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Reconnaissance wadi-sediment geochemical survey of the Bi'r Jarbuah area, Kingdom of Saudi Arabia

by

Rashid M. Samater, Ralph P. Christian, and Bruce M. Walker

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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ABSTRACT

A reconnaissance wadi-sediment geochemical survey for gold was conducted in the Bi'r Jarbuah Area (lat 20° 45' 00"-21° 00' 00" N., long 43° 30' 00"- 43° 41' 00" E.). The area is located in the northern part of a regional concentration of gold occurrences, the Jabal Ishmas-Wadi Tathlith gold belt. Panned concentrates and minus-80-mesh fractions were obtained from 300 samples collected from a 320 km^2 area and analysed by atomic-absorption spectroscopy. Analyses of the panned-concentrate samples proved to be more definitive than sieved samples in delineating areas of mineralization.

Most of the anomalous gold-and arsenic-bearing wadi-sediment samples are located along an irregular contact between gneissic and dioritic rocks in the center of an area characterized by the presence of subparallel dacitic dike swarms. Most of the ancient gold mines are also located along this contact. Gold is associated with arsenic but not with silver. Five areas containing gold-anomalies areas and 6 areas containing tellurium anomalies and the contact zone between the diorite and the paragneiss are recommended for further investigation of precious-metals resources.

INTRODUCTION

A reconnaissance wadi-sediment geochemical survey was conducted in the Bi'r Jarbuah area during R. Awal 1409 (October 1988). The area investigated is located in the northernmost part of the Jabal Ishmas-Wadi Tathlith gold belt (Worl, 1979) and is located within the Nabitah mobile belt (Stoeser and Camp, 1984), a linear zone of intensely deformed rocks that strikes north-northwest across the Arabian Shield. This gold belt is known to contain deposits of gold and base metals (Boyle and others, 1984). The purpose of this study is to identify geochemical anomalies that may be related to known and undiscovered gold and silver mineralization. The study is a part of a larger exploration program conducted between Rajab 1408 (April 1988) and Jumad Thani 1409 (February 1989) designed to assess the mineral potential of the Bi'r Jarbuah ancient mine (DGMR project 3.11.29). It included, mapping, trenching, sampling, drilling, and economic assessment of the Bi'r Jarbuah mine (Walker and others, 1989); wadi-sediment geochemical sampling at a regional scale of 1:50,000 (the subject of this report); and electromagnetic, magnetic, and gravimetric surveys of Bi'r Jarbuah gold prospect (Miller and others, 1989).

Location and Topography

The sparsely inhabited Bi'r Jarbuah area (320 km^2) lies between lat 20° 45' 00" N. and 21° 00' 00" N. and long 43° 38' 00" E. and 43° 41' 00" E. in the northern part of the Ishmas-Wadi Tathlith gold belt within the Jabal Yafikh quadrangle, 20/43B, (Schmidt, 1981) (fig. 1). The area is located 80 km south-southeast of Ranyah and 150 km north-northeast of Bisha. A desert track connects the area to Ranyah. Much of the study area consists of low-relief old erosional surface with a regional west-to-east gradient. The drainage crosses old north-trending structures and is radially developed at the center where there is a possible east to west elongate domal rise. The two major wadis draining the study area are Wadi Al Jarbuah to the south and Wadi Al Jereibie to the north. Both wadis ultimately drain southeastward. Wadi sediments are very fine grained and contain little or no gravel.

Previous Work

The Jabal Yafikh quadrangle 20/43B, which includes the area under study was mapped by Jackson and others (1963) as part of the Southern Najd quadrangle at 1:500,000 scale and later at 1:100,000 scale by Schmidt (1981). The area was subsequently mapped (at 1:250,000) by Kellogg and others (1983) as part of the geology of the Precambrian rocks in the wadi Tathlith quadrangle. The Bi'r Jarbuah mine (MODS 01454), which is located within the study area, was mapped and sampled by Worl (1979) and Bishop (1982) as part of a study of the Jabal Wadi Tathlith gold belt. Walker and others (1989) conducted a trenching, mapping, and drilling program at the Bi'r Jarbuah ancient mine.

Present Investigation

The purpose of this investigation was to acquire and interpret wadi-sediment and wadi-concentrate geochemical data and to outline anomalous areas potentially related to gold and silver mineralization. The work was undertaken in Safar 1409 H (October 1988). Three hundred samples were collected using a helicopter for 6 days, collecting an average of 50 samples a day. Sample preparation and panning was completed in 6 days by field assistants Mohsin Mohamed Ahmed and Hassan Musa Mohamed (USGS). Three hundred minus-80-mesh fraction samples and 300 panned concentrate samples were obtained from the original wadi-sediment samples. The samples were then sent to Skyline Labs, Inc. (Denver, Colorado) for analysis. The analytical results were entered into the Rock Analysis Storage System (RASS). Computer plots of the geochemical data were generated by Ralph Christian of the USGS Computer Section, Jeddah, using the USGS computer programs GSDRAW and GSMAP (Selner and Taylor, 1988).

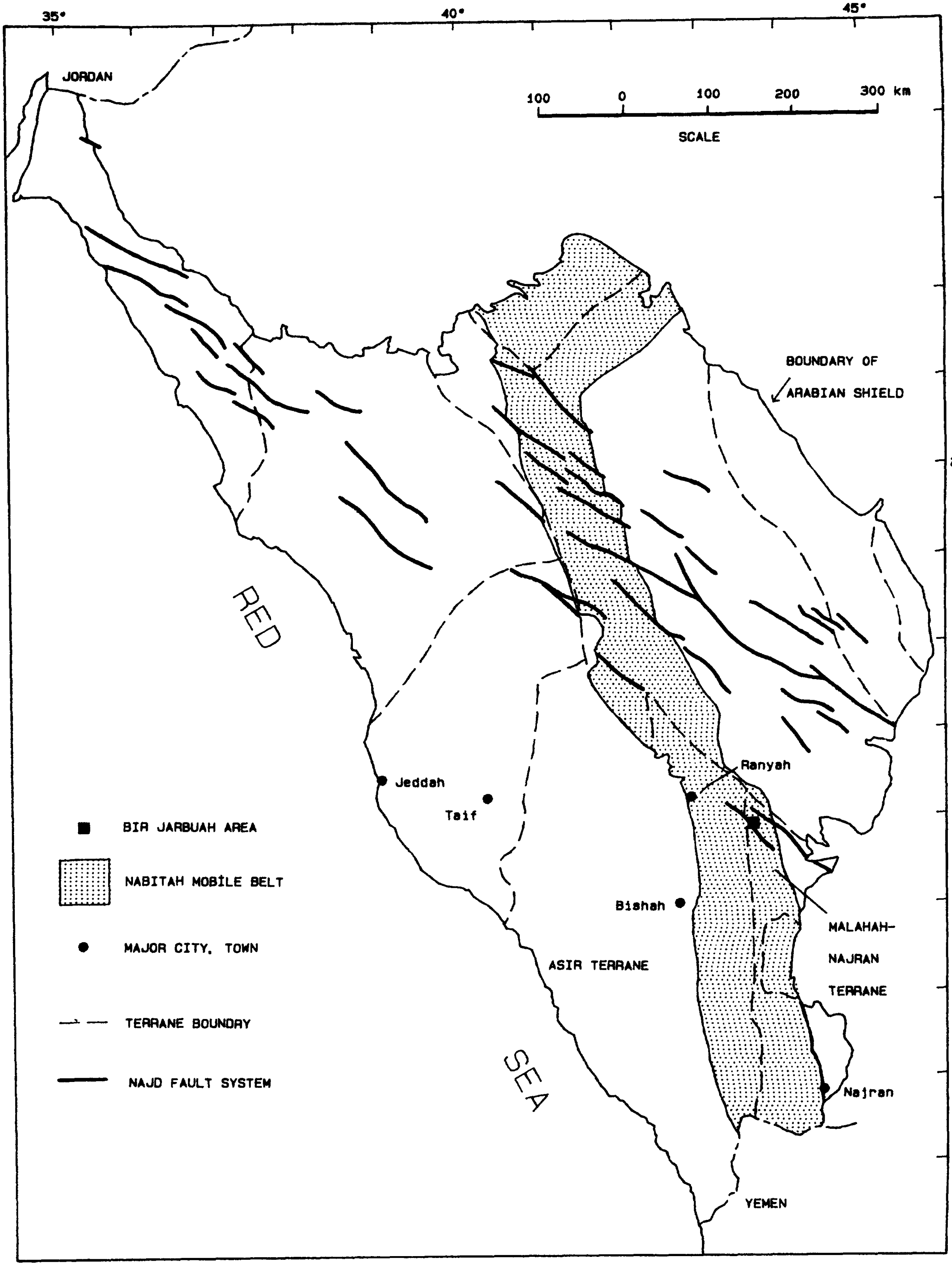

Figure 1.--Index map of Saudi Arabia showing the location the of Bi'r Jarbuah area.

ACKNOWLEDGMENTS

The authors would like to thank Mohsin Mohamed Ahmed and Hassan Musa Mohamed for their diligence in sample preparation and panning, and Eric Bookstrom and Mumtaz Khan for their assistance with the computer work. The authors are also grateful to P.R. Johnson for technically reviewing this report.

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GEOLOGY

The geology of the region has been described by Schmidt (1981) as part of the geology of the Jabal Yafikh quadrangle, and by Kellogg (1983) as part of the geology of the Precambrian rocks in the Wadi Tathlith quadrangle. Two major sequences of layered rocks are recognized: The Halaban group and the Murdama group. The oldest rocks in the area, the Halaban group, are predominantly metabasalt, meta-andesite, and interbedded derivative sandstone that is thought to have formed in an island-arc environment at about 785 to 700 Ma (Kellogg, 1983). These layered rocks are intruded principally by subvolcanic dioritic and tonalitic plutonic rocks.

Between 660 and 640 Ma, a regional-compression event isoclinally deformed the rocks of the Halaban group about north-trending axes and locally metamorphosed them to upper-amphibolite facies. Dioritic and tonalitic rocks were subsequently cataclastically deformed and intruded by large bodies of gneissic granodiorite and monzogranite.

Rocks of the Murdama group were deposited between 640 and 610 Ma in Andean-type back-arc basin (Kellogg, 1983). These rocks of a thick basal polymictic conglomerate and arkose sequence with sparse basalt and rhyolite flows that grade into a diverse sandstone sequence. Between 610 and 595 Ma, the Murdama-group were faulted and deformed into open and isoclinal folds having generally north to northwest trends and metamorphosed to green-schist facies. During the Najd-faulting event (600 to 550 Ma; Kellogg, 1983), final regional compression of the crust resulted in intense pervasive shearing of the Murdama rocks and underlying Halaban rocks thereby producing a cataclastic zone 10 - 20 km wide.

More than 80 percent of the study area (fig. 2) is comprised of Halaban-group rocks and associated intrusive rocks. The Murdama rocks are restricted to the northeastern corner of the study area. The Halaban-group rocks consist of paragneiss and paraschist, and can be divided into amphibolite and biotite paragneiss units (Schmidt 1981) as follows:

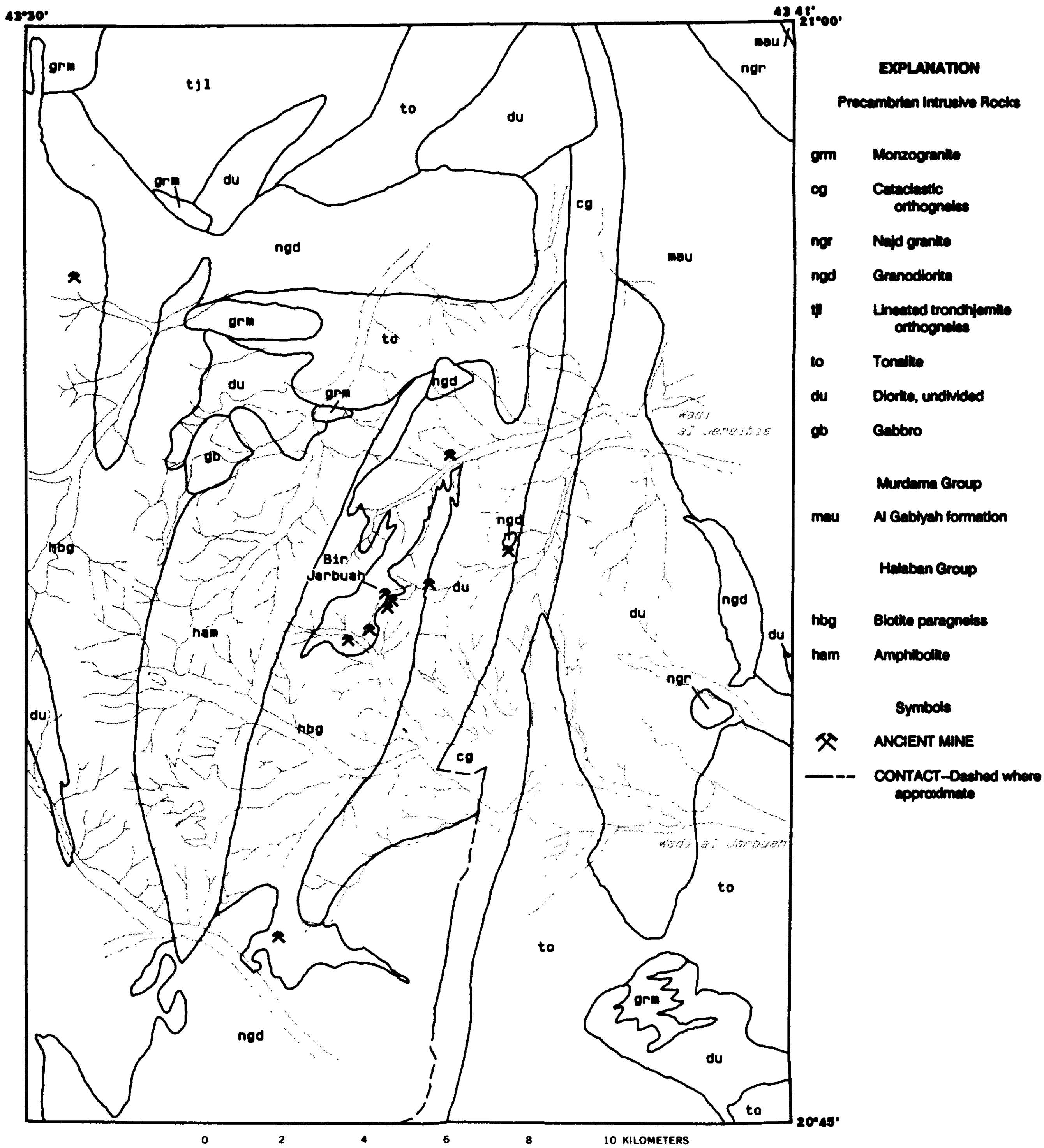

Figure 2.--Generalized geology of the Bi'r Jarbuah area (geology after Schmidt, 1981) showing wadi courses (gray).

HALABAN GROUP

Amphibolite

These rocks (ham) consist of very fine grained dark-gray, dark-green, and dark-blue to black layered gneisses. The composition is predominantly amphibolite. Most of the rocks are interlayered basaltic and andesitic volcanic rocks and associated greywackes that have been metamorphosed to epidote-amphibolite and almandine-amphibolite facies.

Biotite Paragneiss

These rocks (hbg) consist of very fine grained gray-brown gneiss characterized by distinct gneissic layering and schistosity. The composition is predominantly that of a leucocratic biotite and feldspar-rich schist or gneiss. Many rocks are calcareous. Conspicuous layers and lenses of marble and tactite are derived from limestone and dolomite.

In the Jabal Yafikh quadrangle, the Murdama group is divided into three formations: the Al Ghabiyah, the Jarbuah, and the Jabal Yafikh formations. Only the Al Ghabiyah formation is represented in the study area.

MURDAMA GROUP

Al Ghabiyah Formation

This formation (mau) consists of arkosic conglomerate and sandstone, quartz greywacke, and sparse silicic volcanic rocks. The formation is divided into five members that in general becomes finer grained upwards. The basal member is a coarse conglomerate; the uppermost exposed member is a fine-grained sandstone and siltstone.

PRECAMBRIAN INTRUSIVE ROCKS

The plutonic rocks of the Jabal Yafikh quadrangle range in composition from gabbro to alkali-feldspar granite; they range age from those rocks synchronous with Halaban volcanism and to those synchronous with Najd faulting. These plutonic rocks underlie about 70 percent of the study area and consist of the following lithologies:

Gabbro

A small olivine gabbro (gb) pluton in contact with diorite units is exposed on the western side of the area.

Diorite, Undivided

Undifferentiated dark-grey hornblende diorite and gray quartz diorite (du) are widespread throughout the study area. The quartz diorite is closely related to the hornblende diorite and in part grades into it.

Tonalite

The undifferentiated tonalite (to) unit consists of light-gray, leucocratic tonalite and trondhjemite and is very well exposed in the study area.

Lineated Trondhjemite Orthogneiss

The lineated trondhjemite orthogneiss (tjl) is best exposed in the northwestern corner of the study area. It is light reddish gray, strongly lineated, and contains mineral assemblages of garnet, epidote, hornblende, and oligoclase.

Granodiorite

The leucocratic granodiorite (ngd) is an undifferentiated rock that ranges in composition from quartz diorite and tonalite-trondhjemite, through granodiorite, to monzogranite. The rock is porphyritic and locally contains large potassium-feldspar phenocrysts.

Najd Granite

The Najd granite (ngr) occupies the extreme northeast part of the study area. The granite is pink to brownish gray, medium grained, and slightly porphyritic. It contains accessory allanite, sphene, and zircon.

Cataclastic Orthogneiss

The cataclastic orthogneiss (cg) forms a distinct unit within a large, north-trending fault zone that extends across most of the western part of the Jabal Yafikh quadrangle all the way through the eastern part of the study area. This orthogneiss is a complex, sheared mixture of all the plutonic host rocks adjacent to the fault zone. The rocks are dark to light gray to reddish brown and are very fine grained. Most of the rocks are gneiss units that grade to mylonite.

Monzogranite

Five small hypabyssal plutons and stocks are mapped in the study area. One pluton in the northwestern corner of the area is part of a larger body extending west into the Jabal Ishmas quadrangle (Gonzalez, 1974). Other stocks are less than 3 km^2 in area. The monzogranite (grm) is commonly red or gray fine grained, leucocratic with micrographic texture in part.

GOLD MINERALIZATION

Small low-grade, milky-white gold-bearing mesothermal-hydrothermal quartz veins are found in the rock units throughout the region mapped by Schmidt (1981). They occur in pyritic, hydrothermally altered wall rock that conspicuously weathers to a reddish brown color. Schmidt (1981) suggested that the gold mineralization is related to small, widespread, tensional and shear fractures that formed during the Najd-faulting event. However, Kellogg (1983) suggested that substantial gold mineralization may slightly predate the period of Najd faulting and be synchronous with north-south faulting and folding of the Murdama-group rocks, as evidenced by the occurrence of gold in quartz veins that trend generally north-south and their association with diorite plutons that intrude the Murdama-group rocks but predate Najd faulting.

Ancient miners thoroughly prospected and exploited the gold-bearing quartz veins. The Bi'r Jarbuah mine (MODS 01454) is the largest of five ancient mines in the study area and consists of sand-filled pits that follow quartz veins. The mine workings are approximately 50 m wide and 550 m long. The veins strike N. 5° E., dip 40° W. and are principally grey-blue quartz fillings containing possible carbon inclusions (Walker, and others, 1989). The strike of these veins is not typical of the Najd system, but is the result of local faulting (Walker and others, 1989). The mine is situated partly within graphitic phyllite 50-100 m east of a diorite intrusive contact. The highest concentrations of significant elements collected from trench samples include: 162 ppm Au (the mean for 3 repeat analyses over 7m), 42 ppm Ag (5m), and 5000 ppm As (7m)(Walker and others, 1989).

Other ancient mines in the area are smaller and consist of several small pits and dumps that follow quartz veins.

FIELD AND LABORATORY PROCEDURES

A total of 300 wadi-sediment samples (subsequently split into 300 panned-concentrate and 300 minus-80-mesh fraction samples) were collected from the 320 km^2 study area; the average sampling density is about one sample per square kilometer. Rock analysis storage system (RASS) numbers assigned to these begin at 242001 and end at 242600 (the first 300 numbers are for panned concentrates, second 300 numbers are for minus-80-mesh fraction). About 8 kg of unconsolidated wadi material was collected (at a depth of 20 cm) at each sample site. Each sample was then mechanically split and a quarter of one split sieved to minus-80-mesh while the remaining portion was panned using standard gold-panning techniques. Magnetite was removed from the panned concentrate using a hand magnet. The resultant samples were sent to Skyline Labs, Inc. (Denver, Colorado, USA) for analysis. Gold was analyzed by the AA graphite-furnace method which has a lower detection limit of 0.002 ppm. Silver, copper, lead, zinc, molybdenum, arsenic, and tellurium analyses were conducted using atomic-absorption spectroscopy techniques.

DATA ANALYSIS AND PRESENTATION OF RESULTS

All analytical results and other information pertaining to the samples were archived in RASS. The analytical data were statistically treated using the STATPAC routines developed for the U.S. Geological Survey (Sower and others 1971). The geometric mean and the standard deviation were calculated by element for the sample population. The geometric means were adjusted using Cohen's method (Miesch, 1967) for estimation of means and standard deviations for censored distributions. Element concentrations in all 300 samples (those with values above the detection limit and those with interpolated values below it) were included in the calculations. Frequency-versus-concentration histograms were plotted by element by computer for the sample population (fig. 3). The geometric midpoints (1., 0.7, 0.5, 0.3, 0.3, 0.2, 0.15, 0.1, e.g. figs. 3G and 3H) of geometric brackets having boundaries 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, 0.083, etc., are used as class intervals for the construction of the histograms. (Note: gaps occur between the bars in the histogram figures because the computer program used in plotting the figures is more suited to bar graphs than histograms.) The threshold between background and anomalous categories of analytical data was selected by inspection of concentration histograms and is reported as the midpoint value of the histogram class that marks the threshold. In this study, the term "background" refers to element values at or below the threshold; the term "anomalous" refers to element values above the threshold. Histograms for lead, copper, zinc, and molybdenum in the minus-80-mesh fraction samples were not plotted because very few sample concentrations were above the lower limit of detection.

The mean, standard deviation, and threshold values for each element distribution derived from the panned concentrates and the minus-80-mesh fraction samples are shown on Table 1. Computer-generated plots of sample concentrations greater than the threshold value are shown on figures 4 to 11 for the panned concentrates and figures 12 to 15 for the minus-80-mesh fractions. Note: figures 4 through 15 are shown at the end of the following section, see page 17.

DISCUSSION OF RESULTS

ELEMENTAL DISTRIBUTION

Distribution of gold in the panned-concentrate samples shows marked skewness (fig. 3A) because of the constraints of the analytical method. Tellurium exhibits normal distribution in panned concentrates and in minus-80-mesh fractions (fig. 3F). However, the distribution of tellurium in the panned concentrate samples shows a marked shift to the right relative to the minus-80-mesh tellurium population. This may be due to either the effect of a concentration factor as a result of panning or the presence of coarse-grained tellurium lost with the minus-80-mesh fraction. All distributions show increased elemental abundance in the panned concentrates with the exception of silver (fig. 3G). Fine-grained silver, probably washed off during panning, is readily detected in the minus-80-mesh (fig. 3K) fraction samples. Lead distribution in the panned concentrates is log normal, while no distribution was observed in the minus-80-mesh fractions. The selection of the heavy-mineral concentrate of stream-sediment geochemical analysis for mineral exploration is strongly supported by: 1) the increase in size of the element sample population above the detection limit (except for silver and molybdenum); and 2) by increased gold-arsenic-tellurium dispersion patterns (see below).

Table 1.--Geometric mean, standard deviation, and threshold value for 300 wadi-sediment samples from Bi'r Jarbuah area.

[N = number of samples with concentrations greater than the lower detection limit. All values are in ppm. Geometric mean and standard deviation calculated by methods of Sower and others (1971), assigning values to samples below the detection according to Cohen's method for estimating means of censored distributions (Miesch, 1967).]

Panned concentrates

Element	N	Lower limit of detection(ppm)	Geometric mean	Standard Deviation	Selected Histogram Threshold Value
Gold	115	0.002	0.002	0.28	0.005
Silver	12	0.2	0.11	0.10	0.2
Arsenic	238	5.0	9.23	17.4	30
Copper	300	5.0	19.3	6.3	30
Lead	55	5.0	3.3	18.75	10
Zinc	300	5.0	27.6	7.73	50
Molybdenum	11	2.0	1.0	0.19	2
Tellurium	300	0.005	0.06	0.058	0.1

Minus-80-mesh fraction samples

Element	N	Lower limit of detection(ppm)	Geometric mean	Standard Deviation	Selected Histogram Threshold Value
Gold	12	0.002	0.011	0.013	0.002
Silver	52	0.2	0.12	0.078	0.2
Arsenic	22	5.0	2.68	1.69	5
Copper	300	5.0	14.75	2.3	20
Lead	2	5.0	2.51	0.20	5
Zinc	300	5.0	29.83	3.78	50
Molybdenum	79	2.0	1.2	0.47	2
Telluruim	239	0.005	0.61	0.009	0.02

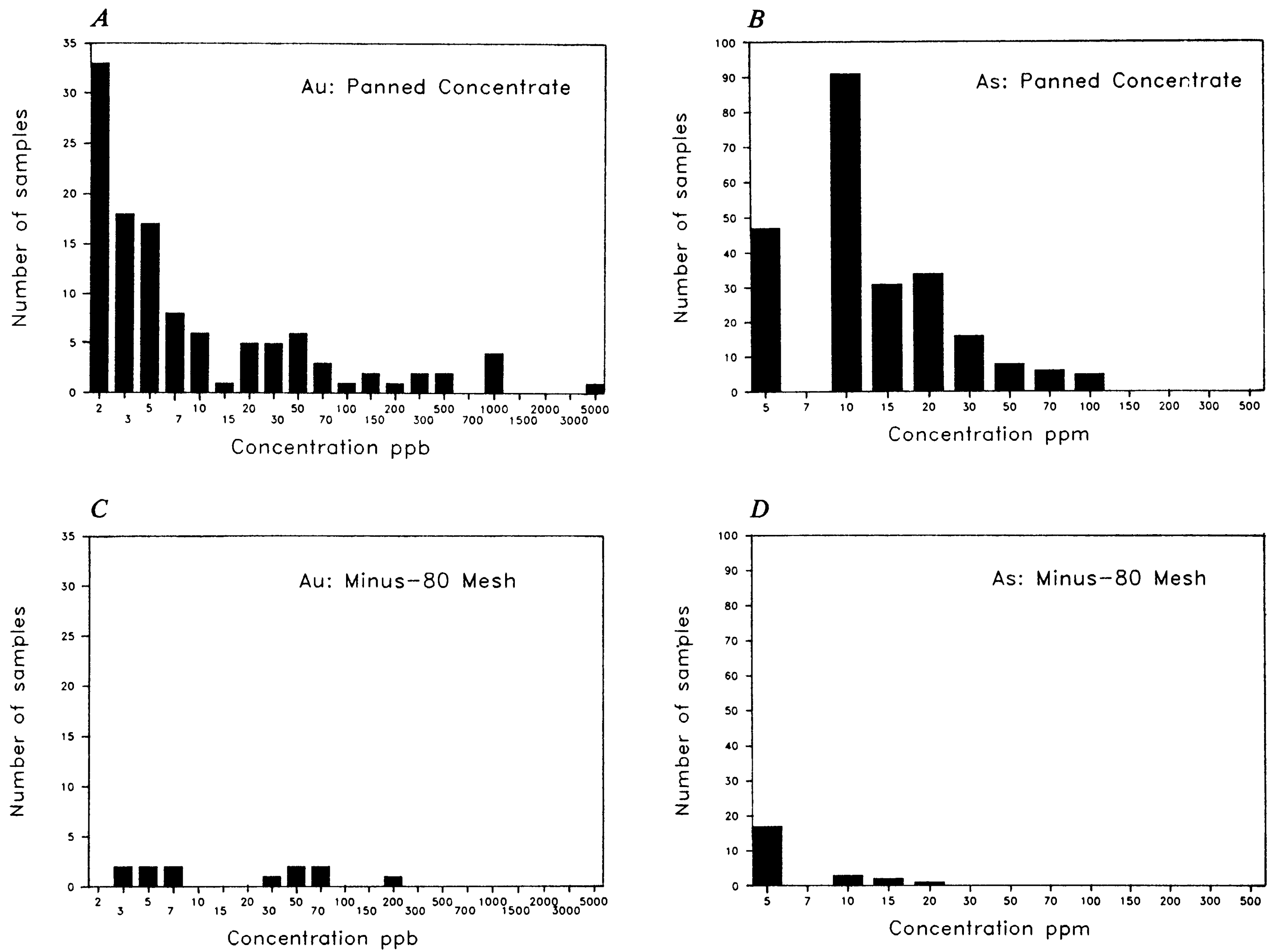

Figure 3.--Frequency-versus-concentration histograms for the sample population by element.

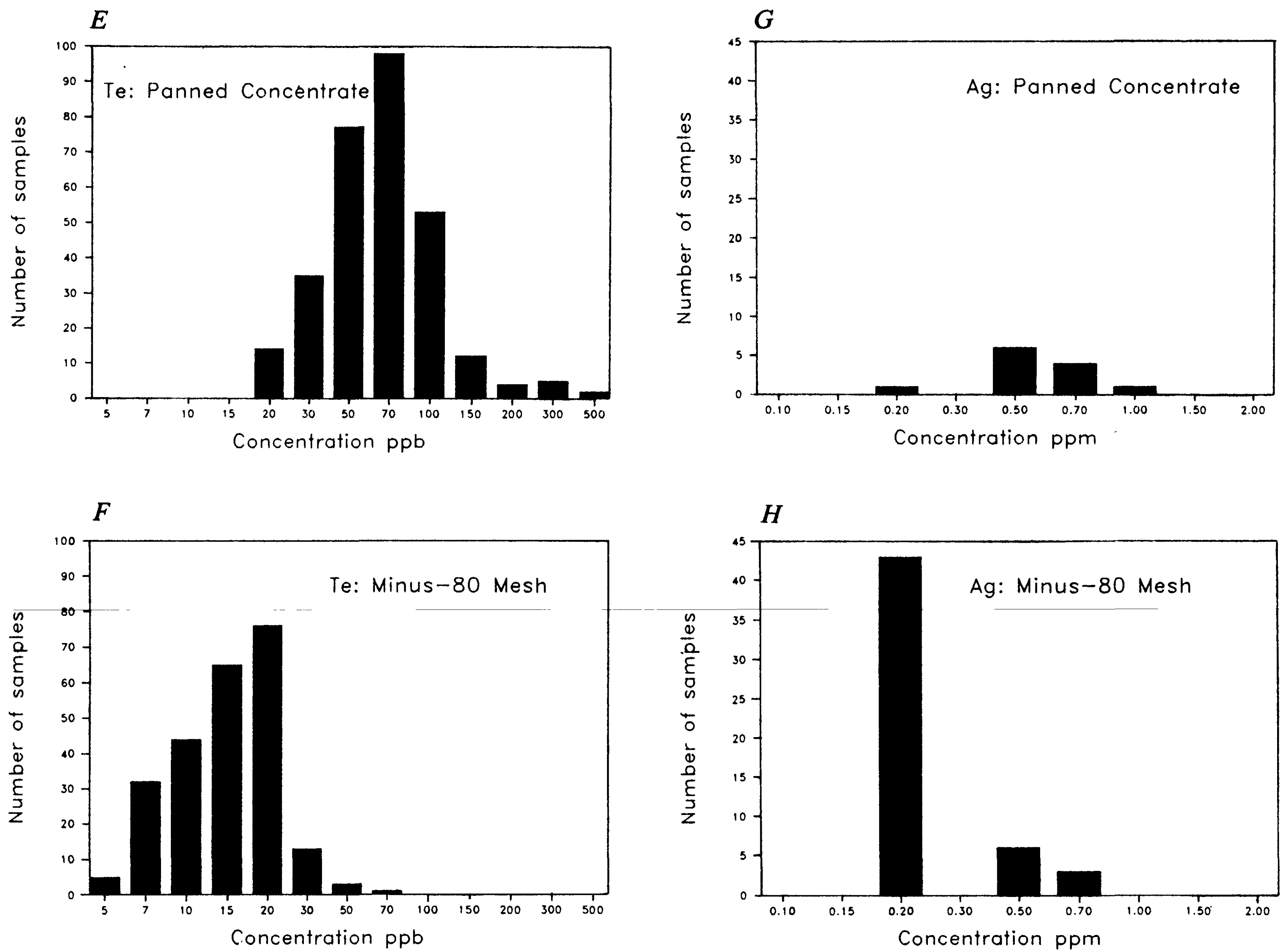

Figure 3.--Frequency-versus-concentration histograms for the sample population by element--Continued.

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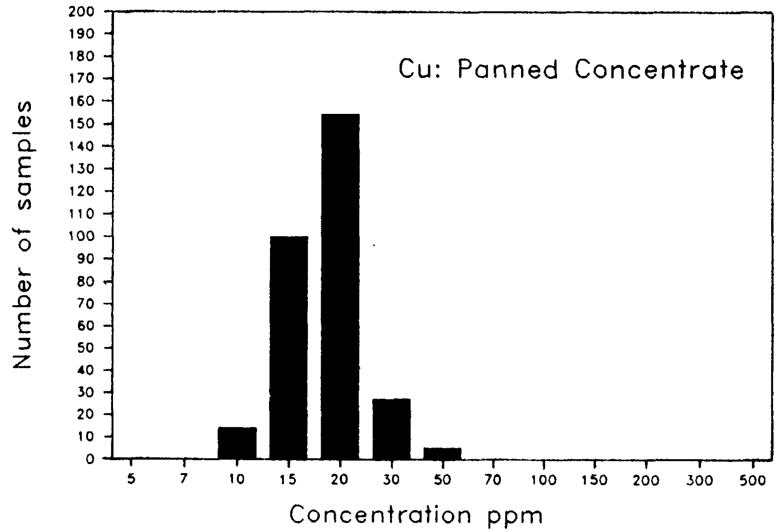

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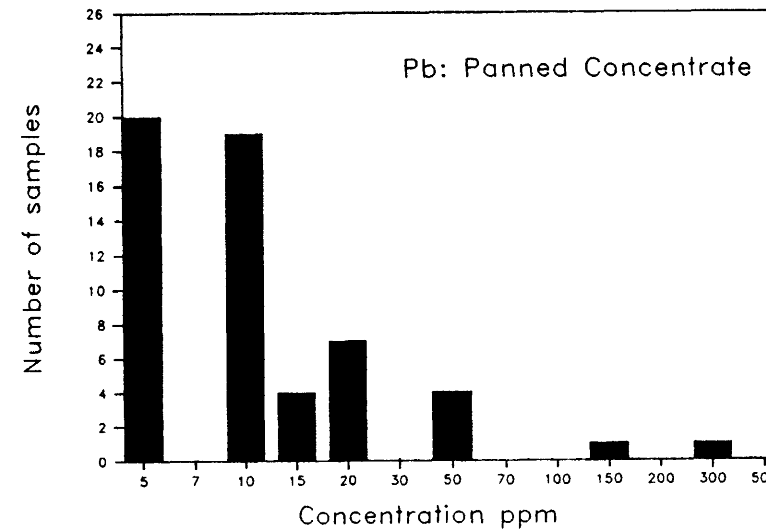

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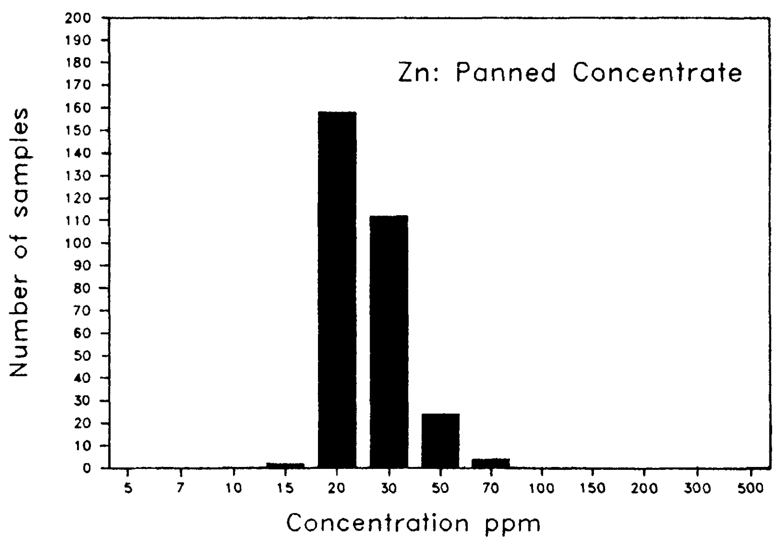

Figure 3.--Frequency-versus-concentration histograms for the sample population by element--Continued.

Geochemical Anomalies

Panned Concentrates

Gold and Arsenic--One hundred and fifteen of the samples collected contained detectable gold concentrations within the range of 2 to 4,400 ppb. Most samples containing anomalous concentrations of gold were collected along the contact of the diorite with biotite paragneiss; and six drainages containing anomalous concentrations of gold (areas A to F, fig. 4) are proximal to this intrusive contact. Samples were collected from anomalous areas A and B downstream from Bi'r Jarbuah ancient mine. The mine was exploited extensively by the ancient miners, as indicated by the presence of grindstones and an ancient village near the site. Two dump samples collected by Worl (1979) contained 4.2 and 7.0 g/t gold. The highest concentration (162 ppm Au), the mean of 3 repeated analyses, was obtained from a trench (Walker and others, 1989).

Anomalous concentrations (in areas C and D) are present in samples collected from wadis that do not drain the Bi'r Jarbuah mine. Gold concentrations in samples of area C range from 12 to 540 ppb with the highest concentrations found farthest south from Bi'r Jarbuah mine; therefore, these concentrations represent the probable existence of another site of gold mineralization.

The highest gold concentration (4,400 ppb) in the entire region is present in anomalous area E; other gold concentrations are lower. This anomaly is close (and probably related) to anomalous area F. There is gold mineralization in area F as indicated by the existence of an ancient mine. The two anomalous areas may be an upper-level manifestation of a larger gold-producing, igneous hydrothermal system underneath.

Arsenic was detected in 76 percent of the samples. The distribution patterns of anomalous arsenic closely follow the patterns associated with anomalous gold concentrations (fig. 5). The four anomalous areas (A, B, C, and D) are also anomalous in gold. Arsenic is a significant pathfinder element for arsenical gold deposits.

Tellurium and Silver--Tellurium was detected in all 300 samples collected from the study area; anomalous concentrations range from 110 to 550 ppb. Tellurium does not associate with gold and is, in fact, conspicuously absent from areas containing anomalous concentrations (fig. 6). Anomalous tellurium values form a horse-shoe pattern (open at the north end) around areas anomalous in gold and arsenic. Since tellurium is relatively immobile under most weathering conditions, the pattern might be indicative of the primary tellurium dispersion in the area. Eight drainage areas have been outlined (fig. 6) as being anomalous in tellurium. Areas A and B which enclose one or two samples sites contain the highest tellurium concentrations. Most of the anomalous samples occur in the western part of the study area (in areas E, F, and G) in gneissic and amphibolitic rocks.

Eleven samples were found to contain silver concentrations ranging from 0.4 to 1.2 ppm. The anomalous samples do not cluster in discrete areas. However, they are scattered on the periphery of the central gold- and arsenic-rich area and are closely associated with samples that contain anomalous concentrations of tellurium (fig. 7). Silver is closely associated with tellurium, but not with gold (fig. 7) The highest silver concentration (1.2 ppm) occurs in the western part in an area that also contains anomalous concentrations of tellurium (area E, fig. 6).

Lead and Molybdenum--Most of the anomalous lead concentrations are present in the southwestern part of the study area (fig. 8). These concentrations range from 15 to 50 ppm, except for two high values (155 and 270 ppm) in samples collected from wadis draining amphibolite and gneissic rocks. The presence of lenses of tactitic rocks of metamorphosed impure limestone and dolomite in these rock units suggests that lead-carbonate minerals may be the source of the geochemical anomalies

Only 11 samples contained any significant concentrations of molybdenum (fig. 9). These concentrations are at the detection limit (2 ppm) and scattered around the area whose anomalous gold and arsenic concentrations form a pattern similar to that of silver.

Copper and Zinc--Although copper and zinc were detected in all samples collected, only 11 samples are anomalous in copper; and 7 samples are anomalous in zinc. Copper concentrations are low (30-55 ppm)(fig. 10) and form two anomalous areas in the west and center of the study area. These areas also contain anomalous concentrations of zinc. Zinc concentrations are also low (50-70 ppm)(fig. 11).

Minus-80-Mesh Fraction Samples

Gold and Arsenic--Only 10 samples contain gold concentrations that are considered anomalous. Anomalous gold concentrations range from 3 to 210 ppb. The highest gold concentrations were detected in samples collected in wadis draining the ancient mines at Bi'r Jarbuah (areas A, B, and C; fig. 12). Other areas (D, E, and F, fig. 4) that are delineated as anomalous by the panned concentrate samples were not anomalous in the minus-80-mesh fraction samples. Comparison of figures 4 and 12 shows that the panned concentrate samples delineate larger anomalies and, hence, have greater dispersion trains than the minus-80-mesh fractions.

Arsenic is associated with gold. Only 6 samples contain anomalous arsenic concentrations (10-20 ppm) and all were collected from wadis draining the ancient mines of Bi'r Jarbuah (fig. 13).

Tellurium and Silver--Anomalous tellurium concentrations range from 20-59 ppb. The dispersion pattern of tellurium in the minus-80-mesh fraction is not similar to that in panned concentrate samples. Unlike the panned concentrate samples, most anomalous concentrations occur on the eastern and east-central parts of the study area, particularly in wadis draining the ancient mines (fig. 14) and areas of dioritic and sheared, faulted orthogneiss bedrock. Five areas (A, B, C, D, and E) are delineated as anomalous. Unlike the panned concentrates, tellurium in the minus-80-mesh samples is associated with gold specially in samples collected from wadis draining Bi'r Jarbuah ancient mine (area A). Fine-grained minus-80-mesh tellurium is dominant in the areas containing gold anomalies while coarse-grained plus-80-mesh tellurium prevails outside this region.

Anomalous silver was detected in 9 samples (fig. 15). Silver concentrations (0.4 to 0.8 ppm) are not associated with gold and the ancient mines in the area. In fact samples with concentrations of silver are scattered away from and around the area that is anomalous in gold and arsenic.

Copper, Zinc, Lead, and Molybdenum--Few of the samples collected contain anomalous concentrations of copper, lead, zinc, and molybdenum. Since these concentrations are not high and do not cluster, they are not plotted.

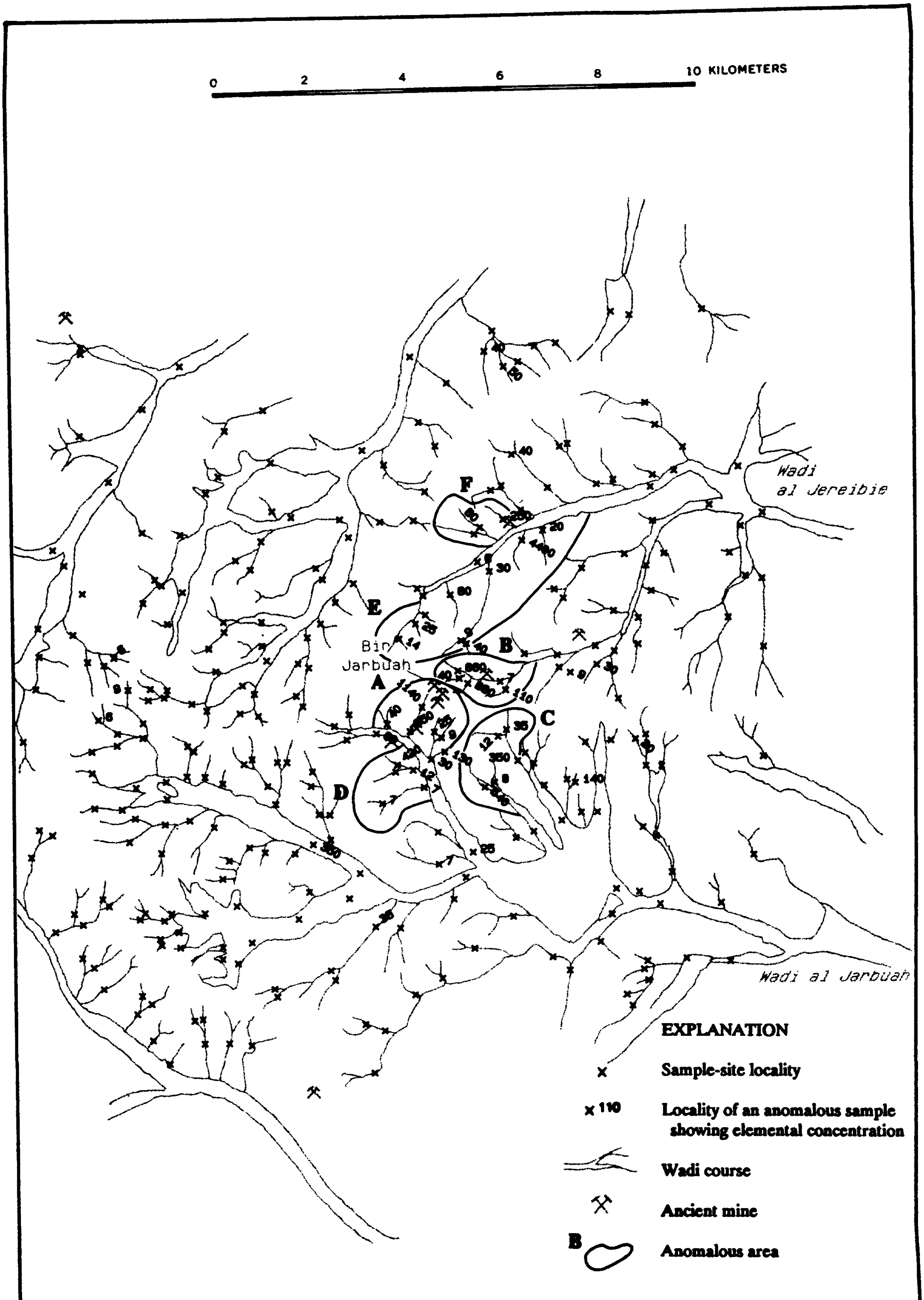

Figure 4.--Map showing panned-concentrate sample sites and areas anomalous in gold (concentration in ppb).

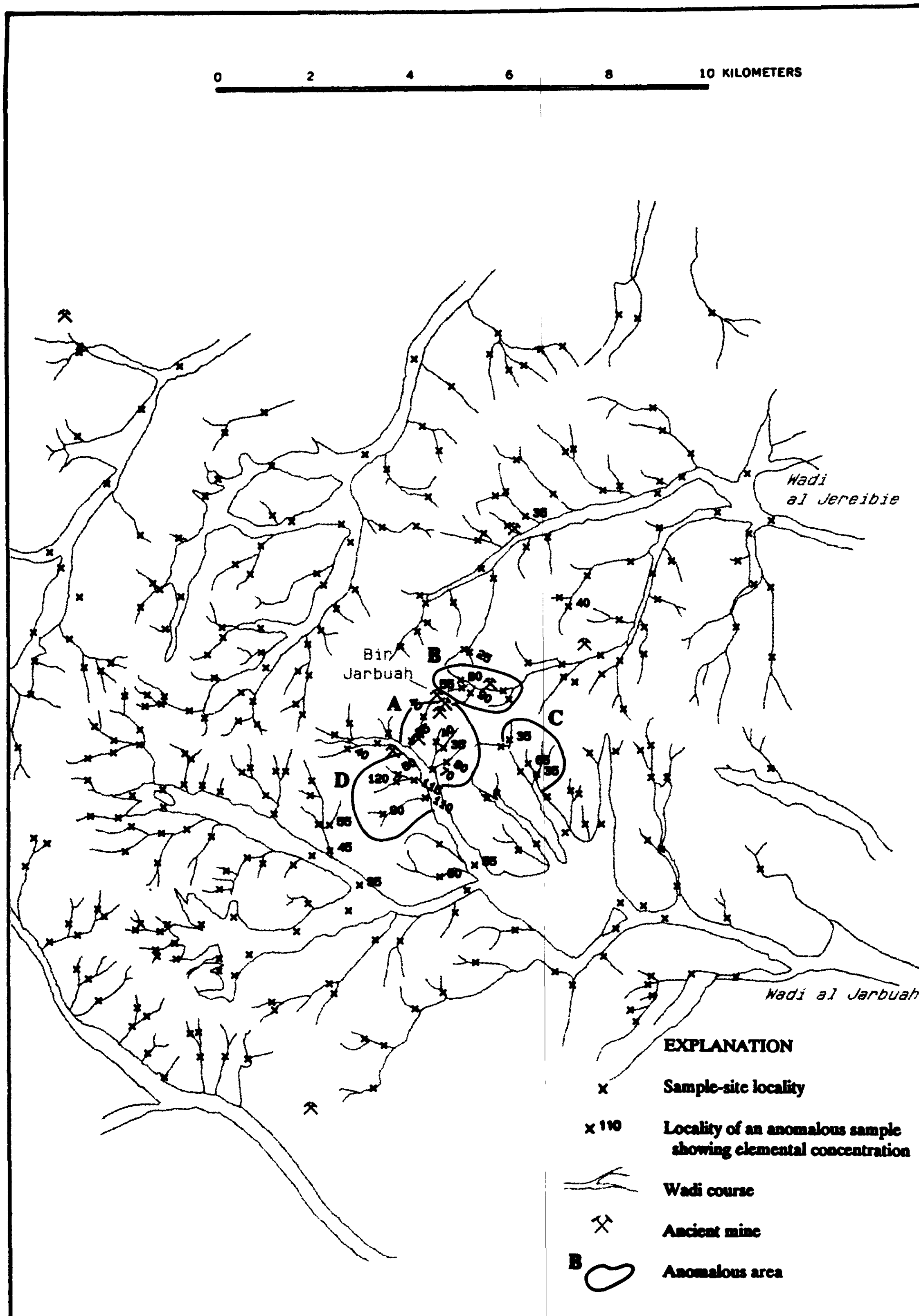

Figure 5.--Map showing panned-concentrate sample sites and areas anomalous in arsenic (concentration in ppm).

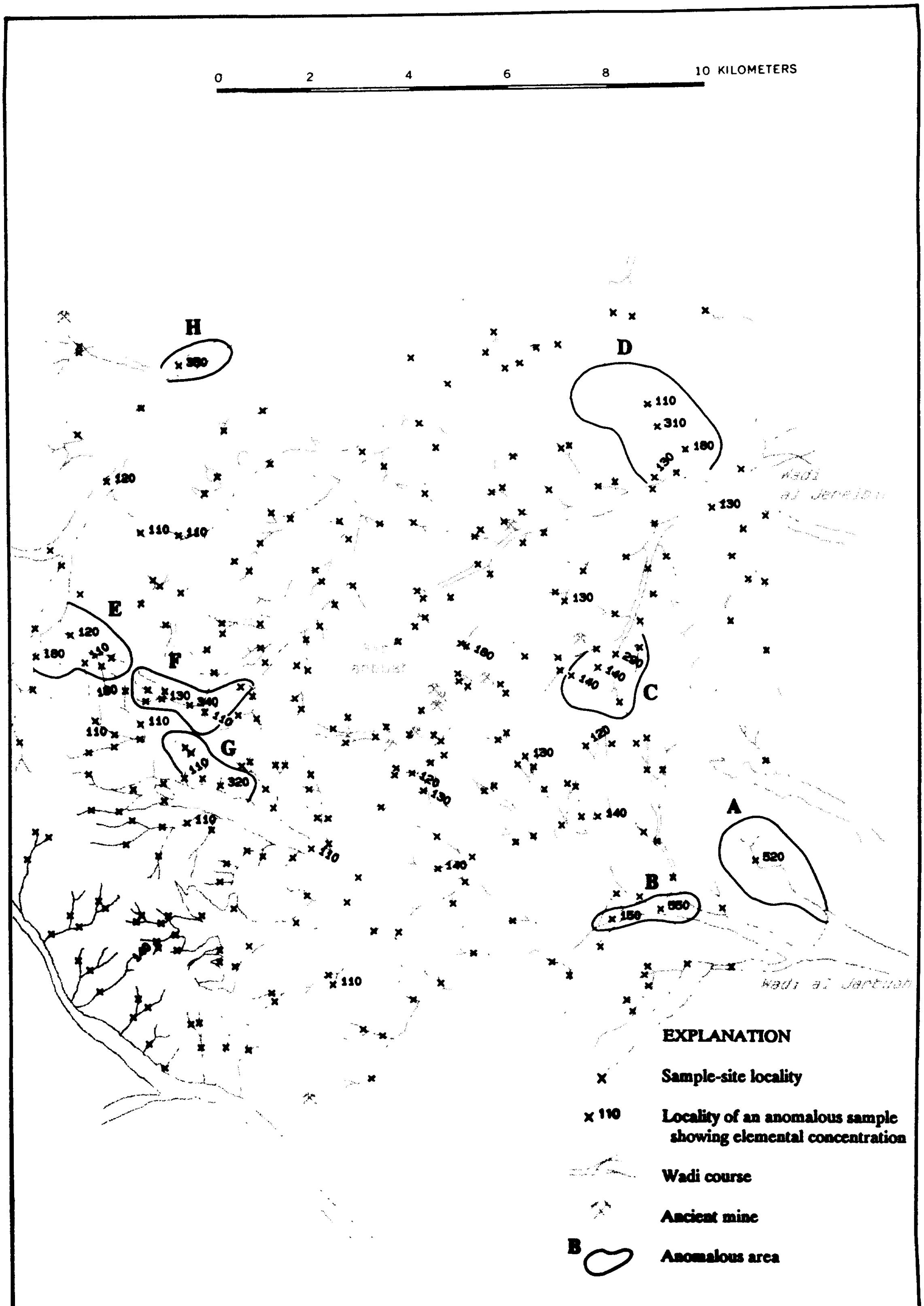

Figure 6.--Map showing panned-concentrate sample sites and areas anomalous in tellurium (concentration in ppb).

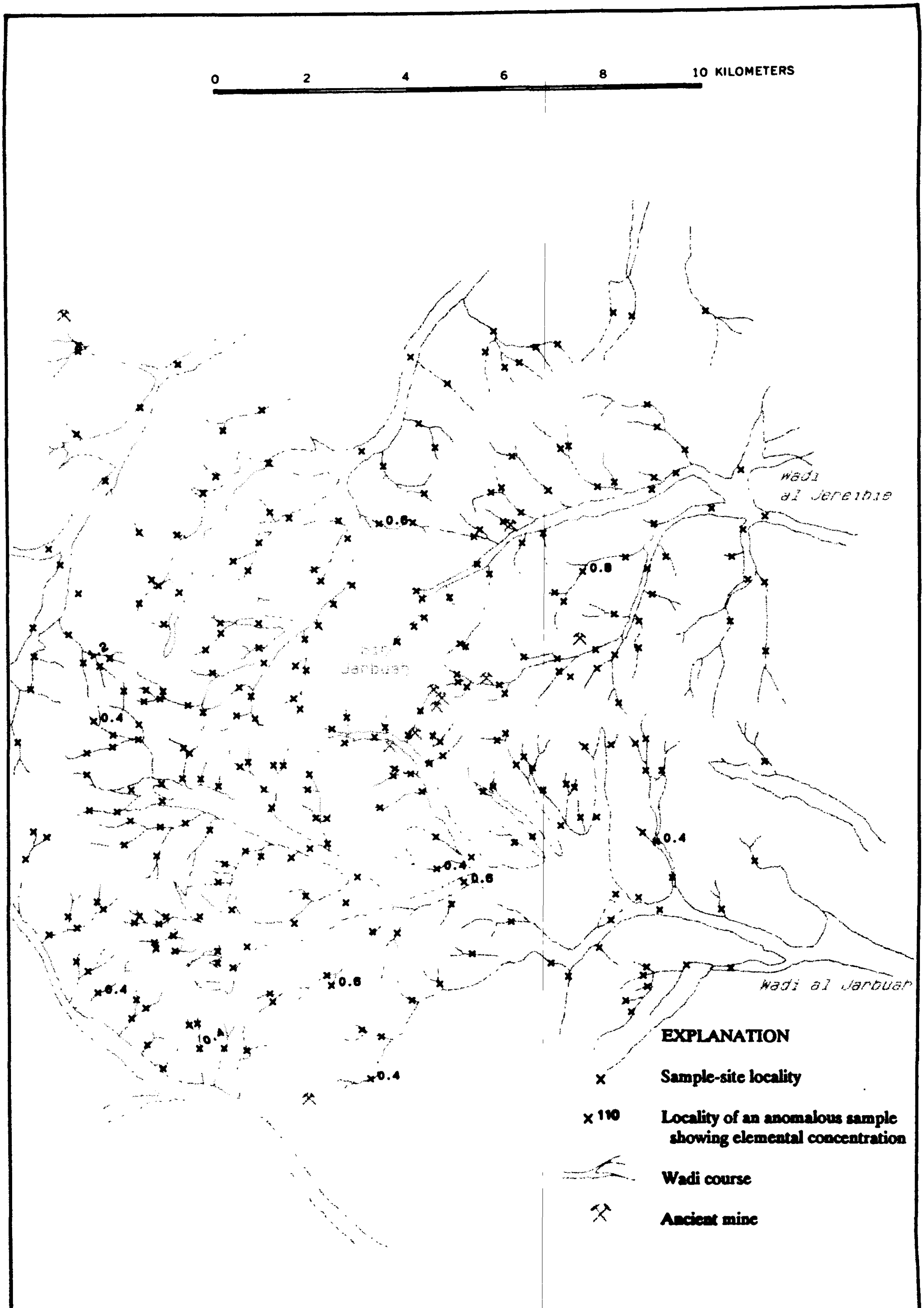

Figure 7.--Map showing sites of panned-concentrate samples anomalous in silver (concentration in ppm).

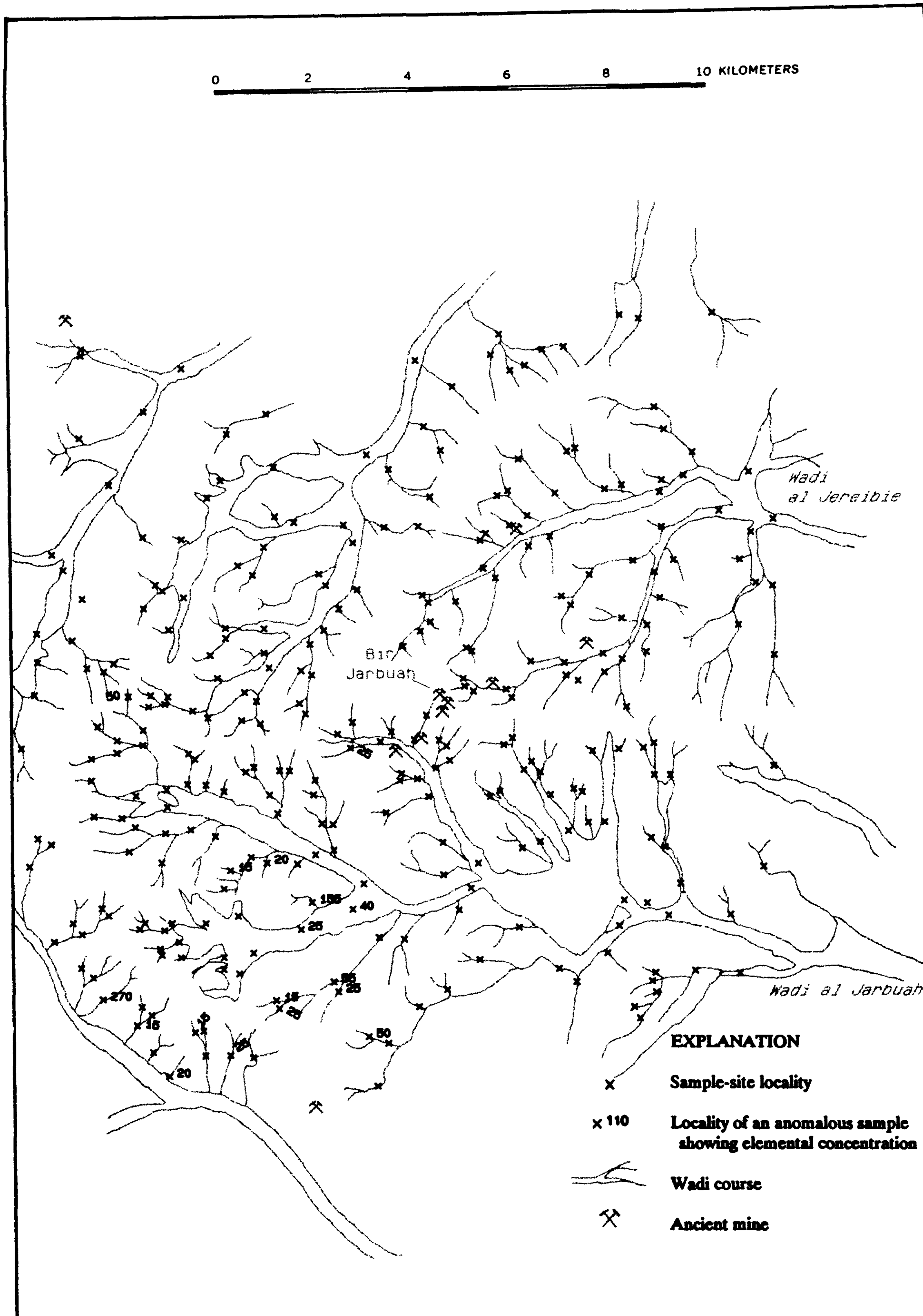

Figure 8.--Map showing sites of panned-concentrate samples anomalous in lead (concentration in ppm).

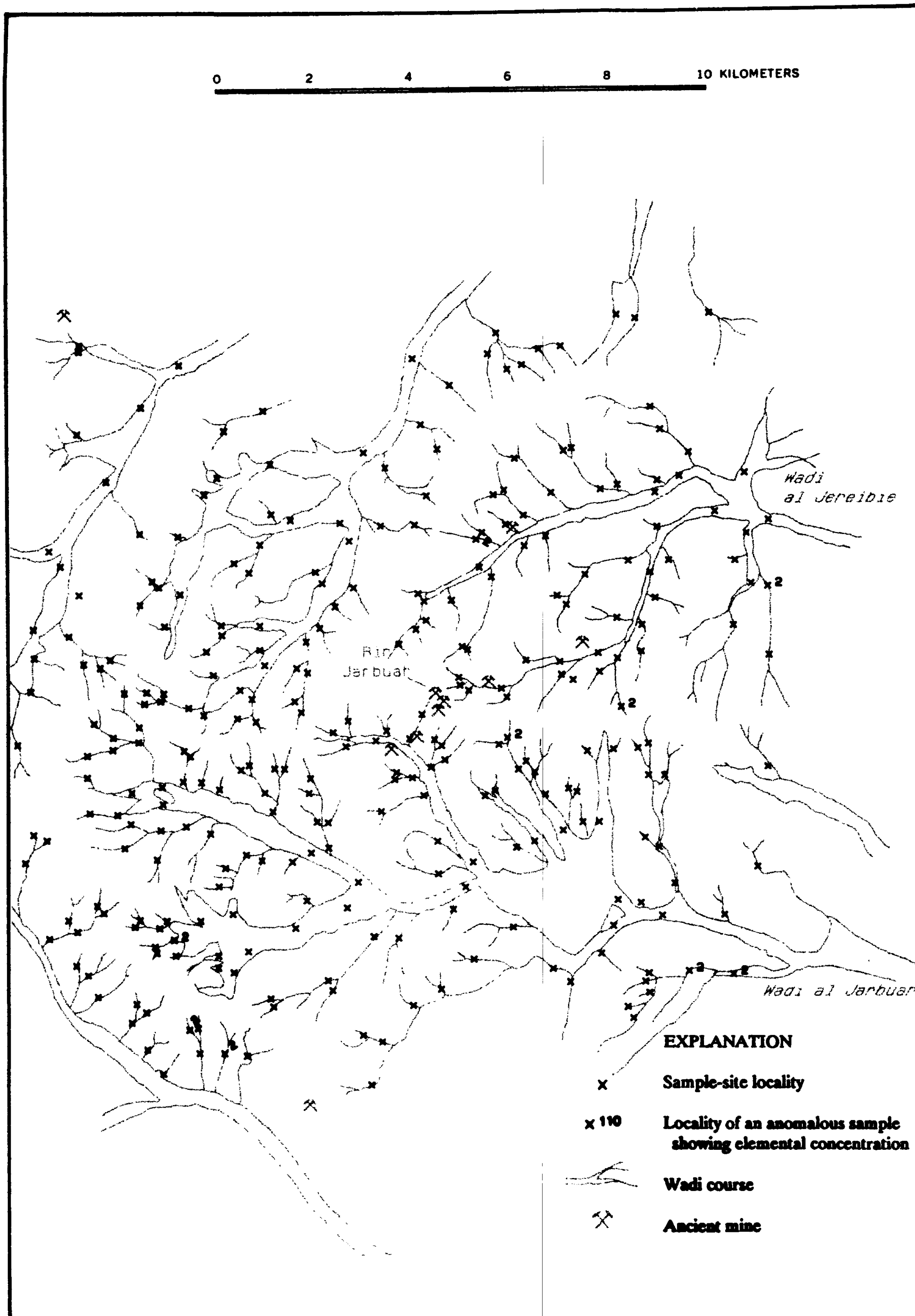

Figure 9.--Map showing sites of panned-concentrate samples anomalous in molybdenum (concentration in ppm).

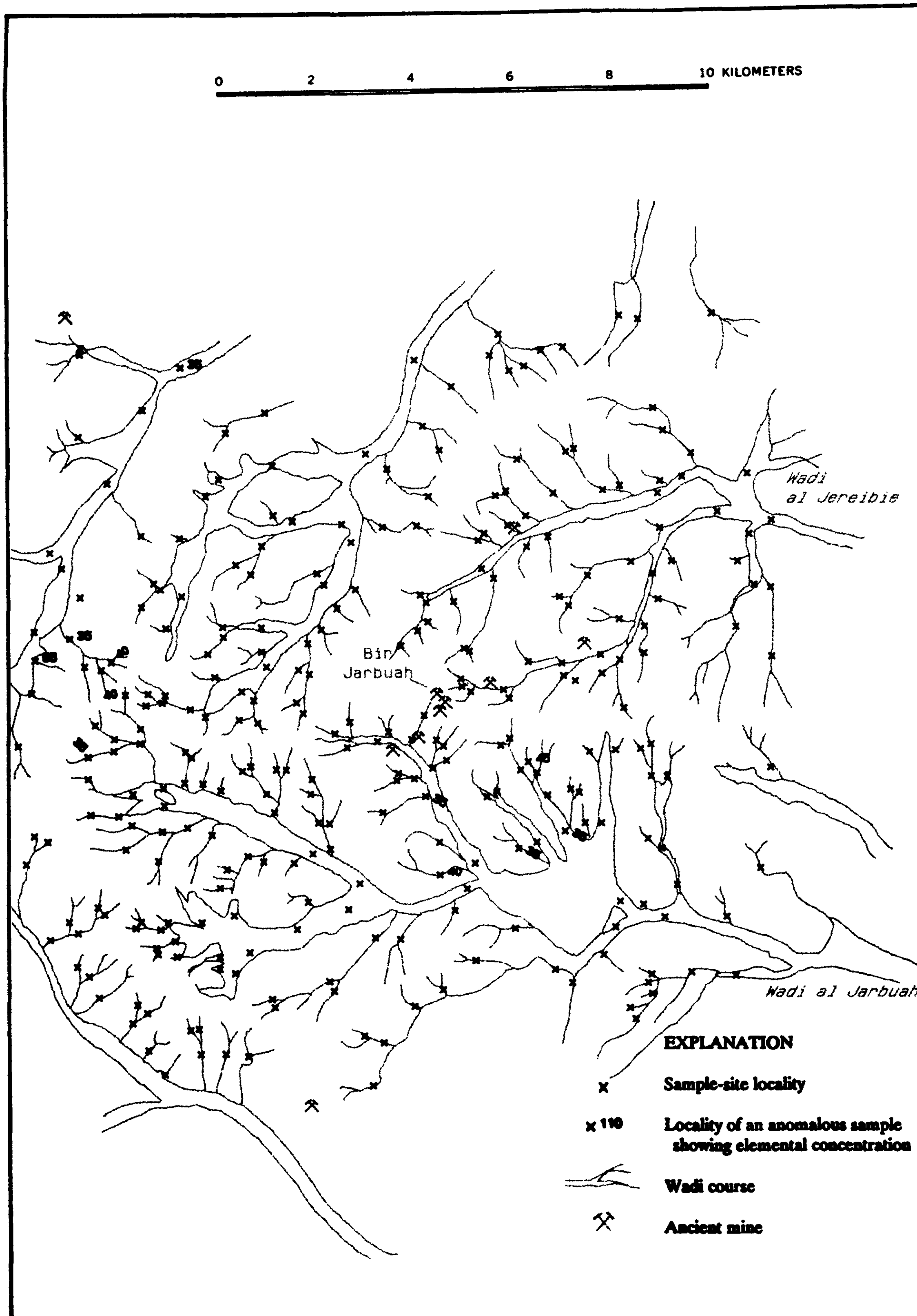

Figure 10.--Map showing sites of panned-concentrate samples anomalous in copper (concentration in ppm).

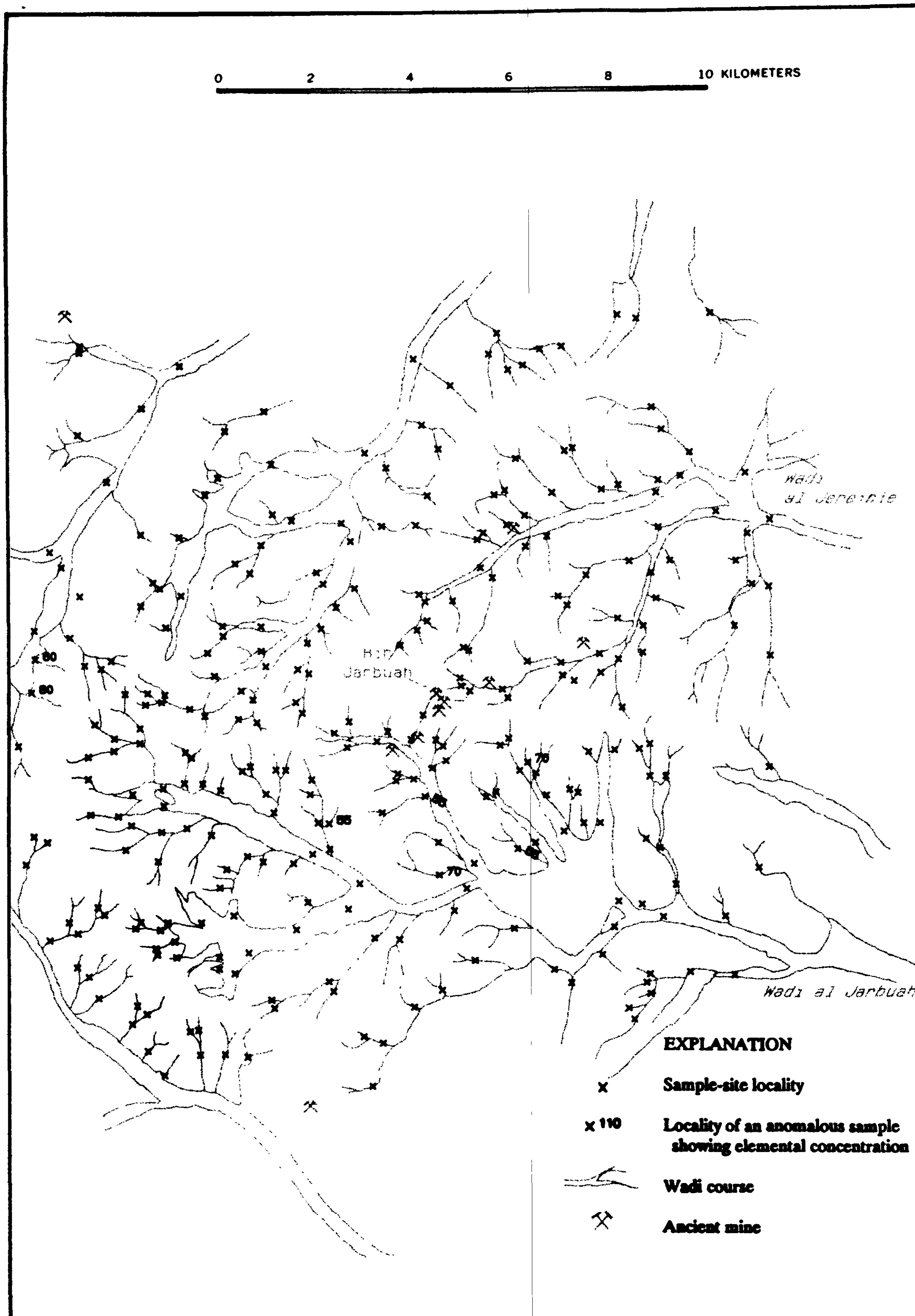

Figure 11.--Map showing sites of panned-concentrate samples anomalous in zinc (concentration in ppm).

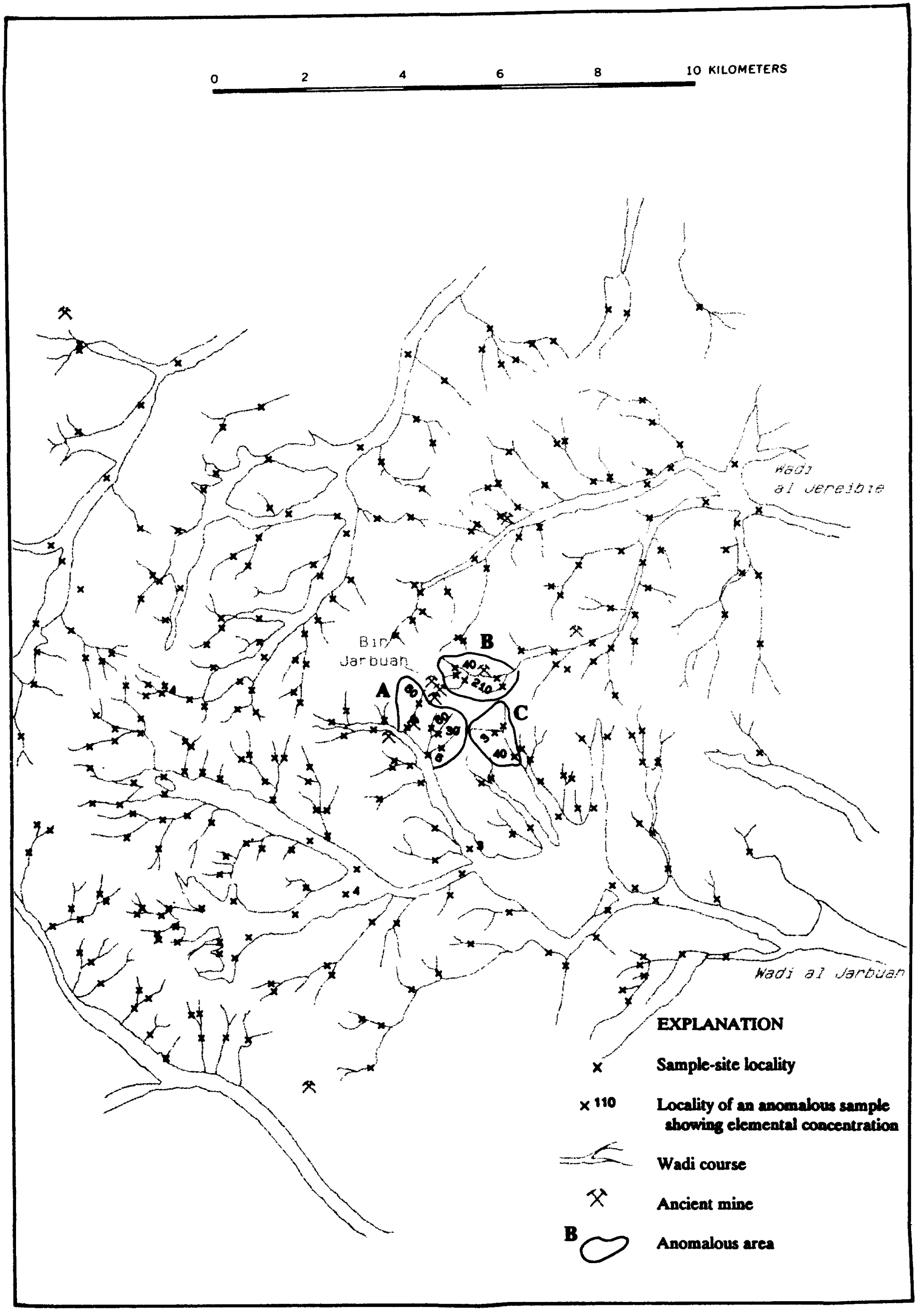

Figure 12.--Map showing minus-80-mesh sample sites and areas anomalous in gold (concentration in ppb) .

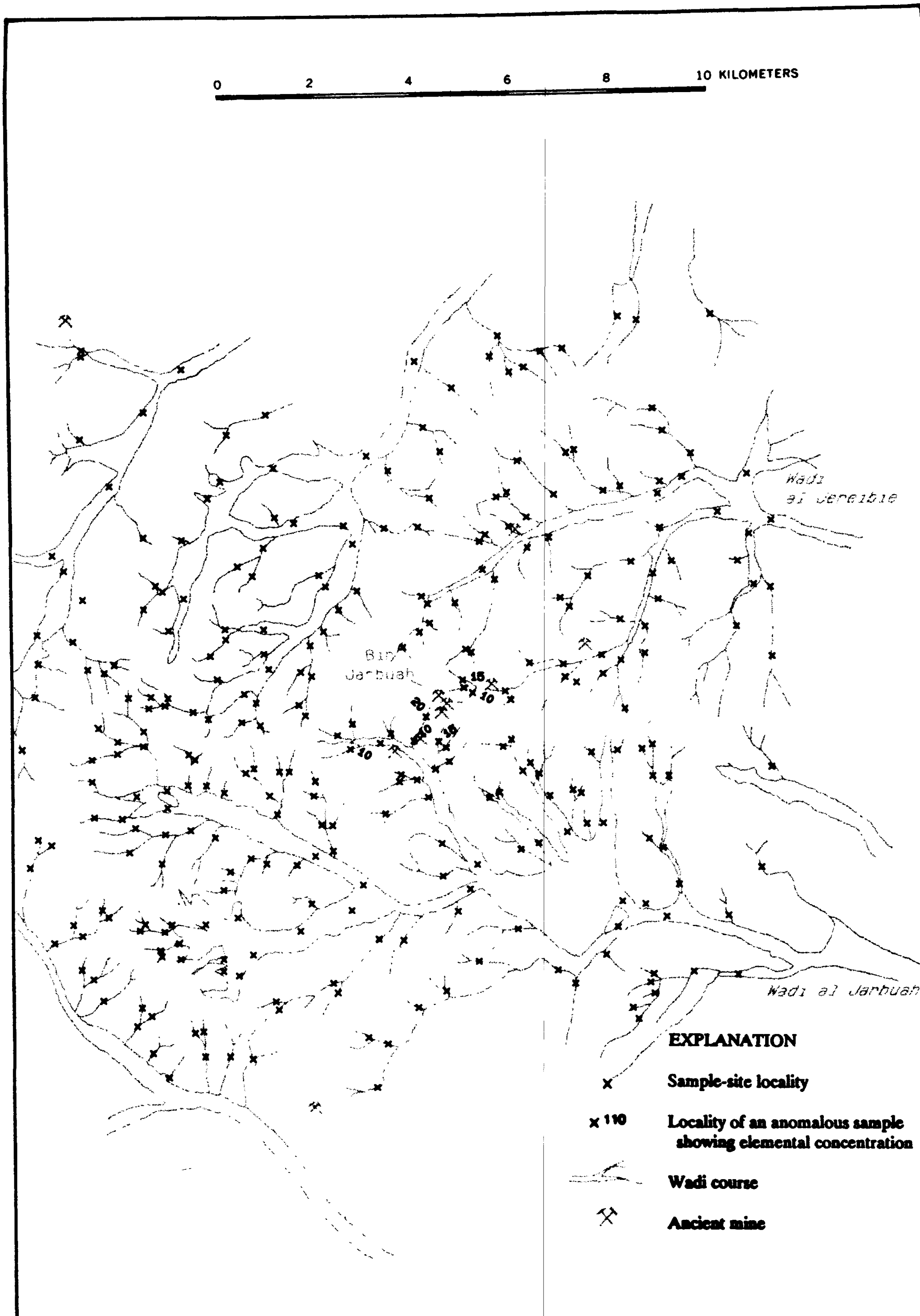

Figure 13.--Map showing minus-80-mesh sample sites and areas anomalous in arsenic (concentration in ppm).

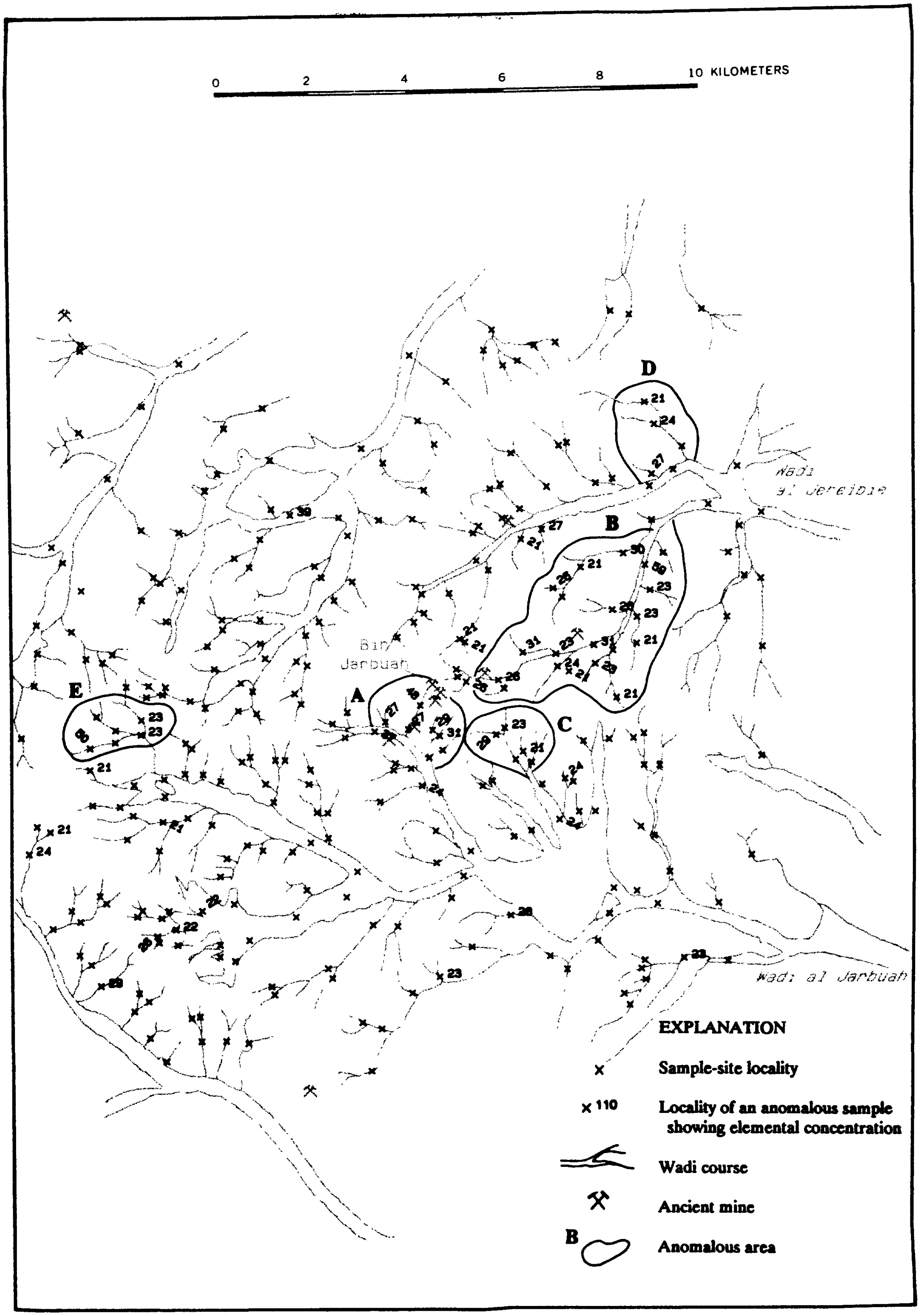

Figure 14.--Map showing minus-80-mesh sample sites and areas anomalous in tellurium (concentration in ppb).

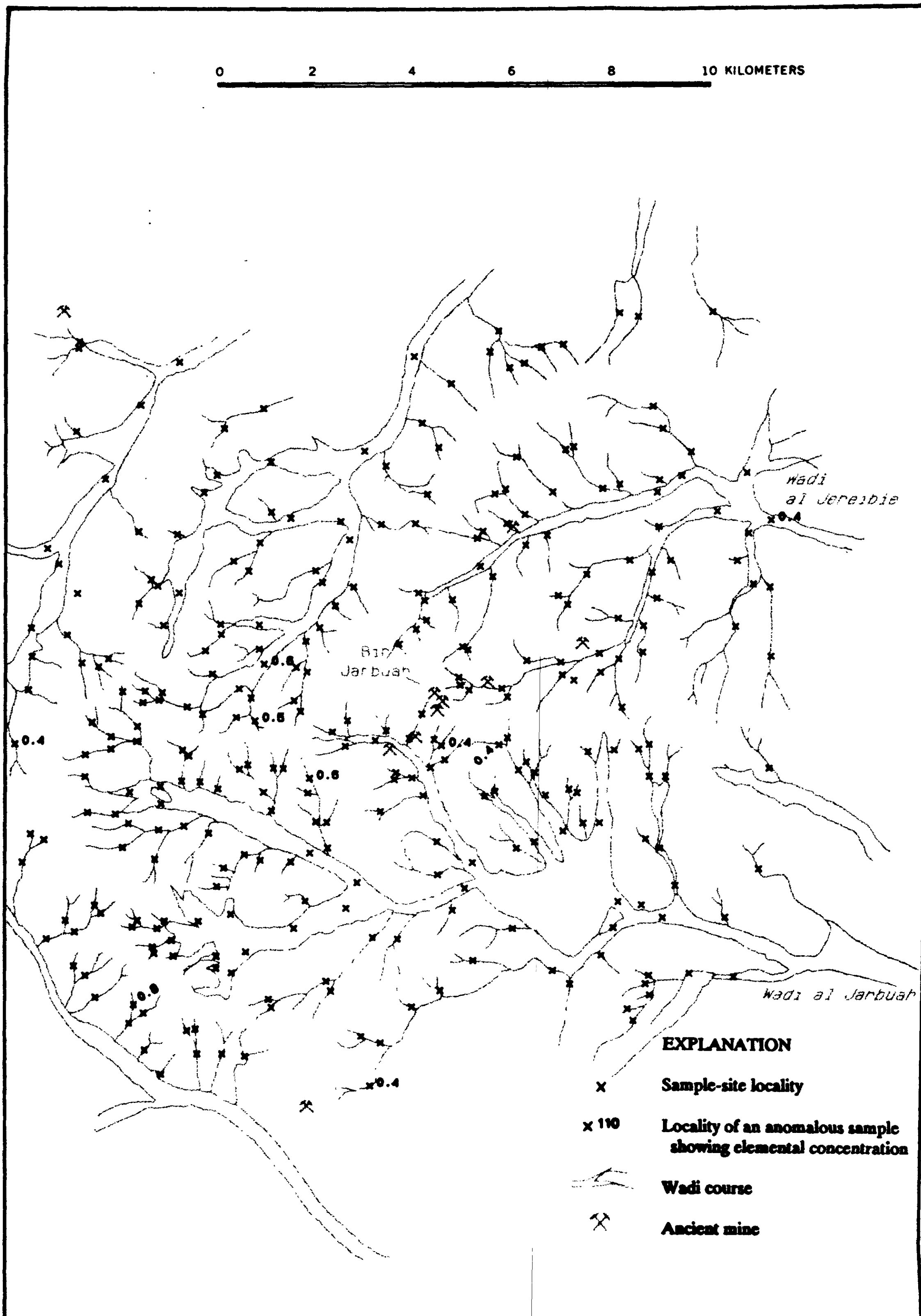

Figure 15.--Map showing sites of minus-80-mesh samples anomalous in silver (concentration in ppm).

CONCLUSIONS AND RECOMMENDATIONS

The irregular regional contact between the diorite pluton (du) and the gneiss (hbg) is proposed to be a topologic expression of the intersection between a well-developed erosional surface and a flat-lying diorite-gneiss intrusive contact (fig. 2). This contact may be representative of the most apical position of a dioritic cupola. The presence of later dacitic, trachytic, aplitic, and granitic dikes indicates the occurrence of multiple intrusive events in the area. Conceivably, this suite of dikes could characterize nested igneous plutons just underlying the modern erosional surface.

Four of the elements (gold, arsenic, lead, and tellurium) are more frequently detected in panned concentrate samples than in the minus-80-mesh fraction samples. Ancient mines and areas of mineralization are more clearly defined by gold and arsenic concentrations in the panned concentrate samples. The assessment of the two sample media provides strong support for the selection of the panned concentrate samples on the basis of three parameters :

1) Relative concentration levels: Several important elements like gold, arsenic, and lead have low concentrations in stream sediments and any medium that enhances the levels is desirable as an exploration tool. The number of panned concentrate samples with detectable gold concentrations are approximately 10 times the minus-80-mesh fraction samples (table 1).

2) Contrast between anomalous and background populations: For stream-sediment exploration to be effective, target-element concentrations in sediments must be sufficiently distinctive for them to be distinguished from the regional background and must be anomalous out to a considerable distance from the source. Gold concentrations above 5 ppb in the panned concentrate samples (fig. 3A) show a clearly defined anomalous population compared to the minus-80-mesh fraction samples (fig. 3C).

3) Length of dispersion train: The medium with the higher contrast between anomalous and background populations might be expected to provide longer dispersion trains away from the mineralization as exemplified by the dispersion of gold in the panned concentrate samples (fig. 4) and in the minus-80-mesh fraction samples (fig. 12).

Gold is associated with arsenic and probably with fine-grained tellurium. Most of the anomalous gold concentrations are contained in samples collected from wadis in area of ancient mining activity. The possibility that most of these anomalies are caused by contamination can not be ruled out. However, the following areas are recommended for additional work with top priority given to areas containing gold anomalies:

1. Areas that contain gold anomalies (A, B, C, D, E, and F) should be studied further (fig. 4). Particular attention should be given to the contact between the paragneiss and the diorite where most of the anomalous gold values seem to be located.

2. Since tellurium is a pathfinder element for gold, gold-bearing rocks in areas A, B, C, D, E, and F (fig. 6) should be further investigated.

3. Minus-80-mesh samples define the tellurium anomalies in areas B, D, and E (fig. 14). These areas should be investigated further.

DATA STORAGE

DATA FILE

All field and laboratory data for this report, including sample-location maps, anomaly maps, and results of chemical analyses, are stored in Data File USGS-DF-10-2 in the Jeddah office of the U.S. Geological Survey Saudi Arabian Mission.

MINERAL OCCURRENCE DOCUMENTATION SYSTEM

Updated information was added to the Mineral Occurrence Documentation System (MODS) for Bi'r Jarbuah, MODS 1454. No new MODS files were established.

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