STUDIES RELATED TO WILDERNESS

PRIMITIVE AREAS

GALIURO WILDERNESS AND FURTHER PLANNING AREAS, ARIZONA

GEOLOGICAL SURVEY BULLETIN 1490

Mineral Resources of the Galiuro Wilderness and Contiguous Further Planning Areas, Arizona

By S. C. CREASEY, U.S. GEOLOGICAL SURVEY, *and by* J. E. JINKS, F. E. WILLIAMS, *and* H. C. MEEVES, U.S. BUREAU OF MINES

With a section on AEROMAGNETIC SURVEY AND INTERPRETATION

By W. E. DAVIS, U.S. GEOLOGICAL SURVEY

STUDIES RELATED TO WILDERNESS—PRIMITIVE AREAS

GEOLOGICAL SURVEY BULLETIN 1490

An evaluation of the mineral potential of the area

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1981

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, *Secretary*

GEOLOGICAL SURVEY

Doyle G. Frederick, *Acting Director*

Library of Congress Cataloging in Publication Data

Galiuro Wilderness and Further Planning Areas, Arizona

Geological Survey Bulletin 1490. Studies related to wilderness--primitive areas
Bibliography: p. 93-94
1. Mines and mineral resources--Arizona. I. Creasey, S. C. (Saville Cyrus), 1917- . II. Series. III. Series: Studies related to wilderness--primitive areas.
QE75.B9 no. 1490 (TN24.A6) 557.3s(553'.09791'54) 81-607019

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington, D. C. 20402

STUDIES RELATED TO WILDERNESS

PRIMITIVE AREAS

In accordance with the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and the Conference Report on Senate bill 4, 88th Congress, the U.S. Geological Survey and the U.S. Bureau of Mines are making mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System. Areas classed as "primitive" were not included in the Wilderness System, but the act provides that each primitive area be studied for its suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. This report discusses the results of a mineral survey of the Galiuro Wilderness and contiguous Further Planning Areas, southeastern Arizona, that may come under discussion when the area is considered for wilderness designation.

CONTENTS

ILLUSTRATIONS

TABLES

STUDIES RELATED TO WILDERNESS—PRIMITIVE AREAS

MINERAL RESOURCES OF THE GALIURO WILDERNESS AND CONTIGUOUS FURTHER PLANNING AREAS, ARIZONA

By S. C. CREASEY, U.S. Geological Survey, and J. E. JINKS, F. E. WILLIAMS, and H. C. MEEVES, U.S. Bureau of Mines

SUMMARY

The Galiuro Wilderness, in southeastern Arizona about 50 airline miles (80 km) northeast of Tucson, comprises an area of about 53,000 acres (21,500 ha) along two parallel high ridges separated by a pass and two medial valleys, one sloping north, the other south. Elevations range from about 4,000 to 7,600 feet (1,200 to 2,300 m). The climate is warm and dry on the lower slopes, cool and moderately moist along the ridge crests; annual precipitation is about 15 to more than 20 inches (40–50 cm). The field investigations, undertaken by six men over a total of about 20 man-months, were largely made by traverses on foot and on horseback.

Access to the wilderness is difficult. Four-wheel-drive jeep roads lead to points about a mile from both the northern and southern boundaries of the wilderness, and easy trails follow the canyons. Access from either east or west is by jeep trails to the mountain front and thence by steep trails up the range fronts.

The geology of the Galiuro Wilderness-Further Planning Areas is dominated by the mid-Miocene Galiuro Volcanics, a sequence of andesitic to rhyolitic volcanic rocks. These volcanics, though complex in their relations, collectively form a gently eastward dipping blanket that conceals older rocks ranging in age from Precambrian to Late Cretaceous or early Tertiary.

The older rocks include Precambrian schists, granites, and quartzites; Paleozoic quartzites; and Late Cretaceous and (or) early Tertiary intermediate volcanic rocks and granitic stocks. Structures are complex in the older rocks and include fractures related to igneous intrusion, folding, and faulting. Extensive metallization, chiefly copper, is spatially associated with the younger granitic intrusive rocks along the margin of the Galiuro Volcanics a short distance outside the wilderness. The economic potential of the Galiuro Wilderness-Further Planning Areas is primarily in the possibility that the Galiuro Volcanics conceal ore deposits within the older rocks.

Metal production from the Galiuro Wilderness-Further Planning Areas is small; 163 ounces (4.6 kg) gold, 2,310 ounces (66 kg) silver, and 12,203 pounds (5,500 kg) copper. The Copper Creek mining district, which is adjacent to the Galiuro Wilderness-Further Planning Areas has produced 1,354 ounces (38.4 kg), gold, 194,851 ounces (5,523.9 kg) silver, more than 11 million pounds (5 million kg) copper, and more than 3 million pounds (1,361,000 kg) lead.

The objective of the study was to appraise the mineral resources of the Galiuro Wilderness-Further Planning Areas through geologic, geochemical, and geophysical studies and through evaluation of mines and prospects. The geologic studies consist chiefly of the preparation of a geologic map to separate favorable from unfavorable host rocks and altered and mineralized rocks from fresh rocks; to locate visible occurrences of ore minerals, chiefly copper; and, for the areas covered by the Miocene Galiuro Volcanics, to provide a basis for estimating the depth to older rocks more favorable for the occurrence of copper deposits. Geochemical studies consist of systematic sampling and analysis of (1) the -80 mesh fraction of stream sediments and (2) altered bedrock and prospect pits where ore minerals were not visible. A total of 481 stream sediment samples and 82 bedrock samples were collected. Geophysical studies consisted of an aeromagnetic survey made to delineate areas having higher or lower magnetic properties that may be associated with ore deposits. Evaluation of mines and prospects involved locating, mapping, and systematic sampling of all known claims, mines, and prospects.

The geologic and geochemical studies revealed a large area of altered rock containing anomalous quantities of copper in older rocks in the Copper Creek area, which is outside, but adjoining, the Galiuro Wilderness-Further Planning Areas. These older rocks, which extend into the northwestern corner of the wilderness beneath the Galiuro Volcanics, are potential hosts for copper deposits. Within the boundary of the Galiuro Wilderness-Further Planning Areas, pyritized and argillized volcanic rocks occur in two areas and along the major north-trending fault that extends almost throughout the length of the wilderness. Although anomalous trace quantities of several metals occur within these altered areas, clear indications of commercial deposits were not observed. Whether these near-surface metal anomalies indicate commercial metal deposits at depth in the older rocks beneath the volcanic rocks cannot be evaluated from data obtained from the surface exposures.

The aeromagnetic survey shows a number of magnetic highs and lows. The differences in magnetic intensities all appear to reflect either topography or difference in magnetic properties of volcanic rocks, or some combination of both, rather than concentrations of highly magnetic minerals. Examination and sampling by the U.S. Bureau of Mines of prospects and mines did not reveal economic ore deposits.

INTRODUCTION

The Galiuro Wilderness-Further Planning Areas is in the Coronado National Forest in southeastern Arizona about 50 miles northeast of Tucson (fig. 1). The wilderness, an area of about 52,700 acres (21,350 ha), was created in September 1964 when Congress passed the Wilderness Act (Public Law 88–577). Essentially the same area, however, had been designated by the Forest Service as the Galiuro Primitive Area from 1932 until 1940, when it was reclassified as the Galiuro Wild Area, a designation that held until 1964.

The Galiuro Wilderness (Forest Service NF–3026) is surrounded by the Forest Services' 03901 Galiuro additions and the 03124 Galiuro Wilderness contiguous area. The boundaries of the Galiuro Wilderness, the Further Planning Areas, and the Coronado National Forest are shown on plate 2 and the Coronado National Forest on plate 1. In many places, boundaries coincide, particularly those of the Further

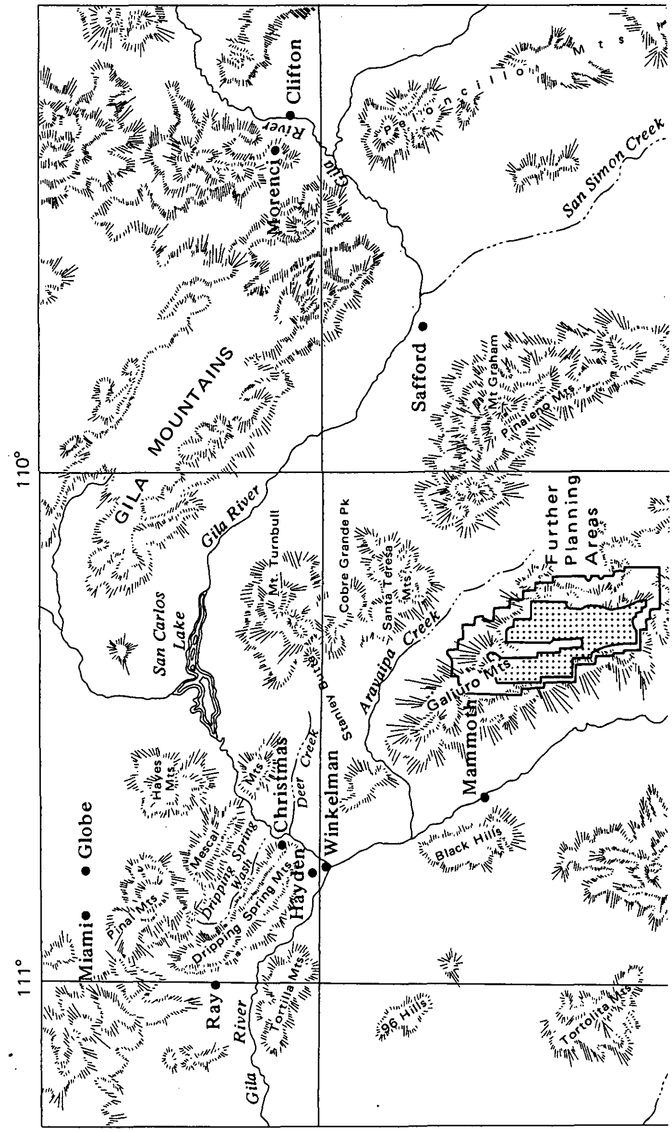
Planning Areas and the Coronado National Forest. For convenience, the entire area of plate 1 will be referred to as the study area. It includes areas near Sombrero Butte and Copper Creek outside the National Forest. The combined Galiuro Wilderness and Further Planning Areas will be referred to as "Galiuro Wilderness-Further Planning Areas."

The outline of the Galiuro Wilderness in relation to the boundary of the Coronado National Forest is shown on plate 2. In general, the Galiuro Wilderness follows the high country, forming a broad U-shaped area that opens toward the north (fig. 4); the two limbs are hereinafter referred to as the East and West Divides. The area within the limbs of the "U" is about 10 miles (16.0 km) long and 1 to 1½ miles (1.6 to 2.4 km) wide. This excluded land, essentially the floor of Rattlesnake Valley, is the most accessible and scenic part of the entire area. Much of it is open and parklike; majestic oaks, pines, and sycamores rise above the grass-covered flood plain of Rattlesnake Creek. It is the natural access to the wilderness from the north and northeast and will undoubtedly be used by many visitors.

The Galiuro Wilderness-Further Planning Areas lie entirely within the Galiuro Range, one of the large northwest-trending mountain ranges in southern Arizona that form the Basin and Range province. The range is bounded on the west by the San Pedro Valley, on the east by the Aravaipa Valley. In the wilderness, the range is two ridges separated by two medial valleys, Rattlesnake and Redfield. The two valleys are separated by a low pass about 2 miles (3.0 km) east of the Powers mine. From the pass, Rattlesnake Creek flows northward to beyond the wilderness, where it turns eastward to join Aravaipa Creek, whereas Redfield Creek flows southward to beyond the wilderness, where it turns westward to join San Pedro River. The deeply incised valleys, developed parallel to the lengths of the ranges, provide access, scenic beauty, and water for most of the year to the core of the wilderness; they are not typical of the Basin and Range province. The long medial valleys bounded by high ridges on both sides induce a feeling of isolation from civilization that is one of the wilderness' greatest assets.

The Further Planning Areas surround the Galiuro Wilderness and include most of the area lying between the boundary of the wilderness and the boundary of the Coronado National Forest in the Galiuro Mountains.

The drainages of the main streams in the study area, with the notable exceptions of Rattlesnake and Redfield Creeks, are at high angles to the range fronts. Even Rattlesnake and Redfield Creeks have courses at high angles to the range fronts where they enter the range, but inside the ranges, the two streams turn at nearly right


110°
111°
33°
Clifton
Morenci
River
GILA MOUNTAINS
Safford
Mt Graham
Pinaleno Mts
San Simon Creek
Gila River
San Carlos Lake
Mt. Turnbull
Cobre Grande Pk
Santa Teresa Mts
Aravaipa Creek
Further Planning Areas
Galiuro Mts
Mammoth
Stanley Butte
Globe
Miami
Hayes Mts
Mescal Mts
Christmas
Deer Creek
Winkelman
Hayden
Black Hills
Pinal Mts
Dripping Spring Wash
Dripping Spring Mts
Ray
Gila River
Tortilla Mts
96 Hills
Tortolita Mts

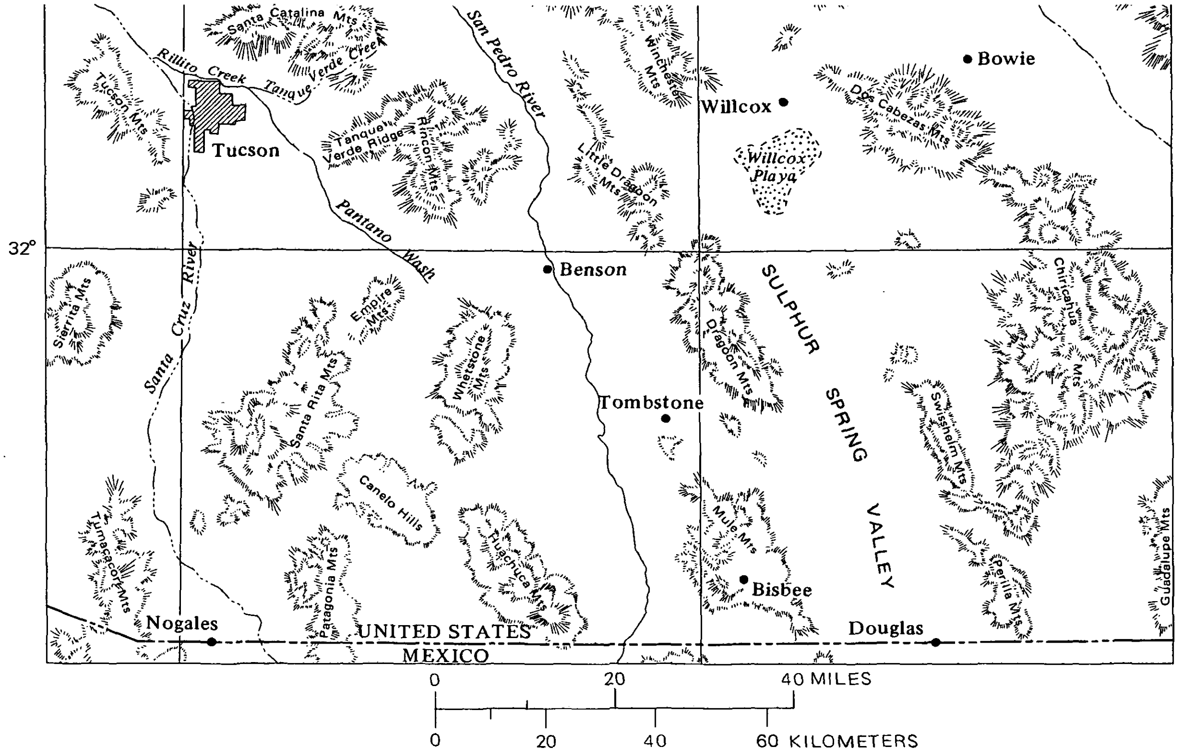


FIGURE 1.—Index map showing the location of the Galiuro Wilderness Further Planning Areas (outlined) in relation to the principal ranges and valleys in southeastern Arizona.

angles and parallel the range for many miles. Apparently these two stream courses developed through headward erosion along the medial fault that extends almost the entire length of the wilderness. Where underlain by ash-flow tuffs, the fronts of the range are marked by awesome cliffs, many of which drop vertically several hundred feet. Locally, access to the upper slopes is difficult at best, and falls make even the stream canyons locally inaccessible. For those who plan to hike into the wilderness, the designated trails are the only certain access routes.

Elevations range from about 4,000 feet (1,220 m) along the western range front to 7,650 feet (2,330 m) at Bassett Peak. Because the range is well dissected, a hike across the range would involve traversing relief considerably greater than the 3,650 feet (1,113 m) of relief in the area. Hikes parallel to the range, such as trails along either the West or East Divide Ridges or along the medial valleys (Rattlesnake and Redfield), cross terrain of far less relief. The views from the divide ridges are spectacular, but the medial valleys offer trees, shelter, and locally water (fig. 2).

For those hiking into the Galiuro Wilderness-Further Planning Areas, potable water is a major concern. Although no attempt was made to locate all springs with potable water, the use of springs

FIGURE 2.—View southwestward from the East Divide trail across the headwaters of Redfield Canyon at the ash-flow tuffs forming the West Divide Ridge. The Rincon Mountains are on the horizon.

during the field investigations has provided some information that may be useful to others. For these entering the wilderness from the north along Fourmile Creek, the creek itself contains water here and there during the dry season and runs continuously during the wet. Juniper Spring has a large supply of water to serve those hiking the trail from Fourmile into the North Fork of Pipestone Canyon.

For those entering the Galiuro Wilderness-Further Planning Areas via the jeep trail from the Klondyke road, Rattlesnake Creek flows strongly at the base of Powers Hill, and commonly for several miles upstream. The spring at Powers Garden provides excellent water; the spring, or well, about 3 miles (5 km) upstream from Powers Garden contained fresh water during the dry summer of 1972.

For those entering via the trail from the Deer Creek ranch, Mud Springs has a concrete stock tank but no provision for obtaining water from the inlet pipe. There is no water along the trail to Powers Garden via Horse Canyon, but the trail via Corral Canyon has good water at Corral Spring.

For those entering the Galiuro Wilderness-Further Planning Areas from the south, there is good water at Jackson's Cabin, at the end of the jeep trail. In the dry spring of 1972, pools of fresh water occurred in Redfield Creek downstream from the confluence with Muleshoe Canyon. At Hooker Cabin, water was obtained by digging a shallow well in the streambed about 100 yards (90 m) upstream from the cabin, and a moderate flow of potable water was entering Redfield from Negro Canyon. Upstream from Negro Canyon, Redfield was dry to springs about a mile south of the point where the trail leaves Redfield and enters a side canyon. Here the trail turns from a northeast course in Redfield to a northwest course in the side canyon.

In the central part of the Galiuro Wilderness-Further Planning Areas, potable water was found at Holdout Spring, Knothe Spring, and at the cement dam across Kielberg Canyon along the trail from Rattlesnake to Redfield via Cedar Flat. There is excellent water in a covered unnamed spring about 200 feet (60 m) downstream from the old cabin in the side canyon about 3,500 feet (1,000 m) north-northwest of the Long Tom mine.

Along the east side of the Galiuro Range, potable water was found at the Deer Creek Forest Service cabin, at the High Creek Spring in High Creek, and at Lower and Upper Ash Creek Springs in Ash Creek. No water was found in Paddy's River upstream from where the trail from the Deer Creek Ranch joins the creek.

So far as known, there is no water along either the West or the East Divide trails, which follow the crests of the divides, unlikely locations for springs. There are a number of good springs in and around the wilderness. With forethought, a hiker can camp near potable water every night.

CLIMATE AND VEGETATION

The climate of the Galiuro study area ranges from warm and dry for the lower slopes typical of the Sonoran Desert to cool and moderately moist along the range crest and in the interior valleys of the range, chiefly Fourmile, Rattlesnake, and Redfield. Rainfall at Klondyke, which is about 8 miles (13 km) north of the study area, at an elevation of 3,467 feet (1,057 m), is estimated at 14–17 inches (36–43 cm) per year, and the average precipitation at Oracle, which is about 20 miles (32 km) west of the area at an elevation of 4,600 feet (1,400 m), is 19 inches (48 cm). For the study area, precipitation probably averages 20 inches (51 cm) for elevations between 3,500 and 5,000 feet (1,000 and 1,500 m). The two wet seasons, July–September and December–March, account for almost all of the precipitation.

The wilderness supports yellow pine and fir in scattered stands on East and West Divides and in the larger canyons, chiefly Rattlesnake, Fourmile, and Redfield. Pinon pine and juniper occur mixed with the yellow pine and at lower elevations along the flanks of East and West Divides. White oaks and sycamores are common in the larger canyons at higher elevations, and Rattlesnake has several stands of what appear to be small-leafed variety of Bigtooth Maple. In the Further Planning Areas, chaparral, in part scrub oak, manzanita, algerita, and other shrubs, predominates in the dry lower slopes of the range. Mesquite, palo verde, bear grass, yucca, cat claw, and sotol are common in the washes and on the alluvial plain at the mountain front.

Cacti abound at low elevations in the range and along the alluvial plain in front of the range. Saguaro, several species of cholla, hedgehog, pin cushion, barrel, ocotillo, prickly pear, agave (mescal), and strawberry cacti were recognized.

A great variety of wild flowers appear in April following normal rainfall. Many were not identified; flowers recognized include poppy, lupine, mallow, Indian paintbrush, four-o'clock, evening primrose, pentstemon, mariposa lily, and desert marigold.

ACCESSIBILITY

The interior part of the Galiuro Wilderness-Further Planning Areas is accessible by relatively few trails. The quickest and most direct access to the northern part of the wilderness is by the jeep trail that starts from the Klondyke road at the cattle guard near the driveway to the Roy Claridge ranch house in sec. 27, T. 7 S., R. 20 E., and terminates at the top of Powers Hill. Permission to use the road should be obtained from Mr. Claridge, or if he is unavailable, from Mr. Carl Bott, who owns a ranch a quarter of a mile (0.4 km) east on the Klondyke road. Access to the southern part of the wilderness is through either the Muleshoe ranch, owned by Alvin Browning, or the Carlink ranch, Manager, Mr. Smallhouse. The private jeep road from the Muleshoe starts at the ranch house and ends at Jackson Cabin. A private road that enters the Carlink ranch through a locked gate can be negotiated by a two-wheel-drive truck from the highway that starts near the ranch headquarters and ends at an abandoned cabin site in sec. 19, T. 11 S., R. 20 E. From the cabin site, a trail leads east into Redfield Canyon. Permission to pass on these roads must be obtained from personnel at the Muleshoe and Carlink ranches.

Two trails lead from the west side of the range into the wilderness. One starts at Rhodes ranch and enters Rattlesnake Creek via the North Fork of Pipestem Canyon. The other is reached by a jeep trail that starts at the A. C. Gruwell ranch on the San Pedro River and ends at a water tank about a mile (1.6 km) upstream from the old abandoned YLE ranch site. The trail goes up the canyon past Geronimo Camp and joins the West Divide trail on Grassy Peak. The easiest access from here is southeast along the West Divide trail to the pass above the Powers mine, from which easy trails lead both north and south. Permission to pass and the conditions of the roads and trails can be obtained at the ranches.

From the east side of the range, three trails into the wilderness start from near the Deer Creek Forest Service cabin and the Deer Creek ranch, about a mile (1.6 km) southeast of the cabin. The main trail branches near Mud Spring, the southerly route entering the wilderness via Corral Canyon, the northerly route through Horse Canyon. Both are well-defined trails commonly used by Deer Creek ranch, which has a grazing permit in the wilderness. An alternative trail utilizes Paddy's River. The first few miles of this route are well maintained, but the trail leading from Paddy's River to the East Divide trail is overgrown to the point of being virtually nonexistent. Although there are no locked gates on any of these trails, the Deer Creek ranch personnel should be advised of plans and schedules, because the local ranchers are the first to be called upon for help in the event of sickness or injury.

Good access from the east side by truck roads and trails is had through both High Creek and Ash Creek. These trails are maintained, marked, and easy to follow. There are no locked gates and no nearby ranches.

PREVIOUS STUDIES

Little has been published on either the regional geology or the ore deposits in the Galiuro Wilderness-Further Planning Areas. The earliest report is a short account of the Gold Mountain property in

Rattlesnake Canyon by Blake (1902). In 1930 Davis and Brooks published the physiographic evidence for faulting along the west side of the Galiuro Range; their report included a sketchy account of the rocks based mostly on information supplied by others. The Galiuro Wilderness-Further Planning Areas are included in the larger area considered by Davis and Brooks (1930). Highly simplified representations of the regional geology are shown on the first edition of the Arizona State Geologic Map (Darton and others, 1924), on the second edition of the Arizona Geologic Map (Wilson and others, 1969), on the geologic map of Graham and Greenlee Counties (Wilson and others, 1958), and on the reconnaissance geologic map of the San Pedro and Aravaipa Valleys (Creasey and others, 1961). A brief description of the entire Galiuro Range is given in Darton (1925). No reports specifically describe the Galiuro Wilderness-Further Planning Areas.

The geology and ore deposits of the Galiuro Wilderness-Further Planning Areas north of lat 32°45′ are described in detail by Simons (1964), who gives a good account of the ore deposits in Copper Creek including bibliographic references to earlier accounts of the deposits.

PRESENT INVESTIGATION AND ACKNOWLEDGMENT

J. E. Jinks, F. E. Williams, and H. C. Meeves, of the U.S. Bureau of Mines, found and examined all claims, prospects, and mine workings. In addition, they made reconnaissance examinations of areas with no known history of mining activity. They sampled veins, dumps, and altered zones. The Bureau of Mines collected a total of 36 bedrock samples weighing 1 to 2½ pounds and 48 stream-sediment samples.

Richard Buss, James Jacobs, and S. C. Creasey, all of the U.S. Geological Survey, collected 433 stream-sediment samples, most at half-mile intervals on the major streams some from the larger tributaries near their confluences with the major streams. W. J. Keith, of the U.S. Geological Survey, and S. C. Creasey collected 46 rock samples, chiefly from altered zones, and mapped the geology of the study area (pl. 1). Maureen Johnson, of the U.S. Geological Survey, compiled the data on history and production of the Copper Creek and Rattlesnake mining districts.

Harry Little, U.S. Forest Service District Ranger, Willcox, Ariz., provided helpful information and use of the Deer Creek and Powers Garden Forest Service cabins. William Hamilton, Virgil Mercer, Jr., Tom Rhodes, A. C. Gruwell, LeMar Bingham, and Alvin Browning, all ranchers in the area, were most helpful in granting access to their lands and in providing information on roads, trails, and mines and prospects. Their friendly help is gratefully acknowledged. Joe Ruiz, of

Mammoth, supplied much helpful information on the Copper Creek district.

GEOLOGY

GEOLOGIC SETTING

The Galiuro study area is underlain chiefly by the Miocene Galiuro Volcanics, a sequence of andesitic to rhyolitic volcanic rocks. These volcanic rocks, though complex in their relations, form a gently eastward dipping blanket that conceals older rocks ranging in age from Precambrian to Late Cretaceous or early Tertiary.

The older rocks include Precambrian schists, granites, and quartzites; Paleozoic quartzites; and Late Cretaceous and (or) early Tertiary intermediate volcanic rocks and granitic stocks. Structures in the older rocks include folds, faults, and features related to igneous intrusion. Extensive metallization, chiefly copper, is spatially associated with the younger granitic intrusives along the margin of the Galiuro Volcanics. The economic geology of the study area is primarily concerned with the possibility that the Galiuro Volcanics conceal ore deposits within the older rocks.

PINAL SCHIST

The name Pinal Schist was given by Ransome (1902, p. 23) to the metamorphic schists in the Pinal Range southwest of Globe, Ariz. The name was later extended to include all older Precambrian metasedimentary and interlayered volcanic rocks in southeastern Arizona. In the study area, the Pinal Schist crops out only in a small area immediately southeast of Sombrero Butte. It is bounded on the west by a fault contact with the Galiuro Volcanics, on the east by a fault contact with the Glory Hole Volcanics. To the north, it is intruded by the Copper Creek Granodiorite; to the south, it is covered by the andesite unit of the Galiuro Volcanics.

The stratigraphic relations of the Pinal Schist are not shown in the outcrops within the study area, but from studies elsewhere, the Pinal Schist (Precambrian X) is recognized as the oldest formation in southeastern Arizona. It is intruded by the Ruin Granite (Precambrian Y), and is unconformably overlain by the Apache Group (Precambrian Y).

Typically, the Pinal Schist is a sequence of gray to green, weakly metamorphosed graywacke, siltstone, shale, and volcanic rocks. As much of the sediment was derived from the weathering of volcanic rock, the entire formation has a volcanic affinity. The metamorphic facies is greenschist; typical assemblages are chlorite-sericite-quartz-albite and quartz-sericite-sodic plagioclase. Biotite occurs in some assemblages, but it is not as prevalent as chlorite. The assemblage sericite-biotite-quartz occurs in the study area.

Most of the schists are weakly to strongly foliated, and lineation in the foliation plane is typical. Locally, as in the study area, the foliation is weak, and individual beds, graded bedding, and minor folds are easily recognized. Where exposures of relict structures are clearest, refolded folds attest to multiple periods of deformation.

The Pinal is a favorable host for metal deposits. In the Globe-Miami district, the Pinal is the host for much of the Miami-Inspiration porphyry copper ore deposit. In central Arizona, similar, but slightly older, rocks enclose the massive sulfide deposits of the United Verde, Iron King, and Old Dick mines, although no massive sulfides have been found in the Pinal in southeastern Arizona.

RUIN GRANITE

The Ruin Granite, named by Ransome (1903, p. 73–75) for exposures in the Ruin Basin, about 20 miles (16 km) northwest of Globe, Ariz., is a coarse-grained porphyritic quartz monzonite consisting of large phenocrysts of K-feldspar (microperthitic microcline) set in a hypidiomorphic granular aggregate of quartz microcline, oligoclase, and biotite. An exposure of Ruin Granite, about 500 feet (150 m) long and 100 feet (30 m) wide, crops out in the south-central part of the study area near the confluence of Redfield and Negro Canyons. The granite is overlain by an andesitic tuff bed, estimated to be 100–200 feet (30–60 m) thick, which is succeeded by andesite flows; both are part of the andesite unit. For several feet above the massive granite, the andesitic tuff contains partly rounded clasts of the Ruin Granite; the contact is clearly depositional.

The Ruin Granite is porphyritic, containing K-feldspar phenocrysts as much as 1 inch (2.5 cm) in diameter set in a medium- to coarse-grained holocrystalline hypidiomorphic-granular groundmass of plagioclase, quartz, and biotite.

APACHE GROUP

The Apache Group was named by Ransome (1903) for exposures near Globe, Ariz., about 50 miles (80 km) northwest of the study area. The Apache Group crops out on the ridge north of the Mercer ranch in the northwestern corner of the study area. The total outcrop is less than a square mile (2.6 km^2) in area, but within this small area the Pioneer Formation, the Dripping Spring Quartzite, which in the study area includes the Barnes Conglomerate Member, and the Mescal Limestone were recognized; each unit is shown separately on the geologic map.

The Pioneer Formation comprises interbedded maroon to gray shale or slate and light-colored fine-grained tuffaceous sandstone or quartzite; bedding is typically thin. Where detailed petrographic studies have been made, as in the Santa Catalina Mountains (Creasey, 1967), the Pioneer was found to contain much tuff. What appears to be a sandstone is a partly recrystallized crystal tuff, and the shales and slates are reconstituted fine-grained tuffs. Although detailed studies of the Pioneer were not made in the study area, there is no reason to believe it is significantly different from the section exposured in the Santa Catalina Mountains a few miles west.

The Barnes Conglomerate Member, Dripping Springs Quartzite, and Mescal Limestone form continuous stratigraphic units that dip and face westward. The Barnes, here about 10–15 feet (3–4½ m) thick, consists of pebbles, cobbles, and boulders of well-rounded quartz, quartzite, and jasper set in a quartzite matrix. Both quartz and quartzite clasts are abundant, but chert is scarce.

The Dripping Springs Quartzite lying above the Barnes is pink, cream, and tan in color; individual beds range in thickness from a few inches to as much as 10 feet (3 m). The quartzite, which is feldspathic, is medium to coarse grained and commonly well sorted. Locally conglomeratic lenses were noted, unusual features for the Dripping Spring. Quartz makes up about 80–90 percent of the rock by estimate, feldspar the remainder. The grains are rounded and interlocking; overgrowths are common and account for the quartzitic characteristics.

The Mescal Limestone occurs in three separate masses bounded by the Dripping Spring Quartzite on the east and a fault on the west. The Mescal is gray, cream, or white in color and is everywhere recrystallized and deformed.

BOLSA QUARTZITE

The Bolsa Quartzite, of Middle Cambrian age, was named by Ransome (1904) from exposures near Bisbee, Ariz., about 80 miles (130 km) southeast of the study area. The Bolsa crops out only in a small patch west of Sombrero Butte along the western edge of the study area. It is both in fault contact with, and overlain unconformably by, the Galiuro Volcanics; the westward extension of the Bolsa is covered by alluvium of the San Pedro Valley.

The Bolsa is a light-tan, well-bedded, medium-grained orthoquartzite, locally mottled by iron oxide stain to shades of pink, brick red, and ochre. More than 95 percent of the Bolsa by estimate is made up of well-rounded interlocking quartz grains, many of which have quartz overgrowths that accentuate the mosaic texture. Here and there small amounts of interstitial argillic material occur; judged by birefringence, some of it is sericite or mixed-layer micaceous material.

GLORY HOLE VOLCANICS

The Glory Hole Volcanics were named by Simons (1964, p. 38) for exposures around the Glory Hole mine, about 1,000 feet (300 m) from the northwest boundary of the study area in the Copper Creek drainage. The Glory Hole Volcanics crop out in the northwestern corner of the study area; they are a small mass separated by the Copper Creek Granodiorite from the main mass lying to the north. Within the study area they form a north-trending belt about 3 miles (5 km) long by 1 mile (1.6 km) wide. On the north, west, and south they are bounded by the Copper Creek Granodiorite and the Pinal Schist, on the east by the overlying Galiuro Volcanics. Outcrops are scarce; most exposures occur in the walls of washes.

The Glory Hole Volcanics unconformably overlie the Pioneer Formation of the Apache Group and are overlain unconformably by the Galiuro Volcanics; they are intruded by the Copper Creek Granodiorite, which is 68 m.y. old on the basis of a K-Ar isotopic age on biotite. From these relations, the Glory Hole Volcanics are most likely Late Cretaceous.

Simons (1964, p. 38) described the Glory Hole Volcanics as a "heterogeneous group of tuffs, welded tuffs, breccias, lavas, and flow breccias probably dominantly of andesitic or dacitic composition." Not all of these types of rocks were recognized in the study area, but flows, breccias, and bedded volcanic sediments were noted.

The Glory Hole ranges from light brown to gray to purplish gray. The lavas are porphyritic with a pilotaxitic groundmass. Most of the specimens are propylitized; the mafic minerals, hornblende and possibly pyroxene, are altered to chlorite, the plagioclase to argillic material and carbonate, the groundmass to a complex aggregate of chlorite, carbonate, sericite, and unidentified argillic material. In one specimen from near the contact with the Copper Creek Granodiorite, the groundmass has been hornfelsed (recrystallized) to an aggregate of granular plagioclase and interstitial green biotite.

Three landslide masses of brecciated Dripping Spring Quartzite are intercalated in the Glory Hole in the northwesternmost corner of the study area. Two of these appear to be at the same stratigraphic horizon, but they probably represent different masses. The source of the landslides is probably the large outcrop of Dripping Spring Quartzite about 2 miles (3.0 km) east. Within the landslides, the quartzites are strongly brecciated and crackled, but mixing of other rock types did not occur; apparently the landslides moved as coherent masses.

Large areas of altered Glory Hole Volcanics are shown on the map showing geochemical anomalies and geochemical sample localities (pl. 2) as quartz-sericite-pyrite and, locally, secondary biotite. Elsewhere both types of hydrothermal alteration are associated with commercial porphyry copper deposits. The economic significance of such alteration is discussd under "Mineral Resource Appraisal."

COPPER CREEK GRANODIORITE

The Copper Creek Granodiorite, named by Simons (1964, p. 56) for exposures in Copper Creek, crops out in the northwestern corner of the study area over an area of about 4 or 5 square miles (10 or 13 km^2). The granodiorite weathers to smooth-rounded surfaces, but outcrops of fresh rock are common, especially in the deeply incised Copper Creek Canyon.

The Copper Creek Granodiorite intrudes the Pinal Schist, the Apache Group, and the Glory Hole Volcanics; it is overlain unconformably by the Galiuro Volcanics. The potassium-argon isotopic age of the biotite from the granodiorite is 68 m.y. (Simons, 1964, p. 56).

The Copper Creek Granodiorite varies in texture, appearance, and mineral composition from place to place; some, if not all, of these variations may result from different intrusive phases. If this is so, the granodiorite is composite and possibly was emplaced over a measurable range in time. Because the copper deposits are temporally and spatially associated with the granodiorite, or with some phase of the granodiorite, the question of whether or not the granodiorite is composite is important in determining the history of mineralization of the copper deposits.

The texture of the granodiorite is either porphyritic or seriate porphyritic with a holocrystalline groundmass that in some places is aphanitic, in others phanerocrystalline. The phenocrysts are principally plagioclase of intermediate composition but commonly include biotite and, rarely, hornblende or clinopyroxene. Quartz and K-feldspar are typically interstitial; commonly they poikilitically enclose plagioclase and biotite. The groundmass is granular and consists of anhedral quartz and feldspar and lesser amounts of biotite. Accessory minerals are apatite, zircon, sphene, and iron ores.

The two southernmost isolated exposures of the granodiorite shown on the geologic map are so different from the rest of the granodiorite that they may well represent a separate intrusive. They were so small, however, and their relations to other rock so obscure that they are here included with the Copper Creek Granodiorite. The rock is a fine- to medium-grained diorite. It consists of plagioclase, clinopyroxene, a few scattered grains of biotite, and less than 10 percent each by estimate quartz and K-feldspar.

GALIURO VOLCANICS

Blake (1902, p. 546) gave the name Galiuro Rhyolite to volcanic rocks in the Galiuro Range. Because rock types other than rhyolite are represented in the formation, Cooper and Silver (1964, p. 87) changed the name to Galiuro Volcanics.

The Galiuro Volcanics extend for about 20 miles (32 km) northwest of the study area into the area around Stanley Butte (fig. 1) and about 20 miles (32 km) southeastward as far as the southern end of the Winchester Mountains. They do not extend west of the San Pedro Valley or east of the Aravaipa-Sulfur Springs Valley. Although volcanic rocks of about the same age are widespread in southeastern Arizona, the restricted outcrop area of the Galiuro Volcanics suggests a local volcanic field centered in the Galiuro Range.

ANDESITE UNIT

With the possible exception of the ash-flow tuff unit of the Galiuro Volcanics, the andesite unit is the most extensive of all the rock units in the study area. The andesite extends from the northern to the southern end of the study area, and locally it also extends from the western to the eastern edge of the area. The andesite and the overlying ash-flow tuff unit of the Galiuro Volcanics together form a gently eastward dipping blanket that covers more than 90 percent of the study area. Where the andesite is missing, it was removed by erosion (fig. 3).

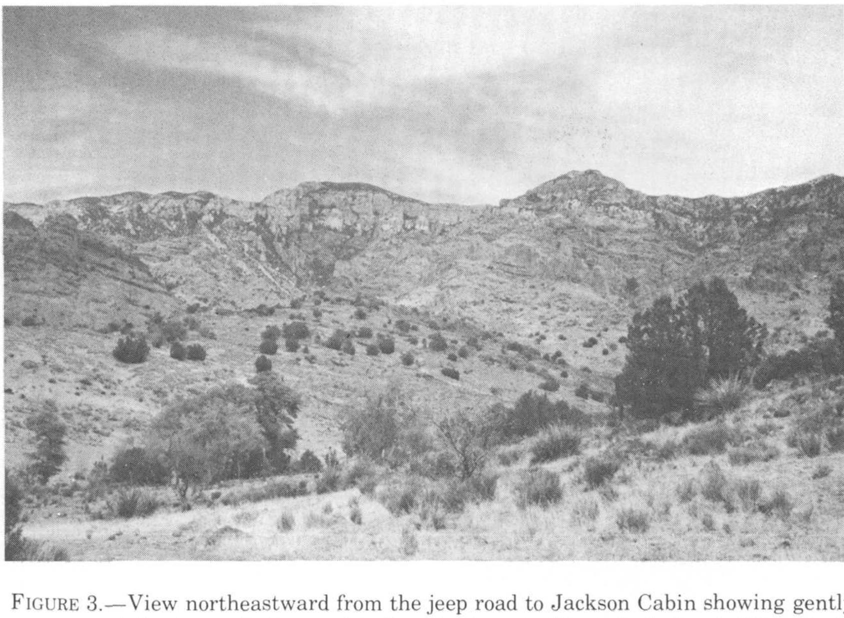


FIGURE 3.—View northeastward from the jeep road to Jackson Cabin showing gently eastward dipping andesite overlain by a few hundred feet of ash-flow tuff (skyline).

The lower contact of the andesite is a profound unconformity, the andesite resting on deformed rocks ranging in age from Precambrian to Late Cretaceous or early Tertiary. The igneous intrusive rocks and the structural paroxysm related to the copper deposits in the Copper Creek area all predate the andesites. The upper contact of the andesite where it is overlain by ash-flow tuff is also an erosional unconformity, although not as profound as the lower. The erosional relief on the top of the andesite in the study area is perhaps as much as 1,000 feet (300 m). The time interval represented by the lower unconformity is probably about 40 m.y.; that represented by the upper unconformity is presumed to be not more than 1 or 2 m.y. and may be considerably less.

Locally, the andesite interfingers with and underlies the rhyolite obsidian unit of the Galiuro Volcanics. Apparently neither a time nor a structural discontinuity intervened between accumulation of the andesite and rhyolite units. These rhyolites, similar to the andesite, are unconformably overlain by the ash-flow tuffs.

The andesite, which dips at low angles, crops out boldly, forming cliffs along stream canyons and along the mountain fronts. Gross layering produced by individual flows stands out in vertical sections; locally flow tops, fragmental beds, and columnar jointing are conspicuous.

The andesite includes minor amounts of latite that were not mapped separately, although they could be mapped if the contacts were walked. Zones of latite lie just beneath the rhyolite unit of the west side of the study area from the latitude of Rhodes ranch southward as far as Keilberg Canyon, near the confluence of Redfield and Negro Canyons in the south-central part of the study area, and near the base of the Galiuro Volcanics on the ridge about a mile east of Rhodes ranch.

At the north end of the study area, there are three small latite flows mapped separately by Simons (1964) that are not shown on the geologic map; for use in this report, Simon's map of the area north of lat 32°45′ was modified to correspond to the rock units used in this report.

The andesites and latites are a succession of lava flows with only minor amounts of intercalated fragmental agglomerates, bedded tuffs, and water-deposited volcanic sediments. Scoriaceous flow tops were observed, and, in places, individual flows could be recognized by differences in structures (such as columnar jointing), textures, and color.

Where the rocks are fresh and iron oxide minerals are in the reduced state, the andesites and latites are black, purplish gray, or dark gray; where the iron oxide minerals are in the oxidized state, they range from bright red to brick red. Oxidation is locally a result of weathering, oxidation of sulfides, and volcanic processes.

The typical andesite is porphyritic; phenocrysts of plagioclase and clinopyroxene are set in an aphanitic pilotaxitic (felty) groundmass of plagioclase microlites and granular clinopyroxene. An estimated 10 percent of the andesites is nonporphyritic, that is entirely crystalline but aphanitic. The microscopic texture of these rocks is chiefly pilotaxitic, but some are microgranular. Of the porphyritic andesites, about 15 percent have a microgranular groundmass. About a third of the andesites are either vesicular, amygdaloidal, or both. The phenocrysts consist of plagioclase of intermediate composition, clinopyroxene, and, in a few flows, intensely altered olivine. Magnetite and (or) hematite are characteristic. The mafic minerals are commonly altered to iron oxide and a soft, green unctuous mineral thought to be an iron-bearing clay or serpentine. Argillic alteration of the plagioclase is present in some specimens, and secondary carbonate occurs here and there. Most amygdules consist of the green unctuous mineral, but some are carbonate or quartz.

All of the specimens of the latite studied are porphyritic, and in sharp contrast to the typical pilotaxitic groundmass of the andesites, all have a microgranular groundmass. Phenocrysts consist of plagioclase of intermediate composition, biotite, and clinopyroxene. Biotite occurs in all samples examined, clinopyroxene in only a fourth. Plagioclase and some mafic minerals are groundmass constituents. Commonly iron oxide so floods the groundmass of both the latites and andesites that groundmass minerals are difficult to resolve. Apatite, iron ores, and zircon are accessory minerals in both latite and andesite.

Chemical analyses and norms of the andesite are given in the following table. Analyses 1 and 2 are from localities a few miles north of the study area; 3 is from Redfield Canyon in the southern part. According to the classification of Rittman (1952), 1 and 2 are trachyandesites, and 3 is on the boundary between a trachyte and latite.

In Sombrero Butte and southward along the western front of the Galiuro Range, three ash-flow tuffs are interbedded in the andesites and latites. One crops out extensively, the others only locally; one of the two smaller ash-flow tuffs crops out at the north end of Sombrero Butte beneath the extensive ash-flow tuff, the other just above the extensive ash-flow tuff in the South Fork of Clark Wash. Possibly other thin ash-flow tuffs not found during the reconnaissance geologic mapping occur here and there in the lower andesites and latites.

Chemical analyses, in percent, of trachyandesites and latite

Bulk analyses				Normative minerals			
Constituent	1	2	3	Mineral	1	2	3
SiO_2	57.59	52.45	63.4	Q	10.68	4.38	14.10
Al_2O_3	16.70	16.99	17.2	or	17.24	6.12	31.69
Fe_2O_3	6.55	6.11	4.2	ab	34.06	31.96	36.15
FeO	.99	2.88	.20	an	18.90	21.41	3.89
MgO	2.15	3.10	1.5	C	------	------	2.96
CaO	5.37	7.02	.90	wo	1.74	3.36	------
Na_2O	4.05	3.79	4.3	en	5.40	7.70	3.80
K_2O	2.87	2.71	5.4	mt	------	4.41	------
H_2O^+	.72	.86	.30	hm	6.55	3.04	4.16
H_2O^-	1.02	1.08	.80	il	2.28	3.50	.46
TiO_2	1.37	1.79	.58	ap	.39	------	------
P_2O_5	.38	.67	.30	ti	.39	------	------
MnO	.10	.13	.06	ru	------	------	.01
CO_2	.01	.13	.06				
Cl	.01	.01	------				
F	.06	.07	------				
Subtotal	99.84	99.79					
Less 0	.03	.03					
Total	99.81	99.76	99				
Powder density	2.71	2.79					

1. Trachyandesite flow in lower andesite unit, Galiuro Volcanics, west edge sec. 13, T. 7 S., R. 18 E. Analyst: Dorothy F. Powers, U.S. Geological Survey. From Simons (1964, p. 71).
2. Porphyritic "turkey track" trachyandesite, Little Table Mountain (N½ sec. 27, T. 7 S., R. 18 E.) at top of lower andesite unit, Galiuro Volcanics. Analyst: Dorothy F. Powers, U.S. Geological Survey. From Simons (1964, p. 72).
3. Latite flow in andesite, Galiuro Volcanics, Redfield Canyon (unsurveyed sec. 21/28, T. 10 S., R. 20 E.). Laboratory No. W 182411. Rapid analysis by Paul Elmore, U.S. Geological Survey.

The extensive ash-flow tuff crops out from the north end of Sombrero Butte southward for about 8½ miles (14 km) to where it is covered by the alluvium of the San Pedro Valley. About 2 miles (3 km) farther south, it appears again, cropping for 1½ miles (2 km) before being covered by the alluvium.

The ash-flow tuffs are predominantly welded; they form bold outcrops marked by alternating cliffs and slopes. Except for the vitrophyres, they range in color from light pinkish gray to pale red purple; in outcrop, the tuffs are paler shades of fresh fracture colors. The vitrophyres are either black or dark brown. The tuffs consist of phenocrysts of plagioclase, sanidine, and dark-red-brown biotite in a groundmass of partly to completely devitrified glass or glass. About all that can be recognized in the devitrified glass are feldspar microlites. Here and there crystals of altered clinopyroxene were observed, but these are probably exotic. Iron ores, sphene, apatite, and zircon are accessory. Without chemical analyses, the rock classifications are uncertain; rhyodacites, quartz latites, or dacites are the most likely.

Five small masses of intrusive andesite (unit Tgia) were recognized in the study area. About half a mile (1 km) east of the Deer Creek (Simms) ranch, a dome or plug of andesite stands out as a hill. All are regarded as an integral part of the andesitic volcanism whose major product was andesitic flows. Perhaps the intrusive masses fed the higher level flows, possibly even the andesitic flows intercalated in the ash-flow tuffs.

The mineralogic composition of the intrusive andesite approximates that in the andesite flows. The intrusive andesites are porphyritic with either an aphanitic pilotaxitic or an allotriomorphic granular groundmass. The phenocrysts, which make up about 50 percent of the rock, consist of plagioclase laths of intermediate composition, oxyhornblende, and oxybiotite. The intrusive andesite differs from the flows by containing oxyhornblende and more phenocrysts, and the grain size of the groundmass is coarser, probably the result of a slower cooling rate.

Two pyroclastic cones occur within the andesite unit in that part of the northern end of the study area mapped by Simons (1964). The largest cone consists of a central core of fine-grained hard andesite (?) surrounded by an outward-dipping accumulation of tuff, breccia, agglomerate, and volcanic conglomerate.

Interlayered in the andesite unit is sec. 31, T. 8 S., R. 19 E., is a lenticular mass of conglomerate (unit Tgarc) and rhyolite (unit Tgar) flows. The conglomerate, which underlies the flows, consists of poorly sorted, slightly rounded volcanic clasts, the largest about 1 foot in diameter. The rhyolite, light gray to pink, is brittle and flintlike under the hammer and is conspicuously flow banded. A thin interbed of volcanic sandstone suggests that the rhyolite is made up of two or more flows. The rhyolite is porphyritic with an aphanitic microcrystalline groundmass. The one specimen studied microscopically contained phenocrysts of sanidine (common) and biotite (rare) in a microcrystalline allotriomorphic groundmass of felsic minerals.

RHYOLITE-OBSIDIAN UNIT

The rhyolite-obsidian (unit Tgr) crops out in the west-central part of the study area (pl. 1) entirely on the west side of the drainage of Rattlesnake Canyon. It is unconformably overlain by the rhyolite-breccia unit and by the ash-flow tuff unit; it overlies, and interfingers with, the andesite (unit Tge), and because the andesite is lenticular, the distal flows are overlapped by middle and lower units of the ash-flow tuffs. In general, this large pile of rhyolite and obsidian, some of which is intrusive, did not extend far in any direction from its source. When extruded, the rhyolite-obsidian formed a topographic high and in part at least the rhyolite-breccia formed through rapid erosion of this high.

The rhyolite-obsidian is more closely related in time to the andesite than to the ash-flow tuff. Near the base of the rhyolite-obsidian, it interfingers with the andesite. At least one tuff marker bed, designated "bedded tuff," at its northern end lies within the andesite, but at its southern end, it is entirely within the rhyolite-obsidian. These relations indicate essentially contemporaneous extrusion of andesite and rhyolite-obsidian.

The rhyolite-obsidian ranges in color from white to black; the devitrified rhyolites and those that were originally microcrystalline range from off-white to pale reds, pinks, and oranges. The obsidians are dark hues of brown, green, yellow, and red brown; uncommonly the obsidian is nearly black. Flow banding is characteristic; although not all outcrops exhibit banding. The microscope shows that some banding results from unequal devitrification, but this is not the common origin.

The typical rhyolite-obsidian consists of quartz and sanidine phenocrysts set in a spherulitic groundmass. Albitic plagioclase and biotite occur in some of the rhyolites, and the groundmass of some is vitric or partly vitric. Obsidians are common but distinctly subordinate in amount to the rhyolites with microcrystalline or cryptocrystalline (devitrified) groundmasses.

Several tuff beds (unit Tgrt) and one andesite flow (unit Tgra) are interbedded with rhyolite-obsidian. The largest tuff bed lies within the andesite east of the YLE ranch site, where the tuff is composed of fragments of andesite and crystals of plagioclase, biotite, and quartz in an ash matrix that has recrystallized into a cryptocrystalline aggregate. Where the tuffs are entirely in rhyolite-obsidian, they consist of fragments of pumice and crystals of quartz and feldspar, chiefly sanidine, in an ash matrix. Commonly the tuffs are intensely silicified, presumably owing to silica released from alteration of the ash. Thin sections show the ash is devitrified to a cryptocrystalline aggregate of felsic minerals.

The single andesite flow in the rhyolite-obsidian is similar to the underlying andesite. It is porphyritic and has a microcrystalline pilotaxitic groundmass. The phenocrysts, which constitute about 40 percent of the rock, are plagioclase and clinopyroxene; the groundmass is a mat of feldspar microlites.

Pyritic alteration is spatially and probably genetically related to the rhyolite-obsidian and more specifically to the intrusive parts of the unit. Most intrusive rhyolites were mapped separately from the flows, but undoubtedly some masses were not recognized. The alteration is discussed in the section on "Mineral Resource Appraisal."

RHYOLITE-BRECCIA UNIT

The rhyolite-breccia unit crops out in the center of the study area entirely within the drainage of Rattlesnake Creek. It forms bold outcrops and resists erosion, as do the surrounding ash-flow tuffs. The breccia is underlain by the rhyolite-obsidian unit and is overlain by the ash-flow tuff unit.

The breccia is crudely bedded; the beds typically dip gently eastward except near the fault that bounds the eastern side of the breccia, where dips as steep as 80° E. resulted from active movement along the fault during the accumulation of the breccia. The basin in which the breccia accumulated probably formed entirely by normal movement on the fault.

Individual beds are disordered accumulations of angular clasts ranging in size from microscopic to several feet in diameter. Sorting appears to be nonexistent within beds and is very crude between beds. Rounding of fragments is minimal. The source of the fragments is primarily the underlying rhyolite-obsidian unit, although fragments of ash-flow tuff are common and fragments of the andesite occur here and there. The rhyolite-breccia is a locally derived sedimentary breccia that accumulated against an active fault.

ASH-FLOW TUFF UNIT

The ash-flow tuff unit caps the Galiuro Range from the latitude of Sombrero Butte southward to beyond the limits of the study area. The original thickness of the unit is not known, because the top is erosional; the thickest remaining section, as much as 2,100 feet (640 m), is along the western front of the Galiuro Range in the southern part of the study area. Along the eastern side of the range, the ash-flow tuffs are somewhat thinner owing to erosion on the upthrown block of the long fault that extends through the center of the range.

A large part of the ash-flow tuffs is welded. Locally basal vitrophyres crop out conspicuously for several miles. Elsewhere color and texture differences between welded and nonwelded parts of ash flows result in markedly different appearing rocks in sharp contact. Their contacts are irregular, commonly crossing the flow layers at high angles. We did not attempt to separate individual ash flow units, but most, if not all, could be separated and internal characteristics of individual flows determined by detailed mapping. Such mapping would be time consuming and arduous owing to the poor access, chaparral, and rugged terrain.

The ash-flow tuffs dip about 10° E, forming a cliff and slope topography. Near-vertical cliffs 100 feet (30 m) or more high are common, especially on west-facing exposures. The cliffs are not continuous, and upper slopes are commonly accessible along major canyons (fig. 4). In color, the tuffs range widely: The vitrophyres are black or dark reddish brown; devitrified tuffs are hues of reddish brown, pink, and pale red; unwelded tuffs are gray, white, or pale yellow to brown. Reddish hues predominate owing to the widespread primary oxidation of the iron in the tuffs; even the mafic silicate minerals in the ash-flow tuffs are strongly oxidized.

The ash-flow tuffs in general are about 20–25 percent crystals, the remainder either glass or devitrified glass. The parent magma, therefore, was no more than a quarter crystallized at the time of eruption, and minerals cystallized were insufficient to accurately characterize the rock. About 60 percent of the 45 ash-flow tuff specimens studied contained crystals of plagioclase (oligoclase-andesine) and quartz with or without oxybiotite. Judged by this mineral assemblage, the rock is a dacite, but 28 percent of the ash-flow tuff specimens contained plagioclase and oxybiotite with or without clinopyroxene, which suggests a trachyandesite or latite. Hornblende occurred in 8 percent of the specimens; quartz and plagioclase always accompanied the hornblende; and about half of the specimens contained oxybiotite.

In the Holy Joe Peak quadrangle, north of the study area, M. H. Krieger (oral commun., 1974) had chemical analyses made of three

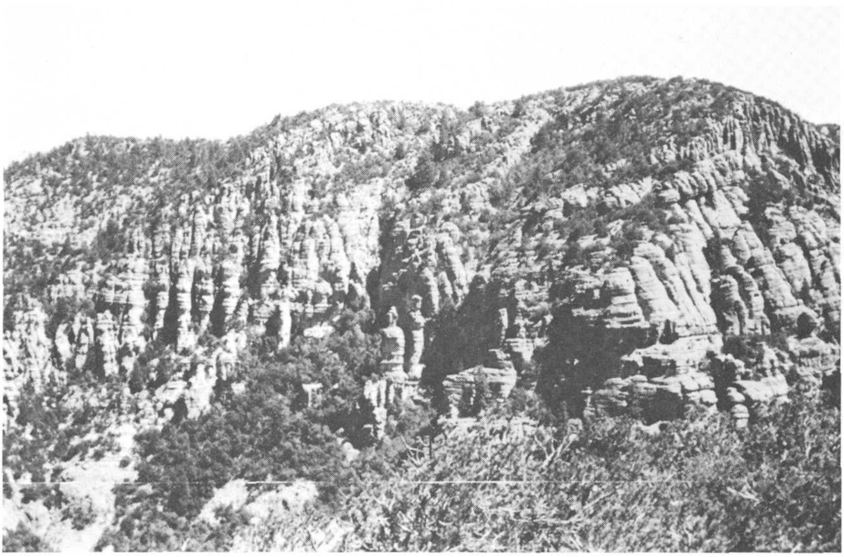


FIGURE 4.—View southeastward from the end of the East Divide trail showing the cliff and slope topography in ash-flow tuffs southeast of Bassett Peak in the Ash Creek drainage.

specimens of the ash-flow tuff, and Simons (1964, p. 78) published an analysis of one specimen. The norms calculated from all four chemical analyses indicate that the ash-flow tuffs are normal quartz latites. The potash is confined to the groundmass, as is most of the silica. Normative quartz ranged from 21 to 25 percent, normative K-feldspar from 28 to 34 percent, and normative plagioclase ranged from 15 to 20 percent (oligoclase), whereas that of the actual plagioclase is estimated to be closer to 25–30 percent (oligoclase-andesine).

Chemical analyses and norms of three samples of the ash-flow tuff from the Holy Joe Peak quadrangle northwest of the study area, of one sample from the Holy Joe Peak quadrangle (Simons, 1964, p. 78) north of the study area, and one sample from Redfield Canyon within the study area are listed in table 1. Samples 2, 3, and 4 are rhyolites using the classification of Rittmann (1952), and samples 1 and 5 are quartz latites but near the rhyolite boundary. The phenocrystic minerals in the tuff do not reflect the high normative orthoclase and quartz, because the potash and most of the silica are confined to the groundmass. On hand-specimen classification alone, much of the ash-flow tuff appears to be a rhyodacite, or even a dacite.

Five or six andesite flows (Tgta), at least one of which includes subordinate amounts of interbedded andesitic tuff, are interlayered with the ash-flow tuffs on China Peak and to the south (fig. 2). These andesites and the andesite unit (Tga) are alike in texture, mineralogy, and alteration. They typically contain phenocrysts of plagioclase and clinopyroxene set in an aphanitic pilotaxitic groundmass. The associated tuff beds consisted of lithic fragments of andesite and welded tuff and crystals of plagioclase and quartz in a matrix of devitrified ash.

INTRUSIVE RHYOLITE

The intrusive rhyolite occurs in 14 separate masses in the study area. Four of the masses, including the largest, are in, or near, outcrops of the rhyolite-obsidian unit. These intrusive rhyolites are similar in appearance and mineral composition to the flow rhyolites; it is possible, therefore, that they are consanguineous and essentially coeval.

All masses of intrusive rhyolite are porphyritic with an aphanitic microcrystalline or cryptocrystalline groundmass that is locally spherulitic. The most typical intrusive rhyolite contains phenocrysts of sanidine and quartz; about half of the specimens studies contain dark-red-brown oxybiotite, one specimen contains green hornblende, and plagioclase occurs in about a quarter of the specimens. Accessory minerals are iron ores, sphene, zircon, and apatite. Quartz occurs in two modes: as large, partly resorbed phenocrysts that appear to be of

TABLE 1.—*Chemical analyses, in percent, of ash-flow tuffs*

Bulk analyses						Normative minerals					
Constituent	1	2	3	4	5	Mineral	1	2	3	4	5
SiO_2	65.17	67.2	68.5	67.1	68.4	Q	25.20	22.62	21	19.26	22.08
Al_2O_3	14.67	14.4	15.2	15.4	15.7	or	27.80	31.69	33.92	30.58	28.36
Fe_2O_3	2.04	1.5	2.5	2.6	2.6	ab	25.15	30.39	31.96	34.06	34.58
FeO	.22	.63	.30	.33	.16	an	6.12	4.73	5.56	8.06	7.78
MgO	1.40	.77	.80	.77	.54	C	2.45	------	------	------	.92
CaO	1.44	1.1	1.3	1.8	1.6						
Na_2O	2.97	3.6	3.8	4.0	4.1	en	3.50	1.0	2	1.90	1.40
K_2O	4.73	5.4	5.7	5.2	4.8						
H_2O^+	3.48	3.5	.53	.58	.70	mt	------	.70	------	------	------
H_2O^-	2.73	.40	.32	.56	.42	hm	2.04	.96	2.56	2.56	2.56
TiO_2	.49	.48	.56	.60	.61	il	.46	.91	.76	.76	.46
P_2O_5	.10	.12	.16	.19	.12	ti	.59	------	------	------	------
MnO	.07	.07	.08	.05	.09	ru	------	------	------	------	.01
CO_2	.01	<.05	<.05	<.05	.08	ap	------	.34	.34	.34	.34
Cl	.05	------	------	------	------	fl	.07	------	------	------	------
F	.11										
Subtotal	99.68										
Less O	.05										
Total	99.63	99	100	99	100						

1. Ash-flow tuff, Galiuro Volcanics, center N½ sec. 27, T. 7 S., R. 18 E. Laboratory No. G2965 Analyst June W. Goldsmith. From Simons (1964, p. 78).
2. Ash-flow tuff, Galiuro Volcanics, sec. 5/6, T. 7 S., R. 18 E. Rapid analysis by P. Elmore, S. Botts, and G. Chloe. From M. H. Krieger (oral commun.).
3. Ash-flow tuff, Galiuro Volcanics, sec. 5/6, T. 7 S., R. 18 E. Rapid analysis by P. Elmore, S. Botts, and G. Chloe. From M. H. Krieger (oral commun.).
4. Ash-flow tuff, Galiuro Volcanics, sec. 5/6, T. 7 S., R. 18 E. Rapid analysis by P. Elmore, S. Botts, and G. Chloe. From M. H. Krieger (oral commun.).
5. Ash-flow tuff from Rattlesnake Canyon, Galiuro Volcanics, SE¼ sec. 36, T. 8 S., R. 19 E. Rapid analysis by P. Elmore.

the same generation as the sanidine and as small anhedral blebs that appear to have recrystallized from the microcrystalline groundmass, or to be secondary, or both.

DIKES

Dikes occur throughout the study area, in swarms and individually. As all dikes shown on the geologic map (pl. 1) are unaltered and similar in mineralogic composition to the Galiuro Volcanics, they are assumed to be about the same age as the volcanic rocks and to be derived from the same magmatic source.

The dikes range in mineral composition from andesitic to rhyolitic, but the andesite dikes recognized were sparse and restricted to the northern part of the study area. About 90 percent of all the dikes studied are quartz bearing; 70 percent contain sanidine, and 60 percent plagioclase. Biotite is the common mafic mineral; hornblende occurs in a few dikes. On the basis of phenocrysts, the quartz-bearing dikes are dacites, quartz latites, and rhyolites. The large dike swarm in the south-central part of the study area is quartz latitic, and the swarm west of the Deer Creek Ranch is dacitic. Rhyolite dikes, however, are widespread.

Range of the quartzose dikes in chemical and normative compositions is not known because no chemical analyses were made. It is possible that the extent of crystallization accounts for most of the range in phenocrystic composition and that most of the quartzose dikes are of the same age and are consanguineous.

All but a few of the dikes are younger than middle and lower parts of the ash-flow tuff unit. A dacite dike in Paddy's Wash cuts the andesite unit but is overlain by the oldest ash-flow tuffs. The youngest remaining ash-flow tuff overlies the rhyolite-breccia unit along West Divide near Grassy Ridge; because dikes neither cut nor are they overlain by the tuffs, it is not known whether the quartzose dikes are younger than the youngest ash-flow tuff.

BASALT

Basalt occurs only in the southeastern corner of the study area, where it covers between 2 and 3 square miles (5 and 8 square km). Southeast of the study area basalt crops out extensively.

The basalt unconformably overlies the Galiuro Volcanics and is unconformably overlain by the alluvium of the Sulfur Springs Valley. It is flat lying, or nearly so, and forms mesas and isolated hills that rise above the gently eastward sloping alluvial plain of the Sulfur Springs Valley.

The basalt is a gray to black aphanitic rock that locally contains gas cavities lined with quartz crystals and amygdules of a soft claylime material. Examination under the microscope shows it to be microcrystalline and consist of a felty mat of plagioclase microlites. Phenocrysts were not observed, but the study of the basalt was cursory, as it has little bearing on the mineral potential of the Galiuro Wilderness-Further Planning Areas.

ALLUVIUM

Alluvium, within the study area made up of gravels of different origins and ages, was not differentiated on the anomaly map (pl. 2). It includes sands and gravels that make up the basin fill of the San Pedro, Aravaipa, and Sulfur Springs Valleys, sands and gravels that mantle the pediments that locally cap the interfluves of the drainage into the San Pedro and Aravaipa Valleys, and Holocene sand and gravel that forms the floors of the washes that drain the study area. The alluvium ranges in age from Tertiary (probably Pliocene) to Holocene. It was not studied in detail, because it does not concern the metal resources of the wilderness and has no economic potential for sand and gravel owing to its inaccessibility and long distance from urban areas where the product is needed.

STRUCTURE

The most prominent structures in the study area are northwest-trending faults belonging to the Basin and Range period of deformation. The Galiuro Range, a tilted fault block (sec. *A–A′*, pl. 1), is bounded on the west by a west-dipping high-angle normal fault, exposed for about 5½ miles (9 km) along the east flank of Sombrero Butte. The fault here separates Galiuro Volcanics on the west from older rocks on the east, and the vertical offset parallel to the dip of the fault is at least 5,000 feet (1,500 m). Southward from Sombrero Butte, the alluvial fill of the San Pedro Valley covers the fault.

A parallel west-dipping normal fault extends about three-quarters of the way through the central part of the study area from the south boundary. This normal fault has a vertical offset parallel to the dip of 3,000–4,000 feet (900–1,200 m) at the point where the fault is intersected by section *B–B′* (pl. 1). In part at least, this fault was active during the accumulation of the Galiuro Volcanics, and the rhyolite-breccia accumulated in a local basin formed by movement along the fault. Prospect pits, mine workings, and hydrothermally altered rock here and there along the fault attest to permeability sufficient for mineralizing solutions to carry small amounts of base and precious metals.

Between the north end of this fault and the range-front fault, there are three other normal faults; two are antithetic, one synthetic. Hydrothermally altered rock was found at one locality along the synthetic fault (pl. 2).

The movement along these normal faults produced a gentle (~10°) eastward dip in the volcanic rocks. Locally, as near China Peak, the volcanic rocks are essentially horizontal. A 10° dip over a distance of 10 miles (16 km), approximately the width of the Galiuro Range, produces a structural relief of about 10,000 feet (3,000 m), a distance that approximates the vertical offset on the west-dipping normal faults, evidence that the Basin and Range deformation here resulted from vertical movements along normal faults.

Evidence of earlier periods of deformation occurs in the rocks older than the Galiuro Volcanics; these older rocks crop out over a few square miles between Sombrero Butte on the west and the Galiuro Range on the east. The small outcrop area vitiates the interpretations on the extent and significance of these older structures, but types of structure can be recognized.

The Pinal Schist is locally foliated; refolded folds in some of the less foliated outcrops suggest at least two periods of Precambrian compressive deformation, at least one of which was sufficiently intense to produce a foliation. The fault that separates the Pinal Schist from the Glory Hole Volcanics is older than both the Galiuro Volcanics and the Copper Creek Granodiorite; it is locally mineralized with copper. In the Copper Creek area, strong premineral fractures and faults are marked by conspicuous east-northeast-trending veins and alteration zones.

The unconformity at the base of the Galiuro Volcanics resulted from deformation, or deformations, that cannot be evaluated from exposures in the study area. All of the Paleozoic rocks, which were at least 3,000 feet (900 m) thick, and all but a local patch of the Apache Group, about 1,000 feet (300 m) thick, were eroded, and the Copper Creek Granodiorite stock was unroofed. Elsewhere similar stocks crystallized at depths of 1 to 2 miles (2 to 3 km). These few data indicate deformation between the time of the intrusion of the Copper Creek Granodiorite (68 m.y.) and the accumulation of the Galiuro Volcanics (~20–25 m.y.) Whatever its nature, it resulted in erosion of at least 5,000 feet (1,500 m) of strata. From work in other areas in southern Arizona, normal and thrust faults, sedimentary basins, and ore deposits are known to have formed during this interval.

MINERAL RESOURCE APPRAISAL

SETTING

The mineral potential of the Galiuro Wilderness-Further Planning

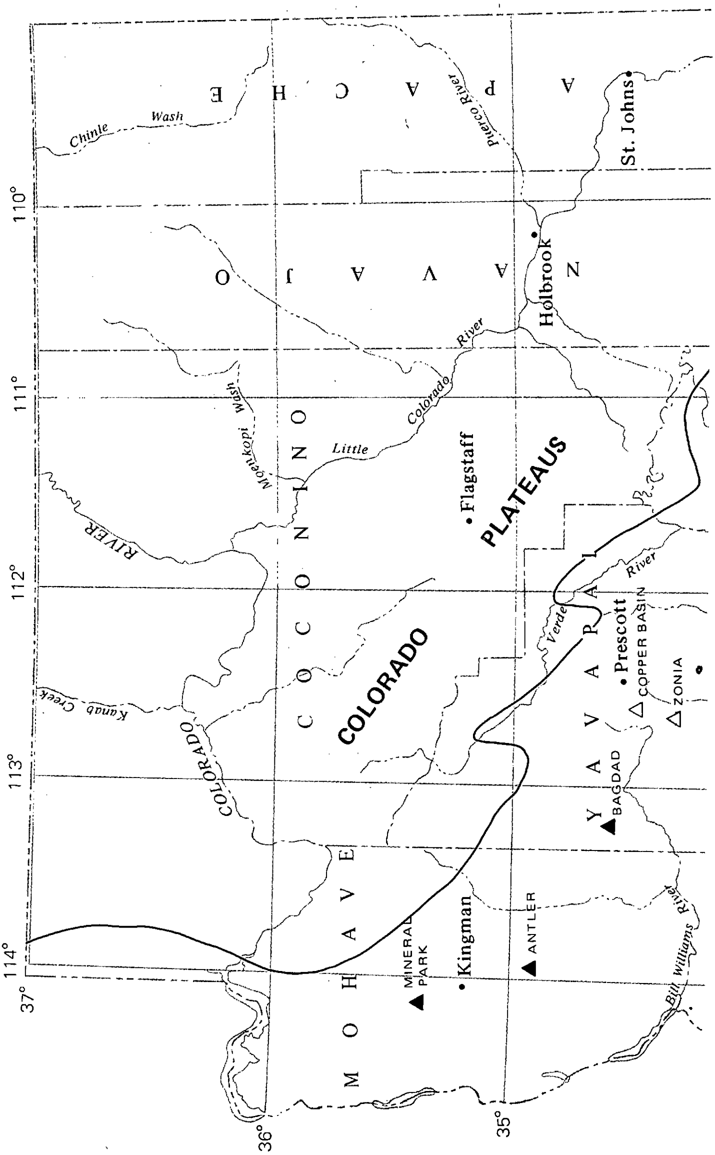
Areas is difficult to assess. The study area lies within one of the world's most productive copper provinces, yet the principal surface rock units in the area are younger than the copper deposits. Within 3,000 feet (900 m) of the surface, two separate groups of rocks occur, one highly favorable for commercial copper deposits, the other highly unfavorable and overlying the favorable rocks such that an area evaluated from outcrop as unfavorable for metal deposits may possibly be favorable at depth.

The extent of the Arizona copper province is only partly known, but the relation of the Galiuro study area to the known major copper deposits in southern Arizona, as shown on the index map (fig. 5), indicates that the area is well within the known extent of the province. The rock units in the Galiuro Wilderness-Further Planning Areas are younger than the copper deposits and therefore conceal older rocks that may, or may not, contain significant copper deposits. Some indication of the copper potential is given by the occurrence of economic copper deposits in Copper Creek, adjacent to the northwest corner of the wilderness. The altered and mineralized older rocks between Copper Creek and Rhodes ranch (pl. 2) no doubt extend beneath these younger volcanic rocks and beneath the northwestern corner of the Galiuro Wilderness-Further Planning Areas. In the Fourmile drainage area, secs. 1 and 12, T. 8 S., R. 19 E., drilled holes transected the younger rocks to explore the mineral potential in the underlying rocks. Exploration geologists believe that the older rocks are close enough to the surface in areas marginal to the Galiuro Wilderness-Further Planning Areas to warrant exploration through deep drill holes.

HISTORY AND PRODUCTION

Two mining districts lie within the study area, Copper Creek (Bunker Hill) and Rattlesnake. The Copper Creek (Bunker Hill) district, outside the Galiuro Wilderness, is centered around the mines in Copper Creek; it extends north of the study area and as far south as Sombrero Butte, thereby including the Magma and Bunker Hill mines.

The Rattlesnake district, in the approximate geographic center of the study area, includes the Powers and Long Tom (also Knothe or Boulder Plug) mines and the Gold Mountain workings. The boundaries of the Galiuro Wilderness have been drawn to exclude these properties, but they are included in the Further Planning Areas. The alteration associated with these deposits extend from the Further Planning Areas into the contiguous Galiuro Wilderness. The Jackson and Sixteen-to-One mines are isolated properties not part of any rec-


APACHE
NAVAJO
COCONINO
MOHAVE
YAVAPAI
COLORADO
PLATEAUS
Chinle Wash
Puerco River
Little Colorado River
Moenkopi Wash
RIVER
COLORADO
Kanab Creek
Verde River
Bill Williams River
St. Johns
Holbrook
Flagstaff
Prescott
Kingman
COPPER BASIN
ZONIA
BAGDAD
ANTLER
MINERAL PARK
110°
111°
112°
113°
114°
37°
36°
35°

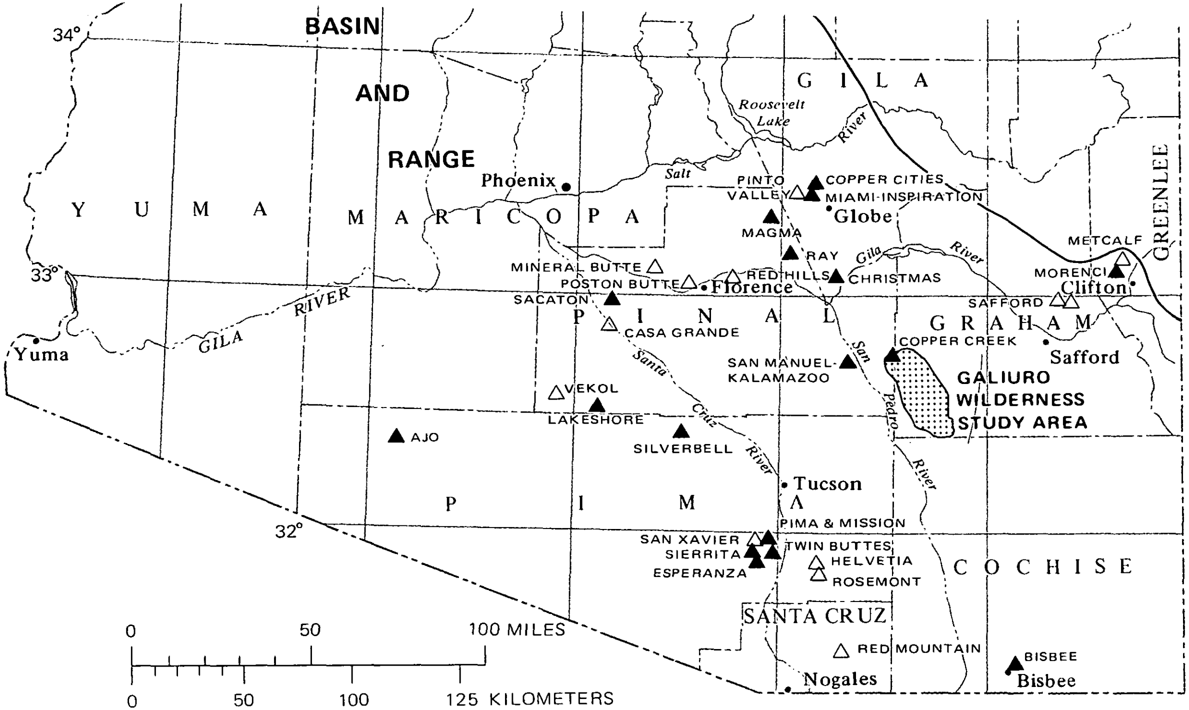


FIGURE 5.—Index map showing location of the Galiuro Wilderness Further Planning Areas in relation to the major copper deposits with production records (closed triangles) and potential copper deposits (open triangles).

ognized mining district. If either had recorded production, it probably would have been assigned to the Rattlesnake district.

COPPER CREEK (BUNKER HILL) MINING DISTRICT

1863—Rich lead-silver ore from the Blue Bird mine was shipped to Swansea, Wales, by way of Yuma.

1883—The Copper Creek area was organized as the Bunker Hill mining district.

1903—The Copper Creek Mining Co. acquired claims along Copper Creek; subsequently the successors to this company, Minnesota-Arizona Mining Co. and Copper State Mining Co., prospected breccia pipes and produced some copper.

1907—The Calumet and Arizona Mining Co. acquired claims and prospected breccia pipes, including Copper Prince, Globe, and Superior.

1933—The Arizona Molybdenum Corp. purchased the Childs-Aldwinkle property and produced molybdenum and copper ore until 1938, at which time lessees acquired the property and mined until the fall of 1943.

1972—Ranchers Exploration and Development Corp. shattered the Old Reliable mine by detonation of 4×10^6 pounds (1.8×10^6 kg) of explosives; in-place leaching of copper ores followed.

Production from 1905 to 1959 of the Copper Creek (Bunker Hill) district is given in table 2, production from 1863 to 1931 by mines in table 3.

RATTLESNAKE DISTRICT

1908—Approximate date of location of Powers mine. Mine worked by the Powers family.

1917—A two-stamp mill erected in Rattlesnake Canyon, 2 miles (3 km) north of the Powers mine, but never operated.

1933—A small Ellis mill was erected 5 miles (8 km) north of Powers mine. Local residents report about 100 tons (91 metric tons) of ore valued at $7.50/ton was milled.

The production of the Rattlesnake mining district from 1908 to 1973 is given in table 4. The Long Tom (Knothe) mine, Powers mine, and Gold Mountain property are known to have contributed to the production of this district (Wilson and others, 1934, p. 194).

The production data on the two mining districts show significant differences: The Copper Creek district had a substantial production, the Rattlesnake a modest one. The Copper Creek is primarily a base-metals district from which 1,354 fine ounces (38,385 g) gold was

TABLE 2.—*Production of the Copper Creek (Bunker Hill) District, Pinal and Graham Counties, 1905–1959*

Year	Number of mines producing	Tons of ore	Total value when sold	Gold, fine (Troy oz)	Silver, fine (Troy oz)	Copper (lbs)	Lead (lbs)
1905	1	63	358		593		
1907	1	35	1,453	0.36	362	6,031	
1909	1	114	3,924	1.67	85	29,579	
1910	1	35	924	------	28	7,161	
1911	1	67	5,887	6.00	3,551	5,598	70,687
1912	1	6,156	38,264	4.04	1,906	218,696	20,507
1913	1	6,172	41,910	------	230	269,488	------
1914	3	6,308	57,688	8.58	777	428,943	819
1915	5	52	4,762	1.46	1,665	15,334	25,626
1916	5	153	33,251	5.00	2,951	124,159	9,618
1917	3	9,262	84,271	1.60	3,079	270,565	91,115
1918	4	671	29,800	6.15	2,228	97,887	46,180
1919	4	196	12,142	8.10	1,460	48,622	24,452
1920	3	306	19,473	1.20	1,394	86,025	26,180
1921	1	20	2,078	1.00	959	850	21,948
1922	6	114	7,285	3.55	3,540	19,554	18,769
1923	8	223	24,009	8.80	17,056	37,818	61,179
1924	3	268	19,923	42.40	6,893	32,482	127,158
1925	9	645	59,901	42.31	18,368	96,105	375,067
1926	6	1,778	84,803	49.95	25,372	149,300	587,955
1927	3	567	47,468	32.00	19,989	34,515	491,288
1928	4	625	19,234	29.20	6,786	28,237	182,655
1929	3	2,709	34,924	24.66	8,593	169,514	------
1930	4	492	32,845	46.45	13,073	44,779	420,164
1931	1	35	581	1.80	323	2,124	6,953
1932	1	68	3,248	6.05	2,163	3,175	77,100
1933	2	285	2,299	2.42	817	14,250	28,405
1934	2	39	1,512	4.12	809	4,127	13,892
1935	1	57	2,933	4.86	224	31,349	------
1936	4	165	124,852	111.60	6,164	1,245,500	34,478
1937	5	98,933	352,587	210	9,661	2,791,504	------
1938	4	70,610	346,213	457	16,765	3,252,469	18,870
1939	1	3,977	56,094	85	2,796	492,510	------
1940	3	1,035	13,58	23	5,573	15,385	138,900
1941	1	624	7,805	17	2,551	21,00	51,200
1942	2	580	7,740	8	976	48,000	143,000
1943	2	865	14,234	2	211	107,800	------
1944	2	842	15,027	------	249	110,000	------
1945	1	58	1,041	------	21	7,600	------
1947	1	598	6,021	3	1,085	2,100	31,200
1948	3	322	9,770	4	1,011	4,200	43,600
1954	1	6,473	68,144	3	306	229,700	------
1955	2	404	5,695	------	28	15,200	------
1956	1	50	1,468	------	25	3,400	------
1957	2	7,351	75,405	46	1,162	241,700	------
1958	2	559	54,664	39	888	199,600	------
1959	1	122	------	2	126	9,500	------

TABLE 3.—*Production by mines of the Copper Creek (Bunker Hill) district, 1863–1939*

Mine	Period	Copper (lbs)	Molybdenite (lbs)	Lead (lbs)	Silver (fine ounces, Troy)	Gold (fine ounces, Troy)	Estimated value (dollars)
Bluebird	1863–1920	------	------	------	------	------	150,000
	1926–39	200,000	------	4,000,000	119,000	------	350,000
	1948	2,100	------	31,200	1,085	3	6,000
Childs-Aldwinkle	1933–38	5,859,033	6,946,782	------	26,938	723	------
Copper Prince	1937	1,227,667	------	------	------	------	------
Copper States Mining Co.[1]	1905–16	700,000	------	------	55,000		
Clark and Scanlon properties	1905–30	200,000	------	------	15,000	------	------
Total		8,188,800	6,946,782	4,031,200	217,023	726	506,000

[1]Source uncertain but presumed to be the Old Reliable and American Eagle mines (after Simons, 1964).

recovered as a byproduct, whereas the Rattlesnake district yielded only 163 fine ounces (4,621 g) gold. These statistics reflect the relative economic significance of the ore deposits of Laramide age (50–70 m.y.) and of the deposits that are of Miocene age (25 m.y.), or younger. The Laramide mineral deposits lie beneath the Galiuro Volcanics and are therefore the chief concern of this report.

TABLE 4.—*Production of the Rattlesnake mining district, Graham County, 1908–1973*

Year	Number of mines producing	Ore (short tons)	Total value, when sold	Gold (fine ounces, Troy)	Silver (fine ounces, Troy)	Copper (lbs)
1908		200	891	43.02	4	
1918		29	2,230	------	195	8,238
1921		8	195	------	169	199
1922		14	568	------	79	3,624
1923		1	349	5.36	290	
1924		2	116	1.70	120	
1925		4	318	5.80	286	
1926		2	386	8.00	355	
1927		4	237	5.50	217	
1928		2	74	1.40	78	
1932	2	71	488	23.51	7	
1933	3	37	394	16.30	163	
1934	1	2	102	1.20	93	
1935	2	4	273	4.00	185	
1940	2	157	1,710	47.00	69	142
Total		537	8,331	162.79	2,310	12,203

METHODS OF EVALUATION

The objective of the study of the Galiuro Wilderness-Further Planning Areas was to appraise the mineral resources through geologic, geochemical, and geophysical techniques and through mine and prospect evaluation. The geologic methods were chiefly the preparation of a geologic map to separate favorable from unfavorable host rocks and altered and mineralized rocks from fresh rocks; to record visible occurrences of ore minerals, chiefly copper; and for the areas covered by Miocene volcanic rocks, to provide a basis for estimating the depth to older rocks more favorable for the occurrence of copper deposits. Geochemical methods consisted principally of systematic sampling of the −80 mesh fraction of stream sediments, as well as altered bedrock and exposures in prospect pits where ore minerals were not visible. The geophysical study consisted of an aeromagnetic survey made to help separate the areas favorable for ore deposits from those unfavorable. Mine and prospect evaluation, made by the U.S. Bureau of Mines, consisted of locating, mapping, and systematic sampling of all claims, mines, and prospects. Both geologic and geochemical data were gathered outside the Coronado National Forest in the altered and mineralized area between Copper Creek and Rhodes ranch to provide a basis for estimating the area favorable for the occurrence of copper deposits within the national forest.

The geologic map (pl. 1) was prepared at a scale of 1 inch (2.54 cm) equals 1 mile (1.6 km) by traversing at about 1-mile (1.6 km) intervals, chiefly along ridges. Contacts were traced between traverses on aerial photographs while in the field, and side trips were made to inspect and sample prospect pits and altered areas. Where base metals, chiefly copper, were visible in the outcrop, samples for chemical analyses were not collected, because base metals are obviously anomalous where visible to the unaided eye. The locations were recorded and appear on the anomaly map, plate 2, as sight anomalies. Systematic sampling of these outcrops would have required time and equipment not available to us.

Alteration in the ash-flow tuffs commonly is restricted to the porous nonwelded parts, irregularly interspersed through the welded parts. The pattern of altered and unaltered tuffs is too complex to illustrate at the mapping scale. To counter this difficulty, boundaries are drawn around generalized areas in which altered rocks are common, but within these areas no attempt is made to estimate the ratios of altered to unaltered rock. Here and there, largely along faults in areas of generally unaltered rocks, there are small areas or outcrops of altered rocks, shown on the map (pl. 2) by a symbol.

For the geochemical evaluation, a total of 481 stream-sediment samples (48 by the U.S. Bureau of Mines and 433 by the U.S. Geological Survey) were collected from all the major stream valleys and their principal tributaries at half-mile intervals. The locations of the samples are shown on plate 2, and the analyses are listed in table 5. Side streams were sampled near their confluence with the major streams, which explains why two sample sites, shown on plate 2, are commonly close together. Locally, when clay-size material could not be found at the prescribed sample site, the sample interval was extended until suitable sediment was found. We tried to find sediment that had long and frequent contact with the stream waters and was free of organic matter. In the bedrock, a total of 46 carefully selected samples of altered and mineralized rock were collected where metals were not visible. These samples supplement the more extensive sampling of mine workings and prospect pits by the U.S. Bureau of Mines. The results of the Bureau's studies are included in this report as a separate chapter.

The geochemical stream-sediment samples were dried and sieved, and the −80 mesh fraction sent to the analytical laboratories where representative fractions were analyzed by semiquantitative spectrographic, atomic absorption, and colorimetric methods similar to those described by Ward and others (1963). The rock samples were sent to the laboratory, where they were pulverized and treated like the stream-sediment samples. Six-step semiquantitative analyses for 30 elements were made on all samples. In addition, the stream-sediment samples were analyzed for citrate-soluble copper (CxCu of table 5) and for citrate-soluble heavy metals (CxHm of table 5), which include copper, lead, zinc, and cobalt, all reported as zinc equivalent. The citrate-soluble metals are ions held weakly by unsatisfied charges on the disrupted edges of clay particles, which abound in the −80 mesh fraction of the stream sediments. The rock samples were analyzed for gold and copper by atomic absorption methods described

TABLE 5—*Analyses of samples from the Galiuro Wilderness*

[All analyses on −80 mesh unless otherwise noted. Samples analyzed by semiquantitative spectrographic analyses are reported to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, which represent approximate midpoints of group data on a geometric sacle. The assigned groups for the series will include the quantitative value about 30 percent of the time. The data should not be quoted without stating these limitations. All samples were analyzed for Ag, As, Au, Bi, Cd, La, Mo, Nb, Sb, Sc, Sn, W, and Y. Those containing 150 ppm, or more, La and 100 ppm, or more, Nb, Sc, and Y are shown in footnotes. Analyses for As, Au, Bi, and Sb revealed no significant values, and no determinations are shown. Samples containing amounts equal to or greater than the lower spectrographic detection limits for the following elements are also shown in footnotes: Mo (5), Sn (10), W (50). Stream-sediment samples analyzed for citrate soluble combined heavy metals and copper by colorimetric methods are shown as CxHm and CxCu, respectively. Analyses for copper and gold in altered rock samples by atomic absorption. Symbols used are: N, looked for but not found; G, the amount of the element present is greater than the sensitivity limit; L, an undetermined amount of the element is present below the sensitivity limit]

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colori-metric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
WESTSIDE DRAINAGE AREA Stream sediments																			
1	10	0.7	700	L	500	1	30	150	70	100	30	300	150	N	150	------	------	5	4
2	10	.7	700	L	500	1	30	150	50	70	30	500	150	N	150	------	------	7	4
3	10	.7	700	L	300	L	30	150	50	70	30	300	150	N	200	------	------	5	5
4	10	.7	1,000	L	500	1	30	150	50	70	30	300	150	N	150	------	------	7	5
5	7	.7	1,000	10	300	1	30	150	70	70	30	500	150	N	150	------	------	7	4
6	10	.7	1,000	10	300	1	30	150	100	100	30	500	150	N	200	------	------	14	5
7	10	1	700	L	300	L	50	200	50	100	20	300	150	N	200	------	------	7	5
8	10	.7	1,000	L	500	1	50	150	50	100	30	500	150	N	150	------	------	7	4
9	7	.5	500	10	300	1	30	100	50	70	20	300	100	N	200	------	------	11	5
10	7	.7	700	10	300	1	30	150	50	100	20	300	150	N	150	------	------	7	5
11	7	.7	700	L	300	1	30	150	70	100	30	500	150	N	150	------	------	7	10
12	15	1	1,000	L	700	2	70	500	70	150	20	500	200	N	150	------	------	10	3
13	15	1	1,000	L	700	1.5	50	200	100	150	15	300	200	N	150	------	------	10	7
14	15	G(1)	1,500	L	500	1.5	50	500	70	100	15	500	300	N	150	------	------	10	5
15	15	G(1)	1,500	L	500	1.5	50	500	100	100	20	300	300	N	150	------	------	10	5
16	7	.7	700	15	500	1.5	15	30	300	30	50	300	150	N	100	------	------	40	14
17	5	.5	700	L	500	1	15	30	500	30	160	300	150	N	100	------	------	G(100)	45
18	10	1	1,000	10	500	1.5	20	100	150	50	50	300	150	N	200	------	------	60	17
19	10	1	700	L	500	2	15	100	70	50	20	300	200	N	200	------	------	40	20
20	10	G(1)	1,500	10	500	2	20	200	70	100	50	300	300	N	150	------	------	10	5
21	10	G(1)	1,500	L	500	2	50	300	70	150	70	300	300	N	150	------	------	10	4
22	10	1	700	L	500	1.5	30	150	70	100	30	300	200	N	150	------	------	7	3
23	15	G(1)	1,000	L	500	2	50	200	70	100	15	300	200	N	150	------	------	7	7

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colori-metric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
WESTSIDE DRAINAGE AREA																			
Stream sediments																			
24	10	G(1)	1,000	L	500	2	20	150	70	100	20	300	200	N	150	------	------	10	7
25	15	1	700	L	500	1.5	50	300	70	150	15	300	200	N	150	------	------	4	3
26	7	1	1,000	L	500	2	30	100	70	100	50	300	200	N	150	------	------	20	3
27	10	0.5	700	L	200	1	70	70	70	30	30	150	200	N	100	------	------	7	7
28	15	G(1)	1,500	L	300	L	70	150	100	70	20	100	300	N	100	------	------	5	4
29	20	G(1)	1,500	L	300	L	70	300	100	70	30	150	500	N	150	------	------	10	2
30	20	1	700	L	300	L	70	150	100	50	20	200	300	N	150	------	------	10	2
31	10	.5	1,000	10	300	1	20	70	100	50	30	200	200	N	70	------	------	20	2
32	10	.5	700	10	300	1	30	100	70	70	10	200	150	N	70	------	------	7	3
33	10	.7	1,000	50	500	2	20	70	70	50	30	300	150	N	150	------	------	7	9
34	20	G(1)	1,000	20	500	1.5	70	150	100	100	30	200	300	N	150	------	------	10	2
35	15	1	1,000	20	300	1.5	70	150	70	70	50	300	300	N	150	------	------	10	2
36	10	1	1,000	15	500	2	50	100	100	70	50	300	150	N	150	------	------	15	7
37	7	0.5	500	L	500	1.5	20	70	100	70	20	300	150	N	150	------	------	10	3
38	10	.7	700	L	700	2	30	150	70	150	30	300	150	N	150	------	------	5	2
39	10	1	1,000	L	700	2	20	50	100	50	50	500	150	N	200	------	------	15	4
40	3	.3	1,000	15	300	2	15	70	70	30	30	200	150	N	150	------	------	10	5
41	15	G(1)	1,500	100	500	2	20	150	70	50	70	150	500	N	200	------	------	15	4
42	7	.7	1,000	30	500	2	15	50	50	40	20	150	100	N	150	------	------	7	3
43	10	1	1,500	70	300	2	20	100	50	50	50	150	200	N	150	------	------	7	3
44	3	.3	1,500	50	500	2	10	50	30	30	15	150	70	N	100	------	------	7	5
45	5	.5	500	L	300	2	15	30	70	30	15	200	200	N	200	------	------	10	7
46	5	.7	1,000	L	500	3	5	20	20	10	20	200	70	N	500	------	------	15	4
47	3	.5	700	L	300	3	5	15	15	10	30	200	50	N	200	------	------	5	7
48[1]	15	G(1)	2,000	L	700	3	20	70	70	20	30	100	300	N	1,000	------	------	10	4
49	7	.7	1,000	L	700	2	15	30	30	20	30	150	100	N	200	------	------	5	2
50	3	.3	300	L	700	2	10	15	15	15	10	150	70	N	150	------	------	3	1
51	3	.5	700	L	700	2	10	20	20	10	30	150	70	N	200	------	------	4	4
52	5	.7	700	L	700	2	10	15	15	10	30	100	70	N	700	------	------	4	5
53	5	.5	1,000	10	700	2	10	20	20	10	20	200	70	N	300	------	------	10	7
54	7	.5	1,500	70	500	1.5	20	70	70	100	30	150	100	N	200	------	------	4	5
55	10	1	700	L	700	2	20	15	15	70	30	300	150	N	200	------	------	5	2
56	10	1	1,000	L	700	2	20	30	30	30	30	150	200	N	500	------	------	2	2
57	5	.5	700	10	700	2	10	30	30	20	20	150	70	N	300	------	------	5	1
58	10	.5	700	L	700	2	10	20	20	20	15	20	150	70	N	300	------	------	10
59	5	.5	700	50	500	2	15	30	30	30	30	150	100	N	200	------	------	4	3
60	3	.3	700	L	700	1.5	5	20	50	10	50	100	50	N	200	------	------	7	7

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colori-metric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
WESTSIDE DRAINAGE AREA Stream sediments																			
61	3	.5	1,000	10	700	2	5	20	50	10	50	150	50	N	1,000	------	------	15	9
62	3	.3	700	L	700	3	10	30	30	20	15	100	70	N	200	------	------	10	4
63	3	.5	1,000	L	500	3	10	20	70	10	30	150	70	N	300	------	------	10	5
64	5	.7	700	L	1,000	3	10	20	20	10	20	150	70	N	300	------	------	3	5
65[2]	5	.5	700	10	500	3	10	30	70	20	20	150	70	N	300	------	------	20	7
66	7	1	1,000	L	500	3	15	30	70	15	30	150	150	N	500	------	------	10	4
67	3	.3	700	L	300	5	10	20	50	15	50	200	50	N	200	------	------	15	5
68	3	.5	700	L	300	2	5	20	70	10	50	100	50	N	300	------	------	20	9
69	3	.3	500	10	300	2	5	30	70	20	50	100	70	N	150	------	------	15	4
70	0.5	.7	700	L	700	2	10	30	100	10	50	200	70	N	150	------	------	15	11
71	10	1	1,000	L	500	3	15	30	70	20	50	200	150	N	200	------	------	4	4
72	3	4.3	700	L	300	2	15	30	30	30	20	200	100	N	150	------	------	7	7
73	5	1	700	L	700	3	10	30	70	20	50	200	100	N	200	------	------	10	4
74	3	.3	700	L	300	3	L	15	70	7	20	150	50	N	200	------	------	10	9
75	3	.3	700	L	200	3	5	30	70	15	30	150	30	N	150	------	------	10	9
76	3	.3	700	10	300	3	10	30	70	20	30	200	70	N	150	------	------	15	9
77	5	.5	700	L	300	2	15	20	50	30	20	300	100	N	150	------	------	5	5
78	5	.5	700	L	500	2	15	30	30	15	15	300	150	N	150	------	------	5	7
79	5	.5	700	L	500	2	15	30	50	15	20	300	150	N	200	------	------	7	5
80	3	.3	700	L	500	2	10	30	20	15	20	300	70	N	200	------	------	4	7
81	5	.5	700	L	500	2	15	30	20	30	30	300	150	N	150	------	------	2	4
82	5	.7	700	10	300	3	10	30	50	30	30	150	100	N	300	------	------	10	3
83	5	.7	700	10	500	2	10	30	50	15	50	150	100	N	300	------	------	10	3
84	5	.5	700	L	500	2	15	30	15	30	20	300	100	N	200	------	------	2	4
85	5	.5	700	10	300	3	10	30	50	20	50	150	100	N	300	------	------	10	4
86	3	.3	700	10	300	3	5	20	50	15	20	150	70	N	200	------	------	5	4
87	3	.5	500	L	300	3	15	50	50	30	20	150	100	N	200	------	------	10	7
88	5	.5	700	10	500	3	15	30	70	20	30	300	70	N	300	------	------	10	2
89	2	.2	700	L	500	3	10	15	70	10	15	150	30	N	150	------	------	15	2
90[3]	3	.3	700	L	300	3	5	20	15	15	50	150	50	N	200	------	------	4	5
91	3	.3	500	L	700	2	5	20	50	15	30	150	70	N	150	------	------	2	3
92	3	.2	700	L	700	2	10	20	15	20	30	200	70	N	200	------	------	2	3
93	3	.3	700	10	300	5	5	30	10	15	50	150	30	N	300	------	------	1	4
94	1.5	.2	700	L	70	3	5	L	20	7	30	150	20	N	200	------	------	2	3
95	1.5	.3	700	L	150	3	L	15	15	7	50	L	30	N	150	------	------	4	N(1)
96	3	.3	700	L	700	2	5	20	15	15	15	200	50	N	150	------	------	2	3
97	2	.3	700	L	500	3	L	20	20	10	50	150	30	N	200	------	------	5	5

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colori-metric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
98	2	.3	700	L	300	3	L	20	20	10	70	200	70	N	200	------	------	3	14
99	.5	.5	700	L	700	3	10	50	20	30	30	200	70	N	200	------	------	L(1)	7
100	2	.2	700	L	700	3	L	10	20	7	50	100	30	N	300	------	------	L(1)	9
101[4]	1.5	.15	700	L	300	3	5	L	15	7	15	150	20	N	150	------	------	2	2
102	3	.3	700	L	500	3	10	20	20	15	15	150	30	N	150	------	------	3	3
103	1.5	.2	500	L	300	3	L	15	10	10	30	100	30	N	150	------	------	2	3
104	.5	.5	700	L	500	3	5	20	30	15	70	100	70	N	1,000	------	------	2	4
105	0.3	.3	1,000	L	150	3	L	L	5	5	30	N	20	N	300	------	------	3	4
106	3	.3	700	L	300	3	5	15	30	10	50	150	70	N	150	------	------	7	7
107	3	.3	500	L	300	2	5	15	30	10	30	150	50	N	200	------	------	5	5
108	3	.3	500	L	300	3	5	15	30	15	30	150	70	N	300	------	------	5	5
109	3	.3	500	L	500	2	5	20	15	15	30	150	70	N	150	------	------	5	4
110	.5	.5	700	L	500	2	10	15	50	15	30	150	100	N	500	------	------	10	3
111	1.5	.15	700	L	70	3	L	L	5	7	15	N	15	N	150	------	------	2	4
112	3	.3	1,000	L	150	3	5	15	20	7	30	100	30	N	200	------	------	7	7
113	2	.2	700	10	200	3	5	15	20	10	30	100	30	N	150	------	------	4	4
114	1.5	.15	500	L	150	3	L	10	15	7	30	N	30	N	100	------	------	2	5
115	1.5	.2	500	L	150	3	5	15	20	7	50	100	30	N	150	------	------	5	9
116	1.5	.2	500	L	150	3	L	10	15	7	30	N	50	N	150	------	------	2	3
117	3	.3	700	10	300	3	5	20	50	10	70	100	50	N	200	------	------	5	14
118	1.5	.15	300	L	150	2	L	15	15	10	50	L	30	N	100	------	------	N(1)	11
119	2	.2	1,000	10	200	3	5	15	30	10	30	100	30	N	150	------	------	5	7
120	3	.3	700	L	300	2	15	50	70	30	20	200	100	N	150	------	------	10	5
121	.5	1	700	10	500	3	15	30	50	50	50	200	150	N	200	------	------	7	4
122	3	.5	700	L	300	2	10	20	70	20	30	150	70	N	200	------	------	10	9
123	2	.3	700	10	200	2	5	30	10	15	15	150	50	N	150	------	------	1	7
124[5]	3	.5	700	10	300	2	15	50	70	30	30	150	70	N	150	------	------	5	7
125	3	.5	700	L	300	2	10	30	50	30	20	150	70	N	200	------	------	5	4
126[6]	3	.3	300	10	300	2	10	30	50	30	50	200	70	N	200	------	------	7	7
127	3	.5	700	L	300	2	10	30	20	30	15	200	70	N	150	------	------	5	5
Altered rocks																			
A[7]	1	.2	200	L	1,000	2	N	N	10	L	L	1,000	20	N	150	N	5	------	5
B	2	.15	300	10	300	L	7	L	7	7	30	300	70	N	50	N	6	------	N
C	3	.2	150	50	150	L	7	L	10	7	70	N	100	N	100	N	15	------	N
D	7	.3	150	20	50	L	15	15	15	7	N	N	150	N	70	N	40	------	N
E	1.5	.15	150	1,000	150	1	N	L	7	N	15	N	30	N	200	N	5	------	N
F	10	.2	100	20	300	L	N	30	300	5	30	100	150	N	100	N	150	------	2
G	1.5	.3	30	L	700	N	N	30	30	N	200	1,500	100	N	200	N	50	------	N

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colori-metric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
Altered rocks																			
H	3	.2	50	L	70	L	N	70	30	L	100	500	100	N	200	N	45	------	N
J[8]	10	1.5	1,500	15	50	1.5	50	1,500	70	150	10	N	150	N	30	N	75	------	5
K[9]	10	1	200	70	3,000	1	20	100	20,000	50	20	150	200	N	150	0.2	30,000	------	G(100)
L	7	.2	200	30	150	L	N	20	50	7	15	L	100	N	100	.5	90	------	7
M	1.5	.15	70	20	150	L	L	N	70	L	30	150	10	N	200	N	130	------	30
N	3	.5	100	20	1,000	1.5	L	N	30	15	15	700	100	N	150	N	25	------	L
P	7	.3	150	30	300	1	N	L	30	L	L	1,000	100	N	150	N	30	------	2
Q	15	.7	100	30	300	L	L	L	30	7	10	1,000	200	N	300	N	20	------	2
R	3	.3	L	L	300	L	N	N	10	N	N	300	70	N	100	N	20	------	L
S[10]	7	.07	100	20	5,000	7	5	N	30	5	30	N	20	N	70	L	5	------	1
T[11]	1.5	.2	150	L	2,000	3	5	N	150	5	500	100	50	N	70	L	190	------	35
U[12]	.07	.07	100	L	5,000	1.5	N	L	20,000	N	200	150	30	300	150	0.40	19,000	------	G(100)
V[13]	2	.2	70	10	700	1	5	N	10	L	30	N	10	N	200	N	L	------	2
W	1	.1	200	10	700	1.5	5	N	51	L	15	N	10	N	150	N	L	------	2
X[14]	5	.2	500	L	1,000	1	N	N	7	L	100	N	20	N	200	N	L	------	3
Y[15]	1.5	.1	50	L	500	1.5	5	N	5	L	15	N	10	N	150	N	L	------	2
Z	.5	.05	150	L	N	1.5	5	N	10	L	15	N	10	N	100	N	L	------	L
FOURMILE DRAINAGE AREA																			
Stream sediments																			
1	10	0.7	700	10	700	1	30	150	50	70	20	500	150	N	200	------	------	5	2
2	10	1	1,500	10	700	1	30	150	50	70	30	500	150	N	200	------	------	5	4
3	10	.7	700	10	700	1	30	150	50	70	30	500	100	N	200	------	------	7	4
4	10	.7	1,000	L	700	L	30	150	30	70	30	500	100	N	200	------	------	7	2
5[16]	10	1	1,500	10	500	L	30	150	100	100	30	500	150	N	150	------	------	1	4
6	10	.7	1,000	L	500	L	30	200	100	100	20	300	150	N	150	------	------	5	4
7	10	.7	700	15	300	L	30	150	100	100	20	300	150	N	150	------	------	3	4
8	10	1	1,000	L	300	L	30	150	100	100	20	500	150	N	200	------	------	5	2
9	7	1	700	L	700	L	30	150	100	100	20	500	150	N	200	------	------	7	10
10	7	.7	700	L	700	L	30	150	50	70	20	500	100	N	200	------	------	7	4
11	10	.7	700	L	700	1	20	150	30	70	15	300	150	N	150	------	------	5	10
12	10	1	1,500	L	500	L	30	200	70	100	20	500	150	N	200	------	------	3	2
13	7	.7	700	L	500	L	20	100	30	70	15	300	100	N	150	------	------	3	4
14	10	7	1,000	L	500	L	20	100	70	70	20	300	150	N	150	------	------	7	5
15	10	1	1,000	L	500	L	30	200	100	100	20	300	300	N	150	------	------	5	5

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colori-metric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
FOURMILE DRAINAGE AREA Stream sediments																			
16	10	.7	700	10	300	L	50	150	100	100	20	500	150	N	150	------	------	5	5
17	7	.7	700	L	1,000	2	30	300	100	100	30	700	150	N	150	------	------	25	2
18	7	.7	1,000	L	1,000	2	30	300	70	150	30	500	200	N	150	------	------	20	2
19	7	.7	500	L	700	2	30	300	70	100	20	500	150	N	200	------	------	10	1
20	10	.5	700	L	300	1	30	70	100	100	20	300	150	N	20	------	------	5	5
21	1	.7	1,000	L	500	L	30	150	100	100	20	300	200	N	150	------	------	5	5
22	10	1	1,000	L	700	2	50	300	100	150	20	500	200	N	200	------	------	20	4
23	5	.5	700	L	700	2	20	100	70	70	20	300	100	N	150	------	------	20	3
24	7	.5	700	L	700	2	20	100	50	70	20	500	100	N	200	------	------	4	L
25	5	.5	700	L	700	2	20	150	70	70	20	500	100	N	150	------	------	20	1
26	7	.7	700	100	700	3	30	150	100	70	30	500	150	N	150	------	------	15	L
27	7	.7	700	100	1,000	3	30	150	100	100	30	500	150	N	150	------	------	20	2
28	7	.7	700	L	700	2	30	200	70	100	50	700	150	N	150	------	------	20	2
29	10	1	1,000	L	1,000	2	50	500	70	150	30	700	200	N	200	------	------	20	2
30	7	1	1,000	L	700	2	30	300	70	150	30	500	150	N	150	------	------	20	2
31	7	.7	1,000	L	700	2	30	300	70	100	50	500	150	N	150	------	------	15	2
32	5	.5	700	L	700	3	20	150	70	70	30	700	100	N	150	------	------	15	N
33	7	.7	700	70	700	3	30	100	100	70	30	300	150	N	150	------	------	20	2
34	7	.5	700	L	700	2	30	150	70	100	30	500	150	N	150	------	------	20	3
35	5	.7	700	L	700	1.5	30	200	70	150	20	500	150	N	150	----	------	20	7
36	5	.5	1,000	L	1,500	3	20	100	50	50	50	700	100	N	150	------	------	7	3
37	5	.5	700	L	700	2	30	300	70	150	20	500	150	N	100	------	------	25	4
39	7	.7	700	L	1,500	3	30	200	50	70	50	700	150	N	150	------	------	1	3
40	7	.7	1,000	L	1,500	2	30	200	50	50	30	700	150	N	150	------	------	3	4
41	7	.7	1,000	L	1,000	2	30	300	50	70	30	700	200	N	150	------	------	4	2
42	7	.7	1,000	L	1,500	2	50	300	70	70	50	700	150	N	150	------	------	3	3
43	7	.7	1,000	L	1,500	2	50	500	70	70	50	500	150	N	100	------	------	10	L
44	7	.7	700	L	1,500	2	30	150	30	50	30	700	100	N	100	------	------	4	N
45	5	.7	700	L	1,000	3	20	50	30	30	30	500	70	N	150	------	------	4	2
46	5	.5	700	L	700	2	20	70	50	30	30	500	50	N	150	------	------	3	2
47	7	.7	700	L	1,000	2	30	200	70	70	50	500	150	N	200	------	------	10	2
48	7	.7	700	L	700	2	30	200	70	100	30	500	150	N	200	------	------	5	2
49	7	.5	500	L	700	2	20	70	70	50	30	500	50	N	200	------	------	7	5
50	7	.5	500	L	700	2	20	150	70	50	50	500	50	N	200	------	------	5	5
51	5	.5	300	10	700	2	15	70	30	30	30	300	30	N	200	------	------	4	1
52	7	.5	700	L	700	2	20	100	50	30	30	500	50	N	200	------	------	4	2

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colorimetric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
FOURMILE DRAINAGE AREA — Stream sediments																			
53	5	.7	500	L	1,500	2	20	70	30	30	50	500	100	N	200	------	------	2	2
54	7	.7	700	L	1,000	3	20	70	50	30	50	500	150	N	150	------	------	1	2
55	5	.5	500	10	1,000	2	20	50	30	20	30	300	70	N	150	------	------	2	2
56	7	.7	700	L	1,000	2	30	70	70	30	50	500	15	N	200	------	------	3	2
57	5	.3	500	L	700	1.5	15	50	30	20	30	500	70	N	150	------	------	4	5
Altered rocks																			
A	7	0.3	100	50	700	1.5	N	30	50	5	10	700	100	N	200	N	25	------	1
B	7	.7	200	30	700	1	N	L	20	L	30	1,500	150	N	300	N	15	------	1
C	7	.7	300	100	500	1	L	70	70	30	20	300	150	N	300	N	70	------	N
D	5	.5	10	15	150	N	N	50	70	10	15	1,500	100	N	200	N	60	------	N
E	3	.7	150	L	300	1.5	7	70	50	30	15	500	150	N	200	N	70	------	5
RATTLESNAKE DRAINAGE AREA — Stream sediments																			
1	8	0.7	1,000	L	700	3	30	300	70	100	30	300	150	N	200	N	70	15	2
2	5	.5	500	20	500	2	20	100	70	70	30	300	100	N	100	N	70	10	3
3	7	.5	500	50	500	2	20	70	50	70	20	300	150	N	150	N	50	7	2
4	7	.5	700	50	700	3	30	150	50	70	20	300	150	N	150	N	50	3	1
5	7	.7	700	50	700	2	30	200	70	100	20	300	150	N	150	N	70	4	2
6	7	.7	700	30	700	2	20	100	70	70	20	500	150	N	150	N	70	4	1
7	7	1	700	L	700	2	30	100	70	100	30	700	150	N	150	N	70	10	2
8	7	.7	1,000	L	1,000	2	30	150	70	100	30	700	150	N	150	N	70	10	L(1)
9	7	.7	700	L	700	2	50	300	70	100	20	700	150	N	100	N	70	10	2
10	7	.7	700	L	700	2	30	200	70	100	20	500	150	N	150	N	70	15	2
11	7	1	1,000	L	700	2	30	300	70	150	20	700	200	N	150	N	70	15	2
12	7	1	700	L	700	3	30	150	70	100	20	700	150	N	150	N	70	15	2
13	5	.5	500	L	700	2	15	100	70	50	20	500	150	N	100	N	70	4	1
14	7	.7	700	L	700	2	30	150	70	100	30	500	150	N	150	N	70	10	2
15	7	.5	700	L	500	2	30	100	70	100	20	300	150	N	150	N	70	10	5
16	10	1	700	L	700	2	30	500	100	150	30	500	300	N	200	N	100	20	4
17	7	.7	700	L	500	2	30	200	70	150	15	300	150	N	70	N	70	20	3

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colorimetric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
RATTLESNAKE DRAINAGE AREA Stream sediments																			
18	.7	.7	700	L	700	2	30	300	70	150	20	500	150	N	100	N	70	15	3
19	.7	.7	700	L	700	2	30	150	70	100	20	500	150	N	150	N	70	15	3
20	.7	.5	700	L	1,000	3	15	150	30	50	30	500	100	N	150	N	30	1	2
21	.5	.5	700	L	700	3	20	70	50	30	30	500	100	N	150	N	50	4	2
22	.7	1	1,500	10	700	3	30	150	70	50	50	500	200	N	500	N	70	3	2
23	.5	.5	500	L	700	3	15	50	50	50	20	500	70	N	150	N	50	5	4
24	.5	.5	700	L	700	3	10	70	50	20	50	500	70	N	300	N	50	7	3
25	.7	.7	700	L	700	3	20	70	50	30	30	300	100	N	700	N	50	4	2
26	.7	.7	1,000	L	1,000	3	20	100	70	50	50	700	150	N	150	N	70	10	5
27	.5	.5	700	L	700	3	20	70	50	30	30	300	100	N	300	N	50	2	3
28	.5	.5	700	L	700	3	15	70	70	30	30	500	70	N	200	N	70	10	3
29	.7	.7	1,000	10	1,500	3	20	150	70	70	50	500	150	N	500	N	70	5	2
30	.7	.7	1,000	10	700	3	15	70	70	20	70	300	100	N	500	N	70	7	3
31	.5	.7	700	10	700	3	15	50	30	15	30	300	100	N	700	N	30	7	4
32	.5	.3	700	L	700	3	15	50	70	20	30	300	70	N	200	N	70	3	2
33	.3	.5	500	L	1,000	3	10	15	20	7	30	200	70	N	300	N	20	2	3
34	.3	.5	700	10	700	3	15	50	30	15	50	200	70	N	300	N	30	1	2
35	.3	.3	700	L	700	3	15	70	30	15	50	200	70	N	300	N	30	3	3
36	.2	.3	500	L	700	3	5	50	70	7	30	300	50	N	200	N	70	5	5
37	.5	.5	1,000	L	700	3	15	70	30	20	30	300	70	N	300	N	30	3	4
38	.5	.5	500	L	700	3	10	30	50	10	30	200	70	N	300	N	50	4	5
39	.3	.3	700	L	700	3	15	50	30	20	50	300	70	N	150	N	30	4	5
40	.3	.3	700	L	700	3	10	30	30	15	15	300	70	N	200	N	30	4	5
41	.7	.7	700	L	700	3	20	100	70	30	50	500	150	N	200	N	70	10	5
42	.7	.7	700	L	700	3	20	150	70	30	50	500	100	N	300	N	70	7	5
43	.3	.3	700	L	700	3	15	50	50	20	70	300	70	N	150	N	50	7	5
44	.3	.3	700	L	500	3	10	30	20	10	20	200	70	N	100	N	20	L(1)	5
45	.5	.5	1,000	10	700	5	15	30	70	20	50	300	70	N	150	N	70	10	7
46	.5	.5	700	L	700	3	20	70	70	30	50	500	150	N	200	N	70	10	4
47	.2	.3	700	L	700	5	10	100	50	15	70	300	70	N	200	N	50	3	4
48	.5	.5	1,000	10	700	5	15	100	30	30	50	300	70	N	300	N	30	L(1)	3
49	.3	.3	700	10	700	5	10	100	50	15	30	300	70	N	300	N	50	3	7
50	.3	.3	700	10	700	7	10	70	20	15	50	200	70	N	200	N	20	L(1)	2
51	.3	.3	700	10	500	3	10	70	15	15	30	200	70	N	200	N	15	3	5
52	.5	.5	1,000	L	700	3	20	70	50	20	30	200	100	N	500	N	50	4	3
53	.7	.7	1,500	L	700	5	20	100	70	30	70	300	150	N	300	N	70	15	4
54	.3	.3	700	10	700	3	20	50	30	20	20	200	70	N	300	N	30	5	5

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colorimetric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
RATTLESNAKE DRAINAGE AREA																			
Stream sediments																			
55	2	.3	700	L	700	3	10	30	30	15	30	200	50	N	300	N	30	2	2
56	.5	.3	700	L	700	3	20	70	30	30	30	150	70	N	300	N	30	10	3
57	5	.5	1,000	L	100	3	10	50	100	20	70	300	70	N	200	N	100	7	2
58	3	.3	700	L	700	5	10	50	70	20	50	300	70	N	200	N	70	7	5
59	5	.5	500	10	1,000	3	10	150	70	30	50	300	70	N	200	N	70	3	7
60	7	.7	1,000	10	700	3	30	150	70	70	50	500	150	N	300	N	70	3	3
61	7	.7	700	10	700	5	20	200	70	70	50	300	100	N	500	N	70	4	5
62	7	.7	700	10	1,000	3	10	150	50	30	50	300	100	N	300	N	50	4	7
63	5	.3	700	L	700	3	10	70	70	30	50	300	70	N	150	N	70	10	5
64	5	.5	700	L	700	5	10	70	70	30	50	200	70	N	300	N	70	10	3
65	3	.2	500	L	500	3	5	30	100	15	30	200	50	N	150	N	100	4	3
66	5	.3	700	L	1500	3	20	70	70	30	50	500	100	N	300	N	70	4	1
67	5	.5	700	L	1,000	3	15	50	50	20	30	500	70	N	300	N	50	10	3
68	3	.3	700	L	1,000	3	15	70	50	30	30	500	70	N	300	N	50	4	1
69	5	.3	700	L	700	3	15	50	50	20	30	500	70	N	300	N	50	7	2
70	5	.5	700	L	1,000	3	15	70	30	20	50	500	70	N	300	N	30	4	2
71	3	.5	1,000	10	500	5	5	30	30	15	50	300	70	N	500	N	30	7	5
72	3	.3	700	L	700	3	10	50	30	15	50	500	70	N	300	N	30	15	3
73	3	.3	700	L	700	3	10	30	70	30	20	300	70	N	150	N	70	15	7
74	3	.5	700	L	500	5	10	30	20	20	30	200	70	N	200	N	20	L(1)	4
75	7	.5	700	L	700	3	20	150	50	30	30	300	70	N	300	N	50	5	1
76	7	.7	700	L	700	3	30	100	50	50	30	300	100	N	200	N	50	4	4
77	2	.3	700	L	500	5	10	70	50	20	30	200	50	N	200	N	50	4	7
78	2	.3	500	L	700	5	5	70	30	20	30	300	70	N	200	N	30	3	7
79	7	.5	700	L	700	3	20	30	70	50	30	300	100	N	150	N	70	15	5
80	5	.5	1,000	L	500	3	5	30	30	20	50	200	70	N	300	N	30	4	4
81	3	.3	700	L	700	3	5	50	70	15	50	300	70	N	300	N	70	4	7
82	5	.5	700	L	1,000	3	15	100	50	30	50	300	70	N	300	N	50	4	4
83	1.5	.3	700	L	500	3	5	50	30	20	15	200	70	N	150	N	30	3	7
84	7	.7	700	L	700	3	20	30	70	50	30	300	150	N	200	N	70	10	2
85	1.5	.2	700	L	200	3	L	15	15	7	30	150	30	N	300	N	15	10	5
86	7	.7	1,000	L	300	3	15	30	70	30	20	150	150	N	300	N	70	7	9
87	7	1	1,000	L	700	3	15	30	70	30	50	300	150	N	300	N	70	25	9
88	7	.5	500	L	700	1.5	20	150	70	70	50	300	70	N	150	N	70	20	4
89	7	1	700	L	1,000	3	20	70	70	50	50	500	150	N	300	N	70	20	5
90	3	.3	700	L	300	5	5	20	30	10	30	100	50	N	500	N	30	5	4
91	7	.7	700	L	700	3	20	70	100	50	50	300	150	N	300	N	100	20	5
92	7	1	700	L	1,000	3	15	30	100	30	50	500	150	N	300	N	100	20	3
93	7	1	700	L	1,000	3	20	50	70	50	50	300	150	N	300	N	70	10	5

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colorimetric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
RATTLESNAKE DRAINAGE AREA																			
Stream sediments																			
94	3	.3	700	L	300	3	5	15	20	7	30	100	20	N	200	N	20	3	7
95	.3	.3	700	L	700	3	L	15	20	7	30	150	30	N	200	N	20	4	2
96	3	.3	700	L	300	3	5	15	20	7	30	100	20	N	200	N	20	2	7
97	1.5	.15	700	L	300	3	L	10	20	7	50	N	15	N	200	N	20	15	4
98	.3	.3	700	L	700	3	L	15	50	7	50	100	30	N	300	N	50	5	3
99	3	.3	1,000	L	700	3	L	20	50	7	30	150	30	N	200	N	50	7	5
100	3	5	1,500	L	700	3	5	10	10	7	30	100	30	N	150	N	10	2	3
101	5	.5	1,500	L	1,000	3	5	30	30	15	70	150	50	N	200	N	30	10	5
102	5	.7	1,000	L	700	3	5	20	70	10	50	150	70	N	300	N	70	15	5
103	5	.5	1,500	L	700	5	10	50	70	15	70	200	70	N	300	N	70	10	5
104	3	.3	700	L	700	3	5	15	150	15	50	100	50	N	150	N	150	20	5
105	3	.3	700	L	700	3	5	15	20	10	50	100	30	N	200	N	20	15	2
106	2	.3	500	L	300	3	N	L	10	5	30	L	20	N	200	N	10	3	3
107	1.5	.2	700	L	200	3	N	L	5	5	30	N	15	N	700	N	5	3	2
108	3	.3	700	L	500	3	N	15	10	10	50	100	30	N	150	N	10	2	5
109	1.5	.15	700	L	200	3	N	L	10	5	30	N	15	N	300	N	10	4	2
110	1.5	.15	300	L	200	3	L	L	5	7	30	N	15	N	200	N	5	15	2
111	3	.3	700	L	700	3	L	15	20	5	30	150	30	N	300	N	20	4	4
Altered rocks																			
A	0.5	0.05	100	L	N	3	5	N	5	L	30	N	10	N	200	N	L	------	5
B	1.5	.07	150	L	L	1.5	N	L	30	N	30	N	15	N	100	N	30	------	4
C[17]	3	.1	100	L	150	1.5	5	N	5	L	30	N	10	N	200	N	L	------	1
D	2	.1	70	L	1,000	1.5	N	N	5	L	30	N	10	N	200	N	L	------	2
E[18]	5	.02	150	50	150	2	N	N	5	L	10	N	10	N	200	L	15	------	2
F[19]	7	.05	70	L	700	2	N	N	5	L	50	100	20	N	200	N	L	------	L
REDFIELD DRAINAGE AREA																			
Stream sediments																			
1	5	0.3	700	10	500	3	10	30	30	15	30	200	70	N	150	------	------	2	5
2	5	.3	500	10	500	2	10	30	20	20	30	150	70	N	200	------	------	L	3
3	5	.3	1,000	L	700	3	10	15	20	15	30	200	50	N	200	------	------	1	2

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colori-metric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
REDFIELD DRAINAGE AREA																			
Stream sediments																			
4	.7	.7	700	10	1,000	2	15	100	70	50	30	300	150	N	200	------	------	2	3
5	.2	.2	500	15	500	3	5	10	30	10	30	150	30	N	200	------	------	10	5
6	.3	.3	700	10	700	3	10	30	30	10	30	100	30	N	300	------	------	L	7
7	.3	.3	700	10	700	3	5	10	30	10	30	100	30	N	200	------	------	4	4
8	.7	.7	700	L	1,000	3	15	20	50	20	30	500	150	N	300	------	------	7	4
9	.5	.3	1,000	10	700	3	5	10	70	15	20	150	70	N	300	------	------	3	7
10	.7	.5	700	L	1,500	3	10	20	50	20	20	500	100	N	300	------	------	2	4
11	.7	.5	700	L	700	2	15	20	50	20	20	500	100	N	200	------	------	5	2
12	.5	.5	700	L	700	2	10	20	30	15	20	300	100	N	150	------	------	3	3
13	.3	.3	500	L	700	3	5	15	50	15	30	300	70	N	200	------	------	1	3
14	.5	.5	700	L	700	2	10	30	50	20	15	500	100	N	150	------	------	5	2
15	.3	.3	700	L	700	1.5	5	15	30	15	15	300	70	N	100	------	------	5	2
16	.1	.1	500	L	50	3	5	N	50	L	15	N	L	N	70	------	------	N	1
17	.7	.3	700	L	700	2	10	20	50	30	15	500	100	N	150	------	------	4	2
18	.3	.2	700	L	300	3	5	7	50	7	15	200	30	N	200	------	------	5	2
19	.3	.3	500	L	700	3	5	15	30	15	15	500	70	N	150	------	------	10	2
20	.5	.3	500	L	700	2	10	15	50	20	50	700	70	N	100	------	------	7	2
21	.7	.7	700	L	1,500	2	15	20	30	30	20	700	100	N	150	------	------	4	2
22	.7	.7	1,000	L	700	2	15	50	70	30	30	500	100	N	300	------	------	7	5
23	.7	.7	1,000	L	1,000	2	15	70	70	50	30	500	150	N	300	------	------	5	5
24	.7	.5	700	L	700	2	15	10	70	20	30	700	100	N	200	------	------	5	4
25	.7	.5	500	L	1,000	2	15	15	70	20	30	700	100	N	150	------	------	5	7
26	.3	.3	700	L	700	2	10	10	30	15	20	500	70	N	150	------	------	7	5
27	.5	.5	500	L	1,000	1.5	20	15	50	15	30	500	70	N	150	------	------	4	9
28	.7	.5	700	L	1,000	2	15	15	30	20	20	700	100	N	150	------	------	5	2
29	.2	.2	700	L	700	3	5	N	20	5	15	300	50	N	150	------	------	4	2
31	.7	.5	700	L	1,000	2	10	20	50	20	20	700	100	N	150	------	------	7	4
32	.7	.5	700	L	1,000	1.5	20	15	50	30	30	700	150	N	150	------	------	5	3
33	.7	.7	1,000	L	1,000	1.5	30	300	70	150	30	300	150	N	150	------	------	5	11
34	.7	1	1,000	L	1,000	2	30	300	100	100	30	500	200	N	200	------	------	7	5
35	.7	.7	1,000	L	700	1	30	300	70	150	20	500	150	N	150	------	------	7	5
36	.7	.7	700	L	1,000	1.5	20	20	70	30	30	700	150	N	150	------	------	10	5
37	.7	1	1,000	L	1,000	2	30	150	100	150	20	700	200	N	150	------	------	10	2
38	.7	.7	1,000	L	700	1.5	20	150	70	100	20	700	100	N	150	------	------	5	3
39	.7	.7	700	L	700	1	20	300	100	100	30	500	150	N	150	------	------	5	9
40	.5	.3	700	L	700	2	5	10	20	15	15	300	70	N	100	------	------	4	2

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colori-metric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
REDFIELD DRAINAGE AREA																			
Stream sediments																			
41	2	.3	700	L	200	5	5	30	15	70	30	100	30	N	200	------	------	2	4
42	2	.3	700	L	300	3	5	30	20	7	20	150	30	N	200	------	------	2	4
43	2	.2	700	L	150	5	5	20	30	10	30	100	30	N	150			3	5
44	5	.3	500	N	700	2	10	15	30	15	15	500	70	N	150	------	------	4	2
45	1.5	.2	500	L	150	5	5	15	20	7	30	100	20	N	200	------	------	4	7
46	7	.7	700	L	700	3	15	100	70	70	30	500	150	N	200	------	------	10	4
47	7	.7	1,500	L	1,000	3	20	100	50	70	20	700	150	N	150	------	------	10	2
49	2	.3	1,000	L	200	5	5	15	70	10	30	L	30	N	300	------	------	4	7
50	1	.15	300	L	100	3	5	N	100	5	20	100	10	N	70	------	------	L	3
51	1	.1	500	L	100	3	L	N	20	5	15	100	10	N	70	------	------	1	3
52	.7	.07	300	L	100	2	L	L	20	5	15	100	L	N	50	------	------	1	3
53	5	.5	1,500	L	700	1.5	15	150	50	70	15	500	100	N	150	------	------	5	4
54	7	1	1,000	L	700	2	30	300	70	150	30	500	200	N	200	------	------	10	3
55	7	.7	1,000	L	700	2	20	150	70	150	20	500	100	N	200	------	------	7	2
56	7	.7	1,000	L	700	2	20	300	70	150	15	500	150	N	200	------	------	3	4
57	5	.5	700	L	500	2	10	100	50	70	20	200	70	N	150	------	------	4	2
58	5	.7	700	L	1,000	3	15	300	30	70	30	500	70	N	150	------	------	4	3
59	5	.5	700	L	700	3	15	150	50	100	30	300	70	N	200	------	------	3	1
60	7	1	1,000	L	700	1.5	30	200	50	150	30	500	150	N	150	------	------	15	2
61	10	1	1,500	L	700	1.5	50	300	70	150	20	300	200	N	150	------	------	5	4
62	5	.5	1,000	L	700	3	20	150	50	70	20	300	100	N	150	------	------	7	3
63	2	.2	700	L	300	3	5	30	30	10	30	100	30	N	200	------	------	3	9
64	5	.3	700	L	700	2	10	100	20	70	20	300	70	N	100	------	------	5	2
65	5	.5	1,000	10	300	5	5	20	100	10	50	100	70	N	500	------	------	10	N
66	3	.3	t00	15	300	5	5	30	50	10	50	100	70	N	500	------	------	10	7
67	7	.5	700	L	700	2	15	150	50	70	15	500	100	N	100	------	------	7	3
68	7	.7	1,000	L	700	2	30	300	70	100	20	500	150	N	150	------	------	7	4
69	1.5	.15	500	L	150	3	L	10	70	5	30	100	15	N	70	------	------	1	3
70	1.5	.15	500	L	100	5	L	L	5	5	20	100	10	N	70	------	------	1	3
71	7	.7	1,000	L	700	2	20	300	70	70	20	500	150	N	200	------	------	5	3
72	7	.7	700	L	500	1.5	20	300	70	100	30	300	150	N	150	------	------	7	4
73	7	.7	700	L	700	2	30	300	70	100	15	300	100	N	100	------	------	10	7
74	2	.2	500	L	300	3	10	100	70	30	50	150	70	N	100	------	------	5	11
75	7	.7	1,500	10	700	2	20	200	70	70	30	300	150	N	150	------	------	7	7
76	7	.5	700	L	700	1.5	20	300	70	100	20	200	150	N	150	------	------	10	5
77	7	.7	1,000	L	700	2	20	300	50	70	20	300	100	N	150	------	------	7	7

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colorimetric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
REDFIELD DRAINAGE AREA																			
Stream sediments																			
78	1.5	.15	500	L	100	3	L	L	70	5	20	100	10	N	150	------	------	L	2
79	7	.7	700	L	700	2	15	100	30	70	20	500	150	N	200	------	------	5	2
80	1	.15	300	L	100	3	L	L	20	5	15	300	15	N	70	------	------	L	3
81	7	.7	700	L	500	1.5	20	200	30	70	20	100	100	N	100	------	------	5	1
82	5	.3	700	L	500	3	15	100	30	70	15	300	100	N	70	------	------	10	2
83	7	.7	700	10	700	2	20	200	30	70	20	200	150	N	300	------	------	7	7
84	7	.7	700	L	700	2	20	200	70	100	15	300	100	N	100	------	------	15	7
85	7	.7	700	L	700	2	20	300	100	100	20	500	150	N	200	------	------	20	7
86	7	.7	1,000	L	700	2	50	300	100	150	20	700	150	N	300	------	------	10	5
87	7	.7	1,000	L	700	1.5	30	300	70	200	15	500	150	N	200	------	------	15	4
88	3	.5	500	L	500	3	15	150	70	70	20	300	70	N	150	------	------	10	7
89	7	1	1,000	L	1,000	1.5	50	300	70	150	30	700	150	N	200	------	------	7	3
90	7	1	1,000	L	1,000	1.5	30	200	70	100	15	500	150	N	150	------	------	15	5
91	7	.7	700	L	700	1.5	20	200	50	100	15	500	150	N	150	------	------	4	3
92	7	.5	700	L	1,000	1.5	20	15	30	30	30	700	100	N	100	------	------	10	2
93	7	.5	1,000	L	1,000	2	15	50	70	30	20	700	150	N	150	------	------	10	2
Altered Rocks																			
A	2	0.2	70	L	150	2	5	N	7	L	30	N	10	N	200	N	L	------	1
B	2	.1	70	L	150	1.5	5	N	7	L	15	N	10	N	200	N	L	------	2
C	2	.2	1,000	L	200	1.5	N	N	5	L	150	N	10	N	200	N	L	------	4
D[20]	2	.1	500	L	150	1.5	N	N	5	L	100	N	10	N	150	N	L	------	4
E	1	.1	200	N	70	2	5	N	15	5	10	N	L	N	150	L	5	------	2
F[21]	2	.3	300	L	300	70	7	30	50	30	30	100	70	N	70	0.02	20	------	3
G[22]	1.5	.15	300	L	200	150	7	20	150	30	150	100	70	500	50	0.20	120	------	11
H[23]	0.3	.02	100	L	70	7	5	10	500	7	1,000	N	300	3,000	N	0.75	1,500	------	30
J[24]	0.5	.1	150	10	150	10	5	15	70	10	700	N	30	500	50	L	100	------	7
K	2	.2	500	L	200	3	7	15	20	20	10	N	30	N	150	N	20	------	3
L[25]	3	.3	2,000	L	1,000	1	7	20	70	30	200	100	100	300	150	N	25	------	30
M[26]	1	.2	2,000	L	500	5	5	15	50	15	20	100	50	N	70	L	40	------	17

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colorimetric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
EASTSIDE DRAINAGE AREA — Stream sediments																			
1	7	.5	1,000	10	1,000	3	20	300	70	50	70	300	100	N	1,000	N	70	5	4
2	7	.7	1,000	L	1,000	3	15	200	70	30	50	300	100	N	700	N	70	10	4
3	3	.3	700	L	1,000	5	10	70	70	30	70	300	70	N	500	70	N	10	5
4	7	.7	1,000	L	1,00	5	20	100	70	50	70	300	100	N	500	N	70	15	4
5	7	.5	1,000	L	700	3	15	100	100	50	70	300	100	N	300	N	100	10	7
6	5	.7	1,000	10	1,500	3	15	70	30	20	70	300	100	N	700	30	4	4	
7	7	.7	1,000	L	1,500	5	15	100	50	30	50	300	100	N	1,000	N	50	5	4
8[27]	3	.3	700	10	700	3	10	70	50	20	70	300	70	N	500	N	50	3	9
9	5	.5	700	10	1,500	3	10	70	50	20	50	300	70	N	300	N	50	7	4
10	3	.3	700	L	1,000	5	10	30	50	20	50	300	50	N	500	N	50	4	7
11	7	7	1,000	L	700	3	15	100	70	50	70	300	100	N	500	N	70	4	3
12	5	.7	700	L	1,000	3	20	100	50	50	70	500	100	N	200	N	50	10	4
13	7	.7	700	L	700	3	15	100	70	50	70	300	70	N	300	N	70	10	3
14	7	.7	700	L	1,000	3	20	150	70	50	70	300	70	N	500	N	70	15	3
15	5	.7	700	L	1,000	2	20	150	70	50	50	500	100	N	200	N	70	10	4
16	5	.7	1,000	10	1,500	3	20	200	50	30	70	300	70	N	500	N	50	5	7
17[28]	5	.5	1,000	L	300	5	10	100	50	20	70	150	70	N	200	N	50	3	2
18	3	.5	1,000	L	300	3	10	50	30	15	50	150	70	N	300	N	30	4	2
19[29]	5	.5	1,000	L	500	3	15	150	70	30	70	150	70	N	300	N	70	3	2
20	3	.5	500	L	700	3	15	70	70	50	70	500	100	N	150	N	70	4	5
21	3	.3	700	L	700	3	10	30	50	30	70	200	70	N	150	N	50	15	5
22	7	.5	700	L	1,000	3	20	150	70	70	70	700	100	N	300	N	70	10	9
23	5	.5	700	L	1,000	2	20	150	50	70	50	700	100	N	200	N	50	15	4
24	3	.3	700	L	500	3	10	50	70	50	50	300	70	N	200	N	70	3	5
25	5	.5	700	L	1,000	3	20	150	50	70	50	700	100	N	200	N	50	10	4
26	3	.3	700	L	700	3	10	70	20	30	50	300	70	N	200	N	20	3	2
27	3	.3	1,000	L	500	3	10	70	20	30	50	200	50	N	200	N	20	2	11
28	3	.3	700	L	700	3	10	70	20	30	30	500	70	N	300	N	20	4	2
29	2	.2	700	L	300	3	5	30	20	15	50	150	30	N	150	N	20	4	3
30	1.5	.15	700	L	300	3	5	50	30	10	70	150	20	N	100	N	30	4	3
31	3	.5	1,000	L	700	3	10	70	30	30	50	300	70	N	200	N	30	4	3
32	3	.5	1,000	L	700	3	10	70	30	30	70	300	70	N	200	N	30	2	3
33	1.5	.2	700	L	500	5	L	10	30	20	50	200	50	N	300	N	30	10	5
34	5	.5	700	L	700	3	15	70	30	30	50	300	70	N	500	N	30	2	4
35	5	.5	700	L	700	3	15	150	50	70	50	300	70	N	200	N	50	1	4
36	5	.5	700	L	700	3	15	100	30	30	70	300	70	N	300	N	30	L(1)	4
37	5	.7	1,000	L	500	5	10	70	30	15	70	300	70	N	500	N	30	L(1)	2

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colori-metric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
EASTSIDE DRAINAGE AREA **Stream sediments**																			
38	2	.3	1,000	L	500	5	N	10	20	7	50	150	50	N	300	N	20	5	5
39	2	.3	700	L	500	1.5	7	10	5	5	30	100	30	N	200	N	5	2	3
40	1	.3	700	L	500	1.5	5	20	5	5	20	100	30	N	200	N	5	2	4
41	2	.5	1,000	L	500	1.5	7	15	20	5	30	200	70	N	300	N	20	2	9
42	2	.5	1,000	L	700	2	10	10	30	5	50	200	70	N	300	N	30	5	6
43	3	.5	1,500	L	700	1	5	20	20	5	50	200	50	N	300	N	20	3	7
44	3	.5	1,000	L	700	1	10	30	30	10	50	200	70	N	300	N	30	5	6
45	2	.5	1,000	L	500	2	10	15	30	7	30	200	70	N	300	N	30	7	6
46	2	.5	1,000	L	500	1.5	7	70	50	15	20	200	100	N	300	N	50	7	9
47	5	.5	1,000	L	700	1.5	10	100	50	30	30	200	70	N	300	N	50	5	7
48	3	.5	1,000	L	700	2	20	100	50	50	20	300	70	N	200	N	50	5	6
49	1.5	.2	500	L	500	1	5	15	10	10	10	200	30	N	100	N	10	7	6
50	3	.5	700	L	700	2	20	100	50	50	20	300	70	N	300	N	50	7	5
51	2	.5	300	L	500	1	10	70	20	70	15	200	70	N	150	N	20	7	6
52	2	.3	1,000	L	500	1.5	N	10	15	5	30	N	20	N	300	N	15	5	6
53	2	.3	1,000	L	500	1.5	N	10	10	7	30	N	20	N	300	N	10	4	6
54	2	.2	1,000	10	200	1.5	N	10	15	5	30	N	20	N	300	N	15	3	7
55	3	.5	1,000	L	700	1.5	30	100	50	70	50	300	100	N	200	N	50	7	7
56	3	.5	1,000	L	500	1.5	10	50	50	50	30	200	70	N	300	N	50	7	7
57	5	.5	1,000	L	700	1.5	30	100	50	70	30	300	150	N	300	N	50	5	5
58	3	.5	1,000	L	1,000	1.5	20	100	50	50	30	300	70	N	300	N	50	7	7
59	5	.5	1,000	L	700	1.5	30	150	50	70	30	300	100	N	300	N	50	7	5
60	2	.3	1,000	L	500	1	5	10	15	5	30	100	20	N	300	N	15	5	7
61	2	.5	1,000	L	500	1.5	7	20	50	10	30	100	50	N	300	N	50	4	5
62	2	.5	1,000	10	500	2	7	20	20	10	30	100	50	N	300	N	20	5	6
63	2	.3	1,000	L	300	2	7	15	15	5	30	100	30	N	300	N	15	5	6
64	2	.5	1,500	L	700	2	5	10	20	5	50	100	20	N	500	N	20	3	5
65	1	.3	1,000	L	700	2	5	15	20	5	30	100	20	N	300	N	20	5	5
66	2	.3	1,500	L	700	2	5	10	10	5	30	100	30	N	300	N	10	2	6
67	3	.5	1,500	L	1,000	1.5	5	10	5	5	50	100	30	N	300	N	5	2	5
68	2	.3	1,000	L	200	2	5	10	20	5	50	N	30	N	300	N	20	2	5
69	2	.3	500	L	500	1.5	7	100	20	20	30	200	50	N	200	N	20	4	9
70	1	.2	1,000	L	500	2	N	10	15	5	30	100	30	N	300	N	15	2	9
71	3	.3	1,000	L	500	3	10	100	50	50	30	300	70	N	300	N	50	10	7
72	2	.3	700	L	500	2	7	50	50	30	30	200	30	N	200	N	50	5	7
73	1	.3	1,000	L	500	3	5	10	10	5	30	100	30	N	200	N	10	4	7

TABLE 5—*Analyses of samples from the Galiuro Wilderness*—Continued

Sample	Semiquantative spectrographic analyses															Chemical analyses			
	Percent		Parts per million													Atomic absorption (ppm)		Colorimetric (ppm)	
	Fe (0.05)	Ti (0.002)	Mn (10)	B (10)	Ba (20)	Be (1)	Co (5)	Cr (10)	Cu (5)	Ni (5)	Pb (10)	Sr (100)	V (10)	Zn (200)	Zr (10)	Au (0.02)	Cu (10)	CxCu (1)	CxHm (0.5)
EASTSIDE DRAINAGE AREA — Stream sediments																			
74	2	.2	500	L	500	2	5	50	10	10	30	150	30	N	200	N	10	2	5
75	2	.3	1,000	L	500	2	5	15	10	7	30	100	30	N	200	N	10	2	5
76	3	.5	1,500	L	500	1.5	7	70	20	20	50	150	50	N	500	N	20	4	5
77	1	.2	700	L	300	2	5	10	15	5	30	100	20	N	200	N	15	5	7
78	2	.3	1,500	L	500	3	10	20	15	10	50	200	50	N	200	N	15	3	7
79	1	.2	700	L	300	2	5	10	10	5	30	100	20	N	100	N	10	4	7
80	3	.5	1,000	L	500	2	10	30	15	10	30	200	50	N	500	N	15	4	7
81	2	.3	500	L	300	2	5	20	30	5	30	100	30	N	200	N	30	5	7
82	1.5	.15	500	10	150	1.5	L	15	7	7	30	150	30	N	150	N	7	7	2
83	2	.2	700	20	150	1.5	L	20	7	7	30	150	30	N	150	N	7	7	4
84	1.5	.15	700	15	150	1.5	L	20	7	7	30	150	30	N	150	N	7	7	1
85	3	.3	700	20	150	1.5	L	30	10	10	30	150	50	N	200	N	10	5	2
86	2	.3	700	L	500	2	10	30	70	15	30	200	50	N	300	N	70	30	25
87	2	.3	700	L	300	2	5	20	70	7	50	100	30	N	300	N	70	20	25
88[30]	2	.3	500	L	500	1	10	70	70	10	20	200	30	N	200	N	70	20	25
89	2	.3	1,000	L	200	2	5	15	70	5	30	100	30	N	500	N	70	15	20
90	2	.5	700	L	700	1.5	10	70	100	10	30	300	50	N	200	N	100	30	30
91	2	.15	700	20	150	1.5	L	15	10	10	30	150	30	N	150	N	10	9	L(1)
92	2	.15	700	20	150	1.5	L	10	15	7	30	150	30	N	150	N	15	9	2
93	2	.2	700	15	150	2	N	10	15	7	30	150	30	N	150	N	15	11	2
94	3	.2	700	15	200	1.5	L	30	15	7	30	150	30	N	100	N	15	11	1

1. 150 ppm La
2. 15 ppm Sn
3. 15 ppm Sn
4. 0.5 ppm Ag
5. 30 ppm Sn
6. 30 ppm Sn
7. 1 ppm Ag
8. 1,500 ppm Cr
9. 3 ppm Ag
10. 300 ppm W
11. 70 ppm Ag
12. 1,500 ppm Ag; 150 ppm Sb
13. 10 ppm Sn
14. 10 ppm Sn
15. 1 ppm Ag
16. 7 ppm Mo
17. 5 ppm Mo
18. 7 ppm Mo
19. 10 ppm Mo
20. 5 ppm Mo
21. 5 ppm Ag; 500 ppm As; 100 ppm Sb
22. 15 ppm Ag; 1,500 ppm As; 7 ppm Mo; 150 ppm Sb
23. 150 ppm Ag; 200 ppm As
24. 5 ppm Ag; 100 ppm Sb
25. 20 ppm Ag
26. 1 ppm Ag
27. 1 ppm Ag
28. 1,000 ppm Sn
29. 1,000 ppm Sn
30. 1.5 ppm Ag

by Ward and others (1969). All analyses in table 5 were made by U.S. Geological Survey personnel. Analytical results in parts per million (ppm) are recorded by drainage areas in table 5, and the sample locations and drainage basins are on figure 8. Table 6 is included to show the conversion of parts per million to percent and to ounces per ton and vice versa.

The U.S. Bureau of Mines examined records of the U.S. Bureau of Land Management, Phoenix, Ariz., and of the U.S. Forest Service, Albuquerque, N. Mex., for patented claims and leased ground, and the Graham County Courthouse records for location notices of unpatented claims. In the field, all claims and prospect workings that could be found were examined, and in areas that had no history of mining, reconnaissance examinations were made. Field examinations comprised Brunton and tape surveys of underground workings and sampling exposed veins and alteration zones. Whenever possible, rock-chip samples were collected across entire veins or altered zones, and dumps were sampled either by collection of grab sampls on a preselected grid pattern based on the size of the dump or by selection of highly mineralized specimens. From these activities, samples were collected. All were assayed for gold and silver at the U.S. Bureau of Mines metallurgical facilities in Reno, Nev., and were analyzed

TABLE 6.—*Conversion of parts per million to percent and to ounces per ton and vice versa*

[Conversion factors: 1 lb. avoirdupois=14.583 ounces troy: 1 ppm=0.0001 percent=0.0291667 ounce troy per short ton=1 gram per metric ton; 1 ounce per ton (Au or Ag)=34.286 ppm=0.0034286 percent]

Parts per million to percent to ounces per ton			Ounces per ton to percent to parts per million		
Parts per million	Percent	Ounces per ton	Ounces per ton	Percent	Parts per million
0.01	0.000001	0.0003	0.01	0.00003	0.3
.02	.000002	.0006	.02	.00007	.7
.05	.000005	.0015	.05	.00017	1.7
.10	.00001	.003	.10	.00034	3.4
.20	.00002	.006	.20	.00069	6.9
.30	.00003	.009	.30	.00103	10.3
.40	.00004	.012	.40	.00137	13.7
.50	.00005	.015	.50	.00171	17.1
.60	.00006	.017	.70	.00206	20.6
.70	.00007	.020	.70	.00240	24.0
.80	.00008	.023	.80	.00274	27.4
.90	.00009	.026	.90	.00309	30.9
1.0	.0001	.029	1.0	.00343	34.3
10.0	.001	.292	10.0	.03429	342.9
20.0	.002	.583	20.0	.06857	685.7
50.0	.005	1.458	50.0	.17143	1,714.0
100.0	.01	2.917	100.0	.34286	3,429.0
500.0	.05	14.583	500.0	1.71	17,143.0
1,000.0	.10	29.167	1,000.0	3.43	34,286.0
10,000.0	1.00	291.667	10,000.0	34.29	342,857.0

spectrographically to determine other possible minerals of economic significance (table 9). The spectrographic analyses showed anomalous amounts of copper in ten samples; these samples were subsequently assayed for copper by atomic absorption methods.

LIMITATIONS OF THE GEOCHEMICAL DATA

Geochemical prospecting is only one of many exploration tools and used alone, not an infallible guide to areas of metallization. In the Galiuro Wilderness-Further Planning Areas the methods of geochemical sampling and the sample spacing were reconnaissance, which further limited the reliability of geochemical samples to detect small areas anomalously rich in metals. Altered bedrock areas were sampled by randomly selected grab samples of what appeared to be the most intensely mineralized part of the outcrop. Stream sediments were sampled at only half-mile intervals; sampling at this wide interval did not detect some known copper-bearing outcrops along Copper Creek.

In the desert environment, the outcrops of some types of ore deposits are almost completely leached of their economic metals. Such deposits would not be detected by either bedrock or stream-sediment geochemical sampling. And some concealed ore bodies lie beneath impermeable postore cover rocks that cannot be detected by geochemical samples.

All of the geochemical samples were analyzed by semiquantitative spectrographic methods, and selected metals were analyzed by chemical methods, either atomic absorption or colorimetric. The individual values derived from the chemical analyses are reliable, but the reliability of values from the semiquantitative spectrographic analyses have the limitations summarized below:

Reported value (ppm)	*Range of values at 30 percent confidence level (ppm)*	*Range of values at 90–95 percent confidence level*
1	0.82– 1.2	0.56– 1.8
1.5	1.2 – 1.8	.82– 2.6
2	1.8 – 2.6	1.2 – 3.8
3	2.6 – 3.8	1.8 – 5.6
5	3.8 – 5.6	2.6 – 8.2
7	5.6 – 8.2	3.8 –12.0
10	8.2 –12.0	5.6 –18.0

This summary shows that a reported spectrographic analysis of 100 ppm copper has only a 30-percent chance that the true value lies between 82 and 120 ppm copper, but has a 90–95 percent chance that the true value lies between 56 and 180 ppm copper. An individual anomalous value therefore may not be accurate and should not be assigned great validity until it is confirmed. In the present study, neither field time nor funds were available for check sampling.

RESULTS OF GEOLOGIC AND GEOCHEMICAL STUDIES

HYDROTHERMAL ALTERATION IN COPPER CREEK AND ADJACENT AREAS

The porphyry copper deposits in southern Arizona with the exception of those at Bisbee range in age from about 50 to 70 m.y. old. They are spatially and temporally associated with granitic stocks ranging in composition from that of a granodiorite to that of a quartz monzonite. Detailed investigations around porphyry deposits in other parts of southern Arizona have shown that the intrusive histories of the stocks related to porphyry coppers are complex and commonly involve several periods of stock emplacement, separate in space but closely related in time, the oldest stock being the most mafic. Some plutons are composite.

Copper and molybdenum of the porphyry ore deposits occur in the stocks and the contiguous wallrocks. Metallization is accompanied by widespread hydrothermal alteration of the host rocks, and this alteration is an exploration guide for the ore deposits. Areas of hydrothermal alteration in the study area are shown on the map (pl. 2). Igneous rocks, ranging in age from 50 to 70 m.y., are the most favorable for the occurrence of porphyry copper deposits. Older rocks, particularly contiguous to stocks, are potential host rocks for ore deposits, though not as favorable as the 50–70 m.y.-old igneous rocks, because their association with porphyry deposits is only spatial. Rocks younger than 50 m.y. either cover or displace the porphyry ore deposits. Exploration for disseminated porphyry copper deposits in these younger rocks consists of different techniques used to look through the younger rocks to determine the copper potential in the underlying older rocks. The study area is almost entirely underlain by rocks younger than any known porphyry deposit in the southwest. Immediately northwest of the study area, however, mineralized and altered rocks of the most propitious age crop out. These favorable rocks extend eastward beneath the study area and presumably beneath the Galiuro Wilderness-Further Planning Areas. A dotted line on plate 2 indicates the area beneath the Galiuro Volcanics most likely to contain porphyry deposits based on (1) the age, composition, and alteration of the nearest exposed older rocks; (2) the location of known drill sites used to test the older rocks beneath the younger volcanic rocks; and (3) the sporadic occurrence of copper minerals and pyritic alteration in the Galiuro Volcanics.

Four specific alteration assemblages are part of the hydrothermal alteration that is typically associated with porphyry copper deposits:

propylitic, sericitic (phyllic), argillic, and potassic. Perhaps the most common is sericitic, or phyllic, alteration, characterized by the assemblage of quartz-sericite-pyrite, although the quartz and pyrite are not necessarily present with the sericite in all outcrops. Locally, chalcopyrite, a copper sulfide mineral, is part of the assemblage, and if sufficiently abundant, an ore deposit occurs.

Sericitic alteration occurs in sporadic outcrops in the older rocks from north of Copper Creek southward to where the Galiuro Volcanics overlap the older rocks near Rhodes ranch, as shown on the map (pl. 2). Within this area of sporadic sericitic alteration are two subareas of more intense sericitic alteration characterized by prominent and common quartz-sericite-pyrite veins trending from northeast to east-northeast. These subareas (shown on pl. 2 by a crosshatch pattern) have been drilled by major exploration companies, but the results of their explorations have not been made public. The southern of the two subareas, under active exploration by Phelps Dodge Corp. in 1973, is overlain on the east by the Galiuro Volcanics; the extent beneath the volcanic cover is not known to us because the surface geology is not diagnostic and the drill logs from which the extent of the mineralization might be determined are not available. In several isolated outcrops within the southern subarea, hydrothermal biotite, a characteristic mineral of the potassic alteration, was recognized, strongly confirming the sericitic alteration as the type commonly found in the porphyry copper deposits. Both types of alterations strongly support the exploration.

The northern subarea of sericitic alteration is at least 3 miles (4.8 km) from the nearest boundary of the Galiuro Wilderness but it is in a Further Planning Area; it is highly unlikely that any extension of it underlies the wilderness. The data gathered along Copper Creek are included in the geochemical map so that the alteration to the south, which is much closer to the wilderness, can be judged in the context of the entire area of alteration and metallization, of the impressive past production in the Copper Creek district, and of the extensive exploration by major copper companies.

HYDROTHERMAL ALTERATION IN THE GALIURO VOLCANICS

The hydrothermal alteration in the Galiuro Volcanics, shown on the geochemical anomaly map (pl. 2), differs from that in the older rocks; in outcrop, the alteration is pyritic and argillic (clay minerals), but the origin of the clay minerals is ambiguous. The clay could have formed either by the reaction of acid produced by oxidation of the pyrite with Al-bearing minerals or by primary acidic hydrothermal solutions that also deposited the pyrite or by both. Samples from below the depth of oxidation would be necessary to unequivocally determine its origin.

Both faults and permeable zones in the tuffs have locally controlled the distribution of the alteration (fig. 6). It is reasonable to suggest that the altering solutions migrated upward along faults and spread laterally along the permeable zones.

The significance of the pyritic-argillic alteration is not in the small amounts of base and precious metals introduced in the Galiuro Volcanics. Past prospecting and exploration was sufficient to characterize the deposits as low in metal content and tonnage, and our present investigation confirms this evaluation. Rather its significance lies in what can be deduced from the alteration about metals in the older rocks underlying the volcanics. Conceivably sufides from an older copper deposit lying beneath the Galiuro Volcanics could have been remobilized during the volcanism and moved upward along faults to produce the pyritic-argillic alteration. The leakage theory has advocates among some economic geologists, and perhaps it was the basis for the deep drilling in secs. 1 and 12, T. 8 S., R. 19 E.

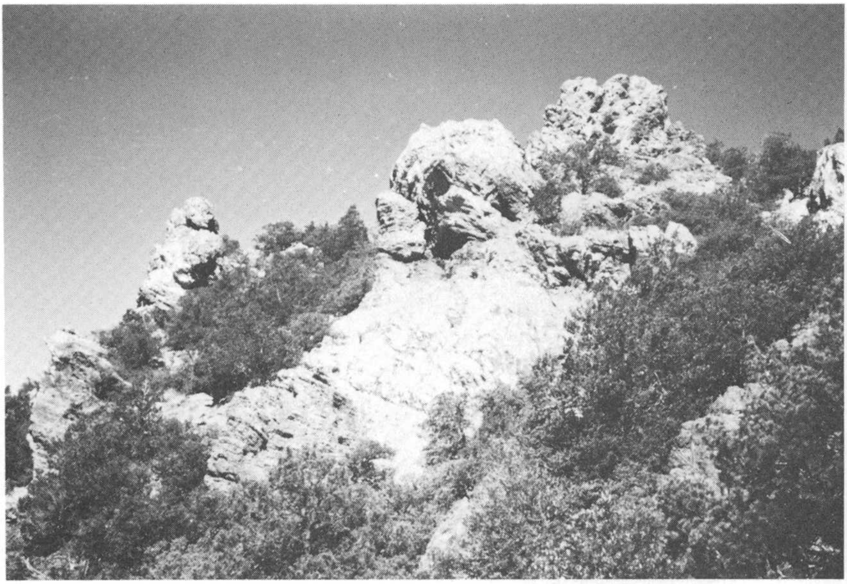


FIGURE 6.—Pyritized ash-flow tuff (light-colored mottled area in center of photograph) about 25 feet thick, parallels bedding. Mottling is bright red from iron stains; areas between are bleached white from acidic solutions derived from oxidation of pyrite. Photograph taken along the trail on the drainage divide between Rattlesnake and Redfield Canyons about one-eighth mile east of 6459 bench mark. Sample F (table 5), Rattlesnake drainage area came from this pyritized outcrop.

The surface outcrops of copper in the Galiuro Volcanics along both sides of Copper Creek are difficult to evaluate. The map (pl. 2) shows about 23 occurrences, and there must be others that were not observed. They are about equal in copper oxides and copper sulfide (chalcocite); some outcrops contain both. The copper occurs in narrow veins trending in general from west-northwest to east-northeast, which includes the trend of the sericite veins in the older rocks. These copper veins do not seem to be associated with either pyrite or widespread hydrothermal alteration. Their origin is enigmatic, and only physical exploration will show whether they are a reflection of copper in the underlying older rocks.

GEOCHEMICAL DATA AND EVALUATION OF ANOMALOUS GEOCHEMICAL SAMPLES

The geochemical data were evaluated by the simplified statistical method described by Lepeltier (1969), by which the frequency distribution of the data set is treated graphically. The method assumes that the chemical elements of interest in the samples are log-normally distributed, an assumption supported by most geochemical surveys (Ahrens, 1957). In normal distribution (Gauss' Law), a plot of frequency against the numbers in the data set produces a bell-shaped curve. In log-normal distribution, the symmetrical bell-shaped curve results only when the logarithms of the numbers in the data set are plotted against the frequency of the numbers. If the numbers themselves in a log-normally distributed set of data are plotted against frequency, the resulting curve is skewed or asymmetrical; hence, the numbers do not have normal distribution, but their logarithms do.

For copper, cumulative frequency curves were plotted by bedrock source of the sediment, by drainage area, and by analytical method; for lead, by rock type; and for equivalent zinc (CxHm), also by rock type. The significant data from the curves are summarized in table 7, and the locations of the individual anomalous samples are shown on the geochemical anomaly map (pl. 2). Anomalous values, indicated in table 7 where the higher number of the range exceeds that of the threshold, occur only for copper and equivalent zinc (CxHm) in ash-flow tuffs. The threshold numbers in table 7 are obtained from the cumulative frequency curves; as they include individual numbers not used in reporting analyses by spectrographic and colorimetric methods, there is not complete agreement in the numbers used to report the threshold and the range. The background, or mean, is the number determined by the intersection of the line representing 50 percent cumulative frequency and the curve.

Cumulative frequency curves for citrate-soluble copper (CxCu) from all stream-sediment samples derived from andesites and for

TABLE 7.—*Summary by drainage basins of semiquantitative spectrographic and citrate-soluble analyses of copper, lead, and zinc in stream sediments from the Galiuro Wilderness study area*

Population	Analyses	Number of samples	Background (ppm) (geometric mean)	Range	Threshold of anomalous values (ppm)	Geometric deviation for one standard deviation[1]	Geometric deviation for two standard deviations[1]
All andesites	CxCu	207	7.5	<1– 25	~30	2.00	3.87
Do.	Spec Cu	207	64	20–100	~125	1.39	1.05
Do.	CxHm	200	6	<1– 10	~10	1.58	2.45
All ash-flow tuff	CxCu	214	6	<1– 30	~22	2.09	3.67
	Spec Cu	214	40	5–150	~250	2.55	6.25
	CxHm	218	4.5	<1– 30	~10	1.57	2.27
Andesite, Redfield drainage	CxCu	53	7	<1–20	~20	1.79	3.10
	Spec Cu	53	60	20–100	~115	1.40	2.50
Andesite, Rattlesnake drainage	CxCu	41	9	5– 25	~30	1.88	3.61
	Spec Cu	41	70	30–100	~110	1.29	1.62
Ash-flow tuff, Rattlesnake drainage	CxCu	70	5.5	<1– 25	~20	1.98	4.06
	Spec Cu	70	46	5–150	~300	2.58	6.25
Andesite, Westside drainage	CxCu	44	9	2– 20	~22	1.54	2.44
	Spec Cu	44	65	30–100	~110	1.28	1.69
Ash-flow tuff, Eastside drainage	CxCu	65	5.5	2– 30	~28	2.23	5.00
	Spec Cu	65	35	5–100	~250	2.86	7.14
Andesite, Fourmile drainage	CxCu	56	6	1– 25	~25	2.03	4.03
	Spec Cu	56	68	30–100	~160	1.56	2.36
Pb from all Galiuro Volcanics	Spec Pb	458	36	10– 70	~70	1.42	1.94

[1] Both multiply and divide the background figure by the geometric deviation to obtain the upper and lower figures for standard deviations. About 68 percent of the population is included within the limits of one standard deviation, 95 percent within the limits of two standard deviations. Threshold figure for anomalous numbers in a normal, or lognormal distribution arbitrarily taken at two standard deviations.

citrate-soluble heavy metals reported as zinc equivalent (CxHm) from all stream sediments derived from ash-flow tuffs, figures 7 and 8, are included to show how the data in table 7 was obtained and how anomalous values skew the curve to higher metal values. The curve for andesites indicates no anomalous values, whereas the curve for the ash-flow tuffs indicates anomalous equivalent zinc above about 9.4 ppm. The threshold of anomalous values is taken at the knickpoint, if one exists, or at two standard deviations, if the curve is normal. On the map (pl. 2) the threshold is at 29+ ppm (the intersection of the 2½ cumulative percent line and the curve), but the highest CxCu analyses from samples other than those known to be contaminated was 25 ppm.[1]

Whether a metal can be treated statistically depends on the relations between the range in concentrations of interest and the lower limit of detection of the analytical method used. The average crustal abundance of eight metals for four different rock types and the lower limits of detection of the eight metals, shown in table 8, were determined by one or more of the three following analytical methods: semiquantitative spectrographic, colorimetric, and atomic absorption. Copper in granitic and basaltic rocks and in shales can be treated statistically by all three analytical methods because the lower limits of detection are well below the average abundances in the rocks. Similarly, lead can be studied statistically in granitic rocks and shales, and equivalent zinc (CxHm) in granitic and basaltic rocks, shales, and sandstones. For zinc, molybdenum, tungsten, tin, silver, and gold, semiquantitative spectrographic analyses are too insensitive to detect average abundances, and a statistical treatment involving average abundances is impossible. Gold is so sparse in average abundance that even atomic absorption methods, which are quite sensitive, are not sensitive enough for a statistical analysis. For semiquantitative spectrographic analyses on zinc, molybdenum, tungsten, tin, silver, and gold, the lower limit of detection is anomalous; the locations of samples from the study area that contained these or greater amounts are located on plate 2. For gold, any amounts detected by atomic absorption are also anomalous; the locations of samples containing detectible gold are shown on the anomaly map (pl. 2). Undoubtedly there are many unrecognized localities in the Galiuro Wilderness-Further Planning Areas that contain zinc, molybdenum, tungsten, tin, silver, and gold in anomalous amounts. It

[1]A normal (Gauss' Law) curve should have 2½ percent of the data set above two standard deviations. For fig. 7, the data set includes 207 samples, of which about 5 should contain 30 ppm, or more, CxCu (0.025 × 207 = 5.175). The reason that none were reported is uncertain but may result from conservative interpretation in the colorimetric method of analysis. By convention, all numbers above the threshold are reported as anomalous regardless of their abundance.

is not likely that any large near-surface ore deposits of base metals went unrecognized during this study because of these analytical limitations. Concentrations of base metals at anything near ore grade are so grossly anomalous that they would be detected by any or all of the analytical methods used. And the typical hydrothermal alteration

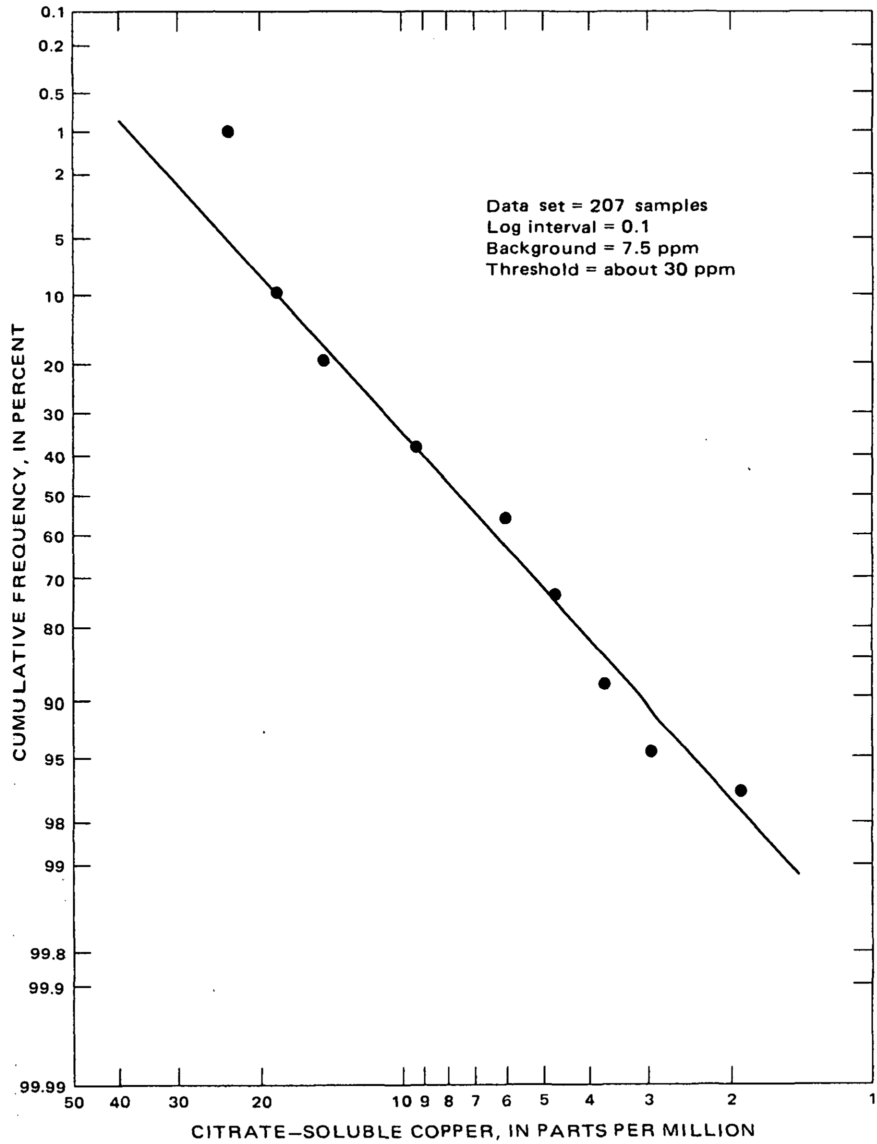


FIGURE 7.—Cumulative frequency distribution of citrate-soluble copper in the −80 mesh fraction of stream sediments derived from andesite.

that accompanies a large near-surface, or surface-exposed, base-metal deposit would have been observed and delineated during geologic mapping. The same assurance for precious-metal deposits, however, does not exist. They form ore deposits at low concentrations

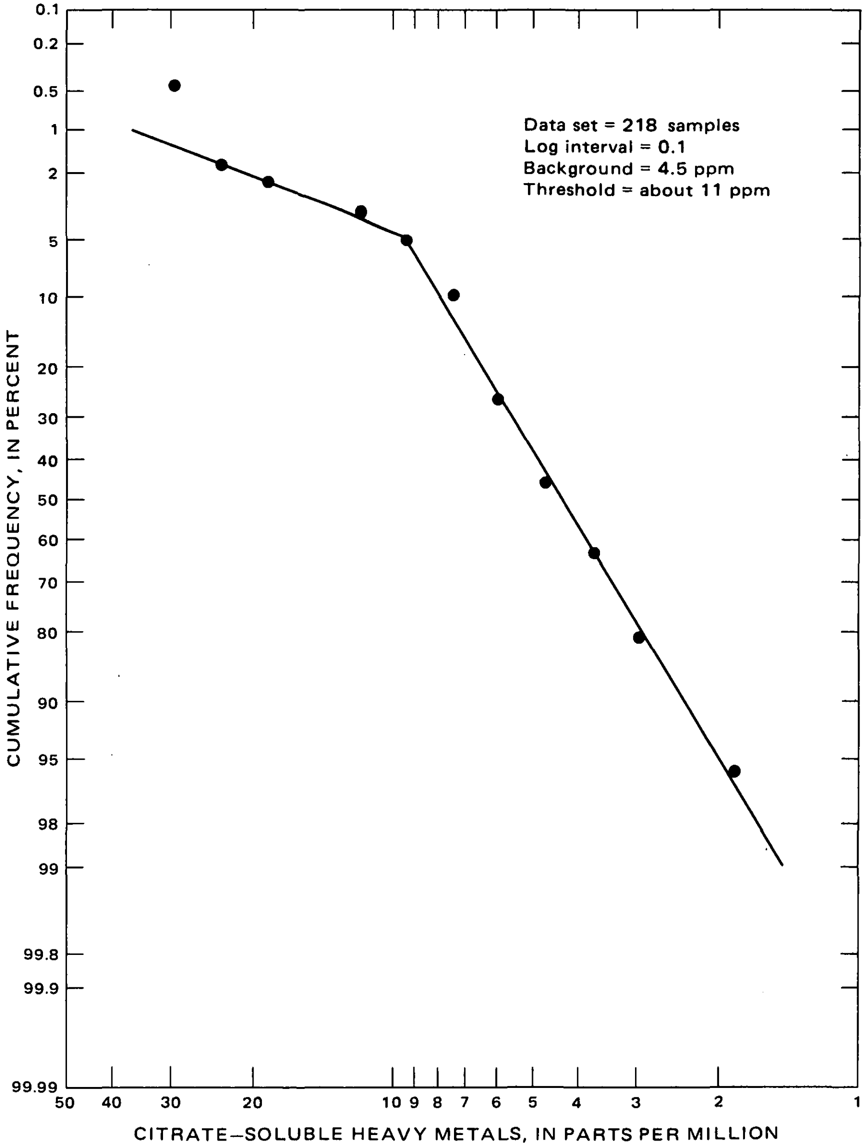


FIGURE 8.—Cumulative frequency distribution of citrate-soluble heavy metals reported as zinc equivalent in the −80 mesh fraction of stream sediments derived from ash-flow tuffs.

relative to base-metal deposits, and commonly the hydrothermal alteration associated with them is much more subtle and restricted. The best indication that precious metal ore deposits capable of development into profitable mines do not exist in the study area is that thorough prospecting based on careful panning and assays of altered rocks over the past century has not revealed such deposits.

Because the metals that may lie in the older rocks beneath the Galiuro Volcanics are of greater economic potential than the metals within the Galiuro, indicator elements, which are associates of the principal ore element, are of special concern. For valid chemical reasons, some indicator elements disperse farther than the ore elements, and on the fringes of geochemical halos, such indicator elements are important guides to the ore deposit. In the study area, indicator elements of interest include molybdenum as an indicator for copper, mercury and arsenic for sulfide deposits, and zinc for base-metal sulfide deposits. Copper also disperses widely, and even small quantities are an excellent guide to richer concealed deposits.

Most of the geochemical metal anomalies can be interpreted rationally from their relations to mines and prospects, to hydrothermally altered rocks, or to contamination by man. The citrate-soluble copper and heavy-metals stream-sediment anomalies (pl. 2) in the drainage north of Sombrero Butte are below the dumps of the Magma and Bunker Hill mines. The dumps have spilled debris into the washes, and copper-stained fragments are visible in the stream gravels at least as far west as the anomalous samples. The anomalous amounts in those samples are therefore attributed to contamination. Two sediment samples anomalously high in tin were collected west of the Deer Creek (Simms) ranch, along the commonly used pack trail leading to the Forest Service cabin at Powers Gardens (pl. 2). The high tin content may have been derived from tin cans. Other isolated tin-rich samples collected along the west side of the study area could

TABLE 8.—*Average crustal abundance of selected metals compared with lower detection limits of semiquantitative spectrographic, colorimetric, and atomic absorption analytical methods*

[×, estimated order of magnitude]

Metal	Average crustal abundance, ppm (Turekian and Wedepohl, 1961, table 2)				Lower limits of detection (ppm)		
	Granitic rocks	Basaltic rocks	Shale	Sandstone	Semiquantitative spectrographic analyses	Colorimetric (CxCu and CxHm)	Atomic absorption
Copper	30	87	45	×	5	1	5
Lead	15	6	20	7	10	------	------
Zinc	60	105	95	16	200	1	------
Molybdenum	1	1.5	2.6	.2	5	------	------
Tungsten	1.3	.7	1.8	1.6	50	------	------
Tin	1.5	1.5	6	.×	10	------	------
Silver	.11	.051	.07	.0×	.5	------	------
Gold	.004	.004	.00×	.00×	10	------	.02

have resulted from contamination, but they are not obviously associated with trails, cabins, or camps.

The three copper-rich sediment samples in Corral Canyon, Rattlesnake drainage, are immediately downstream from an altered area along the longitudinal fault. Areas of sporadic alteration occur along this fault, and the rocks exposed along the fault on the Jackson mine workings are anomalously high in metals. This fault locally has served as a conduit for metal-bearing solutions, and the stream sediments reflect a local anomaly along the fault.

The origin of the stream-sediment anomalies in the southeastern corner of the study area is conjectural. Neither surface outcrops of altered rocks nor prospects indicate metallization. The anomalous samples all are near the local access road and indications of human activities are here and there. Contamination is a possibility, but the existence of anomalies of at least three metals—copper, heavy metals, and silver—is not compatible with this explanation. Additional samples and a careful, detailed examination of the local area are the next step toward determination of the economic significance, if any, of the anomaly.

Many of the anomalous bedrock samples came from prospect pits, some near the mines. The altered rocks in sec. 36, T. 8 S., R. 18 E., anomalous in copper, gold, silver, and chrome, crop out in several prospect pits along the old fault that separates the Glory Hole Volcanics on the north from the Pinal Schist on the south. Some of the prospect pits along the fault contain visible copper. These anomalous concentrations of metals are within the area of alteration favorable for copper (pl. 2).

The metal anomalies in bedrock near the common corner of secs. 10, 11, 14, and 15, T. 10 S., R. 19 E., are part of the metallization in the Sixteen-to-One mine. The anomalous samples came from a prospect pit not part of the main mine workings. The U.S. Bureau of Mines found anomalous amounts of metals in the principal mine workings, described in the section on "Mines, Prospects, and Mineralized Areas." All the samples help support the presence of metals in the Sixteen-to-One mine area in anomalous amounts. Judged by the number of prospect pits, apparently all promising surface leads were investigated without discovery of a major ore body, and it is unlikely that an unrecognized ore body is exposed at the surface.

The altered rock at the collar of the Jackson mine shaft, which is inaccessible, and in the shallow prospect shafts and pits to the south contain anomalous amounts of copper, zinc, arsenic, antimony, silver, and gold. The metallization is along the longitudinal fault; from the surface exposures, it does not appear to extend more than a few feet into the wallrocks. The grade and extent of metallization at depth is conjectural, and physical exploration in conjunction with detailed surface mapping and sampling would be required to determine the ore potential at depth.

The four molybdenum anomalies in the pyritized rocks lying between the Rattlesnake and Redfield Canyons (pl. 2) occur in altered rocks that show no signs of metals other than the iron sulfide, pyrite. The presence of molybdenum in these rocks was unexpected but may be significant if additional samples confirm anomalously high molybdenum. In places, molybdenum is an indicator element, and a high molybdenum content of these altered rocks could be interpreted as an indicator of copper and molybdenum at depth in the older rocks.

In addition to the molybdenum within the pyritized rock, two samples were anomalously high in silver and one in tin. These samples did not come from prospect pits nor mines, and none of the samples contained either visible sulfides or oxides of the metals other than pyrite. They came from clean outcrops on ridge crests, where the possibility of contamination is negligible. Of the six bedrock samples collected from pyritized outcrops within the altered area, four were anomalously high in molybdenum, two in silver, and one in tin. The pyritized area merits two more sample sets: the first set to confirm the seven anomalous samples, and for those that are confirmed, a second set to accurately define the size and magnitude of the anomalous areas.

SUMMARY OF GEOLOGIC AND GEOCHEMICAL EVALUATIONS

For the Copper Creek area, which here includes the area as far south as Rhodes ranch, the past production, the current mining activity and exploration, and the considerable hydrothermal alteration and metallization all indicate an area of base-metal potential. The eastward extension of the area is beneath the Galiuro Volcanics perhaps as far as the boundary indicated on the geochemical anomaly map (pl. 2), well within the northwestern corner of the Galiuro Wilderness.

For the area around the headwaters of the Rattlesnake and Redfield drainages, the altered rocks may be anomalously high in molybdenum and silver. Although the sampling is too dispersed to be certain, the preliminary sampling is encouraging. Exploration geologists undoubtedly will inquire whether the older rocks are close enough to the surface to be explored at a reasonable cost. The geologic map (pl. 1) provides some information.

In Redfield Canyon about a quarter of a mile upstream from Negro Canyon, a small area of the Ruin Granite crops out in the bottom of the canyon at an elevation of about 4,500 feet (1,400 m). The outcrops clearly show older rocks overlain unconformably by the Galiuro Volcanics, which include a basal conglomerate containing rounded boulders of the Ruin Granite. The depositional contact between the two rocks is unequivocal. The elevation of the contact between the Galiuro Volcanics and older rocks near Rhodes ranch, the closest exposure of the contact north of the altered area, also is at an elevation of about 4,500 feet (1,400 m). A line connecting the contact in Redfield Canyon with the contact near Rhodes ranch passes a short distance west of the altered area. As an approximate estimate, then, the elevation of the older rocks beneath the altered area is somewhere around 4,500 feet (1,400 m). The elevations in the altered area range from about 5,300 (1,600 m) to about 6,900 feet (2,100 m). By these estimates, the depth from the surface to the older rocks under the altered area between Redfield and Rattlesnake Canyons would range from about 800 (250 m) to 2,400 feet (750m), well within the range of exploration from the surface.

The metal anomaly around the Jackson and Sixteen-to-One mines appears to be real, but indications of commercial ore in the rocks exposed at the surface are absent. The potential for ore at depth is conjectural.

The inferred anomaly in the southeastern corner of the study area needs to be confirmed.

EVALUATION OF OTHER COMMODITIES

The study area has no economic potential for limestone, quartz sand, or sand and gravel, and there are no known occurrences of uranium (Pierce and others, 1970). The Galiuro Volcanics have a low potential for construction stone and pumice. In addition, they contain vitrophyres and obsidians, some of which might be perlitic in the commercial sense of expanding on heating. The Galiuro Wilderness-Further Planning Areas is remote from market and without access roads; the economics of proximity to markets, transportation, and power supply are the critical factors for the exploitation of lightweight aggregate deposits. As there has been no attempt to explore the volcanic rocks for these materials, they are probably too remote for exploitation.

Despite the nearly complete coverage of the study area by volcanic rocks, indications of a potential for geothermal energy, such as hot springs or chemical deposits from hot springs, were not observed. The age of the Galiuro Volcanics is early Miocene (about 22–24 m.y.), and they are only about 2,100 feet (650 m) thick. We believe that they are too old and too thin to retain enough heat for economic geothermal energy.

About 7 miles (11 km) south of the study area, however, hot springs occur at the Muleshoe ranch (Hookers Hot Springs). The source of the geothermal energy for these hot springs was not investigated, but a possibility is the basalt (Qb), which is younger than the Galiuro Volcanics.

The study area has no potential for combustible fuels.

AEROMAGNETIC SURVEY AND INTERPRETATION

By W. E. Davis

In January 1972, the U.S. Geological Survey made an airborne magnetometer survey of the region between lat 32°26′ N. and 32°45′ N. and long 110°15′ W. and 110°27′ W., which includes the Galiuro Wilderness. Total intensity magnetic data were obtained along north-trending lines flown about 1 mile (1.6 km) apart at an average barometric elevation of 8,000 feet (2,450 m) above sea level. The data were compiled at a scale of 1:62,500 and contour intervals of 25 and 125 gammas relative to an arbitrary datum. No laboratory measurements of rock magnetic properties were made. Sources of the magnetic anomalies interpreted from results of geologic mapping are discussed briefly below.

The magnetic map (pl. 2) shows high magnetic intensity over the northwestern mountains, several discontinuous high-gradient anomalies over the eastern part of the range, and general low magnetic relief in the central and southwestern parts of the area. Most of the major anomalies are associated with parts of the volcanic sequence on the mountain crests and upper slopes. Local high magnetic gradients indicate that sources of the magnetic maximums lie near the ground surface. A topographic effect probably accounts for some of the variations in magnetic intensity across the mountain range.

The partly mapped high-intensity zone in the northwestern part of the area includes Biscuit Peak, Maverick Mountain, and much of the mountain front almost as far south as Kielberg Canyon. A magnetic maximum of about 375 gammas amplitude occurs over slopes west of Maverick Mountain in the northern part of the zone. This feature, the highest magnetic intensity observed in the area, seems to be associated with andesitic flows and welded tuff on the upper slopes. The high-intensity zone very likely extends northwestward to include quartz monzonite that hosts the copper deposits between Copper Creek and Rhodes ranch. Perhaps the higher intensity results from a magnetic effect of quartz monzonite underlying the volcanic rocks on Biscuit Peak and Maverick Mountain. To the south, another maximum of smaller amplitude is indicated by contours over the lower slopes west of Rhodes Peak. The maximum may represent a concealed body of monzonite or a thick accumulation of andesite flows lying near the ground surface. Magnetic gradients indicate that volcanic rocks exposed along slopes to the southeast probably underlie the bordering sedimentary deposits.

Small variations in magnetic relief occur along the east side of the high-intensity zone. East of Maverick Mountain, a contour reentrant indicates a minor magnetic low. The low is probably caused by a change in magnetic properties of the andesitic rocks on a spur of the mountain and by the low magnetic susceptibility of ash-flow tuff that covers a ridge to the east. A magnetic minimum of small amplitude over Rhodes Peak may be caused by low magnetic susceptibility or abnormally directed remanent magnetization in rocks near the peak. To the south, a bulge in the contours indicates a weak magnetic high over the mountain crest near the head of Field Canyon. Tuff and some rhyolite flows that have been displaced by faults could be the source of this anomaly. Low magnetic intensity that seems to be associated with the more siliceous parts of the volcanic sequence occurs near Grassy Peak on the southeast margin of the zone.

A prominent positive anomaly lies over China Peak in the northeast part of the area. The anomaly has an amplitude of about 200 gammas and includes the main part of the mountain and lower slopes east of Oak Creek. Magnetic maxima occur over ash-flow tuff and interbedded andesite flows on the crest and east spurs of the mountain, and over sedimentary deposits on the eastern slopes. The anomaly suggests that a thick accumulation of volcanic rocks lies on the mountain and the older andesite flows extend eastward beneath deposits beyond Oak Creek. Irregularities in contours on the south flank of the anomaly indicate a small magnetic low in line with a north-south trending fault in the tuffs east of China Peak. Perhaps the low represents alteration in rocks along the southward continuation of the fault zone.

North of the Rattlesnake Canyon, a negative anomaly occurs over the tuff and andesite. This feature, though probably caused partly by topography, is considered to be a counterpart of the positive anomaly over China Peak. Small magnetic gradients on the northeast flank of the negative anomaly reflect the nonmagnetic sedimentary deposits near Squaw Creek. Minor low intensity in the southern end of the anomaly is attributed to the weak magnetic response of rhyolitic rocks and younger basalt flows near Rattlesnake Creek.

South of China Peak, a magnetic low lies over volcanic rocks on Kennedy Peak. The low intensity seems to be associated mainly with interbedded andesites and tuffs near the peak and along the ridge north of Corral Canyon. Remanent magnetization and deformation in the andesitic rocks probably causes this low.

A high-gradient positive anomaly with three maxima lies between Kennedy Peak and Sunset Peak to the south. The anomaly has an amplitude of almost 200 gammas and is attributed mostly to welded tuff lying at high elevations. Tuff along the mountain crest seems to be the main source of the northern maxima, but interbedded tuffs and andesites appear to contribute greatly to the southern maximum near Sunset Peak. A small outcrop of rhyolite intrusive rocks near Holdout Spring is expressed weakly in the magnetic pattern. The occurrence of this outcrop and its association with the anomaly suggests that intrusive rocks underlie the mountain crest and could be part of the anomaly source. Contour irregularities indicate a small magnetic low on the southwest flank of the anomaly. The low appears to be related to alteration in rocks along a northeast-trending fault that cuts the mountain crest in the center of the anomaly. Low magnetic intensity also occurs over an extensive zone of argillic alteration along the southwest side of the anomaly. Development of a minimum to the southeast indicates that the alteration may extend into the tuffs along the mountain crest beyond Sunset Canyon. The minimum could be caused by abnormally directed remanent magnetization in rocks near the mountain crest.

Southwest of Sunset Peak, a small magnetic high trends northwestward across mountain spurs between Negro Canyon, Sunset Canyon, and upper Redfield Canyon. Magnetization intensities in tuff along the spurs and in andesitic rocks at lower elevations probably cause the anomaly. Intrusive rhyolite that may underlie part of the anomalous locality crops out in altered rocks near Redfield Canyon on the northeast side of the high. The outcrop was straddled by flight lines and apparently gave little or no magnetic response.

A magnetic high that was not completely mapped lies over mountains in the southeastern part of the area. Superimposed on the high are maxima near Bassett Peak and over the mountain crest to the south. The strongest magnetization intensity seems to be associated with northward-trending dike swarms near the crest where the anomaly reaches an amplitude of about 200 gammas. The maximum near Bassett Peak has an amplitude of approximately 150 gammas and is caused mostly by andesitic rocks. Flight lines straddled the peak, otherwise higher magnetic intensity probably would have been observed over the volcanic rocks there.

In the southwest part of the map area, a positive anomaly lies along the mountain front near Sheep Camp Wash. The anomaly has an amplitude of about 100 gammas and occurs over volcanic rocks and sedimentary deposits. From this anomaly, I infer that andesitic rocks exposed in the front extend southwestward and underlie the unconsolidated deposits along the wash. A weak magnetic low that may be related to the anomaly lies over Bear Canyon and Redfield Canyon to the east. The low occurs over volcanic rocks that have weak remanent magnetization, but the low intensity is probably caused mostly by topography.

Although volcanic rocks seem to be the main source of anomalies, the ore host rocks in mining localities probably are expressed in the magnetic pattern. The higher intensity in the northwest part of the area may represent an extension of the quartz monzonite mass that hosts copper deposits in the Copper Creek mining district. Within the anomalous zone, altered and mineralized parts of the monzonite body may occur beneath volcanic rocks along the flank of the main magnetic maximum. Low intensity indicated by magnetic gradients off the northeast flank of the zone may be related to a southward continuation of alteration in the andesitic rocks southeast of Mescal Peak. The low intensity associated with altered host rocks exposed in and near the mines west and northeast of Kielberg Peak seems to be expressed by low magnetic gradients in the center of the map. Minor magnetic lows that may represent zones of alteration containing metallic mineral deposits occur over faults near Rhodes Peak, China Peak, and in the area north of Sunset Peak.

None of the anomalies has sufficient amplitude to represent large deposits of magnetite or other magnetic ore minerals lying at shallow depths in the wilderness.

MINES, PROSPECTS, AND MINERALIZED AREAS

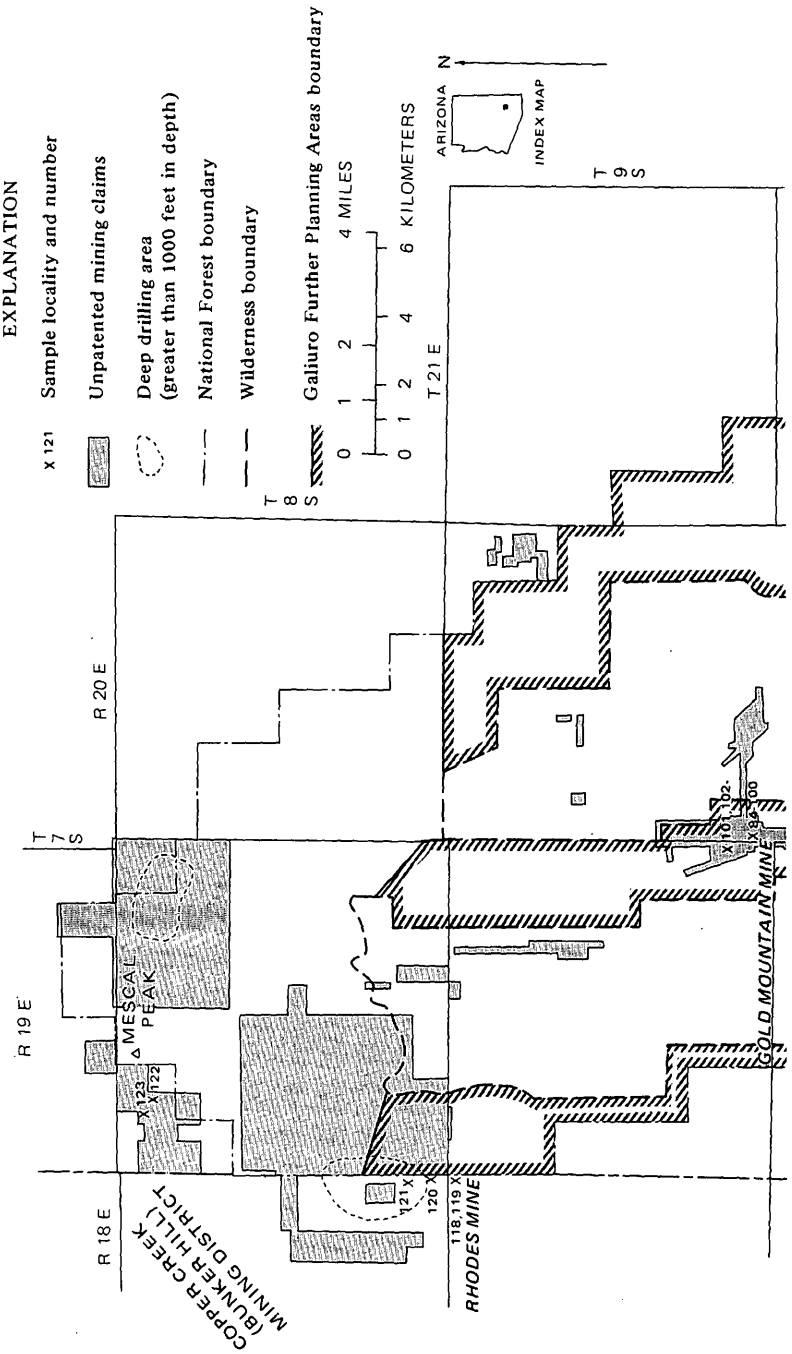
By J. E. JINKS, F. E. WILLIAMS, and H. C. MEEVES

Mine and prospect evaluation consisted of examination of all claims and sampling of all prospect workings that could be found in the field. A reconnaissance was made of several areas that had no history of mining activity. Underground mine workings were mapped by the Brunton-and-tape method, and exposed veins and alteration zones were sampled. Rock chips were taken across entire structures wherever possible. Additional sampling consisted of random selection of dump material on a measured grid pattern based on the size of the dumps.

Courthouse records in Safford, Ariz., were examined for information pertaining to unpatented mining claim locations in and near the wilderness. Figure 9 shows the locations of claims, workings, and samples.* Claims shown were staked at various times by sundry locators. The location figure does not reflect the pattern of claims being held at this time.

At least 300 claims are wholly or partly within the Galiuro Wilderness-Further Planning Areas. Sixty-nine claims are in the corridor of land along Rattlesnake Creek that extends into but is ex-

*In the U.S. Bureau of Mines part of the report, Further Planning Areas include only the Forest Service 03901 Galiuro Additions.



EXPLANATION
X 121 Sample locality and number
Unpatented mining claims
Deep drilling area (greater than 1000 feet in depth)
National Forest boundary
Wilderness boundary
Galiuro Further Planning Areas boundary
0 1 2 4 MILES
0 1 2 4 6 KILOMETERS
ARIZONA
INDEX MAP
N
R 18 E
R 19 E
R 20 E
T 21 E
T 7 S
T 8 S
T 9 S
MESCAL PEAK
X 123
X 122
121 X
120 X
118,119 X
RHODES MINE
COPPER CREEK (BUNKER HILL) MINING DISTRICT
GOLD MOUNTAIN MINE
X 101,102
X 84-100

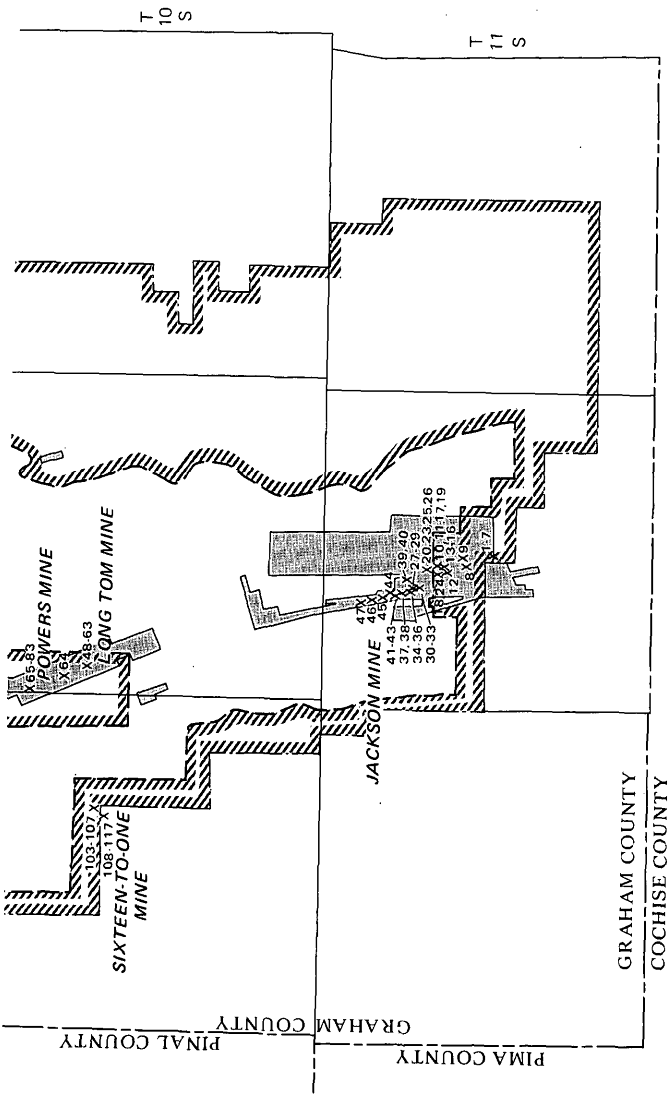


FIGURE 9.—Location of samples and claims in the Galiuro Wilderness Further Planning Areas and adjacent areas, Graham County.

cluded from the central part of the wilderness. These claims, though excluded, are directly associated with many in the wilderness. Of the known claims within the wilderness, 99 are near the northwest corner, 5 in the northeast, 50 in the central area, and 146 in the southern part along Redfield Creek and its tributaries. Approximately 45 claims are in the Further Planning Areas bordering the south end of the wilderness.

POWERS MINE

The Powers mine is in the west half of unsurveyed sec. 6, T. 10 S., R. 20 E., near the south end of a narrow corridor of excluded land that penetrates 10 miles (16 km) southward into the wilderness (fig. 9). The workings are near the head of Kielberg Creek and south of a saddle separating the Kielberg drainage from a short tributary of Rattlesnake Creek at an elevation of 5,470 feet (1,667 m).

The mine workings include a 289-foot (88 m) crosscut, a 101-foot (31 m) drift, a 57-foot (17 m) winze, and a 33-foot (10 m) raise (fig. 10). The entry crosscut bears due east into the hillside. At 166 feet (50 m) in from the portal, a main drift bears 83 feet (25 m) S. 29° E. and a drift bears 22 feet (6 m) in the opposite direction. The drifts were driven in rhyolite on a shear zone ranging from 3 to 6 feet (1 to 2 m) in thickness and dipping 58° SW. In the main drift at about 30 feet (9 m) from the crosscut, a winze was sunk on the structure to a depth of 57 feet (17 m), and a few feet beyond, a raise was driven 33 feet (11 m) up the dip. At a depth of 30 (9 m) in the winze, an irregular sublevel was driven 25 feet (8 m) northwest along the shear zone. At the bottom of the winze, drifting was done 35 feet (11 m) northwest and 15 feet (5 m) southeast along the shear zone.

Three samples (66–68, fig. 10) taken in the main drift assayed a trace of gold and 0.1 ounce (3 g) of silver per ton. Samples 66 and 68 were taken from a 2-inch (5 cm) limonite veinlet exposed in the southwest wall of the drift. The samples consisted of chocolate-brown fine-grained material showing slight kaolinization of orthoclase inclusions. Sample 67 was chipped across a 7-inch (18 cm) gouge zone adjacent to the limonite veinlet of sample 68. The limonite veinlet also was sampled (sample 65) at the face of the northwest drift. At this location, it assayed a trace of gold and 0.2 ounce (6 g) of silver per ton.

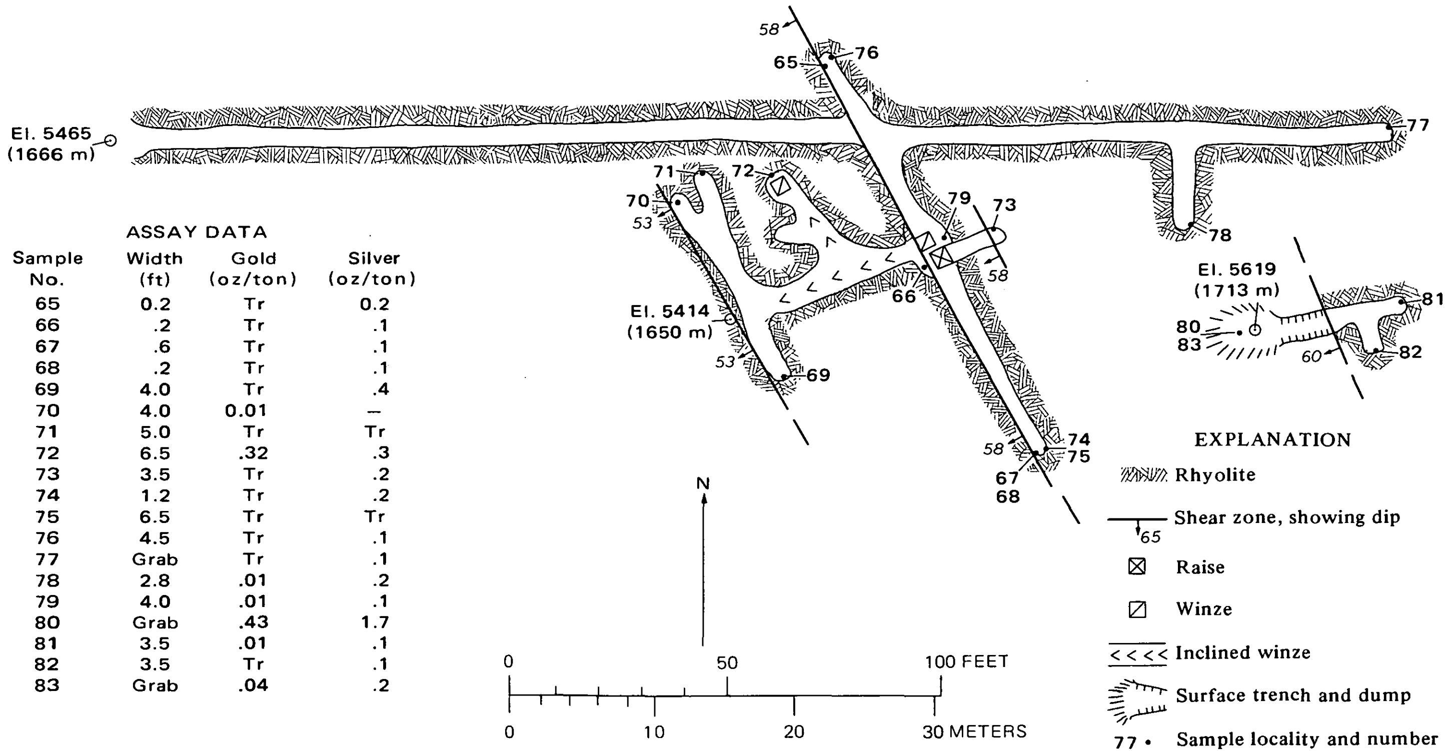
Four additional samples (74–76, 79) were cut from the wall rock adjacent to the samples described above. The gold-silver content of the gouge is nearly identical to that of the wall rock at these sample points. Samples 69–71 were cut at the headings of the short drift at the bottom of the winze. With the exception of sample 69, which contained 0.4 ounce (0.13 g) of silver per ton, the gold-silver content averaged a trace. Sample 72, cut from the heading of a short sublevel about halfway down the winze, contained 0.32 (10 g) ounce of gold and 0.3 ounce (9 g) of silver per ton. As indicated by the low sample values above and below this favorable sample, the mineralization does not extend to the main level or to the lower level. Sample 73, cut across the top of a raise driven updip from the main drift, contained a trace of gold and 0.2 ounce (6 g) of silver per ton. Sample 77, grabbed from a muck pile at the face of the main crosscut, contained a trace of gold and 0.1 ounce (3 g) of silver per ton. Sample 78, cut from the face of a short exploratory crosscut off the main crosscut, contained 0.01 ounce (0.3 g) of gold and 0.2 ounce (6 g) of silver per ton.

About 200 feet (60 m) (slope distance) S. 84° E. from the portal of the main adit and 125 feet (40 m) higher in elevation, a 20-foot (6 m) adit cuts the Powers shear zone, which at this location has pinched to a knife-edge slip. Samples 81 and 82 (fig. 10) were cut from the brecciated tuff in the footwall. The samples contained 0.01 ounce (0.3 g) and a trace of gold per ton respectively and 0.1 ounce (3 g) of silver per ton. Sample 80, grabbed on 5-foot (2 m) centers from a small 60-ton (54 t) waste dump immediately west of the short adit, assayed 0.43 ounce (13 g) of gold and 1.7 ounces (53 g) of silver per ton. Check sample 83, taken in the same pattern from the dump, assayed 0.04 ounce (1.3 g) of gold and 0.2 ounce (6 g) of silver per ton. The range of gold-silver assays indicates a spotty occurrence of these metals in the dump, which is composed of rhyolite-breccia, and in the footwall and the hanging wall of the shear zone. Dump sample 80 and underground sample 72 indicate the presence of small erratic pods that contain relatively high values of gold and silver near the shear zone.

LONG TOM (BOULDER PLUG) WORKINGS

The Long Tom workings, or Knothe workings, now covered by the two Boulder Plug claims, are in the unsurveyed SW¼ sec. 7, T. 10 S., R. 20 E., just north of the saddle between the upper Kielberg drainage and Gold Gulch, a tributary of Redfield Creek. The workings are in the narrow corridor of excluded land approximately 0.8 miles (1.3 km) north of the south end of the corridor (fig. 9).

The main workings (fig. 11) consist of an adit driven 213 feet (65 m) due east and then southerly 242 feet (74 m) in rhyolite. A fault zone striking N. 18° W. and dipping 72° E. is exposed at a point 150 feet (46 m) in from the portal. The same fault appears to have been cut and drifted along in the southern part of the adit. The fault zone ranges from 16 to 36 inches (0.4 to 0.9 m) in thickness and contains highly shattered rhyolite, gouge, and alteration products. Minor amounts of gold and silver are indicated by samples 58 through 62 (fig. 11). Near



ASSAY DATA

Sample No.	Width (ft)	Gold (oz/ton)	Silver (oz/ton)
65	0.2	Tr	0.2
66	.2	Tr	.1
67	.6	Tr	.1
68	.2	Tr	.1
69	4.0	Tr	.4
70	4.0	0.01	—
71	5.0	Tr	Tr
72	6.5	.32	.3
73	3.5	Tr	.2
74	1.2	Tr	.2
75	6.5	Tr	Tr
76	4.5	Tr	.1
77	Grab	Tr	.1
78	2.8	.01	.2
79	4.0	.01	.1
80	Grab	.43	1.7
81	3.5	.01	.1
82	3.5	Tr	.1
83	Grab	.04	.2

FIGURE 10.—Powers mine, Rattlesnake mining district.

the location of Bureau of Mines samples 59 and 60, two samples cut in 1967 by the U.S. Forest Service Mineral Examiner (Jack Pardee, 1968) assayed about 0.03 ounce (0.94 g) gold and 1.5 ounces (47 g) silver per ton.

A shaft believed to be the Knothe shaft is about 700 feet (210 m) southeast of the portal of the main Long Tom workings (fig. 11). The shaft is reputed to be 40 feet (12 m) deep but is filled with debris to within 6 feet (2 m) of the surface. Four samples (54–57) were cut just below the collar on two sides. Assay results show that sample 55 contained 0.14 ounce (4.4 g) gold and 12.5 ounce (391 g) silver per ton across 6.7 feet (2.0 m) of a fault zone, and sample 56 contained 0.06 ounce (1.9 g) gold and 2.4 ounces (75 g) silver per ton in about 8 inches (20 cm) of fault gouge immediately to the east of sample 55. The fault zone strikes N. 45° W. and dips 63° NE. in silicified rhyolite.

In 1967, the Forest Service Mineral Examiner cut two samples just below the collar of the Knothe shaft in about 4.5 feet (1.4 m) of the fault zone. One contained 0.10 ounce (3.1 g) gold and 20.3 ounces (634 g) silver per ton, and the second contained 0.08 ounce (2.5 g) gold and 15.7 ounces (491 g) silver per ton. As nearly as can be determined, Bureau of Mines samples 55 and 56 were cut between the Forest Service sample locations on the south side of the shaft.

About 200 feet (60 m) south of the Knothe shaft, a crosscut was driven 135 feet (41 m) N. 86° E. in rhyolite. The crosscut (fig. 11) penetrated three shear zones that contained alteration and gouge and minor amounts of gold and silver (samples 48–53).

Approximately 600 feet (200 m) north of the portal of the main Long Tom adit, a 20-foot (6 m) adit was driven S. 44° E. along a vertical shear zone consisting of 4 feet (1.2 m) of highly altered pink- to buff-colored rhyolite. Sample 63, cut across the 4-foot (1.2 m) width of the zone at the portal, assayed 0.13 ounce (4.1 g) gold and 0.4 ounce (13 g) silver per ton. Additional sampling was not feasible within the adit.

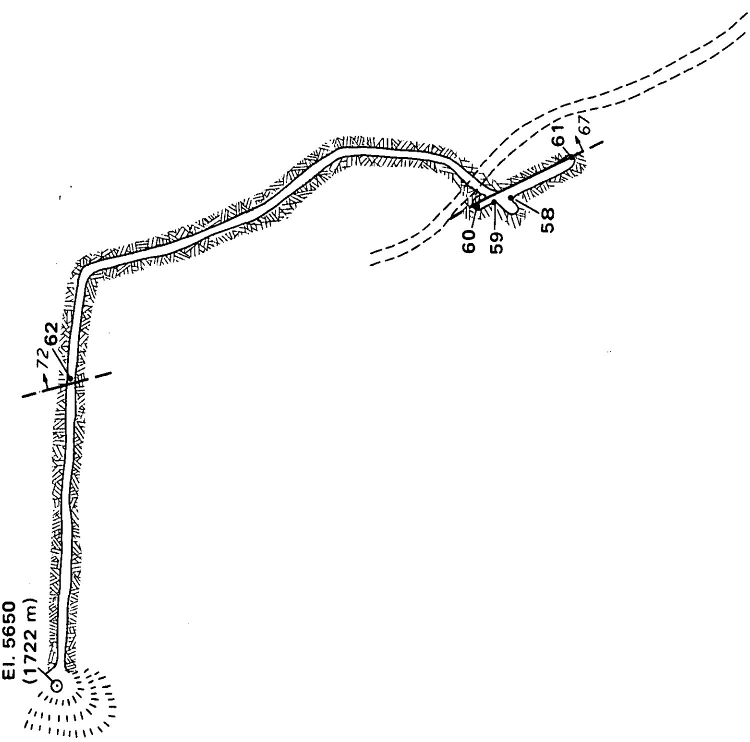
At the mouth of an unnamed tributary to Kielberg Creek about half a mile (800 m) northwest of the Long Tom main working, an adit was driven about 20 feet (6 m) along a limonite gouge zone striking S. 59° E. and dipping 58° SW. in rhyolite. The partly caved adit is within a few hundred feet of the wilderness boundary. Sample 64, chipped across the 18-inch (46 cm) gouge zone exposed above the portal, assayed a trace of gold and 0.7 ounce (22 g) silver per ton. This zone appears to be an extension of the fault system prospected by the Long Tom workings.

GOLD MOUNTAIN WORKINGS

The Gold Mountain workings are in the unsurveyed W½ sec. 31, T. 9 S., R. 20 E., in the east-extending upper reaches of Rattlesnake

ASSAY DATA

Sample No.	Width (ft)	Gold (oz/ton)	Silver (oz/ton)
48	0.7	0.05	0.1
49	3.5	Tr	—
50	4.0	Tr	.1
51	1.0	Tr	.2
52	6.0	Tr	.4
53	.3	Tr	.1
54	6.0	Tr	.4
55	6.7	.14	12.5
56	.7	.06	2.4
57	3.0	Tr	.1
58	1.0	Tr	.1
59	2.0	Tr	.5
60	3.0	.02	1.4
61	3.2	Tr	.1
62	1.3	Tr	.3



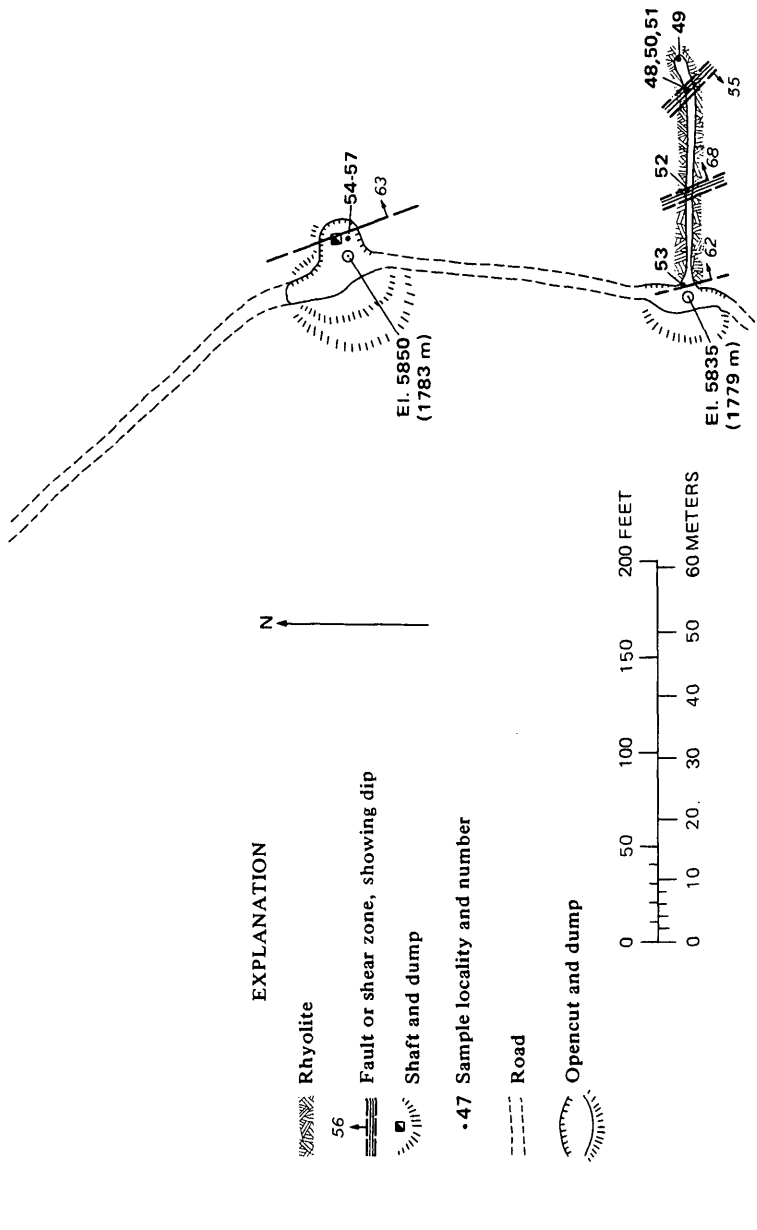


FIGURE 11.—Long Tom workings, Rattlesnake mining district.

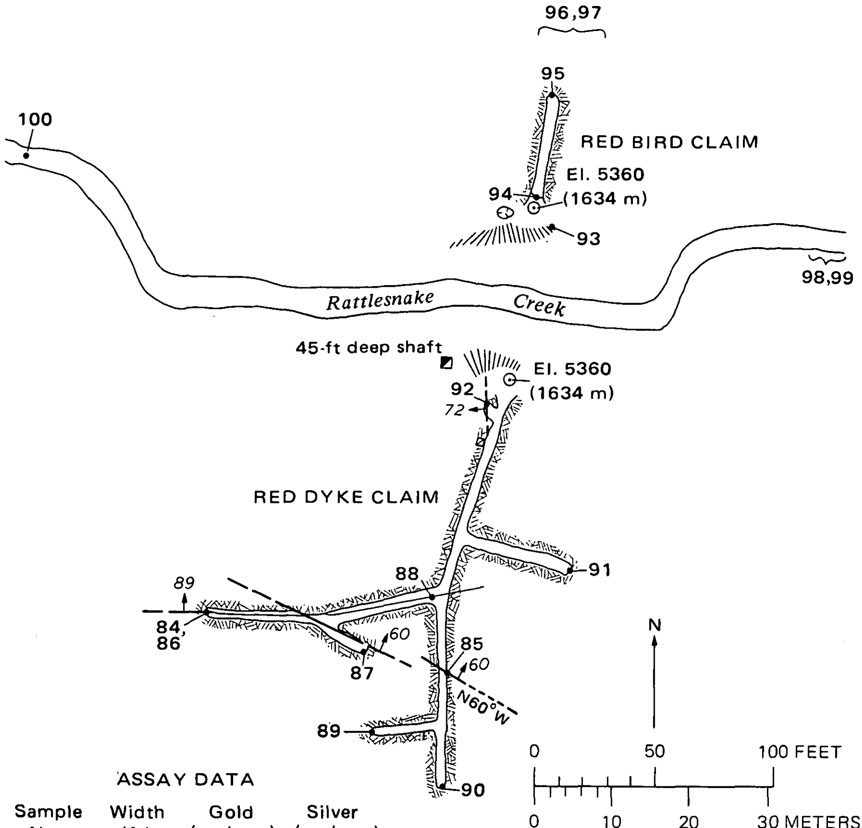
Creek at an elevation of 5,300 feet (1,615 m). The workings are in the narrow corridor of excluded land about half a mile (800 m) from the nearest wilderness boundary (fig. 9) and are covered mainly by two claims, although several others have been recorded in the general vicinity. The Red Dyke claim covers the workings south of the creek; the Red Bird is north of the creek (fig. 12).

The workings were examined shortly after 1900 by W. P. Blake, the Territorial Geologist of Arizona. Blake (1902) prepared a report describing the deposit as having potential for the production of large tonnages of low-grade gold ore. Although he mentions bulk, pan, and cyanide testing conducted by operators of that time, none of the results are presented in terms of actual gold content. Apparently the gold content was too low to justify a large-scale low-grade mining operation regardless of Blake's optimistic report in 1902.

The main Red Dyke working consists of a 170-foot (52 m) adit 5 feet by 7 feet (1.5 m by 2 m) in section from which workings were driven at right angles. Two short crosscuts appear to be in barren rhyolite. A drift was driven 101 feet (31 m) westward along a fractured zone in rhyolite from a point 87 feet (27 m) from the portal. Although no sulfide minerals are evident, a 3-foot-wide (1 m) gouge zone and a 2-inch-wide (5 cm) nearly vertical limonite veinlet can be followed throughout the drift. A similar veinlet is prominent in two other places in the Red Dyke workings: (1) in a 24-foot (7.3 m) stub drift extending southeastward from the middle of the west drift and (2) in a 3-foot-thick (1 m) shear zone 20 feet (6.1 m) south of the intersection of a drift with the adit. Samples 84 through 92 were cut from the shear zones and altered rhyolite in the main Red Dyke workings. Sample 92, from a 1.3-foot-thick (40 cm) silicified shear zone in a stub drift just inside the portal, assayed 0.37 ounce (11.6 g) gold and 0.2 ounce (6 g) silver per ton. The zone contained quartz and hematite and was exposed for a distance of about 5 feet (1.5 m). It did not extend beyond the adit and was not evident as a surface cropping. The remaining eight samples contained minor amounts of gold and silver.

Thirty feet (9 m) west of the Red Dyke portal, a shaft was sunk in rhyolite. The shaft was full of water in 1972 and could not be examined. It was 45 feet (14 m) deep at the time of the investigation but may have contained some waste and debris. Most of the material from the Red Dyke workings either was taken to the mill site area a few miles downstream (see Cascabel de Oro) or was washed away by Rattlesnake Creek.

About 85 feet (25 m), N. 10° E., from the portal of the Red Dyke adit, the Red Bird adit extends northward in fractured and altered rhyolite that contains minor amounts of gold and silver as shown by samples 93 through 95. Sample 93, taken from selected pieces of limonite-stained rhyolite in the dump, contained less gold (trace) and more silver, 0.2 oz (6 g) per ton, than the in-place rhyolite checked by samples 94 and 95. In 1902, Blake reported that gold was found in the



ASSAY DATA

Sample No.	Width (ft)	Gold (oz/ton)	Silver (oz/ton)
84	Grab	Tr	0.1
85	0.2	Tr	.1
86	3.5	Tr	—
87	3.0	Tr	.1
88	4.0	Tr	—
89	2.8	Tr	—
90	3.2	0.06	—
91	3.7	Tr	—
92	1.3	.37	.2
93	Grab	Tr	.1
94	5.0	.02	Tr
95	4.7	.02	—
96	Soil	Tr	.4
97	Soil	Tr	—
98	Soil	.03	.3
99	Soil	—	.4
100	Sed.	—	—

EXPLANATION

Rhyolite

75 Shear zone, showing dip

Winze

Pit

Dump

• 83 Sample locality and number

FIGURE 12.—Gold Mountain workings, Rattlesnake mining district.

loose material along the sides of the rhyolite cropping. Bureau samples 96 through 99, taken from loose surface material in the vicinity of the workings, assayed traces of gold and silver, but the material showed no visible gold when panned. Sample 100, taken in sediments downstream from the workings, contained no visible gold when panned.

The small exposure of shear zone found just inside the portal of the Red Dyke adit is the single spot where a relatively significant gold assay (sample 92) was obtained. Vein material exposed is insufficient to permit adequate sampling for preparation of a reserve estimate. Without repetition of the bulk sampling that was conducted early in the century, a reliable assessment cannot be made of the reported low-grade gold content of the Gold Mountain deposit.

CASCABEL DE ORO MILLSITE

Cascabel de Oro is a 5-acre (2 ha) millsite claim in the NE¼ sec. 36, T. 9 S., R. 19 E.; the claim is in the narrow corridor of land excluded from the wilderness (fig. 9). An abandoned mill is on the west side of Rattlesnake Creek at the mouth of a small west-flowing tributary. The equipment consisted of a ball mill and a modified Wilfley table. Water was supplied from a nearby spring, which was dry in 1972 and 1976. Two samples were collected to test the quality of ore being run through the mill on its last day of operation, the date of which is unknown. Sample 102, fine-grained hard silicified rhyolite taken from the ore bin, assayed 0.01 ounce (0.31 g) of gold and 0.5 ounce (16 g) of silver per ton. Sample 101, taken of fines in the ball mill, assayed 0.43 ounce (13.4 g) of gold and 1.7 ounces (53 g) of silver per ton.

JACKSON MINE AREA WORKINGS

The workings of the Jackson mine area consist of exploration prospects and shafts scattered along and east of a fault zone between rhyolite and andesite that has a regional strike of approximately N. 16° W. The workings (fig. 13) are in secs. 9, 16, and 22, T. 11 S., R. 20 E., at elevations ranging from 4,400 to 5,100 feet (1,340 to 1,550 m), and extend about 7,000 feet (2,100 m) north into the wilderness and about 3,500 feet (1,100 m) south of the southern boundary of the wilderness, into the Galiuro addition.

Where sampled, the fault zone generally contains a trace of gold and less than a half ounce (16 g) of silver per ton and, except for isolated spots, little or no copper. East of the fault, minor amounts of copper, minerals, mostly chrysocolla and malachite, are visible on scattered croppings. In-place samples ranged in width from 0.8 to 8.0 feet (0.2 to 2.4 m), averaging 2.6 feet (0.8 m). A total of 47 samples

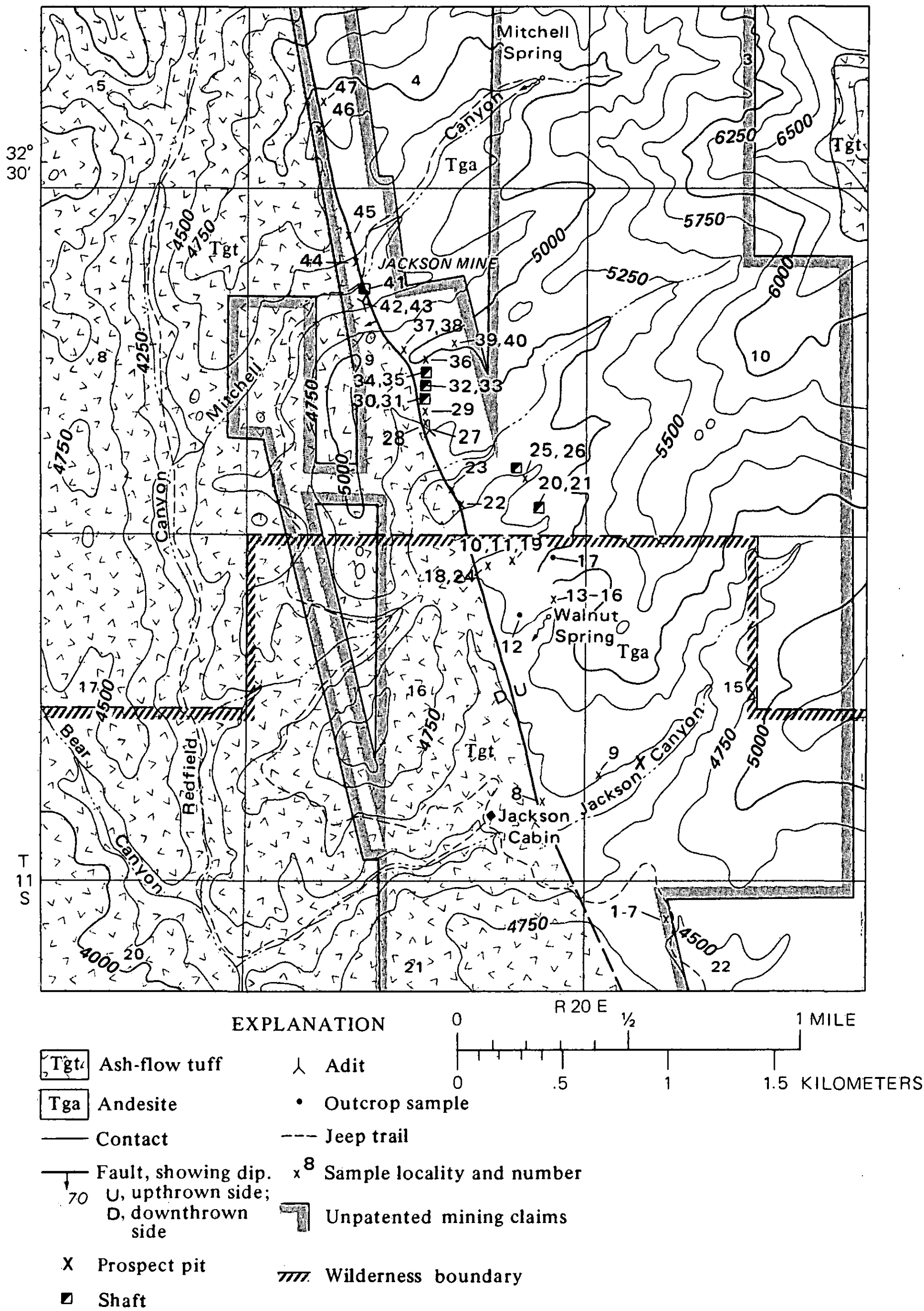


FIGURE 13.—Jackson mine area workings and sample localities.

were collected, the sites of which are shown on figure 13, and assay results are given in table 9.

The southernmost prospect examined during the survey is about 3,500 feet (1,100 m) south of the wilderness boundary in the NW¼ sec. 22. Samples 1–7 were collected from the prospect, which consisted of a 6 by 6 foot (2 × 2 m) pit, a caved shaft, and associated dumps.

TABLE 9.—*Analyses of samples from mines and prospects in the Jackson area*
[Tr., Trace; —, not detected; <, less than]

Sample No.	Width (feet)	Gold (oz/ton)	Silver (oz/ton)	Copper (percent)
1	Grab	0.01	0.8	0.18
2	1.6	.11	8.9	2.20
3	2.0	.12	1.6	1.7
4	2.0	Tr.	.3	.40
5	6.0	Tr.	—	.008
6	2.2	Tr.	.1	.016
7	2.0	Tr.	.1	.006
8	1.0	Tr.	.9	.002
9	Grab	Tr.	.1	<.002
10	Grab	—	.1	—
11	Grab	—	Tr.	—
12	Grab	.01	.8	15.1
13	1.1	Tr.	—	—
14	3.0	Tr.	Tr.	.02
15	1.3	.01	.9	1.2
16	8.0	Tr.	.2	1.2
17	.8	.12	Tr.	7.33
18	2.0	Tr.	.1	.003
19	Grab	Tr.	—	.002
20	3.0	—	.2	—
21	Grab	Tr.	.2	.016
22	Grab	—	.2	.004
23	4.0	Tr.	.2	.003
24	Grab	.02	Tr.	.15
25	1.0	Tr.	.1	.016
26	.3	Tr.	.9	.27
27	.2	Tr.	—	—
28	Grab	Tr.	.2	<.002
29	1.5	Tr.	.4	<.002
30	Grab	Tr.	2.8	—
31	2.0	.01	2.6	.016
32	Grab	.02	5.6	.03
33	Grab	.01	4.2	.003
34	Grab	Tr.	3.7	—
35	Grab	.02	2.8	.008
36	3.0	Tr.	.4	<.002
37	8.0	—	.2	.016
38	8.0	Tr.	.2	<.002
39	1.0	—	—	.002
40	1.0	Tr.	—	.002
41	Grab	.01	1.3	.04
42	2.5	.08	6.5	.12
43	3.0	.02	1.0	.04
44	Grab	Tr.	.2	<.002
45	2.0	Tr.	.4	.004
46	2.0	Tr.	.2	<.002
47	Grab	Tr.	Tr.	<.002

Sample 1 was collected on 5-foot (1.5 m) centers from a dump of about 80 tons (70 t) near the shaft. The composite sample contained 0.01 ounce (0.31 g) gold and 0.8 ounce (25 g) silver per ton and 0.18 percent copper. The material was dark-brown medium-hard fragments of rhyolite showing minor chrysocolla.

Samples 2 through 7 were collected from the exposed vein in a pit at the shaft site. The vein ranges from 8 to 39 inches (0.20 to 1.0 m) in thickness and averages about 17 inches (0.43 m). It strikes N. 26° W. and dips 67° NE. Sample 2, chipped across the vein at its average thickness of 17 inches (0.4 m), contained 0.11 ounce (3.4 g) gold and 8.9 ounces (278 g) silver per ton and 2.2 percent copper. Check sample 4 taken at this spot contained a trace of gold, 0.3 ounce (9 g) silver per ton, and 0.4 percent copper. Sample 3, chipped across 2 feet (0.6 m) of the vein in the upper part of the pit, contained 0.12 ounce (3.8 g) gold, 1.6 ounces (50 g) silver per ton, and 1.7 percent copper.

The relatively wide range of gold-silver-copper values exhibited in samples 1 through 7 indicates a highly erratic distribution of metals within the shattered and silicified fault zone. Because of cover, systematic sampling to the north and south of the shaft would require extensive trenching to locate the zone.

Two prospects on the south slope of Jackson Canyon and about a quarter mile (400 m) and a half mile (800 m) each northeast of Jackson cabin (fig. 13) expose brecciated and altered andesite in separate minor fault zones. Samples 8 and 9, one from each pit, contained minor amounts of gold and silver and no copper.

Three workings and two outcrops were examined and sampled between the southern boundary of the wilderness and Walnut Spring. Samples 10–19 and 24 were collected from these sites (fig. 13). Samples 12 and 17 (table 9) contained relatively high copper values, and sample 17 contained relatively high gold. The remainder of the samples (11–16, 18, 19, 24) contained minor amounts of gold, silver, and copper and were from trenches, pits, and dumps associated with relatively barren shear zones in andesite and rhyolite.

Sample 12 consisted of pieces of float from a ridge about 500 feet (150 m) west of Walnut Spring. In-place material could not be found, and no location work was observed in the vicinity of the float. Sample 17 was chipped across a 10-inch-wide (25 cm) zone of copper and iron oxides in dark-brown silicic rhyolite at the crest of a west-trending ridge just south of the wilderness boundary and about 900 feet (270 m) due north of Walnut Spring. The outcrops of copper and iron-bearing material appears to be limited to an isolated pod or lens, as they could not be traced beyond the immediate vicinity of the sample site. Although samples 12 and 17 contained 15.1 and 7.33 percent, respectively, of copper and sample 17 contained 0.12 ounce (3.8 g) gold per ton, the amount of material exposed at the surface was not favorable for continued investigation at the time of the study.

Two shafts located just north of the wilderness boundary and from 1,600 to 2,200 feet (500 to 700 m) north of Walnut Spring (fig. 13) were examined. The southernmost shaft measured 4 by 6 feet (1.2 × 1.8 m) at the collar and was sunk about 50 feet (15 m) on a 10-inch-wide (25 cm) shear zone in rhyolite. The zone strikes N. 40° W. and dips 87° SW. Access to the shaft and solid vein material was not possible without considerable rehabilitation to meet State and Federal safety requirements. Composite grab samples (20, 21) were taken on 5-foot (1.5 m) centers from the dump estimated to contain 75 tons (68 t) of rock. Minor amounts of gold and silver were detected in both sets of dump samples.

The second shaft, about 600 feet (180 m) to the northwest from the first described, measured 6 by 10 feet (1.8 × 3 m) at the collar and is estimated to be 30 feet (9 m) deep. A drift appears to extend along the structure that strikes N. 27° W. and dips 85° NE. The shaft and drift were inaccessible at the time of the examination. Two samples, 25 and 26, were chipped from the vein exposed in a trench about 40 feet (12 m) southeast from the shaft. Minor amounts of gold and silver were present in both samples. Copper content was nil, although traces of copper oxide are visible in the shear zone. The structure cannot be traced beyond the area between the shaft and the trench.

A pit and two shallow shafts were examined and sampled about 1,000 feet (300 m) west of the above-described workings. These are from 500 to 600 feet (150 to 180 m) inside the south boundary of the wilderness, and all are on the same structure that strikes N. 15° W. and dips 60°–70° W. The southernmost shaft was inaccessible; however, composite sample 22 was taken from the dump on a 3-foot (0.9 m) grid pattern (fig. 13). As indicated in table 9, the gold-silver-copper content of the dump material is insignificant.

Approximately 150 feet (45 m) to the north along the structure, a second shaft, also inaccessible, is estimated to be 25 feet (8 m) deep and is about 25 feet (8 m) south of a shallow pit in which 4 feet (1.2 m) of brecciated quartz and iron oxides are well exposed in andesite. Sample 23 was chipped across the 4-foot (1.2 m) zone within the pit (fig. 13). Analytical results for sample 23 indicate minor amounts of gold and silver and no copper.

The southern workings of the Jackson mine are about 900 feet (275 m) northwest of sample site 23 and are believed to be on the same fault zone. The Jackson mine workings comprise four shafts, two adits, and six pits and cuts trending northward along the fault zone in the center of sec. 9, T. 11 S., R. 20 E. Sample sites 27 through 43, except sites 39–40 (fig. 13), show the location of the workings, all of which are in the wilderness. Samples 27, 29, 31, 36, 37, 38, 42, and 43 were chipped from the fault zone where it was exposed by the workings. As indicated in table 9, the analytical results show minor amounts of gold, up to 6.5 ounces of silver per ton, and negligible amounts of copper across widths ranging from 0.2 to 8.0 feet (6 to 240 cm). Samples 28, 30, 32, 33, 34, 35, and 41 were from the dumps of the shafts and adits and contain minor amounts of gold, up to 5.6 ounces silver per ton, and negligible amounts of copper.

The relatively high silver content of a few of the vein and dump samples indicates the spotty occurrence of the mineralization which apparently was sufficient to stimulate extensive exploration work. Although no production is recorded for the mine or the area in general, small unrecorded shipments may have been made.

The greatest unknown factor is the nature and quantity of gold-silver-copper mineralization at depth. The shaft at sample site 41 (fig. 13) is estimated to be 300 to 400 feet (90 to 120 m) deep and sloping approximately 56° W. As no record of production was found, the sinking probably was for purposes of exploration rather than development. The characteristics of the mineralization at depths greater than those reached by the relatively shallow shafts can be determined only by drilling or by additional sinking and drifting.

From 400 to 2,900 feet (120 to 880 m) northwest of sample sites 41–43, four pits and associated dumps were found along the major fault zone, as indicated by sample sites 44–47. Where sampled, the zone contained minor amounts of alteration and silification in sheared andesite and rhyolite and had no visible copper mineralization. Dump samples 44 and 47 and vein samples 45 and 46 contained minor amounts of gold and silver.

These prospects mark the northernmost limit of the Jackson mine area and appear to be outside of the more favorable zone of silver mineralization noted in the vicinity of the Jackson mine shaft.

In summary, the 10,500 feet (3,200 m) of fault zone and associated gold, silver, and copper mineralization represents an area of geologic and historic interest rather than of economic interest in relation to mineral economics of the mid and late 1970's. The surface croppings were heavily prospected in the past, and in the vicinity of the Jackson mine, exploration is estimated to have reached depths of from 300 to 400 feet (90 to 120 m) with no recorded production. As no more than 20 percent of the zone was tested to those depths, the tenor of precious and base metals is unknown below a depth of 10 feet (3 m) for about 80 percent of the strike length of the zone. Nothing is known of the tenor of the metals for the entire length below the relatively shallow depth of about 400 feet (120 m).

SIXTEEN-TO-ONE MINE

The Sixteen-to-One mine is in a deep tributary canyon of Kielberg Canyon in SE¼SE¼ sec. 10, T. 10 S., R. 19 E., half a mile (800 m) west of the wilderness boundary. No production has been recorded from the property, although it may have yielded some gold and silver many years ago. The main working consists of two crosscut adits that apparently were driven to develop a small ore shoot that was localized at the intersection of two or more faults (fig. 14).

The main adit, about 90 feet (30 m) long, bears S. 15° W. in hard silicified rhyolite and cuts the shattered zone at the fault intersection from 20 to 40 feet (6 to 12 m) below the ground surface. Gold and silver mineralization apparently was sufficiently high to justify stoping to the surface and driving a second crosscut into the zone about 15 feet (5 m) below the first. The stoped area has dimensions of about 10 by 15 feet (3 × 5 m) from the second level to the surface.

Two samples (110, 111, fig. 14) were chipped across the face of a stub drift to check three limonite-stained silicified zones totaling 2 feet (0.6 m) in width. Sample 110 was confined to the silicified zone, and sample 111 included the full 6-foot (1.8 m) width of the face. Both samples contained a trace of gold and 1.3 ounces (41 g) silver per ton. Copper (0.27 percent) was detected in sample 110. The floor of the stope was deeply covered with rubble and showed no evidence that sinking had been attempted.

Two samples of dump rock were collected; 108 was selected from copper oxide fragments that contained 0.01 ounce (0.3 g) gold and 10.2 ounces (319 g) silver per ton, and 0.82 percent copper; 109 was collected on 5-foot (1.5 m) centers and contained a trace of gold, 2.0 ounces (63 g) of silver per ton, and 0.09 percent copper.

About 500 feet (150 m) northeast of the main working and across the canyon, a shear zone in rhyolite was explored by two sets of adits (B, C, fig. 15). The zone strikes N. 30° E. and dips 35°–40° NE. Faults ranging from 2.5 to 6.0 feet (0.8 to 1.8 m) thick were cut by the adits in four places. Five samples (103–107, fig. 15) were chipped across the full thickness of the fault zones. The samples contained traces of gold and from 0.4 to 1.0 ounce (13 to 31 g) silver per ton. Copper content was nil except for a stain in the back of adit C.

On the basis of past development work and to some extent on Bureau of Mines samples results, the Sixteen-to-One mine has a slight potential for the discovery of a small tonnage of relatively high grade gold-silver mineralization below the stope in the main working. The favorable area is confined to shattered rhyolite at the fault intersection and will require drilling or sinking to explore it.

RHODES MINE

The Rhodes mine (fig. 16) is in the NE¼ of unsurveyed sec. 1, T. 9 S., R. 18 E., nearly 2 miles (3.2 km) west of the wilderness boundary and outside the national forest. The working is at an elevation of 4,250 feet (1,295 m) in the foothills west of the Galiuro Mountains.

The main working is a crosscut driven in granodiorite on a bearing of S. 68° E. and extends 128 feet (39 m) to a shear zone beyond which access was not possible. The shear zone is about one foot (0.3 m) thick, strikes N. 5° W., dips 70° E., and primarily is limonite gouge along a granodiorite-andesite contact. Sample 118, taken across the shear zone, and sample 119, a composite from several parts of the dump, contained traces of gold. Apparently, the Rhodes working was an exploration venture.

COPPER CREEK (BUNKER HILL) MINING DISTRICT

Just outside the northwest corner of the Galiuro unit of the Coronado National Forest is the Copper Creek (Bunker Hill) mining district. Copper Creek mines yielded some lead-silver ores, but the production was mainly copper and molybdenum from deposits associated with breccia pipes. Zones of alteration, mostly sericite and kaolinite, containing malachite and chrysocolla extend south from the Copper Creek district to the Rhodes mine and northeast to workings and outcrops on Mescal Mountain. The alteration and mineralization associated with the Copper Creek district are inferred to extend under the Galiuro Volcanics and to underlie much of the northern portion of the Galiuro unit of the Coronado National Forest. The alteration and mineralization may underlie the northwest corner of the wilderness itself. Phelps Dodge Corp. has drilled deep exploratory holes in sec. 25, T. 18 S., R. 8 E., G&SMR, and in surrounding sections both inside and outside the National Forest.

Phelps Dodge informed the U.S. Bureau of Mines by letter, November 20, 1975, that:

> The extensive drilling and geologic work delineated an anomalous region with stockwork porphyry copper type alteration and metallization. No concentrations of copper metallization were encountered that would be of economic interest at this time. Interpretations of the data collected did not indicate definite projections easterly beneath the younger volcanic rocks and no definite target areas were identified in the wilderness area. The thickness of the younger volcanic rock coupled with the lack of determination of a target did not encourage consideration of deep wildcat exploration drill holes in the wilderness. However, we are convinced that the widespread mineralization known to exist west of the range front is only part of a very large system, and that there are excellent possibilities of one or more porphyry copper deposits beneath the Galiuro Wilderness area. These would fall in the "hypothetical" category of ore reserves following the definitions of the U.S.G.S.

In addition to the drilling done by Phelps Dodge, other deep exploratory drilling has been done in secs. 1, 2, and 12, T. 8 S., R. 19 E. No information has been released concerning that drilling.

The scope of the Bureau of Mines investigation for this study did not include detailed work within the Copper Creek (Bunker Hill) mining district. Samples 120–123 were taken on the fringes of the district from one outcrop in schist and three workings in andesite all

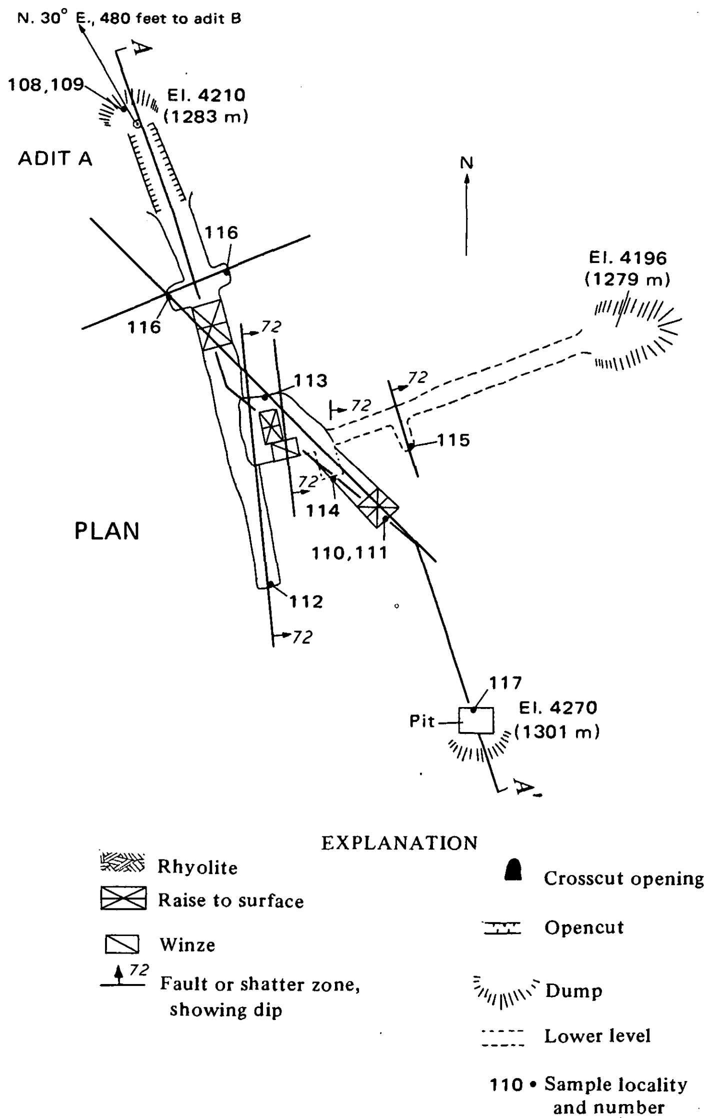
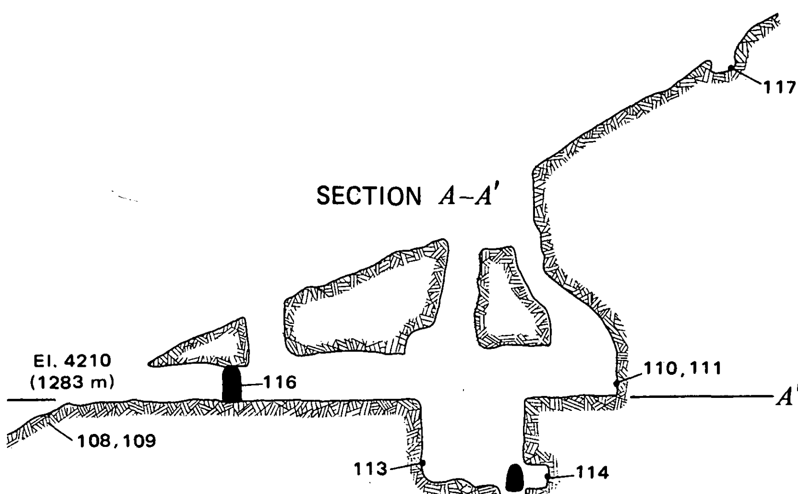


FIGURE 14.—Sixteen-to-One mine, sec. 10, T. 10 S., R. 19 E., Graham County, Arizona.

showing chrysocolla and malachite. All four sample sites are outside the forest (fig. 9).

Sample 120 is a 6 foot (1.8 m) chip sample from a schist outcrop in the wall of a gully. The outcrop is 5×10 feet (1.4×2.8 m), contains minor chrysocolla and malachite. The assay showed a trace gold and 0.08 percent copper. Sample 121, a 3.5-foot (1 m) chip sample from the collar of a shaft of unknown depth in andesite, contained chrysocolla and malachite and assayed a trace each of gold and silver and 2.2 percent copper. Sample 122, a 1.5-foot (0.5 m) chip sample from the back of a 5-foot (1.5 m) adit in andesite, assayed a trace gold, 0.8 ounce (25 g) silver, and 2.2 percent copper. The adit is at the end of a trench that is partly filled with debris. A shaft was sunk at one point



ASSAY DATA

Sample No.	Width (ft)	Gold (oz/ton)	Silver (oz/ton)	Copper (percent)
108	[1]Select	0.01	10.2	0.82
109	[2]Grab	Tr	2.0	.09
110	2.0	Tr	1.3	.27
111	6.0	Tr	1.3	–
112	2.0	Tr	.7	–
113	9.0	Tr	1.2	–
114	5.0	Tr	.4	–
115	3.0	Tr	2.0	–
116	6.5	Tr	1.7	–
117	6.0	Tr	.8	–

[1]Copper-stained dump rock
[2]Dump sampled on 5-ft centers

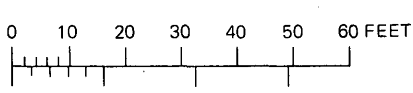
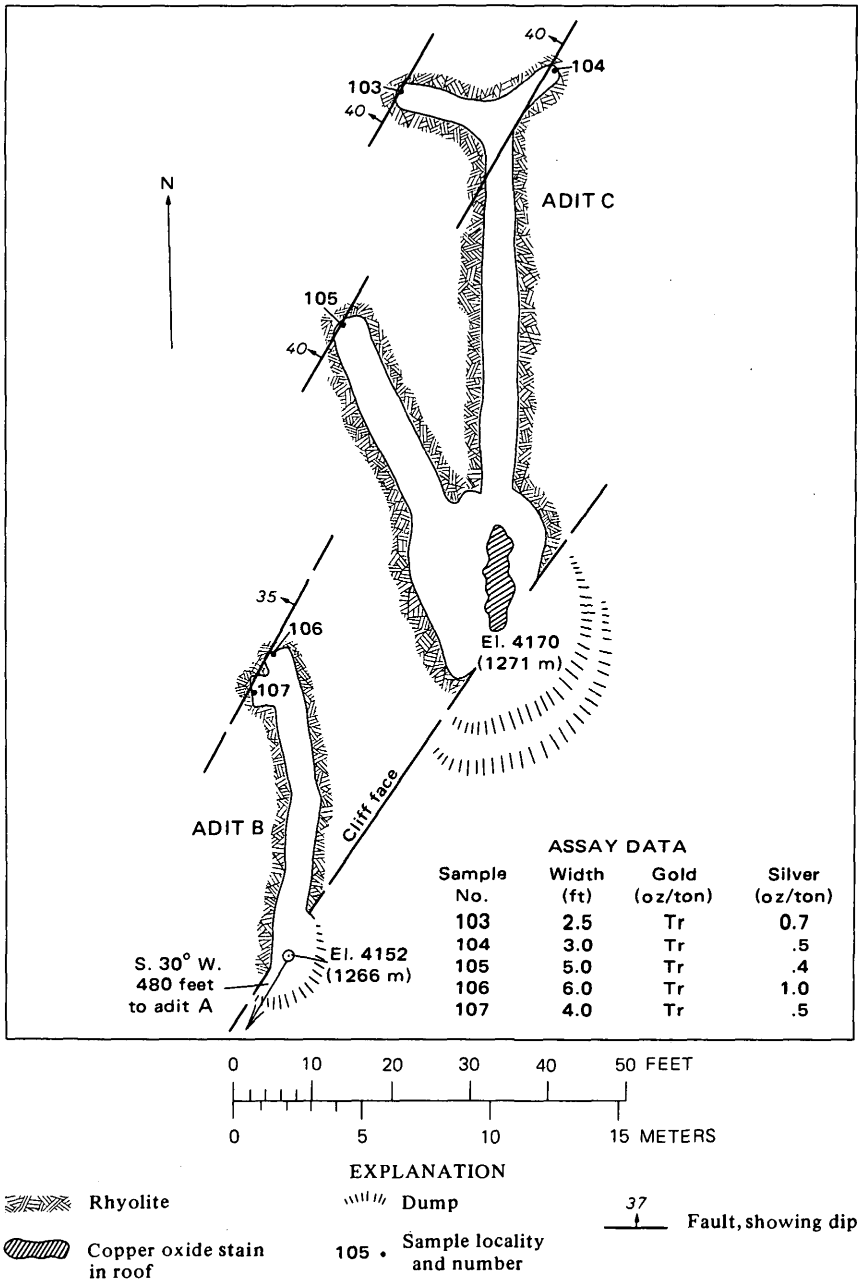


FIGURE 14.—Continued.



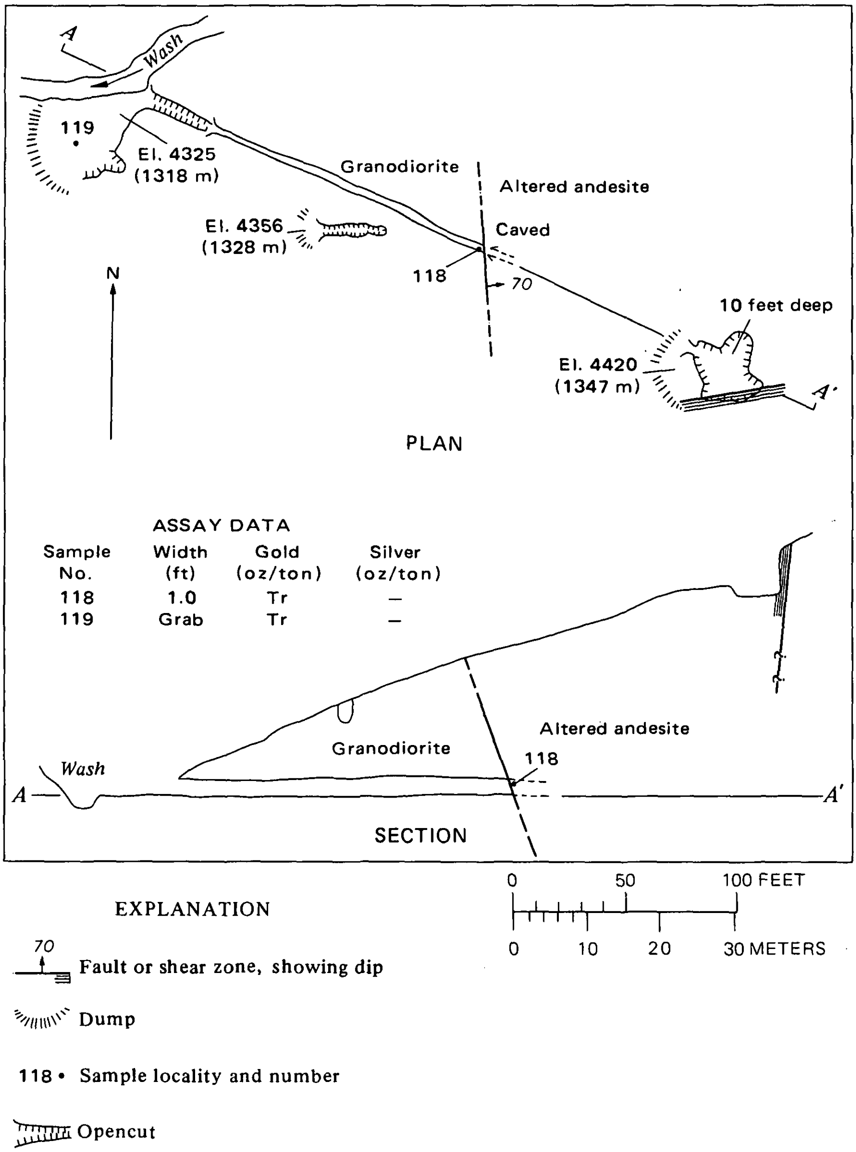
ASSAY DATA

Sample No.	Width (ft)	Gold (oz/ton)	Silver (oz/ton)
103	2.5	Tr	0.7
104	3.0	Tr	.5
105	5.0	Tr	.4
106	6.0	Tr	1.0
107	4.0	Tr	.5

FIGURE 15.—Sixteen-to-One mine, adits B and C.

along the trench but is now filled with dirt and rock. The dump is estimated to contain 125 tons (110 t) of material.

Sample 123 is a grab sample from a vein of chrysocolla, malachite, and azurite in purple andesite. The vein strikes N. 70° E. and dips 78° S., averages 8 to 9 inches (20–23 cm) in width over a distance of 200



ASSAY DATA

Sample No.	Width (ft)	Gold (oz/ton)	Silver (oz/ton)
118	1.0	Tr	–
119	Grab	Tr	–

FIGURE 16.—Rhodes mine.

feet (60 m), and pinches out at both ends. Two shafts and several trenches have been dug on the vein; the shafts have water standing 150 feet (46 m) below the collars. Sample 123 assayed 0.02 ounce (0.6 g) gold, 3.0 ounce (93.3 g) silver, 7.6 percent copper.

MINERAL POTENTIAL OF THE GALIURO WILDERNESS-FURTHER PLANNING AREAS

Within the northwestern part of the study area from Copper Creek southward to Rhodes ranch, the past metal production, wide distribution of mines and prospects, current mining activity and exploration, and widespread hydrothermal alteration and metallization indicate a high potential for one or more commercial porphyry copper deposits. The extent to which this favorable ground extends eastward under the Galiuro Volcanics can be determined only by drilling or shaft sinking, but it could extend to some point within the northwestern boundary of the wilderness (see pl. 2). Because the copper potential of the Copper Creek area is so promising, exploration and mining will probably continue there for many years, and it possible that exploration will eventually impinge on the wilderness. The area most likely to be involved in the Copper Creek district (pl. 3) is largely chaparral-covered hills, the part of the wilderness least likely to be used for recreation.

The near-surface gold in the pyritized volcanic rocks around the divide between Rattlenake and Redfield Canyons consists of low-grade ores in small, disconnected pockets along fractures and small faults that offer little or no potential for development into commercial deposits. The Powers and Long Tom mines and the Gold Mountain workings all lie within this area of scattered pyritic alteration.

The potential for commercial deposits of copper at depth in older rocks, however small, is greater than that for gold in the near-surface volcanics, but the six anomalous reconnaissance samples in the Rattlesnake-Redfield altered area are no more than slightly encouraging. There is a remote possibility that the alteration zones indicate copper in the older rocks at depth. Assuming that additional geochemical samples confirm the anomaly, only additional exploration, including drilling, will prove or disprove the existence of a buried commmercial deposit. Judgment determines whether the chances for success of such long-shot exploration justify the expense, and, with the information at hand, the area is in our judgment a poor exploration target.

The Sixteen-to-One mine area, outside the wilderness, is also a pyritized area containing small pockets of gold ore along fractures and faults. Like the Rattlesnake-Redfield area, it is judged to have little potential for commercial gold deposits in the volcanic rocks exposed at the surface. The small size of the pyritized area at the surface is not encouraging for widespread copper metallization at a depth in the older rocks, unless it somehow connects at depth to the larger Rattlesnake-Redfield altered area 3 miles (4.8 km) to the east. There is no surface indication of continuity between the two altered areas.

The altered and metallized areas around the Jackson mine and the prospects lying to the southeast are closely associated with the fault that separates the andesite from ash-flow tuffs. The alteration zone along the fault is narrow and the metal content too low to form ore. There is nothing in the exposed rocks to indicate commercial mineral deposits. Whether or not this fault zone contains commercial ore at depth where the fault cuts older rocks is conjectural, but the possibility, though remote, exists. To prove or disprove ore would require exploratory drilling. Other isolated metal anomalies along the fault are much less encouraging that those in the Jackson mine area, and are, in our judgment, valueless.

REFERENCES CITED

Ahrens, L. H., 1957, Lognormal-type distribution, [Pt.] 3 *of* The lognormal distribution of the elements—a fundamental law of geochemistry and its subsidiary: Geochim. et Cosmochim. Acta, v. 11, no. 4, p. 205–212.

Blake, W. P., 1902, The geology of the Galiuro Mountains, Arizona, and of the gold-bearing ledge known as Gold Mountain: Eng. and Mining Jour., v. 73, p. 546–547.

Cooper, J. R., and Silver, L. T., 1964, Geology and ore deposits of the Dragoon quadrangle, Cochise County, Arizona: U.S. Geol. Survey Prof. Paper 416, 196 p.

Creasey, S. C., 1967, General geology of the Mammoth quadrangle, Pinal County, Arizona: U.S. Geol. Survey Bull. 1218, 94 p.

Creasey, S. C., Jackson, E. D., and Gulbrandsen, R. A., 1961, Reconnaissance geologic map of parts of the San Pedro and Aravaipa Valleys, south-central Arizona: U.S. Geol. Survey Mineral Inv. Field Studies Map MF–238, scale 1:125,000.

Darton, N. H., 1925, A résumé of Arizona geology: Arizona Bur. Mines Bull. 119, geol. ser. 3, 298 p.

Darton, N. H., and others, 1924, Geologic map of the State of Arizona: Arizona Bur. Mines in cooperation with the U.S. Geol. Survey, scale 1:500,000.

Davis, W. M., and Brooks, Baylor, 1930, The Galiuro Mountains, Arizona: Am. Jour. Sci., 5th ser., v. 19, p. 89–115.

Lepeltier, Claude, 1969, A simplified statistical treatment of geochemical data by graphical representation: Econ. Geology, v. 64, no. 5, p. 538–550.

Pierce, H. W., Keith, S. B., and Wilt, J. C., 1970, Coal, oil, natural gas, helium, and uranium in Arizona: Arizona Bur. Mines Bull. 182, 289 p.

Ransome, F. L., 1903, Geology of the Globe copper district, Arizona: U.S. Geol. Survey Prof. Paper 12, 168 p.

———1904, Geology and ore deposits of the Bisbee quadrangle, Arizona: U.S. Geol. Survey Prof. Paper 21, 168 p.

Rittmann, A., 1952, Nomenclature of volcanic rocks: Bull. Volcanol., ser. 2, v. 12, p. 75–102.

Simons, F. S., 1964, Geology of the Klondyke quadrangle, Graham and Pinal Counties, Arizona: U.S. Geol. Survey Prof. Paper 461, 173 p.

Turkekian, K. K., and Wedepohl, K. H., 1961, Distribution of the elements in some major units of the Earth's crust: Geol. Soc. America Bull., v. 72, p. 175–191.

Ward, F. N., Lakin, H. W., Canney, F. C., and others, 1963, Analytical methods used in geochemical exploration by the U.S. Geological Survey: U.S. Geol. Survey Bull. 1152, 100 p.

Ward, F. N., Nakagawa, H. M., Harms, T. F., and VanSickle, G. H., 1969, Atomic-absorption methods of analysis useful in geochemical exploration: U.S. Geol. Survey Bull. 1289, 45 p.

Wilson, E. D., Cunningham, J. B., and Butler, G. M., 1934, Arizona lode-gold mines and gold mining: Arizona Bur. Mines Bull. 137, 261 p.

Wilson, E. D., Moore, R. T., and others, 1958, Geologic map of Graham and Greenlee Counties, Arizona: Arizona Bur. Mines, scale 1:375,000.

Wilson, E. D., Moore, R. T., and Cooper, J. R., 1969, Geologic map of Arizona: Arizona Bur. Mines, scale 1:500,000.