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Rock geochemistry in the Mahd adh Dhahab district, Kingdom of Saudi Arabia

by

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ROCK GEOCHEMISTRY IN THE MAHD ADH DHAHAB DISTRICT, KINGDOM OF SAUDI ARABIA

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ABSTRACT

Ten sets of geochemical samples from country rock, altered country rock, and quartz veins were collected to determine metal abundances and distributions in the Mahd adh Dhahab district. Gold, silver, copper, lead, and zinc are present throuhgout the district in veins and altered country rock. Although four generations of quartz veins are defined, there is complete gradation between types. The metals present are the same in all four, only the abundances vary. The concentrations of gold, silver, copper, lead, and zinc in altered country rock are zoned around known or projected mineralized-vein zones. Similarities in metal populations of all quartz veins, altered rock, and mineralized zones, plus the distribution of metals and some major elements, suggest that all formed as part of a single hydrothermal system.

Gold in abundances greater than 1 ppm does not correlate with any other element and its distribution is very erratic. The variance in gold values between replicate samples collected in 0.5 m square panels is very high. Radio-element analyses (radium-equivalent uranium, thorium, and potassium) for 40 widely distributed sample localities indicate little variation in these elements throughout the district. If the hydrothermal system had an effect on the distribution of these elements, the system must have extended beyond the limits of the sampled area.

Anomalous values of gold, silver, lead, and to a lesser extent copper and zinc in surface rock samples clearly delineated the northern mineralized zone in the upper agglomerate, and an east-vein area and west-vein area of the southern mineralized zone in the lower agglomerate. A third geochemically anomalous area occurs farther to the west in the lower agglomerate, suggesting that mineralization may have extended at least to this area along the lower agglomerate-lower tuff contact, and possibly even further to the west.

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INTRODUCTION

Mahd adh Dhahab (MODS 00003) is the largest of numerous ancient gold mines scattered across the Precambrian Shield of Saudi Arabia (fig. 1), and the only one with recent production. Approximately 800,000 fine ounces of gold and 1,000,000 ounces of silver were produced from the northern mineralized zone in the period 1939-1954 by the Saudi Arabian Mining Syndicate (SAMS). During ancient times, probably 1,000,000 ounces of gold were produced from this site (Twitchell, 1958). The ancient and recent workings are in the northern part of a north-trending zone of quartz veins and breccias, faults, and altered rock (pl. 1). This area of mineralized rock is known as the northern mineralized zone.

Previous investigations at Mahd adh Dhahab include those by SAMS (Dirom, 1947) and the U.S. Geological Survey (Theobald, 1965; Luce and others, 1975; Roberts and others, 1978; Worl, 1978, 1979). Work by the U.S. Geological Survey (USGS) identified a zone of mineralized rock 700 m south of the northern mineralized zone, containing a potential resource of 1.1 million metric tons of ore with 27 g/t gold and 73 g/t silver (Worl, 1978, 1979). This, the southern mineralized zone, is currently under development by Petromin and Gold Fields Mahd adh Dhahab, Ltd. (GFMAD) as part of an exploration license for this and a large surrounding area.

A multidisciplinary study of the Mahd adh Dhahab deposit was initiated by the USGS in January, 1981. These investigations were conducted in order to gain an understanding of the genesis of the deposit and its regional setting, and to develop concepts useful to exploration programs elsewhere in Saudi Arabia. The objective of this particular study was to determine the trace- and major-element compositions and distribution patterns throughout the district, both on the surface and underground. Companion studies included studies of ore mineralogy, fluid inclusions, stable and lead isotopes (Rye and others, 1982), alteration assemblages and patterns (Doebrich and LeAnderson, 1984), and biogeochemical exploration techniques (Ebens and others, 1983).

This report contains trace-element analyses of ten geochemical sample sets and major-element whole rock analyses of selected sample sets or parts of sample sets. Analyses were performed by the DGMR-USGS chemical laboratory in Jeddah under the direction of K. J. Curry. Radio-element analyses were conducted by C. M. Bunker and C. A. Bush at the USGS laboratories in Denver, Colorado.

ACKNOWLEDGEMENTS

The authors express gratitude and appreciation to Gold Fields Mahd adh Dhahab, Ltd. for logistic support, access to their mine and drill cores, and for providing mine maps and geological information. Work for this study was performed by the U.S. Geological Survey in accordance with a work agreement with the Saudi Arabian Ministry of Petroleum and Mineral Resources.

GEOLOGIC SETTING

Two areas containing ore-grade mineralized rock have been defined within a north-trending zone of quartz veins, breccias, faults, and altered rock that is

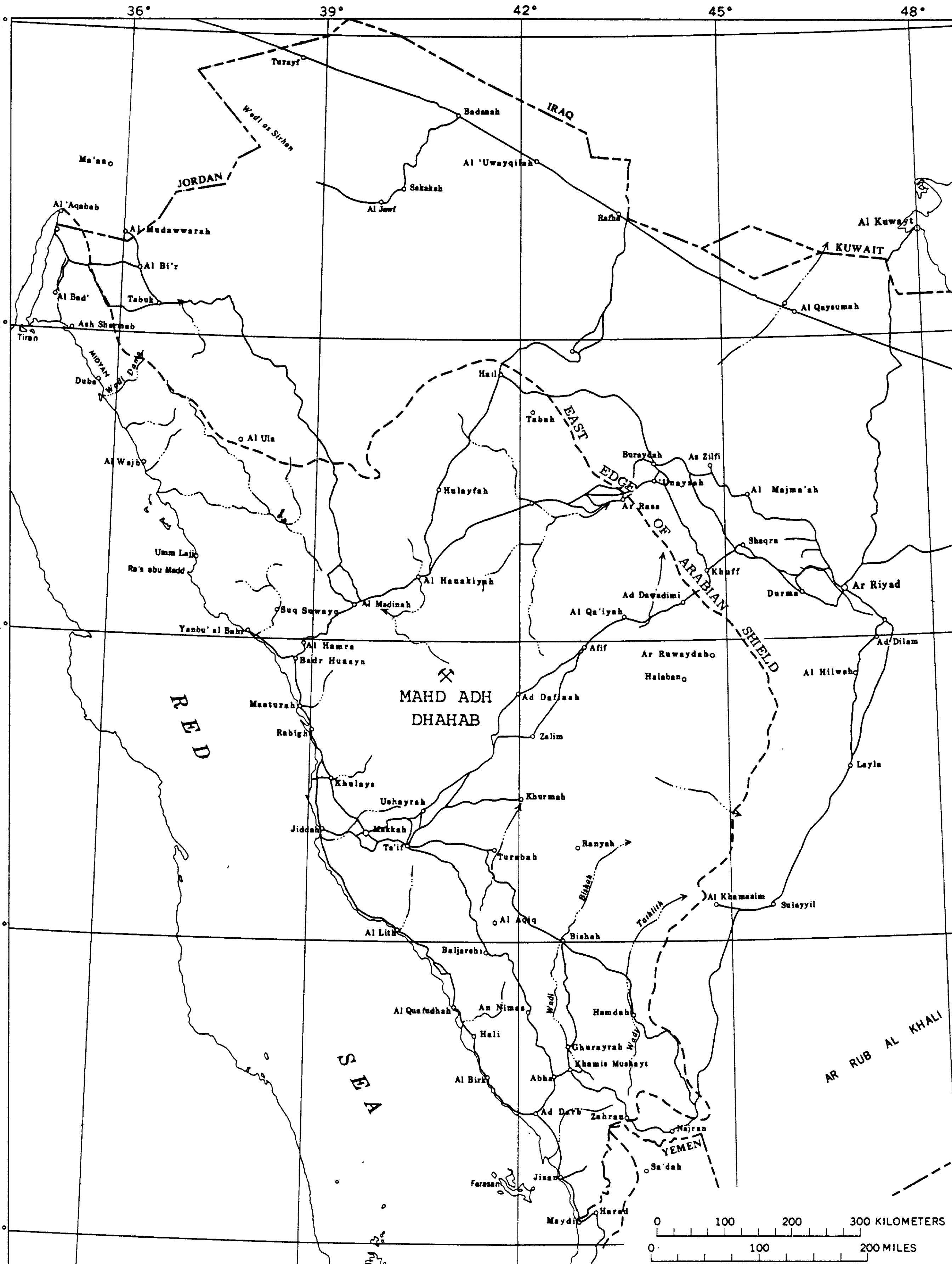

Figure 1.--*Index map of western Saudi Arabia showing the location of Mahd adh Dhahab.*

approximately 400 m wide and 1000 m long. The ancient and SAMS workings are in the northern part of this zone (northern mineralized zone), whereas a significant new discovery is being developed by GFMAD in the southern part (southern mineralized zone) (pl. 1).

Country rocks in the district are composed of a 1-km-thick sequence of volcanic, volcaniclastic, and epiclastic rocks of intermediate to felsic composition that unconformably overlie andesite volcanic rock. From oldest to youngest, the mapped layered units are andesite, lower agglomerate, lower tuff, upper agglomerate, and upper tuff (pl. 1). In general, the intermediate and felsic units are comprised of a mixture of pyroclastic and transported (reworked) pyroclastic and clastic material. Volcanic flow rocks, welded tuff, and breccia are subordinate. Grain size, sorting grading, and bedding are much more variable than the compositions of clasts and matrices; major-element composition is relatively constant throughout most mapped units. Most of the medium- to fine-grained rocks are bedded, commonly graded, and range from coarse agglomerate to very fine grained tuff. Lithic and pyroclastic fragments, in order of decreasing abundance, are andesite to rhyodacite, silicic tuff, chert, and minor but locally abundant broken feldspar grains, diorite clasts, pumice clasts, and relict glass shards. Chlorite, potassium feldspar, sericite, pyrite, and quartz, with locally abundant epidote, hematite, and calcite occur as secondary minerals.

A Precambrian epizonal rhyolite porphyry stock, which may be part of a much larger body at depth, is exposed in the SAMS mine area and in the uppermost portion of the GFMAD decline. In the SAMS mine area the intrusion domed and altered the lower tuff and upper agglomerate during emplacement. A breccia of highly silicified and potassium feldspathized tuff, wacke, and volcanic sandstone mixed with olive-gray, buff-weathering, massive, aphanitic rhyolite crops out on the hill surrounding the SAMS area (Worl, 1978).

MINERALIZATION

Geologic setting of mineralized rock in the northern and southern mineralized zones is similar. Significantly mineralized areas occur only within silicified, chloritized, and fractured agglomerate directly beneath a cap of fine-grained tuff and sedimentary rock where the layered rocks are cut by metalliferous quartz veins. The quartz veins are continuous through all the mapped units and contain trace to anomalous amounts of base and precious metals. Silicic, pyritic, and chloritic hydrothermal alteration were centered on the quartz-vein zones, whereas potassic and propylitic alteration were more widespread and pervasive. The veins include an assemblage of quartz-pyrite-hematite-chalcopyrite-sphalerite-galena and precious metals. Gold and silver are present as electrum and in tellurides.

The vein classification of Luce and others (1979) is used in this report, except that the four vein types are termed A, B, C, and D rather than 1, 2, 3, and 4, in accordance with current usage by workers at the mine. Type A veins formed early and consist of massive milky quartz. They contain sparse pyrite and have low precious-metal contents. Type B veins contain banded and crustified milky to clear quartz, principally with comb or cockade structures and abundant chlorite; massive sulfide ore and precious metals are associated with this stage of vein formation. Type C veins are characterized by comb quartz, sphalerite, chalcopyrite, ankerite, and manganiferous calcite or calcite. Type D veins, the last to form, are characterized by fine-grained white quartz and calcite with only sparse sulfide minerals. The four vein types listed are often difficult to distinguish in the field. Types A and B are generally associated with each other, as are types C and D, but there seems to be a complete gradation among types.

During the period of SAMS mining of the northern mineralized zone individual veins or vein zones of various or mixed mineralogical types were designated with numbers (Dirom, 1947). Some vein-number terminology has been used by GFMAD in the present development of the southern mineralized zone. Two strongly mineralized vein zones occur in the east-vein area that lies at the east end of the crosscut (pl. 1). Designated as the 3-4-5 and 6-7-8 vein systems, they are referred to in this report and were sampled in detail as the HOT-1 and HOT-2 sample sets, respectively. Also referred to in this report is the west-vein area that lies at the west end of the crosscut (pl. 1) and extends a further 200 to 300 meters to the west as defined by underground drilling.

SAMPLING AND ANALYSIS

Ten sets of geochemical samples, each designed to test a different environment or hypothesis, were collected and comprise a total of 538 samples. Sample type, location, purpose, and type of analytical work performed for each sample set is described in appendix 1. Locations of the sample sets are shown on plate 1. Location of individual panel samples for the ALS sample set are shown in figures 2-4, and for the HOT sample set in figures 5 and 6.

Traverse, panel, and grab samples were collected for geochemical analysis. Composite chip samples from traverses consisted of approximately 2 kg of chips 2-5 cm in diameter collected along a 25 m traverse length. Composite chip samples from panels consisted of approximately 2 kg of chips 1-3 cm in diameter taken from square or rectangular panels of variable size. Grab samples were either single specimens or a few chips of varying size selected to characterize a specific target.

Each sample was analyzed by semiquantitative spectrographic methods for 30 elements and by atomic absorption spectroscopy for gold, silver, copper, lead, and zinc. Selected samples were further analyzed for cadmium, arsenic, antimony, tungsten, molybdenum, and tellurium by colorimetry. Sample preparation for gold analysis required serial digestion of a 10-g split in hydrochloric and nitric acids; the washed and centrifuged solution was then fixed with hydrobromic acid and methyl-isobutyl ketone (MIBK). The resulting organic solution was washed again in a weak hydrochloric—hydrobromic acid solution (to remove interfering elements), and collected in a test tube sealed with a polyethylene stopper (K. J. Curry, written commun., 1978).

Selected sample sets and parts of sample sets were submitted for major-element whole-rock analyses. Values for SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, MnO, H_2O+, and H_2O- were obtained by x-ray fluorescence and wet chemistry.

Additional analyses were performed for a subset of the 538 total samples that were selected to represent traverses distant from the main mineralized zones. Radio-element (radium-equivalent uranium, thorium, and potassium) contents were determined by gamma-ray spectrometry. Analytical precision is about $\pm$ 2 percent for radium-equivalent uranium and thorium and about $\pm$ 1 percent for potassium.

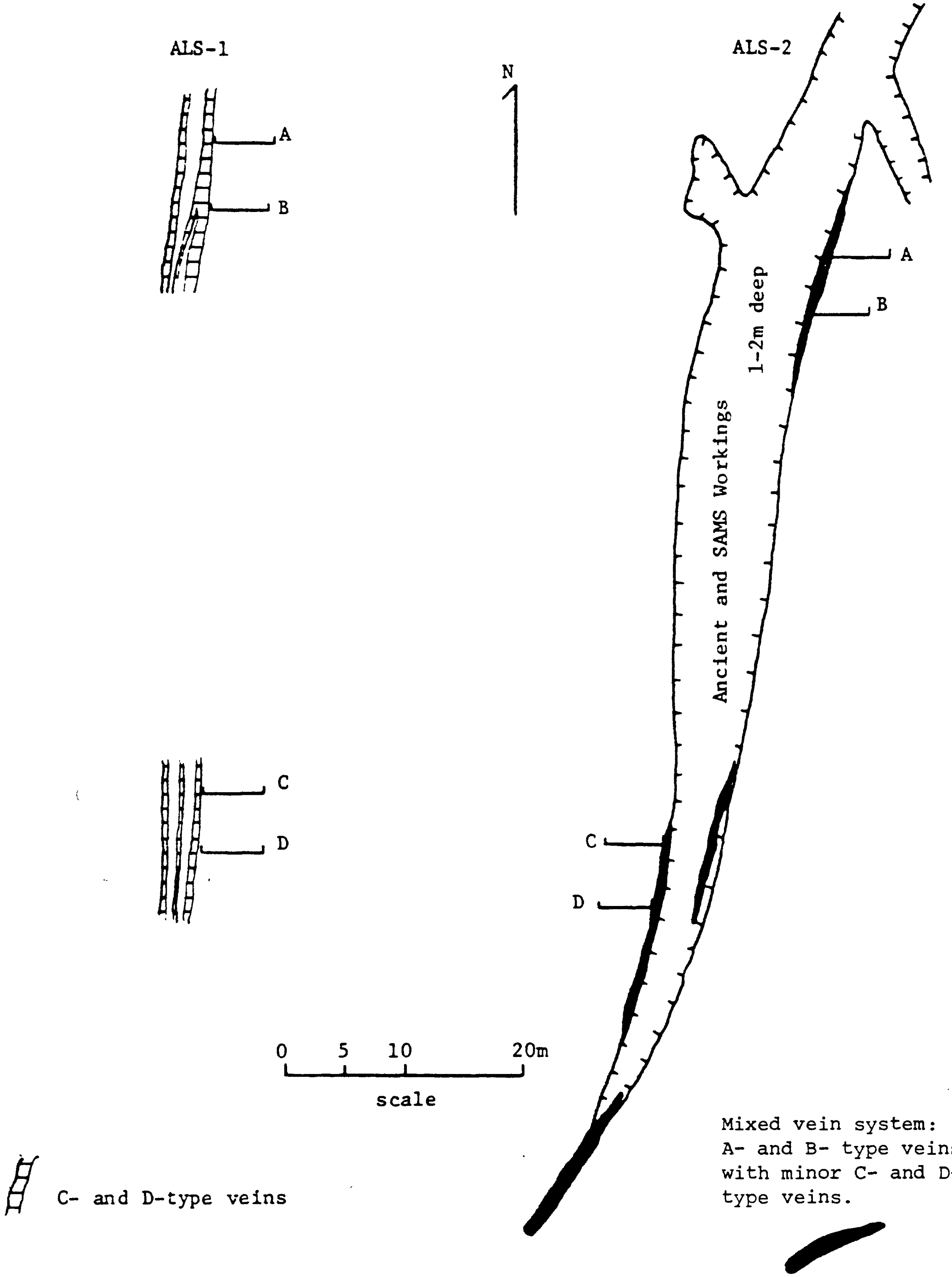

Figure 2.--*Sketch map of ALS sample sites 1 and 2 showing location of sample panels. Scale refers to individual sites, not the distance between them. Location of the sites shown on plate 1.*

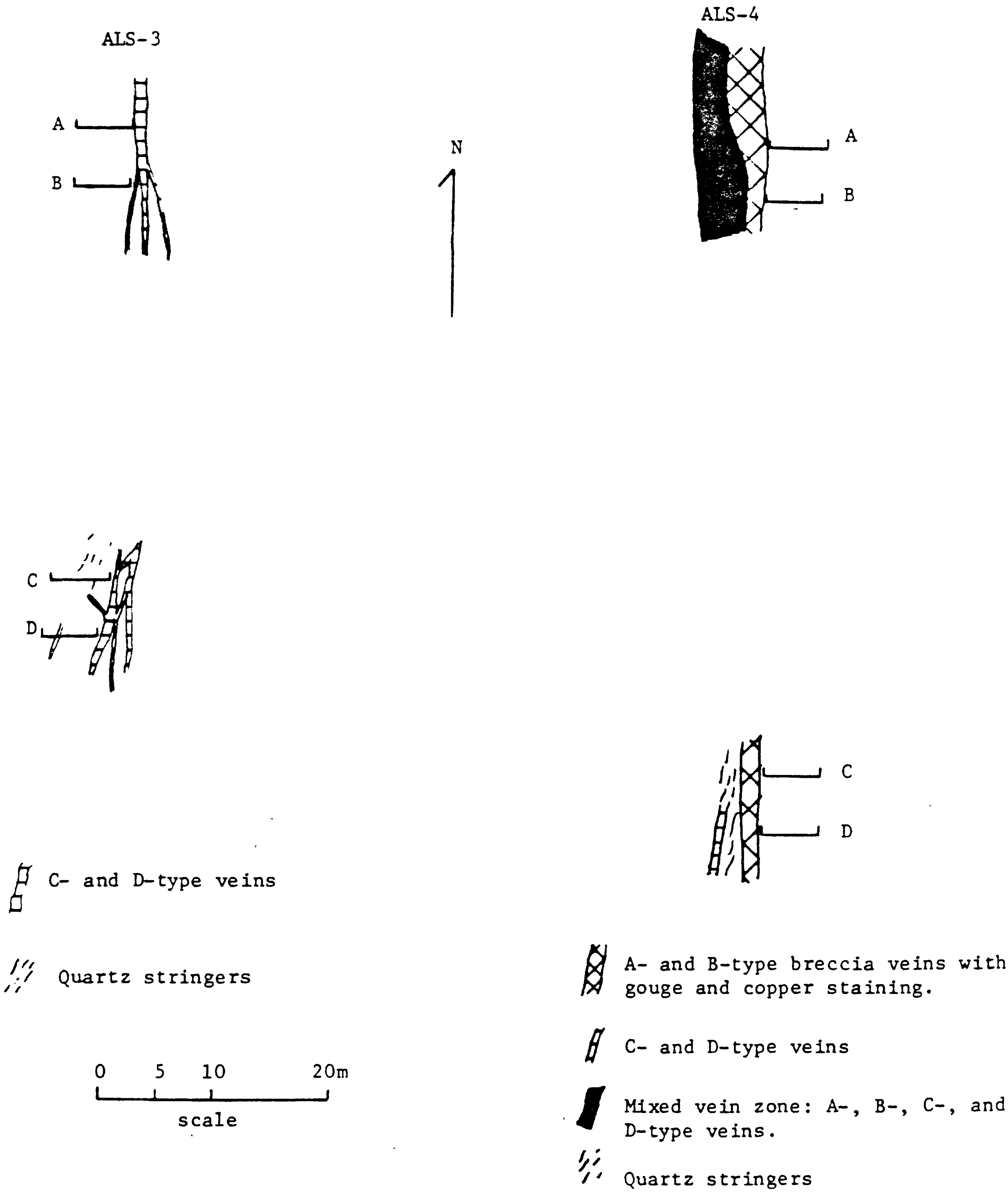

Figure 3.--*Sketch map of ALS sample sites 3 and 4 showing location of sample panels. Scale refers to individual sites, not the distance between them. Location of the sites shown on plate 1.*

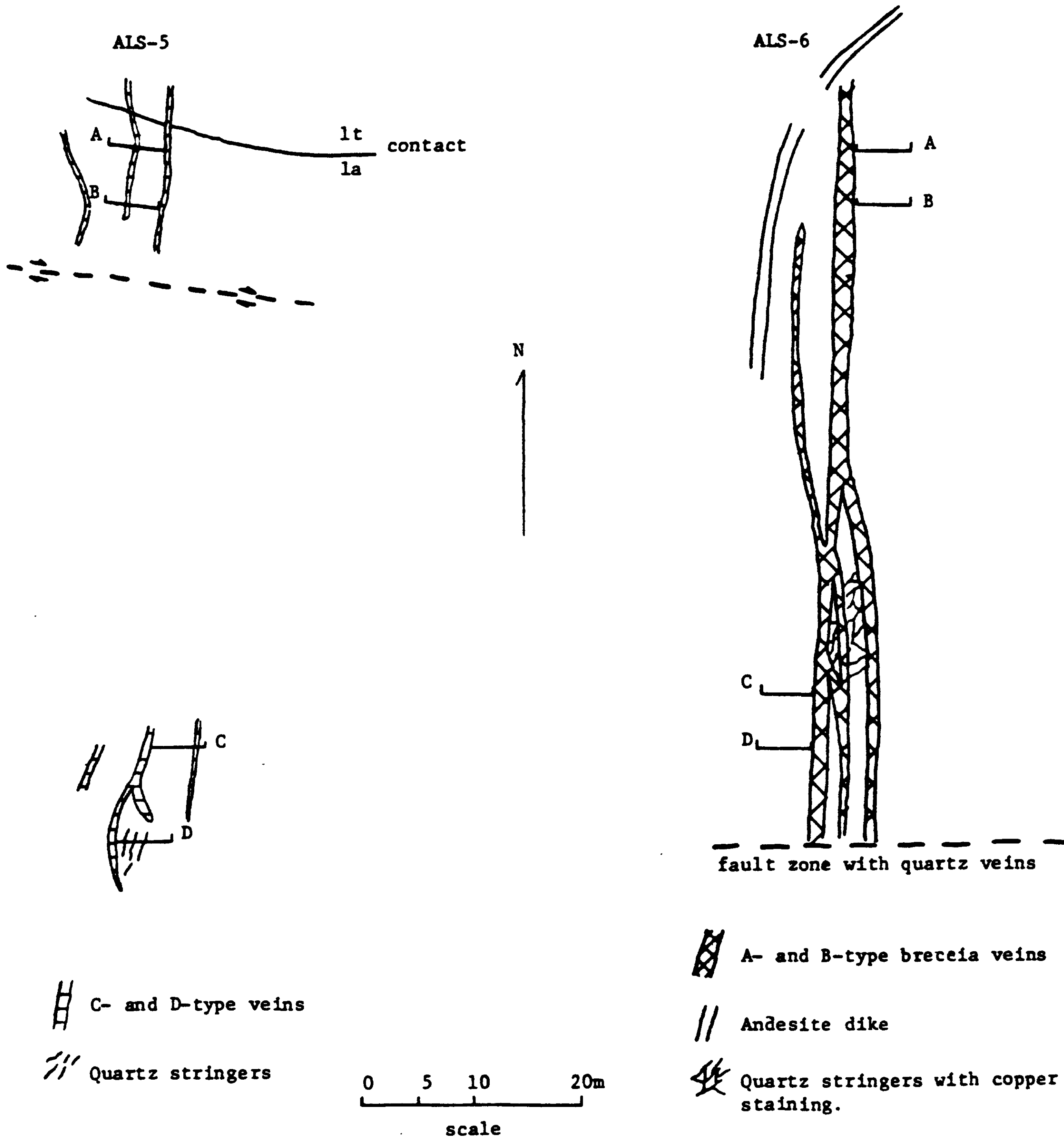

Figure 4.--*Sketch map of ALS sample sites 5 and 6 showing location of sample panels. Scale refers to individual sites, not the distance between them. Location of sites shown on plate 1.*

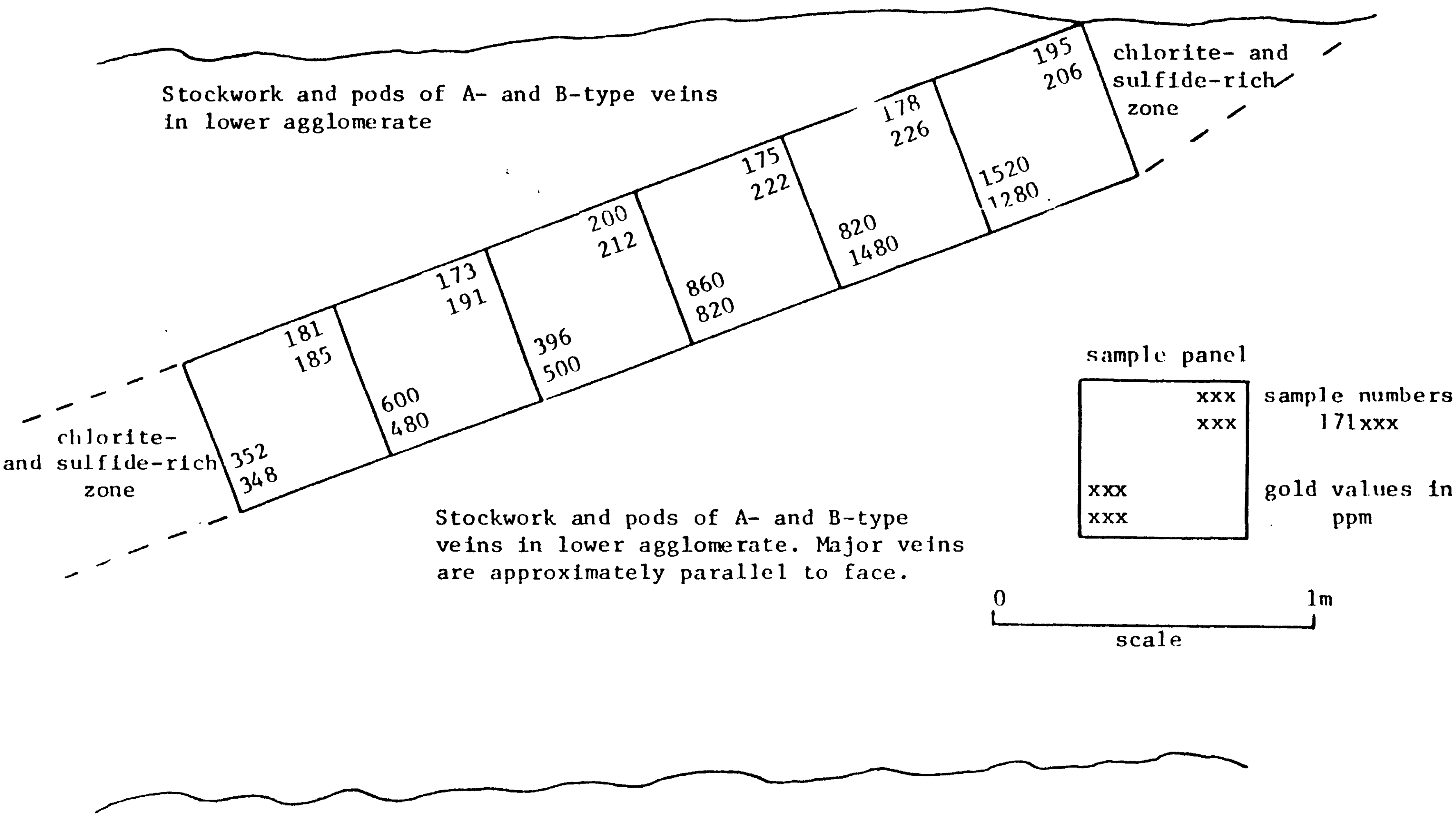

Figure 5.--*Sketch of vertical face at the HOT-1 sample site in the GFMAD workings looking east across the 6-7-8 vein system. For other metal values refer to Appendix 2.*

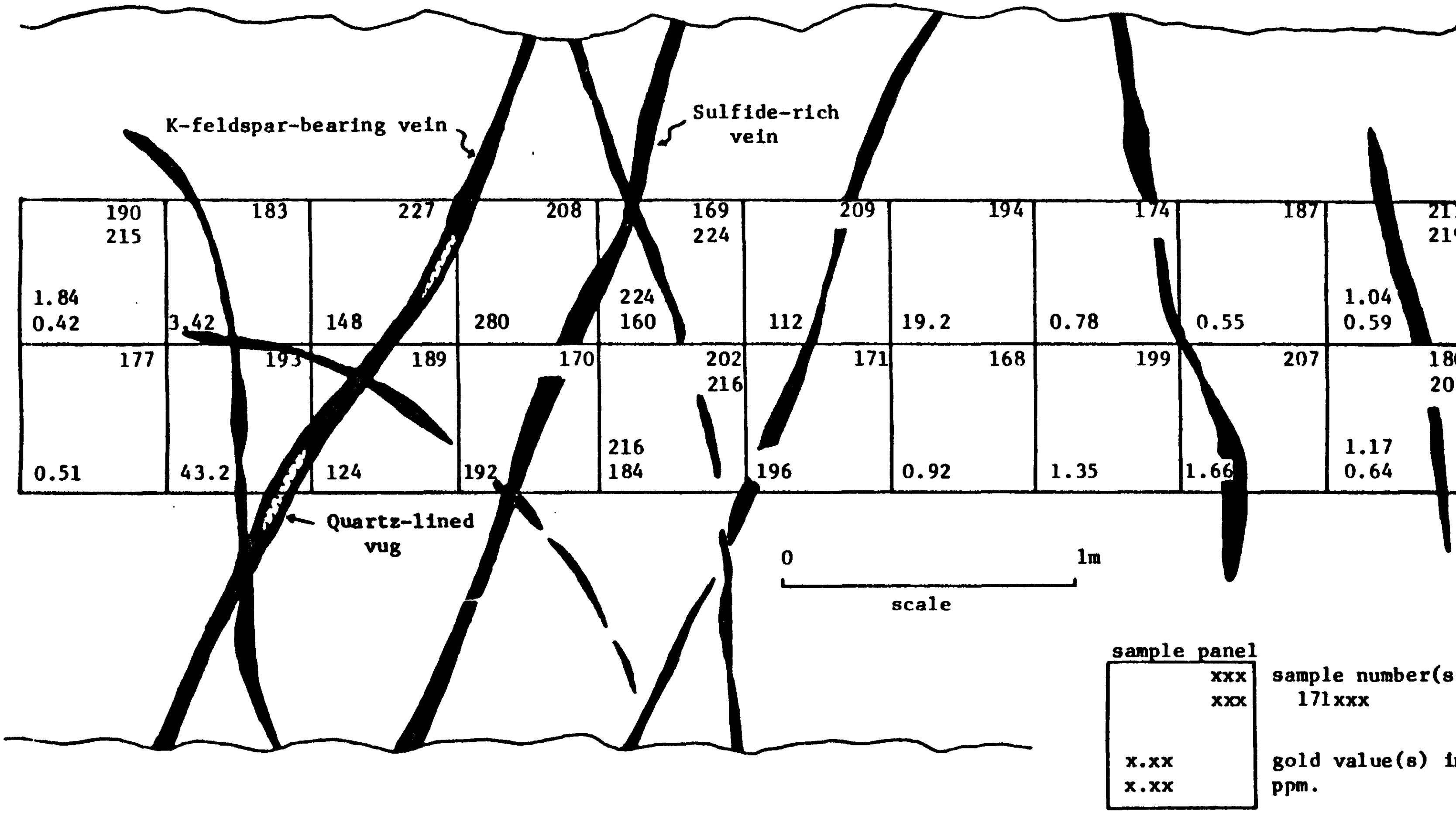

Figure 6.--*Sketch of vertical face at the HOT-2 sample site in the GFMAD workings looking southwest across the 3-4-5 vein system. An extensive veinlet stockwork system is present between the major veins shown above. For other metal values refer to Appendix 2.*

RESULTS AND DISCUSSION

The ten geochemical sample sets are briefly described and the analytical results are discussed in the following sections. Additional descriptive information is presented in appendix 1. Tabulation of the analytical results for trace and major elements are contained in appendixes 2 and 3, respectively. The distributions of base and precious metals, yttrium, and zirconium are plotted in figures 7-13.

The analytical data for this study were reduced through a number of statistical procedures. Data reproducibility and statistically significant variation for each of the analytical methods were determined through the calculation of the standard error of replicate analyses and through the use of a balanced-design hierarchical analysis of variance. Elements that were reproducible and exhibited statistically significant variation were processed through interpretive techniques including calculation of linear correlation coefficients and spatial plotting. Only data that were determined to be reliable and geologically meaningful are discussed in this report.

DATA REPRODUCIBILITY

Replicate samples were taken at 78 sites in the UAS, LAS, LTS, LAT, RHY and MIN sample sets. Geochemical data from replicate samples was tested by analysis of variance techniques to determine the source of variation for each element. The design was to determine the variance components for "between sample sites" and "within sample sites". The variance component for "within sample sites" includes sampling error and analytical error. The data was reduced in two groups; traverse samples of country rock (table 1) and panel samples of mineralized rock (table 2). The variance component in percent is given for "between sample sites" and "within sample sites" along with an F-ratio and a level of confidence for each element. The level of confidence indicates how suitable the analytical data is, for an element from a data set, for use in statistical analyses that define areal zonation, factor groupings, or correlations. An element with the major component of variation within the sample set, such as gold in the traverse samples of country rock (table 1) would not be suitable, and should be used with no confidence. An element with the major component of variation between sample sets, such as gold in the panel samples of mineralized rock, would be suitable and could be used with high confidence. The level of confidence defines the suitability for use in statistical analyses, the geologic significance of the distribution depends upon other factors discussed elsewhere.

ALS SAMPLE SET

The ALS sample group was collected from vein edges at six sites (pl. 1). Each site consisted of four sets of samples (figs. 2-4); sets A and B, 5 m apart, were approximately 50 m from sets C and D, also 5 m apart. Five 0.5 x 2 m panel samples were collected for each set. The sample panels were parallel to the veins at 0 to 0.5, 0.5 to 1, 1.0 to 1.5, 1.5 to 2.0, and 5.0 to 5.5 m, numbered 1, 2, 3, 4, and 5, respectively, from the vein edge outward. Analytical data for gold, silver, copper, lead, and zinc for each panel set is given in appendix 2.

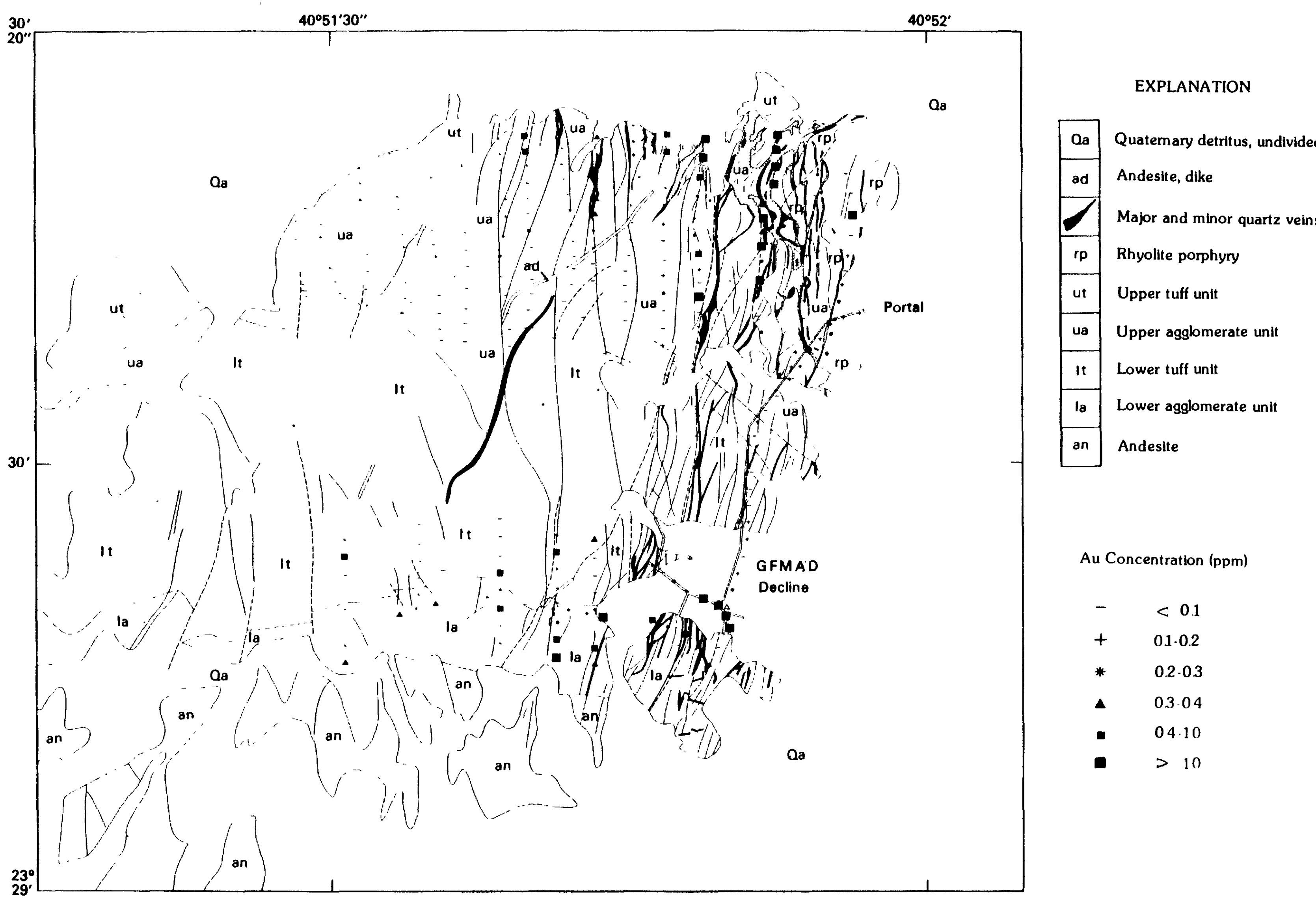

Figure 7.--*Distribution of gold in the Mahd adh Dhahab district.*

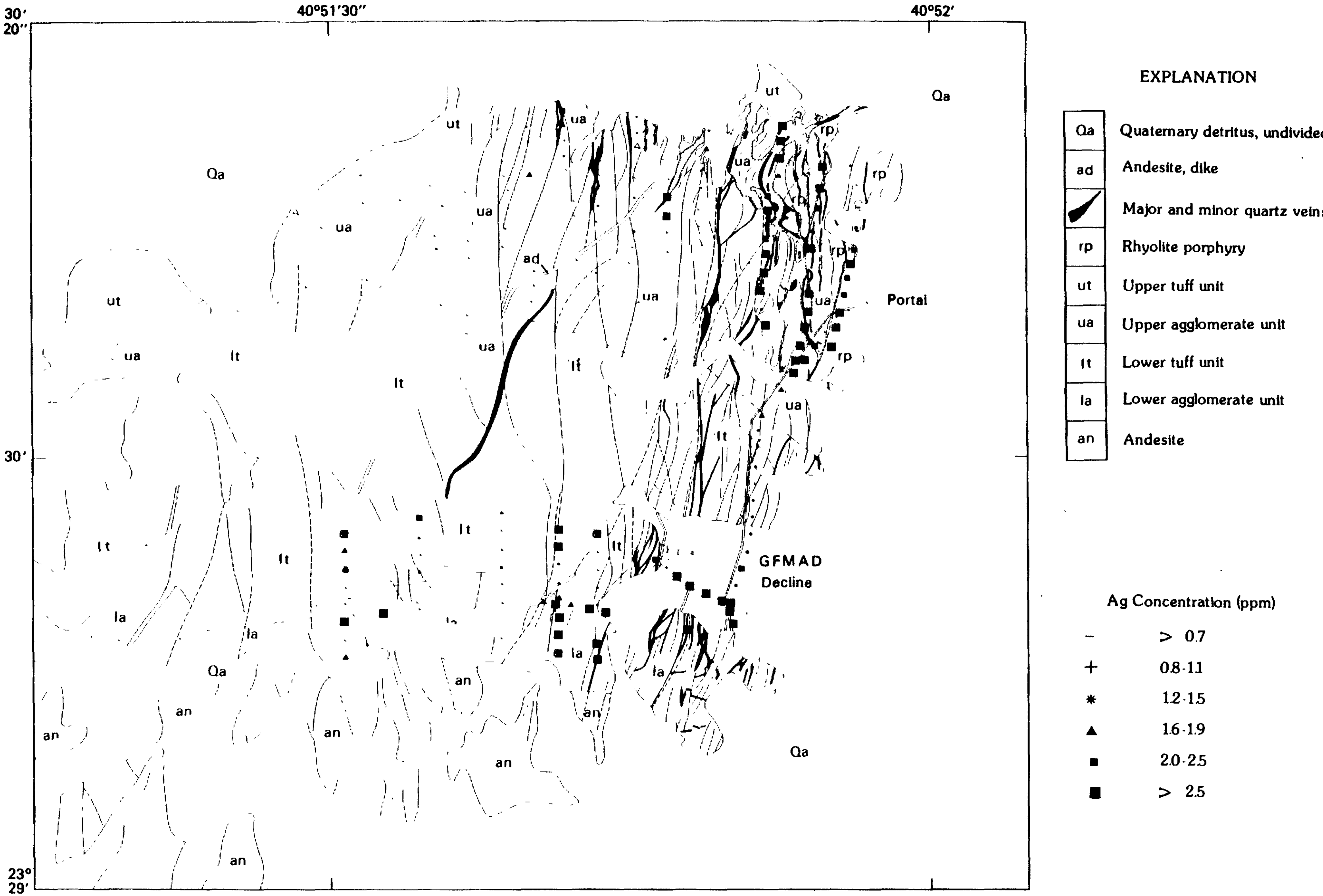

Figure 8.--*Distribution of silver in the Mahd adh Dhahab district.*

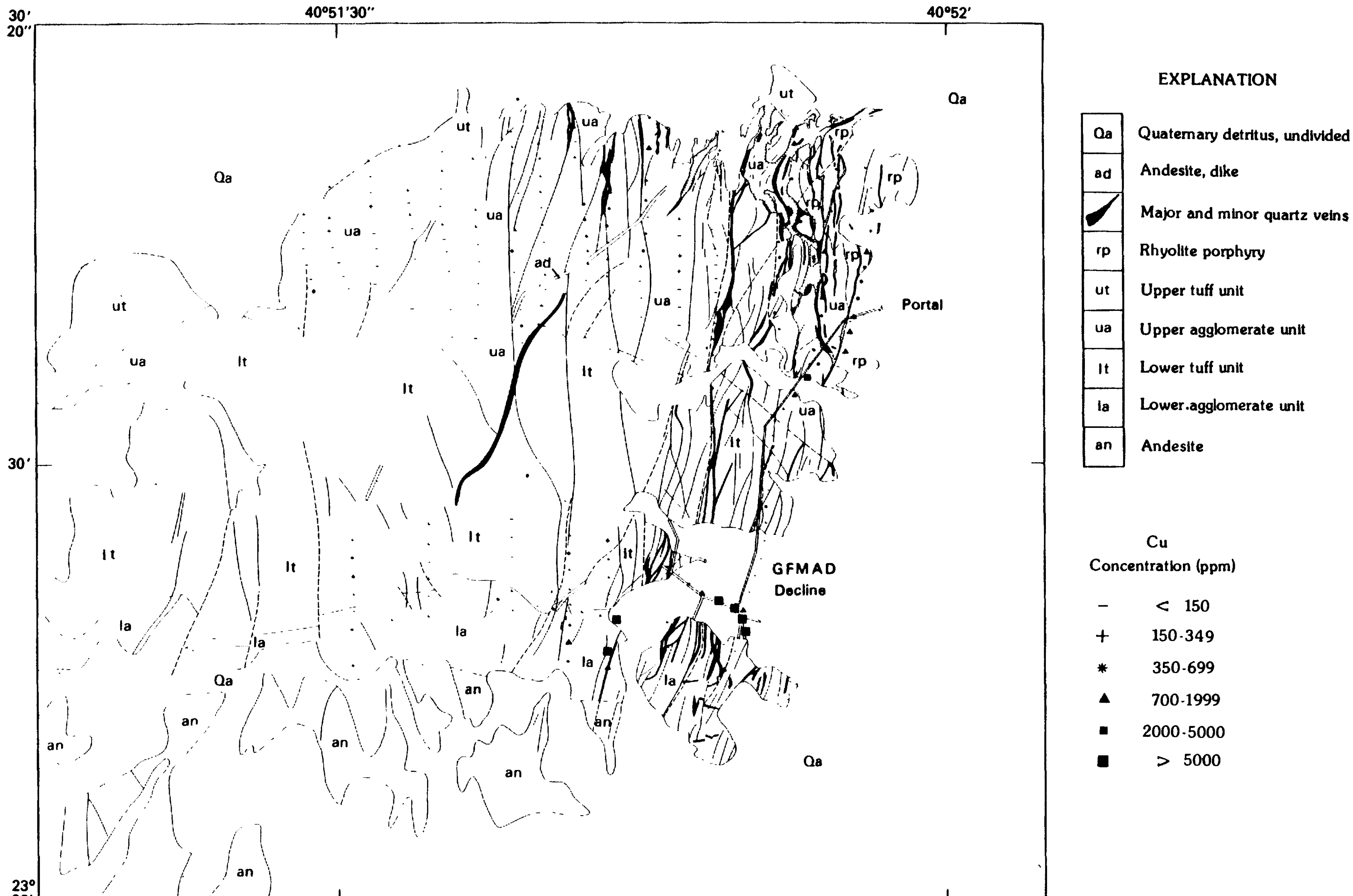

Figure 9.--*Distribution of copper in the Mahd adh Dhahab district.*

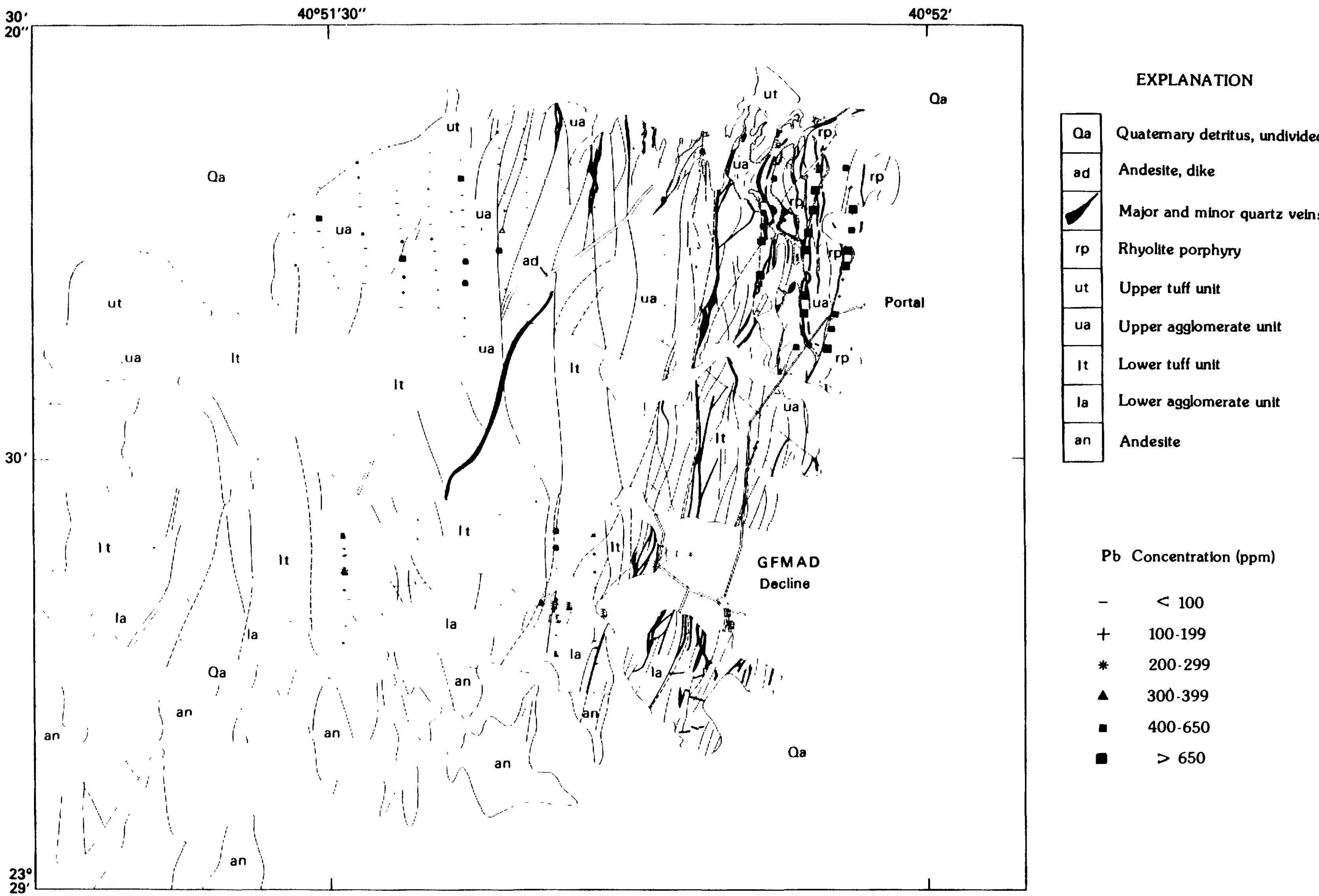

Figure 10.--*Distribution of lead in the Mahd adh Dhahab district.*

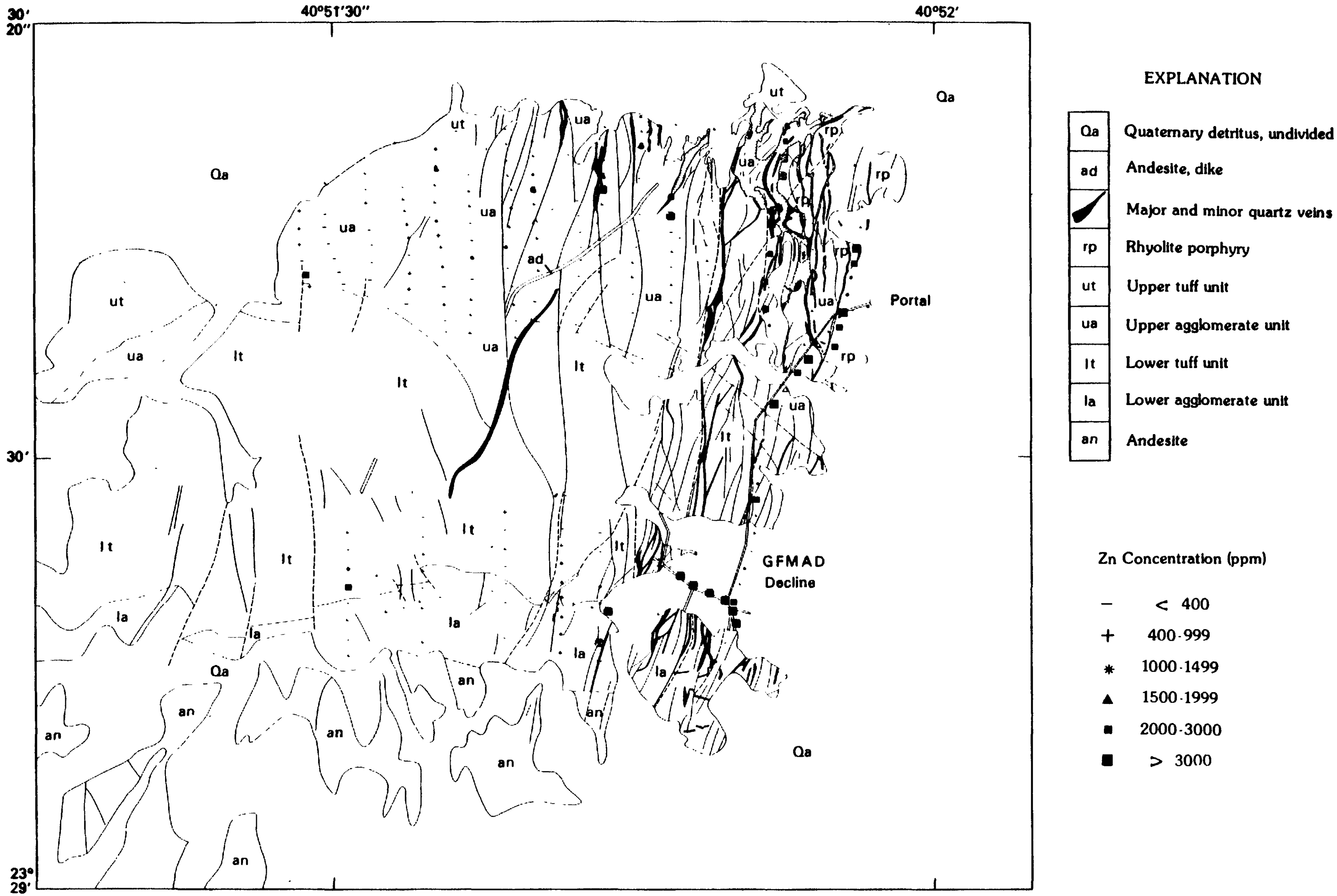

Figure 11.--*Distribution of zinc in the Mahd adh Dhahab district.*

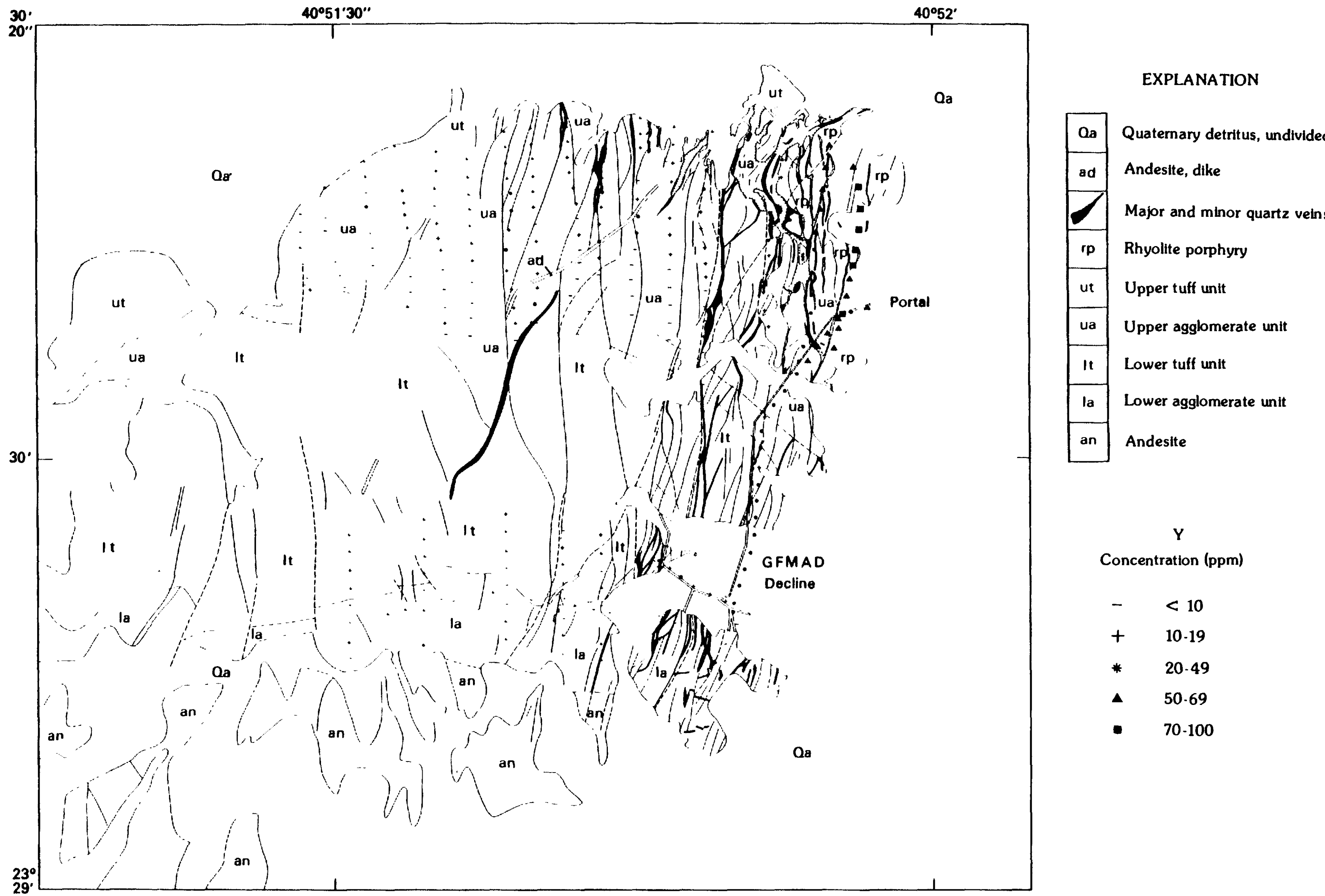

Figure 12.--*Distribution of yttrium in the Mahd adh Dhahab district.*

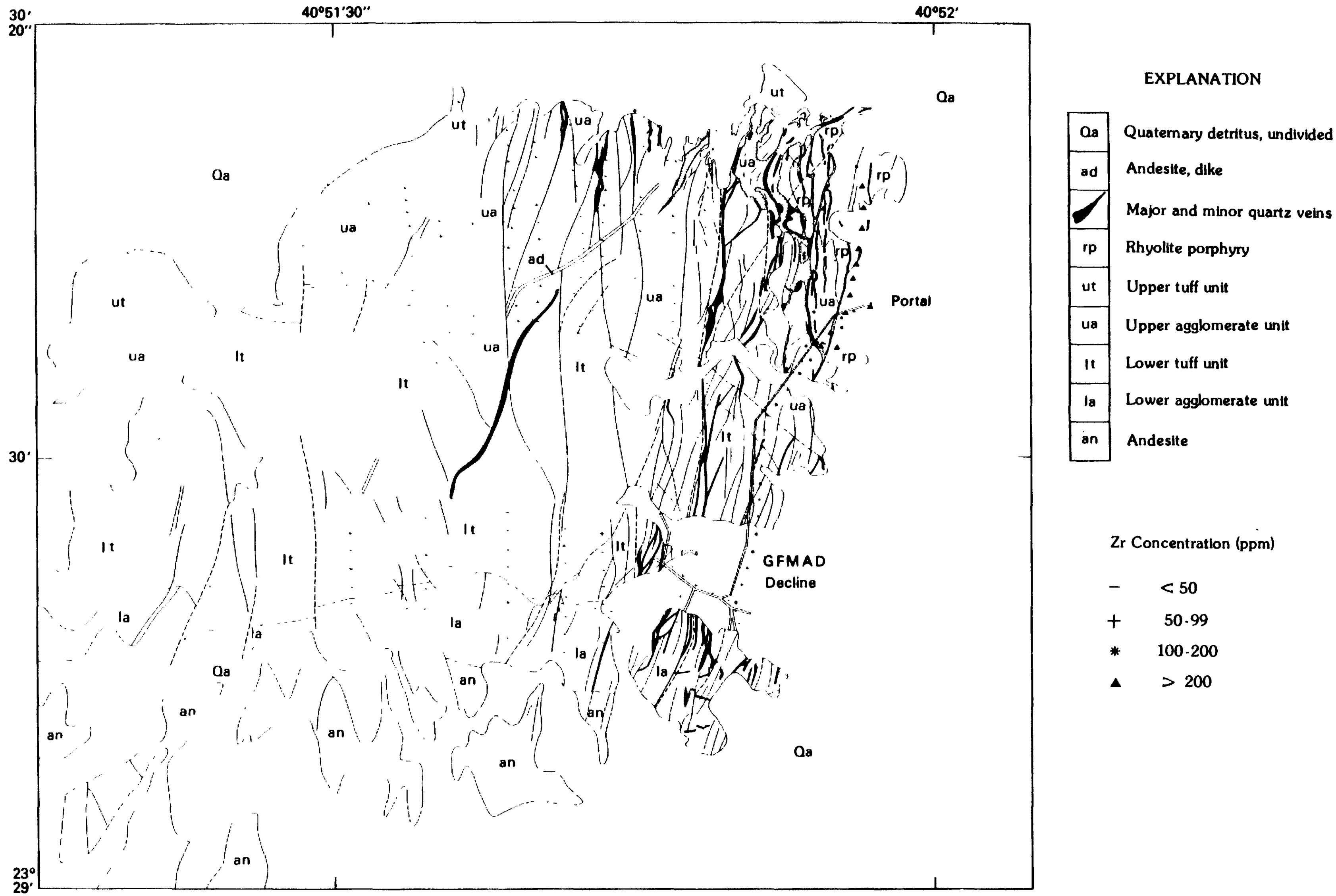

Figure 13.--*Distribution of zirconium in the Mahd adh Dhahab district.*

Table 1.--*Variance components for analytical values of replicate traverse samples of wall rocks.*

[n-number of samples, S-emission spectrographic analysis, AA-atomic absorption analysis]

Element	n	Between Sets	Within Sets	F-ratio	Confidence level
Fe -S	44	51.7 %	48.4 %	3.1	Moderate
Mg -S	44	30.1	69.9	1.9	Low
Ca -S	44	48.4	51.6	2.9	Low
Ti -S	44	45.2	54.8	2.6	Low
Mn -S	44	37.4	62.7	2.2	Low
Ba -S	44	40.7	59.3	2.4	Low
Cr -S	44	44.6	55.4	2.6	Low
Cu -S	44	73.2	26.8	6.5	High
Cu AA	44	22.4	77.6	1.6	None
Pb AA	44	61.3	38.7	4.2	Moderate
Zn AA	44	73.1	27.0	6.4	High
Au AA	44	4.2	95.8	1.1	None
Ag AA	44	64.6	35.4	4.7	Moderate
SiO_2 %	23	48.9	51.1	2.9	Low
AL_2O_3 %	23	85.7	14.3	13.0	High
Fe_2O_3 %	23	54.2	45.8	3.4	Moderate
FeO %	23	69.4	30.6	5.5	Moderate
MgO %	23	70.6	29.4	5.8	High
CaO %	23	0.0	100.0	0.8	None
Na_2O %	23	84.1	15.8	11.8	High
K_2O %	23	60.5	39.5	4.1	Moderate
H_2O+ %	23	23.9	76.1	1.6	None
H_2O- %	23	31.6	68.4	1.9	None
TiO_2 %	23	67.4	32.6	5.1	Moderate
P_2O_5 %	23	46.1	53.9	2.7	Moderate
MnO %	23	0.0	100.0	0.7	None

Table 2.--*Variance components for analytical values of replicate panel samples of mineralized rock.*

[n-number of samples, S-emission spectrographic analysis, AA-atomic absorption analysis]

Element	n	Between Sets	Within Sets	F-ratio	Confidence Level
Fe -S	11	79.8	20.2	8.9	High
Mg -S	11	24.1	76.0	1.6	None
Mn -S	11	30.3	69.7	1.9	None
Cr -S	11	51.2	48.8	3.1	Low
V -S	11	53.9	46.1	3.3	Low
Te AA	11	84.9	15.1	12.2	High
Cu AA	11	64.4	35.6	4.6	Moderate
Pb AA	11	96.6	3.4	57.9	High
Zn AA	11	43.1	56.9	2.5	None
Cd AA	11	35.3	64.7	2.1	None
Au AA	11	90.1	9.9	19.2	High
Ag AA	11	75.8	24.3	7.2	High

Table 3.--*Variance components for ALS sample set.*

Element	Vein types	50 m along	5 m along	Panel sets
Au	11.2	49.5	0.0	39.3
Ag	36.1	0.0	27.3	36.6
Cu	54.2	1.8	13.6	30.4
Pb	36.5	0.7	0.0	62.9
Zn	3.7	24.9	28.3	43.0

Geochemical data from the ALS group was tested by analysis of variance techniques to determine the source of variation for each element. The design was to determine the variance components for vein types, 50 m intervals along veins, 5 m intervals along veins, and within sample sets (table 3). A large component of variation for gold, silver, lead, and zinc is within the sample sets precluding their use to distinguish between vein types. Of these, gold has its largest component of variation at 50 m intervals, and lead and silver have a major component of variation between vein types. Copper has its largest component of variation between vein types with the remaining variation distributed among the other three groupings.

The variance components, reflecting the nature of element distribution in the wall rocks next to mineralized and unmineralized veins, suggest the following. There is little significant distinction in metal content of wall rocks between vein types except for copper. This suggests that copper may have been largely related to the mineralized vein systems, whereas gold, silver, lead, and zinc were related to all vein systems. The largest variation component of gold at 50 m along a vein, with a major component within the sample set probably reflects the nature of the gold ore-bodies as isolated shoots along the vein systems. The small amount of variation component at 5 m along the vein indicates that the shoots are generally larger than 5 meters, but less than 50 m in size. Silver does not reflect this with its variance components distributed evenly among vein types, 5 m along veins, and within sample sets.

Distributions of metals within the sample sets were examined for possible zonation away from the veins. Gold values are generally higher away from the vein, and in the case of some of the mineralized veins increase systematically outward from the vein, which may indicate leaching of gold from the wallrock. Silver values do not exhibit a sytstematic change with respect to distance from a vein. Base-metal values commonly increase toward a vein, particularly in the case of mineralized veins. This may indicate that the base metals were introduced into the rock by hydrothermal solutions.

In summary, the analytical results for samples from the ALS set indicate that, with regard to base- and precious-metal contents, the wallrock adjacent to A-B (mineralized) type veins as compared to the wallrock adjacent to C-D (unmineralized) type veins is the same, except for copper contents. Gold values tend to be higher away from the veins and base-metal values tend to increase towards the veins, particularly in the case of mineralized veins.

MIN AND HOT SAMPLE SETS

The MIN sample set consists of 25 grab samples from selected geologic settings. Descriptions and analytical results of the MIN grab samples are presented in appendix 2. The data suggests that gold occurs in significant amounts only in A-B type veins when associated with sulfides and(or) chlorite. Not all sulfide-rich zones contain gold and altered and stockwork-veined agglomerate does not necessarily carry gold even in the main mineralized zones. Silver content is more uniform throughout the mineralized zones, and is not characterized by isolated high values like gold. Samples with high gold values usually also have high Ag, Cu, Pb, Zn, Cd, and Te values. Higher As values, however, are from samples with lessor gold values (appendix 2).

The HOT sample set consists of panel samples at two highly mineralized sites in the GFMAD workings (pl. 1). The HOT-1 sample set was collected along a 40- to 50-cm-thick chlorite- and sulfide-rich zone in an A-B type quartz breccia stockwork of the 6-7-8 vein system (fig. 5). The zone contains large amounts of galena, chalcopyrite, and sphalerite, and minor stringers, veinlets, and pods of quartz. The contact with the quartz breccia stockwork is slightly sheared and chlorite-rich. Each of the six 50 cm x 40- to 50-cm panels were sampled in duplicate.

The HOT-2 sample set was collected from 0.5 x 0.5 m panels (fig. 6) across the 3-4-5 vein system in the GFMAD workings (pl. 1). This was a typical face for this vein system. A majority of the veins are A-B type and the wall rock is an agglomerate highly altered to quartz-sericite-pyrite with zones of dark chlorite. Chlorite is also common along and within some of the veins. The altered wall rock has a pervasive network of quartz veinlets. Pink potassium feldspar occurs in the veins and altered wall rock. Sulfide-rich and sulfide-poor veins are both present. Five of the twenty panels were sampled in duplicate.

Analysis of variance of the analytical values of the replicate panel samples for HOT-1 and HOT-2 indicated the major source of variation for each element, within and between panels (table 2). The within-panel variation includes analytical error. Although there is considerable apparent difference in values for gold between the two replicate samples the major variance compontent is between panels. A high degree of confidence can be assigned to the differences in gold values between individual panels. This is also true for Ag, Pb, Te, and Fe (table 2). A moderate degree of confidence can be assigned to Cu values, but with all other elements determined, the amount of variation within the panels does not allow comparison of values between panels.

Gold values from the HOT-1 panels range from 348 to 1520 ppm, average 788 ppm, and have a standard deviation of 428 ppm. The first set of panel samples from HOT-1 has an average gold value of 758 ppm (standard deviation 427 ppm), whereas the second (duplicate) set of samples yielded an average of 818 ppm gold (standard deviation 466 ppm). The gold values suggest an increase in gold content upward and toward the south along the 6-7-8 vein system (fig. 5). Gold/silver ratios range from 0.8 to 3.56, average 1.13, and show considerable variation within and between panels. Distribution of gold does not seem to relate directly to any other element (appendix 2). Copper and lead values generally increase upward while silver values show no distinct vertical variation.

The top row of ten panels of the HOT-2 sample set has an average gold content of 73 ppm (standard deviation 100 ppm) as compared to 80 ppm (standard deviation 93 ppm) for the bottom row of ten panels, which are reasonably similar values. Gold/silver ratios of the ore-grade zone range from 0.052 to 0.635, averaging 0.41. Gold and silver values show a positive correlation with the amount of quartz veins and veinlets exposed in the panels, with the higher values in panels with more veins and veinlets (fig. 6). Copper and lead relate to the presence or absence of metal-rich veins, while Te shows an erratic distribution.

DEC, LAU, LAS, LTS, UAS, AND RHY SAMPLE SETS

These sample sets are similar because they are all composed of composite chip samples along 25 m traverses. The LAS and LTS sets were separated into two subsets each to examine metal variation perpendiclar to the lower agglomerate-lower tuff contact (pl. 1). The trace-element data for all theses sample sets are presented in appendix 2 and plotted in figures 7-13. The major-element whole-rock compositions are tabulated in appendix 3.

Gold values in the range 0.1 to 1.0 ppm for samples from the UAS set are strongly zoned. Values increase toward the upper agglomerate-upper tuff contact and toward the SAMS and ancient workings (fig. 7). The higher values (greater than 1.0 ppm), including those from the RHY set, are erratically distributed in areas of known ore occurrence. Gold values in the LAS and LTS sample sets suggest the presence of two mineralized areas in the lower agglomerate (fig. 7); one area is beneath the eastern two lines of the the LAS set and corresponds to the GFMAD west-vein area. The other area is under the westernmost line of the LAS sample set. Gold values of LAT samples, collected parallel to bedding in the lower agglomerate, delineate the same two areas as well as the GFMAD east-vein area under the eastern most end of the traverse (fig. 7).

Silver distribution is zoned similar to that of gold, but values are less erratic. Silver values in the southern part of the district (LAS, LTS, LAT sets) are all high relative to those of the UAS set and also outline three anomalous areas within the lower agglomerate coincident with the areas identified with higher gold values (fig. 8). High silver values associated with the eastern most traverse in the UAS set and the RHY sample set correspond to the northern mineralized zone. Lead distribution corresponds extremely well to that of silver (fig. 10), which implies a mineralogical control.

Copper and zinc distributions are also zoned in a manner similar to that of gold, but with a wider spread of high values, particularly in the UAS sample set. Weak zonation of copper and zinc distribution in the lower agglomerate also outline the west-vein area, and a potentially mineralized area further to the west (figs. 9 and 11). The less pronounced zonation of copper and zinc distributions around known mineralized areas, compared to that of lead and the precious metals, may indicate greater mobility of copper and zinc in the supergene environment.

Metal zonation was tested along the lower agglomerate-lower tuff contact in the southern part of the district (pl. 1). From stratigraphic bottom to top, the sample sets collected along five traverses perpendicular to the contact were LAS-3 and LAS-1 (within the lower agglomerate) and LTS-1 and LTS-3 (within the lower tuff). Samples collected farther from the contact (LAS-3 and LTS-3) contained the highest metal concentration, particularly precious metals (appendix

2). The difference in base-metal content between these samples and the near-contact samples (LAS-1 and LTS-1), however, may not be statistically significant. For example, there is a reversal of this generalization for zinc in the lower tuff; the near-contact samples contain more zinc (mean 921 ppm) than the samples collected away from the contact (mean 358 ppm) (appendix 2).

A comparison of all surface geochemical traverse samples (UAS, RHY, LAS, LTS, and LAT sets), indicates geochemical similarities, especially of trace-metal content, of the various sampled areas. The metal contents of the LAS, LTS, and LAT sets are similar to those parts of the UAS and RHY sets that cover known mineralized areas. By this comparison all of the LAS, LTS, and LAT sample sets must be considered anomalous in gold, silver, copper, lead, and zinc; the three areas detected in the lower agglomerate, as described above, are considered highly anomalous.

Within the DEC sample set there is no systematic variation of any of the metals toward either the northern or southern mineralized zones (figs. 7-11). However, yttrium and zirconium distributions in the DEC and RHY sample sets clearly delineate the exposures of the altered rhyolite porphry underground and on the surface, respectively (figs. 12 and 13).

The LAU sample set, collected from a drift through the southern mineralized zone (pl. 1), shows a wide range of metal values (appendix 2). All base- and precious-metal values are relatively high along the east half of the traverse and decrease dramatically toward the west (figs. 7-11; appendix 2). This traverse corresonds to the east-vein area of the southern mineralized zone, and the barren interval separating it from the west-vein area. In comparing the LAT and LAU sample sets (pl. 1), the distribution of higher gold, silver, and lead values on the surface do reflect the presence of the east-vein area at depth, while copper and zinc values do not. This again is believed to reflect the greater mobility and depletion of copper and zinc in the supergene environment.

Major-element whole-rock compositons are zoned in several ways. Within the LAS sample set, SiO_2 contents increase toward the lower agglomerate-lower tuff contact whereas the opposite is true for the LTS sample set (appendix 3), suggesting a possible redistribution of SiO_2 from the lower tuff into the lower agglomerate by hydrothermal fluids along the contact. Fe_2O_3 and MgO contents are relatively high along LTS traverse lines that overlie areas of anomalous base- and precious-metal concentration (appendix 3), which probably corresponds to the abundance of chlorite in these areas. Within the UAS sample set, K_2O contents increase as the upper agglomerate-upper tuff contact is approached from south to north. In addition, SiO_2 and Fe_2O_3 contents increase, and Al_2O_3, MgO, and K_2O contents decrease from west to east in the upper agglomerate as the northern mineralized zone is approached (appendix 3).

Traverse line 1 of the RHY sample set (western most line) crosses the contact between the rhyolite porphyry stock and the upper agglomerate. Major-element compositions change dramatically at this point, represented by sample locality 171524 (pl. 1 and appendix 3). The greater SiO_2 content of the adjacent country rock corresponds to the silicic alteration aureole that surrounds the intrusion. The overall composition of the rhyolite clearly indicates that it is altered. The high Al_2O_3, Fe_2O_3, and K_2O contents of these samples, as compared to most rhyolites, correlate with the evidence suggesting these rocks underwent an intense episode of quartz-sericite-pyrite alteration (Doebrich and LeAnderson, 1984).

RADIO-ELEMENT ANALYSES

The natural radio-element content of selected samples was determined as previously described and values are presented in appendix 2. The RaeU values are similar throughout, except that lower values were determined in some samples with high gold contents. The thorium values are higher in samples from tuff and rhyolite porphyry and lower in samples with high gold values, relative to the whole population. Uranium/potassium ratios are higher in samples of tuff. The uniformity of values throughout the area suggests that the sampling was not extended far enough to exceed the range of effects of the hydrothermal system.

CONCLUSIONS

Distributions of gold, silver, copper, lead, and zinc throughout the Mahd adh Dhahab district were determined by analyzing 538 samples comprising ten data sets, collected for specific study purposes. Results from all data sets suggest that the formation of all quartz veins and altered and mineralized zones were related to one continuous hydrothermal event. Most metals and some of the major oxides are zoned relative to the known major mineralized and altered zones, and to the contact between lower agglomerate and lower tuff or between upper agglomerate and upper tuff. The metal component of all vein types is the same, only the abundance differs. In general, gold contents decrease and base-metal contents increase toward a vein, particularly a mineralized vein, in systematic samples taken outward from a vein edge. This may suggest that gold initially was leached from the surrounding wall rock, and that the base metals were initially in the hydrothermal fluids and were introduced into the wall rock.

Distribution of lower gold values (0.05 to 1.0 ppm) in the country rocks is well zoned and indicates broad anomalies. The distributon of high gold values appears as randomly spaced spikes within the broader anomalous zones defined by the lower values. The variance of high gold values for replicate samples at a 0.5-m scale is very high. Large bulk samples across zones of several meters width are needed to eliminate the high variance resulting from very erratic gold distribution.

Silver has a more consistent distribution than gold and does not define the erratic, high-concentration anomalies that typify gold. The extreme range in gold/silver ratios reflects this distribution difference. The distribution of lead values correlate extremely well with that of silver, and this may reflect a mineralogical control.

Copper and zinc distributions reflect a zonal pattern around the major mineralized areas and mimic that of gold, silver, and lead, though much weaker. The greater mobility of copper and zinc in the supergene environment, compared to lead and the precious metals, may have caused a dispersion of these two base metals, thus deminishing their usefulness for indentifying mineralized areas geochemically, on the surface.

There are several mineralized areas in the Mahd adh Dhahab district, all of which occur at agglomerate-tuff contacts. Those areas along the upper agglomerate-upper tuff contact make up the northern mineralized zone while those along the lower agglomerate-lower tuff contact comprise the southern mineralized zone. However in all cases, mineralization was contained within agglomerate. The distribution of anomalous metal concentrations clearly defines the northern mineralized zone in the northeast part of the district. The entire sampled area of the lower agglomerate is altered and the metal zonation suggests the presence of three mineralized areas. The two eastern-most areas define the current known extent of the southern mineralized zone and correspond to the east-vein and west-vein areas. The western-most area suggests the presence of another potential mineralized zone. Further exploration in the district should be concentrated in the southwest part to evaluate the potential for additional mineralized occurences in the lower agglomerate.

DATA STORAGE

Analytical results are on file in the Rock Analysis Storage System (RASS) computerized data bank; each sample has been assigned a unique six-digit number in the 171000-171999 series. Inquiries regarding RASS may be directed to the office of Technical Advisor, Deputy Ministry for Mineral Resources, Jeddah. All supporting data for this study are on file with the Jeddah office Of the U.S. Geological Survey, catalogued as Saudi Arabian Ministry for Mineral Resources Data File USGS-DF-04-23.

No updated information was added to the Mineral Occurrence Documentation System (MODS) data bank, and no new files were established.

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APPENDIX 1

DESCRIPTION OF GEOCHEMICAL SAMPLE SETS

DEC sample set (21 samples): RASS 171000-018, 020, 023
Composite chip samples from a continuous underground traverse along the east wall of the GFMAD decline. Sample set collected to provide background geochemical information on various lithologic units and to test for metal zonation around the southern mineralized zone. ANALYSES: semiquantitative spectrography for 30 elements; atomic absorption for base and precious metals; selected samples for radio-element determinations by gamma-ray spectrometry.

LAU sample set (8 samples): RASS 171019, 021, 022, 024-028
Composite chip samples along a 25 meter, continuous underground traverse, consisting of one sample line oriented perpendicular to the trend of the quartz vein system ,in vein-free, unmineralized lower agglomerate. Sample set collected to compare analytical results with a similar traverse on the surface and with samples of lower agglomerate collected away from the southern mineralized zone. ANALYSES: semiquantitative spectrography for 30 elements; atomic absorption for base and precious metals; selected samples for cadmium, arsenic, antimony, tungsten, molybdenum and tellurium; selected samples for radio-element determinations by gamma-ray spectrometry.

ALS sample set (120 samples): RASS 171047-166
Composite chip samples from 0.5 x 2 m surface panels oriented parallel to veins at 6 sites, 3 mineralized (sites 2, 4, and 6) and 3 unmineralized (sites 1, 3, and 5). Sample set collected to determine the degree of element variation in wallrock at 5 m and 50 m distances along strike of the vein, and up to 5.5 m away from the vein. ANALYSES: semiquantitative spectrography for 30 elements; atomic absorption for base and precious metals.

HOT sample set (38 samples): RASS 171167-228
Composite chip samples from 0.5 m square panels along continuous traverses across selected mineralized areas in the GFMAD underground workings. Each sample was duplicated. Sample set collected to test the ability to adequately sample and analyze for gold at this scale and to indicate the variation of gold content across the vein system. ANALYSES: semiquantitative spectrography for 30 elements; atomic absorption for base and precious metals; colorimetry for cadmium, arsenic, antimony, tungsten, molybdenum, and tellurium.

MIN sample set (24 samples): RASS 171167-228 (part)
Single specimen samples of selected mineralized rock, such as "dark chlorite" selvage along edge of C-D type quartz vein. Sample set collected to indicate where, at sampling scale, gold occurs within the vein-stockwork. ANALYSES: common analytical submittal with the HOT sample set.

APPENDIX 1 (continued).

LAS-1 sample set (11 samples): RASS 171229-239
LAS-3 sample set (10 samples): RASS 171253-275 (part)
Composite chip samples along 25 meter, continuous surface traverses, consisting of four samples along 5 sample lines starting from the lower tuff-lower agglomerate contact into the lower agglomerate. Sample set collected to test for metal and alteration chemical variation in the lower agglomerate as the lower tuff is approached. ANALYSES: semiquantitative spectrography for 30 elements; atomic absorption for base and precious metals; LAS-1 samples for SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, H_2O+, H_2O-, TiO_2, P_2O_5, and MnO by X-ray fluorescence.

LTS-1 sample set (12 samples): RASS 171241-252
LTS-3 sample set (13 samples): RASS 171253-275 (part)
Composite chip samples along 25 meter, continuous surface traverses, consisting of four samples along 5 sample lines starting from the lower tuff-lower agglomerate contact into the lower tuff. Sample set collected to test for metal variation in the lower tuff as the lower agglomerate is approached. ANALYSES: common analytical submittal of LTS-3 with LAS-3 and LTS-1 with LAS-1.

LAT sample set (17 samples): RASS 171276-292
Composite chip samples along 25 meters, continuous surface traverse along one sample line oriented perpendicular to the trend of the quartz vein system. Sample set collected to compare to those from a similar traverse underground. ANALYSES: semiquantitative spectrography for 30 elements ; atomic absorption for base and precious metals; selected samples for radio-element determinations by gamma-ray spectrometry.

UAS sample set (187 samples): RASS 171293-479
Composite chip samples along 25 meter, continuous surface traverses, consisting of 14 samples lines in the upper agglomerate, each extending from the lower tuff contact to the upper tuff contact. Sample set collected to test for metal and alteration chemical variation in the upper agglomerate as the either tuff contact is approached. ANALYSES: semiquantitative spectrography for 30 elememts; atomic absorption for base and precious metals; sample lines 2,5,8, and 11 for SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, H_2O+, H_2O-, TiO_2, P_2O_5, and MnO by X-ray fluorescence; selected selected samples for radio-element determinations by gamma-ray spectrometry.

RHY sample set (32 samples): RASS 171491-538
Composite chip samples along 25 meter, continuous surface traverses, consisting of 2 sample lines in the rhyolite and upper agglomerate. Sample set collected to test for metal and alter ation chemical variations in and adjacent to the rhyolite and to determine the geochemical signature of the rhyolite. ANALYSES: semiquantitative spectrography 30 elements; atomic absorption for base and precious metals; X-ray fluorescence for SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, H_2O+, H_2O-, TiO_2, P_2O_5, and MnO.

APPENDIX 2

Results of trace-element analyses for the ten geochemical sample sets. All traverse lines are numbered from west to east. See plate 1 for the location of the traverse lines.

Analytical results for the ALS Sample Set. All values are in ppm. Sites 1, 3, and 5 are unmineralized, whereas sites 2, 4, and 6 are mineralized. Refer to figures 2-4 and plate 1.

Site	Set	Panel	sample number	Au	Ag	Cu	Pb	Zn
Refer to fig. 2								
1	A	1	171114	0.14	0.8	1500	50	3500
1	A	2	088	0.22	1.4	700	35	2000
1	A	3	095	0.22	1.4	1000	30	2000
1	A	4	166	0.18	1.5	1000	40	3500
1	A	5	130	0.12	1.0	300	65	1100
1	B	1	089	0.14	1.2	700	55	3000
1	B	2	149	0.11	1.0	300	25	1500
1	B	3	137	0.12	1.0	150	25	1100
1	B	4	091	0.14	1.2	200	80	1100
1	B	5	151	0.09	1.0	100	30	600
1	C	1	139	0.12	0.8	500	15	500
1	C	2	153	0.15	0.7	150	35	450
1	C	3	072	0.10	1.1	100	30	300
1	C	4	080	0.10	0.9	200	30	350
1	C	5	127	0.15	0.6	300	25	200
1	D	1	087	0.12	1.6	300	15	350
1	D	2	110	0.08	0.8	150	30	450
1	D	3	050	0.12	L(0.5)	300	150	400
1	D	4	075	0.20	0.7	300	25	250
1	D	5	060	0.14	1.0	400	25	500
2	A	1	142	0.49	1.7	200	215	650
2	A	2	134	0.76	1.5	150	530	750
2	A	3	164	0.91	2.0	200	290	850
2	A	4	104	1.12	0.6	700	215	300
2	A	5	064	0.16	0.8	70	105	850
2	B	1	157	0.30	1.7	300	730	700
2	B	2	161	0.30	1.0	70	75	550
2	B	3	073	0.83	1.8	70	25	550
2	B	4	156	0.69	1.0	100	140	300
2	B	5	102	1.47	0.9	100	200	700
2	C	1	061	0.38	2.7	500	65	700
2	C	2	086	0.22	1.0	500	35	350
2	C	3	112	0.94	0.7	300	20	800
2	C	4	141	0.33	1.2	300	85	550
2	C	5	078	0.22	1.8	150	100	750

APPENDIX 2 (continued)

Analytical results for the ALS Sample Set. All values are in ppm. Sites 1, 3, and 5 are unmineralized, whereas sites 2, 4, and 6 are mineralized. Refer to figures 2-4 and plate 1.

Site	Set	Panel	sample number	Au	Ag	Cu	Pb	Zn
2	D	1	171133	0.49	2.0	200	225	2500
2	D	2	105	0.87	1.0	200	140	1300
2	D	3	048	0.38	1.1	200	170	2000
2	D	4	057	0.38	0.7	300	325	1200
2	D	5	065	0.18	0.6	300	205	750
Refer to fig. 3.								
3	A	1	135	0.09	0.8	300	30	550
3	A	2	148	0.09	0.8	300	20	700
3	A	3	101	0.12	0.9	500	15	600
3	A	4	109	0.06	0.8	500	20	650
3	A	5	165	0.12	0.8	300	30	550
3	B	1	055	0.10	0.8	500	40	440
3	B	2	152	0.12	1.0	150	30	850
3	B	3	079	0.10	1.7	200	30	550
3	B	4	074	0.10	1.1	100	80	500
3	B	5	106	0.10	1.9	700	30	400
3	C	1	147	0.09	0.6	1000	15	600
3	C	2	162	0.11	0.8	200	35	650
3	C	3	097	0.10	1.1	300	75	600
3	C	4	099	0.08	0.6	700	305	600
3	C	5	118	0.11	0.9	700	315	650
3	D	1	051	0.06	0.9	2000	105	950
3	D	2	155	0.11	1.0	1000	100	1050
3	D	3	054	0.10	0.9	500	60	650
3	D	4	082	0.94	1.4	700	150	700
3	D	5	071	0.10	1.6	1500	150	500
4	A	1	160	0.12	0.7	3000	25	600
4	A	2	090	0.10	0.8	2000	20	600
4	A	3	077	0.22	1.0	3000	30	550
4	A	4	052	0.14	1.1	3000	25	500
4	A	5	145	0.12	0.6	1000	10	1200
4	B	1	069	0.06	0.8	2000	135	1100
4	B	2	120	0.12	0.7	2000	15	500
4	B	3	094	0.10	0.6	700	15	750
4	B	4	143	0.09	0.6	700	20	650
4	B	5	123	0.14	0.8	700	15	500

APPENDIX 2 (continued)

Analytical results for the ALS Sample Set. All values are in ppm. Sites 1, 3, and 5 are unmineralized, whereas sites 2, 4, and 6 are mineralized. Refer to figures 2-4 and plate 1.

Site	Set	Panel	sample number	Au	Ag	Cu	Pb	Zn
4	C	1	083	0.14	3.6	2000	85	850
4	C	2	047	0.18	0.9	2000	95	1200
4	C	3	093	0.06	0.8	2000	135	1100
4	C	4	068	0.22	1.2	1000	105	1550
4	C	5	117	0.12	1.0	1000	40	1150
4	D	1	171062	0.10	1.4	2000	155	700
4	D	2	121	0.12	1.4	2000	90	1000
4	D	3	119	0.12	0.7	1500	15	500
4	D	4	059	0.14	1.3	1000	65	900
4	D	5	124	0.15	1.2	1500	65	1500

Refer to figure 4

5	A	1	084	0.14	2.0	1000	15	250
5	A	2	159	0.09	0.5	1000	10	550
5	A	3	115	0.06	0.5	700	20	550
5	A	4	053	0.10	0.5	700	15	450
5	A	5	131	0.15	0.5	200	10	450
5	B	1	126	0.15	0.6	700	25	750
5	B	2	138	0.14	0.8	200	L(10)	800
5	B	3	058	0.10	0.7	150	20	750
5	B	4	111	0.08	0.8	200	40	350
5	B	5	163	0.12	0.6	300	20	700
5	C	1	132	0.14	1.0	150	25	250
5	C	2	056	0.14	0.8	50	15	150
5	C	3	140	0.12	0.7	50	15	200
5	C	4	128	0.15	0.7	200	30	200
5	C	5	158	0.09	0.7	30	10	200
5	D	1	067	0.12	0.5	200	35	350
5	D	2	103	0.10	0.9	150	20	500
5	D	3	129	0.12	0.5	200	15	700
5	D	4	113	0.06	0.7	100	35	550
5	D	5	098	0.10	0.5	100	20	300
6	A	1	108	0.06	1.9	200	1005	1100
6	A	2	122	0.14	1.5	300	45	1200
6	A	3	144	0.15	3.0	300	130	1050
6	A	4	049	0.10	3.7	300	310	1050
6	A	5	125	0.12	1.2	500	680	1300

APPENDIX 2 (continued)

Analytical results for the ALS Sample Set. All values are in ppm. Sites 1, 3, and 5 are unmineralized, whereas sites 2, 4, and 6 are mineralized. Refer to figures 2-4 and plate 1.

Site	Set	Panel	sample number	Au	Ag	Cu	Pb	Zn
6	B	1	107	0.16	13.0	1500	1000	4500
6	B	2	076	0.10	15.0	1000	370	3500
6	B	3	066	0.12	15.0	700	275	2500
6	B	4	081	0.12	3.8	500	185	2000
6	B	5	146	0.27	2.0	500	250	1500
6	C	1	092	1.76	3.3	700	300	1000
6	C	2	100	0.98	8.0	1000	555	1500
6	C	3	154	0.95	2.2	1000	170	1000
6	C	4	096	1.93	2.4	700	75	900
6	C	5	116	0.92	11.0	300	80	4500
6	D	1	063	1.47	5.6	300	665	650
6	D	2	150	0.39	2.3	150	180	600
6	D	3	136	0.52	2.0	500	1500	1000
6	D	4	085	0.76	0.7	200	70	700
6	D	5	070	1.36	5.0	200	145	600

APPENDIX 2 (continued)

Descriptions and analytical results for the MIN sample set. All values are in ppm.

Sample number	Description	Au	Ag	Cu	Pb	Zn	Cd	As	Te
171167 -	Pod of A-type quartz in Goldfields 3-4-5 vein system with minor sulfide stringers.	1.07	7.8	2300	800	25000	50	2	3.9
172 -	Fe- and Mn-oxides along a 4 cm wide water course cutting the number 2 vein.	0.42	3.0	2250	400	60000	15	5	5
176 -	Rose quartz with minor chlorite.	1.58	12.2	300	75	250	Nil	Nil	5.4
179 -	Agglomerate with one minor K--feldspar-bearing inlet.	1.41	8.0	150	60	600	Nil	Nil	4
182 -	Dump sample of sulfide-rich ore	12.73	200	20000	700	40000	250	2	155
184 -	Stockwork of quartz veinlets close to fault.	0.78	40	2250	220	4500	Nil	20	5.9
186 -	Chloritic gouge from small shear cutting 6-7-8 vein system.	0.82	8.0	1100	105	2000	10	10	5
188 -	Agglomerate with minor 2-5 cm quartz vein stockwork.	0.25	2.8	250	40	350	Nil	14	1
192 -	Shear zone, 5 to 15 cm wide, with gouge.	1.72	3.7	450	160	3000	Nil	20	4.1
196 -	Fault gouge from east-trending fault.	0.92	1.3	350	35	4000	Nil	2	0.9
197 -	Stringy C- and D- type quartz vein, 35 cm wide, with 2-3 cm wallrock inclusions.	0.19	4.0	4100	30	1550	Nil	2	1
198 -	Massive yellow sulfide pod.	516	520	105000	410	5500	300	2	1980
201 -	Sphalerite-bearing stringers close to 20 cm wide vein and water course.	10.4	34	3300	150	135000	550	24	70
204 -	Banded, 10 -15 cm wide, vein with bands of chlorite, quartz and sulfides less than 1 cm thick.	200	100	10000	105	50000	145	4	98
205 -	Edge of selvage zone from a C-D type vein in agglomerate.	0.73	4.0	300	35	300	Nil	16	2.7

APPENDIX 2 (continued)

Sample number	Description	Au	Ag	Cu	Pb	Zn	Cd	As	Te
210	- Major chlorite-rich B-type quartz vein with sulfide bands.	200	440	18000	565	135000	450	2	318
211	- Breccia dike, 10 cm wide, cut by later quartz veins.	0.94	5.3	250	75	650	5	34	3.7
214	- Sulfide-bearing quartz vein, 5 cm wide, with a 1 cm selvage zone.	10.4	97.2	10500	130	40000	150	Nil	9.6
217	- Dark chlorite stringers from quartz-stockwork zone.	120	89.6	12000	50	12500	35	2	98
218	- Stockwork of quartz veinlets next to a major quartz vein and water course.	0.34	3.3	200	10	1000	Nil	16	2.5
220	- Dark sulfide-bearing chlorite next to a C-D type vein.	0.42	5.0	6000	550	3500	10	4	12.2
221	- Stockwork of quartz veinlets next to an A-type vein.	1.97	17.8	7000	100	7000	20	Nil	15
223	- Pod of sulfide-bearing, chloritized country rock between two 20 cm stringy quartz veins about 30 cm apart.	25.2	120	15500	65	15000	50	10	94
225	- Pyrite- and chalcopyrite-rich quartz stringers next to a 20 cm wide quartz vein.	0.29	15.0	31500	10	1150	Nil	2	1.4
228	- Chlorite and sulfide pod with very minor quartz veinlets in the 3-4-5 vein system.	108	520	18000	215	55000	150	2	304

APPENDIX 2 (continued)

Analytical results for the HOT sample set. All values are in ppm. Refer to figures 5 and 6 and plate 1 for sample locations.

Sample number	Au	Ag	Cu	Pb	Zn	Cd	As	Te
HOT-1 See fig. 5								
171181	352	440	8000	1650	75000	450	2	625
185	348	420	10500	6300	45000	155	4	1020
173	600	660	13000	13500	50000	150	2	100
191	480	460	8000	10000	6000	200	2	334
200	396	360	13500	7000	55000	200	2	1200
212	500	600	12000	8500	45000	200	2	1560
175	860	650	22000	73000	60000	200	2	2180
222	820	320	10500	70000	35000	130	4	1240
178	820	380	12000	21000	40000	155	Nil	1900
226	1480	430	13000	18000	45000	250	2	1600
195	1520	540	13000	74000	70000	250	4	2580
206	1280	360	16500	52500	55000	300	4	1660
HOT-2 See fig. 6								
171190	1.84	31.0	2600	185	9000	400	10	19.3
215	0.42	5.3	1050	140	8000	35	18	4.1
177	0.51	4.0	2200	115	8000	25	6	1.6
183	3.42	40.0	5500	165	9000	15	12	20.0
193	43.2	260	7500	750	5000	140	10	154
227	148	480	14000	295	160000	150	2	392
189	124	480	15000	430	11000	300	2	360
208	280	630	18000	700	155000	450	2	388
170	192	420	16000	630	160000	450	2	520
169	224	400	2500	385	20000	450	2	625
224	160	300	14000	200	75000	250	8	320
202	216	340	19500	315	85000	3000	10	388
216	184	440	25000	305	140000	500	4	455
209	112	400	14500	120	100000	350	4	270
171	196	260	15500	385	100000	350	2	131
194	19.2	120	9500	110	30000	115	4	88
168	0.92	9.6	1800	385	8000	30	4	6.0
174	0.78	5.5	2450	455	11500	35	4	2.3
199	1.35	19.4	2950	655	13000	35	12	21
187	0.55	6.5	3400	615	1400	25	10	4
207	1.66	22.7	5500	635	12500	30	6	13.2
213	1.04	11.5	4750	55	2500	Nil	4	7.5
219	0.59	9.4	6000	250	75000	20	4	8.7
180	1.17	16.7	2200	45	2000	Nil	2	8.8
203	0.64	12.2	3500	485	2000	Nil	4	8.3

APPENDIX 2 (continued)

Analytical results for the DEC sample set. All values are in ppm. Lithologic labels (rp, etc.) are the same as plate 1.

	Sample number	Au	Ag	Cu	Pb	Zn	Y	Zr
	171023	0.12	0.6	60	30	1100	50	300
rp	020	0.17	1.0	30	60	200	30	200
	010	0.10	L(0.5)	30	15	650	50	200
	011	0.10	0.8	85	40	700	50	500
	004	0.12	2.1	1000	125	1500	50	300
	001	0.12	3.0	450	55	3000	50	200
ua	006	0.10	2.8	2500	40	2500	20	150
	013	0.08	1.7	750	340	1500	20	70
	000	0.08	1.0	350	40	3500	20	150
	009	0.10	1.6	175	45	500	15	70
	012	0.08	1.3	120	15	200	20	70
	016	0.08	1.1	300	115	500	20	100
	007	0.08	1.2	145	20	300	15	70
	003	0.08	0.9	110	10	1400	20	150
lt	015	0.08	1.3	300	25	2500	30	70
	008	0.10	1.5	245	40	950	30	100
	018	0.10	1.4	60	45	900	30	150
	014	0.08	1.2	90	15	200	30	150
	005	0.10	2.2	140	L(10)	1250	20	70
Ta	017	0.20	1.2	60	30	500	30	70

APPENDIX 2 (continued)

Analytical results for the LAU sample set. All values are in ppm. See plate 1 for sample locations.

	Sample number	Au	Ag	Cu	Pb	Zn	Cd	As	Te
West	171028	0.12	2.0	300	40	1250	5	60	0.9
	021	0.08	1.0	20	15	200	10	20	0.6
	025	0.24	2.7	600	190	9000	10	80	2.4
	022	0.12	2.7	1200	105	3500	10	80	2
	027	74.74	250	10000	375	50000	300	Nil	98
	019	4.73	28.5	7000	275	20000	55	60	14
	026	440	680	16000	3250	7000	30	60	620
East	024	16	80	7500	1400	50000	150	Nil	17

APPENDIX 2 (continued)

Analytical results for the LAS sample set. All values are in ppm. Traverse lines are numbered from west to east. See plate 1 for the location of the traverse lines.

Sample number		Au	Ag	Cu	Pb	Zn
L	171253	0.32	1.7	500	445	950
I	257	0.20	4.1	300	350	800
N	239	0.07	5.5	500	900	750
E 1	230	0.09	0.8	70	15	200
L	269	0.06	1.0	70	100	850
I	259	0.11	1.1	150	200	300
N	238	0.09	0.8	200	25	500
E 2	229	0.11	0.7	150	25	300
L	261	0.15	1.1	100	30	300
I	254	0.06	0.7	100	20	300
N	235	0.07	0.9	150	L(10)	400
E 3	234	0.40	1.1	100	10	300
	237	0.17	0.8	300	30	350
L	263	4.59	4.0	500	520	1000
I	267	0.87	5.1	1000	165	1100
N	233	0.28	3.5	500	1500	1150
E 4	231	0.09	1.8	200	200	1000
L	271	0.32	5.1	1000	950	1600
I	266	0.82	7.0	20000	1600	3000
N	236	0.07	1.4	100	10	600
E 5	232	0.13	1.2	150	15	950

APPENDIX 2 (continued)

Analytical results for the LTS sample set. All values are in ppm. Traverse lines are numbered from west to east. See plate 1 for the location of the traverse lines.

Sample number		Au	Ag	Cu	Pb	Zn
L	171255	0.19	2.4	200	550	600
I	273	0.44	1.6	500	800	130
N	245	0.07	2.1	200	380	800
E 1	251	0.09	1.9	500	800	1250
	242	0.06	1.1	200	285	2000
L	256	0.09	2.0	200	155	400
I	265	0.09	1.2	200	185	400
N	248	0.07	1.0	150	70	500
E 2	243	0.06	1.4	200	65	800
	249	0.07	1.1	300	55	700
L	258	0.06	1.2	150	30	500
I	260	0.07	1.1	100	25	500
N	268	0.06	0.8	70	20	350
E 3	244	0.09	1.0	150	20	650
	241	0.40	1.2	150	15	450
L	262	0.17	8.0	300	605	350
I	264	0.42	7.0	700	225	650
N	272	0.32	4.8	300	620	450
E 4	250	0.11	1.3	200	80	1000
	246	0.07	1.2	300	45	1000
L	270	0.32	3.5	300	315	250
I	275	0.09	1.0	500	240	35
N	274	0.07	0.9	300	295	35
E 5	247	0.07	1.1	300	280	450
	252	0.06	1.4	300	120	1450

APPENDIX 2 (continued)

Analytical results for the LAT sample set. All values are in ppm. Refer to plate 1 for the location of the traverse line.

Sample number		Au	Ag	Cu	Pb	Zn
West	171276	0.18	4.1	300	190	550
	290	0.38	L(0.5)	20	15	100
	279	0.11	0.8	100	90	650
	286	0.38	0.7	70	25	350
	284	0.11	0.7	500	15	350
	281	0.06	0.6	150	10	400
	283	0.11	1.9	500	445	800
	291	0.22	3.6	300	1500	1250
	278	0.19	1.7	300	1000	850
	280	0.17	2.7	200	55	500
	277	15.97	37	10000	1050	11000
	287	0.50	L(0.5)	200	20	500
	289	0.20	0.7	50	25	450
	285	0.58	20	500	2500	650
	288	0.17	2	300	95	700
East	292	L(0.05)	L(0.5)	150	10	400

APPENDIX 2 (continued)

Analytical results for the UAS sample set. All values are in ppm. Traverse lines are numbered from west to east. See plate 1 for the location of the traverse lines.

	Sample number	Au	Ag	Cu	Pb	Zn
L	171411	0.07	0.6	200	35	450
I	389	L(0.05)	1.0	700	35	650
N	447	L(0.05)	0.5	100	45	2250
E 1	415	L(0.05)	L(0.5)	100	280	300
	432	L(0.05)	0.5	70	35	900
	377	0.07	0.7	100	55	650
	354	0.07	3.4	200	20	650
	428	L(0.05)	1.6	150	135	400
L	405	L(0.05)	0.7	70	15	95
I	417	L(0.05)	0.5	50	15	150
N	467	0.10	L(0.5)	100	10	150
E 2	368	L(0.05)	L(0.5)	50	10	250
	444	0.14	0.8	300	85	45
	461	0.14	L(0.5)	150	35	250
	475	0.06	0.8	300	560	300
	470	0.06	0.5	300	25	550
L	473	0.06	L(0.5)	50	10	200
I	414	L(0.05)	0.8	30	10	250
N	380	L(0.05)	0.6	7	20	200
E 3	478	0.06	0.7	100	45	200
	395	0.07	0.8	100	225	90
	472	0.06	0.8	200	30	650
	374	0.07	0.6	200	15	500
	420	0.22	0.8	150	55	250
	357	0.12	1.2	150	165	900
	465	0.10	0.6	300	270	350
L	313	0.13	L(0.5)	10	Nil	50
I	330	0.08	L(0.5)	10	Nil	100
N	297	0.09	L(0.5)	20	1155	1850
E 4	350	0.06	0.7	30	260	1500
	321	0.09	L(0.5)	100	605	450
	323	0.10	0.5	150	225	600
	306	0.09	0.7	70	15	600
	295	0.09	0.5	200	80	500
	342	0.08	L(0.5)	100	80	250
	303	0.09	1.0	70	10	500
	316	0.19	L(0.5)	200	L(10)	150
	346	0.14	0.5	200	60	500

APPENDIX 2 (continued)

UAS (continued).

Sample number		Au	Ag	Cu	Pb	Zn
L	454	0.06	L(0.5)	20	25	100
I	451	L(0.05)	0.5	20	60	250
N	399	L(0.05)	0.8	70	155	500
E 5	376	0.07	0.7	50	55	650
	407	L(0.05)	0.7	100	110	500
	386	0.12	1.3	150	55	650
	364	0.07	0.8	150	30	900
	442	L(0.05)	0.8	100	120	700
	360	0.07	0.8	300	70	1150
	422	L(0.05)	L(0.5)	70	30	750
	359	0.07	1.0	150	115	600
	371	0.12	0.7	300	15	2000
	437	L(0.05)	L(0.5)	70	15	1350
	427	L(0.05)	0.9	100	35	1100
L	391	L(0.05)	0.5	15	35	550
I	372	0.07	L(0.5)	10	95	400
N	401	L(0.05)	0.08	20	155	500
E 6	433	L(0.05)	L(0.5)	15	85	550
	410	0.07	0.6	100	410	400
	440	0.07	1.0	150	590	1150
	406	L(0.05)	0.9	150	30	450
	468	0.06	0.5	300	30	400
	476	0.06	L(0.5)	200	30	600
	355	0.07	0.9	150	20	950
	382	0.07	0.8	100	510	130
	361	0.12	1.0	200	30	350
L	299	0.09	L(0.5)	150	35	600
I	327	0.08	L(0.5)	150	65	550
N	343	0.08	0.7	500	40	200
E 7	305	0.09	0.5	70	Nil	550
	340	0.08	0.6	100	105	850
	318	0.09	L(0.5)	70	L(10)	350
	294	0.15	1.6	500	465	1200
	325	0.08	1.0	300	85	950
	301	0.17	1.4	300	350	950
	298	0.13	0.5	150	135	1250
	322	0.17	0.8	100	10	500
	308	0.09	0.8	50	25	850
	348	0.08	0.6	100	55	500
	332	0.08	0.8	150	10	350
	312	0.13	0.6	200	L(10)	650
	320	0.11	L(0.5)	200	105	650

APPENDIX 2 (continued)

UAS (continued).

Sample number		Au	Ag	Cu	Pb	Zn
L	366	0.07	0.8	200	25	600
I	455	0.06	0.7	200	40	250
N	450	L(0.05)	0.9	100	50	350
E 8	363	0.07	0.8	150	25	200
	403	L(0.05)	0.9	200	60	700
	448	L(0.05)	0.6	150	25	250
	429	L(0.05)	0.6	100	40	500
	424	0.22	0.6	100	60	1900
	379	0.07	0.6	150	20	200
	418	L(0.05)	0.7	200	30	500
	369	0.17	1.8	200	75	1400
	457	0.12	1.2	200	165	900
	471	0.22	1.0	300	45	550
	400	0.43	2.8	150	45	750
	394	0.49	1.5	200	115	350
L	390	L(0.05)	0.6	50	20	250
I	425	L(0.05)	0.6	70	60	1900
N	404	L(0.05)	0.8	200	25	300
E 9	453	0.06	0.6	300	25	200
	477	0.06	L(0.5)	700	25	200
	466	0.10	0.8	700	30	200
	463	0.10	0.9	200	25	200
	459	0.12	0.7	300	30	300
	396	L(0.05)	0.6	150	20	110
	435	0.09	0.8	100	25	110
	446	0.09	0.7	70	20	150
	413	0.12	1.4	200	35	450
	385	0.12	1.4	100	30	350
	421	L(0.05)	1.8	700	230	1500
	431	0.33	2.3	300	140	500
L	338	0.08	0.6	100	60	900
I	333	0.08	0.8	300	40	750
N	319	0.09	L(0.5)	150	Nil	650
E 10	329	0.08	0.5	200	Nil	450
	300	0.17	0.5	200	20	1100
	351	0.10	1.0	700	40	1500
	307	0.32	1.2	500	110	500
	344	0.35	0.7	200	55	2000
	293	0.26	0.7	300	45	3000
	336	0.14	1.0	150	10	2000
	314	0.06	1.2	100	35	1100
	311	0.24	0.7	70	30	700
	349	0.35	0.9	100	65	950

APPENDIX 2 (continued)

UAS (continued).

Sample number		Au	Ag	Cu	Pb	Zn
L	381	L(0.05)	0.6	50	20	450
I	438	0.07	0.5	150	25	400
N	419	L(0.05)	0.7	100	30	500
E 11	352	0.07	0.8	300	40	850
	393	L(0.05)	0.9	500	65	400
	365	0.12	1.3	300	55	350
	375	0.07	.05	70	110	300
	460	0.10	1.3	700	15	250
	412	0.12	1.0	300	20	400
	442	L(0.05)	0.8	100	120	700
	356	0.12	1.8	700	165	2000
	370	0.22	2.7	1000	120	1500
	388	0.22	1.2	150	30	500
	408	0.12	1.4	200	70	1000
L	458	0.12	1.2	100	30	500
I	363	0.07	0.6	100	15	100
N	383	0.07	L(0.5)	100	30	550
E 12	436	0.22	0.7	150	25	600
	464	0.10	L(0.5)	200	70	450
	367	0.07	1.0	200	30	900
	474	0.06	0.9	100	10	200
	378	0.07	0.8	100	25	450
	358	0.17	2.5	100	30	3000
	441	0.17	2.8	200	440	2000
	353	0.14	1.3	150	70	350
	479	0.06	0.7	100	45	200
	469	0.06	0.7	50	35	200
	397	0.71	0.8	70	30	90
	373	0.89	0.5	100	40	900
L	328	0.08	1.5	500	65	250
I	339	0.08	0.6	200	50	500
N	304	0.24	0.7	200	25	700
E 13	326	0.08	L(0.5)	30	20	450
	310	0.09	0.6	70	60	450
	341	0.12	L(0.5)	100	55	250
	335	0.08	L(0.5)	70	Nil	150
	337	0.14	0.6	100	15	650
	324	0.44	0.8	150	130	550
	345	0.20	1.1	150	95	450
	334	0.14	0.8	100	10	300
	315	0.26	1.3	300	100	350
	302	0.82	1.2	200	105	650
	309	0.13	1.7	200	125	650
	347	1.93	1.8	300	640	350
	331	1.73	1.8	200	315	350
	317	1.66	0.7	200	900	700
	296	0.65	0.7	200	385	700

APPENDIX 2 (continued)

UAS (continued).

Sample number		Au	Ag	Cu	Pb	Zn
L	387	0.22	2.4	200	315	1350
I	452	0.06	0.6	500	120	1500
N	445	0.09	1.3	700	130	2250
E 14	384	0.12	2.5	700	210	200
	430	2.68	2.8	700	405	850
	392	0.33	3.8	700	685	700
	398	0.22	2.8	500	335	2500
	462	1.04	2.2	700	720	110
	434	0.35	1.6	500	420	3000
	426	25.33	31.5	500	500	3500
	409	0.94	2.3	500	1300	1300
	456	1.23	1.8	700	635	7500
	439	12.87	8.5	200	1150	3500
	449	17.56	14.9	1000	5500	2350
	423	2.10	6.1	1500	2500	2500

APPENDIX 2 (continued)

Analytical results for the RHY sample set. All values are in ppm. Traverse lines are numbered from west to east. See plate 1 for the location of the traverse lines.

	Sample number	Au	Ag	Cu	Pb	Zn	Y	Zr
	171518	0.16	3.6	300	85	750	20	150
	511	0.10	3.8	700	415	700	20	150
	514	0.08	2.7	300	165	650	30	200
L	499	L(0.05)	5.5	500	660	900	20	150
	527	0.16	10	1500	2000	1450	30	100
I	533	0.16	5.4	1000	1950	1700	30	150
	524	0.08	1.6	700	725	200	50	200
N	508	0.12	2.3	500	750	130	70	300
	521	0.06	4.1	500	1200	160	70	300
E 1	534	0.20	3.9	700	1350	1250	50	200
	536	0.12	1.1	500	800	200	50	200
	513	0.16	6.8	700	510	900	70	300
	531	0.28	5.1	1500	890	2500	30	150
	538	0.20	1.2	500	180	200	30	200
	522	0.22	3.0	1000	555	2500	70	200
	510	0.26	3.3	1000	495	4000	100	300
L	520	0.22	2.0	700	115	1250	70	300
	505	0.14	0.7	700	30	1450	70	300
I	526	0.12	0.9	500	90	1100	50	200
	502	0.10	2.0	300	150	1050	70	300
N	491	L(0.05)	5.1	700	880	2500	100	300
	515	0.08	3.4	500	780	1300	70	300
E 2	517	0.08	2.7	700	625	2000	100	500
	497	0.10	1.3	1000	720	4000	70	300
	492	L(0.05)	2.6	300	415	500	100	300
	507	0.06	1.4	300	240	400	100	300
	494	8.10	5.5	500	950	650	100	300
	500	L(0.05)	0.7	100	275	500	100	300
	504	L(0.05)	L(0.5)	20	140	200	100	300
	535	0.06	0.8	70	360	175	50	200
	523	0.08	1.0	200	505	800	70	200
	529	0.08	1.2	150	520	750	50	200

APPENDIX 2 (continued)

Radio-element concentrations, Mahd adh Dhahab; Radium-equivalent uranium [RaeU, ppm], thorium [Th, ppm], and potassium [K, weight percent].

Sample Number	Sample Set	RaeU	Th	K	Th/ RaeU	RaeU/ Kx10-4	Th/ Kx10-4
171000	DEC	0.56	1.24	2.82	2.2	0.20	0.44
004*	DEC	0.42	1.14	2.58	2.7	0.16	0.44
005*	DEC	0.58	1.10	1.75	1.9	0.33	0.63
006*	DEC	0.45	0.86	2.15	1.9	0.21	0.40
007*	DEC	0.65	1.20	2.00	1.8	0.33	0.60
010	DEC	0.74	1.34	1.96	1.8	0.38	0.68
012*	DEC	0.50	0.92	1.65	1.8	0.30	0.56
015	DEC	0.47	1.06	2.59	2.3	0.18	0.41
018*	DEC	0.59	1.02	2.04	1.7	0.29	0.50
023	DEC	0.53	1.11	1.42	2.1	0.37	0.78
024	LAU	0.15	0.33	0.42	2.2	0.36	0.79
025*	LAU	0.35	0.71	1.27	2.0	0.28	0.56
026*	LAU	0.25	0.10	0.74	0.40	0.34	0.14
027*	LAU	0.10	0.15	0.70	1.5	0.14	0.21
028	LAU	0.34	0.80	2.29	2.4	0.15	0.35
276	LAT	0.45	0.71	3.45	1.6	0.13	0.21
277	LAT	1.08	0.30	1.08	0.28	1.0	0.28
278	LAT	0.55	0.49	2.82	0.89	0.20	0.17
283	LAT	0.43	0.64	1.97	1.5	0.22	0.32
284	LAT	0.60	0.61	3.04	1.0	0.20	0.20
285	LAT	0.30	0.40	1.52	1.3	0.20	0.26
286	LAT	0.43	0.78	3.88	1.8	0.11	0.20
287	LAT	0.49	0.43	2.36	0.88	0.21	0.18
290*	LAT	0.55	0.91	3.11	1.7	0.18	0.29
292	LAT	0.48	0.80	3.58	1.7	0.13	0.22
301	UAS	0.52	0.82	2.97	1.6	0.17	0.28
306	UAS	0.51	0.74	3.11	1.5	0.16	0.24
345	UAS	0.52	0.77	4.23	1.5	0.12	0.18
351	UAS	0.52	0.81	3.10	1.6	0.17	0.26
360	UAS	0.72	0.92	4.09	1.3	0.18	0.22
365	UAS	0.54	0.72	3.02	1.3	0.24	0.17
368	UAS	0.55	1.17	1.93	2.1	0.61	0.29
378	UAS	0.49	0.68	2.85	1.4	0.17	0.24
395	UAS	0.41	0.48	2.86	1.2	0.14	0.17
424	UAS	0.50	0.69	3.42	1.4	0.15	0.20
432	UAS	0.45	0.57	4.42	1.3	0.10	0.13
462	UAS	0.60	0.86	3.25	1.4	0.18	0.26
466	UAS	0.55	0.72	3.13	1.3	0.18	0.23
468	UAS	0.47	0.80	3.58	1.7	0.13	0.22
474	UAS	0.55	0.78	3.11	1.4	0.18	0.25

* Indicates nonstandard sample size; analytical errors are probably greater than normal.

APPENDIX 3

Results of major-element whole-rock analyses. All sample numbers belong to the 17xxx series. All values are in weight percent. Traverse lines are numbered from west to east. See plate 1 for the location of the traverse lines.

LAS-1 to LAS-5

Entry	1	2	3	4	5	6	7	8
Sample	239	230	LAS1AVG	238	229	LAS2AVG	235	234
SIO2	77.70	78.50	78.10	75.10	79.70	77.60	74.50	74.10
AL2O3	8.40	7.10	7.75	9.10	8.20	8.65	9.50	9.50
FE2O3	3.41	5.94	4.68	3.66	3.19	3.43	4.64	5.10
FEO	0.56	0.36	0.46	0.40	0.38	0.39	0.60	0.44
MGO	1.68	1.01	1.35	2.11	1.07	1.59	2.08	2.53
CAO	0.85	0.56	0.71	0.86	0.63	0.75	0.67	0.69
NA2O	0.50	0.96	0.73	0.95	0.52	0.74	1.15	1.06
K2O	4.42	1.73	3.08	4.75	3.82	4.29	2.79	3.15
H2O+	1.45	2.57	2.01	2.19	1.72	1.96	2.51	1.91
H2O-	0.10	0.22	0.16	0.13	0.07	0.10	0.36	0.24
TIO2	0.53	0.59	0.56	0.61	0.43	0.52	0.64	0.67
P2O5	0.01	0.17	0.09	0.05	0.05	0.05	0.05	0.10
MNO	0.08	0.09	0.09	0.07	0.05	0.06	0.06	0.10
Sum	99.69	99.80	99.77	99.98	99.83	100.13	99.55	99.59

Entry	9	10	11	12	13	14	15	16
Sample	237	LAS3AVG	233	231	LAS4AVG	236	232	LAS5AVG
SIO2	76.90	75.10	73.20	77.70	75.45	73.10	70.30	71.70
AL2O3	8.50	9.17	9.10	7.90	8.51	10.80	10.50	10.65
FE2O3	3.87	4.45	5.38	3.23	4.31	4.32	4.85	4.59
FEO	0.48	0.51	1.16	0.62	0.89	0.66	0.54	0.60
MGO	1.99	2.20	2.80	3.00	2.90	3.03	2.60	2.82
CAO	0.66	0.67	0.65	0.53	0.59	0.62	0.77	0.70
NA2O	0.62	0.94	0.42	0.41	0.41	0.71	0.56	0.64
K2O	3.65	3.20	3.14	2.75	2.95	4.82	5.33	5.08
H2O+	2.27	2.23	2.63	2.75	2.69	0.96	2.92	1.94
H2O-	0.13	0.24	0.11	0.14	0.12	0.04	0.10	0.07
TIO2	0.57	0.63	0.71	0.43	0.57	0.61	0.76	0.69
P2O5	0.01	0.05	0.16	0.27	0.22	0.02	0.23	0.13
MNO	0.08	0.08	0.13	0.09	0.11	0.09	0.10	0.10
Sum	99.73	99.47	99.59	99.82	99.72	99.78	99.56	99.71

APPENDIX 3 (Continued)

LTS-1 thru LTS-5

Entry	1	2	3	4	5	6	7	8
Sample	245	251	242	LTS1AVG	248	243	249	LTS2AVG
SIO2	83.10	79.60	79.30	80.67	78.30	78.30	77.40	78.00
AL2O3	6.20	6.20	6.70	6.37	8.90	8.50	6.70	8.03
FE2O3	1.49	2.27	2.39	2.05	2.43	2.23	3.52	2.73
FEO	0.64	1.16	0.84	0.88	0.64	0.90	0.84	0.79
MGO	2.70	4.81	4.06	3.86	2.80	2.41	2.77	2.66
CAO	0.57	0.73	0.54	0.61	0.50	0.50	0.53	0.51
NA2O	0.39	0.68	0.67	0.58	0.71	0.67	0.70	0.69
K2O	3.02	2.46	2.63	2.70	3.35	3.10	3.57	3.34
H2O+	1.01	1.44	2.10	1.52	1.47	2.27	2.72	2.15
H2O-	0.07	0.04	0.25	0.12	0.08	0.33	0.20	0.20
TIO2	0.21	0.27	0.35	0.28	0.33	0.30	0.53	0.39
P2O5	0.01	0.01	0.07	0.03	0.01	0.06	0.01	0.03
MNO	0.09	0.10	0.11	0.10	0.07	0.08	0.11	0.09
Sum	99.50	99.77	100.01	99.77	99.59	99.65	99.60	99.61

Entry	9	10	11	12	13	14	15	16
Sample	244	241	LTS3AVG	250	246	LTS4AVG	247	252
SIO2	78.80	81.00	79.90	80.00	77.20	78.60	81.70	79.30
AL2O3	8.10	7.50	7.80	7.10	8.40	7.75	7.10	7.00
FE2O3	2.64	1.92	2.28	2.19	2.60	2.40	1.96	2.02
FEO	1.04	0.84	0.94	0.96	0.78	0.87	0.68	1.02
MGO	3.03	2.43	2.87	3.13	3.45	3.29	2.14	4.42
CAO	0.52	0.50	0.51	0.44	0.53	0.49	0.41	0.55
NA2O	0.73	0.83	0.78	0.61	0.40	0.51	0.56	0.67
K2O	2.76	2.62	2.69	2.76	3.01	2.89	3.45	2.75
H2O+	0.79	1.60	1.20	2.02	2.78	2.40	1.16	1.29
H2O-	0.22	0.25	0.24	0.07	0.15	0.11	0.06	0.05
TIO2	0.43	0.27	0.35	0.25	0.34	0.30	0.24	0.34
P2O5	0.42	0.01	0.22	0.01	0.01	0.01	0.01	0.01
MNO	0.09	0.09	0.09	0.10	0.09	0.09	0.09	0.10
Sum	99.57	99.86	99.87	99.64	99.74	99.71	99.56	99.52

APPENDIX 3 (Continued)

LTS Lines 1-5 (Continued)

Entry	17
Sample	LTS5AVG
SIO2	80.50
AL2O3	7.05
FE2O3	1.99
FEO	0.85
MGO	3.28
CAO	0.48
NA2O	0.62
K2O	3.10
H2O+	1.23
H2O-	0.05
TIO2	0.30
P2O5	0.01
MNO	0.10
Sum	99.56

APPENDIX 3 (Continued)

UAS - 4

Entry	1	2	3	4	5	6	7	8
Sample	313	330	297	350	321	323	306	295
SIO2	76.00	78.50	76.20	76.80	79.60	77.40	76.90	75.00
AL2O3	11.50	9.80	9.40	8.50	8.30	9.40	9.00	10.10
FE2O3	2.10	1.77	1.60	1.95	1.81	2.07	2.22	2.51
FEO	0.60	0.32	0.70	0.38	0.30	0.40	0.74	0.72
MGO	1.68	2.25	3.61	2.88	2.45	2.66	3.63	2.97
CAO	0.42	0.56	0.74	1.99	1.08	0.65	0.61	0.58
NA2O	0.29	0.39	0.29	0.98	0.28	0.32	0.28	0.32
K2O	5.92	4.10	4.32	3.74	4.06	5.22	3.61	5.22
H2O+	1.31	2.13	3.04	1.87	1.82	1.94	2.56	1.98
H2O-	0.17	0.09	0.04	0.17	0.11	0.03	0.09	0.17
TIO2	0.22	0.15	0.17	0.24	0.20	0.25	0.29	0.35
P2O5	0.13	0.03	0.03	0.19	0.01	0.07	0.26	0.02
MNO	0.07	0.06	0.10	0.05	0.09	0.06	0.10	0.09
Sum	100.41	100.15	100.24	99.74	100.11	100.47	100.29	100.03

Entry	9	10	11	12	13
Sample	342	303	316	346	UAS4AVG
SIO2	76.20	74.20	80.00	77.70	77.04
AL2O3	9.90	10.60	9.00	8.90	9.53
FE2O3	3.51	2.82	2.75	2.87	2.33
FEO	0.20	0.58	0.18	0.32	0.45
MGO	1.42	2.52	1.19	1.81	2.42
CAO	0.47	0.62	0.62	0.60	0.75
NA2O	0.75	0.30	0.38	0.92	0.46
K2O	3.91	5.63	3.64	4.25	4.47
H2O+	2.64	2.14	1.70	1.61	2.06
H2O-	0.17	0.19	0.13	0.14	0.13
TIO2	0.36	0.31	0.27	0.32	0.26
P2O5	0.08	0.05	0.04	0.01	0.08
MNO	0.04	0.10	0.07	0.05	0.07
Sum	99.65	100.06	99.97	99.50	100.05

APPENDIX 3 (Continued)

UAS - 10

Entry	1	2	3	4	5	6	7	8
Sample	338	333	319	329	300	351	307	344
SIO2	77.50	80.30	80.20	81.40	79.20	79.30	79.80	78.80
AL2O3	8.10	7.90	9.10	8.40	8.60	8.80	8.60	8.80
FE2O3	2.59	3.44	2.61	2.47	3.08	2.83	3.15	2.92
FEO	0.76	0.32	0.28	0.34	0.52	0.30	0.30	0.20
MGO	3.02	1.24	0.88	0.86	0.86	0.94	0.83	0.71
CAO	0.58	0.93	0.88	0.77	1.42	0.56	0.53	0.67
NA2O	1.26	0.37	0.28	0.31	0.28	0.87	0.33	0.85
K2O	2.74	2.63	2.97	2.94	3.21	3.22	3.57	4.05
H2O+	2.32	1.77	1.93	1.74	1.64	1.96	1.73	2.02
H2O-	0.18	0.18	0.08	0.27	0.25	0.30	0.09	0.02
TIO2	0.25	0.29	0.23	0.21	0.29	0.38	0.37	0.32
P2O5	0.19	0.08	0.06	0.01	0.15	0.01	0.06	0.11
MNO	0.07	0.07	0.06	0.07	0.09	0.05	0.10	0.04
Sum	99.56	99.52	99.56	99.79	99.59	99.52	99.46	99.51

Entry	9	10	11	12	13	14
Sample	293	336	314	311	349	UAS10AVG
SIO2	80.10	78.00	81.10	79.00	79.80	79.58
AL2O3	8.70	9.40	8.20	8.60	8.30	8.58
FE2O3	2.74	2.90	2.47	2.25	2.38	2.76
FEO	0.36	0.42	0.28	0.18	0.14	0.34
MGO	0.77	0.96	0.51	0.46	0.68	0.98
CAO	0.63	0.90	1.05	1.35	1.51	0.91
NA2O	0.39	0.36	0.27	0.28	0.97	0.52
K2O	4.11	4.43	4.16	5.06	3.96	3.62
H2O+	1.69	1.53	1.01	2.68	1.42	1.80
H2O-	0.06	0.20	0.10	0.19	0.11	0.16
TIO2	0.31	0.36	0.28	0.27	0.23	0.29
P2O5	0.18	0.01	0.04	0.06	0.01	0.07
MNO	0.08	0.07	0.07	0.08	0.04	0.07
Sum	100.12	99.54	99.54	100.46	99.55	99.68

APPENDIX 3 (Continued)

UAS - 7

Entry	1	2	3	4	5	6	7	8
Sample	299	327	343	305	340	318	294	325
SIO2	79.50	79.40	77.40	79.10	76.80	81.20	77.80	77.10
AL2O3	8.70	8.00	8.60	9.10	8.10	7.90	8.10	7.80
FE2O3	2.24	2.65	3.06	1.97	2.45	2.15	2.99	3.09
FEO	0.68	0.58	0.36	0.68	0.66	0.24	0.66	0.52
MGO	2.42	2.42	1.54	1.87	3.42	0.97	2.56	2.15
CAO	0.46	0.63	0.60	0.69	0.56	0.73	0.98	1.36
NA2O	0.27	0.33	2.55	0.28	2.21	0.28	0.31	0.35
K2O	3.58	3.17	3.45	4.35	2.97	4.40	3.26	3.94
H2O+	1.69	2.10	1.53	2.03	2.44	1.32	2.31	3.55
H2O-	0.03	0.07	0.06	0.19	0.11	0.10	0.18	0.06
TIO2	0.33	0.31	0.37	0.30	0.33	0.27	0.29	0.23
P2O5	0.17	0.01	0.01	0.05	0.07	0.01	0.05	0.01
MNO	0.08	0.06	0.04	0.05	0.09	0.08	0.09	0.06
Sum	100.15	99.73	99.57	100.66	100.21	99.65	99.58	100.22

Entry	9	10	11	12	13	14	15	16
Sample	301	298	322	308	348	332	312	320
SIO2	77.60	77.10	79.70	76.60	78.70	79.40	78.50	80.10
AL2O3	8.30	10.30	8.60	9.70	9.00	8.40	9.10	8.40
FE2O3	2.64	2.90	3.11	3.05	2.93	2.02	2.87	2.51
FEO	0.70	0.28	0.18	0.40	0.16	0.09	0.08	0.26
MGO	2.53	0.88	0.74	1.85	0.97	0.48	0.37	1.38
CAO	1.48	0.69	0.68	0.73	0.39	0.76	1.72	0.54
NA2O	0.28	0.32	0.29	0.29	1.14	0.38	0.30	0.31
K2O	3.51	5.24	4.86	5.31	4.78	5.14	5.97	4.14
H2O+	2.01	1.67	1.45	1.61	1.13	1.31	0.80	1.42
H2O-	0.10	0.13	0.07	0.21	0.07	0.21	0.21	0.06
TIO2	0.26	0.34	0.33	0.34	0.31	0.35	0.28	0.30
P2O5	0.02	0.05	0.03	0.01	0.01	0.01	0.06	0.03
MNO	0.08	0.11	0.08	0.11	0.04	0.05	0.08	0.08
Sum	99.51	100.01	100.12	100.21	99.63	98.60	100.34	99.53

APPENDIX 3 (Continued)

UAS - 7 (Continued)

Entry	17
Sample	UAS7AVG
SIO2	78.50
AL2O3	8.63
FE2O3	2.66
FEO	0.41
MGO	1.66
CAO	0.81
NA2O	0.62
K2O	4.25
H2O+	1.77
H2O-	0.12
TIO2	0.31
P2O5	0.04
MNO	0.07
Sum	99.85

APPENDIX 3 (Continued)

UAS - 13

Entry	1	2	3	4	5	6	7	8
Sample	328	339	304	326	310	341	335	337
SIO2	83.70	78.20	80.50	81.80	83.80	83.90	81.10	79.20
AL2O3	5.10	7.90	9.10	8.50	7.10	7.40	9.10	9.20
FE2O3	6.07	2.11	1.97	2.47	1.60	1.84	2.37	2.41
FEO	0.20	0.90	0.68	0.30	0.28	0.18	0.14	0.20
MGO	0.38	2.83	0.91	0.64	0.54	0.46	0.56	0.74
CAO	0.70	0.60	1.21	0.70	0.74	0.70	0.87	0.95
NA2O	0.32	1.13	0.27	0.32	0.53	0.92	0.34	0.57
K2O	1.29	3.18	3.87	2.86	3.07	2.41	4.00	4.26
H2O+	1.33	2.60	1.60	1.50	1.27	1.50	0.74	1.64
H2O-	0.17	0.10	0.09	0.14	0.23	0.18	0.34	0.30
TIO2	0.19	0.19	0.17	0.20	0.22	0.18	0.35	0.38
P2O5	0.01	0.01	0.03	0.01	0.06	0.01	0.01	0.01
MNO	0.04	0.08	0.09	0.06	0.08	0.04	0.07	0.07
Sum	99.50	99.83	100.49	99.50	99.52	99.72	99.99	99.93

Entry	9	10	11	12	13	14	15	16
Sample	324	345	334	315	302	309	347	331
SIO2	77.50	78.40	79.30	79.30	75.60	77.50	80.10	79.60
AL2O3	9.30	8.70	8.80	9.00	8.70	8.90	7.90	8.00
FE2O3	4.02	2.51	2.76	2.85	4.11	3.01	2.64	2.98
FEO	0.22	0.40	0.14	0.26	0.94	0.96	0.40	0.52
MGO	0.75	0.74	0.42	0.75	1.32	1.92	0.76	1.20
CAO	0.94	0.77	0.69	0.59	1.43	0.61	0.77	0.64
NA2O	0.58	2.14	0.35	0.33	0.31	0.30	0.71	0.34
K2O	4.49	4.18	5.50	5.10	5.02	4.96	3.91	4.50
H2O+	1.92	1.15	0.91	1.10	1.71	1.60	1.92	1.28
H2O-	0.01	0.05	0.25	0.15	0.17	0.20	0.08	0.18
TIO2	0.40	0.37	0.31	0.28	0.28	0.25	0.27	0.26
P2O5	0.05	0.05	0.01	0.06	0.03	0.02	0.01	0.01
MNO	0.08	0.05	0.07	0.06	0.10	0.11	0.04	0.06
Sum	100.26	99.51	99.51	99.83	99.72	100.34	99.51	99.57

APPENDIX 3 (Continued)

UAS - 13 (Continued)

Entry	17	18	19
Sample	317	296	UAS13AVG
SIO2	84.30	78.30	80.12
AL2O3	7.50	8.90	8.28
FE2O3	1.85	2.35	2.77
FEO	0.32	0.66	0.43
MGO	1.20	1.64	0.99
CAO	0.44	0.72	0.78
NA2O	0.29	0.33	0.56
K2O	2.53	4.27	3.86
H2O+	1.29	2.09	1.51
H2O-	0.09	0.07	0.16
TIO2	0.25	0.34	0.27
P2O5	0.02	0.04	0.08
MNO	0.06	0.10	0.07
Sum	100.14	99.81	99.88

APPENDIX 3 (Continued)

RHY - 1

Entry	1	2	3	4	5	6	7	8
Sample	518	511	514	499	527	533	524	508
SIO2	79.00	77.00	78.80	78.20	77.10	78.40	76.20	75.00
AL2O3	8.00	9.00	8.00	9.20	8.70	8.20	11.00	11.60
FE2O3	1.67	2.40	1.59	0.88	1.94	2.02	2.34	2.27
FEO	1.56	1.80	1.72	1.64	2.22	1.98	0.50	0.30
MGO	2.35	2.77	2.65	2.73	3.40	2.65	0.24	0.25
CAO	0.93	0.46	0.36	0.29	0.17	0.20	0.13	0.29
NA2O	0.01	0.01	0.01	0.14	0.03	0.07	0.10	0.16
K2O	4.11	4.40	4.35	3.63	2.45	2.92	7.44	7.98
H2O+	1.35	0.92	1.42	2.19	2.79	2.64	1.05	1.15
H2O-	0.40	0.30	0.40	0.19	0.36	0.14	0.29	0.32
TIO2	0.24	0.32	0.28	0.28	0.47	0.40	0.21	0.22
P2O5	0.04	0.06	0.05	0.06	0.10	0.09	0.03	0.05
MNO	0.12	0.13	0.14	0.07	0.17	0.11	0.01	0.01
Sum	99.78	99.57	99.77	99.50	99.90	99.82	99.54	99.60

Entry	9	10	11	12
Sample	521	534	536	RHY1AVG
SIO2	77.00	77.00	74.30	77.09
AL2O3	11.20	10.80	12.20	9.81
FE2O3	2.04	2.61	2.46	2.02
FEO	0.36	0.26	0.30	1.15
MGO	0.25	0.29	0.40	1.63
CAO	0.18	0.16	0.23	0.31
NA2O	0.14	0.09	0.20	0.09
K2O	7.20	6.41	7.78	5.33
H2O+	1.10	1.68	1.47	1.61
H2O-	0.31	0.18	0.19	0.28
TIO2	0.13	0.18	0.20	0.27
P2O5	0.04	0.02	0.03	0.05
MNO	0.01	0.04	0.01	0.07
Sum	99.96	99.72	99.77	99.71

APPENDIX 3 (Continued)

RHY - 2

Entry	1	2	3	4	5	6	7	8
Sample	513	531	538	522	510	520	505	526
SIO2	73.80	75.90	74.40	76.10	73.90	76.20	76.00	77.60
AL2O3	11.90	10.70	12.40	11.90	11.80	11.40	11.70	11.40
FE2O3	2.71	2.38	1.92	2.18	3.44	1.53	1.86	2.07
FEO	0.80	1.01	0.72	0.62	0.86	1.12	0.76	0.40
MGO	0.74	1.39	0.70	0.59	0.76	0.92	0.74	0.50
CAO	0.18	0.21	0.40	0.19	0.27	0.56	0.30	0.25
NA2O	0.48	0.10	0.84	0.54	1.60	2.23	2.33	2.76
K2O	7.60	5.87	6.14	5.82	4.30	3.51	3.36	3.14
H2O+	1.12	1.88	2.14	1.04	1.73	1.33	1.95	1.46
H2O-	0.47	0.32	0.14	0.46	0.59	0.66	0.18	0.43
TIO2	0.24	0.18	0.17	0.22	0.24	0.16	0.21	0.21
P2O5	0.03	0.07	0.03	0.05	0.02	0.05	0.04	0.04
MNO	0.04	0.07	0.04	0.04	0.05	0.07	0.07	0.02
Sum	100.11	100.08	100.04	99.75	99.56	99.74	99.50	100.28

Entry	9	10	11	12	13	14	15	16
Sample	502	491	515	517	497	492	507	494
SIO2	76.10	74.50	75.10	75.10	75.70	74.80	73.70	74.20
AL2O3	11.40	11.30	11.70	11.80	11.50	11.50	11.80	11.20
FE2O3	2.52	2.04	2.40	2.57	2.48	1.68	1.58	4.30
FEO	0.52	0.50	0.72	0.66	0.56	0.74	0.92	0.36
MGO	0.49	0.61	0.58	0.55	0.53	0.95	1.25	0.40
CAO	0.29	0.34	0.28	0.45	0.43	0.34	0.37	0.43
NA2O	2.51	0.95	0.83	1.67	1.65	0.33	0.15	0.15
K2O	3.14	5.23	5.74	4.99	4.40	7.40	7.71	6.48
H2O+	1.81	3.75	1.36	1.14	1.74	1.13	1.50	1.60
H2O-	0.31	0.23	0.58	0.64	0.33	0.23	0.23	0.18
TIO2	0.23	0.21	0.24	0.22	0.12	0.24	0.24	0.22
P2O5	0.03	0.03	0.03	0.03	0.04	0.03	0.05	0.03
MNO	0.16	0.10	0.01	0.03	0.03	0.13	0.02	0.06
Sum	99.51	99.79	99.57	99.85	99.51	99.50	99.52	99.61

APPENDIX 3 (Continued)

RHY - 2 (Continued)

Entry	17	18	19	20	21
Sample	500	504	535	529	RHY2AVG
SIO2	73.70	73.70	73.70	74.40	74.93
AL2O3	11.40	12.10	12.00	11.70	11.63
FE2O3	2.94	1.81	2.39	1.62	2.32
FEO	0.50	1.16	0.60	1.43	0.75
MGO	0.79	0.89	0.82	1.21	0.77
CAO	0.58	0.37	0.38	0.15	0.32
NA2O	0.14	0.44	0.19	0.35	1.01
K2O	7.74	7.57	7.91	7.04	5.75
H2O+	1.40	1.42	1.34	1.08	1.60
H2O-	0.16	0.12	0.18	0.25	0.33
TIO2	0.20	0.20	0.20	0.15	0.21
P2O5	0.03	0.03	0.03	0.05	0.03
MNO	0.03	0.03	0.10	0.10	0.06
Sum	99.61	99.84	99.84	99.53	99.71