the eastern or carbonate assemblage of strata in the lower plate of the Roberts Mountains thrust. Within the area of the geologic map of the Gold Acres area (fig. 2), these rocks consist of Wenban Limestone of Devonian age, but small exposures outside the area of figure 2 consist of fissile siltstone of the Pilot Shale of Devonian and Mississippian age near the south end and at the north end of the window. We find no firm evidence that the Roberts Mountains Formation—the host for the gold deposits at Carlin and Cortez—crops out in the Gold Acres window, outside of the mine area as reported by Gilluly and Gates (1965).

Rocks of the western or siliceous assemblage of the Roberts Mountains thrust crop out extensively on the

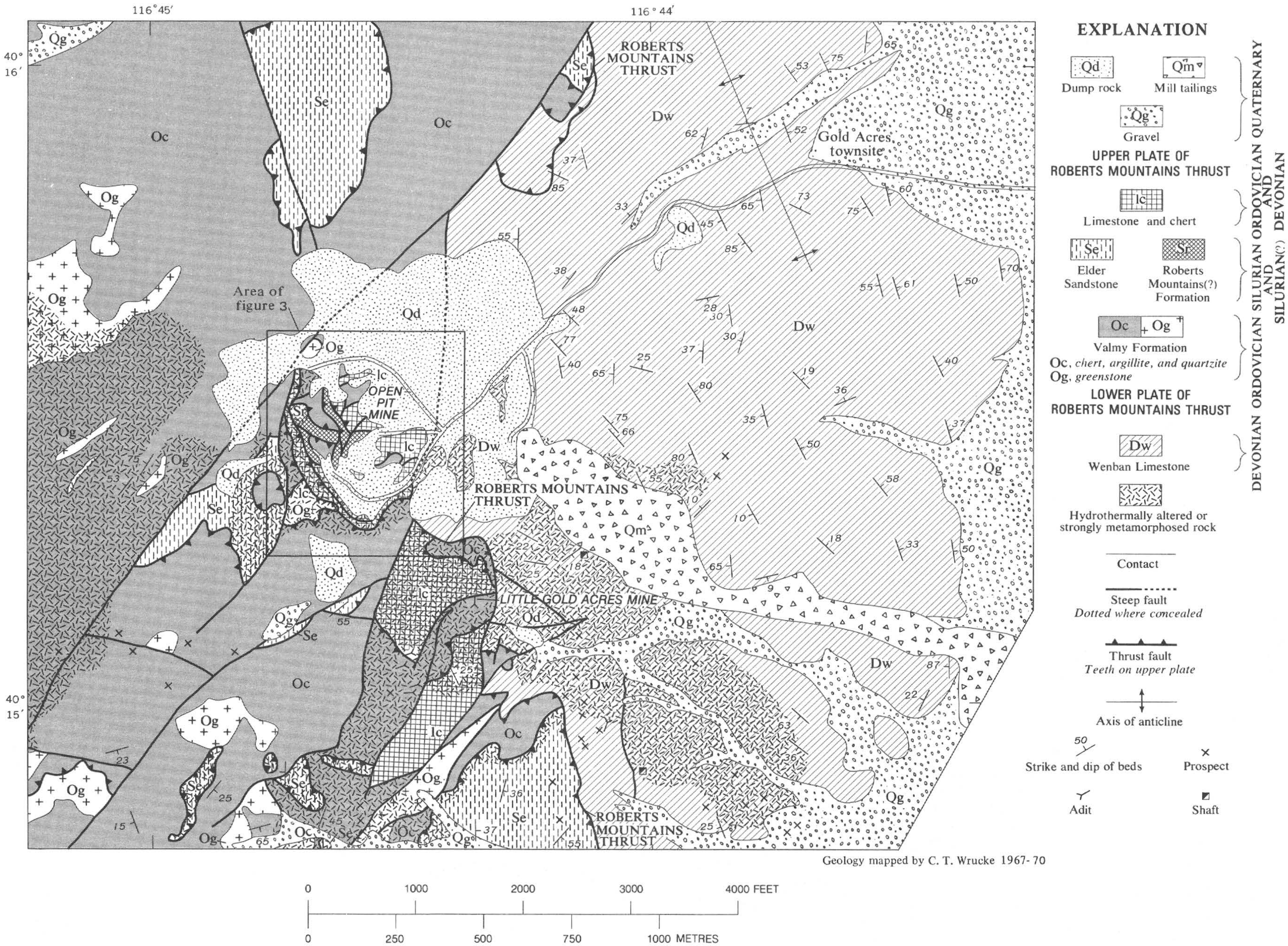
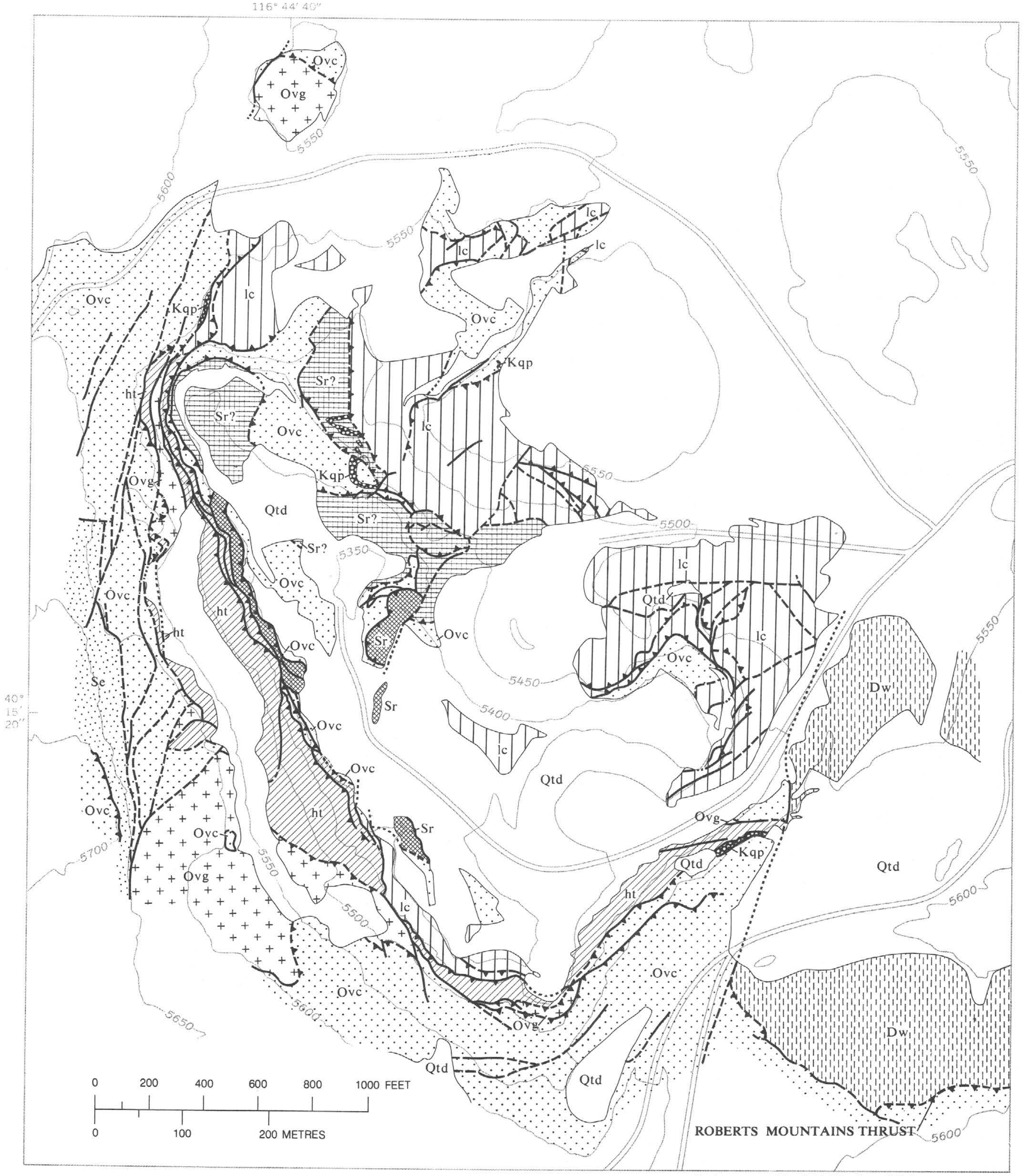



FIGURE 2.—Geology of the Gold Acres area.




Geology mapped by C. T. Wrucke and T. J. Armbustmacher, 1967-68; assisted by W. R. Jones, Jr. and M. J. Maxson, 1967; and W. L. Simpson, 1968

FIGURE 3.—Generalized geology of the Gold Acres open-pit mine.

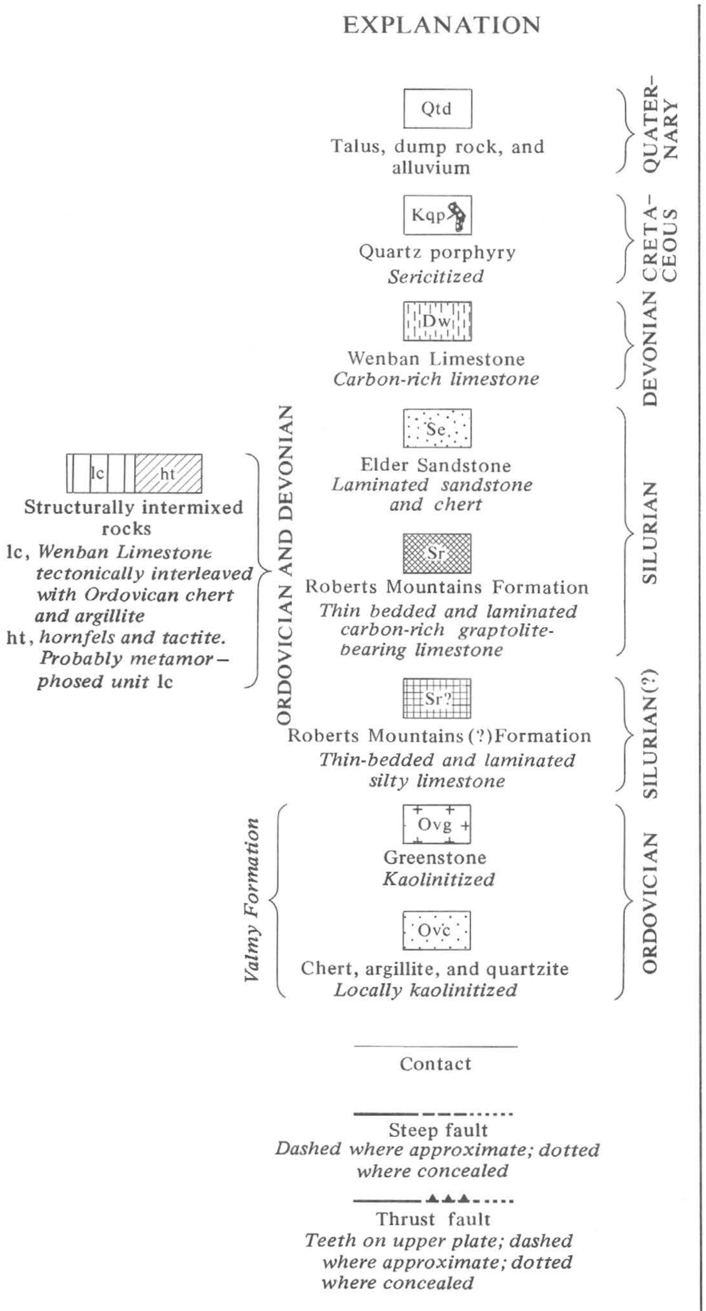



FIGURE 3.—Continued.

east side of the Shoshone Range. In the vicinity of Gold Acres, they consist mostly of chert, argillite, greenstone, and limestone, of the Valmy Formation of Ordovician age, but siltstone and chert of the Elder Sandstone of Silurian age crop out locally. Along the southwest side of the window, the upper plate comprises numerous thrust slices only a few tens to a few hundreds of feet thick that juxtapose many rock types, including limestone torn from the lower plate and incorporated in the upper plate during thrust movement. The upper-plate rocks moved into the area an unknown distance from the west; conceivably some could have traveled 100 miles.

A granitic body underlies part of the Gold Acres area but nowhere is exposed. The distribution of contact metamorphic rocks and the configuration of a magnetic high (see Wrucke and others, 1968; Philbin and others, 1963) indicate that the pluton, centered about 1 mile southwest of the open-pit mine, trends northwest and may be a few miles in greatest dimension. Judged by the erratic occurrence of the metamorphic rocks, the intrusion has an irregular upper surface. A drill hole at the bottom of the mine enters the pluton at a depth of about 400 feet. Biotite from granitic rock cored in the hole was dated at 98.8±2.0 million years (Silberman and McKee, 1971), which may be a minimum age for the body, as the biotite is partly altered to chlorite and sericite. The biotite could be of hydrothermal origin, but the alteration, dated at 92.8±1.0 million years (Silberman and McKee, 1971) from a determination on the associated sericite, is related to the waning stages of intrusive activity.

The only other intrusive rock in the area is quartz porphyry that forms a few dikes restricted to the mineralized area, a distribution suggesting the porphyry may be related genetically to the mineralization. The dikes and the pluton may well be part of the same intrusive episode. Sericite in one of these dikes was dated at 94.3±1.9 million years (Silberman and McKee, 1971), about the same age as sericite in the pluton.

The contact metamorphic rocks in the Gold Acres area occur in a zone 1,000–3,000 feet wide and about 2 miles long that extends from the mountain front northwest across the window and into the area of upper-plate rocks. Impure dolomitic limestone has been converted to calc-silicate rock in this zone, and chert, argillite, and greenstone have been altered to hornfels and bleached almost white. The mine lies at the northeast edge of this zone and exposes metamorphosed and unmetamorphosed rock.

The gold deposit was mostly superposed on the zone of metamorphic rocks. At the surface, the gold deposit extends at least 1,200 feet southeastward from the northwest end of the open-pit mine and has a width of 500 feet at the surface. The Little Gold Acres mine to the southeast and several shafts and prospects occur in the same deposit.

## GENERAL GEOLOGY OF THE MINE

The Gold Acres open-pit mine lies in a part of the upper plate of the Roberts Mountains thrust consisting of many subhorizontal, generally southwest-dipping, tabular blocks and lenses a few feet to a few tens of feet thick and commonly a few hundred feet across (fig. 3). Many of these thrust slivers are composed of such typical upper-plate rocks as argillite, chert, and greenstone of Ordovician age and siltstone of Silurian age, whereas other blocks and lenses consist of limestone of Silurian, Silurian(?), and Devonian age atypical of formations in the upper plate of the Roberts Mountains thrust. The Silurian limestone belongs to the Roberts Mountains Formation and forms a few blocks that overlie chert in the mine. The Devonian limestone is part of the Wenban Limestone but is tectonically interleaved with lenses 1–30 feet thick of chert and argillite of Ordovician age (map unit lc on figure 3). Evidently the thrust slivers of Silurian and Devonian limestone and of the Silurian(?) limestone discussed next were dislodged from the lower plate and dragged into their position within the upper plate.

Structurally, the lowest rock exposed in the mine is silty limestone. If this rock, identified as the Roberts Mountains(?) Formation on the geologic map of the mine (fig. 3), actually is part of that formation, it almost certainly lies above the Roberts Mountains thrust, for the Roberts Mountains Formation does not crop out in the Gold Acres window a short distance to the east as would be expected if it is below the thrust. The sole of the thrust would then be in the upper part of the 400-foot section of limestone and tactite drilled below the bottom of the mine, as that section, from considerations of structural geology, is too thick to be composed entirely of the Roberts Mountains Formation.

A few dikes of quartz porphyry cut thrust sheets and were intruded along faults in the mine. All the dikes are sericitized, some so thoroughly that identification is possible only because quartz phenocrysts remain unaltered.

More than half of the exposures in the mine, in particular those on the southwest and southeast walls and benches, consist of altered and metamorphosed rock. The original widespread chert and argillite in these areas have been recrystallized or converted to hornfels. Greenstone now contains numerous rosettes of tremolite–actinolite, and some of the original calcareous rocks have been metamorphosed to tactite. Nearly all these rocks have locally been kaolinized to such an extent that the identity of the original rock is almost completely masked. Hornfels, tactite, and metagreenstone contain abundant pyrite and sphalerite and varying amounts of galena, chalcopyrite, pyrrhotite, arsenopyrite, and marcasite. Some blocks of carbon-rich silty rock low on the southwest wall and some limestone immediately east of the mine have had part of the original calcite and dolomite removed and are now coal black. The gold-bearing silty limestone that lies at the base of the west wall at the north end of the open pit has had some calcite and dolomite removed and has been weakly silicified.

In addition to sphalerite and the other sulfide minerals in metamorphic rocks, molybdenite has been found in the mine and elsewhere in the Gold Acres area and has been found in small amounts in tactite core taken from several drill holes. Irregular masses of molybdenite as much as 0.4 inch across make up one-fourth of a 2-inch length of core in garnet-diopside tactite penetrated 135 feet below the bottom of the mine, and smaller concentrations of molybdenite occur in core of hybrid granite-tactite from the upper part of the buried pluton below the open pit. The molybdenite occurs in and adjacent to quartz-calcite-pyrite veinlets.

Numerous north- to northeast-trending faults that dip steeply west or northwest cut the rocks of the mine. The mine itself lies between two steep faults that can be traced for 1 mile or more (fig. 2). One of these faults trends north along the east edge of the pit; rocks to the west, which contain the mine, have been downdropped about 200 feet relative to rocks east of the fault. The other trends northeast and passes a few hundred feet west of the open pit. Rocks on the northwest side of this fault north of the mine may have been dropped several hundred feet relative to rocks southeast of the fault, but the amount of offset probably decreases to the southwest. Half a mile north of the mine, the fault east of the pit joins the one to the west, which continues to the northeast along the west side of the Gold Acres window (fig. 2).

The original sulfide minerals at the mine have been largely oxidized. In the Roberts Mountains(?) Formation, pyrite thought to have been syngenetic has been almost completely converted to hydrous iron oxides, most of which remain as pseudomorphs, some have been dispersed through the rock and coat fracture planes. Hornfels, tactite, and metagreenstone are undergoing intense oxidation where they contain sulfide minerals; consequently, these rocks show varying degrees of decomposition. Locally the hornfels, tactite, and metagreenstone are laced with hexahydrite, a magnesium sulfate that resembles gypsum. Other rocks at the open-pit mine contain only sparse sulfides and, in general, are only lightly stained with iron oxides. Fault zones contain abundant hydrous iron oxides but no sulfides. Any sulfide minerals that may have been present in the fault zones have been completely oxidized. Probably much of the iron in these zones was transported by supergene processes thought to have redistributed other metals also.

## LOCATION OF THE MINE RELATIVE TO MINERALIZED AREAS ON THE EAST SIDE OF THE SHOSHONE RANGE

A narrow zone of mineral deposits (fig. 4) crosses the Shoshone Range along a northwest trend coincident

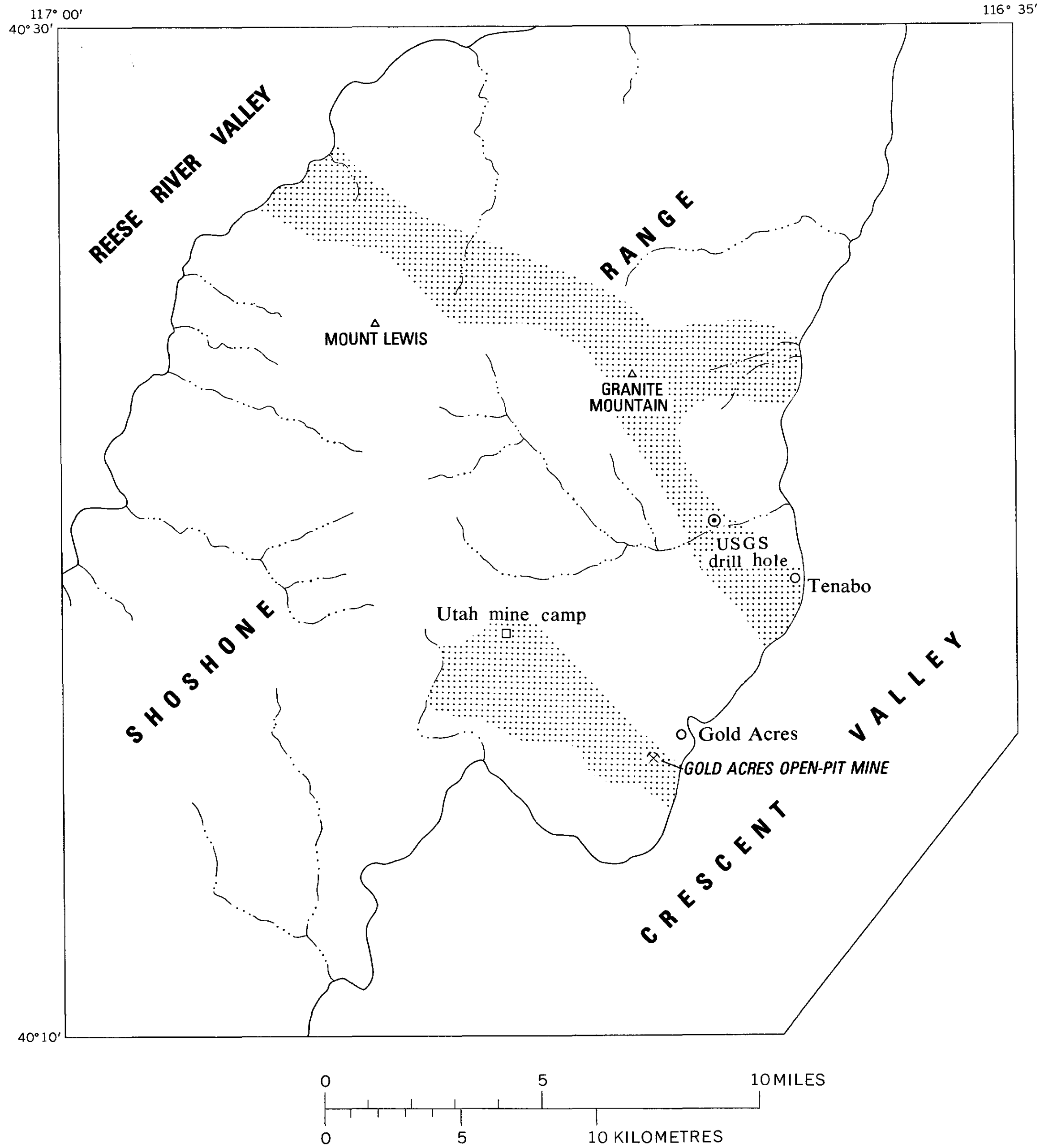



FIGURE 4.—Belts of anomalous concentrations of metals in part of the northern Shoshone Range.

with the Battle Mountain–Eureka mineral belt of Roberts (1966). Data from geochemical samples collected on the east flank of the range (Wrucke and others, 1968) show that the southeast part of the zone splits into two belts paralleled on the southwest by a third, all defined by the distribution of copper, lead, zinc, mercury, silver, and other metals. The Gold Acres open-pit mine lies at the southeast end of the southernmost belt. Gold has been the focus of investigation and exploration on the east side of the range because it forms the largest mineral deposits in that area, including those at Tenabo in the middle belt and Gold Acres in the southern belt.

A characteristic feature of the southern belt is that antimony, lead, silver, and tin are more abundant toward the northwest end, whereas gold and tungsten are concentrated toward the southeast at Gold Acres. Arsenic, bismuth, copper, mercury, and zinc are distributed rather evenly throughout the belt (Wrucke and others, 1968).

In a general way, at least the southeast half of the southern belt follows the zone of metamorphic rocks thought to overlie the buried granitic mass at Gold Acres. Possibly the west end of the belt occurs above another intrusion, as suggested by a weak magnetic anomaly near the Utah mine camp. (See Wrucke and others, 1968.) This belt, like the belts to the north, may extend southeast of the mountain front under the gravels of the adjacent valley.

## ROCKS COLLECTED FOR GEOCHEMICAL STUDIES

Samples weighing about 1–2 pounds were collected from drill core, outcrops, and mine workings. The drill core was obtained in 1967–68 from holes drilled in the Tenabo–Gold Acres area by the Geological Survey to obtain information on the depth to the Roberts Mountains thrust. Samples from outcrops and mine workings were gathered in 1966–68 to evaluate the distribution of trace elements in a 70-square-mile area on the east flank of the Shoshone Range (Wrucke and Armbrustmacher, 1973). Results of this study are summarized by Wrucke, Armbrustmacher, and Hessin (1968). Samples from the mine at Gold Acres were obtained in 1967–68 concomitantly with detailed geologic mapping of the mine. Data from all these sources allow comparison of the concentrations of elements at the mine with those in the unmineralized and weakly mineralized rocks of the Gold Acres area.

### UNMINERALIZED ROCKS

Unmineralized rocks used for determining the background concentrations of elements were collected from the Roberts Mountains Formation in the lower plate of the Roberts Mountains thrust at Rattlesnake Canyon in the Cortez Range and drill core from the upper plate of the thrust near Tenabo. Samples were collected from these sources rather than from the mine because appropriate unaltered rocks are sparse in the Gold Acres area.

The Roberts Mountains Formation in Rattlesnake Canyon, 14 miles southeast of Gold Acres, exposes the complete section of the formation closest to Gold Acres. As discussed under "Geologic Setting," rocks previously mapped by Gilluly and Gates (1965) as the Roberts Mountains Formation in the lower plate of the thrust in the Gold Acres window adjacent to the open-pit mine are now thought to belong to the Wenban Formation and therefore could not be used for comparison with samples from the mineralized thrust blocks of definite and possible Roberts Mountains Formation in the mine. However, Devonian limestone in the upper plate at the mine is lithologically so similar to the Roberts Mountains Formation that use of the Roberts Mountains as a measure of background values is reasonable. At Rattlesnake Canyon, T. E. Mullens, of the U.S. Geological Survey, collected samples at 38 localities throughout the section as part of a study of the regional stratigraphy of the Roberts Mountains Formation. Chemical data from 33 of these samples were used for this report.

Core samples from rocks in the upper plate of the Roberts Mountains thrust were obtained during drilling of a hole 5.3 miles northwest of Tenabo (fig. 4). This hole, 3,996 feet deep, penetrated 3,032 feet of the upper plate of the thrust and 964 feet of the lower plate. Lower-plate rocks, once thought by Wrucke, Armbrustmacher, and Hessin (1968) to resemble the Roberts Mountains Formation, consist either of tactite not readily amenable to stratigraphic identification or of fine-grained limestone rather than silty limestone or dolomite characteristic of the Roberts Mountains Formation. Because a stratigraphic assignment was not possible, the core from the lower plate was not sampled as a source of background data. The core from the upper plate contains mainly dark-gray to black carbon-rich chert and argillite similar to rocks that occur above the thrust on much of the east flank of the Shoshone Range; these rock types are interbedded on a scale of inches to a few feet. Thin beds of blue-gray to dark-gray limestone in sets as much as 2 feet thick form a minor part of the section. Fine-grained pyrrhotite and pyrite, probably syngenetic, occur in variable but minor amounts in the upper-plate rocks. Although the hole was collared in Valmy Formation, some upper-plate rocks penetrated may belong to the Slaven Chert of Devonian age.

Although much of the core consists of unaltered rock, below about 1,100 feet thin beds of tactite take the place of limestone, and certain intervals of chert and argillite are bleached or hornfelsed. A few quartz-calcite veins one-half inch thick or less that contain pyrite, sphalerite, and galena in various combinations occur throughout the upper plate but were not sampled.

Some intervals of the core contain contorted or tightly folded chert and argillite that is in places intensely sheared into phacoids about 1 inch long. Cutting both deformed and undeformed rocks are slip planes coated with slickensided carbon-rich material that locally contains pyrite or marcasite. The folds, phacoids, and slip planes originated during the Antler orogeny.

Two hundred ninety-one composite chip samples representing approximately 10 feet of lithologically uniform core were submitted for analysis. Where sections of similar lithology were shorter than 10 feet, the sample interval was adjusted accordingly. Veins were not sampled, nor was the bottom 176 feet of the upper plate, as the proportion of carbonate rock in that part of the core was greater than normal for an upper-plate section.

### WEAKLY MINERALIZED ROCKS

During an earlier study of the distribution of trace elements on the east flank of the Shoshone Range (Wrucke and others, 1968), 779 samples were collected in areas of little or no mineralization adjacent to the mineralized zones around Tenabo and Gold Acres (fig. 4). Samples from this area provided analytical data from rocks so weakly mineralized that they contain few prospect pits, yet the concentrations of certain elements are greater than in samples collected for determination of background values. Samples from this weakly mineralized area might ordinarily be collected in a reconnaissance geochemical sampling program as a source of background data. But because these rocks lie along a prominent segment of the Battle Mountain–Eureka mineral belt, the concentrations of elements in them are taken to represent threshold values, defined as the upper limit of background for a single population (Hawkes and Webb, 1962, p. 27).

Bedrock in the weakly mineralized area consists principally of chert and argillite in the upper plate of the Roberts Mountains thrust; argillite, abundant in the drill core, probably is more widespread than seems apparent from outcrops, as it weathers easily and becomes covered with colluvium. Other upper-plate rocks in the area include greenstone, siltstone, quartzite, and limestone, in decreasing abundance; together they form less than 10 percent of the exposures. Most of the upper-plate consists of the Valmy Formation; however, the siltstone is assigned to the Elder Sandstone, and some of the chert and argillite may be part of the Slaven Chert. Limestone in the area lies mostly in the lower plate in the Gold Acres window, but some western facies Devonian limestone interlayered with chert forms small thrust blocks and sedimentary layers in the upper plate. Calcareous siltstone of the Pilot Shale forms a small part of the window in the weakly mineralized area.

Chip samples from the weakly mineralized area were collected chiefly from veins, fractures, and breccia zones in an attempt to detect any existing mineralization. In areas where mineralization was especially weak, the material that appeared most altered was collected. These threshold samples typically contained yellow, brown, or red hydrated iron oxides, rarely jarosite, natrojarosite, or turquoise; probably much of the iron oxide resulted from oxidation of syngenetic iron sulfides. Most of the samples, including those collected from veins and breccia zones, were diluted by a high percentage of host rock.

### ROCKS FROM THE OPEN-PIT MINE

At the open-pit mine, 437 chip samples were collected at 265 localities. Most samples showed indications of mineralization or alteration. However, to achieve a reasonably uniform distribution of sample localities and to learn the range in concentration of elements at the mine, samples were collected from apparently unaltered rock.

Twenty-seven percent of the samples were obtained from fault zones. The fault zones, both high angle and low angle, are as much as a few feet wide and contain gouge and fragments of adjacent bedrock. Samples from fault zones consisted mainly of iron oxide-rich clayey gouge. X-ray analyses show that the gouge is mainly kaolinite, 1 M muscovite, quartz, and hydrated iron oxides amorphous to X-rays, but locally includes goethite, hematite, jarosite, gypsum, hexahydrite, quartz, dolomite, and calcite. Spectrographic analyses show that the gouge is 20 percent or more iron (Fe). Reddish iron oxides are common in the gouge, but yellow and yellow-brown varieties occur locally. The iron oxides probably formed chiefly from oxidation of sulfides originally present in the fault zones and from iron carried into the faults by supergene waters.

Commonly samples were collected from the most iron oxide-rich or the most intensely altered rock available, although at some localities separate collections were made of other materials to obtain data from rocks that show a range of alteration intensity or type. Samples collected away from fault zones commonly were stained with iron oxides because these oxides are disseminated widely in most rock types and iron oxides occur as coatings on joint planes, which, as a result of the shattered nature of the rock throughout the mine, usually are only 1 inch to several inches apart. Care was taken to collect samples from which part of the carbonate content had been removed as well as specimens of kaolinized, sericitized, and silicified rocks and their apparently unaltered equivalents. Numerous collections were made in hornfels, tactite, and metagreenstone because of the sulfides present in these partly oxidized rocks. Samples of sulfide-bearing chert and limestone were sought, but few were found because chert generally is not mineralized appreciably and because almost all sulfides in the limestone have been oxidized.

## ANALYTICAL TECHNIQUES

Most analytical determinations for this study were performed in mobile field laboratories of the U.S. Geological Survey. Gold was determined by a wet chemical method using atomic absorption spectrophotometry (Thompson and others, 1968). Mercury was analyzed instrumentally by an atomic absorption technique outlined by Vaughn and McCarthy (1964). Determinations for 29 other elements were made by a semiquantitative spectrographic method (Ward and others, 1963; Grimes and Marranzino, 1968) for which concentrations, in weight percent, are reported in six geometric steps discussed subsequently. Quantitative gold and mercury were grouped into the same six-step intervals used for reporting spectrographic analyses.

Median and range of concentration of elements were calculated from gold analyses done by W. L. Campbell, T. G. Ging, Jr., R. F. Hanson, E. E. Martinez, R. L. Miller, M. S. Rickard, T. A. Roemer, T. M. Stein, A. J. Toevs, G. H. VanSickle, and J. Viets; mercury analyses by J. V. Desmond, R. F. Hanson, S. Hoffman, C. Jacobson, V. D. James, H. D. King, R. L. Marshall, E. E. Martinez, K. R. Murphy, R. J. Smith, and J. Viets; spectrographic analyses by W. B. Crandell, K. J. Curry, A. Farley, D. J. Grimes, E. L. Mosier, J. M. Motooka, K. C. Watts, and H. W. Worthing.

## METHODS USED TO INTERPRET THE DATA

The geochemical data for 31 elements are summarized in histograms (pl. 1) that show the frequency of observations in each class interval. These histograms allow a visual estimate of the symmetry of the frequency distribution, the range in values reported, and the amount of data above and below analytical detection limits. Included in the column for values less than the lowest class interval are those observations that a given element occurs in concentrations less than the detection limit and those that the element was not detected at all. The abscissa of each histogram is divided into logarithmic intervals defined as having midpoints at 1.468, 2.154, 3.162, 4.642, 6.813, 10.00, 14.68, . . . , which are in logarithmic progression; as used in this report, the midpoints are rounded to 1.5, 2.0, 3.0, 5.0, 7.0, 10, 15, . . . . (See explanation on pl. 1.) Over the histogram from each element, the median value is shown by an arrow, and for elements having polymodal distributions, medians for each mode are given. The ordinate represents the frequency of observations, in percent.

The median is the measure of central tendency chosen here for comparing concentrations of a given element because it is readily determined and is not greatly influenced by a few unusually high or unusually low values. Although use of arithmetic means would be desirable because they provide a true measure of abundance (Miesch, 1967, p. 8), they can be calculated only for elements that have a log-normal distribution; histograms of many elements on plate 1 have polymodal or asymmetrical distributions. Use of the median for this report is justified because in general we are searching for relatively large differences in the concentrations of elements in different data sets.

For this report, the background concentration of an element is the median value of analytical data obtained from unmineralized rocks, as discussed under "Elements in the Unmineralized Rocks." Threshold concentrations are the median values, discussed subsequently, of elements in the weakly mineralized rocks. For some elements, the values given in the threshold data set of table 1 are the same as background values; for others, threshold concentrations are slightly higher. Although any value above the threshold concentration would be considered anomalous, as used by Hawkes and Webb (1962), variations of one reporting interval may result from the combined effects of analytical and sampling errors; consequently, for this report an element is considered to occur in anomalous amounts if the median value is at least two reporting intervals above the threshold value.

## ELEMENTS IN THE UNMINERALIZED ROCKS

Geochemical background for this study was established by combining data on the concentration of elements from lower-plate carbonate rocks at Rattlesnake Canyon with data from upper-plate siliceous rocks in the core from drill hole 1 in a ratio of about 1:2. This ratio reflects the relative abundance of carbonate and siliceous rocks in the samples collected at the mine. Information from greenstone and siltstone is not in-included in the background data. Neither of these lithologies occurs in the drill core but even if represented in the correct proportion, probably would not change the background values significantly.

The histograms (pl. 1) for the background data set show that 16 of the 31 elements looked for occur in more than 50 percent of the samples analyzed. They also show that copper and titanium are markedly bimodal and that calcium is trimodal, indicating contributions from two or more populations.

The data presented in the histograms (pl. 1) and summarized in table 1 show that the Roberts Mountains Formation in Rattlesnake Canyon has about the same minor-element content as unmineralized Roberts Mountains Formation at the Carlin mine (Radtke and others, 1972) and as the average carbonate rocks of Turekian and Wedepohl (1961) and of Graf (1960). Although direct comparisons between the means of these authors and the medians in table 1 and plate 1 are not statistically valid, the similarities are worth noting. Principal differences include lower concentrations of manganese and greater concentrations of barium and vanadium in the Roberts Mountains Formation.

Values for the minor elements in samples from the drill hole (table 1; pl. 1) closely resemble the means and medians for Paleozoic black shales of the Western United States reported by Vine (1966), including

**Table 1.**—*Summary of analyses of samples collected at the Gold Acres open-pit mine and nearby areas*

[Calculated from analyses made in the laboratories of the U.S. Geological Survey; values in weight percent, except those in parts per million (ppm); *n* = number of analyses]

| | | | | | | | | Subsets, open-pit mine | |
|---|---|---|---|---|---|---|---|---|---|
| | | Background (*n* = 105) | | Threshold (*n* = 779) | | Open-pit mine (*n* = 547) | | Fault zones (*n* = 162) | |
| | Detection limit | Median | Range | Median | Range | Median | Range | Median | Range |
| Fe | 0.05 | 1.5 | 0.05–10 | 5 | 0.15–>20 | 3 | 0.15–>20 | 5 | 0.3<20 |
| Mg | .02 | 1.5 | .1–7 | .3 | <.02–5 | .7 | <.02–7 | .5 | .03–7 |
| Ca | .05 | 1.5 | .05–>20. | .7 | <.05–>20 | .7 | <.05–>20 | .7 | .05–20 |
| Ti | .002 | .07 | .01–1 | .1 | .007–1 | .2 | .003–1 | .2 | .003–>1 |
| Mn | .001 | .015 | .003–.3 | .015 | .001–.5 | .05 | .0007–7.5 | .07 | .002–.5 |
| Ag | .00005 | <.00005 | <.00005–.0005 | <.00005 | <.00005–.015 | .00005 | <.00005–.01 | .00007 | <.00005–.007 |
| As | .02 | <.02 | <.02–.15 | <.02 | <.02–.5 | .07 | <.02–>1. | .1 | <.02–>1 |
| B | .001 | .001 | <.001–.015 | .002 | <.001–.015 | .005 | <.001–.05 | .005 | <.001–.05 |
| Ba | .002 | .05 | <.002–>.5 | .07 | .002–>.5 | .015 | <.002–>.5 | .015 | .005–.3 |
| Be | .0001 | <.0001 | <.0001–.0003 | .0001 | <.0001–.001 | <.0001 | <.0001–.0015 | <.0001 | <.0001–.0015 |
| Bi | .001 | <.001 | <.001–.005 | <.001 | <.001–.007 | <.001 | <.001–.02 | <.001 | <.001–.02 |
| Cd | .002 | <.002 | <.002 | <.002 | <.002–.015 | <.002 | <.002–>.05 | <.002 | <.002–.03 |
| Co | .0005 | .0005 | <.0005–.005 | <.0005 | <.0005–.01 | .0007 | <.0005–.07 | .0007 | <.0005–.015 |
| Cr | .001 | .003 | <.001–.03 | .002 | <.001–.02 | .007 | <.001–.07 | .007 | <.001–.05 |
| Cu | .0005 | .002 | <.0005–.07 | .01 | <.0005–.2 | .007 | <.0005–>1 | .01 | .0007–.3 |
| La | .002 | <.002 | <.002–.01 | <.002 | <.002–.01 | .002 | <.002–.02 | .002 | <.002–.01 |
| Mo | .0005 | <.0005 | <.0005–.01 | .0007 | <.0005–.015 | .0007 | <.0005–.05 | .001 | <.0005–.05 |
| Nb | .001 | <.001 | <.001–.0015 | <.001 | <.001–.001 | <.001 | <.001–.01 | <.001 | <.001–.003 |
| Ni | .0005 | .003 | <.0005–.02 | .003 | <.0005–.03 | .005 | <.0005–.07 | .007 | <.0005–.05 |
| Pb | .001 | <.001 | <.001–.03 | .001 | <.001–>2. | .0015 | <.001–.1 | .002 | <.001–.1 |
| Sb | .01 | <.01 | <.01 | <.01 | <.01–.1 | <.01 | <.01–.15 | <.01 | <.01–.05 |
| Sc | .0005 | .0005 | <.0005–.003 | .0005 | <.0005–.003 | .0007 | <.0005–.007 | .0007 | <.0005–.005 |
| Sn | .001 | <.001 | <.001 | <.001 | <.001–.003 | <.001 | <.001–.001 | <.001 | <.001–.001 |
| Sr | .01 | <.01 | <.01–.15 | <.01 | <.01–.1 | <.01 | <.01–.07 | <.01 | <.01–.07 |
| V | .001 | .01 | .0007–.3 | .01 | .001–.2 | .02 | .001–.2 | .02 | .003–.2 |
| W | .005 | <.005 | <.005–.01 | <.005 | <.005 | <.005 | <.005–.07 | <.005 | <.005–.05 |
| Y | .001 | .001 | <.001–.007 | .001 | <.001–.02 | .002 | <.001–.01 | .002 | <.001–.007 |
| Zn | .02 | <.02 | <.02–.03 | <.02 | <.02–>1.0 | .03 | <.02–>1.0 | .03 | <.02–1.0 |
| Zr | .001 | .007 | <.001–.03 | .007 | <.0001–.07 | .015 | <.001–>.1 | .015 | <.001–.05 |
| Au | .02 ppm | <.02 ppm | <.02–3 ppm | <.02 ppm | <.02–7 ppm | .5 ppm | <.02–70 ppm | 2 ppm | <.02–70 ppm |
| Hg | .01 ppm | .1 ppm | <.01–3 ppm | .2 ppm | <.01–>10 ppm | 2 ppm | <.01–>10 ppm | 3 ppm | .05–>10 ppm |

**Table 1.**—*Summary of analyses of samples collected at the Gold Acres open-pit mine and nearby areas*—Continued

| | | Subsets, open-pit mine—Continued | | | | Subsets, background | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hornfels-tactite-metagreenstone (*n* = 58) | | Limestone-dolomite (*n* = 137) | | Roberts Mountains Formation Rattlesnake Canyon (*n* = 33) | | Upper-plate rocks, DDH–1 (*n* = 291) | |
| | Detection limit | Median | Range | Median | Range | Median | Range | Median | Range |
| Fe | 0.05 | 5 | 0.7–20 | 2 | 0.15–20 | 0.5 | 0.05–1.5 | 1.5 | 0.5–10 |
| Mg | .02 | 1 | .05–7 | 1.5 | .03–10 | 3 | .7–7 | 1 | .1–5 |
| Ca | .05 | 1 | .05–10 | 7 | .1–>20 | <20 | 10.–>20 | .7 | .05–5 |
| Ti | .002 | .7 | .03–>1 | .1 | .003–.7 | .05 | .01–.2 | .2 | .03–1 |
| Mn | .001 | .07 | .002–.5 | .05 | .002–>.5 | .015 | .005–.03 | .015 | .003–.3 |
| Ag | .00005 | <.00005 | <.00005–.007 | .00007 | <.00005–.01 | <.00005 | <.00005 | <.00005 | <.00005–.0005 |
| As | .02 | <.02 | <.02–.2 | .05 | <.02–>1.0 | <.02 | <.02 | <.02 | <.02–.15 |
| B | .001 | .001 | <.001–.01 | .005 | <.001–.05 | .001 | <.001–.007 | <.001 | <.001–.015 |
| Ba | .002 | .015 | <.002–.2 | .01 | .002–.5 | .01 | <.002–.03 | .1 | .005–>.5 |
| Be | .0001 | <.0001 | <.0001–.0002 | <.0001 | <.0001–.0005 | <.0001 | <.0001 | <.0001 | <.0001–.0003 |
| Bi | .001 | <.001 | <.001–.015 | <.001 | <.001–.005 | <.001 | <.001 | <.001 | <.001–.005 |
| Cd | .002 | <.002 | <.002–>.05 | <.002 | <.002–.005 | <.002 | <.002 | <.002 | <.002 |
| Co | .0005 | .0015 | <.0005–.015 | .0005 | <.005–.002 | <.0005 | <.0005–.0005 | .007 | <.0005–.005 |
| Cr | .001 | .01 | <.001–.07 | .005 | <.001–.02 | .002 | <.001–.007 | .005 | <.001–.03 |
| Cu | .0005 | .03 | .0015–.5 | .003 | <.0005–.5 | .0015 | <.0005–.005 | .005 | .0005–.07 |
| La | .002 | <.002 | <.002–.007 | .002 | <.002–.01 | <.002 | <.002–.002 | <.002 | <.002–.01 |
| Mo | .0005 | <.0005 | <.0005–.007 | .001 | <.0005–.015 | <.0005 | <.0005–.002 | <.0005 | <.0005–.01 |
| Nb | .001 | <.001 | <.001–.005 | <.001 | <.001–.002 | <.001 | <.001 | <.001 | <.001–.0015 |
| Ni | .0005 | .007 | <.0005–.03 | .005 | <.0005–.07 | .001 | <.0005–.007 | .003 | <.0005–.02 |
| Pb | .001 | .0015 | <.001–.03 | .0015 | <.001–.03 | .001 | <.001–.005 | <.001 | <.001–.03 |
| Sb | .01 | <.01 | <.01 | <.01 | <.01–.15 | <.01 | <.01 | <.01 | <.01–.02 |
| Sc | .0005 | .001 | <.0005–.007 | .0005 | <.0005–.002 | <.0005 | <.0005–.0005 | <.0005 | <.0005–.003 |
| Sn | .001 | <.001 | <.001–.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 |
| Sr | .01 | <.01 | <.01–.02 | <.01 | <.01–.05 | .07 | <.01–.15 | <.01 | <.01–.15 |
| V | .001 | .015–.02 | .005–.07 | .03 | .001–.2 | .01 | .001–.1 | .01 | .0007–.3 |
| W | .005 | <.005 | <.005–.007 | <.005 | <.005–.05 | <.005 | <.005 | <.005 | <.005–.01 |
| Y | .001 | .0015 | <.001–.005 | .002 | <.001–.01 | .0015 | <.001–.002 | .001 | <.001–.007 |
| Zn | .02 | .2 | <.02–>1. | <.02 | <.02–>1.0 | <.02 | <.02–.03 | <.02 | <.02–.03 |
| Zr | .001 | .015 | <.001–.03 | .007 | <.001–>.1 | .01 | .001–.03 | .007 | <.001–.03 |
| Au | .02 ppm | .02 ppm | <.02–30 ppm | .7 ppm | <.02–30 ppm | <.02 ppm | <.02 ppm | <.02 ppm | <.02–3. ppm |
| Hg | .01 ppm | .7 ppm | <.01–>10 ppm | 2 ppm | <.01–>10 ppm | .1 ppm | .01–.7 ppm | .1 ppm | <.01–3. ppm |

siliceous eugeosynclinal rocks from Nevada, except that boron is lower in the core.

The only other data available on background concentrations in the region are from the core of the eugeosynclinal Scott Canyon Formation at Battle Mountain (Theodore and Roberts, 1971), but the values reported for many elements in those rocks are greater—some by an order of magnitude—than in the core from drill hole 1 (table 1). Available evidence indicates that the upper-plate rocks of drill hole 1 and the Roberts Mountains Formation of Rattlesnake Canyon have minor-element contents suitable for combining into a background data set against which data from mineralized rocks at the mine can be compared.

## ELEMENTS IN THE WEAKLY MINERALIZED AREA

The 779 samples collected in the area adjacent to the mineral belts at Tenabo and Gold Acres (fig. 4) provide data on threshold values as summarized in table 1 and on plate 1. These data show that boron, copper, iron, mercury, and molybdenum are enriched in the weakly mineralized rocks and have median values two or more class intervals higher than background values. The data show that antimony, arsenic, beryllium, cadmium, lead, silver, and zinc are also enriched in the weakly mineralized rocks, even though the median for these elements falls close to or below the detection limit, as a greater percentage of values lies above the detection limit than in the unmineralized rocks. All other elements in the threshold set have medians and ranges similar to those in the background set.

The histograms for the background, threshold, and drill-hole data sets suggest that the median value of copper in the threshold set results in part from the contribution made by chert and argillite, the most abundant rocks in the weakly mineralized area. But the broad range in the histogram for threshold copper suggests a complex distribution from several populations and implies that copper was introduced into the weakly mineralized area. The wide geographic distribution of copper in concentrations of 200 ppm (parts per million) or more (Wrucke and others, 1968) in the Gold Acres and Tenabo areas further supports the suggestion that this element has been introduced into the weakly mineralized rocks.

Although medians of elements in rocks from the weakly mineralized area provide a measure of threshold concentrations for the Gold Acres area, the differences between these medians and those established for background are generally so small that they could serve as an approximate measure of background.

## GEOCHEMICAL ANOMALIES AT THE MINE

Data summarized in table 1 show that collectively the rocks at the Gold Acres mine contain anomalous concentrations of gold, arsenic, boron, cobalt, chromium, magnesium, manganese, mercury, titanium, vanadium, yttrium, zinc, and zirconium, and the histograms of plate 1 suggest that silver and tungsten should be included with these elements. Medians for gold and mercury in the mine samples are at least an order of magnitude greater than threshold values. The median value for arsenic in the mine samples is 3½ times greater than the threshold value, and, significantly, the element was detected in 76 percent of the rock collected from the mine but in only 21 percent of those used to calculate the threshold concentration. Zinc has a median value an order of magnitude greater for samples from hornfels, tactite, and metagreenstone than for samples from the weakly mineralized area. Tungsten almost certainly occurs in anomalous amounts at the mine, for even though the spectrographic technique is relatively insensitive the metal was detected in 20 percent of the mine samples and was not detected in samples from the weakly mineralized area. Silver also was detected in a much higher percentage of the samples from the mine than in samples from the outlying rocks. Additional evidence that silver occurs in anomalous amounts can be seen in the histograms for each subset of the mine data—the large number of values at the upper end of the range in the hornfels-tactite-metagreenstone subset and the high median values in the subsets for fault zones and limestone-dolomite. Magnesium and vanadium, which occur in anomalous concentrations in samples collected throughout the mine, are contributed in relatively large amounts by tactite and carbonate rocks; similarly, the concentrations of cobalt, chromium, and titanium reflect the abundance of metagreenstone, as discussed subsequently. Yttrium and zirconium are present in anomalous concentrations at the mine according to the definition used here, but the geochemistry of these elements is poorly understood and will not be discussed further. Of the elements concentrated at the open-pit mine, gold, arsenic, boron, manganese, mercury, silver, tungsten, and zinc are thought to be introduced elements important in the history of mineralization. Bismuth and cadmium, though not present in anomalous concentrations, also may have been introduced during mineralization; iron almost certainly was introduced.

Copper, lead, and molybdenum are widely distributed in the Gold Acres area but show no significant enrichment at the mine relative to threshold values. Antimony shows no enrichment in the mine, as the range of values from the mine samples and the weakly mineralized samples is similar. Maps showing the distribution of antimony, copper, lead, and molybdenum (Wrucke and others, 1968) support these observations. Although Erickson, VanSickle, Nakagawa, and McCarthy (1966) indicate that antimony is associated with gold at many of the gold deposits in northern Nevada, antimony is not clearly concentrated with gold at Gold Acres.

The median of 0.5 ppm for gold is not a measure of abundance or tenor of ore at the mine. Certainly the wide range of values shown by the frequency distribution for gold (pl. 1) offers little confidence that the median approximates abundance. The histogram suggests superposition of data from several populations, each characterized by a different frequency distribution; examples of differing distribution patterns include the histograms of gold for the hornfels-tactite-metagreenstone subset and for the limestone-dolomite subset. In addition, the median value for the mine samples differs greatly from the arithmetic mean of 3.0 ppm calculated from the entire Gold Acres data set. This mean reflects the high concentrations of gold found in some samples. Median and mean values for gold calculated from the data used for this paper give a value less than the tenor of the ore because the samples included unmineralized as well as mineralized rock.

#### LIMESTONE AND DOLOMITE

Median values (pl. 1) indicate that of the many elements present in greater concentrations in limestone and dolomite at the mine than in the Roberts Mountains Formation of Rattlesnake Canyon, only gold, arsenic, boron, chromium, manganese, mercury, silver, vanadium and yttrium occur in anomalous amounts. Tungsten also would probably be shown as occurring in anomalous concentrations if a more sensitive analytical technique had been used, because the histograms (pl. 1) show that it was detected in a relatively high percentage of samples from these rocks. Included in the list of elements that occur in anomalous or probably anomalous amounts in the limestone-dolomite subset are the same metals—gold, arsenic, mercury, and tungsten—that were reported (Erickson and others, 1966) as forming a geochemical association at several disseminated gold deposits in Nevada.

#### HORNFELS, TACTITE, AND METAGREENSTONE

Samples of hornfels, tactite, and metagreenstone from the mine contain a median concentration of zinc more than an order of magnitude above the threshold value (pl. 1). Gold is considered to be anomalously concentrated in these rocks because it occurs in a wide range of values extending to 30 ppm. Silver, as reported, occurs in anomalous concentrations in the hornfels, tactite, and metagreenstone, for the histogram (pl. 1) shows a greater than normal frequency of high values; for the same reason, arsenic, bismuth, and cadmium are considered as concentrated in anomalous amounts in these rocks. Copper, with a median value three class intervals above threshold, is clearly concentrated in anomalous amounts in these rocks, although not in the entire mine. Although cobalt, chromium, magnesium, manganese, nickel, scandium, titanium, and zirconium have medians two class intervals above threshold, they occur in amounts expected in a subset composed of basaltic rocks (greenstone) and hornfels in the proportions found at the open-pit mine. Some of these elements could have been deposited, at least in small amounts, during hypogene mineralization. Manganese, which is common in base-metal deposits, may have been introduced, as it occurs in anomalous concentrations in all mineralized rock types considered here. Of the elements discussed here, and likely to have been introduced, bismuth, cadmium, copper, and zinc are concentrated more strongly in the hornfels-tactite-metagreenstone subset than in other subsets of data from the mine. Arsenic, iron, and lead are associated with these elements; they occur in sulfide minerals in hornfels, tactite, and metagreenstone, as do copper and zinc and probably bismuth, cadmium, and manganese. The possibility that silver may belong to this association of elements is discussed under the section "Association of Elements."

#### FAULT ZONES

The highest concentrations of gold in the open-pit mine—as much as 70 ppm—occur in fault zones. Gold in samples from these zones has a median value four times greater than in samples from the mine as a whole and nearly three times greater than in samples from carbonate rocks (pl. 1). Other elements associated with gold in limestone and dolomite occur in anomalous concentrations in fault zones. In addition to gold, the fault zones contain anomalous concentrations of arsenic, boron, chromium, cobalt, lead, manganese, mercury, nickel, silver, titanium, vanadium, yttrium, zinc, and zirconium. Using the reasoning just mentioned, evidence for tungsten's being enriched in fault zones is the range in values shown in the histograms (pl. 1). Although iron does not occur in anomalous amounts in fault zones using the definition followed in this paper, our observations show that it is strongly concentrated there. The same median value for iron in fault zones as in the threshold value results from the fact that most samples from the weakly mineralized area were selected for enrichment in iron oxides.

### GEOGRAPHIC DISTRIBUTION OF ELEMENTS

As a supplement to the data on median and range of concentrations present in tabular form (table 1) and in histograms of frequency distribution (pl. 1), the geographic distribution of eight elements that occur in anomalous concentration in samples from the open-pit mine is shown in figures 5–12. Of these elements, gold, arsenic, and mercury have similar distributions. They occur mainly in the lower part of the open pit, where many conspicuous westward-dipping low-angle, probably imbricate, faults lie 10–30 feet apart vertically. In the upper half of the mine, strong concentrations of gold and arsenic occur at considerably fewer localities than in the lower half. It is significant that the few localities where samples containing high concentrations of tungsten were collected are almost exclusively in the lower part of the mine, where gold, arsenic, and mercury also are strongly concentrated. Copper and silver are distributed much more evenly throughout the mine than most other elements considered here. Of note is that gold mining began at the surface near the present east edge of the pit and followed the low-angle faults to the steep northwest-trending wall that marks the west limit of the mine. Before mining began, geochemical anomalies of these elements almost certainly formed a northwest-trending pattern along the exposed traces of the faults.

Zinc, although detected in samples from most localities, occurs in anomalous amounts mainly in the southern part of the mine. Clearly, the distribution of zinc differs from that of most other metals present in anomalous amounts and corresponds with the distribution of sphalerite-bearing hornfels, tactite, and metagreenstone. Cadmium, not plotted, has the same distribution as zinc.

Our data suggest that boron probably is distributed much the same as gold and that manganese is widely dispersed in all rock types, chiefly as dendrites. Molybdenum occurs in small concentrations in many rock types at the mine as well as between Gold Acres and Tenabo (Wrucke and others, 1968).

Gold and zinc, which form the strongest anomalies in the Gold Acres area, occur beyond the open-pit mine (Wrucke and others, 1968). Gold, for example, occurs in the parts per million range in rocks between the open-pit mine and the mines and prospects to the southeast. The distribution patterns of zinc and gold overlap, but zinc, unlike gold, is anomalous in concentration as far as 1 mile northwest of the open-pit mine.

Elements that occur in anomalous concentrations in specific lithologic types, in fault zones, and in the lower part of the mine are summarized in table 2. Distribution shown by this table affirms that gold and elements associated with it do not necessarily occur where zinc and its associated elements are found. Many elements not associated with either gold or zinc occur in fault zones. The mine thus hosts a gold suite and a base-metal suite of elements, and possibly a third suite found in the fault zones. As suggested by the concentrations and distributions of elements, the gold suite consists of gold, arsenic, boron, mercury, tungsten, and perhaps silver; the base-metal suite contains copper, zinc, arsenic, bismuth, cadmium, and manganese; and the suite in the fault zones includes metals in the gold suite as well as chromium, cobalt, lead, manganese, nickel, silver, titanium, vanadium, yttrium, zirconium, and zinc. Refinements in these associations are possible using techniques described subsequently.

## ASSOCIATION OF ELEMENTS

The concentrations of 31 elements detected in the samples collected throughout the open-pit mine were compared statistically to determine the strength of the association between element pairs as a means of defining suites of geochemically related elements. Associated elements are termed coherent if they vary in concentration sympathetically: An increase in the concentration of one occurs with an increase in the concentration of the other, or a decrease of one occurs with a decrease in the other. (See Miesch, 1963, p. 6.) Coherent elements tend to have the same geographic distribution, but the strength of the association is best determined statistically.

Spearman rank correlation coefficients were used to measure the coherence of pairs of elements at the mine (table 3) because this method can be applied to data that is ranked or has a nonnormal frequency distribution. Data from the spectrographic analyses of the mine samples are ranked, as the concentrations were reported in stepped intervals, and the frequency distribution of gold and some of the other elements (pl. 1) is not normal. The Spearman test makes no assumption about population distribution (Siegel, 1956). For each element, analytical determinations above the upper detection limit were assigned a value one spectrographic reporting interval above that limit; determinations below the lower detection limit were not replaced and therefore were not included in the calculations. Each correlation coefficient was tested for significance at the 95 and 99 percent confidence levels using Student's $t$ test (Flanagan, 1957, p. 316), which is

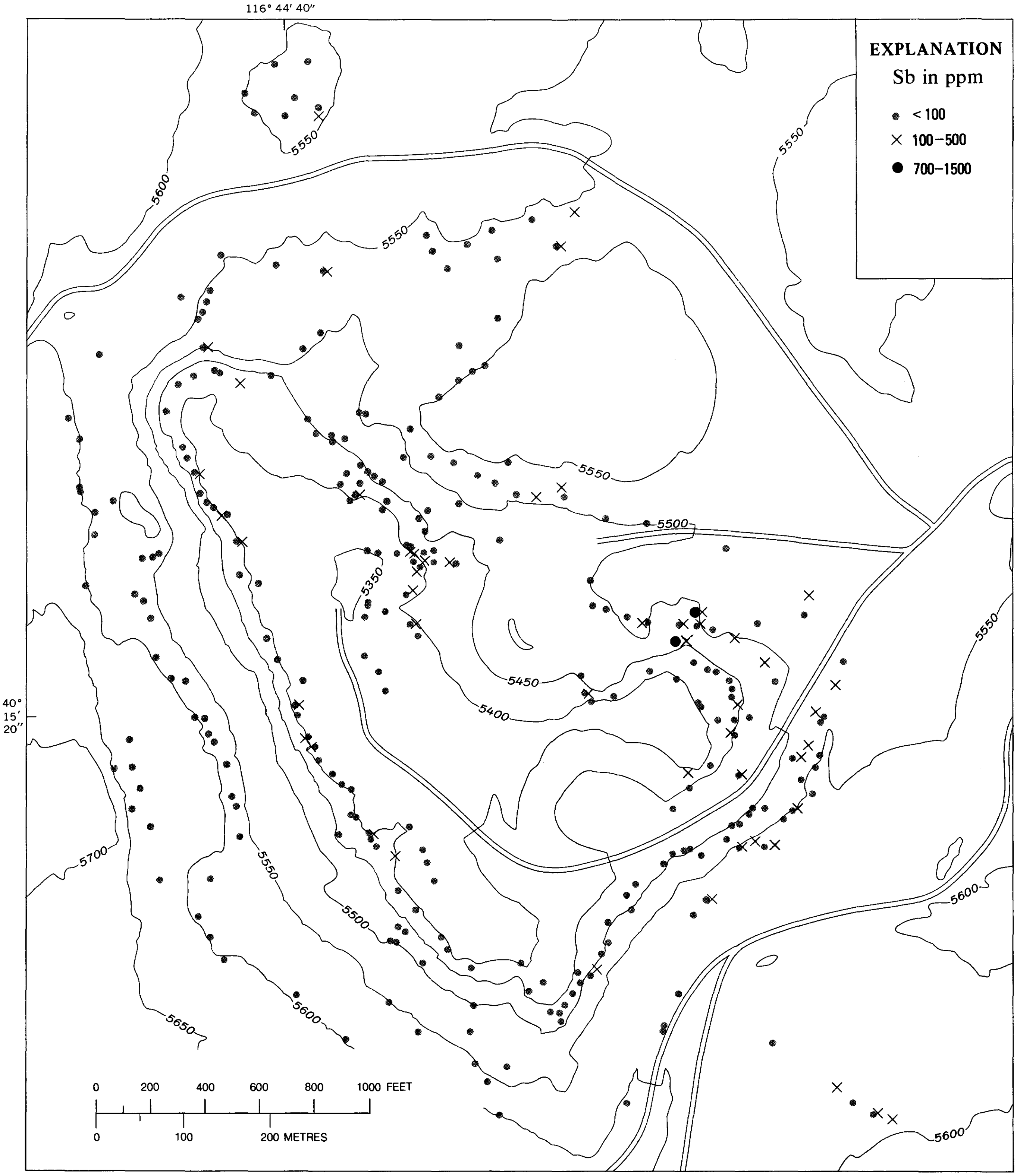



FIGURE 5.—Distribution of antimony at the Gold Acres open-pit mine.

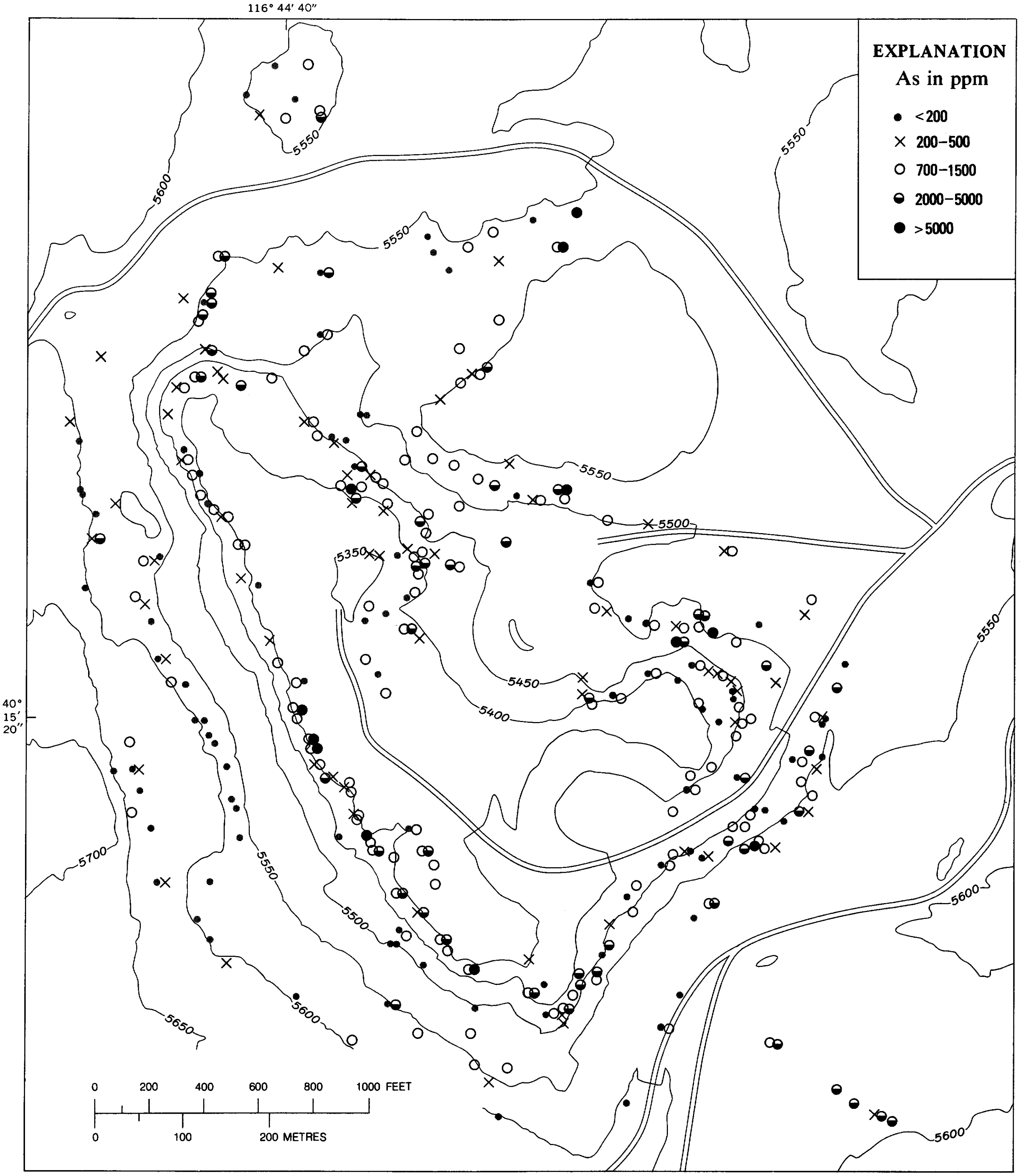



FIGURE 6.—Distribution of arsenic at the Gold Acres open-pit mine.

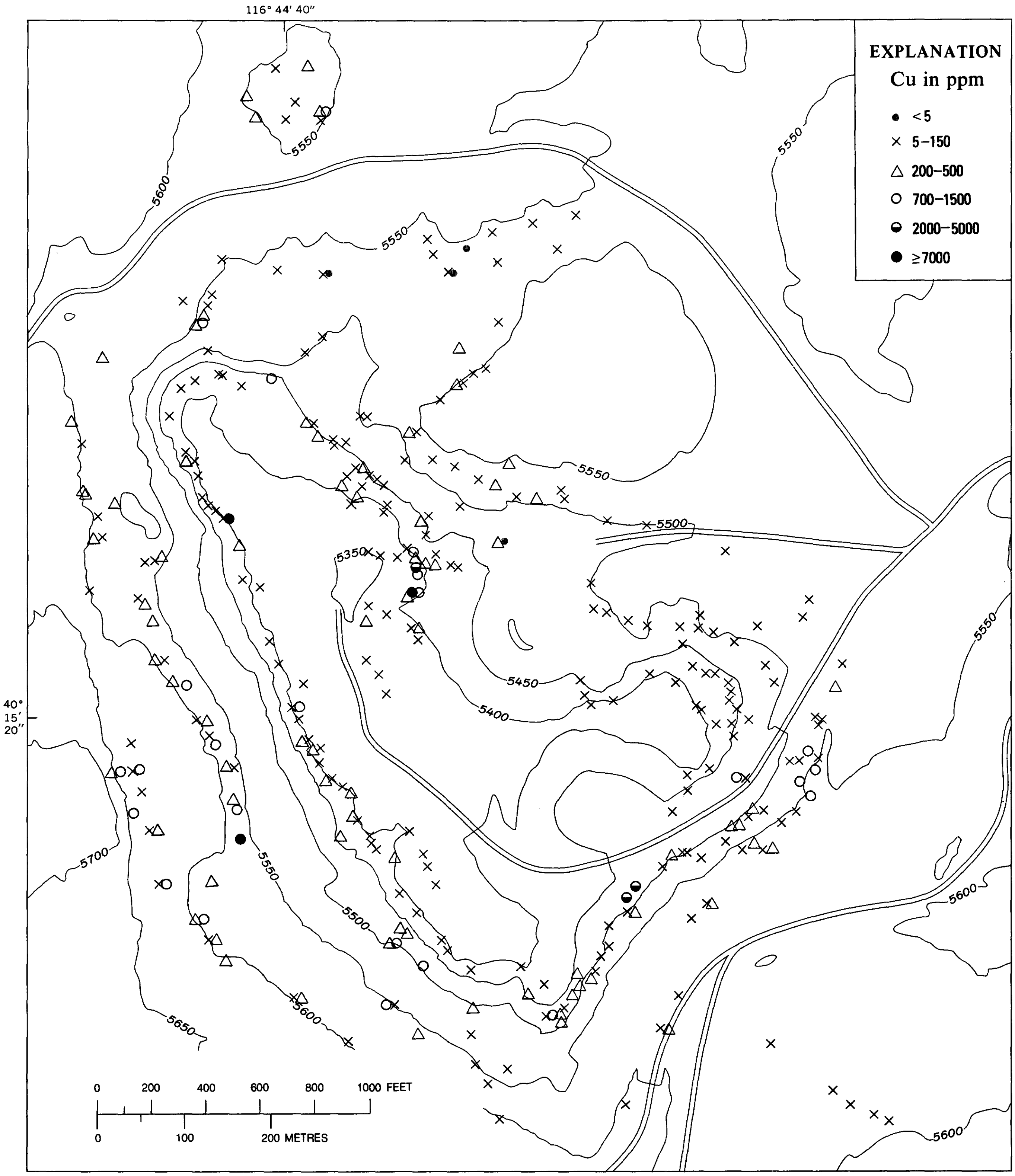



FIGURE 7.—Distribution of copper at the Gold Acres open-pit mine.

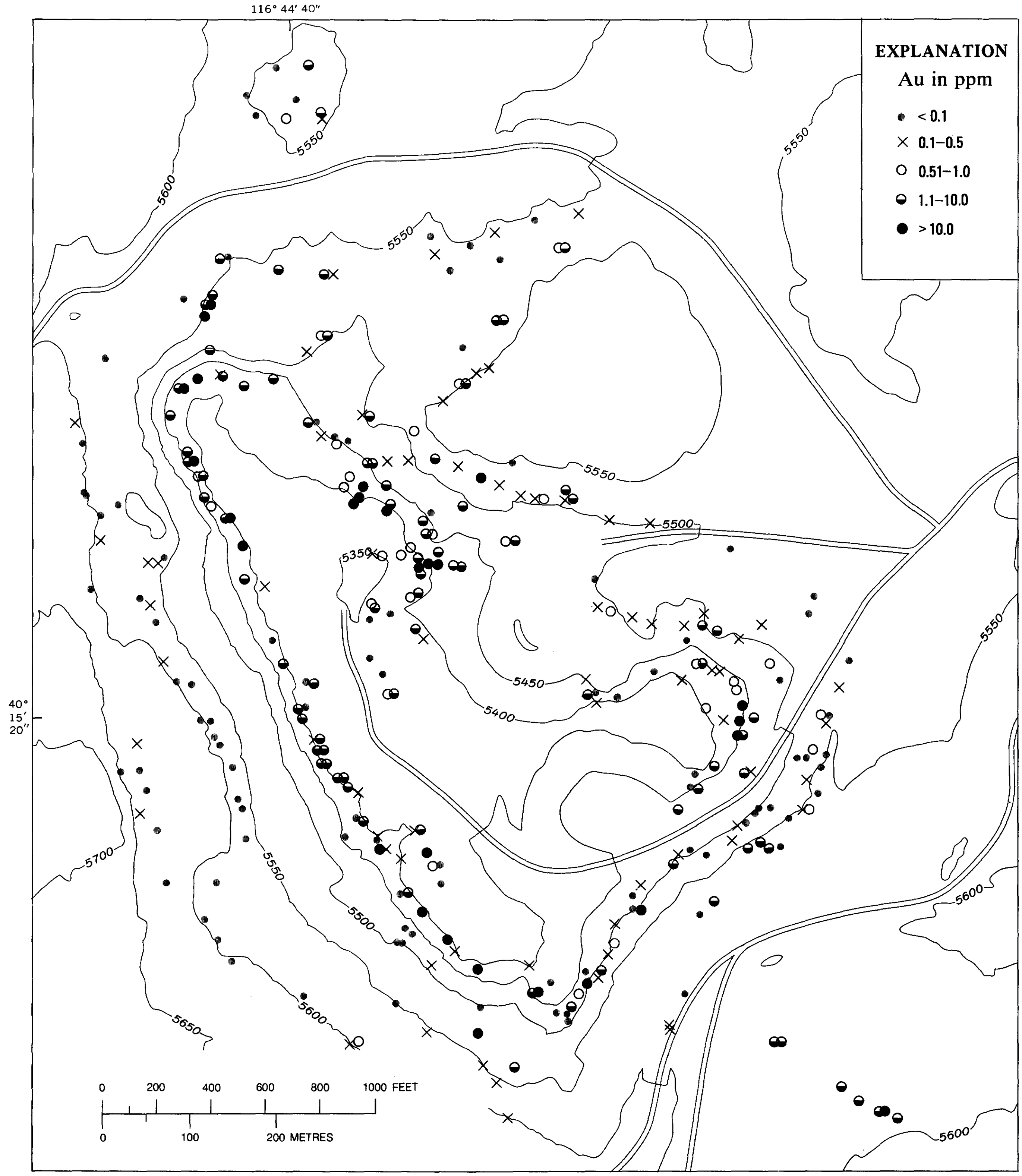



FIGURE 8.—Distribution of gold at the Gold Acres open-pit mine.

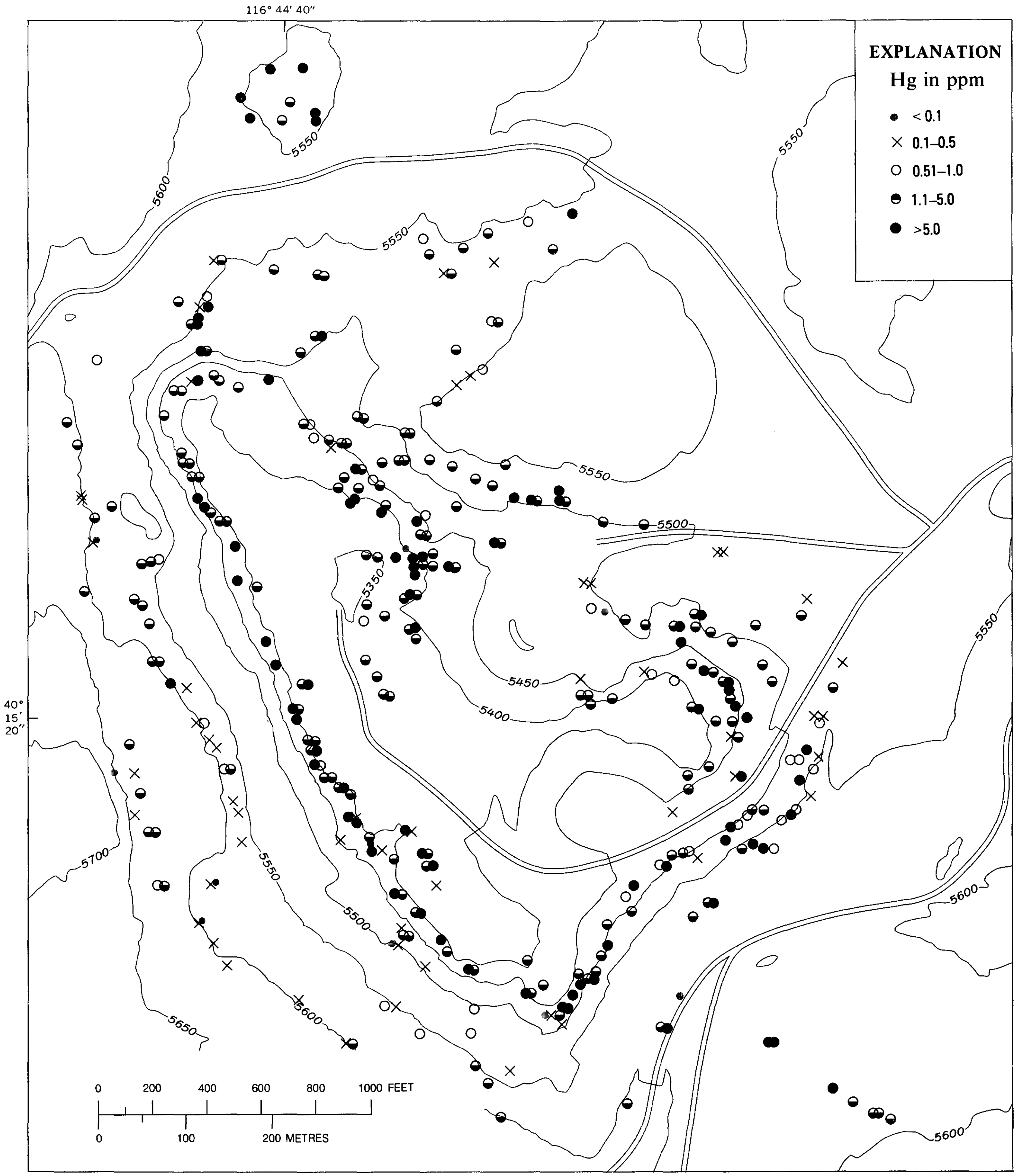



**Figure 9.**—Distribution of mercury at the Gold Acres open-pit mine.

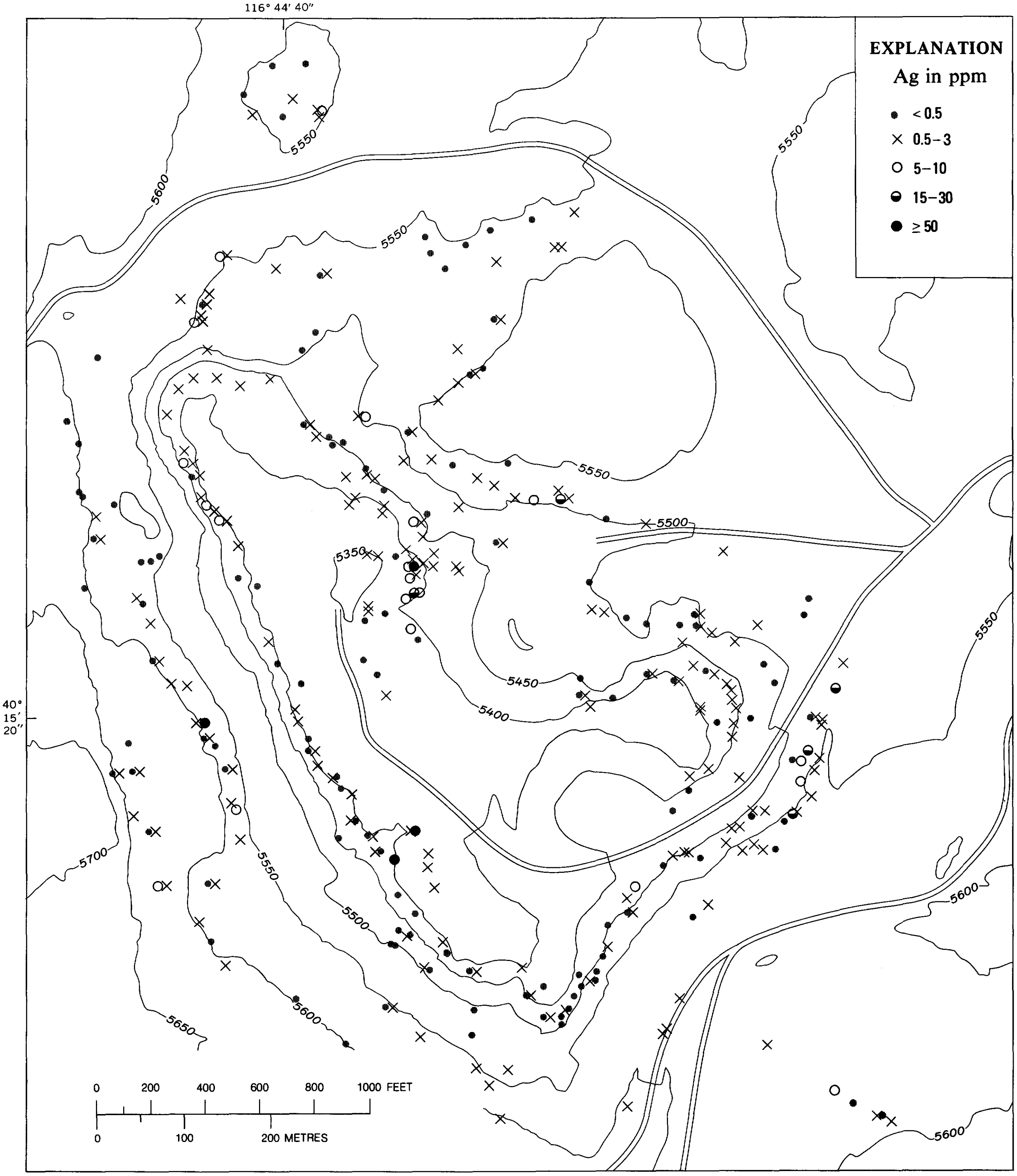



FIGURE 10.—Distribution of silver at the Gold Acres open-pit mine.

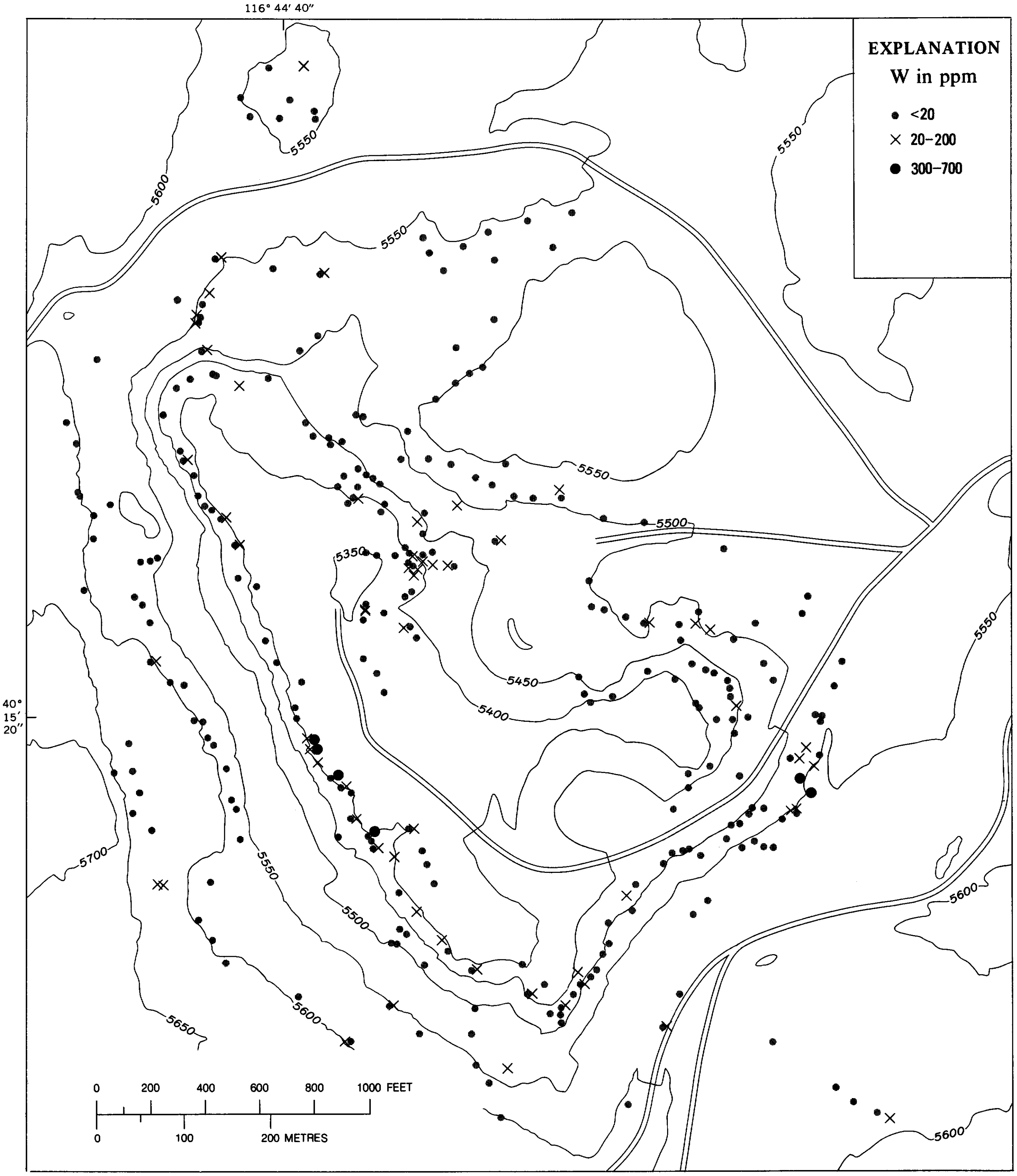



FIGURE 11.—Distribution of tungsten at the Gold Acres open-pit mine.

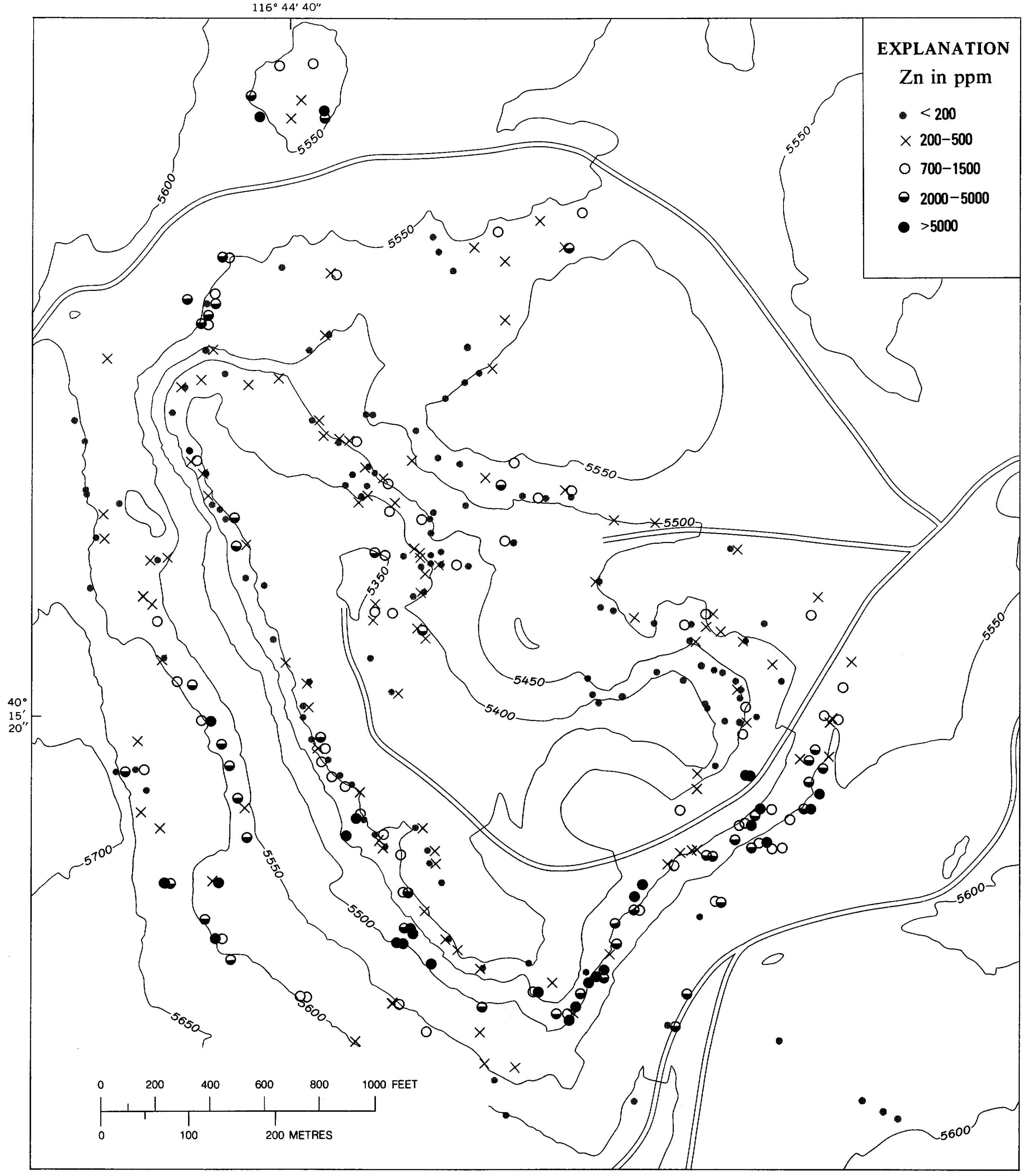



FIGURE 12.—Distribution of zinc at the Gold Acres open-pit mine.

TABLE 2.—*Environments that contain anomalous concentrations of elements at the Gold Acres open-pit mine*

| | Ti | Mn | Ag | As | B | Bi | Cd | Co | Cr | Cu | Ni | Pb | V | W | Y | Zn | Zr | Au | Hg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lower part of mine[1] | ---- | ---- | × | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | × | × |
| Limestone and dolomite[2] | ---- | × | × | × | × | ---- | ---- | ---- | × | ---- | ---- | ---- | × | × | × | ---- | ---- | × | × |
| Hornfels, tactite, and metagreenstone[2] | ---- | × | × | × | ---- | × | × | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | × | ---- | × | × |
| Fault zones[2] | × | × | × | × | × | ---- | ---- | × | × | ---- | × | × | × | × | × | × | × | × | × |

[1]Information obtained from distribution maps for antimony, arsenic, copper, gold, mercury, silver, tungsten, and zinc (figs. 5–12).
[2]Information derived from table 1 and plate 1.

dependent on the number of pairs of observations used in the calculations. In this report, the only correlation coefficients used are those calculated from 100 or more pairs of elements because the confidence level of a specific coefficient changes very little as the degrees of freedom (number of samples less one) increase above about 100. (See Krumbein and Greybill, 1965, table A–5, p. 421.)

Spearman correlation coefficients presented in table 3 confirm the associations of elements suggested on the distribution maps (figs. 5–12) and discussed in the section on geochemical anomalies at the mine. Gold shows relatively strong correlations with mercury, arsenic, and boron. Zinc (fig. 12) has a different distribution pattern from gold (fig. 8), and the two elements have a negative correlation coefficient. The negative correlation means that high concentrations of one of these elements tend to occur with low concentrations of the other. The number of pairs antimony and tungsten form with other elements is not sufficient for computing a significant correlation coefficient at the 95-percent confidence level. Mercury correlates with the elements associated with gold and with gold itself. It is surprising that the data indicate no affinity of mercury for zinc or between mercury and the elements associated with zinc, as was expected from the broad mercury halo around those parts of the mineral belt on the east flank of the Shoshone Range where zinc and other metals, but not gold, are abundant.

Data in table 3 reveal that arsenic, copper, manganese, and zinc of the base-metal suite tend to be interrelated as a group even though the correlation coefficient of each pair of these elements is not significant at the 95-percent confidence limit. The number of pairs bismuth and cadmium form with these elements is not sufficient for measuring the correlation at this confidence level, but from geologic considerations they are considered as belonging to the base-metal suite. Iron, lead, and molybdenum are not present in anomalous concentrations in the hornfels, tactite, and metagreenstone, where the base-metal suite occurs, but they probably belong to this suite of elements also, as they correlate with other metals in it.

Silver shows a significant correlation at the 95-percent confidence level with many elements in the base-metal suite. Silver also correlates with gold, and silver accounted for a remarkably consistent proportion of the annual production at the open-pit mine, averaging 9.8 percent and having a range of 5.9–13.8 percent, suggestive of a geochemical association. Joralemon (1951) reported a similar gold-silver ratio, 10:1, for the entire production from the disseminated gold deposit at Getchell, Nev.; unfortunately, data on this ratio from other disseminated gold deposits are not available. Although there could be a fairly uniform gold-silver ratio at the open-pit mine even if the metals are not associated geochemically, the consistent annual production ratio and the low but positive correlation coefficient suggest a silver-gold association. Silver may well have been deposited during both sulfide and gold mineralizations at the open-pit mine.

Data in table 3 show that iron and manganese correlate with numerous elements, and many of these elements occur in anomalous concentrations in fault zones at the open-pit mine. They form a suite of elements that correlate with one another. Copper and scandium, though not present in anomalous concentrations at the mine, have high concentrations in fault zones compared with background values and probably should be considered as part of this suite because they correlate with the other elements in it. An association of iron and manganese with many elements was expected because iron and manganese oxides, widely distributed at the mine, are known to scavenge minor elements (Hawkes and Webb, 1962). Iron, manganese, arsenic, boron, chromium, cobalt, copper, nickel, scandium, titanium, yttrium, and zirconium are interpreted as forming a suite of associated elements referred to here as the iron-manganese suite. Some of the more important associations of elements at the mine as determined from correlation coefficients and geologic relations are summarized in table 4.

TABLE 3.—*Spearman rank correlation coefficients*

[Values are significant at the 95 percentile level except italic values are significant at the 99 percentile

| | Fe | Mg | Ca | Ti | Mn | Ag | As | B | Ba | Be | Bi | Cd | Co | Cr | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fe | | ---- | −0.100 | *0.197* | *0.355* | *0.175* | *0.503* | *0.229* | *0.170* | *0.296* | ---- | ---- | *0.487* | *0.279* | *0.620* |
| Mg | 432 | | *.626* | .100 | *.276* | ---- | ---- | *.126* | *−.129* | ---- | ---- | ---- | ---- | *.220* | ---- |
| Ca | 429 | 432 | | *−.248* | *.390* | ---- | ---- | ---- | *−.236* | ---- | ---- | ---- | *−.174* | ---- | *−.168* |
| Ti | 419 | 422 | 419 | | −.097 | ---- | ---- | *.362* | *.335* | ---- | ---- | ---- | *.288* | *.626* | *.239* |
| Mn | 421 | 424 | 421 | 411 | | *.220* | *.309* | ---- | ---- | *.184* | ---- | ---- | *.220* | ---- | *.310* |
| Ag | 270 | 273 | 272 | 265 | 263 | | .123 | *.165* | .103 | −.160 | ---- | ---- | ---- | ---- | *.324* |
| As | 315 | 318 | 318 | 310 | 308 | 222 | | *.232* | *.223* | .175 | ---- | ---- | *.337* | *.141* | *.198* |
| B | 360 | 363 | 361 | 350 | 356 | 237 | 288 | | *.136* | ---- | ---- | ---- | .122 | *.344* | ---- |
| Ba | 430 | 433 | 430 | 420 | 422 | 271 | 316 | 361 | | *.189* | ---- | ---- | *.278* | *.190* | *.152* |
| Be | 165 | 166 | 166 | 160 | 160 | 116 | 153 | 156 | 165 | | ---- | ---- | .175 | ---- | ---- |
| Bi | 34 | 36 | 36 | 32 | 36 | 32 | 21 | 30 | 36 | 6 | | ---- | ---- | ---- | ---- |
| Cd | 32 | 32 | 32 | 30 | 28 | 27 | 18 | 19 | 32 | 10 | 8 | | *.485* | ---- | ---- |
| Co | 335 | 336 | 334 | 325 | 326 | 221 | 269 | 294 | 334 | 155 | 27 | 28 | | *.217* | *.396* |
| Cr | 431 | 434 | 431 | 421 | 423 | 273 | 318 | 363 | 432 | 166 | 36 | 32 | 336 | | *.273* |
| Cu | 428 | 431 | 428 | 418 | 420 | 273 | 317 | 363 | 429 | 166 | 36 | 32 | 336 | 431 | |
| La | 231 | 231 | 231 | 225 | 224 | 157 | 196 | 217 | 229 | 132 | 15 | 11 | 200 | 231 | 231 |
| Mo | 315 | 317 | 316 | 310 | 306 | 222 | 257 | 267 | 315 | 135 | 24 | 24 | 252 | 316 | 315 |
| Nb | 109 | 112 | 112 | 101 | 109 | 80 | 93 | 110 | 112 | 73 | 18 | 6 | 96 | 112 | 112 |
| Ni | 428 | 431 | 428 | 418 | 420 | 272 | 317 | 361 | 429 | 166 | 36 | 32 | 335 | 430 | 429 |
| Pb | 275 | 273 | 277 | 267 | 268 | 219 | 219 | 244 | 277 | 123 | 35 | 29 | 218 | 278 | 278 |
| Sb | 50 | 51 | 51 | 49 | 47 | 47 | 51 | 45 | 50 | 41 | 2 | 1 | 47 | 51 | 51 |
| Sc | 340 | 343 | 343 | 330 | 335 | 224 | 271 | 314 | 341 | 157 | 31 | 22 | 289 | 343 | 343 |
| Sn | 3 | 3 | 3 | 1 | 3 | 3 | 0 | 3 | 3 | 1 | 2 | 0 | 1 | 3 | 3 |
| Sr | 99 | 100 | 100 | 97 | 96 | 65 | 63 | 79 | 100 | 30 | 4 | 7 | 64 | 99 | 96 |
| V | 432 | 435 | 432 | 422 | 424 | 273 | 318 | 363 | 433 | 166 | 36 | 32 | 336 | 434 | 431 |
| W | 92 | 93 | 93 | 86 | 91 | 71 | 90 | 85 | 92 | 69 | 14 | 7 | 81 | 93 | 93 |
| Y | 365 | 367 | 367 | 356 | 356 | 245 | 289 | 316 | 365 | 160 | 31 | 26 | 300 | 367 | 367 |
| Zn | 263 | 266 | 265 | 259 | 256 | 178 | 204 | 211 | 264 | 119 | 35 | 31 | 216 | 265 | 264 |
| Zr | 422 | 425 | 422 | 412 | 416 | 269 | 315 | 363 | 423 | 166 | 36 | 30 | 333 | 425 | 423 |
| Au | 364 | 367 | 365 | 356 | 357 | 244 | 299 | 320 | 365 | 153 | 21 | 19 | 288 | 366 | 364 |
| Hg | 420 | 432 | 429 | 420 | 421 | 271 | 316 | 360 | 430 | 165 | 36 | 32 | 333 | 431 | 428 |

TABLE 4.—*Summary of association of elements in the gold, base metal, and iron-manganese suites at the Gold Acres open-pit mine*

| Suite | Associated elements | Principal occurrence |
|---|---|---|
| Gold | Au, Ag(?), As, B, Hg, W | Fault zones, limestone, and dolomite. |
| Base metal | Cu, Pb, Zn, Ag(?), As, Bi, Cd, Fe, Mn, Mo. | Hornfels, tactite, and metagreenstone. |
| Iron-manganese | Fe, Mn, As, B, Cr, Co, Cu, Ni, Sc, Ti, Y, Zr. | Fault zones. |

## PHYSICAL CONDITIONS DURING MINERALIZATION

### PRESSURES

Interpretation of pressure conditions during mineralization at Gold Acres is possible from considerations of the depth of burial of the deposit. By mid-Cretaceous time, when mineralization is interpreted to have taken place, the cover over the part of the mineral deposit now exposed consisted of lower Paleozoic rocks in the upper plate of the Roberts Mountains thrust and perhaps also rocks of late Paleozoic and Mesozoic age. The minimum depth of cover must have been at least 2,000 feet, based on the present topographic relief of 1,000 feet in upper-plate rocks within a few miles of the mine and on the probable existence of an additional 1,000 feet of these rocks at the mine in Oligocene time, when granitic plutons were emplaced 5–10 miles north at Tenabo and Granite Mountain. As the mine occurs near the sole of the thrust, the overburden could have been as great or greater than the 6,000–8,000 feet Gilluly and Masursky (1965) show as the combined thickness of the upper-plate rocks plus late Paleozoic strata in the Cortez quadrangle, 10–15 miles east of Gold Acres. But the presence near Walti Hot Springs, 15 miles south of the Cortez quadrangle of Lower Cretaceous rocks a few miles laterally and possibly only a few thousand feet above the thrust (Roberts and others, 1967), shows that by mid-Cretaceous time the thrust fault need not have been buried so deeply as in the Cortez quadrangle. These relations suggest that 5,000 feet is a reasonable estimate for the depth of overburden at Gold Acres during mineralization.

The relatively shallow depth of emplacement postulated for Gold Acres indicates that pressures were low during mineralization. Under hydrostatic conditions, a depth of 5,000 feet corresponds to 145 atmospheres; under lithostatic conditions and cover mainly of chert and argillite (density 2.65 g/cm$^3$), a depth of 5,000 feet corresponds to 390 atmospheres. Independent evidence of the pressure during early stages of mineralization at Gold Acres was not found, but by the time gold was deposited, pressures were probably hydrostatic.

### TEMPERATURES

Fluid inclusions in garnet associated with molybdenite in tactite at the mine are estimated by J. T. Nash (oral commun., 1972) to have homogenization temperatures of 350°±50°C. These estimates are based on the proportions of liquid and vapor phases in the inclusions. Adjusted for a possible lithostatic overburden of 5,000 feet using correction curves of Lemmlein and Klevtsov (1961) and assuming 10 percent salinity, the temperatures are 380°±50°C.

Estimated homogenization temperatures of fluid inclusions in quartz associated with sphalerite in three *for element pairs at the Gold Acres open-pit mine*

level. Values on left side are number of element pairs; those on right are correlation coefficents]

| La | Mo | Nb | Ni | Pb | Sb | Sc | Sn | Sr | V | W | Y | Zn | Zr | Au | Hg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.464 | 0.252 | ---- | 0.455 | 0.147 | ---- | 0.421 | ---- | −0.322 | 0.146 | ---- | 0.296 | 0.392 | 0.187 | 0.155 | 0.085 |
| .151 | .203 | ---- | ---- | ---- | ---- | .134 | ---- | ---- | .257 | ---- | .176 | −.100 | .136 | .164 | ---- |
| ---- | .150 | −0.242 | ---- | ---- | ---- | ---- | ---- | −.159 | .177 | ---- | .147 | −.189 | −.102 | ---- | .080 |
| .204 | ---- | .207 | .200 | ---- | ---- | .536 | ---- | ---- | .141 | ---- | .286 | ---- | .647 | .199 | ---- |
| .142 | .216 | ---- | .373 | ---- | ---- | .133 | ---- | ---- | .147 | ---- | .303 | .231 | ---- | .163 | ---- |
| ---- | .306 | ---- | ---- | .331 | ---- | ---- | ---- | ---- | .261 | ---- | .115 | ---- | .120 | .198 | .317 |
| .314 | .196 | ---- | .268 | .128 | ---- | .322 | ---- | ---- | ---- | ---- | .259 | .167 | .196 | .334 | .255 |
| .342 | .114 | ---- | .137 | ---- | ---- | .276 | ---- | ---- | .208 | ---- | .339 | −.159 | .479 | .404 | .208 |
| .116 | ---- | ---- | .108 | ---- | ---- | .184 | ---- | ---- | ---- | ---- | .167 | ---- | .243 | ---- | −.082 |
| .240 | .191 | ---- | .280 | ---- | ---- | .222 | ---- | ---- | ---- | ---- | .254 | .265 | .135 | ---- | ---- |
| ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| .316 | ---- | ---- | .311 | −.134 | ---- | .422 | ---- | ---- | −.091 | ---- | .178 | .279 | .161 | ---- | ---- |
| .351 | .189 | ---- | .384 | .172 | ---- | .501 | ---- | ---- | .478 | ---- | .456 | ---- | .443 | .162 | −.091 |
| .292 | .309 | ---- | .449 | .253 | ---- | .413 | ---- | ---- | .178 | ---- | .290 | .461 | .195 | ---- | ---- |
| | .209 | ---- | .157 | ---- | ---- | .483 | ---- | ---- | .244 | ---- | .453 | ---- | .309 | .144 | .113 |
| 181 | | ---- | .514 | .267 | ---- | .103 | ---- | ---- | ---- | ---- | .330 | ---- | .180 | ---- | .116 |
| 83 | 80 | | ---- | ---- | ---- | .211 | ---- | ---- | −.186 | ---- | ---- | ---- | ---- | ---- | −.219 |
| 231 | 316 | 112 | | .165 | ---- | .307 | ---- | ---- | .377 | ---- | .376 | .214 | .253 | ---- | ---- |
| 165 | 223 | 88 | 278 | | ---- | ---- | ---- | ---- | .152 | ---- | .193 | ---- | .168 | .139 | .139 |
| 35 | 49 | 17 | 51 | 44 | | .322 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 222 | 260 | 110 | 343 | 236 | 44 | | ---- | ---- | .092 | ---- | .419 | ---- | .406 | ---- | −.138 |
| 0 | 2 | 3 | 3 | 3 | 0 | 3 | | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 53 | 80 | 17 | 97 | 72 | 14 | 68 | 0 | | ---- | ---- | ---- | ---- | ---- | −.207 | ---- |
| 231 | 317 | 112 | 431 | 278 | 51 | 343 | 3 | 100 | | ---- | .374 | ---- | .246 | .189 | .118 |
| 69 | 74 | 52 | 93 | 72 | 32 | 85 | 2 | 13 | 93 | | ---- | ---- | ---- | ---- | ---- |
| 220 | 280 | 108 | 366 | 246 | 50 | 308 | 2 | 82 | 367 | 85 | | ---- | .447 | .124 | ---- |
| 148 | 207 | 83 | 266 | 190 | 43 | 218 | 3 | 55 | 266 | 72 | 235 | | ---- | −.107 | ---- |
| 230 | 309 | 112 | 422 | 274 | 50 | 342 | 3 | 95 | 425 | 93 | 363 | 260 | | .282 | .104 |
| 209 | 280 | 96 | 364 | 238 | 50 | 290 | 2 | 85 | 367 | 88 | 314 | 216 | 359 | | .468 |
| 230 | 315 | 111 | 428 | 276 | 51 | 340 | 3 | 99 | 431 | 93 | 364 | 265 | 422 | 365 | |

thin sections range from 150°–225°C. A measured homogenization temperature of 265°C from quartz not directly associated with sulfides (Nash, 1972) may represent this stage of mineralization. Assuming hydrostatic conditions, which seem reasonable for such low homogenization temperatures and shallow depths, corrections for fluid-inclusion temperatures in sphalerite-bearing samples from the mine would be not more than 10°C.

Homogenization temperatures measured with a heating stage on fluid inclusions in 12 samples of quartz collected in auriferous rocks at the mine range from 150° to 185°C (Nash, 1972). A correction based on hydrostatic pressures would add 10°C to these temperatures. The highest temperature (185°C) was determined from quartz cut by pyrite, whereas a temperature of 160°C was from quartz interpreted to be younger than pyrite. The lowest estimate (150°C) was obtained from chalcedony in tactite.

## HISTORY OF MINERALIZATION AT THE OPEN-PIT MINE AND SUMMARY OF THE DATA

The existence of gold, base-metal, and iron-manganese suites and information on the occurrence of molybdenite suggest multistage mineralization at the mine. Rock types and minerals associated with these suites supplemented by the data from fluid inclusions indicate that mineralization may have begun during the contact metamorphic stage and continued episodically under conditions of decreasing temperature and pressure.

Possibly one of the first elements introduced during mineralization at the open-pit mine was molybdenum deposited as molybdenite. The observation that molybdenite occurs only in tactite, together with data from fluid inclusions suggestive of crystallization at about 380°C, points to deposition during a late stage of contact metamorphism. Scheelite in tactite about 1 mile from the mine could have formed under similar conditions.

Introduction of a base-metal suite of elements apparently followed deposition of molybdenite because fluid-inclusion temperatures estimated from quartz associated with sphalerite are lower than temperatures from garnet in molybdenite-bearing tactite. Although the base-metal suite is not spatially associated with molybdenite in the mine, it does occur with molybdenite locally in tactite outside the mine, indicating that the differences in temperatures of formation are not the result of differences in distance from granitic rock.

The gold suite of elements is interpreted as the last to be deposited at Gold Acres. The similar geographic distribution and the relatively strong correlation of gold, arsenic, boron, and mercury at the mine suggests that these elements were deposited together. Tungsten of low-temperature origin also was deposited with these elements. Miesch (1963) emphasized that coherent elements do not necessarily form under the same geochemical conditions. Yet the association of these elements with gold at Gold Acres has been recognized in the disseminated gold deposit at Carlin (Radtke and others, 1972), and the association gold-arsenic-mercury-tungsten has been found at the disseminated gold deposits at Bootstrap, Cortez, and Getchell (see Erikson and others, 1964, 1966; Wells and others, 1969), thereby suggesting that these mineral deposits are similar genetically and that the coherence of the elements is the result of deposition under similar geochemical conditions.

Probably all these gold deposits formed at temperatures between about 150°–250°C (Roberts and others, 1971). Hausen and Kerr (1968) believed that the Carlin deposit formed in the root zone of a thermal spring system, and Joralemon (1951) thought that the ore body at Getchell may have originated during hot spring activity. Nash (1972) believed that the Carlin and Cortez deposits formed at about 200°C; he suggested that hot spring systems provide an excellent model of the physical and chemical conditions during deposition of the disseminated-type gold deposit.

The iron-manganese suite is interpreted to have formed by supergene processes after hypogene mineralization.

Evidence presented here indicates that at Gold Acres the deposition of gold occurred during the waning stage of hydrothermal activity associated with emplacement of the mid-Cretaceous granitic body buried beneath it. The ore body at Gold Acres lies above the flank of the intrusion, and granitic dikes of Cretaceous age occur only in the vicinity of the auriferous deposit. Roberts (Roberts and others, 1971) stated that gold metallization at Gold Acres may be related to the Oligocene plutons spatially associated with gold deposits at Tenabo, but we find no compelling evidence to support this conclusion. On the contrary, the spatial association of several distinctive suites of elements to the buried Cretaceous mass at Gold Acres suggests a genetic relation between this igneous rock and mineralization.

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