Geochemical Exploration Techniques Based on Distribution of Selected Elements in Rocks, Soils, and Plants, Vekol Porphyry Copper Deposit Area, Pinal County, Arizona

GEOLOGICAL SURVEY BULLETIN 1278-E

Geochemical Exploration Techniques Based on Distribution of Selected Elements in Rocks, Soils, and Plants, Vekol Porphyry Copper Deposit Area, Pinal County, Arizona

By MAURICE A. CHAFFEE

CONTRIBUTIONS TO GEOCHEMICAL PROSPECTING FOR MINERALS

GEOLOGICAL SURVEY BULLETIN 1278-E

A comparison and evaluation of some different types of samples that may be useful for geochemical prospecting for copper in the semiarid environment

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1977

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress Cataloging in Publication Data
Chaffee, Maurice A.
Geochemical exploration techniques based on distribution of selected elements in rocks, soils, and plants, Vekol porphyry copper deposit area, Pinal County, Arizona.
(Contributions to geochemical prospecting for minerals) (Geological Survey Bulletin 1278–E)
Bibliography: p.
1. Geochemical prospecting. 2. Copper ores–Arizona–Pinal Co.
I. Title: Geochemical exploration techniques based on distribution of selected elements . . .
II. Series. III. Series: United States Geological Survey Bulletin 1278–E.
QE75.B9 no. 1278–E [TN271.C6] 557.3'08s [622'.18'43] 77–608116

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402
Stock Number 024-001-02986-3

CONTENTS

ILLUSTRATIONS

TABLES

CONTRIBUTIONS TO GEOCHEMICAL PROSPECTING FOR MINERALS

GEOCHEMICAL EXPLORATION TECHNIQUES BASED ON DISTRIBUTION OF SELECTED ELEMENTS IN ROCKS, SOILS, AND PLANTS, VEKOL PORPHYRY COPPER DEPOSIT AREA, PINAL COUNTY, ARIZONA

By MAURICE A. CHAFFEE

ABSTRACT

A regional geochemical survey was conducted between 1970 and 1972 in the vicinity of the Vekol porphyry copper deposit, Pinal County, Ariz. The complex geology of the Vekol Mountains involves rocks of Precambrian through Quaternary ages. The Vekol porphyry copper deposit occurs in a tilted, layered sequence of Precambrian to Paleozoic rock units near their contact with an Upper Cretaceous(?) quartz monzonite stock. Upper Tertiary(?) conglomerates and Quaternary colluvial and alluvial deposits cover much of the older bedrock and most of the Vekol copper deposit.

The concentration and distribution of as many as 38 elements were determined for samples of bedrock, residual soil, and both nonriparian plant species (creosotebush, ironwood, and foothill paloverde) and riparian plant species (mesquite, blue paloverde, catclaw acacia, and ironwood). The distributions of nine elements in samples of bedrock, residual soil, and nonriparian plants suggest the existence of an aureole of Zn, Mn, Ag, Cd, Pb, Bi, and possibly Hg around a central core of copper and molybdenum.

The distribution of soil-pH values showed no obvious trends that could be related to the Vekol deposit; however, a close correlation was found between soil-pH values and type of parent rock.

In terms of locating the Vekol copper deposit, residual soil was generally a more effective sample medium than either bedrock or nonriparian plants. Of the nonriparian plant species, creosotebush seemed to provide more useful information than did either of the other two nonriparian species.

The distributions of copper and zinc anomalies in the ash of mesquite leaves and stems and of zinc anomalies in the ash of leaves and stems of the other three riparian species correlated best with the areal distribution of mineralized ground near the Vekol deposit.

Anomalies resulting from erosion of the Vekol deposit were detected in analyses of the riparian plants growing in Quaternary alluvium at least 1.5 km (1 mi) downstream from any outcrop. Zinc anomalies extended the farthest of any of the selected elements. These results suggest that analyses of samples of riparian plants for zinc, and perhaps for copper and molybdenum, should be especially effective in reconnaissance surveys searching for another deposit like the Vekol deposit.

INTRODUCTION

This report describes a study of the distribution of Cu, Mo, Zn, Mn, Ag, Cd, and Pb in 121 samples of bedrock; Cu, Mo, Zn, Mn, Ag, Cd, Pb, Bi, and Hg in 121 samples of residual soil; as many as five elements (including Cu, Mo, Zn, Ag, and Cd) in 68–86 samples (depending on species) of nonriparian vegetation; and Cu, Mo, Zn, and Ag in 56–73 samples (depending on species) of riparian vegetation. All samples were collected between 1970 and 1972 in an area of approximately 65 km^2 (about 25 mi^2) in the vicinity of the unexploited Vekol porphyry copper deposit. This deposit is located on the east side of the Vekol Mountains in southwestern Pinal County, Ariz., some 43 km (about 27 mi) southwest of Casa Grande (fig. 1). Elevations in the area range from 505 to 740 m (1,657–2,427 ft). The climate and flora of the area are typical of the lower Sonoran Desert in Arizona. The nearest weather station, at Casa Grande, recorded for 1899–1957 an average annual precipitation of 20.8 cm (8.20 in.) and mean daily maximum

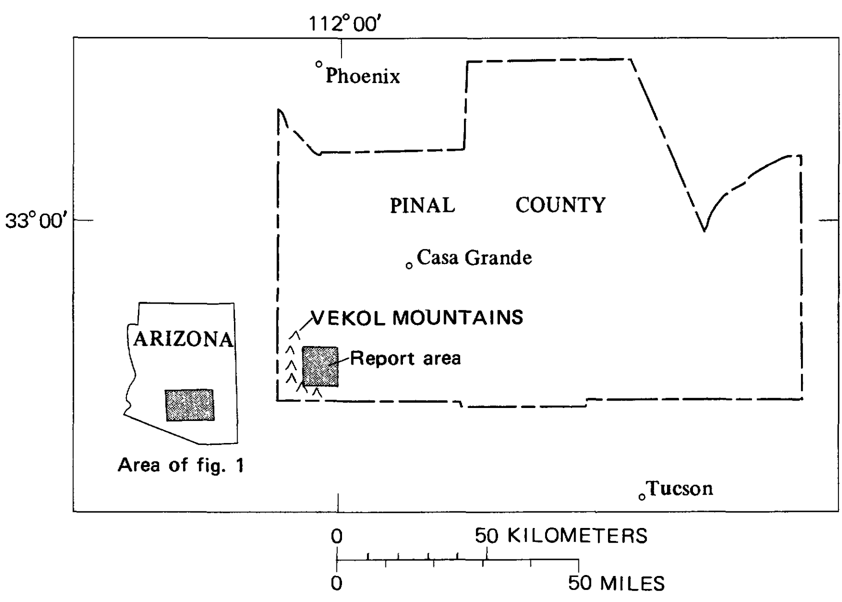


FIGURE 1. — Location of the Vekol porphyry copper deposit area.

and minimum temperatures of 31°C and 11°C (87°F and 52°F) (Green and Sellers, 1964).

The Vekol Mountains support a large variety of desert herbs, shrubs, and trees. Many trees growing in or near the active stream channels reach heights of 10 m (33 ft) or more. The plant species selected for this investigation are species that commonly grow in the region and include creosotebush (*Larrea tridentata* (Sessé and Moc. ex DC) Coville), ironwood (*Olneya tesota* A. Gray), foothill paloverde (*Cercidium microphyllum* (Torr.) Rose and Johnston), blue paloverde (*C. floridum* Benth. ex A. Gray), mesquite (*Prosopis juliflora* var. *velutina* (Wooten) Sarg.), and catclaw acacia (*Acacia greggii* A. Gray) (Shreve and Wiggins, 1964).

The purpose of this study was twofold: (1) to provide basic data on the abundance of selected elements in samples of various media collected in the vicinity of a known copper deposit; and (2) to compare and evaluate these different elements and sample media for their potential usefulness in the search for other copper deposits that might be present in similar environments.

Geochemical exploration studies of surficial material have been conducted around a number of porphyry copper deposits in Arizona and New Mexico. However, few of these other reports describe the distributions of more than a very few elements, usually only one or two elements. Deposits about which some geochemical exploration information has already been published include Ajo (Davis and Guilbert, 1973), Helvetia-Rosemont (Drewes, 1973), Johnson Camp (Cooper and Huff, 1951), Mineral Butte (Chaffee, 1976), Mineral Park (Eidel and others, 1968; Davis and Guilbert, 1973), Morenci (Davis and Guilbert, 1973), Pima district (Huff, 1970), Ray (Clarke, 1953), Safford (Robinson and Cook, 1966; Huff, 1971), San Manuel-Kalamazoo (Lovering and others, 1950; Warren and others, 1951; Brown, 1970), and Vekol (Chaffee and Hessin, 1971), all in Arizona, and Santa Rita (Davis and Guilbert, 1973), in New Mexico.

The Vekol deposit area was selected for study because it contains a relatively large mineral deposit that has been defined by drilling but has not been greatly disturbed by man. Base metals have been extracted intermittently since the late nineteenth century at several small mines in the area surrounding the site of the Vekol porphyry copper deposit, but no widespread contamination has occurred that would affect the investigation reported here.

The Vekol deposit is in a stratigraphic section that includes rocks of Precambrian through Mesozoic age. This stratigraphic section has been intruded by a stock of probable Late Cretaceous age. Many of the wallrocks present in the study area are carbonate rocks or at least contain a significant amount of carbonate minerals. This geochemical environment around the Vekol deposit contrasts with that found at the site of the Mineral Butte porphyry copper deposit, the subject of another geochemical report (Chaffee, 1976) where an Upper Cretaceous stock intruded wallrocks of Precambrian granite that were relatively unreactive in a chemical sense. Study of the Vekol deposit, therefore, allows comparisons to be made of the usefulness of different sample media and chemical elements in two different areas.

ACKNOWLEDGMENTS

The Vekol porphyry copper deposit is located on the Papago Indian Reservation on land leased jointly by Newmont Mining Corporation and The Superior Oil Company. The assistance of Newmont, and especially of Mr. H. J. Steele of that company, is gratefully acknowledged.

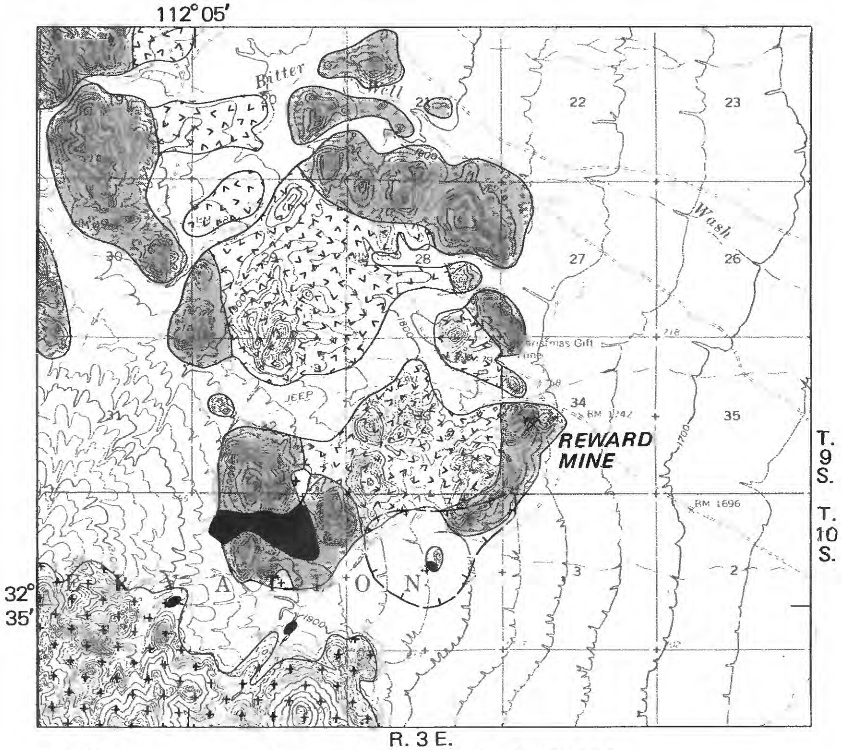
Members of the U.S. Geological Survey who assisted me in collecting, preparing, and (or) analyzing the samples used in this report include R. N. Babcock, E. F. Cooley, R. D. Coolidge, G. W. Day, J. A. Domenico, C. L. Forn, C. G. Gale III, K. L. Kulp, J. M. Nishi, J. H. Reynolds, D. F. Siems, C. D. Smith, Jr., and E. P. Welsch.

In addition, I wish to thank Mr. A. A. M. A. Gadayel of Egypt, who assisted the author in the field while working for the U.S. Geological Survey as a United Nations Special Fund Fellow.

GEOLOGIC SETTING

The geology of the Vekol Mountains is complex. Detailed reports and maps related to the areal geology include those of Hadley (1944), Carpenter (1947), Heindl (1965), Wilson and Moore (1959), and Chaffee (1974). A correlation of some of the Mesozoic units in the Vekol area has been published by Hayes (1970), and Chaffee and Hessin (1971) published a brief description of the Vekol porphyry copper deposit. For the present report no attempt was made to remap in detail any of the areas mapped by the authors cited above.

Based on the aforementioned reports and on reconnaissance field mapping, I have prepared a simplified reconnaissance geologic map (fig. 2) that shows five major subdivisions of the geologic units present in the vicinity of the Vekol copper deposit: (1) Precambrian rocks undivided; (2) Paleozoic sedimentary rocks undivided, and lenses of Tertiary(?) diorite porphyry; (3) Mesozoic sedimentary and volcanic rocks and Tertiary(?) volcanic rocks undivided; (4) Upper Cretaceous(?) intrusive rocks; and (5) Tertiary(?) conglomerate and Quaternary colluvium and alluvium undivided.



Base from
U.S. Geological
Survey, 1:62,500
Vekol Mountains
1963

0 1 2 KILOMETERS

0 1 2 MILES

Contour interval 25 feet

EXPLANATION

Quaternary and Tertiary(?) gravels and colluvium, undivided

Upper Cretaceous(?) intrusive rocks

Tertiary(?) volcanic rocks and Mesozoic sedimentary and volcanic rocks, undivided

Tertiary(?) diorite porphyry lenses and Paleozoic sedimentary rocks

Precambrian rocks, undivided

Contact

Approximate outline of Vekol deposit

FIGURE 2.—Generalized geologic map of the Vekol porphyry copper deposit area, Pinal County, Ariz. Outline of Vekol deposit modified from information supplied by H. J. Steele (written commun., 1969).

The oldest geologic formation exposed in the Vekol area is the Pinal Schist of Precambrian X age.[1] The extreme southeastern outcrop of the Pinal Schist is intruded by a coarse-grained granite thought to be of Precambrian age (fig. 2). Later, in Precambrian Y time,[1] the Apache Group was deposited over the older schist. In the eastern part of the Vekol Mountains, the Apache Group includes (from oldest to youngest) the Pioneer Shale, the Dripping Spring Quartzite, and the Mescal Limestone. During the Precambrian these formations were extensively intruded by diabase sills. Overlying the Precambrian rocks is a sequence of Paleozoic sedimentary formations including the Cambrian Bolsa Quartzite and Abrigo Formation, the Devonian Martin Formation, and the Mississippian Escabrosa Limestone.

During the Mesozoic Era, continental sedimentary rocks were deposited and some intermediate-to-felsic igneous extrusive rocks were implaced in the region. The Upper Cretaceous Vekol Formation (Heindl, 1965) is part of this sequence. A fine-grained quartz monzonite stock, to which the mineralization of the area may be genetically related, intruded at least the Precambrian-to-Paleozoic section, probably during Late Cretaceous time.

During the early Tertiary(?), diorite porphyry intruded the Abrigo Formation and formed sill-like lenses in many localities. The age of this unit is based on its probable relationship to dikes of hornblende diorite porphyry (Hadley, 1944) that cut the Cretaceous sedimentary rocks in the vicinity of the Reward mine. Erosional remnants of volcanic tuffs and basalt flows, which are also considered to be of Tertiary(?) age, are present locally in the north-central part of the study area (fig. 2).

During late Tertiary(?) time extensive gravel deposits, composed of materials derived from all of the preexisting units, accumulated in the topographic basins then present. These gravel deposits were subsequently consolidated into a caliche-cemented conglomerate. Deposits of Quaternary colluvium are present on some hillsides, and deposits of Quaternary alluvium are present in the active stream channels. Basin-and-range-type tectonic activity has caused complex faulting and tilting of all formations up to and including the upper Tertiary(?) conglomerates.

The Vekol porphyry copper deposit, consisting mostly of pyrite, chalcopyrite, and molybdenite, occurs principally in the Precambrian diabase and overlying Paleozoic sedimentary formations near their contacts with the Upper Cretaceous(?) quartz monzonite stock. The approximate outline of the Vekol deposit as defined by assays from

---

[1] An interim scheme for subdivision of Precambrian time recently adopted by the U.S. Geological Survey assigns Precambrian Y time to the interval 800–1,600 m.y. ago, and Precambrian X time to the interval 1,600–2,500 m.y. ago.

samples recovered during drilling is shown in figure 2. Sphalerite, chalcopyrite, and their oxidation products are present as replacement lenses and fracture fillings in the Martin Formation and Escabrosa Limestone in the areas surrounding the stock and the porphyry copper deposit. Probably 70–80 percent of the Vekol deposit is presently covered by upper Tertiary(?) conglomerates and Quaternary colluvium and alluvium.

SAMPLING AND ANALYSIS

SAMPLING

Geochemical samples were collected from bedrock, residual soil, nonriparian vegetation, and riparian vegetation.

BEDROCK AND RESIDUAL SOIL

A rock-soil pair of samples was collected from each formation in the exposed stratigraphic sequence of each major fault block that was identified during mapping and sampling. Where a given fault block extended more than about 300 m (1,000 ft) on strike, two or more pairs of samples were collected at sites spaced at about 300-m (1,000-ft) intervals. Samples of most igneous units were collected at widely spaced, arbitrarily selected locations, thus accounting in part for the apparent lack of uniform sampling density evident on the geochemical maps. In addition, several areas were not sampled because their lithologies were atypical for the formations present or because the formations were postmineralization in age. Outcrops not sampled were principally Mesozoic continental sedimentary rocks, upper Tertiary(?) conglomerates, and Quaternary material.

Bedrock-sample sites were arbitrarily selected within each formation, and at each site a sample was collected that was thought to be representative of the material in that area. Localities where rocks were hydrothermally altered or strongly fractured were avoided, as were localities where rocks were disturbed by drilling or mining.

The soil samples were collected at the bedrock-soil interface as close as possible to the site of the corresponding rock samples. Two observations suggest that these soils are predominantly residual: (1) the texture of the soil from any given formation is normally characteristic only of that particular formation; (2) field examination of soil and bedrock colors indicates a close correlation between the color of the parent rock and the color of the immediately overlying soil.

The rock samples were cobbed to remove obvious surface effects of weathering and were then crushed and pulverized to pieces 0.1 mm or less in diameter (about 150 mesh). The soil samples were sieved and separated into several size fractions. Unpublished investigations by this writer, as well as the results of the study at Mineral Butte (Chaffee, 1976), have indicated that a <0.063-mm fraction (<230 mesh) is usually satisfactory for soil geochemical surveys undertaken in the arid environment of the Southwestern United States; consequently, this fraction was the one used in the present investigation.

NONRIPARIAN VEGETATION

For purposes of this report, plants that grow mainly outside of the active stream channels are classified as nonriparian. For the biogeochemical survey using nonriparian vegetation, samples of leaves and stems were collected from plant species growing throughout the study area. Plants sampled at these sites were all rooted in bedrock or in thin layers of residual soil overlying bedrock. The samples of nonriparian vegetation were collected near the sites picked for the rock and soil samples. No samples were collected of plants growing in the upper Tertiary(?) conglomerates.

Three of the most widespread plant species were sampled: foothill paloverde (*Cercidium microphyllum* (Torr.) Rose and Johnston) (fig. 3*A*), ironwood (*Olneya tesota* A. Gray) (fig. 3*B*), and creosotebush (*Larrea tridentata* (Sessé and Moc. ex DC) Coville) (fig. 3*C*) (Shreve and Wiggins, 1964). Sampling experience from an earlier study (Chaffee and Hessin, 1971) indicated that stems estimated to be 1–2 years old and their associated leaves are the easiest materials to collect, and that these parts also provide meaningful geochemical information. Samples of stems of the fresh, outer 10–20 cm (4–8 in.) (actual age uncertain) of foothill paloverde were collected about 1–1.5 m

(3–5 ft) above the ground from all sides of each tree sampled. Only the stems of this species were collected; the leaves are too small and too sparse to collect in adequate amounts. Both leaves and year-old stems of ironwood were collected in a similar manner. The fresh outer leaves and stems (of uncertain age) of creosotebush were collected as far

FIGURE 3 (left and above).—Nonriparian plant species sampled for this study. *A*, Foothill paloverde (*Cercidium microphyllum*) on the left; *B*, Ironwood (*Olneya tesota*); *C*, Creosotebush (*Larrea tridentata*).

above the ground as possible (usually about 1 m (3 ft) above the ground) in order to avoid the contaminating effects of mud splatter from heavy rains. After all samples were air dried, the leaves and stems were separated, where both were present. The plant materials were then chopped in a Wiley mill and ashed for about 22 hours in an electric furnace at temperatures that did not exceed 450°C (840°F).

RIPARIAN VEGETATION

For the biogeochemical survey using riparian vegetation, leaves and stems were collected from plant species whose distribution is generally restricted to active stream channels. Samples for this survey were collected at about 300-m (1,000-ft) intervals along the stream channels of the study area. Three of the four species sampled are generally considered to be phreatophytes; that is, species known to have deep, extensive root systems that may reach the permanent ground-water table where it is present within about 30 m (100 ft) of the surface: mesquite (*Prosopis juliflora* var. *velutina* (Wooten) Sarg.) (fig. 4*A*), catclaw acacia (*Acacia greggii* A. Gray) (fig. 4*B*), and blue paloverde (*Cercidium floridum* Benth. ex A. Gray) (fig. 4*C*) (Shreve and Wiggins, 1964). The fourth species sampled was ironwood (*Olneya tesota* A. Gray), a species also sampled in the survey of nonriparian vegetation.[2] While not generally recognized as a true phreatophyte, ironwood seems to behave like one locally in that it often grows along stream banks.

[2] The ironwood trees included in the survey of nonriparian vegetation were sampled in the fall of 1970; those included in the survey of riparian vegetation were sampled in the fall of 1972. Because two different time periods were used for sampling, the chemical data for these two sample populations should not be considered strictly comparable.

Sample material for the four riparian species was selected from all sides of a given plant at about 1–1.5 m (3–5 ft) above the ground. Only 1- and 2-year-old stems of mesquite, catclaw acacia, and ironwood were collected; new growth was rejected whenever possible. The age of blue paloverde stems could not be determined; consequently, the outer 10–20 cm (4–8 in.) of live material was sampled.

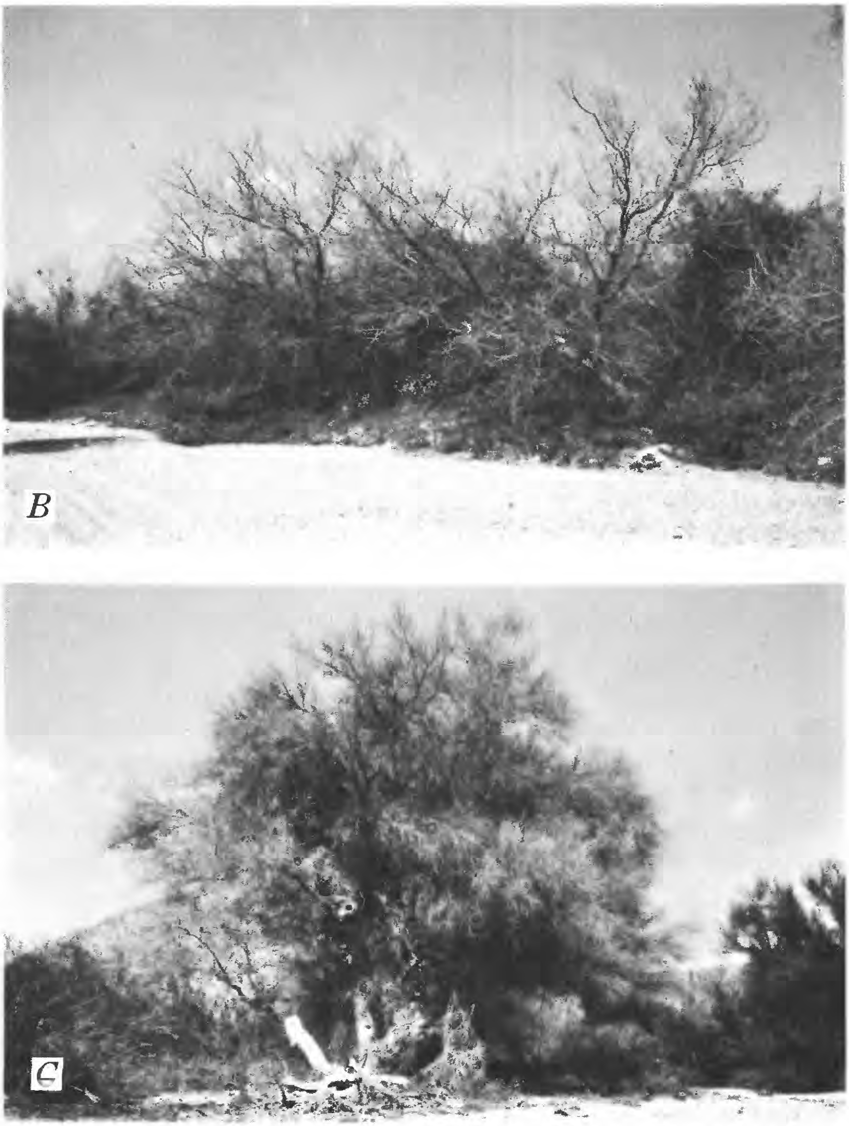


FIGURE 4 (left and above). — Riparian plant species sampled for this study. *A*, Mesquite (*Prosopis juliflora* var. *velutina*); *B*, Catclaw acacia (*Acacia greggii*); *C*, Blue paloverde (*Cercidium floridum*).

GEOCHEMICAL ANALYSIS

The rock and soil samples were analyzed for 30 elements by a six-step semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). The 30 elements (with lower limits of detection in ppm in parentheses) include: Ag (0.5), As (200), Au (10), B (10), Ba (20), Be (1), Bi (10), Ca (500), Cd (20), Co (5), Cr (10), Cu (5), Fe (500), La (20), Mg (200), Mn (10), Mo (5), Nb (10), Ni (5), Pb (10), Sb (100), Sc (5), Sn (10), Sr (100), Ti (20), V (10), W (50), Y (10), Zn (200), and Zr (10). These samples were also analyzed for seven elements by atomic absorption spectrophotometry (Ward and others, 1969). These elements, with their lower limits of detection, include: Cd (0.2), Cu (1), Hg (0.01), K (1000), Li (10), Na (1000), and Zn (5). The rock and soil samples were also analyzed for fluoride ion (F (40)) by selective ion-electrode potentiometry (Ficklin, 1970).

Nine elements were selected for discussion in this report: Mo, Mn, Ag, Pb, and Bi, detected by emission spectrography; and Cu, Zn, Cd, and Hg, detected by atomic absorption.

The vegetation samples were analyzed for 35 elements by a six-step semiquantitative emission spectrographic method (Mosier, 1972). The 35 elements (with lower limits of detection in ppm in parentheses) include: Ag (0.1), As (200), Au (2), B (5), Ba (20), Be (1), Bi (1), Cd (2), Co (10), Cr (5), Cu (1), Fe (500), Ga (2), Ge (2), In (2), La (20), Li (200), Mg (200), Mn (10), Mo (2), Na (100), Nb (50), Ni (5), Pb (1), Sb (50), Sc (5), Sn (5), Sr (100), Ti (20), Tl (2), V (10), W (50), Y (10), Zn (100), and Zr (10). These samples were also analyzed for Cu (1), Mo,[3] and Zn (5) by atomic absorption spectrophotometry (Ward and others, 1969; Nakagawa and others, 1975).

Five elements were selected for discussion in this report: Ag and Cd, analyzed by emission spectrography; and Cu, Mo, and Zn, analyzed by atomic absorption. All metal concentrations in the plant material are given in ppm of ash weight.

Soil-pH values were determined using the method described in U.S. Department of Agriculture Handbook 18 (Soil Survey Staff, 1951, p. 237).

STATISTICAL TREATMENT OF GEOCHEMICAL ANALYSES

The chemical analyses for each selected element and sample medium were separated into concentration classes, and cumulative frequency curves were constructed and evaluated in a manner similar to that used by Lepeltier (1969). The interpretation of these cumulative frequency curves was purposely biased because many of the sam-

---

[3] The lower limit of detection for molybdenum in the vegetation samples varied from 0.5 to 1.5 ppm because of minor differences in the analytical procedure used.

ples in each element-medium population were collected in a region known to contain anomalous metal concentrations. As a consequence, as high as 30 percent of the samples in any population might be anomalous, whereas in a more "normal" population probably less than 5 percent of the sample values would be considered anomalous.

The cumulative frequency curves were used in combination with visual inspection of maps showing the distributions of concentrations of the elements, in order to determine the minimum anomalous value, or threshold value, to be used for each of the geochemical maps included in this report. In all cases the 50th percentile (median value) was chosen for the background value. Background and threshold values and ranges of values for each of the four media sampled are presented in accompanying tables.

In the discussions that follow, the results obtained for the analyzed samples from each medium are extrapolated to the medium in general.

DISTRIBUTIONS OF SELECTED TRACE ELEMENTS

DISTRIBUTIONS IN BEDROCK

A total of 121 samples of bedrock and residual soil were collected and analyzed for 38 elements. Of the 38 elements, only nine (Cu, Mo, Zn, Mn, Ag, Cd, Pb, Bi, and Hg) in the soil samples and seven (Cu, Mo, Zn, Mn, Ag, Cd, and Pb) in the rock samples showed significant anomalies that could be related spatially to the known Vekol deposit. Background (median) and threshold values, summarized by rock unit, and ranges of values for nine elements in bedrock samples appear in table 1. Bismuth and mercury are included in table 1 so that the reader can compare the data for these elements in rock samples with similar information in soil samples. These two elements are not described in the accompanying maps and text, however; bismuth was not detected in any of the rock samples, and the one sample that had a high concentration of mercury was from a rock considered to be Tertiary(?) (postmineralization) in age. The spread of analytical values for mercury in the rest of the rock samples suggests the presence of only a normal background population.

The concentrations of copper, zinc, manganese, and cadmium in the bedrock samples showed significant variations that are attributed to differences in lithology. These natural variations were not observed for the other elements studied, nor were they observed for any of the elements studied in the other three sample types. Because of the effects of differences in lithology on rock chemistry, it was necessary to calculate separate background and threshold values for many of the rock units sampled (table 1).

TABLE 1. — *Summary, by rock unit, of background and threshold values and ranges of values for selected trace elements in bedrock samples, Vekol Mountains, Ariz.*

[All values in ppm. N, not detected at concentrations shown in parentheses; L, detected but in a concentration less than the value shown in parentheses; G, detected but in a concentration greater than the value shown in parentheses]

	Rock unit										Ranges of values (all rock types)
	Escabrosa Limestone	Martin Formation	Bolsa Quartzite	Abrigo Formation	Quartz monzonite	Other[1]	Diorite porphyry	Pinal Schist	Vekol Formation	Diabase	
Number of samples	30	20	14	13	10	9	9	6	6	4	
Background (median) values											
Cu	3	4	10	7	3	7	25	16	25	35	1 – 2,800
Mo	N(5)	N(5)	N(5)	N(5)	N(5)	N(5)	N(5)	N(5)	N(5)	N(5)	N(5) – 100
Zn	10	10	5	40	30	45	55	60	70	65	5 – 850
Mn	100	300	100	700	500	1,500	700	700	700	3,000	10 – G(5,000)
Ag	N(.5)	N(.5)	N(.5)	N(.5)	N(.5)	N(.5)	N(.5)	N(.5)	N(.5)	N(.5)	N(.5) – 3.0
Cd	.3	.2	L(.2)	.6	.2	.2	.3	.2	.4	.6	L(.2) – 2.7
Pb	L(10)	L(10)	10	20	15	20	15	15	20	10	L(10) – 300
Bi	N(10)	N(10)	N(10)	N(10)	N(10)	N(10)	N(10)	N(10)	N(10)	N(10)	N(10) – N(10)
Hg	.03	.03	.02	.03	.03	.02	.02	.02	.03	.02	L(.01) – .19
Threshold values											
Cu	20	20	20	20	20	20	50	50	50	50	
Mo	10	10	10	10	10	10	10	10	10	10	
Zn	40	40	40	100	40	100	100	100	100	100	
Mn	300	700	300	1,500	1,000	2,000	1,500	1,500	1,500	5,000	
Ag	L(.5)	L(.5)	L(.5)	L(.5)	L(.5)	L(.5)	L(.5)	L(.5)	L(.5)	L(.5)	
Cd	.7	.7	.7	1.0	.7	.7	.7	.7	.7	1.0	
Pb	30	30	30	30	30	30	30	30	30	30	
Bi[2]											
Hg[3]											

[1] Includes samples of Precambrian(?) granite, Dripping Spring Quartzite, Mescal Limestone, Tertiary(?) basalt, and rhyolite tuff.
[2] Values not known; element not detected in any samples.
[3] Values not known; only one sample considered anomalous.

The distributions of copper, molybdenum, zinc, manganese, silver, cadmium, and lead in bedrock samples are shown in figures 5–15. For reference, bedrock areas and the Vekol copper deposit area are outlined on these maps.

To overcome the effects of lithology on the copper, zinc, manganese, and cadmium analyses (table 1), two maps have been constructed for each of these four elements. The first map for each (figs. 5, 8, 10, 13) shows the distribution of each element by ranges of concentration without regard to lithology. The second map for each (figs. 6, 9, 11, 14) shows the distribution of sites representing background and anomalous samples based on the differences in lithology noted in table 1. The second map in each of these pairs shows fewer anomalies not related to areas of known mineralized ground and therefore provides a more accurate picture of the effects of hydrothermally related metal concentrations than does the first map. Where two maps have been constructed for an element, the one reflecting differences in lithology is the one referred to in the discussion. The one not reflecting differences in lithology is included mainly for comparison.

The distributions of copper and especially of molybdenum concentrations in bedrock samples (figs. 6, 7) are the strongest indicators that the immediate area of the known deposit is highly anomalous. Concentrations of these two elements are lowest in the outlying areas and increase toward the deposit to maxima directly over the deposit. This distribution of values is in contrast to that seen for the other selected elements. For example, the distribution of zinc concentrations (fig. 9) shows a much different pattern. No zinc anomaly occurs directly over the deposit; the most significant anomaly lies about 1 km (0.6 mi) west of the deposit, mostly in the Paleozoic formations surrounding the exposed quartz monzonite stock (fig. 2). The distributions of manganese, silver, cadmium, and lead concentrations in bedrock samples (figs. 11, 12, 14, 15) also show anomalies of these metals to the west of the Vekol deposit, in the same area as the high zinc concentration (fig. 9).

DISTRIBUTIONS IN RESIDUAL SOIL

A total of 121 samples of residual soil were collected from rock units in the vicinity of the Vekol deposit. These samples were analyzed for soil pH and for 38 elements, of which nine (Cu, Mo, Zn, Ag, Cd, Mn, Pb, Bi, and Hg) showed anomalies that seem to be spatially related to the Vekol deposit.

Soil pH was evaluated using cumulative frequency curves (Lepeltier, 1969); the values were all within normal limits for desert soils and ranged from 7.1 to 8.6 with a median (50th percentile) value of 8.3. The median values by formation are given in table 2.

TABLE 2. — *Summary, by rock unit, of median values for selected*

[All values in ppm except pH. N, not detected

	Rock unit			
	Escabrosa Limestone	Martin Formation	Bolsa Quartzite	Abrigo Formation
Number of samples	30	20	14	13
Cu	20	20	25	25
Mo	N(5)	N(5)	N(5)	N(5)
Zn	70	60	70	60
Mn	700	700	700	700
Ag	N(.5)	N(.5)	N(.5)	N(.5)
Cd	.9	.9	.6	.7
Pb	30	30	20	20
Bi	N(10)	N(10)	N(10)	N(10)
Hg	.07	.08	.05	.05
pH	8.3	8.3	7.9	8.3

No map of the distribution of pH values has been included in this report because the soil-pH values showed no obvious areal trend that could locate the Vekol deposit. However, a comparison of soil-pH values to source-rock type (table 2) indicates a close correlation between soil-pH values and lithology. Median values below 8.0 are typical of soils derived from the felsic and intermediate igneous rock units and the Bolsa Quartzite. Higher soil-pH values are typically associated with soils from calcium-rich formations. The absence of any soil-pH values below 7.0 contrasts with conditions in soil samples from the Mineral Butte copper deposit (Chaffee, 1976) and confirms field observations that, unlike the Mineral Butte area, no important outcrops of oxidizing sulfide minerals are present in the vicinity of the Vekol porphyry copper deposit.

Table 2 also shows the median values for the nine selected elements in the samples of residual soil. Unlike the median values for the bedrock samples (table 1), the values for each element determined for the soil samples remain nearly constant for all parent rock types. As a consequence, the influence of lithology has been ignored in establishing the background and threshold values for soil samples and in constructing the geochemical maps for the nine elements of interest. The background and threshold values and the ranges of values for the nine elements are summarized in table 3.

A comparison of the background (median) values by rock type for the soil samples (table 2) with the corresponding values for bedrock samples (table 1) indicates that for most sample pairs, copper, zinc, manganese, cadmium, lead, and mercury are enriched in the soils of the Vekol area compared with their parent rock. As might be expected, the amount of enrichment varies with the rock type. Samples from the Escabrosa Limestone, the Martin Formation, the Bolsa *trace elements and pH in soil samples, Vekol Mountains, Ariz.*

at concentration shown in parentheses]

Rock unit — Continued					
Quartz monzonite	Other[1]	Diorite porphyry	Pinal Schist	Vekol Formation	Diabase
10	9	9	6	6	4
30	30	25	25	25	25
N(5)	N(5)	N(5)	N(5)	N(5)	N(5)
55	90	50	50	50	60
700	700	700	300	700	700
N(.5)	N(.5)	N(.5)	N(.5)	N(.5)	N(.5)
.7	.7	.5	.4	.6	.7
20	30	20	15	20	20
N(10)	N(10)	N(10)	N(10)	N(10)	N(10)
.05	.06	.04	.07	.05	.05
7.9	8.1	8.4	7.8	7.9	8.3

[1] Includes samples of Precambrian(?) granite, Dripping Spring Quartzite, Mescal Limestone, Tertiary(?) basalt, and Tertiary(?) rhyolite tuff.

Quartzite, and the quartz monzonite, for example, show higher median values for their soil samples than for the corresponding rock samples for the elements Cu, Zn, Mn, Cd, Pb, and Hg. Copper, zinc, manganese, and lead exhibit little or no enrichment in the soil samples relative to the corresponding rock samples of diorite porphyry, Pinal Schist, Vekol Formation, and diabase. Because meaningful median values could not be calculated for molybdenum, silver, and bismuth for both bedrock and soil, it is not possible to compare unequivocally the concentrations of these three elements in the two media. However, the threshold values for molybdenum, silver, and bismuth (tables 1, 3) indicate some enrichment of silver and bismuth in the soil samples; in contrast, the threshold values for molybdenum suggest that this element is depleted in the soils relative to their parent rock material.

A comparison of the ranges of values for the rock and soil samples (tables 1, 3) shows a wider range for Cu, Mo, Mn, Ag, and Pb in the

TABLE 3. — *Summary of background and threshold values and ranges of values for selected trace elements in soil samples, Vekol Mountains, Ariz.*

[All concentrations in ppm. N, not detected at concentration shown in parentheses; L, detected but in a concentration less than the value shown in parentheses]

	Ranges of values	Background (median) values	Threshold values
Cu	8 – 1,200	25	35
Mo	N(5) – 20	N(5)	5
Zn	40 – 2,300	65	100
Mn	200 – 1,500	700	1,000
Ag	N(.5) – .7	N(.5)	.5
Cd	.3 – 5.3	.8	1.4
Pb	10 – 300	30	50
Bi	N(10) – 15	N(10)	L(10)
Hg	.02 – .59	.06	.10

rock samples than for these elements in the soil samples. Zinc, cadmium, and mercury show higher concentrations for both upper and lower limits in the soil samples. The narrow ranges of values for bismuth in the two sample types preclude a meaningful comparison for this element.

The distributions of copper, molybdenum, zinc, manganese, silver, cadmium, lead, bismuth, and mercury concentrations in samples of residual soil are shown in figures 16–23. Of all of these soil maps, those for copper and molybdenum (figs. 16, 17) most clearly locate the Vekol deposit. The copper values (fig. 16) have been divided into three groups, each plotted on the map using a different symbol. The lowest concentration group includes those sites with background concentrations. These sites are principally found outside the area of the Vekol deposit. The second and third concentration groups represent samples containing anomalous copper concentrations, and they illustrate the district-wide extent of the copper anomaly. The cluster of sites of highest copper concentration, as well as the cluster of sites representing anomalous concentrations of molybdenum (fig. 17), are confined to the immediate area of the Vekol deposit. The overall distribution of copper in soil samples indicates a general increase in anomalous copper from background areas toward the immediate area of the deposit.

The distributions of zinc, manganese, silver, cadmium, lead, bismuth, and mercury concentrations (figs. 18–23) are different from those of copper and molybdenum. The highest zinc concentrations (fig. 18) are generally confined to soils formed on the Paleozoic carbonate formations cropping out northeast of the Vekol deposit and to soils formed on outcrops of these same formations about 1 km (0.6 mi) west of the deposit. Zinc was previously prospected for and mined from these carbonate formations.

The distributions of manganese, silver, cadmium, and lead concentrations (figs. 19–22) are similar to that of zinc, suggesting that these four metals may have a common genetic association with zinc. These five elements seem to form a crude aureole around the copper and molybdenum. Similar zoning of metals is recognized around other porphyry copper deposits.

Bismuth (fig. 22) may also belong to this aureole of elements; however, bismuth was detected in only eight samples, which was not enough to substantiate its pattern. High mercury concentrations (fig. 23) are clustered in an area just west of the Vekol deposit. This distribution pattern does not fit that of any other element described in this report. Mercury is normally thought to be concentrated at the outermost fringes of a zoned deposit. Possibly the high mercury concentrations west of the Vekol deposit are related to a later stage of hydrothermal activity than that associated with the copper deposit itself.

DISTRIBUTIONS IN NONRIPARIAN VEGETATION

Three nonriparian plant species were collected and analyzed for 38 elements. Of these 38 elements only five (Cu, Mo, Zn, Ag, and Cd) showed anomalies that seemed to have a spatial relation to the Vekol deposit. For the other 33 elements, either insufficient reported values above the lower detection limit were obtained for a given plant species, or the distributions of the reported values did not show systematic variations that could be related to the known deposit. The background and threshold values and ranges of values for concentrations of the five selected elements in the ash of samples of the nonriparian plants are summarized in table 4. The data in this table are based on 86 samples of foothill paloverde stems, 68 leaf-stem pairs of ironwood, and 84 leaf-stem pairs of creosotebush. Silver and cadmium were not detected in any samples of foothill paloverde and cadmium was not detected in any samples of ironwood; consequently, no maps showing the distribution of these elements in samples of foothill paloverde or ironwood are included in this report. Background and threshold values (table 4) indicate that copper is more concentrated in the ash of creosotebush leaves and stems than in either part of the other two species, molybdenum is most concentrated in the ash of ironwood leaves and stems, and zinc is most concentrated in the ash of foothill paloverde stems. Table 4 also reveals that, when compared with the other two species, the ash of foothill paloverde stems seems to be anomalously impoverished in molybdenum, and that silver seems to be most enriched in the ash of creosotebush leaves and stems and most impoverished in the ash of foothill paloverde stems. Although background and threshold values for cadmium could not be determined in all species, this element is clearly more enriched in the ash of creosotebush than in the other two species. Cadmium, which substitutes for zinc in many natural materials, does not seem to mimic zinc in these nonriparian plant species. The difference in uptake of these two elements may be related to the fact that cadmium is not considered to be an element essential to plant growth, whereas zinc is.

When the background and threshold values for trace elements in the ash of the nonriparian plant species (table 4) are placed alongside the corresponding values for rock and soil samples (tables 1, 3), it is clear that the plant ash is most enriched in copper and zinc. In most cases molybdenum is also most concentrated in the plant ash. For silver and cadmium in plant ash, too few values above the detection limits were found (table 4) to permit a comparison of the background and threshold values for these elements with their associated rock and soil values.

TABLE 4. — *Summary of background and threshold values and ranges of values for selected trace elements in the ash of nonriparian plant species, Vekol Mountains, Ariz.*

[All concentrations in ppm. N, not detected at concentration shown in parentheses; L, detected but in a concentration less than the value shown in parentheses]

Sample description	Number of samples	Ranges of values					Background (median) values					Threshold values				
		Cu	Mo	Zn	Ag	Cd	Cu	Mo	Zn	Ag	Cd	Cu	Mo	Zn	Ag	Cd
Foothill paloverde stems.	86	60–230	L(0.5)–3	120–1,900	N(0.1)[1]	N(2)[1]	120	1.0	450	N(0.1)[1]	N(2)[1]	150	2.5	850	N(0.1)[1]	N(2)[1]
Ironwood leaves.	68	40–210	2.0–47	80–2,400	N(.1)–.1	N(2)[1]	90	7.0	240	N(.1)	N(2)[1]	130	15	500	L(.1)	N(2)[1]
Ironwood stems.	68	40–370	2.0–50	80–2,600	N(.1)–.1	N(2)[1]	90	10	300	N(.1)	N(2)[1]	130	22	550	L(.1)	N(2)[1]
Creosotebush leaves.	84	120–610	2.0–13	105–1,700	N(.1)–10	N(2)–10	220	4.5	230	N(.1)	N(2)	340	6.5	330	.15	L(2)
Creosotebush stems.	84	120–610	1.5–13	110–1,700	N(.1)–10	N(2)–10	260	4.5	250	N(.1)	N(2)	360	6.5	350	.15	2

[1] Element not detected in any samples.

FOOTHILL PALOVERDE

The distributions of copper, molybdenum, and zinc in the ash of foothill paloverde stems are shown in figures 24–26. Locations of the copper anomalies for this species (fig. 24) generally coincide with those for copper in samples of bedrock and residual soil (figs. 6, 16); the distribution of copper in samples of foothill paloverde ash is almost as effective as the distributions of copper in rocks and soils in locating the Vekol deposit.

No good clustering of sites exists for anomalous concentrations of molybdenum in the ash of foothill paloverde stems (fig. 25); the molybdenum map is useful for locating the area of the Vekol deposit only if considered in conjunction with the copper map (fig. 24).

The distribution of zinc in the ash of foothill paloverde stems (fig. 26) shows a significant zinc anomaly about 1 km (0.6 mi) to the west of the Vekol deposit, mostly in the area of the Paleozoic sedimentary rocks. The area of this anomaly is nearly identical to that observed for zinc in bedrock (fig. 9). The map showing the distribution of zinc in residual soils (fig. 18), however, reflects the known zinc occurrences in the district better than do either the bedrock or foothill paloverde maps. Neither silver nor cadmium was detected in any of the samples of foothill paloverde ash.

IRONWOOD

The distributions of copper, molybdenum, zinc, and silver in the ash of ironwood leaves and stems are shown in figures 27–30. Observations at Mineral Butte (Chaffee, 1976) indicated that the most significant[4] plant anomalies were those occurring at sites where samples of both the leaves and stems contained anomalous concentrations of a given element. This observation holds true in the vicinity of the Vekol deposit. Unless otherwise indicated, anomalies for all plant species discussed in succeeding sections are for sites at which both plant parts contained anomalous concentrations of the metal under discussion.

As has been observed for the rock and soil samples, the anomalies for copper and molybdenum in the ash of ironwood leaves and stems (figs. 27, 28) generally lie in the immediate area of the known deposit and also to the west of the deposit in the outcrop of Paleozoic sedimentary rocks. The zinc anomalies for ironwood are restricted to the Paleozoic sedimentary formations west and northeast of the area of the Vekol deposit (fig. 29) but are not so widespread as are the zinc anomalies found in soil samples. The anomalies for silver in ironwood ash (fig. 30), like those in rock and soil samples, are restricted to the

[4] A significant (real) anomaly is one related to elemental concentrations caused by mineralization. A nonsignificant (false) anomaly is one related to elemental concentrations caused by something other than mineralization, such as contamination or statistical variations.

area west of the deposit. Cadmium was not detected in any of the ironwood samples.

A comparison of the maps for foothill paloverde and ironwood (figs. 24–30) suggests that, in terms of locating the Vekol deposit, the molybdenum content of ironwood works best. Foothill paloverde is the better sample medium for zinc; neither plant type is better than the other for copper. The distributions of anomalies for ironwood samples are generally about the same as those for bedrock samples; the distributions of anomalies for soil samples are more widespread than those of either the bedrock samples or the ironwood samples.

CREOSOTEBUSH

The distributions of copper, molybdenum, zinc, silver, and cadmium in the ash of creosotebush leaves and stems are shown in figures 31–35. The maps for copper, molybdenum, and zinc (figs. 31–33) again show the familiar patterns established for bedrock, residual soil, and the other nonriparian plants. However, the concentrations of copper and molybdenum in the ash of creosotebush samples tend to increase gradually toward the center of the Vekol deposit and possibly toward the Upper Cretaceous(?) intrusive where it is exposed west of the Vekol deposit (fig. 2). These concentration trends for copper and molybdenum in the ash of creosotebush are not observed for samples of foothill paloverde or ironwood, but they closely approximate the concentration trends observed for the rock and soil samples.

Anomalies for silver and particularly for cadmium in the ash of creosotebush (figs. 34, 35) are more extensive than are anomalies for these elements in bedrock (figs. 12, 14) or residual-soil samples (figs. 20, 21).

Creosotebush is a widespread plant species in the lower Sonoran Desert and the most widespread of the species described here. This fact, together with the significant anomalies seen for this plant in the study area, suggests that creosotebush may be the best nonriparian plant species to use in other biogeochemical surveys for copper deposits present in similar stratigraphic and geochemical environments. Comparisons of the maps for rock and soil (figs. 5–23) with the equivalent maps for creosotebush (figs. 31–35) also indicate that creosotebush should be as effective a sampling medium as either rock or soil for reconnaissance geochemical surveys in the lower Sonoran Desert.

DISTRIBUTIONS IN RIPARIAN VEGETATION

Four riparian plant species were collected and analyzed for 38 elements. Of these 38 elements only four (Cu, Mo, Zn, Ag) showed anomalies that seemed to be spatially related to the Vekol deposit. For the other 34 elements, either insufficient reported values above the lower detection limit were obtained for a given plant species, or the distributions for the reported values did not show systematic variations that could be related to the known deposit. Background and threshold values and ranges of values for concentrations of these four elements in ashed samples of the four riparian species are given in table 5. The data in this table are based on 70 leaf-stem pairs of mesquite, 74 leaf-stem pairs of catclaw acacia, 54 samples of blue paloverde leaves, 56 samples of blue paloverde stems, 72 samples of ironwood leaves, and 73 samples of ironwood stems.

Background and threshold values indicate that copper and zinc concentrations are similar in these four riparian species, but molybdenum and silver are most concentrated in mesquite ash and most impoverished in blue paloverde ash. Because the molybdenum concentrations in the ash of foothill paloverde stems were also anomalously low (table 4), it seems that in this instance low molybdenum concentrations may be a physiologic peculiarity of the genus *Cercidium.*

The biogeochemical survey of riparian vegetation required sites other than those used to sample rocks, residual soils, and nonriparian vegetation. Because sampling of the four riparian species was done within the same study area as the sampling of the other three media, some general comparisons can be made between background and threshold values for the riparian species and those for other media. A comparison of the background and threshold values for the samples of riparian vegetation (table 5) with similar data for the rock and soil samples (tables 1, 3) indicates clearly that copper and zinc are enriched in the ash of the riparian plants relative to the rocks and soils.

Different lower limits of detection were used for determining the content of molybdenum and silver in the rock and soil samples and in the samples of riparian vegetation. Nevertheless, the background and threshold values for molybdenum in tables 1, 3, and 5 can be compared, in part; such a comparison suggests that molybdenum is enriched in the ash of both mesquite and catclaw acacia samples relative to the rock and soil samples. In the case of silver, most of the detected values for the riparian plants are below the lower detection limit used for the rock and soil data; consequently, any meaningful comparison of the rock and soil values with the values for the riparian plant species is precluded.

The ranges of values for the sample populations for all of the riparian plants are more restricted than those of the sample populations of the rocks and residual soils from the same study area. These restricted ranges make it more difficult to separate concentrations

TABLE 5. — *Summary of background and threshold values and ranges of values for selected trace elements in the ash of riparian plant species, Vekol Mountains, Ariz.*

[All concentrations in ppm. N, not detected at concentration shown in parentheses; L, detected but in a concentration less than value shown in parentheses]

Sample description	Number of samples	Ranges of values				Background (median) values				Threshold values			
		Cu	Mo	Zn	Ag	Cu	Mo	Zn	Ag	Cu	Mo	Zn	Ag
Mesquite leaves.	70	30–420	3.0–39	130– 880	N(0.1)–3.0	110	11	380	0.1	150	20	500	0.3
Mesquite stems.	70	50–250	2.0–41	160– 900	N(.1)– .7	120	9.0	400	L(.1)	160	15	600	.15
Catclaw acacia leaves.	74	35–340	2.5–15	100– 630	N(.1)– .3	120	6.0	250	L(.1)	170	8	330	.1
Catclaw acacia stems.	74	60–200	2.0–19	225– 800	N(.1)– .1	120	7.0	450	N(.1)	170	11	530	L(.1)
Blue paloverde leaves.	54	40–210	L(1.5)–12	220–1,500	N(.1)– .1	100	2.0	350	N(.1)	150	3.0	400	L(.1)
Blue paloverde stems.	56	30–230	L(1.5)–7.0	210– 770	N(.1)[1]	80	1.5	400	N(.1)[1]	110	2.5	500	N(.1)[1]
Ironwood leaves .	72	30–120	L(1.5)–17	100– 550	N(.1)–5.0	75	4.0	220	N(.1)	100	7	260	L(.1)
Ironwood stems. .	73	50–130	L(1.5)–22	100– 840	N(.1)– .2	85	4.0	450	N(.1)	110	9	500	L(.1)

[1] Silver not detected in any samples.

representing background values from concentrations representing anomalous values. Consequently, some difficulty is to be expected in evaluating some of the biogeochemical maps based on samples of riparian vegetation.

Slight but notable differences exist in the background and threshold values for ironwood samples collected for the nonriparian and riparian studies (tables 4, 5). As noted in the section on sampling, these differences may result from the fact that the riparian plants were collected 2 years later than the nonriparian plants. The differences may also be caused in part by the normal spread of analytical values or by different effects of a deep or nonexistent ground-water table at the sites where nonriparian plants were collected, as compared to a relatively shallow ground-water table at the sites where riparian plants were collected.

MESQUITE

The distributions of copper, molybdenum, zinc, and silver in the ash of mesquite leaves and stems are shown in figures 36–39. As mentioned for the nonriparian plants, the sites at which both plant parts are anomalous indicate the truly significant anomalies for the riparian plants. The maps for copper and zinc (figs. 36, 38) show many anomalies over and downstream from the known deposit, where the mesquite trees are growing in thick Quaternary alluvium. These anomalies extend about 1.5 km (about 1 mi) downstream from any outcrop. The copper anomalies that occur upstream from the deposit are not clearly understood; they may be related to small outcrops of altered Upper Cretaceous(?) quartz monzonite that are exposed in the stream channels near these anomalous sites (fig. 2).

The zinc anomalies at those sites just north of the major stream channel that crosses the known deposit (fig. 38) are significant and are related to the high zinc concentrations present in the rocks and soils in the area between the known deposit and the Reward mine.

The map showing the distribution of molybdenum anomalies (fig. 37) is disappointing in view of Huff's (1970) success in using molybdenum in the ash of mesquite stems to locate the copper-molybdenum deposits of the Pima district, Arizona. The molybdenum anomalies seem to be completely random and seem to show no spatial relationship to the Vekol deposit. The spread of analytical values for molybdenum in the ash of mesquite leaves and stems (table 5) seems to be adequate and is evidently not the cause of the poor correlation. Anomalous molybdenum in the ash of either mesquite leaves or stems is not useful in locating the Vekol copper deposit.

Silver (fig. 39) is occasionally anomalous in the ash of samples of mesquite leaves or stems but rarely in both parts from the same site;

thus, few significant silver anomalies exist. The low levels of silver concentration in the samples and the poor spread of analytical values (table 5) make interpretation of silver in the ash of mesquite samples difficult. Silver anomalies in mesquite occur upstream from the known deposit as was observed for copper in this species. The known association of these two elements in porphyry copper deposits may be reflected in these plant samples. Nevertheless, the data for silver in mesquite samples do not seem to be very useful in delineating the Vekol deposit.

CATCLAW ACACIA

The distributions of copper, molybdenum, zinc, and silver anomalies in the ash of catclaw acacia leaves and stems are shown in figures 40–43. The copper, molybdenum, and silver anomalies (figs. 40, 41, 43) do not reveal any systematic distributions that locate the Vekol deposit; but the distribution of zinc (fig. 42) shows significant anomalies in the major stream channel where it crosses outcrops of the deposit and as far as 2 km (1.2 mi) downstream from the deposit where the catclaw acacia trees are growing in Quaternary alluvium. Other significant zinc anomalies are present in the samples from stream channels located between this major stream channel and the area of the Reward mine.

Catclaw acacia is, overall, clearly not so effective a sampling medium as mesquite in locating the Vekol deposit. This same conclusion was reached regarding the use of catclaw acacia as a sampling medium around the copper deposit at Mineral Butte (Chaffee, 1976). The reason for this lower effectiveness is not known but must be related to differences in the physiology of the two species.

BLUE PALOVERDE

The distributions of copper, molybdenum, zinc, and silver anomalies in the ash of blue paloverde leaves and stems are shown in figures 44–47. The distribution of copper anomalies in this species (fig. 44) correlates reasonably well with the location of the Vekol deposit (although not so well as does the distribution of copper anomalies in mesquite). The distributions of molybdenum and silver anomalies in blue paloverde (figs. 45, 47), on the other hand, clearly do not locate the known deposit.

The zinc anomaly present in the major stream channel crossing the Vekol deposit (fig. 46) effectively locates the deposit. This anomaly is present in blue paloverde trees growing in Quaternary alluvium more than 1.5 km (about 1 mi) downstream from any outcrop along that channel. Samples of blue paloverde collected in the stream channels just south of the Reward mine also exhibit zinc anomalies, as did the mesquite and catclaw acacia samples from that area.

Another zinc anomaly is present in the first major east-west stream channel north of the Reward mine area (fig. 46). The other plant species sampled do not show such a well-pronounced zinc anomaly in this channel; field investigations suggest that this anomaly is nonsignificant and is not related to any mineralized ground. Overall, blue paloverde serves to locate the Vekol deposit better than does catclaw acacia, but not so effectively as does mesquite.

IRONWOOD

The distributions of copper, molybdenum, zinc, and silver anomalies in the ash of riparian ironwood leaves and stems are shown in figures 48–51. The copper, molybdenum, and silver anomalies in ironwood ash (figs. 48, 49, 51) do not correlate well with the location of the Vekol deposit. It is noteworthy that most of the anomalies for these three elements at any given site are either for leaves or for stems but not for both parts, suggesting a lack of significant anomalies and a possible explanation for the poor correlation observed.

Zinc anomalies in riparian ironwood ash (fig. 50), in contrast, correlate well with the Vekol deposit. The anomaly present in the main stream channel crossing the deposit is also present in ironwood plants growing in Quaternary alluvium at least 3 km (about 2 mi) downstream from any outcrops. This anomaly extends farther downstream from the deposit than do any of the anomalies for the other elements or plant types. Zinc anomalies are again present in samples from the stream channels that begin just south of the Reward mine.

SUMMARY AND CONCLUSIONS

This report describes and compares different geochemical exploration techniques applied in the area of a partially exposed and relatively undisturbed porphyry copper deposit. The results of the investigation of this deposit are summarized below along with some comments as to how these results might be applied in the search for other similar but as-yet undiscovered porphyry copper deposits that may be present elsewhere.

1. Anomalies of as many as nine elements (Cu, Mo, Zn, Mn, Ag, Cd, Pb, Bi, and Hg) correlated spatially with the Vekol porphyry copper deposit. The distributions of anomalies of these elements in samples of bedrock, residual soil, and nonriparian plants suggest the existence of an aureole of Zn, Mn, Ag, Cd, Pb, and Bi surrounding the Cu-Mo deposit at the present level of erosion. Aureoles of pathfinder elements around a Cu-Mo core should greatly enlarge any potential target area. Thus, geochemical prospecting surveys looking for deposits similar in

nature to the Vekol deposit might be improved by analyzing samples for pathfinder elements as well as for copper and molybdenum.

2. The results of the bedrock geochemical survey in the area of the Vekol deposit revealed significant differences in background concentrations for different rock types. These results emphasize the importance of orientation surveys and indicate that for bedrock geochemical surveys including samples of widely differing lithologies, the analytical results for any element should initially be grouped and evaluated according to the various lithologies present.

3. The distributions of residual-soil anomalies in the vicinity of the Vekol deposit correlated better with the areal distribution of mineralized ground than did the distributions of the bedrock anomalies. Residual soil proved to be a better sample medium than bedrock because samples of residual soil tended to represent the integrated chemistry of a larger volume of material than did bedrock samples.

4. Soil-pH values showed no obvious areal trends that could be related to the site of the Vekol copper deposit, but a close correlation was found between soil-pH values and type of parent rock. These results suggest that soil-pH surveys are probably not generally useful as a prospecting technique in the lower Sonoran Desert environment.

5. The concentrations of the various selected elements in the different plant species collected for this study varied with each element, plant species, and plant part. No one of the plant species sampled for this study was most enriched in every selected element. These differences in concentration emphasize the importance of conducting an orientation study as part of any biogeochemical survey.

6. There was no evidence that the distribution of anomalies of either plant part alone correlated better than the other part with the distribution of mineralized ground in the area of the Vekol deposit. The most significant plant anomalies were those at sites where both plant parts proved anomalous.

7. The distributions of anomalies obtained in the biogeochemical survey of nonriparian vegetation corresponded closely to distributions obtained in the geochemical surveys based on bedrock and residual soil, suggesting that surveys using nonriparian vegetation can effectively locate exposed or partially exposed base-metal deposits. Creosotebush provided more clear-cut and widespread anomalies than did either of the other two nonriparian species sampled. Because samples of bedrock and soil are easier to collect and analyze than are samples of nonriparian plants, there seems to be little justification for conducting surveys using nonriparian vegetation where bedrock or residual soil can be sampled. Surveys using nonriparian vegetation

may be more useful in the future if more effective techniques for identifying anomalous vegetation can be found.

8. The distributions of copper and zinc anomalies in the ash of mesquite leaves and stems and of zinc anomalies in the ash of the leaves and stems of the other three species of riparian plants correlated best with the distribution of mineralized ground in the study area. Furthermore, anomalies related to the Vekol deposit were detected in analyses of the riparian plants growing in Quaternary alluvium at least 1.5 km (about 1 mi) downstream from any outcrop. Zinc anomalies extended the farthest of any of the selected elements. These results suggest that analyses of zinc, and perhaps copper and molybdenum, in samples of riparian plants should be especially effective in reconnaissance surveys searching for another deposit like the Vekol deposit.

REFERENCES CITED

Brown, R. G., 1970, Geochemical survey of the vicinity of Oracle, Arizona: Arizona State Univ. M.S. thesis, 56 p.

Carpenter, R. H., 1947, The geology and ore deposits of the Vekol Mountains, Pinal County, Arizona: Palo Alto, Calif., Stanford Univ. Ph.D. thesis, 108 p.

Chaffee, M. A., 1974, Stratigraphic relations of the Bolsa Quartzite, Vekol Mountains, Pinal County, Arizona: U.S. Geol. Survey Jour. Research, v. 2, no. 2, p. 143–146.

——— 1976, Geochemical exploration techniques based on distribution of selected elements in rocks, soils, and plants, Mineral Butte copper deposit, Pinal County, Arizona: U.S. Geol. Survey Bull. 1278-D, 55 p.

Chaffee, M. A., and Hessin, T. D., 1971, An evaluation of geochemical sampling in the search for concealed "porphyry" copper-molybdenum deposits on pediments in southern Arizona, *in* Geochemical exploration (Internat. Geochemical Explor. Symp., 3d, Proc.): Canadian Inst. Mining and Metallurgy Spec. Vol., no. 11, p. 401–409.

Clarke, O. M., Jr., 1953, Geochemical prospecting for copper at Ray, Arizona: Econ. Geology, v. 48, no. 1, p. 39–45.

Cooper, J. R., and Huff, L. C., 1951, Geological investigations and geochemical prospecting experiment at Johnson, Arizona: Econ. Geology, v. 46, no. 7, p. 731–756.

Davis, J. D., and Guilbert, J. M., 1973, Distribution of the radioelements potassium, uranium, and thorium in selected porphyry copper deposits: Econ. Geology, v. 68, no. 2, p. 145–160.

Drewes, Harald, 1973, Geochemical reconnaissance of the Santa Rita Mountains, southeast of Tucson, Arizona: U.S. Geol. Survey Bull. 1365, 67 p.

Eidel, J. J., Frost, J. E., and Clippinger, D. M., 1968, Copper-molybdenum mineralization at Mineral Park, Mohave County, Arizona, *in* Ridge, J. D., ed., Ore deposits of the United States, 1933–1967 (Graton-Sales Volume): New York, Amer. Inst. Mining, Metall., and Petroleum Eng., v. 2, p. 1258–1281.

Ficklin, W. H., 1970, A rapid method for the determination of fluoride in rocks and soils, using an ion-selective electrode, *in* Geological Survey research 1970: U.S. Geol. Survey Prof. Paper 700–C, p. C186–C188.

Green, C. R., and Sellers, W. D., 1964, Arizona climate: Tucson, Arizona Univ. Press, 503 p.

Grimes, D. J., and Marranzino, A. P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geol. Survey Circ. 591, 6 p.

Hadley, J. B., 1944, Copper and zinc deposits in the Reward area, Casa Grande mining district, Pinal County, Arizona: U.S. Geol. Survey Strategic Minerals Inv. Prelim. Map, sheet 1.

Hayes, P. T., 1970, Cretaceous paleogeography of southeastern Arizona and adjacent areas: U.S. Geol. Survey Prof. Paper 658–B, 42 p.

Heindl, L. A., 1965, Mesozoic formations in the Vekol Mountains, Papago Indian Reservation, Arizona: U.S. Geol. Survey Bull. 1194–G, 9 p.

Huff, L. C., 1970, A geochemical study of alluvium-covered copper deposits in Pima County, Arizona, *with a section on* Analytical methods, by A. P. Marranzino and H. M. Nakagawa: U.S. Geol. Survey Bull. 1312–C, 31 p.

——— 1971, A comparison of alluvial exploration techniques for porphyry copper deposits, *in* Geochemical exploration (Internat. Geochemical Explor. Symp., 3d, Proc.): Canadian Inst. Mining and Metallurgy Spec. Vol., no. 11, p. 190–194.

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

Lovering, T. S., Huff, L. C., and Almond, Hy, 1950, Dispersion of copper from the San Manuel copper deposit, Pinal County, Arizona: Econ. Geology, v. 45, no. 6, p. 493–514.

Mosier, E. L., 1972, A method for semiquantitative spectrographic analysis of plant ash for use in biogeochemical and environmental studies: Applied Spectroscopy, v. 26, no. 6, p. 636–640.

Nakagawa, H. M., Watterson, J. R., and Ward, F. N., 1975, Atomic absorption determination of molybdenum in plant ash, *in* Ward, F. N., ed., New and refined methods of trace analysis useful in geochemical exploration: U.S. Geol. Survey Bull. 1408, p. 29–36.

Robinson, R. F., and Cook, Annan, 1966, The Safford copper deposit, Lone Star mining district, Graham County, Arizona, *in* Titley, S. R., and Hicks, C. L., eds., Geology of the porphyry copper deposits, southwestern North America: Tucson, Ariz. Univ. Press, p. 251–266.

Shreve, Forrest, and Wiggins, I. L., 1964, Vegetation and flora of the Sonoran Desert, Volume 1: Stanford, Calif., Stanford Univ. Press, 840 p.

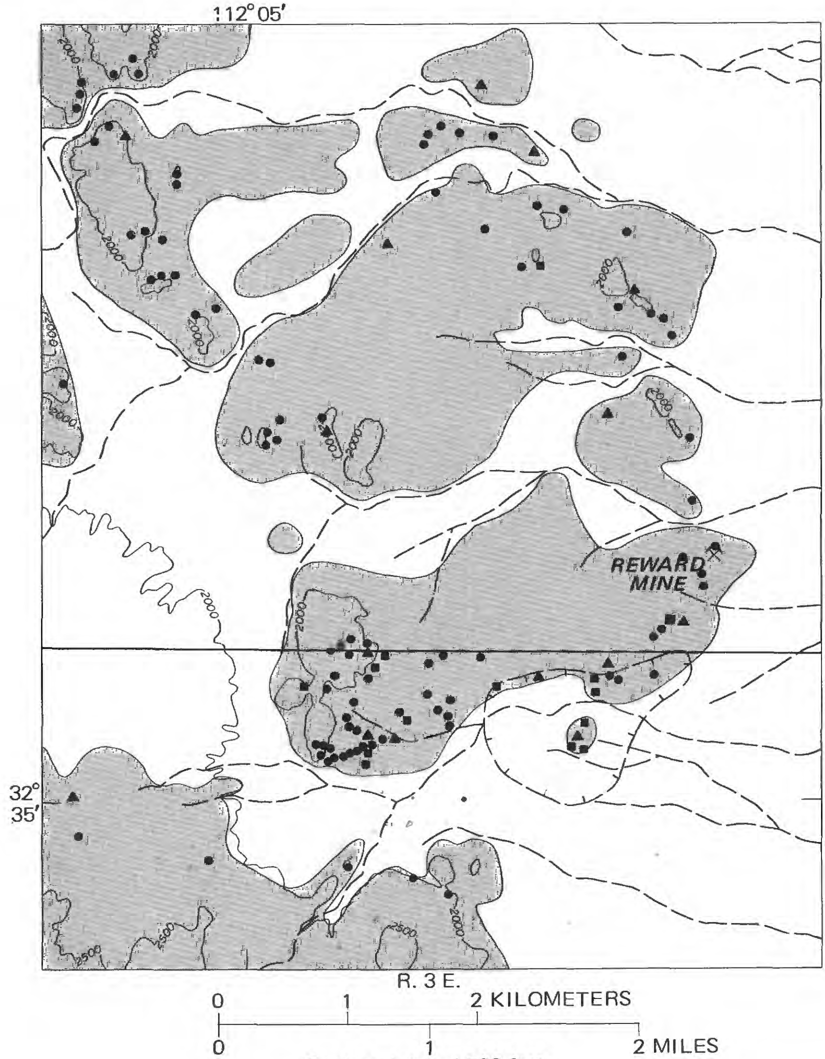
Soil Survey Staff, 1951, Soil survey manual: U.S. Dept. Agriculture, Agriculture Handb. 18, 503 p.

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.

Warren, H. V., Delavault, R. E., and Irish, R. I., 1951, Further biogeochemical data from the San Manuel copper deposit, Pinal County, Arizona: Geol. Soc. America Bull., v. 62, no. 8, p. 919–930.

Wilson, E. D., and Moore, R. T., 1959, Geologic map of Pinal County, Arizona: Tucson, Arizona Bur. Mines.

FIGURES 5–51



EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

Approximate outline of Vekol deposit

Intermittent stream

• 1–19 ppm Cu

▲ 20–49 ppm Cu

■ ≥ 50 ppm Cu

FIGURE 5. — Distribution of copper, bedrock samples, Vekol Mountains, Ariz.

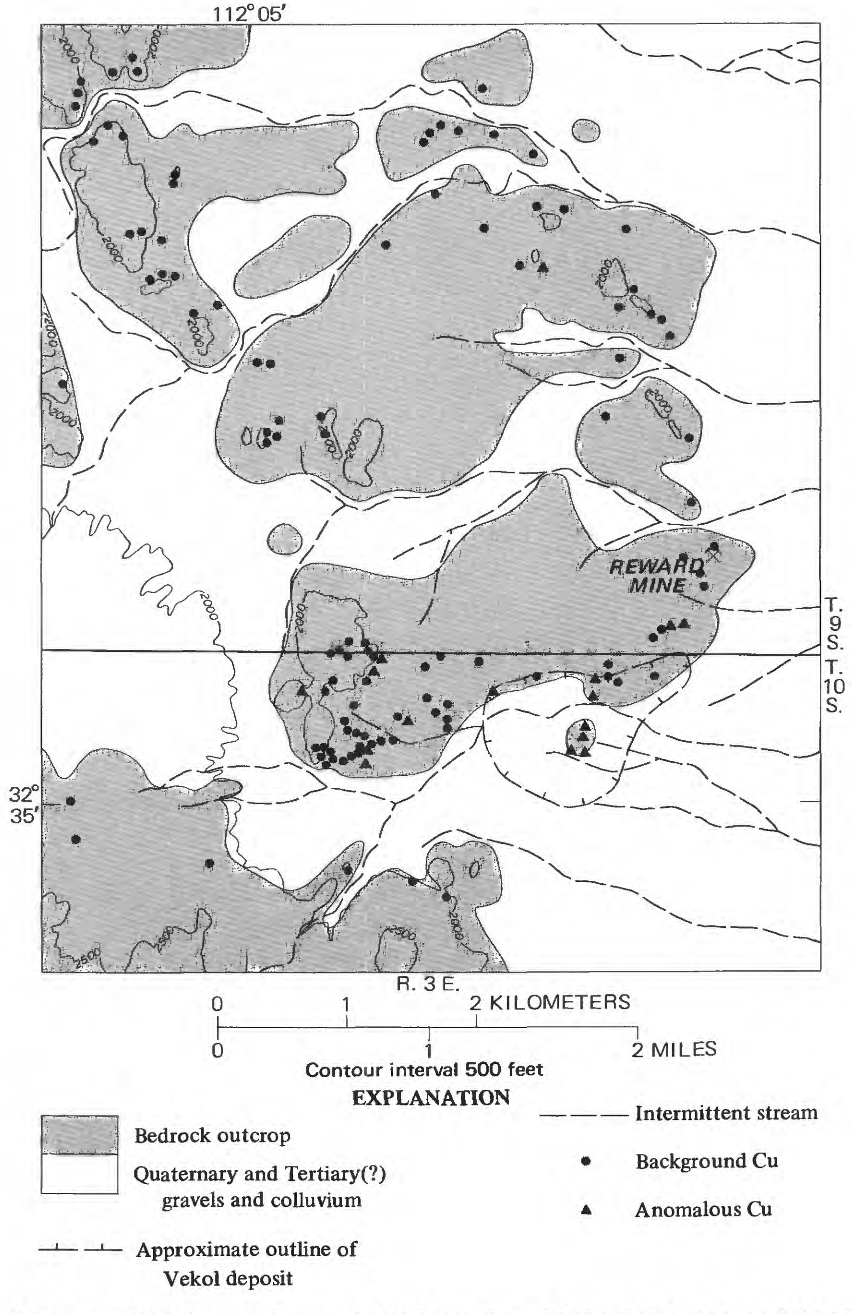


FIGURE 6. — Distribution of copper, bedrock samples, with threshold values established according to lithology, Vekol Mountains, Ariz.

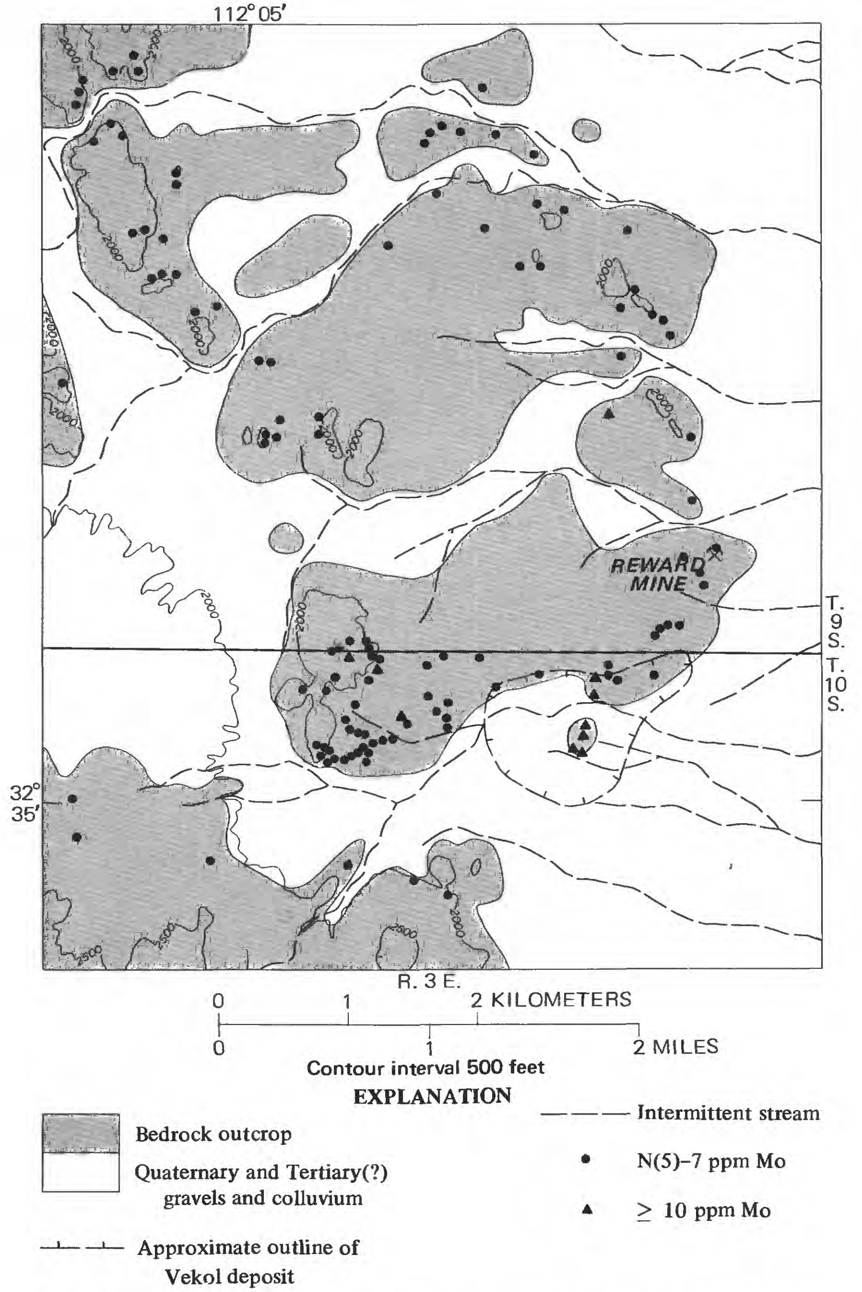
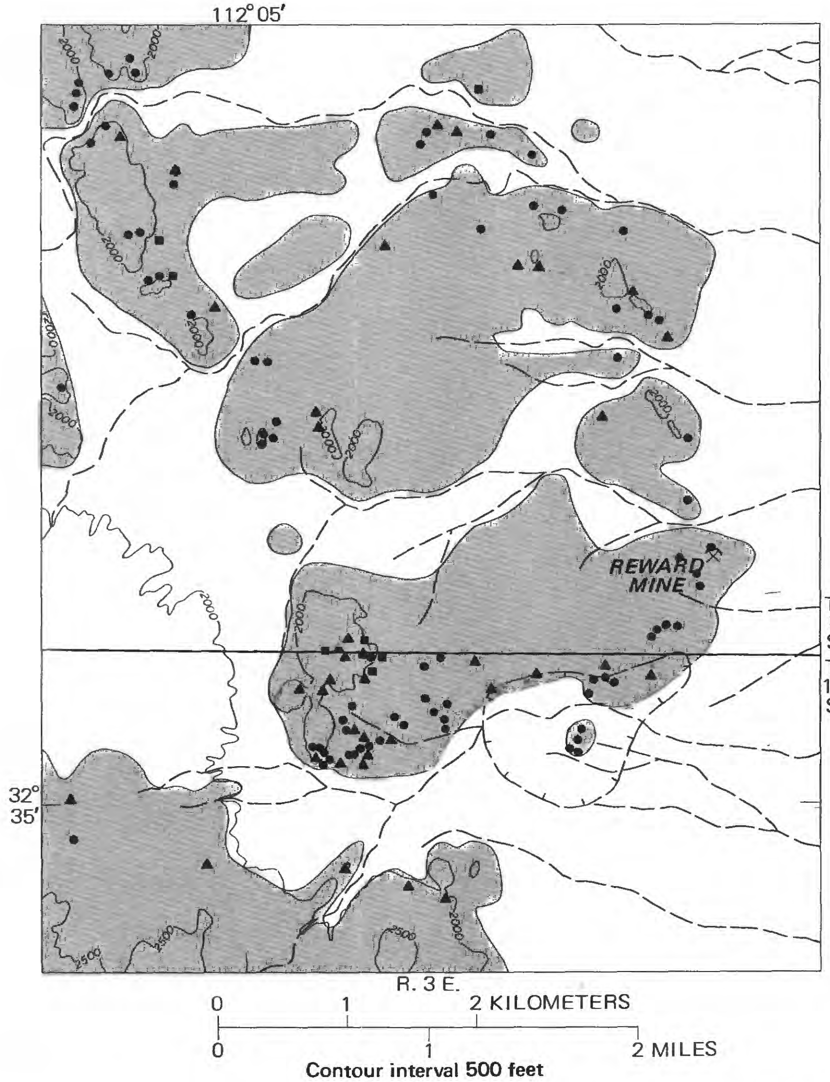


FIGURE 7. — Distribution of molybdenum, bedrock samples, Vekol Mountains, Ariz.



EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

Approximate outline of Vekol deposit

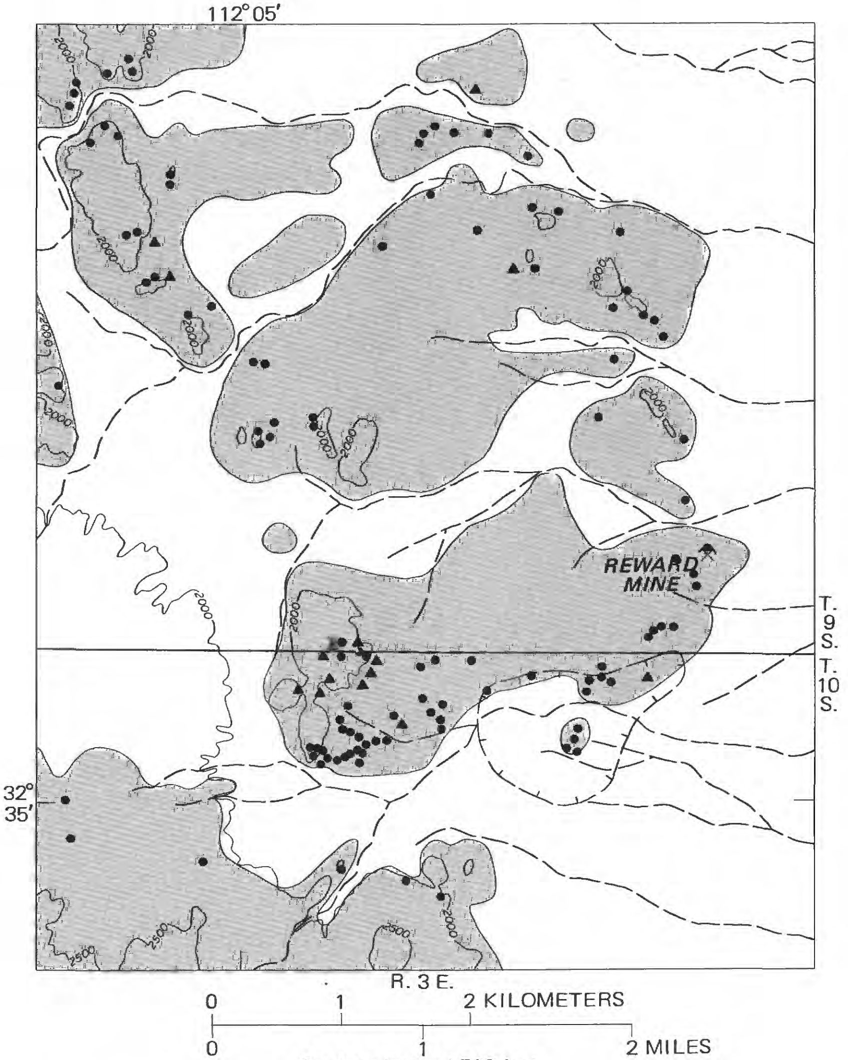
Intermittent stream

● 5–39 ppm Zn

▲ 40–99 ppm Zn

■ ≥ 100 ppm Zn

FIGURE 8. — Distribution of zinc, bedrock samples, Vekol Mountains, Ariz.



EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

Approximate outline of Vekol deposit

Intermittent stream

● Background Zn

▲ Anomalous Zn

FIGURE 9.—Distribution of zinc, bedrock samples, with threshold values established according to lithology, Vekol Mountains, Ariz.

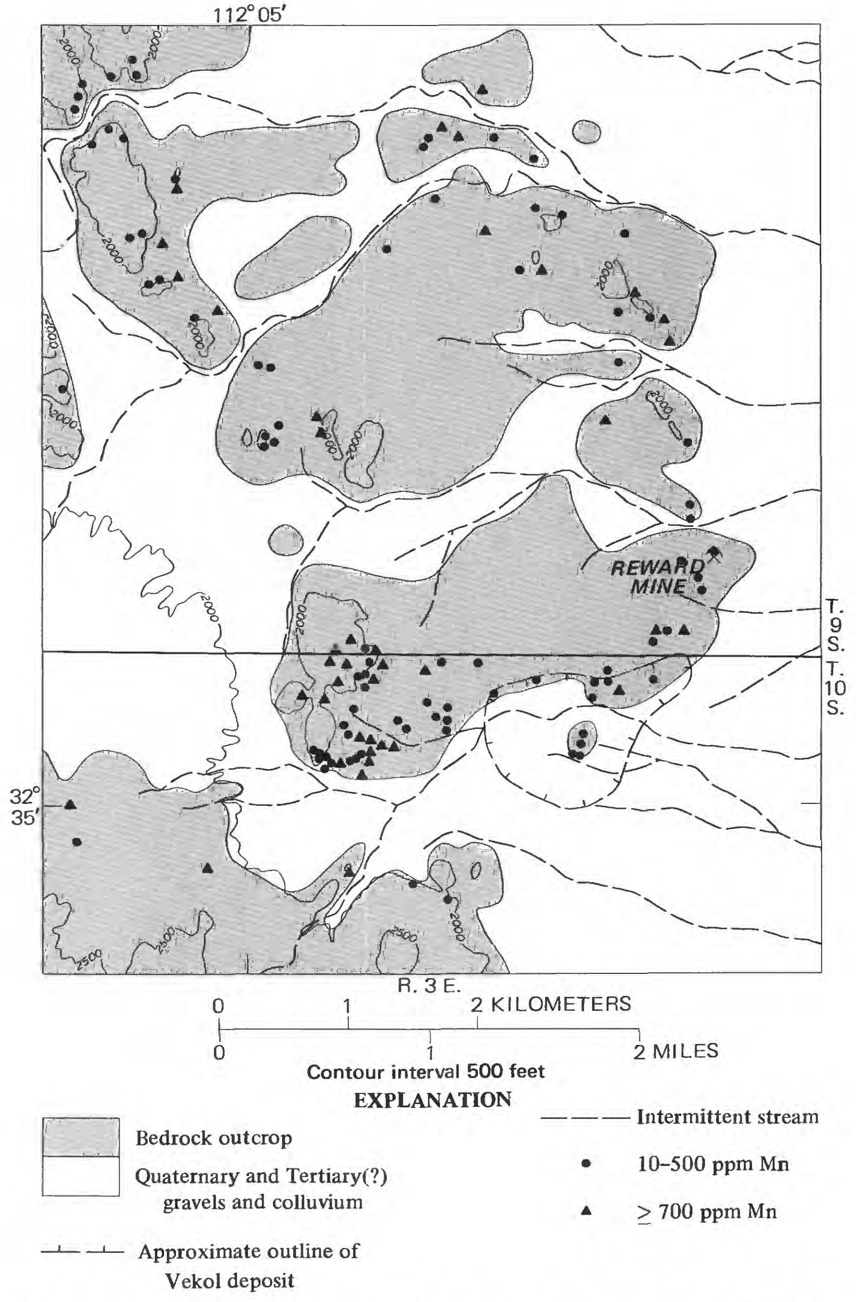


FIGURE 10. — Distribution of manganese, bedrock samples, Vekol Mountains, Ariz.

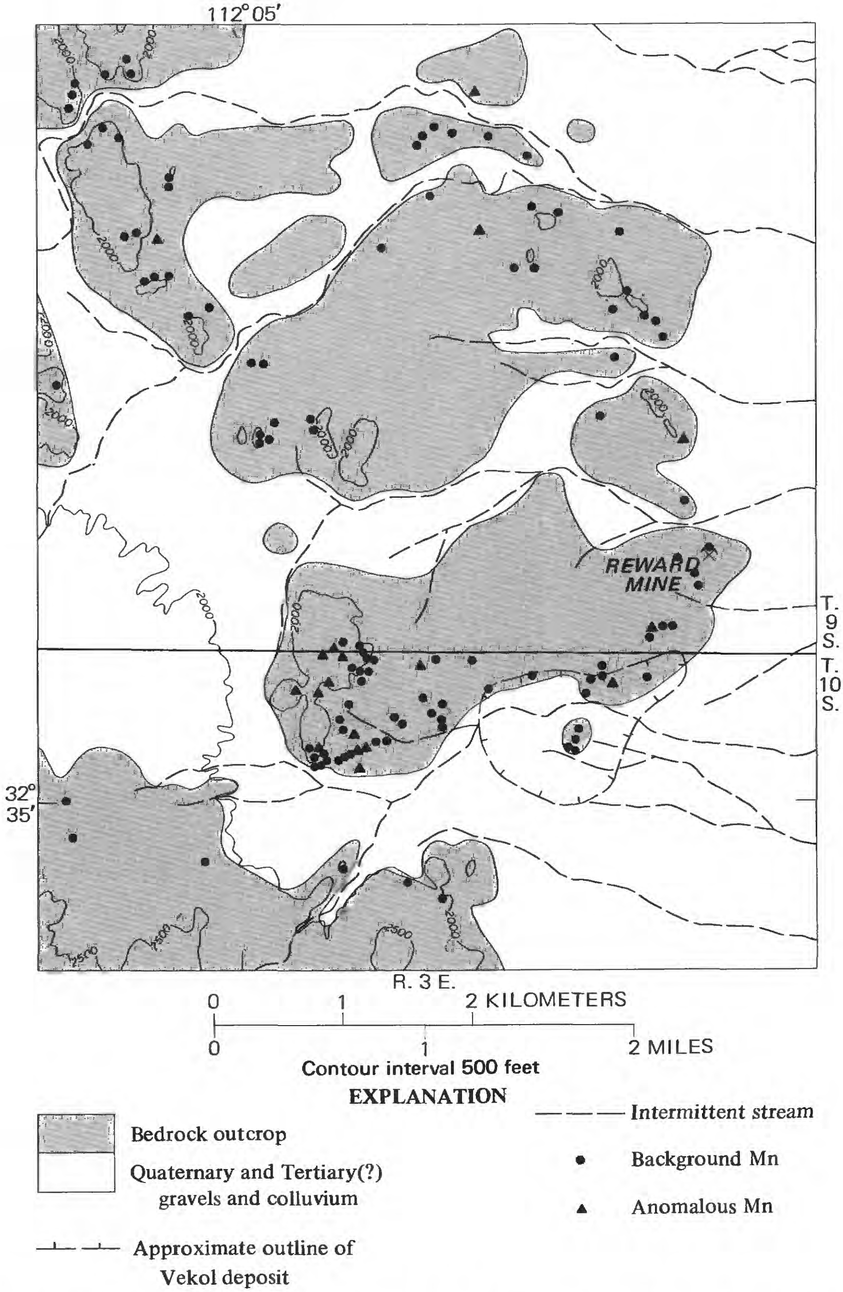
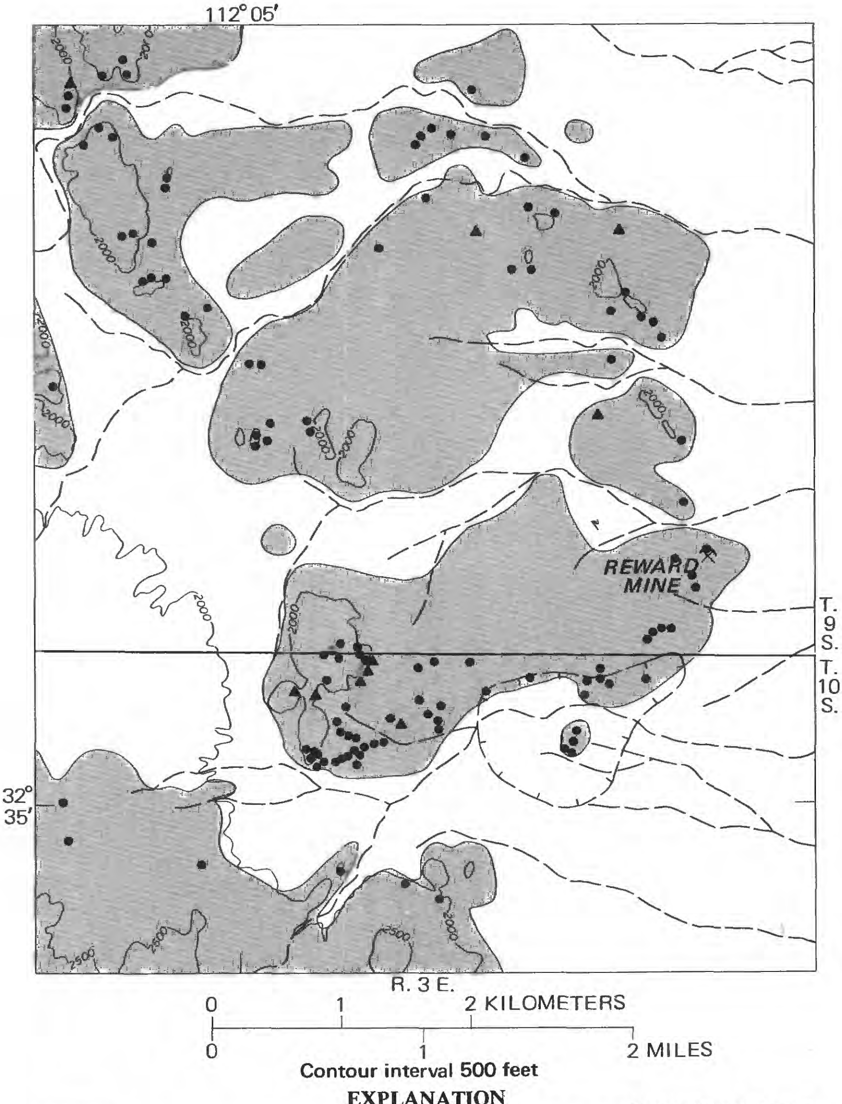


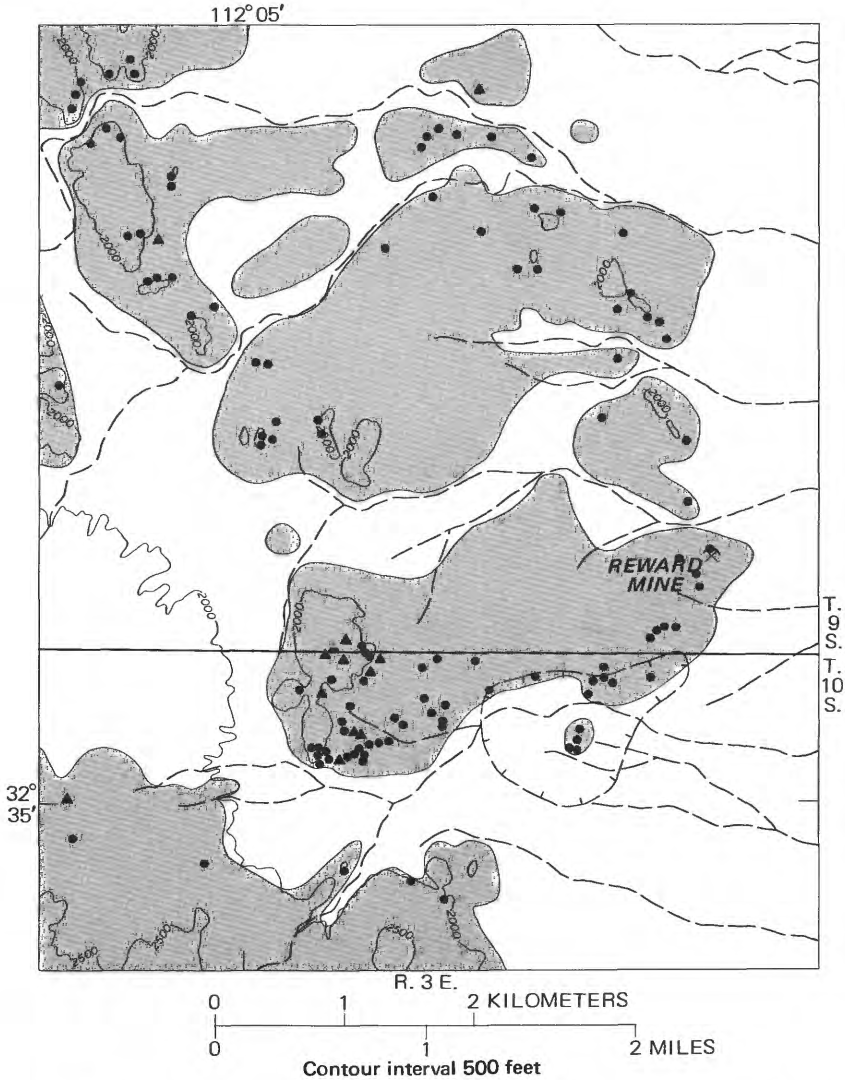
FIGURE 11. — Distribution of manganese, bedrock samples, with threshold values established according to lithology, Vekol Mountains, Ariz.



EXPLANATION

- Bedrock outcrop
- Quaternary and Tertiary(?) gravels and colluvium
- Approximate outline of Vekol deposit
- Intermittent stream
- ● N(0.5) ppm Ag
- ▲ ≥ L(0.5) ppm Ag

FIGURE 12. — Distribution of silver, bedrock samples, Vekol Mountains, Ariz.



EXPLANATION

- Bedrock outcrop
- Quaternary and Tertiary(?) gravels and colluvium
- Approximate outline of Vekol deposit
- Intermittent stream
- ● L(0.2)–0.6 ppm Cd
- ▲ ≥ 0.7 ppm Cd

FIGURE 13. — Distribution of cadmium, bedrock samples, Vekol Mountains, Ariz.

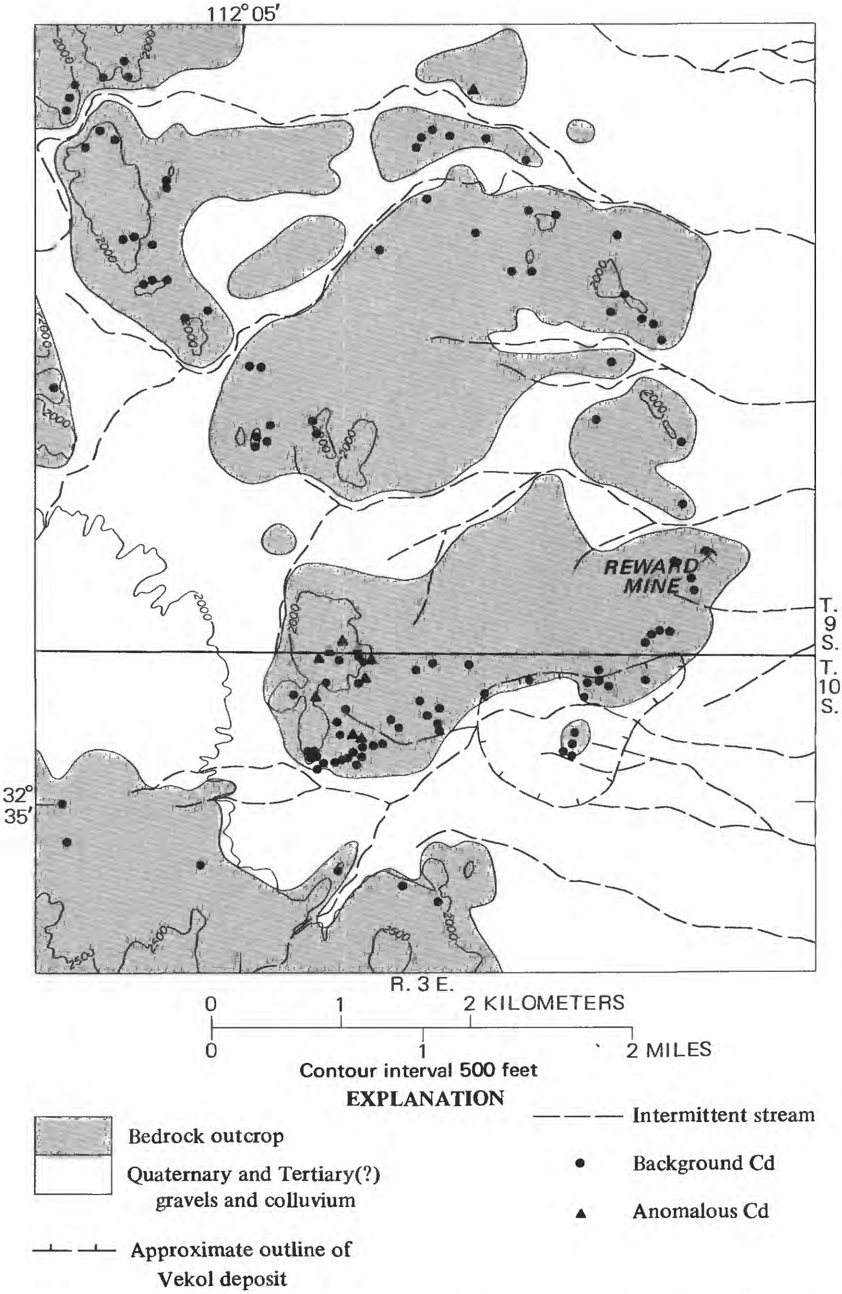


FIGURE 14.—Distribution of cadmium, bedrock samples, with threshold values established according to lithology, Vekol Mountains, Ariz.

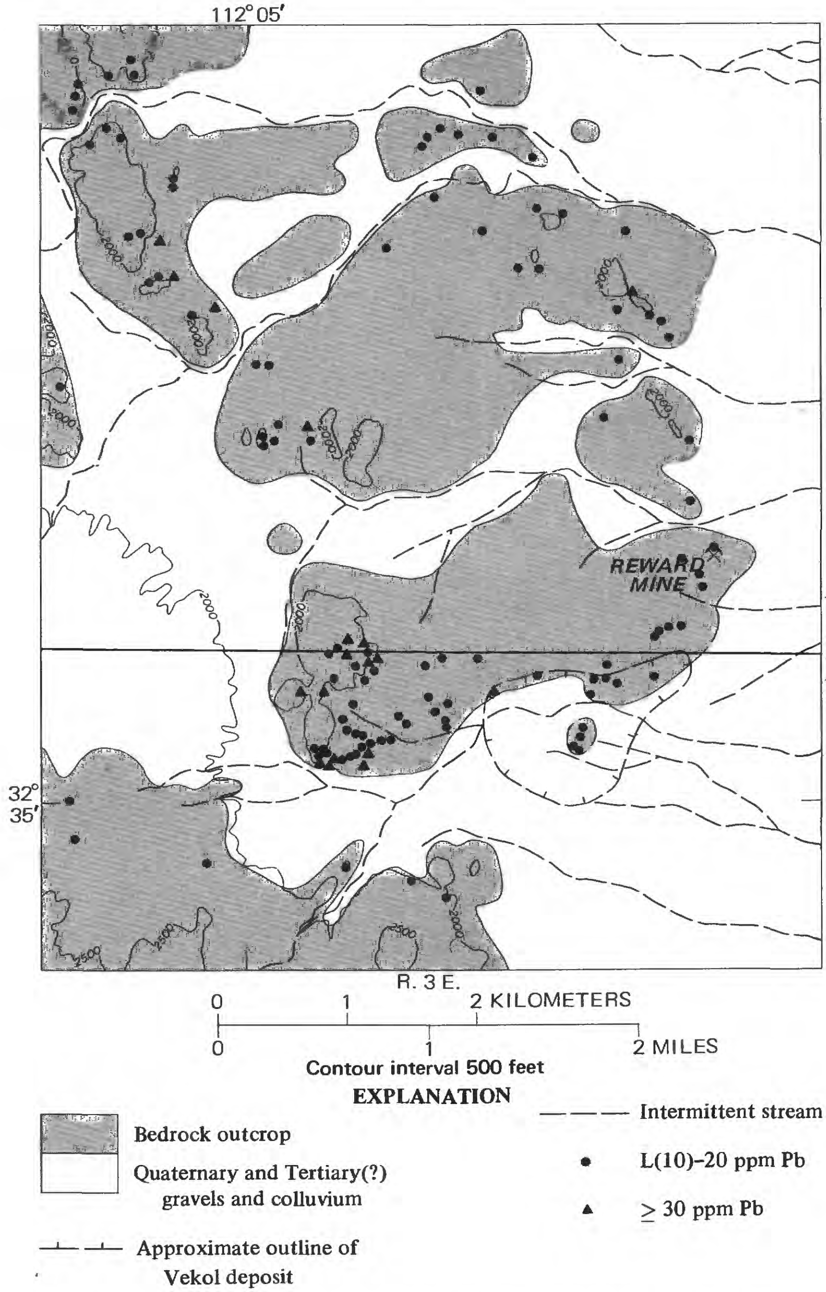
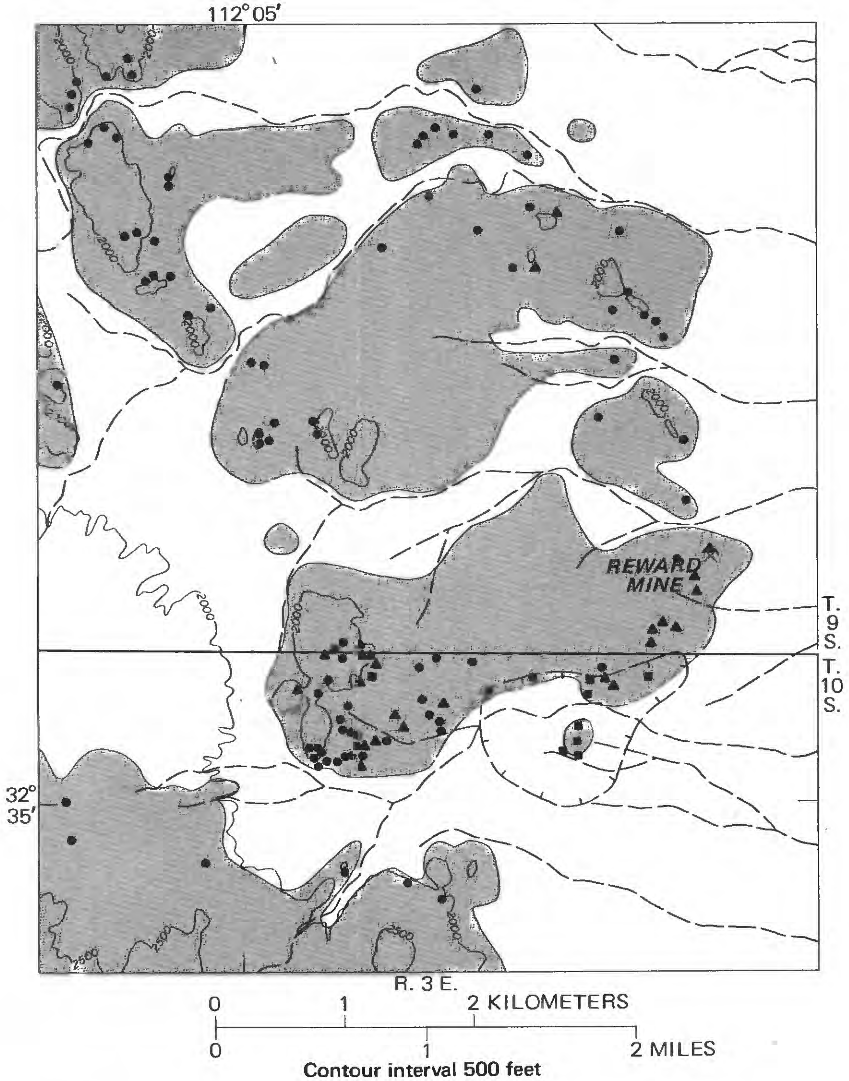


FIGURE 15. — Distribution of lead, bedrock samples, Vekol Mountains, Ariz.



EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

Approximate outline of Vekol deposit

Intermittent stream

● 8–34 ppm Cu (background)

▲ 35–99 ppm Cu (anomalous)

■ ≥ 100 ppm Cu (anomalous)

FIGURE 16. — Distribution of copper, soil samples, Vekol Mountains, Ariz.

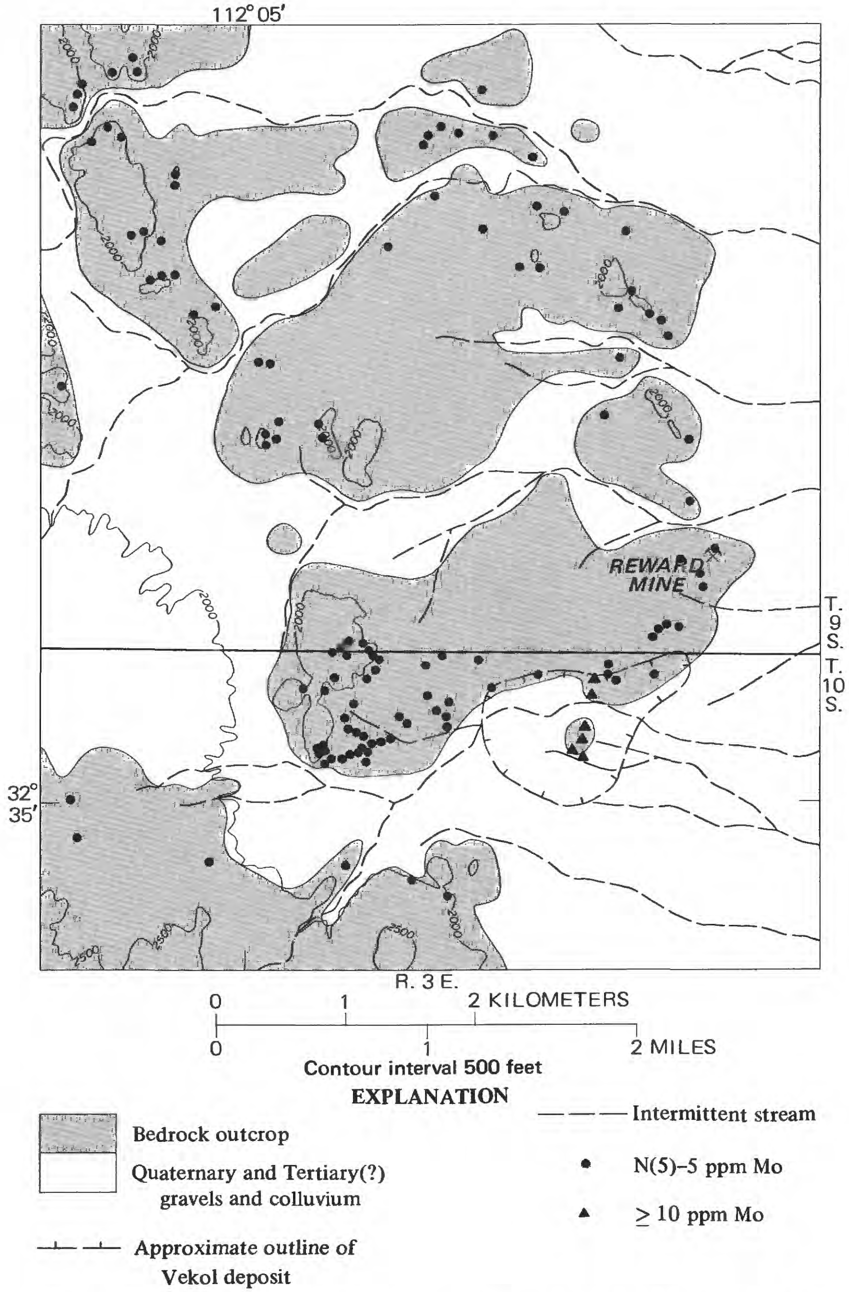


FIGURE 17. — Distribution of molybdenum, soil samples, Vekol Mountains, Ariz.

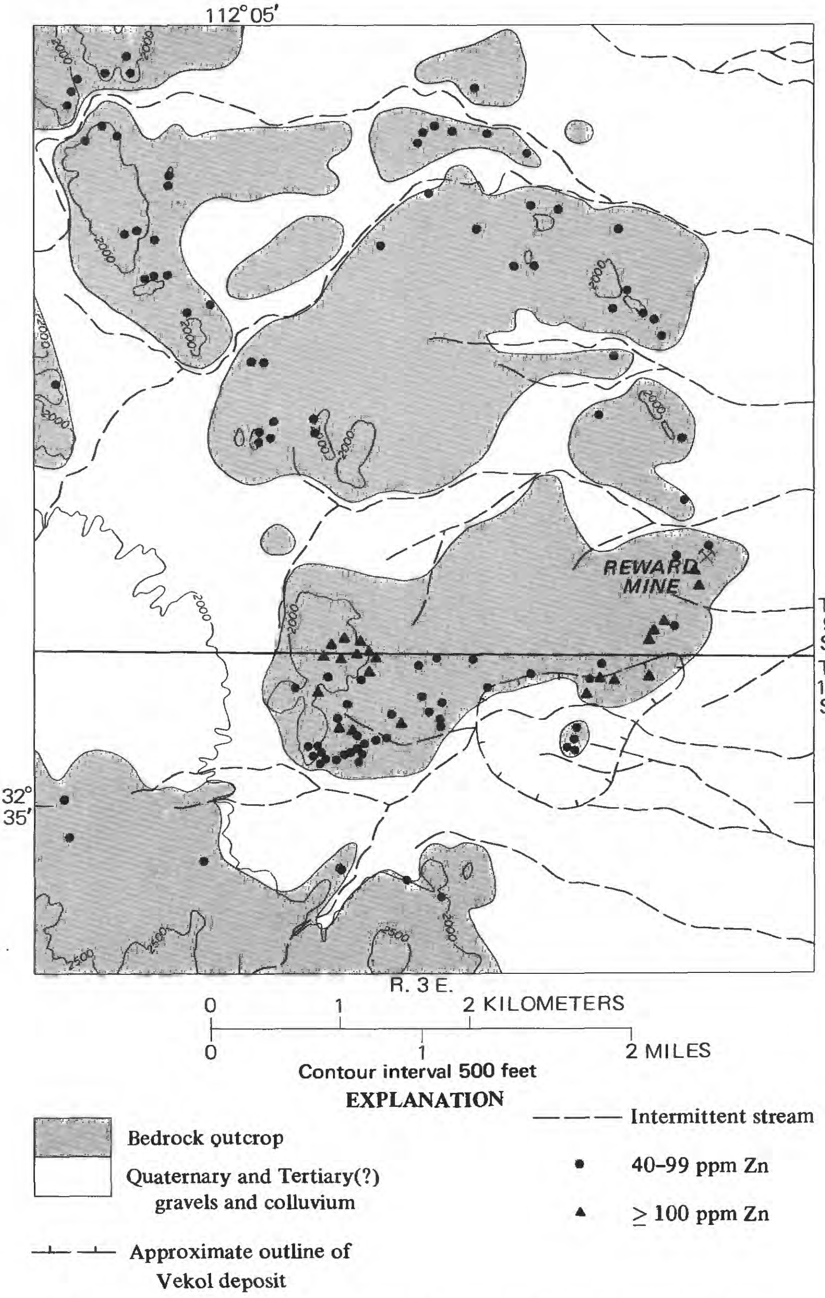
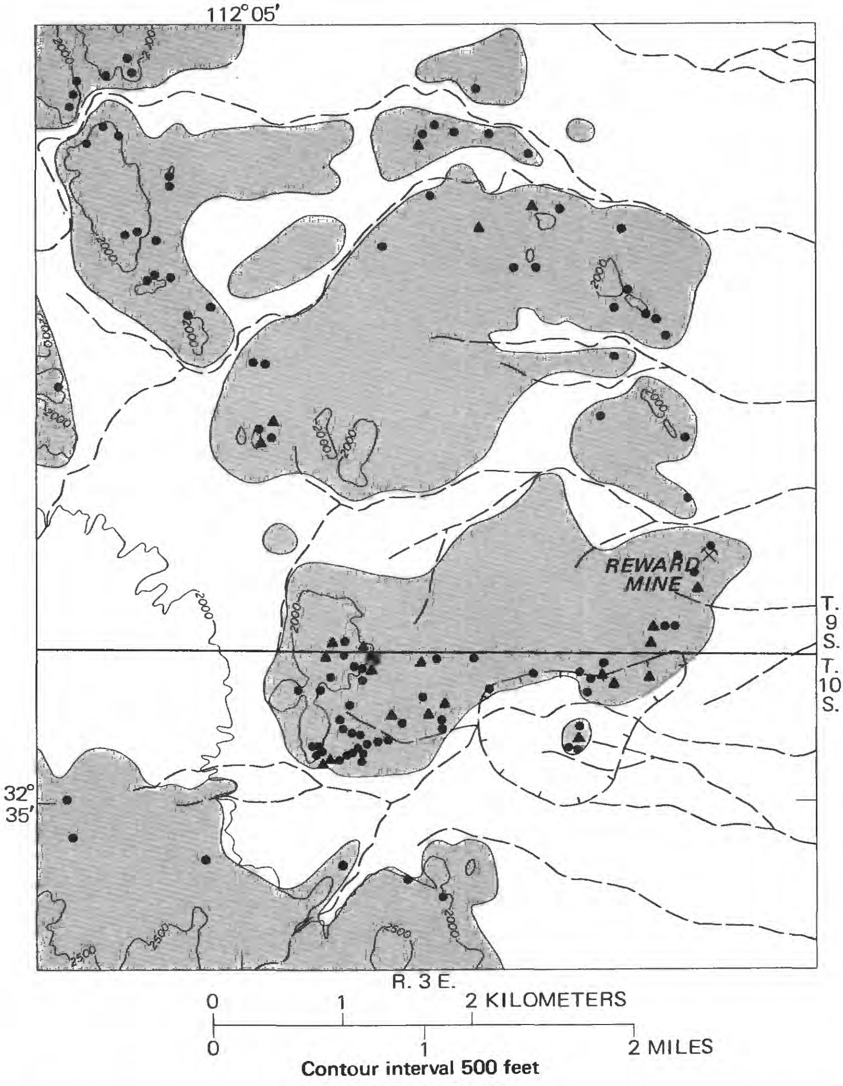


FIGURE 18. — Distribution of zinc, soil samples, Vekol Mountains, Ariz.



EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

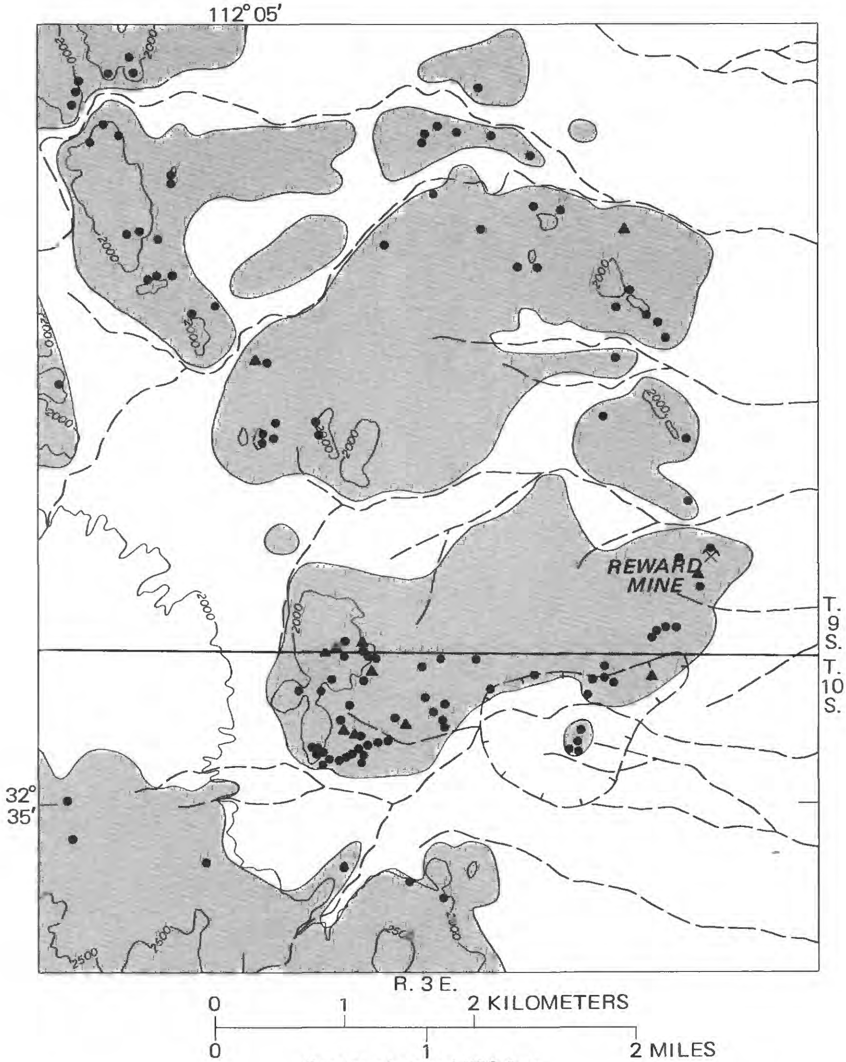
Approximate outline of Vekol deposit

Intermittent stream

200–700 ppm Mn

≥ 1000 ppm Mn

FIGURE 19. — Distribution of manganese, soil samples, Vekol Mountains, Ariz.



Contour interval 500 feet

EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

Approximate outline of Vekol deposit

Intermittent stream

● N(0.5)–L(0.5) ppm Ag

▲ ≥ 0.5 ppm Ag

FIGURE 20. — Distribution of silver, soil samples, Vekol Mountains, Ariz.

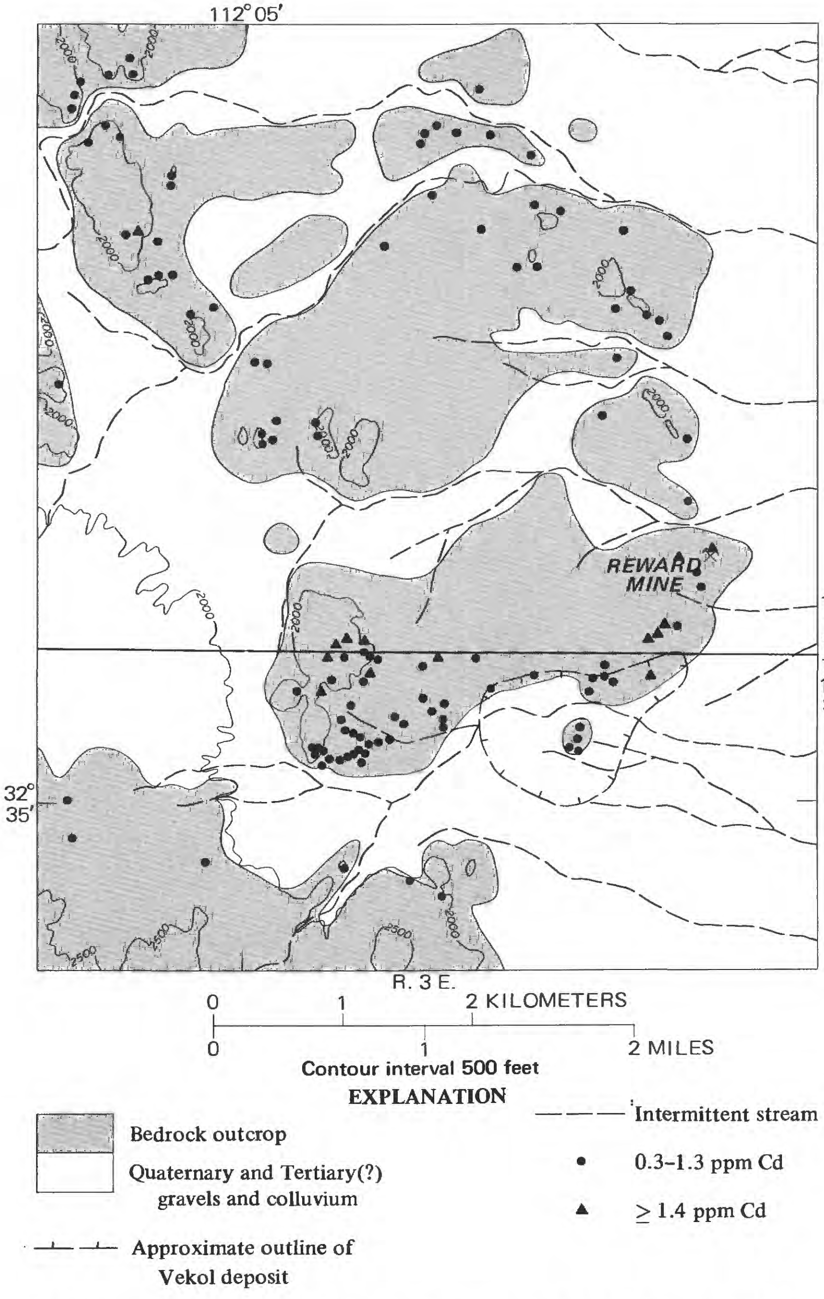
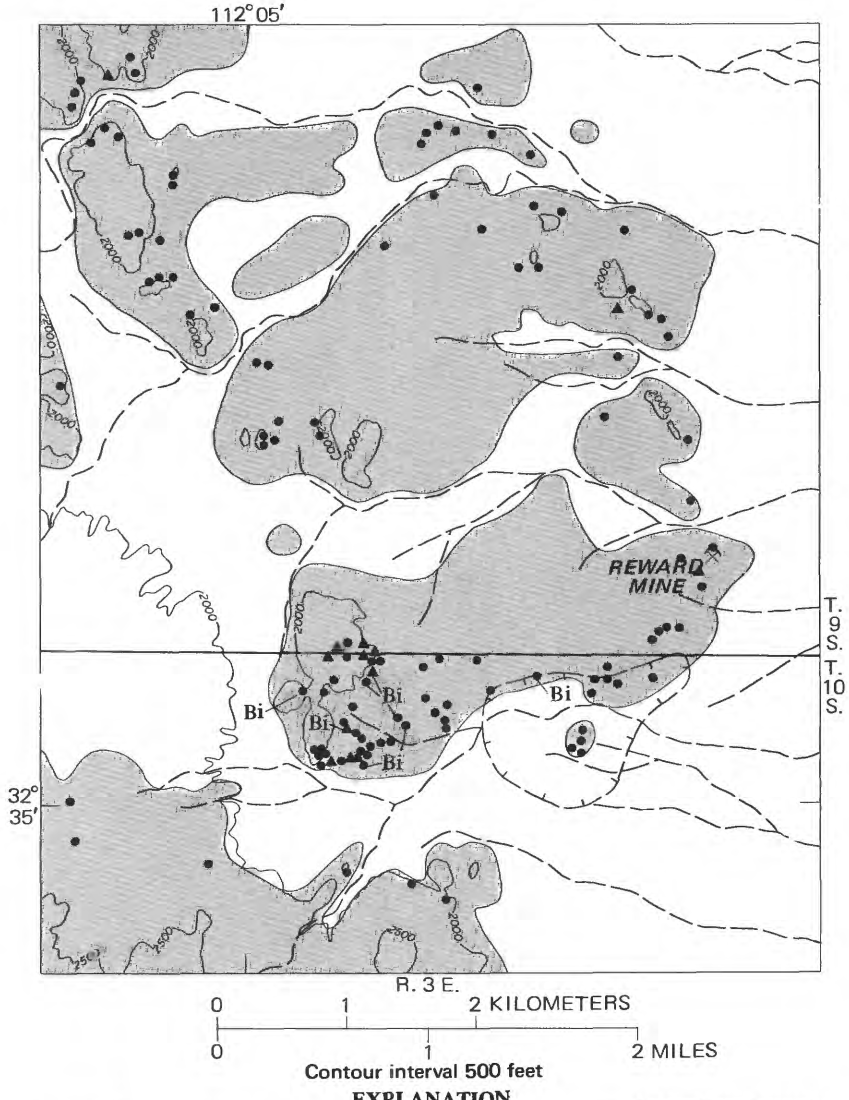


FIGURE 21. — Distribution of cadmium, soil samples, Vekol Mountains, Ariz.



EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

Approximate outline of Vekol deposit

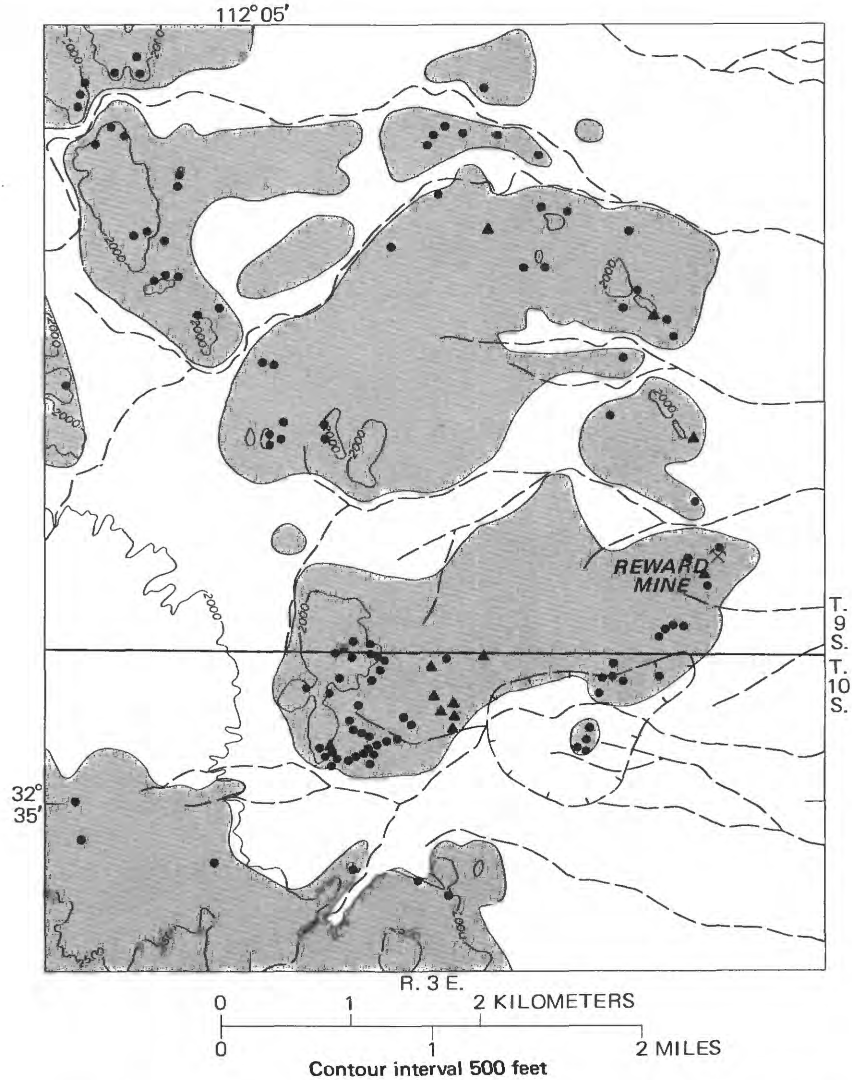
Intermittent stream

• 10–30 ppm Pb

▲ ≥ 50 ppm Pb

Bi ≥ L(10) ppm Bi

FIGURE 22. — Distribution of lead and bismuth, soil samples, Vekol Mountains, Ariz.



EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

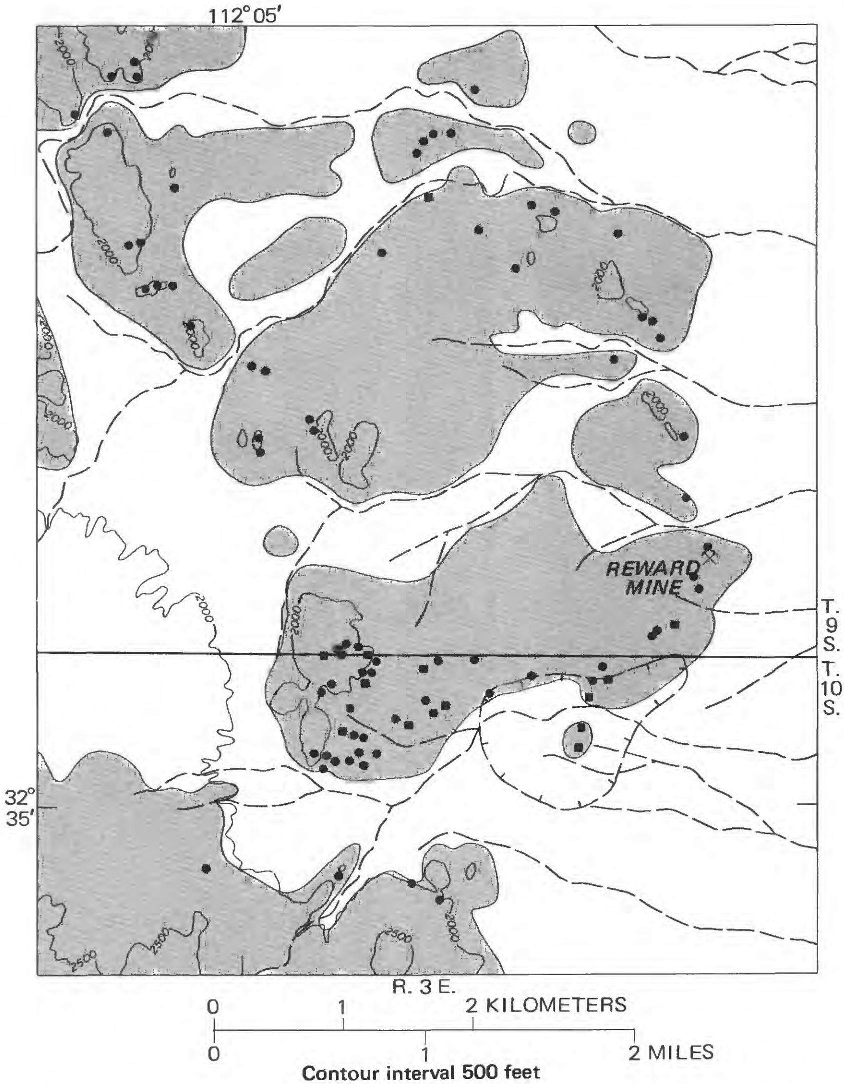
Approximate outline of Vekol deposit

Intermittent stream

● 0.02–0.09 ppm Hg

▲ ≥ 0.10 ppm Hg

FIGURE 23. — Distribution of mercury, soil samples, Vekol Mountains, Ariz.



EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

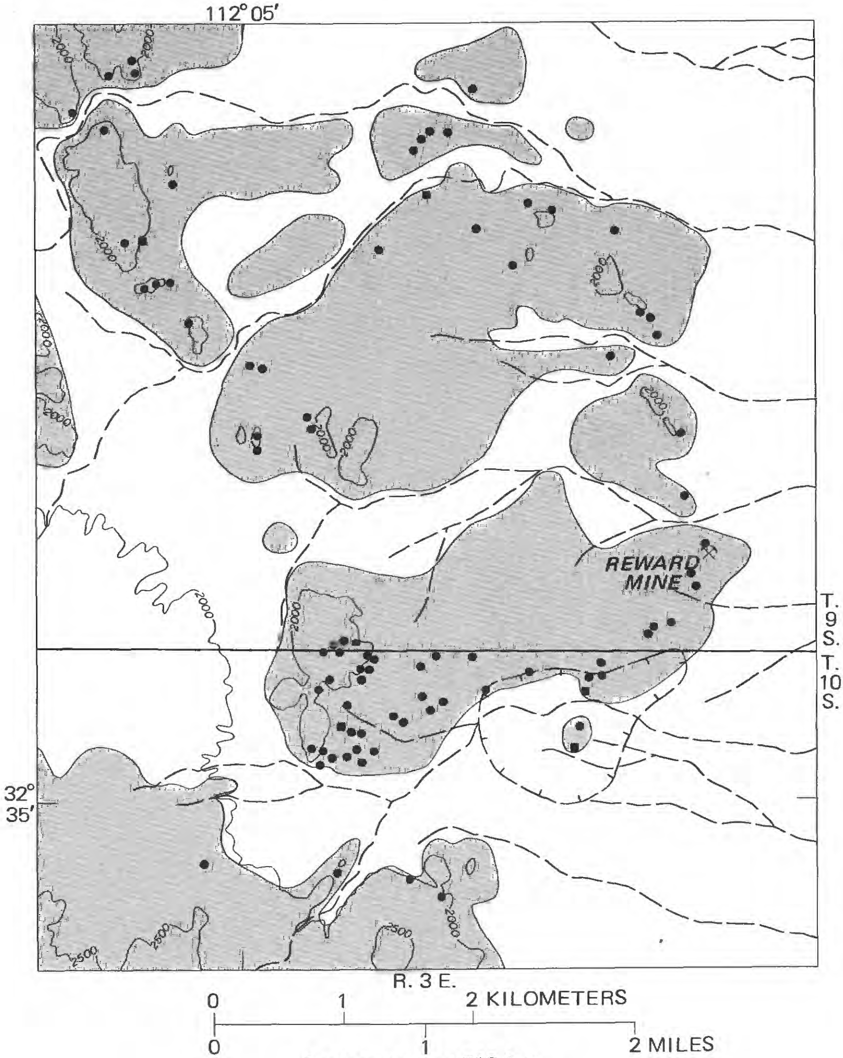
Approximate outline of Vekol deposit

Intermittent stream

● <150 ppm Cu

■ ≥ 150 ppm Cu

FIGURE 24. — Distribution of copper, ash of foothill paloverde stems, Vekol Mountains, Ariz.



Contour interval 500 feet

EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

Approximate outline of Vekol deposit

Intermittent stream

● <2.5 ppm Mo

■ ≥ 2.5 ppm Mo

FIGURE 25.—Distribution of molybdenum, ash of foothill paloverde stems, Vekol Mountains, Ariz.

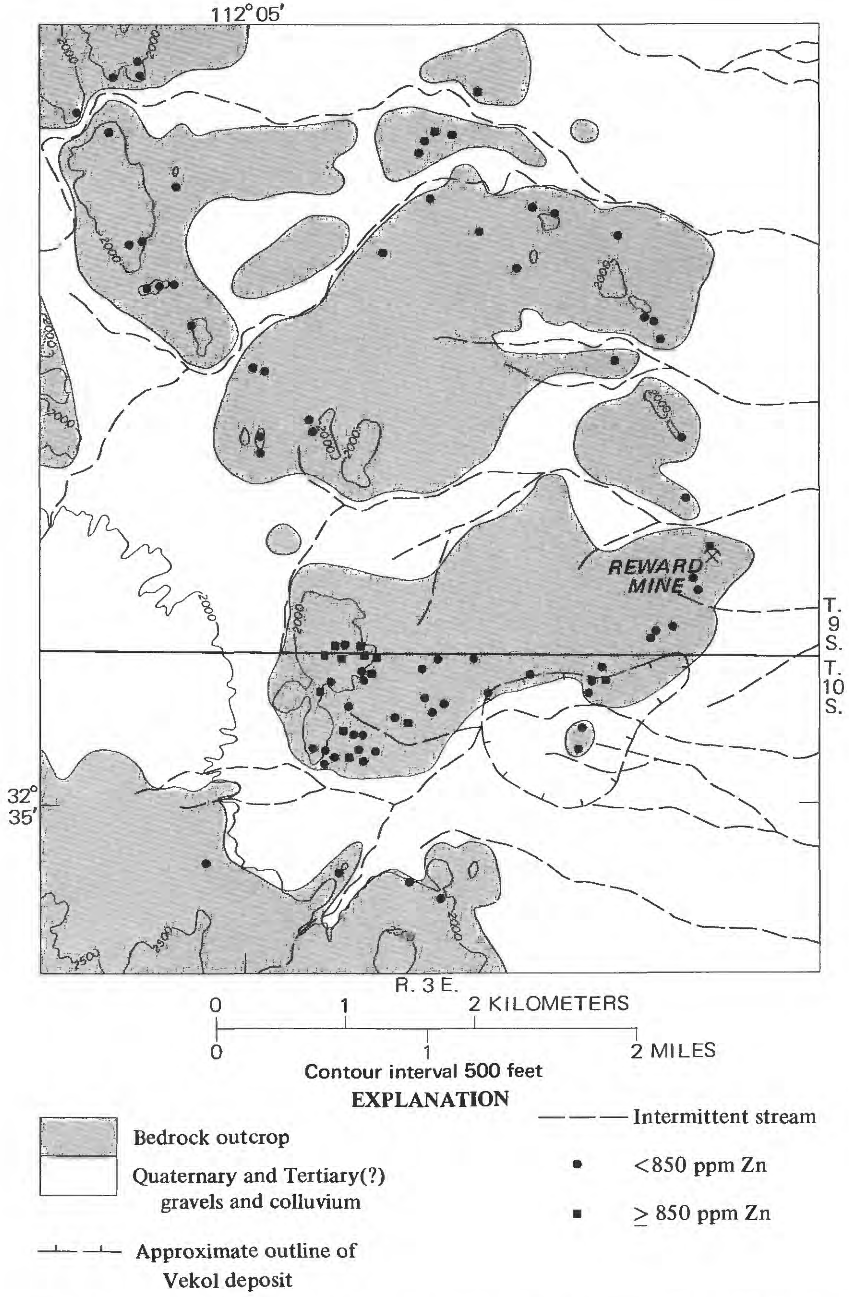
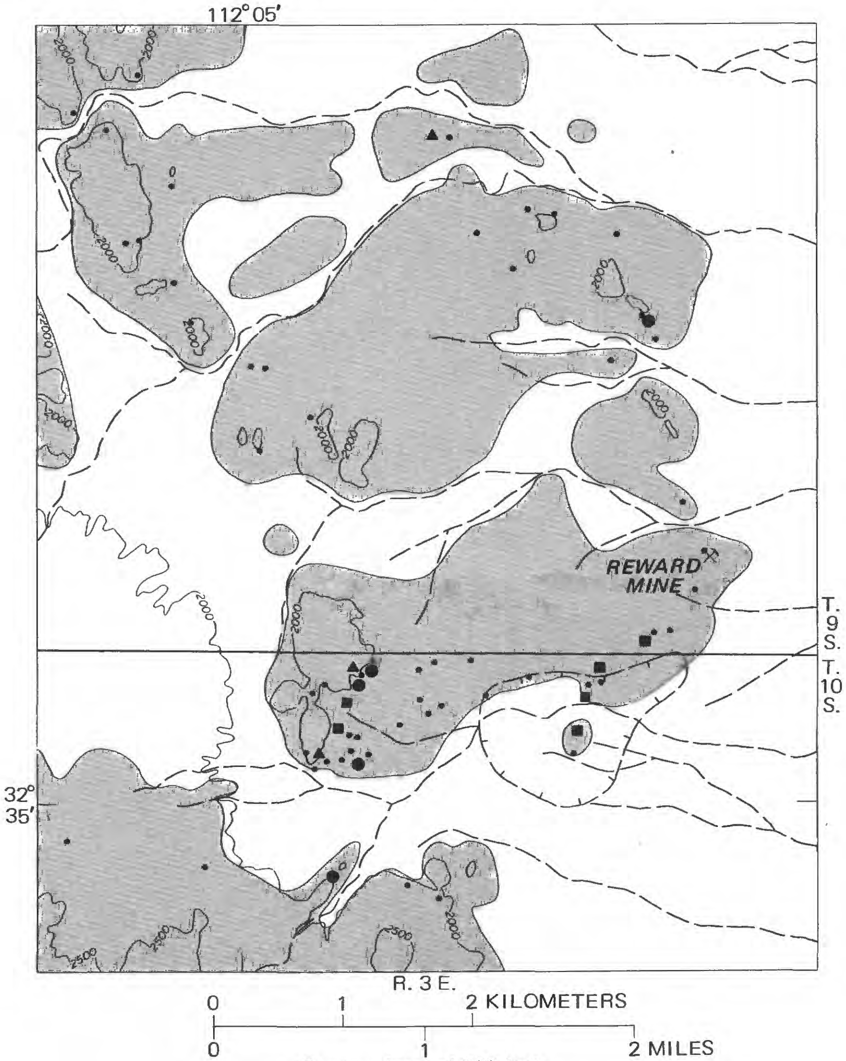


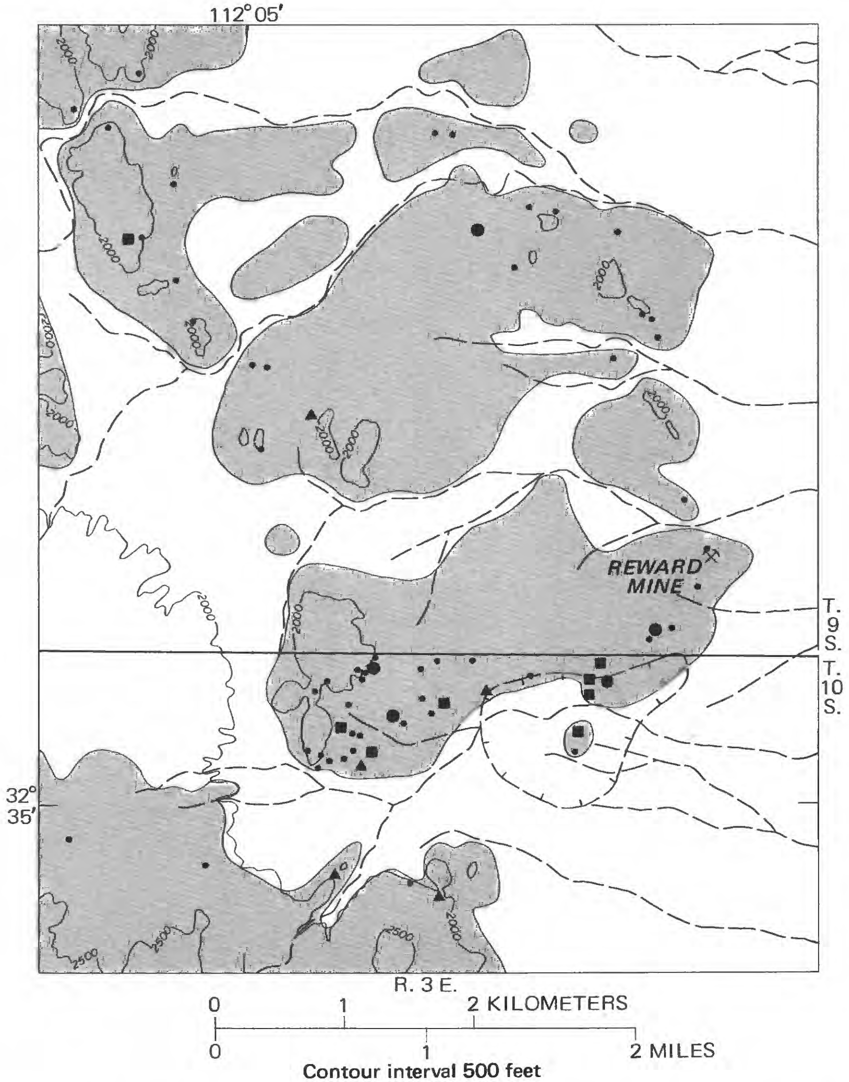
FIGURE 26.—Distribution of zinc, ash of foothill paloverde stems, Vekol Mountains, Ariz.



EXPLANATION

- Bedrock outcrop
- Quaternary and Tertiary(?) gravels and colluvium
- Approximate outline of Vekol deposit
- Intermittent stream
- • Neither plant part anomalous for Cu
- ● Only leaves anomalous ($\geq$ 130 ppm Cu)
- ▲ Only stems anomalous ($\geq$ 130 ppm Cu)
- ■ Both plant parts anomalous for Cu

FIGURE 27.—Distribution of copper, ash of ironwood leaves and stems, Vekol Mountains, Ariz.



Contour interval 500 feet

EXPLANATION

- Bedrock outcrop
- Quaternary and Tertiary(?) gravels and colluvium
- Approximate outline of Vekol deposit
- Intermittent stream
- • Neither plant part anomalous for Mo
- ● Only leaves anomalous (≥ 15 ppm Mo)
- ▲ Only stems anomalous (≥ 22 ppm Mo)
- ■ Both plant parts anomalous for Mo

FIGURE 28.—Distribution of molybdenum, ash of ironwood leaves and stems, Vekol Mountains, Ariz.

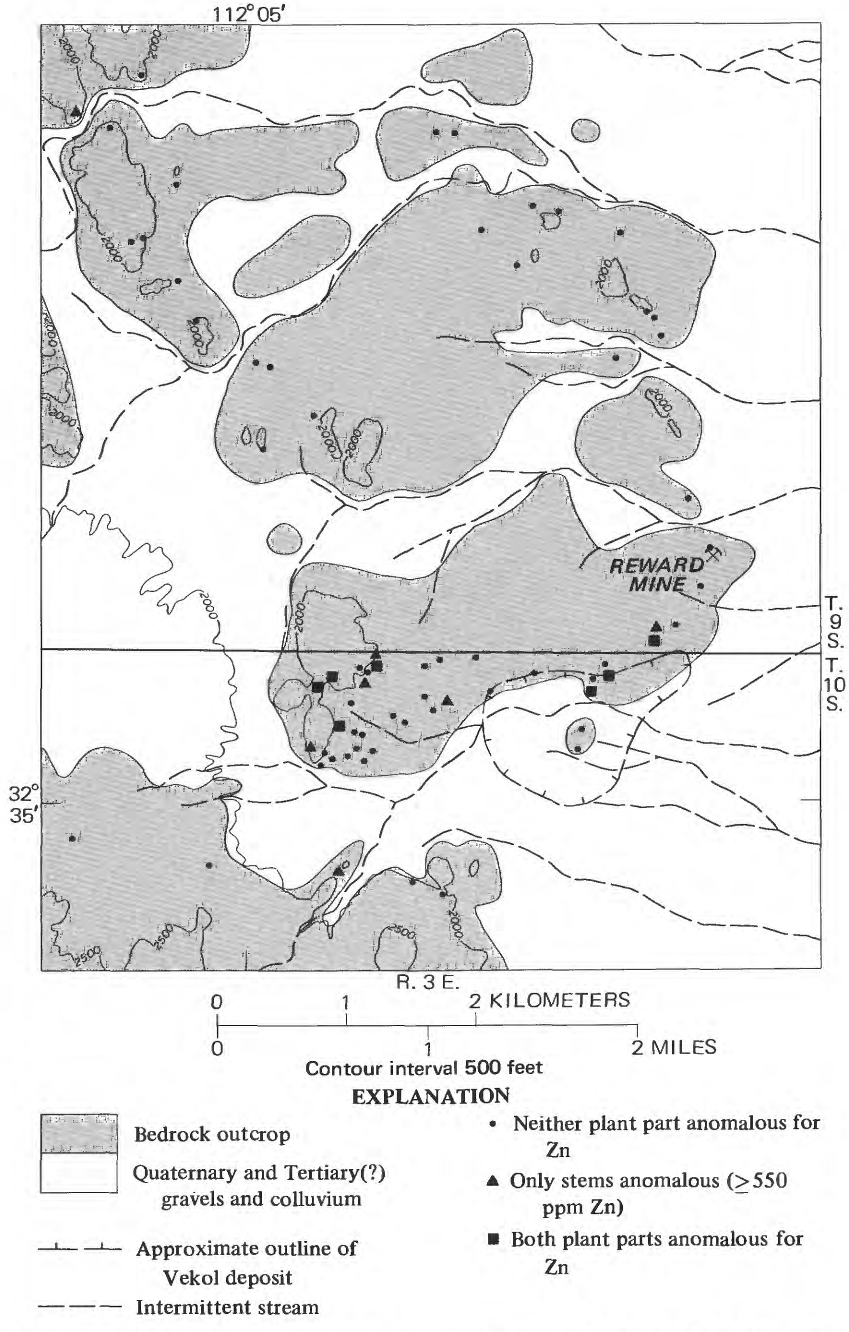
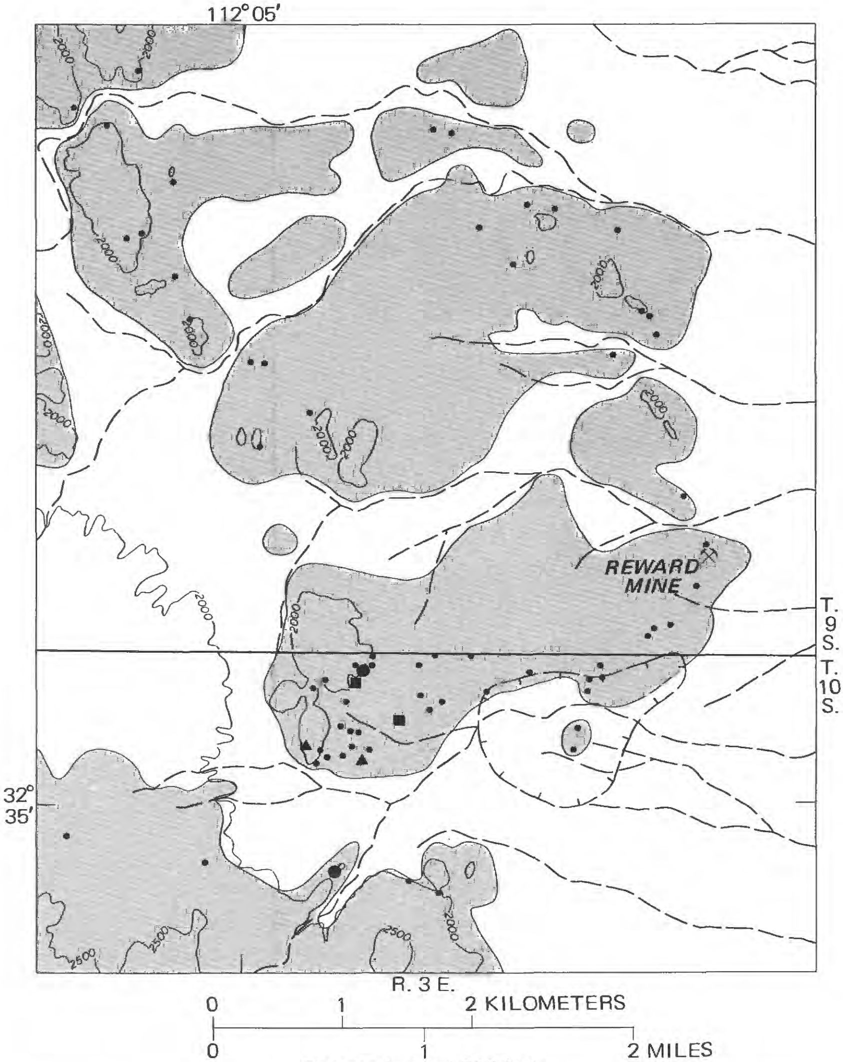


FIGURE 29.— Distribution of zinc, ash of ironwood leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

Approximate outline of Vekol deposit

Intermittent stream

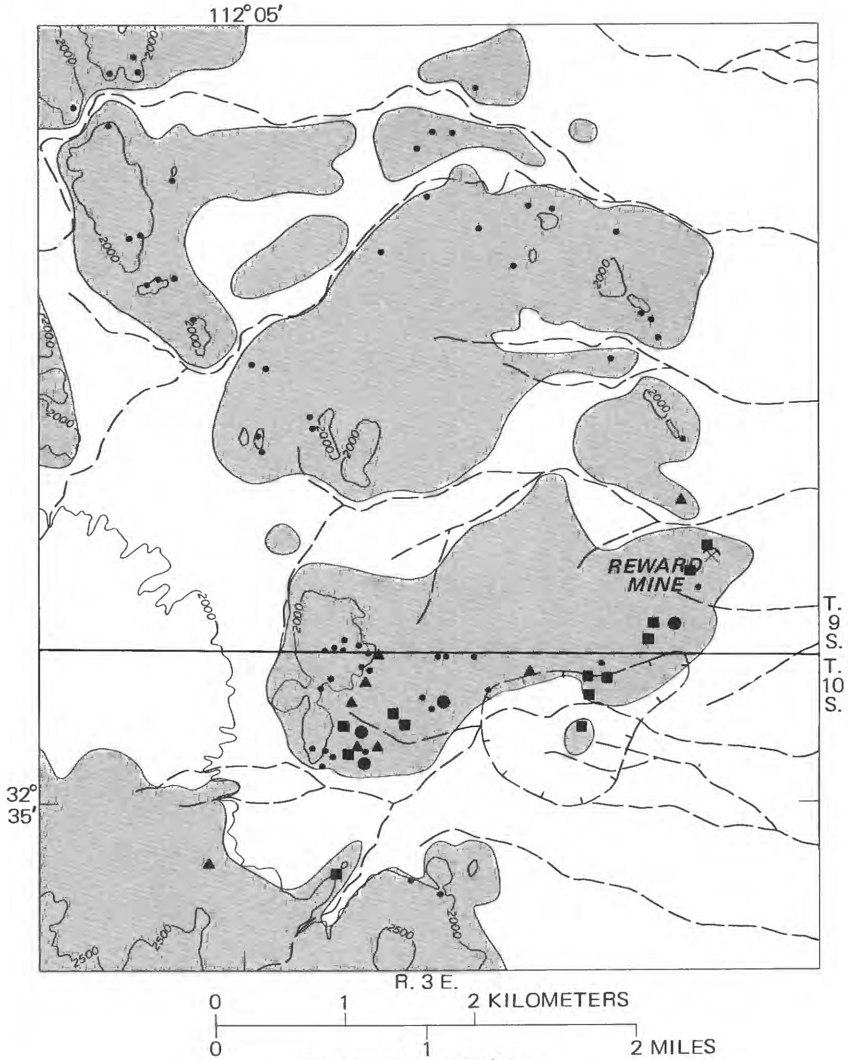
• Neither plant part anomalous for Ag

● Only leaves anomalous (≥"L(0.1)" ppm Ag)

▲ Only stems anomalous (≥"L(0.1)" ppm Ag)

■ Both plant parts anomalous for Ag

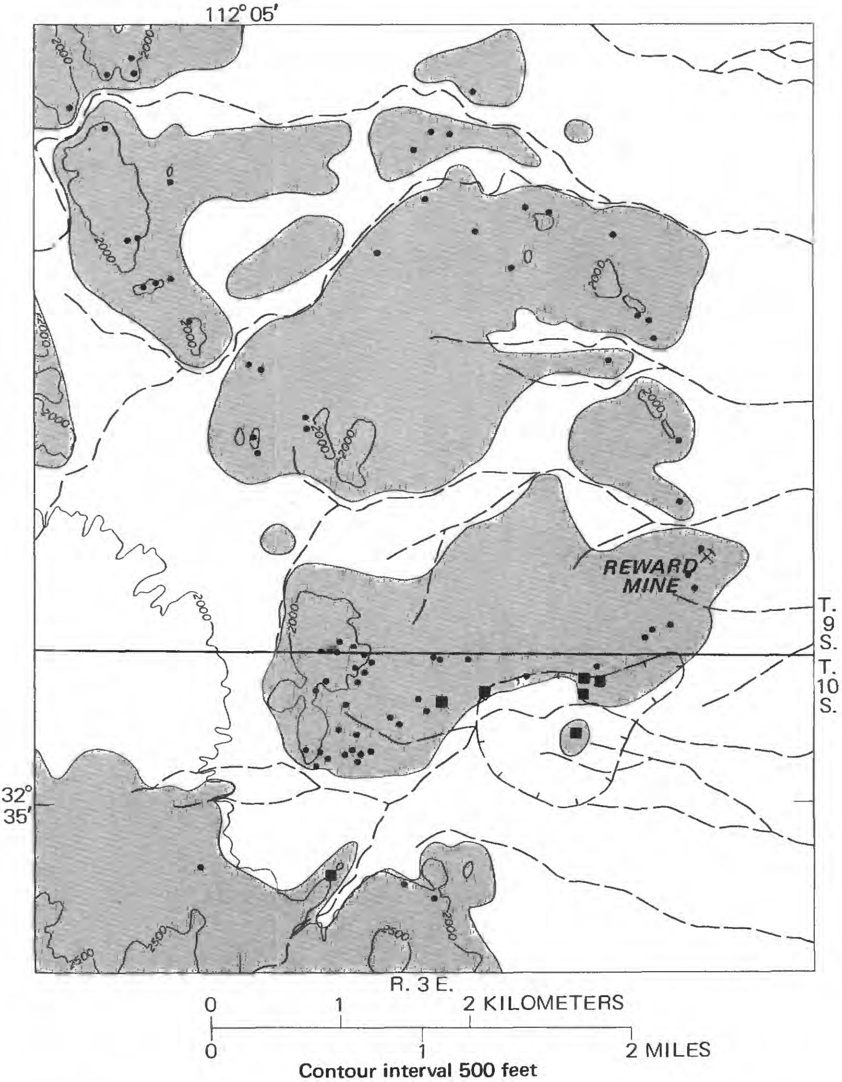
FIGURE 30.—Distribution of silver, ash of ironwood leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

- Bedrock outcrop
- Quaternary and Tertiary(?) gravels and colluvium
- Approximate outline of Vekol deposit
- Intermittent stream
- • Neither plant part anomalous for Cu
- ● Only leaves anomalous ($\geq$ 340 ppm Cu)
- ▲ Only stems anomalous ($\geq$ 360 ppm Cu)
- ■ Both plant parts anomalous for Cu

FIGURE 31.— Distribution of copper, ash of creosotebush leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

Approximate outline of Vekol deposit

Intermittent stream

• Neither plant part anomalous for Mo

■ Both plant parts anomalous (≥6.5 ppm Mo)

FIGURE 32.—Distribution of molybdenum, ash of creosotebush leaves and stems, Vekol Mountains, Ariz.

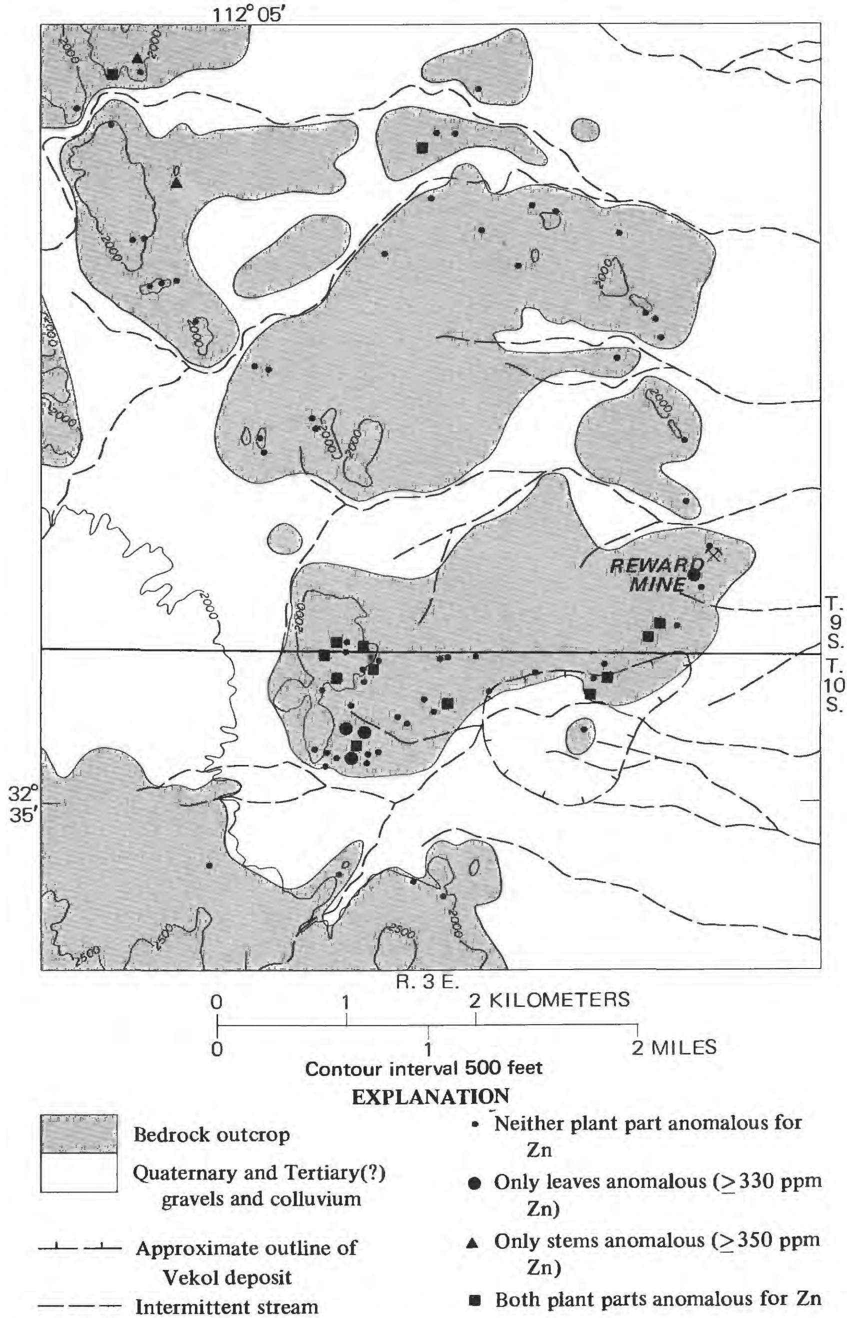
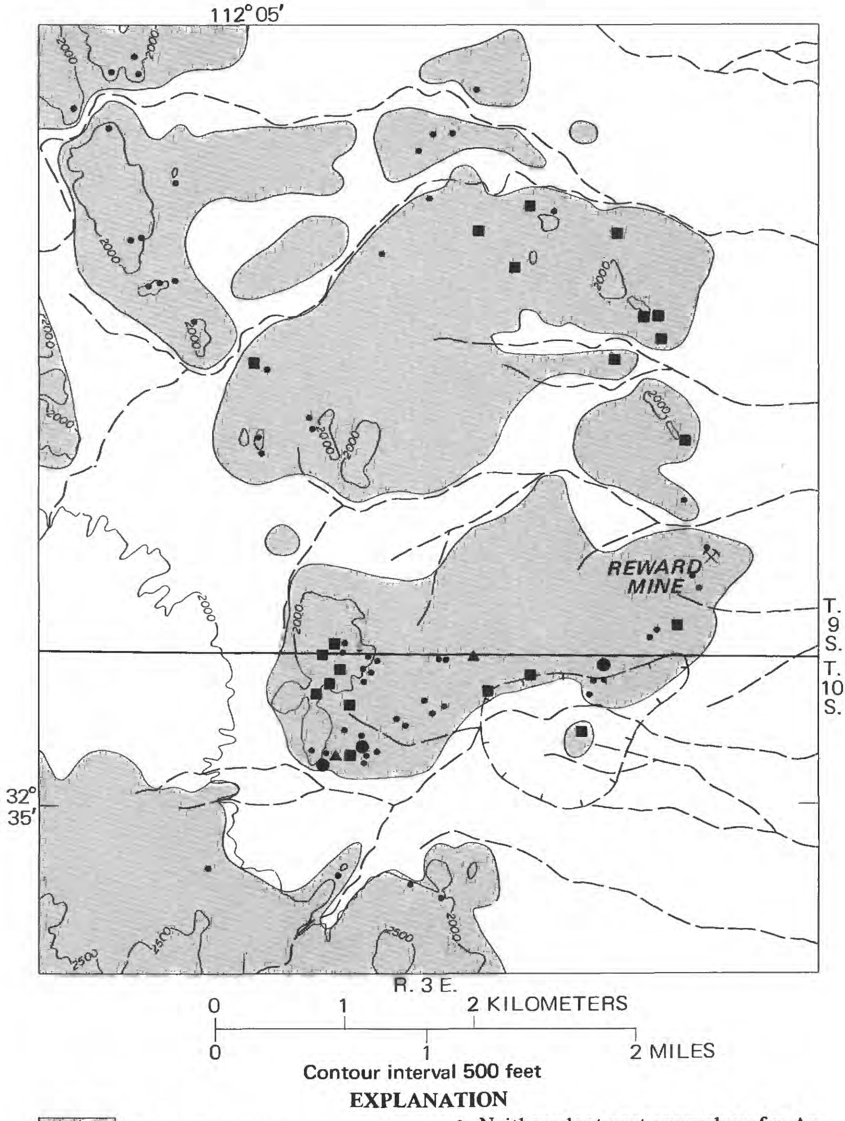


FIGURE 33.—Distribution of zinc, ash of creosotebush leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

Bedrock outcrop

Quaternary and Tertiary(?) gravels and colluvium

Approximate outline of Vekol deposit

Intermittent stream

• Neither plant part anomalous for Ag

● Only leaves anomalous (≥0.15 ppm Ag)

▲ Only stems anomalous (≥0.15 ppm Ag)

■ Both plant parts anomalous for Ag

FIGURE 34.— Distribution of silver, ash of creosotebush leaves and stems, Vekol Mountains, Ariz.

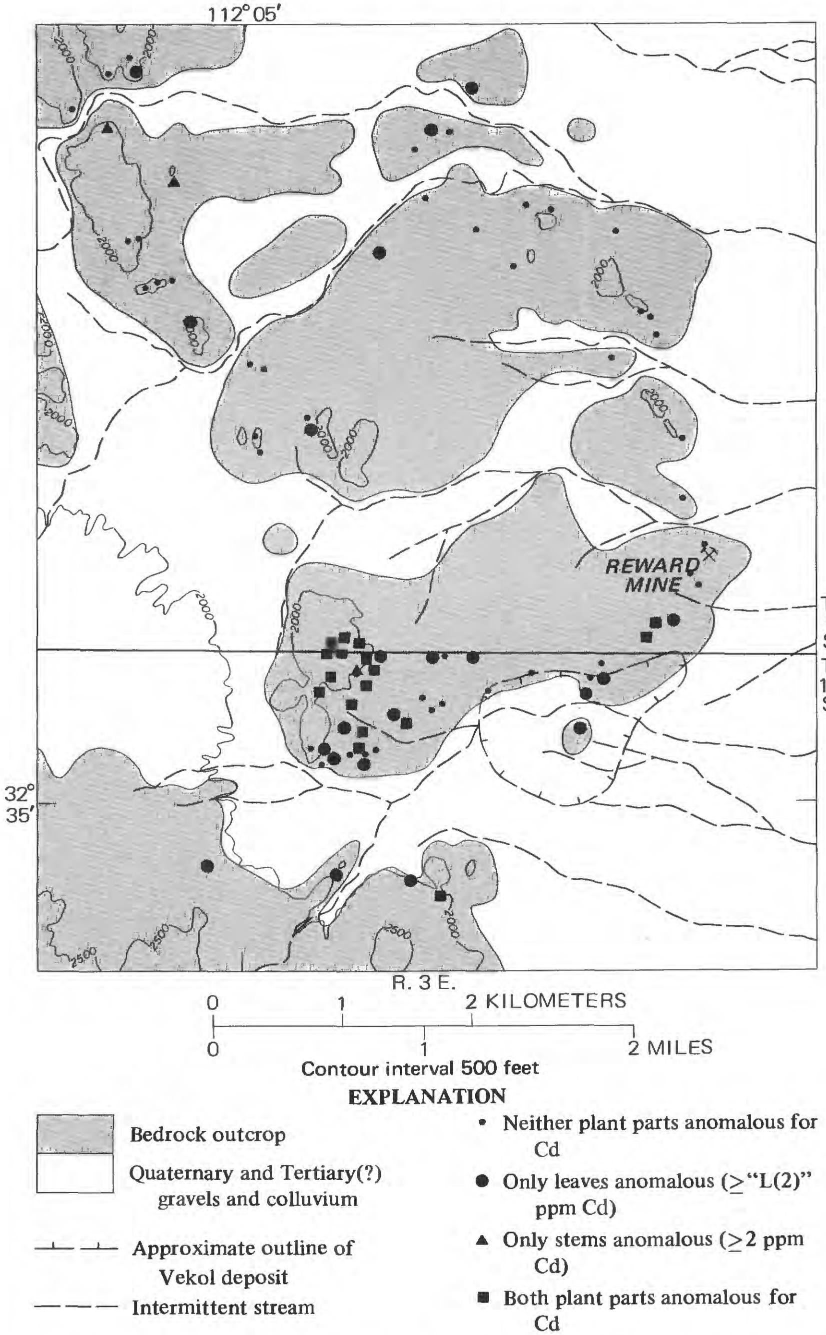
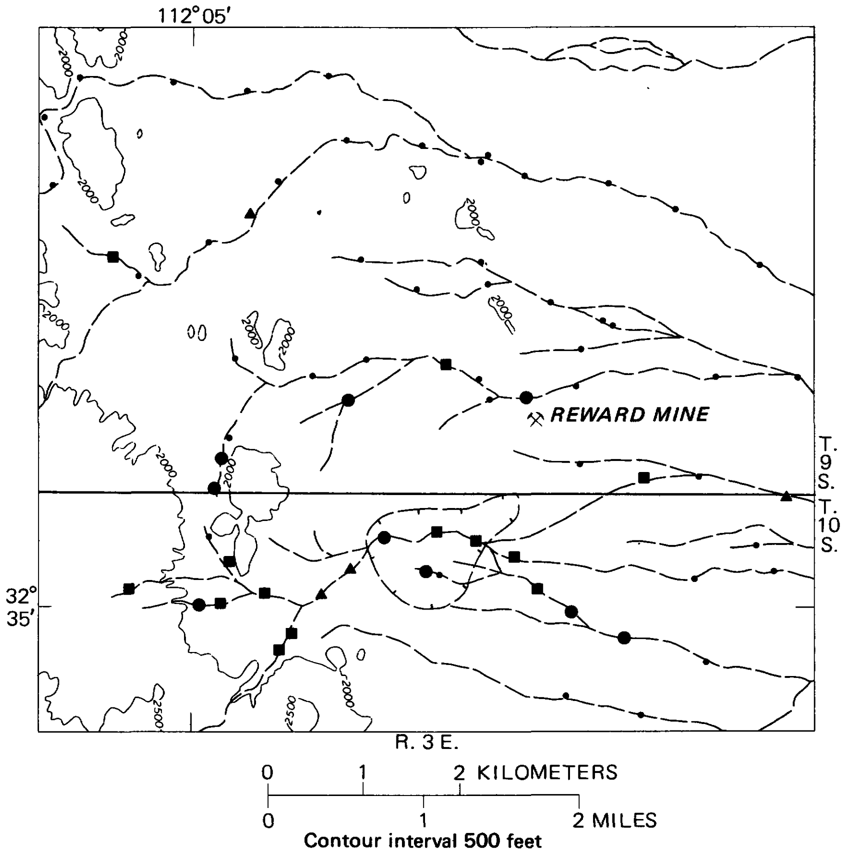


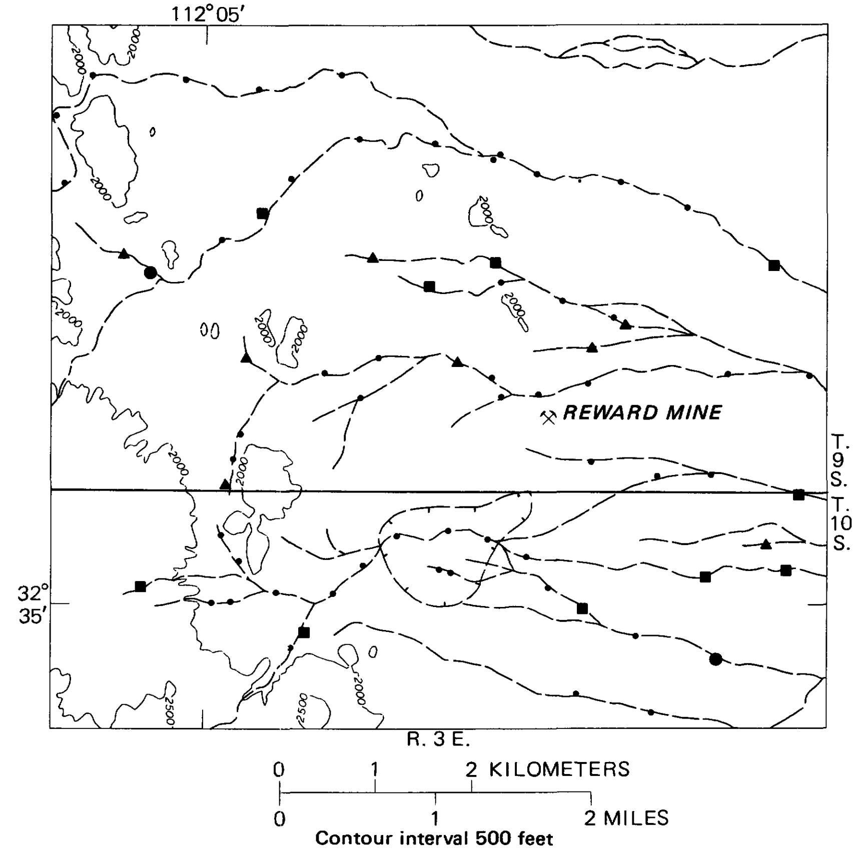
FIGURE 35.—Distribution of cadmium, ash of creosotebush leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

- Intermittent stream
- Approximate outline of Vekol deposit
- Neither plant part anomalous for Cu
- ● Only leaves anomalous (≥150 ppm Cu)
- ▲ Only stems anomalous (≥160 ppm Cu)
- ■ Both plant parts anomalous for Cu

FIGURE 36.— Distribution of copper, ash of mesquite leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

———	Intermittent stream	●	Only leaves anomalous (≥20 ppm Mo)
—⊥—⊥—	Approximate outline of Vekol deposit	▲	Only stems anomalous (≥15 ppm Mo)
•	Neither plant part anomalous for Mo	■	Both plant parts anomalous for Mo

FIGURE 37.—Distribution of molybdenum, ash of mesquite leaves and stems, Vekol Mountains, Ariz.

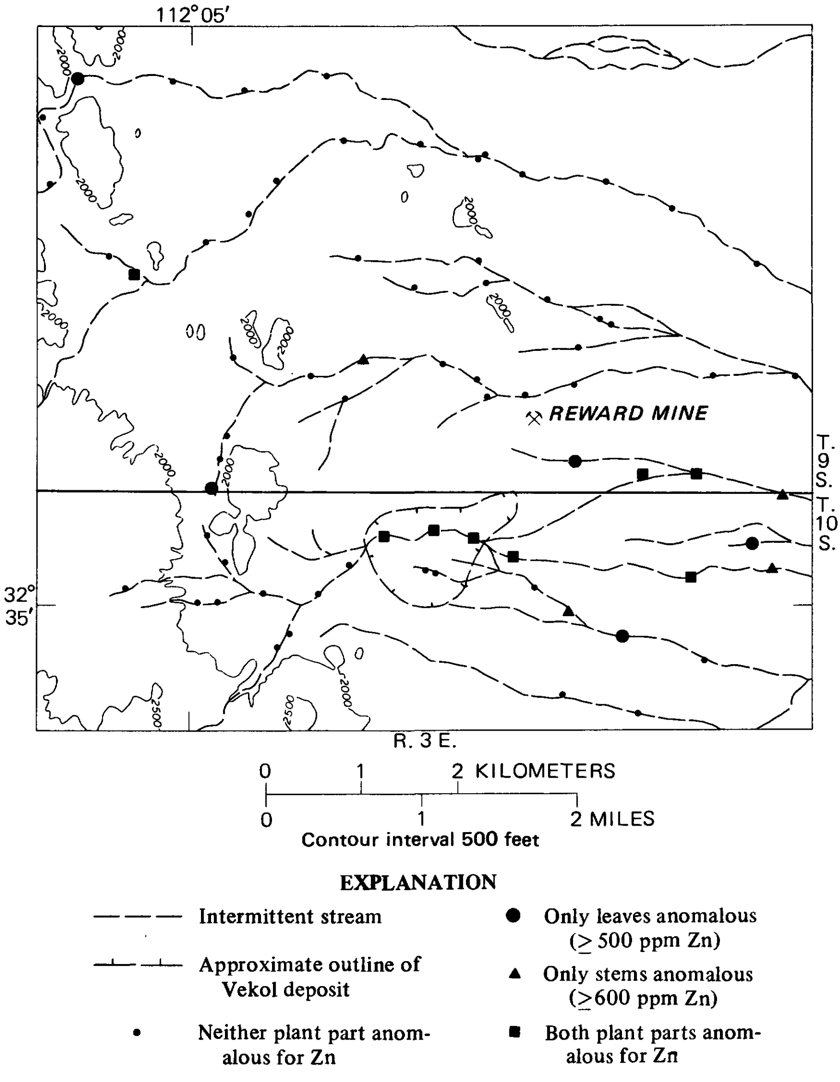
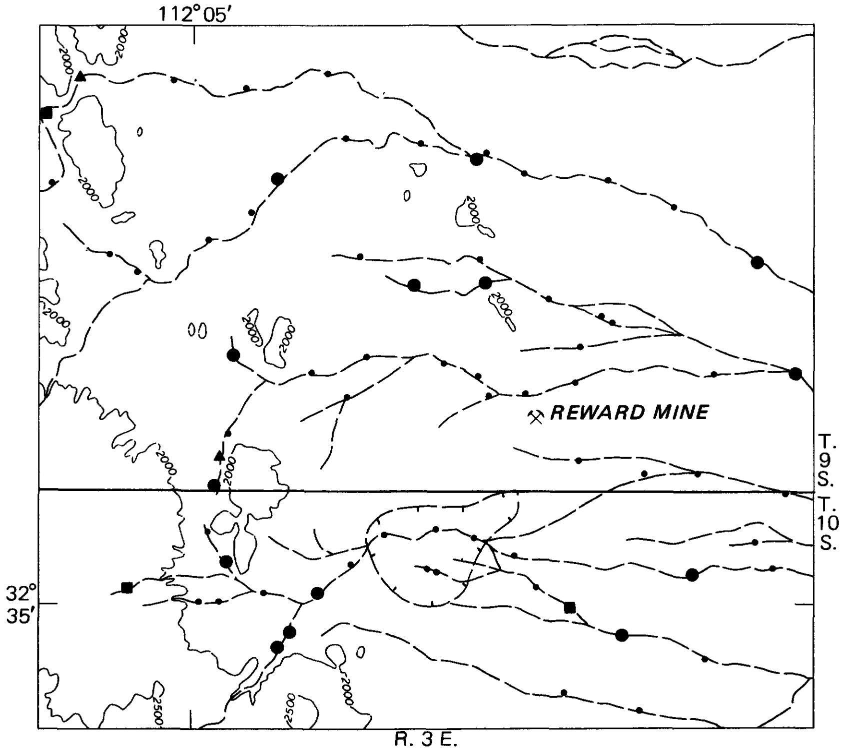


FIGURE 38.— Distribution of zinc, ash of mesquite leaves and stems, Vekol Mountains, Ariz.



0 1 2 KILOMETERS

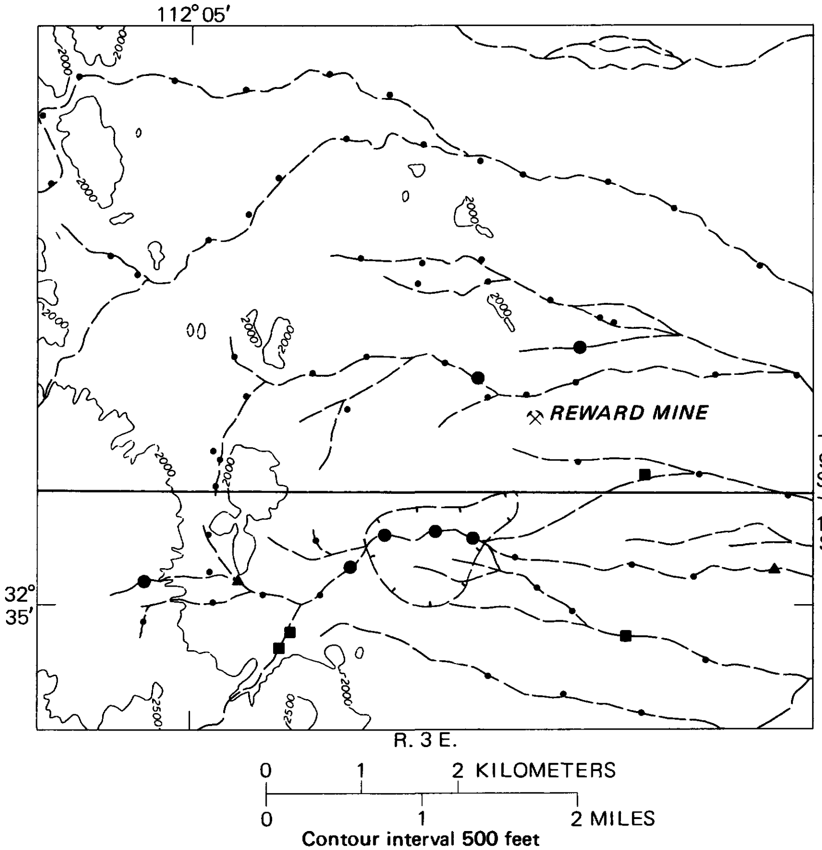
0 1 2 MILES

Contour interval 500 feet

EXPLANATION

- ——— Intermittent stream
- —┴—┴— Approximate outline of Vekol deposit
- • Neither plant part anomalous for Ag
- ● Only leaves anomalous ($\geq$0.3 ppm Ag)
- ▲ Only stems anomalous ($\geq$0.15 ppm Ag)
- ■ Both plant parts anomalous for Ag

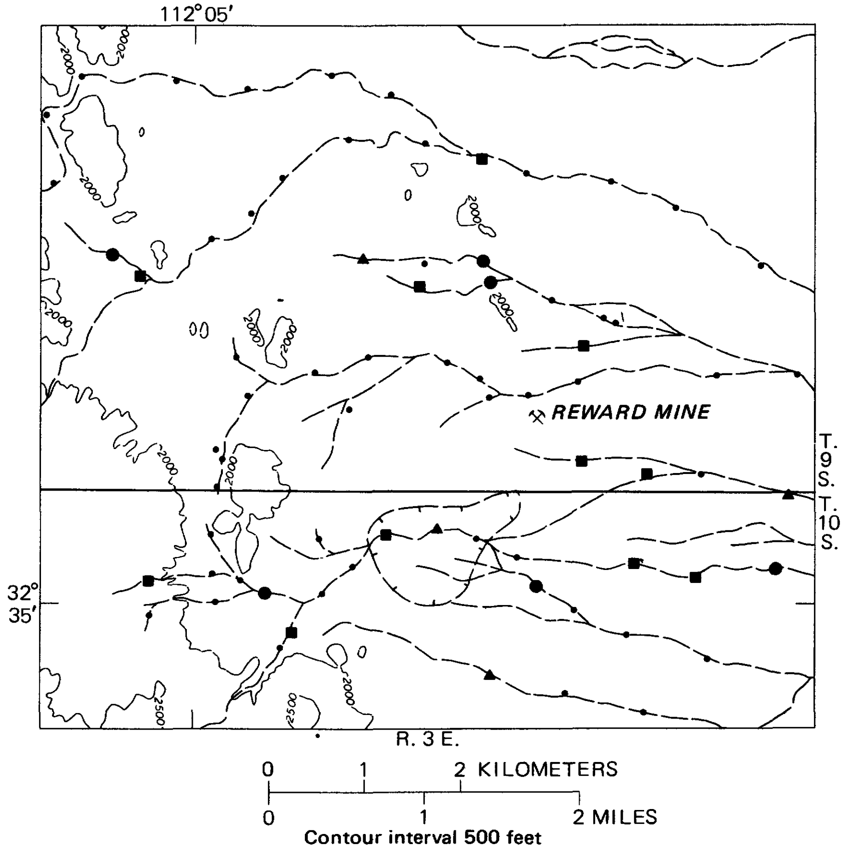
FIGURE 39.— Distribution of silver, ash of mesquite leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

- ——— Intermittent stream
- —⊥—⊥— Approximate outline of Vekol deposit
- • Neither plant part anomalous for Cu
- ● Only leaves anomalous (≥170 ppm Cu)
- ▲ Only stems anomalous (≥ 170 ppm Cu)
- ■ Both plant parts anomalous for Cu

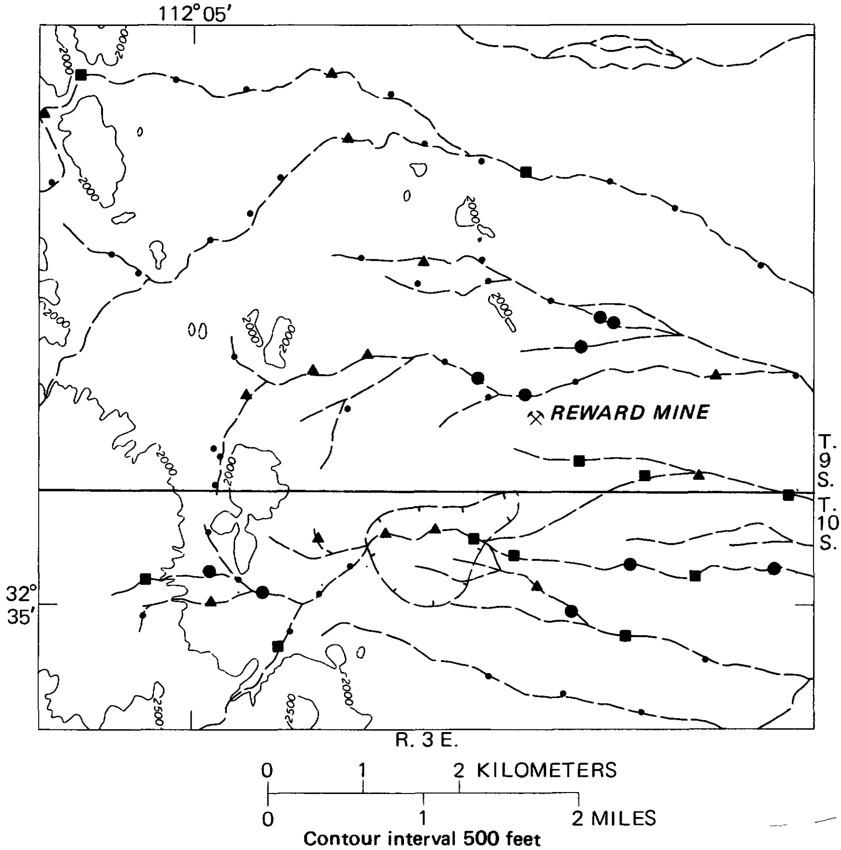
FIGURE 40.— Distribution of copper, ash of catclaw acacia leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

———	Intermittent stream	●	Only leaves anomalous (≥ 8 ppm Mo)
—⊥—⊥—	Approximate outline of Vekol deposit	▲	Only stems anomalous (≥ 11 ppm Mo)
•	Neither plant part anomalous for Mo	■	Both plant parts anomalous for Mo

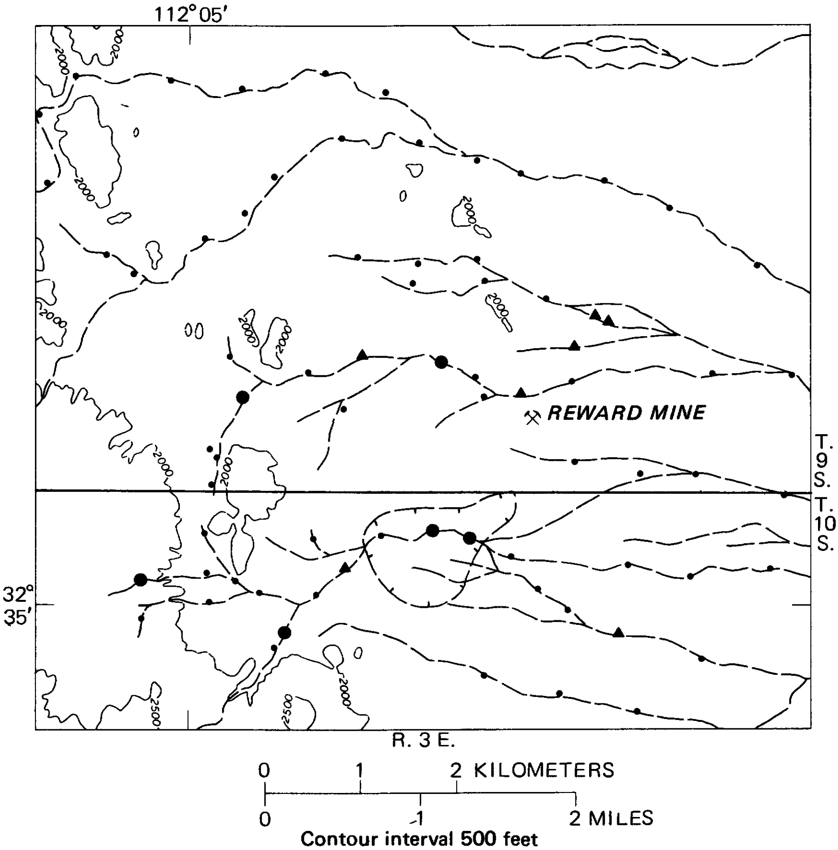
FIGURE 41.— Distribution of molybdenum, ash of catclaw acacia leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

- Intermittent stream
- Approximate outline of Vekol deposit
- • Neither plant part anomalous for Zn
- ● Only leaves anomalous (≥330 ppm Zn)
- ▲ Only stems anomalous (≥530 ppm Zn)
- ■ Both plant parts anomalous for Zn

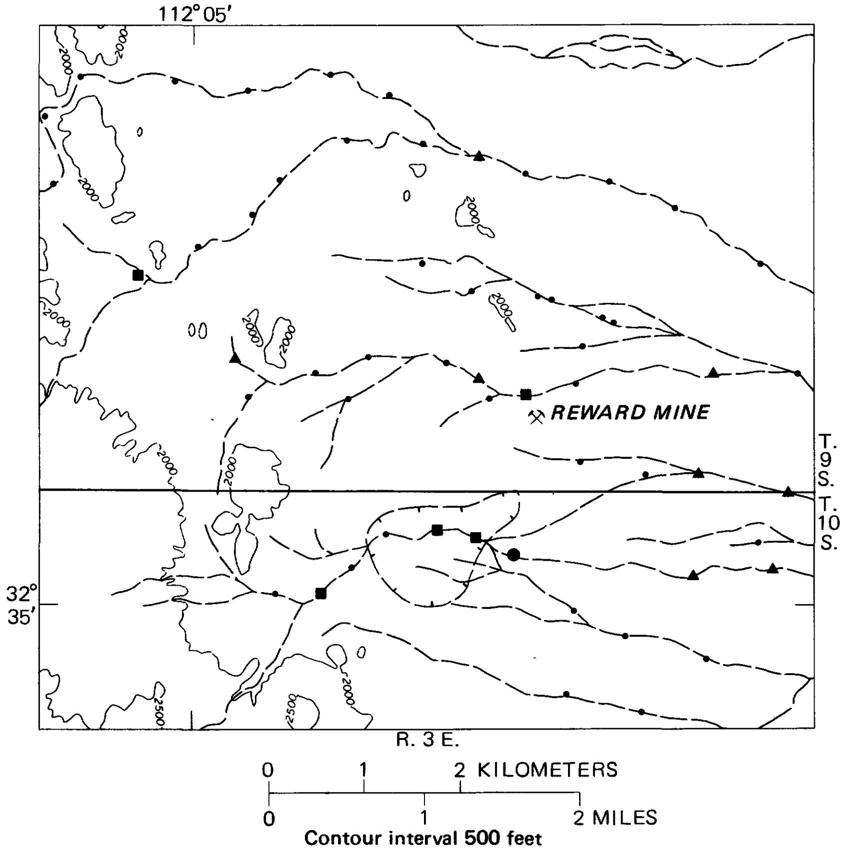
FIGURE 42.— Distribution of zinc, ash of catclaw acacia leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

- Intermittent stream
- Approximate outline of Vekol deposit
- Neither plant part anomalous for Ag
- Only leaves anomalous ($\geq$0.1 ppm Ag)
- Only stems anomalous ($\geq$"L(0.1)" ppm Ag)

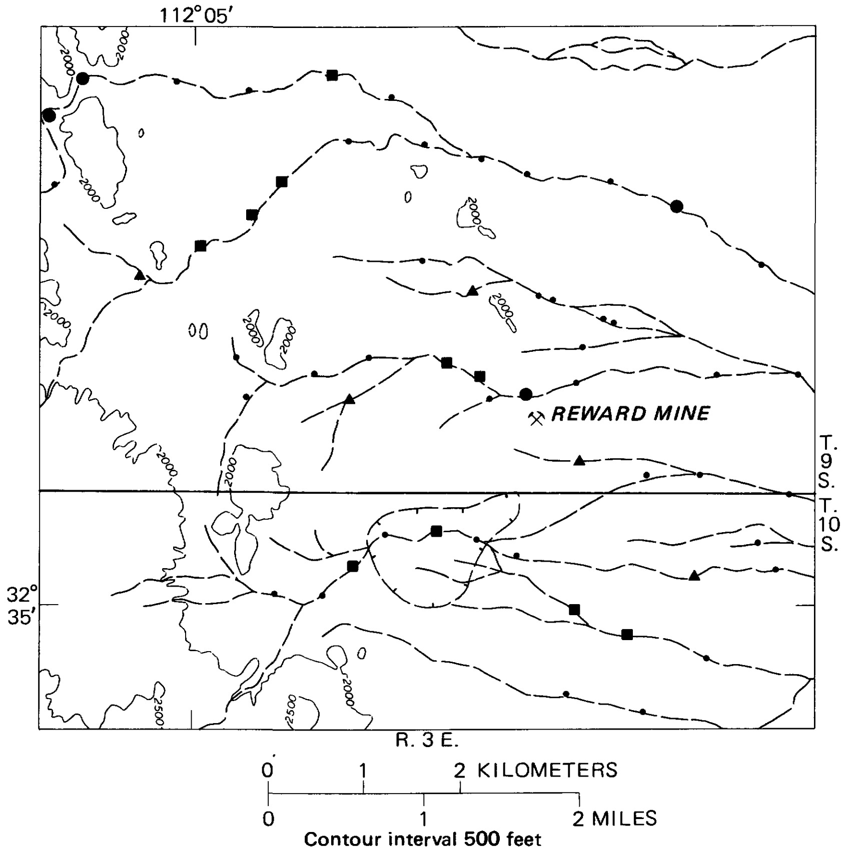
FIGURE 43.— Distribution of silver, ash of catclaw acacia leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

- Intermittent stream
- Approximate outline of Vekol deposit
- • Neither plant part anomalous for Cu
- ● Only leaves anomalous (≥150 ppm Cu)
- ▲ Only stems anomalous (≥110 ppm Cu)
- ■ Both plant parts anomalous for Cu

FIGURE 44.—Distribution of copper, ash of blue paloverde leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

———	Intermittent stream	●	Only leaves anomalous (≥ 3.0 ppm Mo)
—⊥—⊥—	Approximate outline of Vekol deposit	▲	Only stems anomalous (≥2.5 ppm Mo)
•	Neither plant part anomalous for Mo	■	Both plant parts anomalous for Mo

FIGURE 45.— Distribution of molybdenum, ash of blue paloverde leaves and stems, Vekol Mountains, Ariz.

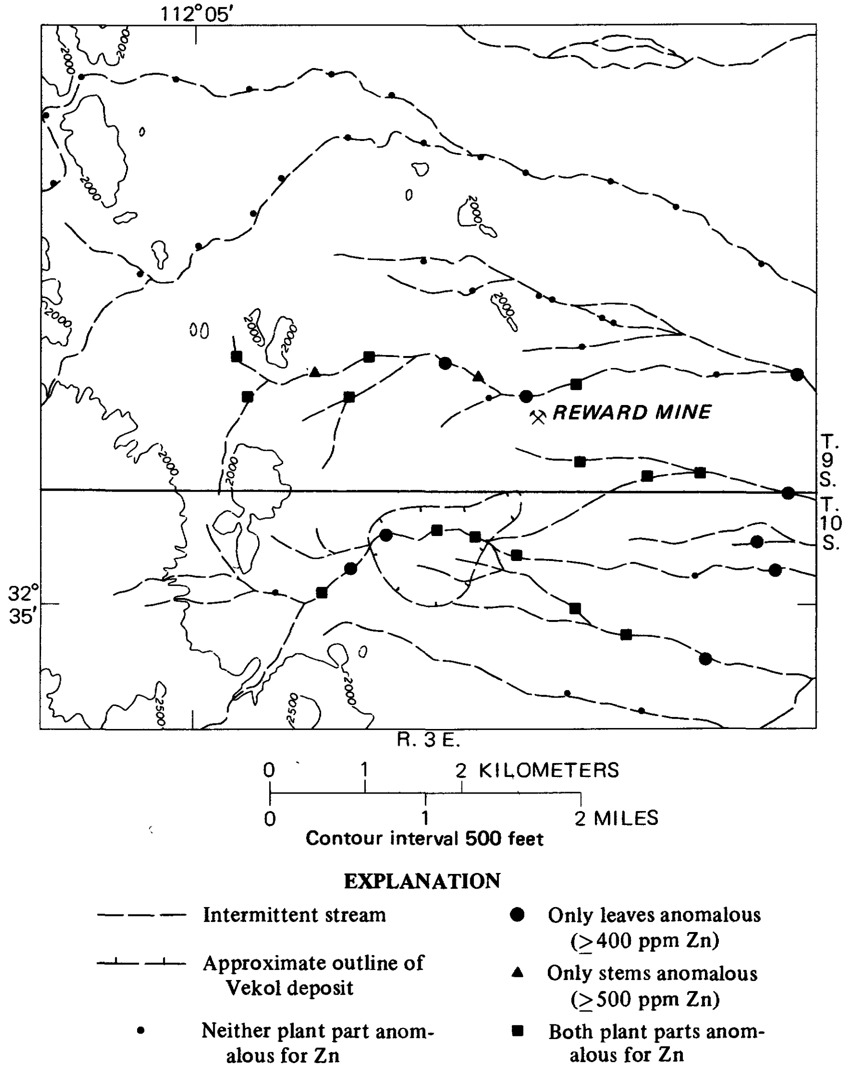


FIGURE 46.— Distribution of zinc, ash of blue paloverde leaves and stems, Vekol Mountains, Ariz.

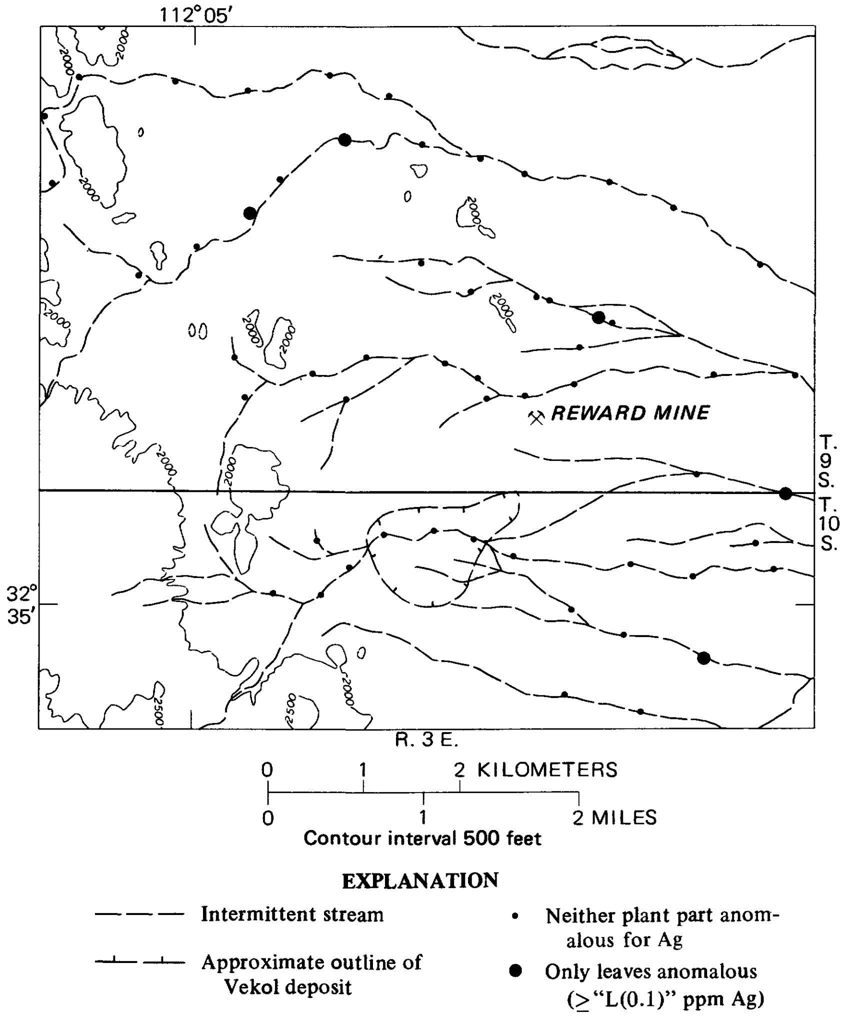
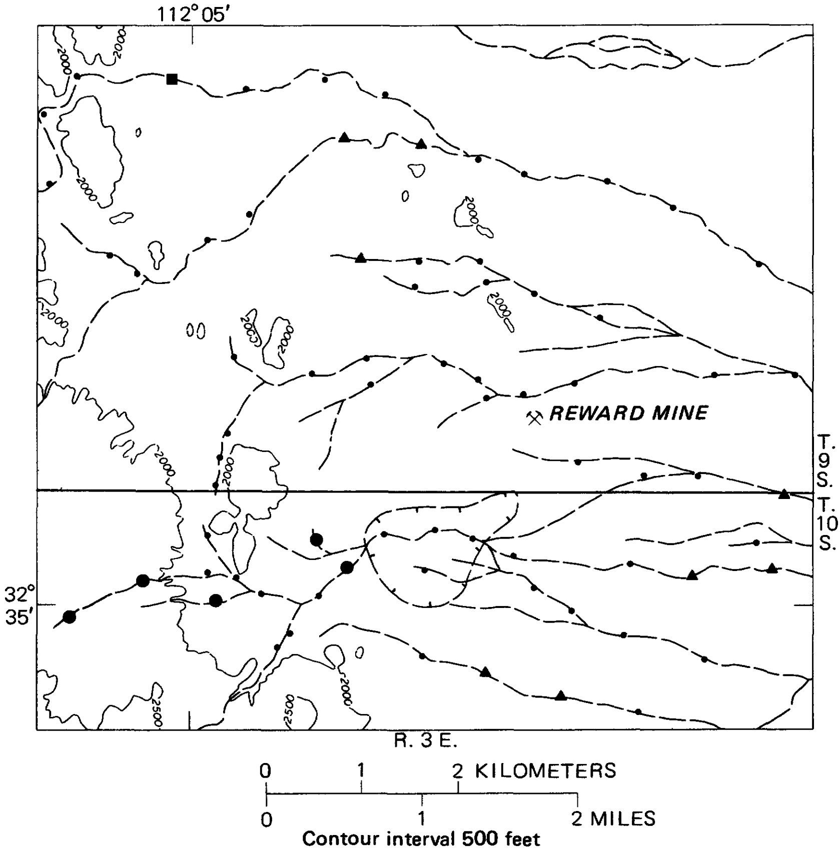


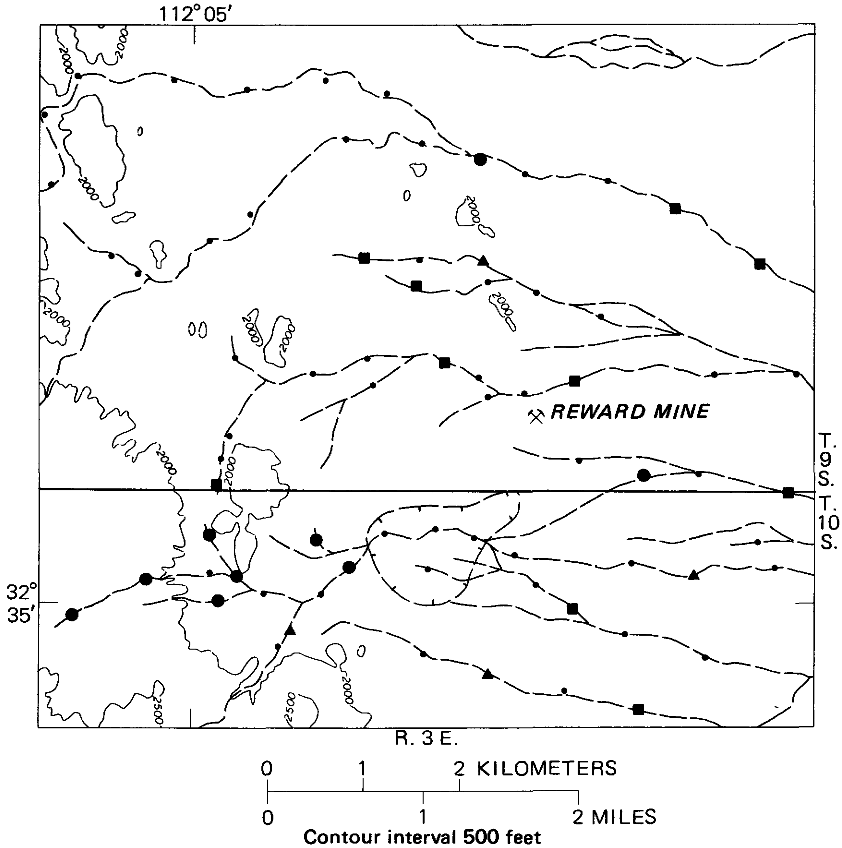
FIGURE 47.— Distribution of silver, ash of blue paloverde leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

- Intermittent stream
- Approximate outline of Vekol deposit
- Neither plant part anomalous for Cu
- Only leaves anomalous (≥100 ppm Cu)
- Only stems anomalous (≥110 ppm Cu)
- Both plant parts anomalous for Cu

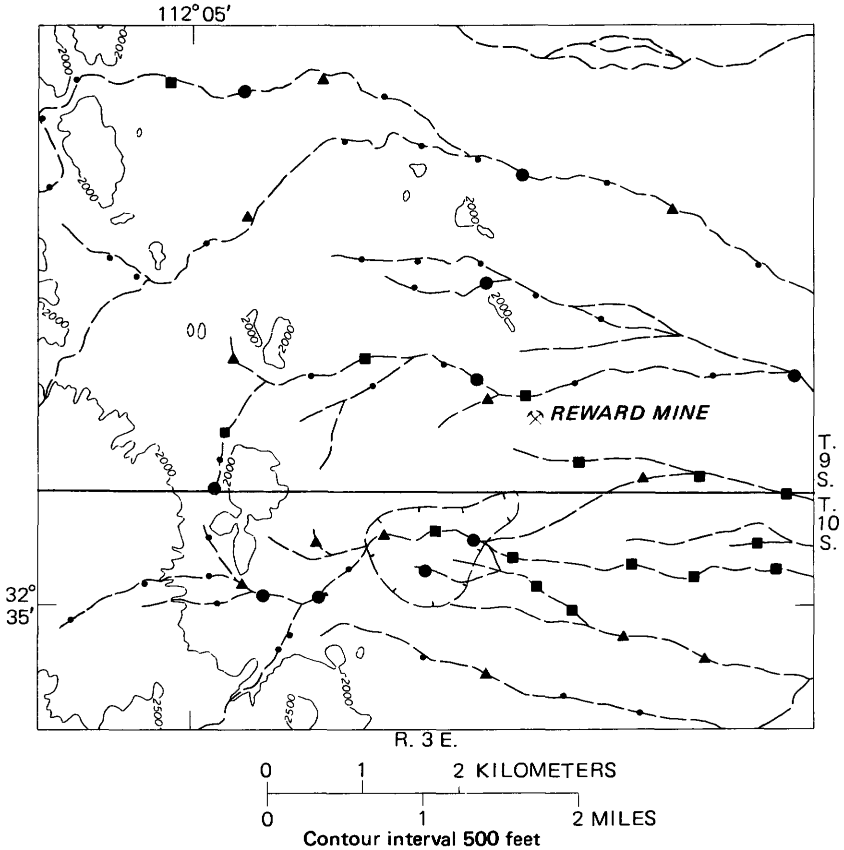
FIGURE 48.— Distribution of copper, ash of riparian ironwood leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

- Intermittent stream
- Approximate outline of Vekol deposit
- • Neither plant part anomalous for Mo
- ● Only leaves anomalous ($\geq$7 ppm Mo)
- ▲ Only stems anomalous ($\geq$9 ppm Mo)
- ■ Both plant parts anomalous for Mo

FIGURE 49.— Distribution of molybdenum, ash of riparian ironwood leaves and stems, Vekol Mountains, Ariz.



EXPLANATION

- Intermittent stream
- Approximate outline of Vekol deposit
- • Neither plant part anomalous for Zn
- ● Only leaves anomalous (≥260 ppm Zn)
- ▲ Only stems anomalous (≥500 ppm Zn)
- ■ Both plant parts anomalous for Zn

FIGURE 50.—Distribution of zinc, ash of riparian ironwood leaves and stems, Vekol Mountains, Ariz.

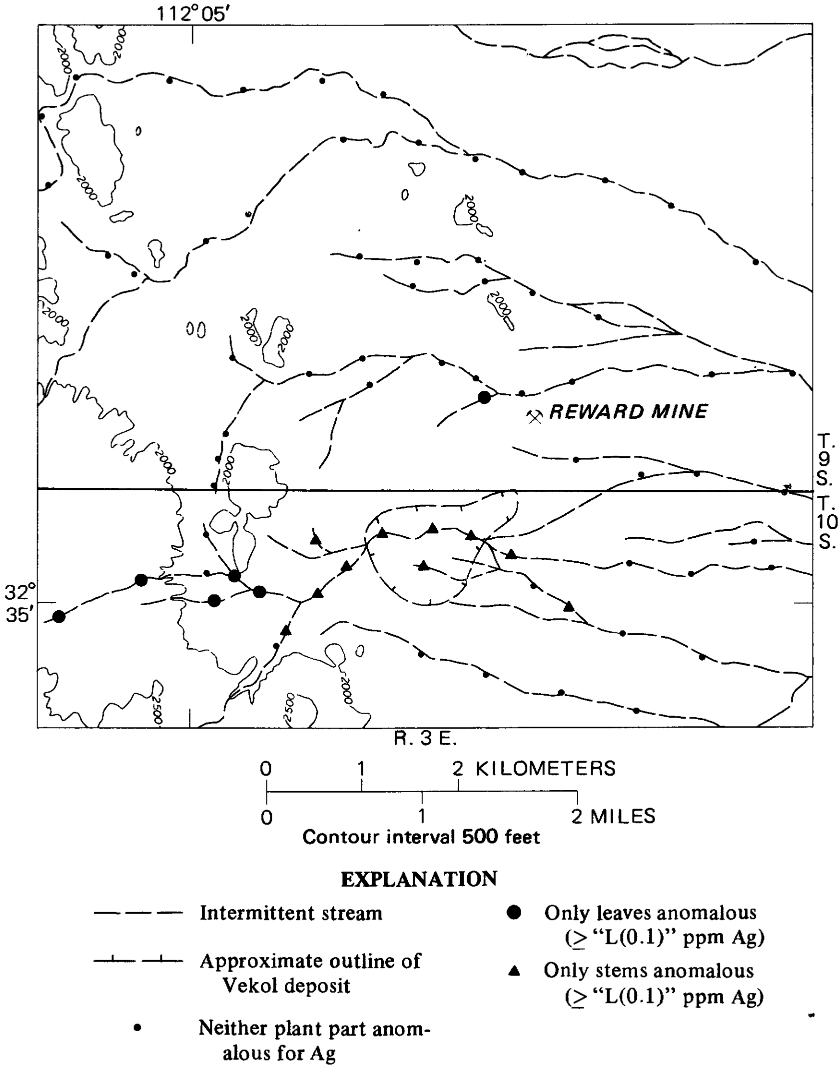


FIGURE 51.— Distribution of silver, ash of riparian ironwood leaves and stems, Vekol Mountains, Ariz.

☆U.S. GOVERNMENT PRINTING OFFICE: 1977-777-034/50