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Geology of the Ar Rahail ancient gold mine, Kingdom of Saudi Arabia

by

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GEOLOGY OF THE AR RAHAIL ANCIENT GOLD MINE, KINGDOM OF SAUDI ARABIA

by

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ABSTRACT

The Ar Rahail ancient gold mine is a collection of ancient workings in metasedimentary rocks of the Murdama Group adjacent to, and above the flanks of the Rahail stock. Injection of mafic dikes of regional origin was followed by emplacement of the Rahail stock, which consisted of early dikes of porphyritic biotite-bearing hornblende granodiorite, and a later cupola of porphyritic monzogranite. Crystallization of the cupola produced a molybdenum-bearing quartz vein stockwork. Intrusion-heated fluids developed chlorite and sericite alteration zones in the older granodiorite dikes.

Pre-existing northwest-trending faults, possibly re-opened by stock emplacement, were invaded by later fluids that precipitated barren quartz veins and, in the adjacent faulted wall rocks, anomalous gold and arsenic. Gold, however, is restricted to the narrow structures, and, although values as much as 4.2 g/t are present, the tonnages are inadequate for profitable mining. No further work is recommended, because the hoped for dissemination of gold between faults does not exist.

INTRODUCTION

LOCATION AND PREVIOUS WORK

The Ar Rahail ancient gold mine, MODS 3272, is located at 26°03"40' N., 42°02"40' E. in the southwest corner of the Samira quadrangle (sheet 26/42C) about 9.8 km south of Jabal ar Ruhayl and 29 km northwest of the village of Uqlat as Suqur (fig. 1). The mine is a collection of ancient workings on the flanks of a circular hill about 14 m high and 660 m in diameter on the edge of Shaib Abu Hashayim, a tributary of Wadi ar Rumah. Access is readily available by dirt track from the paved Madinah-Buraydah highway at Uqlat as Suqur.

The Ar Rahail ancient mine site was first rediscovered by Smith and others (1984, p. 15) in 1981 during regional reconnaissance, although parts of the area within a 12 km radius of Ar Rahail, particularly the extensive An Najady ancient workings, were examined by Fakhry (1941), Schaffner (1956), and Mytton (1970). Based on "moderately high gold and silver values" from a few grab samples and "the presence of hydrothermally altered rocks", Smith and others (1984, p. 16) suggested the need for additional work. Grootenboer and others (1985, p. B9-B10) reached a similar conclusion.

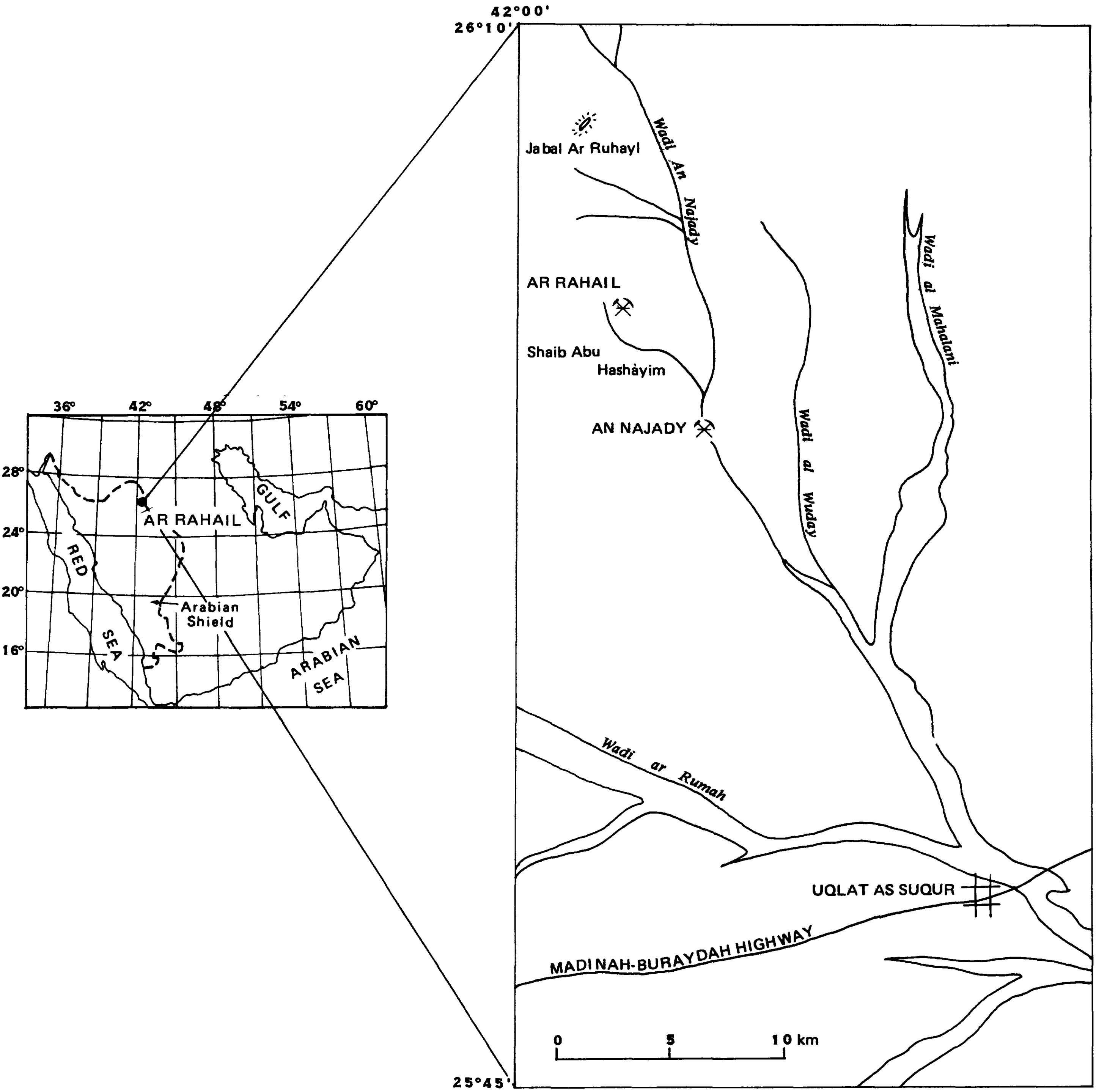

Figure 1.--*Map showing the location of the Ar Rahail ancient gold mine.*

PURPOSE AND METHODS

The present study is in part a result of Smith's recommendation and in part an attempt to further define this type of gold occurrence. Although the gold-bearing veins themselves did not appear large enough for mining, it was hoped that the area between veins, being potentially above and adjacent to an altered intrusive, might contain a lower grade, but larger tonnage deposit. The purpose of this report is to document the geology of the Ar Rahail ancient mine site with special emphasis on the petrography of the plutonic rocks and the character of the gold-bearing structures, to delineate the controls for the concentration of gold, and to evaluate the economic potential.

Work carried out during the 1405 A.H. (1984-1985) field season included geologic mapping at 1:1000 scale, as well as plane table mapping of the topography and drainage to establish base map control. Thirty eight trenches totalling 1486 meters were dug about 30 meters apart, normal to the long direction of ancient mine workings. Trenches were mapped at 1:100 scale and channel sampled at waist height along the north wall in 5-m intervals, yielding 293 samples. An additional 56 rock-chip samples were collected across individual structures that were thought to bear gold, and 32 rock samples were collected for special studies.

R. Samater and J. Doebrich made the plane table map, Samater supervised the trenching and trench sampling, and Doebrich assisted with trench mapping. Ali Dualeh and Eisa Wais collected the samples.

Standard atomic absorption, colorimetric, and semiquantitative emission spectrographic techniques were applied to trench and rock chip samples in the laboratory of the Directorate General for Mineral Resources under the direction of J. Curry (USGS). X-ray fluoresence analysis for selected elements was by Kevex KVX 7000 multichannel X-ray fluoresence spectrometer with Cadmium 109 radioactive excitation source operated by Abdul Malik Helaby. The scanning electron microscope was applied to the identification of selected minerals, the determination of feldspar compositions, and the whole rock chemical analyses of glasses prepared from fused rock. The electron microscope, a JEOL T 300 with a Tracor Northern Si(Li) energy dispersive detector, was operated by Mir Amjad Hussain. Both the X-ray fluoresence unit and scanning electron microscope are in the Digital Services Center of the USGS under the direction of J. Quick.

Polished thin sections and fused rock glasses were prepared by the USGS mineralogy-petrology laboratory under the supervision of C. T. Thornber. Between 2000 and 2500 points were counted per section. R. Kamilli and C. Meissner provided stimulating manuscript comments.

This study was performed in accordance with a work agreement between the U.S. Geological Survey and the Saudi Arabian Ministry of Petroleum and Mineral Resources as subprojects 3.01.61 and 3.11.05.

METASEDIMENTARY ROCKS OF THE MURDAMA GROUP

The metasedimentary country rock at the Rahail ancient mine site is mostly interlayered light-gray siltstone and gray-green claystone, much finer grained than rocks of the same age in adjacent areas (Cole, 1985) (pl. 1). Bedding is best defined by local interbeds of tan fine-grained sandstone as much as 7 cm thick, gray or brown ferruginous carbonate as much as 8.5 cm thick, and rare light-brown chert 2.5 cm thick. The average strike and dip of 69 measurements on bedding is N. 55° E. 64° W. A poorly defined anticline plunges northwestward across the west-central part of the map area. Regionally, the Ar Rahail ancient mine is in the lower part of the upper portion of the Margham formation of the Murdama Group (Johnson and Williams, 1984, p. 12) (C. A. Wallace, 1986)

MAFIC DIKES

At least five mafic dikes, mostly in the southern part of the map area, average 1.5 m in width, strike N. 60°-70° W., and dip steeply (pl. 1). All dikes are light or dark gray, most are equigranular, and two, which were studied in thin section, are composed of quartz-bearing hornblende diorite with an average grain size of 1.1 mm.

This diorite is made up of euhedral twinned plagioclase crystals as long as 2.1 mm and pseudomorphs of hornblende as wide as 1.8 mm. The plagioclase is either cloudy, or partially altered to sericite, and the hornblende is totally altered to chlorite, calcite, and locally epidote. Minor quartz is interstitial, and opaques, which include red-iron oxide and leucoxene, are widely disseminated throughout the rock, and locally concentrated in pseudomorphs of hornblende. The character of the alteration minerals is variable. The chlorite after hornblende in one sample is pleochroic pale green to colorless and in another is pale green to dark green. Epidote is common after hornblende in one occurrence, but absent in another. One sample contains a second generation of abundant unaltered acicular brown hornblende.

Chemically, the rock is similar to the average andesite of Nockolds (1964, p. 1019) (table 1), but is named diorite, because of its hypabyssal occurrence and equigranular texture. The dikes, which also crop out in the area surrounding Ar Rahail, transect the folds in the Murdama siltstone, but are cut by the dikes of the Rahail stock. They are probably associated with a regional intrusive event that preceeded the igneous activity at Ar Rahail.

PLUTONIC ROCKS OF THE RAHAIL STOCK

DISTRIBUTION

The Rahail stock consists of the northeast-trending west and east dikes, a northwest-trending central dike, an irregular north mass, and a circular cupola (pl. 1). The west dike strikes N. 37° E., about 680 m across the western part of the map area. Though irregular in shape, with local bulbous portions as much as 49 m wide, it is generally thickest at its northeastern end and thinnest, about 4 m wide, at its southwestern end. The dike's *en echelon* outcrop pattern is probably the result of original emplacement along paralleling fractures. Contacts are sharp and steep; outcrops are more resistant than surrounding Murdama.

Table 1.-- Major element chemistry and CIPW normative compositions for the mafic dikes, west dike, and cupola compared with the average andesite, granodiorite, and adamellite (monzogranite) of Nockolds (1964)

[In weight percent. Total iron expressed as FeO.]

	1 Mafic Dikes	2 Average Andesite	3 West Dike	4 Average Granodiorite	5 Cupola	6 Average Adamellite
SiO_2	55.98	54.20	67.83	68.88	69.58	69.15
Al_2O_3	15.45	17.17	16.93	15.66	18.54	14.63
TiO_2	1.09	1.31	0.77	0.57	0.03	0.56
Cr_2O_3	0.05	-	0.00	-	0.03	-
FeO	7.24	8.97	3.11	3.92	0.82	3.49
MnO	5.89	4.36	0.27	1.57	0.00	0.99
MaO	0.04	0.15	0.05	0.07	0.05	0.06
CaO	6.24	7.92	3.50	3.56	0.89	2.45
Na_2O	3.86	3.67	4.56	3.84	4.84	3.35
K_2O	1.84	1.11	2.59	3.07	5.69	4.58
P_2O_5	0.35	0.28	0.16	0.21	0.20	0.20
TOTAL	98.03	99.14	99.77	99.35	100.66	99.46
Q	2.23	5.79	22.00	23.83	17.54	25.05
C	-	-	0.66	0.05	3.27	0.19
Or	11.13	6.62	15.36	17.90	33.40	27.21
Ab	33.38	31.32	38.62	32.06	40.65	28.50
An	19.82	27.33	16.33	16.07	3.09	10.91
Di	7.69	8.46	-	-	-	-
Hy	22.15	12.23	5.22	6.67	1.55	4.84
Ol	0.54	-	-	-	-	-
Mt	-	5.09	-	1.90	-	1.78
Il	2.12	2.51	1.46	1.07	0.06	1.07
Ap	0.84	0.67	0.38	0.49	0.46	0.48

1. Average of samples # 214763 and # 214771
2. Average andesite of Nockolds (1964, p. 1019)
3. Average of samples # 214765 and # 214712
4. Average granodiorite of Nockolds (1964, p. 1014)
5. Sample # 214752
6. Average adamellite of Nockolds (1964, p. 1014)

The east dike, which also exhibits an *en echelon* outcrop pattern, strikes N. 45° E. in the southeastern part of the map area; the central dike, a continuous body, trends N. 25° W. in the central region. The irregular north mass and related dikes are in the north and the circular cupola, which measures 65 m by 40 m, crops out at the crest of the centrally located hill (pl. 1). Although contacts of the cupola with adjacent Murdama siltstone are generally near vertical, the northwest contact dips 38° outward. No cross cutting relationships between the dikes, the dikes and the north mass, or between any of the former and the cupola, were observed.

Only the west dike, because of its significant strike length and good exposure, and the cupola, because of its potential as a source for gold, are further described.

LITHOLOGY AND PETROGRAPHY

West Dike

The least-altered rock of the west dike is porphyritic biotite-bearing hornblende granodiorite with phenocrysts of white plagioclase and gray quartz in a dark-gray aphanitic groundmass. Although grain size is variable, depending on whether samples came from the finely crystalline chill zone or the more coarsely crystalline dike interior, the average length of phenocrysts is: plagioclase 2.5 mm, quartz 1.3 mm, hornblende 1.8 mm, and biotite 1.2 mm. The plagioclase crystals also form glomerocrysts as much as 7 mm in diameter. Subhedral groundmass grains, composed of quartz and feldspar, average 0.1 mm.

Phenocrysts of oligoclase (Or_2 Ab_{71} An_{27}) are euhedral, twinned, and show well developed oscillatory zoning. Most quartz phenocrysts are subhedral, with some rounded and embayed. Many are rimmed by 0.4-mm-wide quartz overgrowths that are defined by inclusion trains of sericite. Euhedral hornblende is red brown; biotite is pleochroic dark red brown to yellow brown to pale green. Hornblende contains inclusions of euhedral apatite and magnetite; biotite contains apatite, magnetite, zircon, and rare rutile.

The alteration of primary minerals increases in intensity from southwest to northeast along the strike of the west dike (fig. 2). Rock color changes from dark gray to violet to tan to light gray. Oligoclase, which occurs only in the southwest part of the dike, is totally replaced by albite (Or_6 Ab_{93} An_1), which lacks the oscillatory zoning typical of the original plagioclase (fig. 2). Both primary oligoclase and secondary albite are partially altered to sericite, calcite, and trace kaolinite, and although this type of alteration varies from place to place within the dike, it does not vary systematically along strike. Rare quartz-carbonate-albite (Or_0 Ab_{100} An_0) veins, present in the north-central part of the dike, cut all primary minerals. The albite within these veins is fresh.

Progressive changes in alteration are best recorded by phenocrysts of hornblende, which are replaced by flakey brown biotite that is in turn altered to green chlorite and ultimately to sericite, by far the most widespread alteration mineral in the dike (fig. 2). Carbonate occurs in all three assemblages, but is most abundant with secondary biotite and chlorite. Carbonate is common along remnant hornblende cleavage traces and in the centers of hornblende pseudomorphs. Epidote is rare. Magnetite, which is also aligned along hornblende cleavage, is altered to leucoxene.

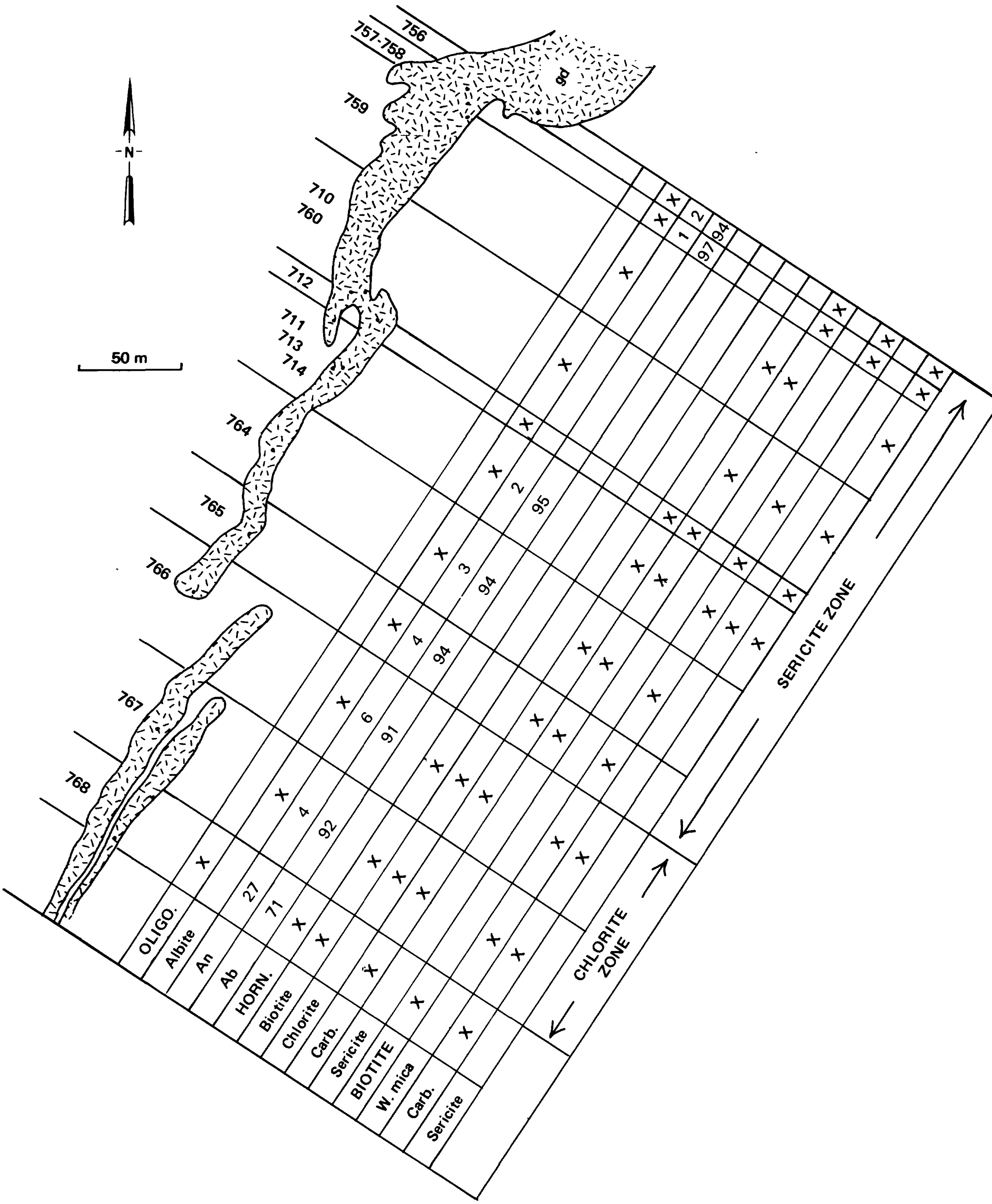

Figure 2.--*Diagram showing the distribution of the alteration products of plagioclase, hornblende, and biotite in the west dike (gd = granodiorite, x = mineral present). The 700-series numbers are sample numbers (214 prefix omitted).*

Primary biotite phenocrysts alter to coarsely crystalline white mica and carbonate with abundant leucoxene after magnetite. The final alteration product is finely crystalline sericite (fig. 2). Although fresh pyrite is rare, euhedral pseudomorphs, mostly hematite, occur as individual crystals averaging 0.7 mm in width and clumps of crystals as much as 3.5 mm wide disseminated throughout the rock. They are especially common in pseudomorphs of hornblende and biotite. Pyrite pseudomorphs, also present in narrow quartz veins, show a progressive increase in abundance from the southwest to the central and northeastern portions of the dike.

Cupola

In hand specimen, the porphyritic monzogranite of the Rahail cupola contains phenocrysts of euhedral white feldspar, subhedral gray quartz and euhedral dark-gray mica in a white to light-gray aphanitic groundmass. In thin section, the average size of phenocrysts is: potassium feldspar 1.0 mm, plagioclase 1.7 mm, quartz 1.2 mm, and white mica 1.6 mm. The groundmass, composed of an equigranular mosaic of potassium feldspar, quartz, and plagioclase, has an average grain size of 0.2 mm.

Potassium feldspar (Or_{92} Ab_8 An_0) is typically perthitic. Individual potassium feldspar crystals contain widely distributed ragged-edged patches of optically continuous twinned plagioclase. Although all patch perthite is not unequivocally the result of replacement, some isolated patches in matrix potassium feldspar crystals are optically continuous with adjacent plagioclase. In addition, irregular boundaries between potassium feldspar and plagioclase, as well as potassium feldspar pseudomorphs of parts of some plagioclase crystals, strongly suggests potassium feldspar replacement of plagioclase.

Potassium feldspar overgrowths containing local myrmekitic intergrowths of quartz are common on potassium feldspar phenocrysts and rarely on phenocrysts of plagioclase. Potassium feldspar also forms local areas of micrographic texture with quartz, particularly in the matrix between crenulate quartz layers. Except for a fine dust and few crystals of white mica, potassium feldspar is mostly fresh. The only exception is the rare intensely altered quartz-sericite rock in which all feldspars are destroyed.

Plagioclase in the Rahail cupola is albite (Or_{1-7} Ab_{93-99} An_0), which is probably a replacement of original oligoclase, although replacement textures are not evident. Polysynthetically twinned phenocrysts, as well as matrix grains, are variably altered to sericite, and traces of carbonate. Some of the patch perthite in potassium feldspar may indicate weak partial replacement of potassium feldspar by albite. The potassium feldspar may have locally replaced original oligoclase as part of a late magmatic K-feldspathization event and then albitization may have affected potassium feldspar as part of a later period of hydrothermal alteration.

Quartz phenocrysts have mild undulatory extinction and rare, weakly developed deformation lamellae. Local quartz overgrowths, typical on partially resorbed quartz phenocrysts, have internal boundaries defined by inclusions of plagioclase, white mica, and minor potassium feldspar, the principal rock-forming minerals, rather than only sericite, as in the west dike.

White mica has two modes of occurrence. First, it forms clusters of radiating inclusion-free crystals that are either interstitial to quartz, plagioclase, and potassium feldspar, or, locally, within potassium feldspar. This occurrence is probably either late magmatic or hydrothermal. Second, it forms tabular inclusion-filled crystals in which linear zones of opaque minerals and carbonate follow the traces of the mica cleavage, and euhedral rutile and zircon are scattered locally throughout. This occurrence is probably a replacement of primary biotite. Euhedral red-iron-oxide pseudomorphs of pyrite occur in white-mica pseudomorphs of biotite, as well as individual disseminations throughout the rock.

Crenulate Quartz Layers

Crenulate quartz layers, which occur throughout the exposed Rahail cupola, are irregular vein-like layers of quartz with smooth borders on one side and uneven, jagged borders caused by euhedral, pyramidal quartz terminations on the other (Shannon and others, 1982) . Individual layers are as wide as 1 cm, although most are less than 3 mm. They are most abundant in the central portions of the cupola where they form as many as 90 layers per 30-cm interval, strike east, and dip about 75° north.

Quartz crystals are oriented at high angles to the planes of individual layers, and all quartz terminations in any one group of layers point in the same direction. The monzogranite between layers generally has normal texture and mineralogy, except in areas of most intense layering, where micrographic intergrowths of quartz and feldspar are common. Crenulate quartz layers are clearly cut by stockwork-type veins.

In thin section the quartz has interlocking grain boundaries and undulatory extinction. Individual crystals locally extend the entire width of the smaller layers. Inclusions of apatite form sheaf-like bundles and radiating clusters with individual crystals as long as 0.2 mm long. Crystals are oriented with their short dimensions towards the euhedral end of the host quartz. Crenulate quartz layers are typical of the cupola areas of volatile rich, ore-forming intrusive bodies (Walker and others, 1984; Carten and others, 1985).

MODAL ANALYSES AND CHEMISTRY

Although modal data for the finely crystalline rocks of the west dike are not available, the estimated proportions of quartz, oligoclase, hornblende, and biotite in phenocrysts and possible potassium feldspar in the matrix, suggests that the rock is probably granodiorite porphyry. Modal analyses of the coarser cupola rocks, assuming that all albite was originally oligoclase and most white mica originally biotite or hornblende, indicate that the rock may be designated either granodiorite porphyry or monzogranite porphyry (table 2, fig. 3). For convenience in this report and to emphasize the small mineralogical and chemical differences between dike and cupola, the cupola rock is termed monzogranite porphyry.

This terminology is supported by the close comparison between the whole rock chemistry of Rahail rocks and that of the average granodiorite and adamellite of Nockolds (1964, p. 1014), respectively (table 1). The adamellite of Nockolds would most closely approximate the monzogranite of Streckeisen (1976, p. 12). Differences, such as the lower FeO, MgO, CaO, and higher Na_2O in the cupola as opposed to the average adamellite, may be explained by the albitization of oligoclase and destruction of mafics in Rahail samples.

A comparison between the whole rock chemistry of the west dike and the cupola shows significantly lower FeO, CaO, and higher K_2O in the cupola. Lower FeO and CaO are probably due to complete destruction of mafics and the lower CaO to the destruction of mafics as well as oligoclase, but higher K_2O reflects the presence of potassium feldspar in the cupola, a primary difference between the two rock types.

Table 2.--Modal analyses of rocks from the Rahail cupola.
[in vol. percent]

	1	2	3	4	5
Quartz	36.9	38.5	41.1	30.6	33.5
Potassium feldspar	21.4	19.6	14.2	26.4	15.3
Plagioclase	34.3	30.8	34.5	35.2	41.3
White mica	6.2	7.7	8.8	5.7	7.5
Opaque	0.2	0.5	0.7	1.2	0.4
Sericite	0.8	2.4	0.1	0.6	1.1
Carbonate	0.2	0.3	-	-	-
Kaolinite	-	0.2	0.3	0.3	0.9
Epidote	-	-	0.3	-	-

1. Sample No. 214721
2. " No. 214722
3. " No. 214723
4. Sample No. 214752
5. " No. 214754

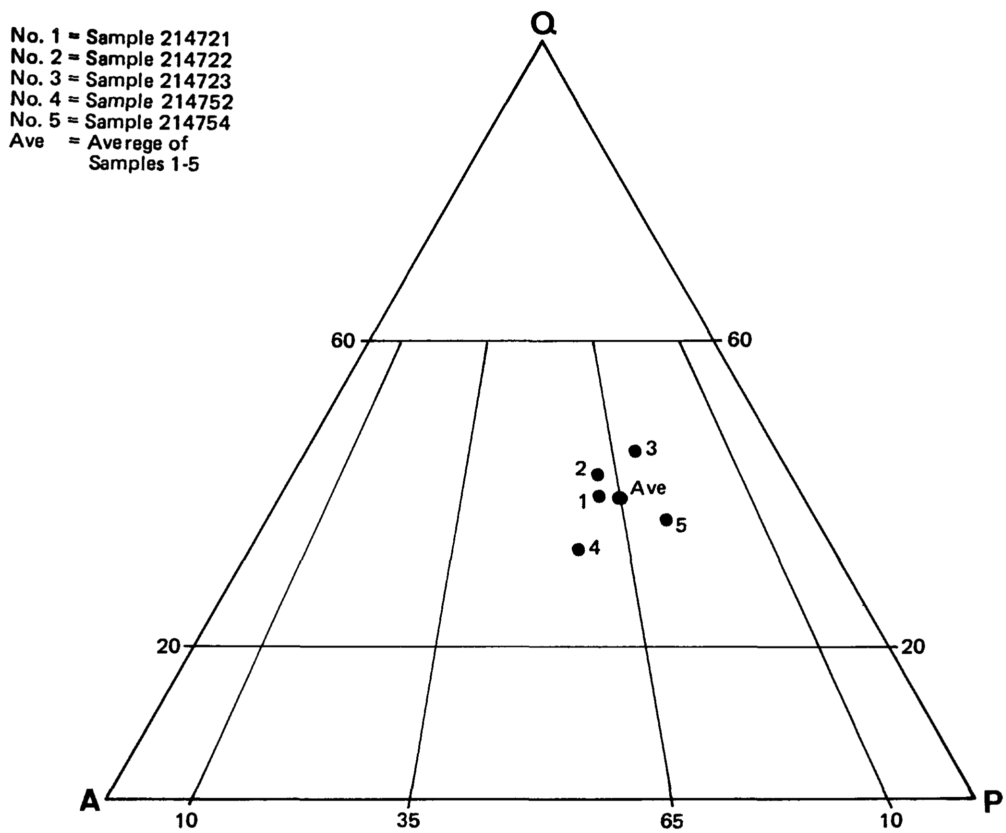

Figure 3.--*Ternary diagram (Streckeisen, 1976) showing modal proportions of quartz* (Q), *alkali feldspar* (A), *and plagioclase* (P) *in rocks of the Rahail cupola (vol.%).*

ALTERATION ZONES

Changes that take place in the primary minerals of the west dike define two zones of hydrothermal alteration at Ar Rahail: the chlorite zone, limited to a narrow interval at the southwest end of the dike, and the sericite zone, which includes all of the dike northeast of the zone of chlorite (fig. 2). The chlorite zone is characterized by the presence of albite after plagioclase; secondary biotite, chlorite and carbonate after hornblende; and white mica and carbonate after biotite. Chlorite is the characteristic alteration mineral. Hornblende, oligoclase, and primary biotite are absent.

The sericite zone is characterized by weak sericite and calcite after plagioclase, total sericite replacement of hornblende and local recrystallization of the white mica after biotite to finely crystalline sericite. Iron oxide pseudomorphs of pyrite are widespread. Sericite is the characteristic alteration mineral.

The southwest boundary of the chlorite zone with relatively fresh rock is drawn where chlorite appears as an alteration product of secondary biotite after hornblende, and where primary hornblende is no longer present. The northeast boundary of the chlorite zone with the sericite zone is established where the biotite-chlorite pseudomorphs of hornblende are totally replaced by sericite.

Although the chlorite zone is recorded only in the west dike, the pattern suggests a zonation around the cupola with the chlorite zone farthest away and the sericite zone closest to and within it (fig. 2). The pattern is thought to exist whether the cupola is defined by the geophysical anomaly or the cupola outcrop. Samples from the east dike, north mass, and cupola are all within the sericite zone.

RELATIVE AGES OF INTRUSIVE UNITS

The similar form, texture, mineralogy, and chemistry of the west, east, and central dikes suggests that they are all of similar age. Because the north mass is similar to dikes in all characteristics but form, it is also considered to be of the same age. The cupola, however, is different. It's circular form, slightly coarser average matrix grain size, greater percentage of potassium feldspar, and higher K_2O content suggest slower cooling and a higher degree of differentiation. Perhaps the early injection of dikes and north mass into the fractured, cool country rocks was followed by the later emplacement of the larger, slower-rising main mass of the intrusion that would have risen into the warmer rocks, cooled more slowly, and acquired additional time for more advanced differentiation. The cupola, as suggested by geophysics, would represent only the exposed portion of such a larger mass. The superposition of probable cupola-related hydrothermal alteration on the west dike further supports this relative age relationship.

ORE ZONES OF THE ANCIENTS

CHARACTER

The ore zones of the ancients are outlined by ten clusters of ancient mine dumps here designated as Groups A through J. Group A, a northwest-trending set of ancient workings, is explored by Trenches #1, #2, and #3 in the northwest portion of the map area (pl. 1) . The ore zone, as exposed in Trench #1, is a 32-cm-wide fault with a 22-cm-wide quartz vein on the hanging wall and 4-cm-wide quartz vein near the footwall. Broken red-iron-oxide stained siltstone occurs between veins and along the footwall.

The ore zone strikes approximately N. 70° W. and dips about 40° S. It is continuous for at least 35 m between Trenches #2 and #3, but is offset 7 m to the north in Trench #1. The offset may be due to the original *en echelon* nature of the fault system or to subsequent faulting. Subparallel ferruginous slips as much as 7 cm wide with quartz veins as much as 3 cm wide occur on the hanging wall to a true distance of 6 m from the main ore-bearing structure. The term slip, as defined in this report, is a small fault.

A subsidiary set of fractures is characterized by ferruginous slips as much as 2 cm wide with quartz veins as thick as 1.5 cm. Most strike about N. 15° E. and dip 38-45° S. although one dips 44° N.

Group B, composed of west-trending ancient workings in the northwest part of the map area, is sectioned by Trenches #29 and #30 (pl. 1). The ore zone is mined out, but the configuration of workings suggests a strike of approximately N. 90° W. and dip of about 30° S. The zone cuts siltstone within 3 m of the contact between siltstone and quartz porphyry.

Group C, a northwest-trending set of ancient workings, is transected by Trenches #4, #5, and #6 in the northeast part of the map area (pl. 1). The ore zone, exposed in Trench #5, is a 14-cm-wide fault composed of red-iron-oxide stained siltstone fragments cut by a 7-mm-wide quartz vein. The fault strikes N. 45° W., dips 53° S., and based on the configuration of ancient workings, extends at least 65 m on strike. Ferruginous slips as much as 2 cm wide containing quartz veins as much as 8 mm wide parallel the strike of the ore zone, but dip steeply north. They are present as much as 11 m from the ore zone hanging wall and 6 m from the footwall.

The ancient workings of Group D, which trend northwest in the northeast part of the map area, are intersected by Trenches #7, #8, #9, #10, and #11 (pl. 1). The main ore zone, as exposed in Trench #10, is a 30-cm-wide fault with alternating strands of broken iron-stained and argillized buff-colored siltstone. The largest 8-cm-wide ferruginous hanging wall strand contains a 4-cm-wide quartz vein. Two additional 1-cm-wide quartz veins occur in the remainder of the structure. The zone strikes N. 70° W., dips 37° S. and extends intermittently about 90 meters on strike. Ferruginous slips strike parallel to the main ore zone as much as 6 m from the hanging wall and 13 m from the footwall, but dip steeply north. The slips, which do not exceed widths of 6 cm, contain quartz veins as much as 2 cm thick.

A second, though less persistent, ore zone trend is defined by single iron-oxide stained faults as much as 11 cm wide in Trenches #9 and #11. The structures contain quartz veins as much as 4 cm thick, strike N. 5°-22° E. and dip 22-33° S.

Group E, a northwest-trending collection of ancient workings in the eastern part of the map area, are explored by Trenches #12, #13, #14, and #15 (pl. 1). The main ore zone is not exposed, but the trend of deeper workings and the attitude of ferruginous slips suggests that it had a strike of about N. 60° W. and dip of about 60° S. A secondary ore zone is marked by ferruginous faults as much as 5 cm wide with quartz veins as much as 1.5 cm thick. They strike about N. 25° E. and dip 30°-48° SE.

Group F, composed of northwest-trending ancient workings in the eastern part of the map area, is transected by Trenches #16, #17, #18, and #19 (pl. 1). The main ore zone, exposed only in Trench #19, is a 22-cm-wide iron-stained fault with a discontinuous white sulfide-free quartz vein as much as 20 cm thick. The zone strikes N. 55° W. and dips 40° S. The alignment of ancient workings suggests that ore-bearing structures were predominantly northwest striking, but it does not permit a confident eastward extension of the individual structure in Trench #19. Northeast-trending gently south dipping ferruginous slips as much as 15 cm wide with quartz veins as much as 5 cm thick are common in the easternmost trenches.

Group G, northwest-trending ancient workings in the south central part of the map area, is explored by Trenches #20 through #26 (pl. 1). The main ore zone is a collection of parallel structures, the best exposed of which, is a 1.9-m-wide iron-stained fault with a 37-cm-thick white quartz vein near the footwall and a 25-cm-wide zone of silicified yellow-iron-oxide stained siltstone at the hanging wall (fig. 4). The altered siltstone, unique to the ore structures in Group G, contains irregular quartz veins averaging 0.5 cm thick and cross-cutting carbonate veins averaging 1 mm thick. It may occur on the hanging wall, as in Trench #21, or on the footwall, as in Trench #22. The main ore zone strikes N. 45° W. and dips 40° S. The most continuous single fracture extends 40 m on strike.

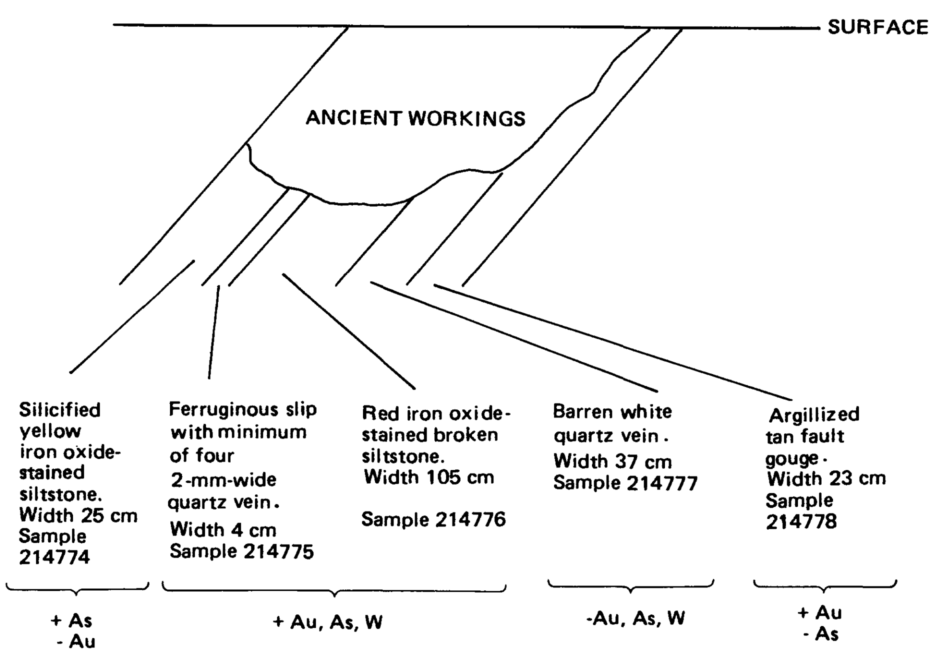

Figure 4.--*Sketch showing cross section of ancient ore zone on the north wall of Trench 21 (plus (+) = element enriched; minus (-) = element depleted).*

A second set of ore-bearing structures, which are not continuous between trenches, include iron-stained faults as much as 2.8 m wide with white quartz veins as thick as 60 cm. Zones of silicified yellow iron-oxide stained siltstone as much as 30 cm thick occur either on the footwall or hanging wall. One quartz vein contains internal red-iron-oxide coated parting surfaces suggesting the presence of pyrite. The fractures strike N. 70° W. and dip an average of 46° S.

The largest of a third subordinate set of ore-bearing structures is a 9-cm-wide iron-stained fault with a 3 cm-thick white quartz vein and footwall traces of silicified yellow-iron-oxide stained siltstone. The fractures strike N. 20°-30° E. and dip 50°-55° NW.

Group H, a series of north-trending ancient workings in the southern part of the map area, is sectioned by Trenches #34, #35, and #36 (pl. 1). No ore zone is exposed, but remnants indicate that they were ferruginous faults with narrow quartz veins. The alignment of ancient workings and attitude of subsidiary ferruginous slips suggests that the ore structures had a N. 0-20° E. strike and steep west dip.

Group I, consists of north-trending ancient workings explored by Trenches #28, #31, #32, and #33 in the western part of the map area (pl. 1). No prominent ore structure is exposed. The largest, an 11-cm-wide ferruginous fault with 5-cm-wide hanging wall quartz vein, strikes N. 20° E. and dips 23° SE. A second ore zone, defined by a 5-mm-wide quartz vein, strikes N. 45° W. and dips 38° SW. Workings occur in porphyry and in siltstone, but are especially concentrated in siltstone along porphyry contacts.

Group J, east-trending ancient workings in the central part of the map area, is sectioned by Trench #27 (pl. 1). Although no ore structure is exposed, the alignment of workings and subsidiary fractures suggests that the principal ore zone had an east-northeast strike and south dip.

In summary, each ore zone of the ancients is a fault composed of broken red-iron-oxide stained siltstone, minor strands of intense argillization, and a single large white quartz vein. Layers of silicified siltstone occur locally on either the footwall or the hanging wall, and paralleling ferruginous slips are present as much as 13 m away.

The largest, most persistent ore zones strike N. 70° W. and dip 37-46° S. in the north and central portions of the map area, and are best exposed in the trenches of Groups A, D, and G. A typical structure is 32 cm wide, and contains a quartz vein 22 cm thick. The longest is 90 m.

A second prominent ore-zone set, exposed in the trenches of Goups C and G, strikes about N. 45° W. and dips 38-53° S. in the northeastern and central areas. Although variable, a typical structure has a 22-cm width and enclosed vein thickness of about 20 cm. The longest continues 65 m on strike. The narrowest, least persistent, but widely distributed structures strike N. 5-30° E. and dip either 22-38° S. or 44-55° N. Most are about 5 cm wide and have quartz veins 3 cm thick.

Ore-zone structures are best developed within siltstone, although the distribution of ancient workings in Group I probably reflects the presence of small ore structures within dikes of the Rahail stock as well. The local concentration of workings along contacts between siltstone and intrusive rocks suggests a possible contact ore control.

Measurement and analysis of 251 ferruginous slips, excluding major ore-bearing structures, showed no systematic change in abundance or width with proximity to outcrops of the Rahail stock. Ferruginous slips average 2.3 per 10 meters throughout the area.

CHEMISTRY

The chemical composition of the ore zones of the ancients is derived from the average of 56 rock chip samples, each taken across a specific iron-stained fracture exposed in the trenches at Ar Rahail (table 3) (Appendix 1). Compared to the average shale of Turekian and Wedepohl (1961), the average ore zone is anomalous in gold and greatly enriched in arsenic, where anomalous is defined as having a concentration greater than ten times the average shale. Tungsten is weakly anomalous, but it's absence from 44 of the 56 samples indicates that it is not a typical ore-zone constituent.

The distribution of elements in the country rock adjacent to the ancient ore zones is best recorded by the 5-m channel samples taken along the north wall of each trench. Although values of all anomalous elements were plotted for all trenches, the relationships between element distributions and ore zones are best displayed in the trenches of Groups A, C, and G where some of the most persistent and well defined ancient ore zones are exposed (figs. 5-10) (Appendix 2).

Gold values greater than 200 ppb all correlate with mapped red-iron-oxide stained slips and fault zones, most of which contain quartz veins, or with ancient workings in which the ore-bearing structures have been removed (Figures 5-7). Where a principal ore zone is well defined, gold is generally restricted to the sample interval that contains the structure and is not anomalous in the adjacent country rock (e.g. Trenches 2, 3, 6, 22, 24, figs. 5-7).

Arsenic values are highest where gold is highest, but arsenic anomalies are more pronounced than gold (e.g. Trenches 2, 3, 6, 21, 23, figs. 8-10). Arsenic is also anomalous, in values greater than 200 ppm, for at least one and locally two sample intervals (10 m) into the country rock either side of a given structure (e.g. Trench 6, fig. 9).

Within an individual ore zone, best exemplified by the exposure in Trench 21 (table 4) (fig. 4) (pl. 1), gold, arsenic, and traces of tungsten are all concentrated in the ferruginous slip and broken siltstone of the vein hanging wall. Gold is anomalous in the silicified siltstone and depleted in the argillized gouge, whereas arsenic is depleted in the silicified siltstone and enriched in the argillized gouge. All elements are depleted in the barren quartz vein, although gold and arsenic remain slightly anomalous. The Trench 21 structure is higher in gold, and particularly arsenic, than the average ore zone of the ancients (table 3), and the quartz has more gold, possibly because of the inclusion of iron-oxide-coated surfaces in the sample, than the average barren quartz vein of the ore zone of the ancients (table 5). In short, most of the gold and related elements occur in the fractured rock of the fault zone on either side of the quartz vein, and not in the quartz vein itself.

Table 3.--Average chemistry of the ore zones of the ancients and the average shale.

[Au in ppb; Fe, Mg, Ca, Ti in percent. All other elements in ppm. ND = not determined.]

	1 Ore Zones of the Ancients Average (56)	2 Average Shale	3 Analytical Methods (1 only)
Fe	3.8	4.7	SES
Mg	1.1	1.5	SES
Ca	2.8	2.2	SES
Ti	0.2	0.46	SES
Mn	528	850	SES
Ba	322	580	SES
Sr	117	300	SES
Rb	ND	140	SES
W	21	1.8	SES
Sn	0	6.0	SES
Mo	9	2.6	SES
Bi	0.6	ND	AA
Zr	59	160	SES
Au	384	0	AA
As	1090	13	AA
Sb	10	1.5	AA
Ag	0.1	0.07	AA
Cu	33	45	AA
Pb	13	20	AA
Zn	48	45	AA
Co	7	19	SES
Ni	34	68	SES
Cr	208	90	SES
V	126	130	SES

1. See Appendix No. 1
2. Turekian and Wedepohl (1961)
3. AA = Atomic absorption; COL = Colorimetry; SES = Semiquantitative emission spectrography

Table 4.--Chemistry of the ore structure in Trench 21, Group G.

[Au in ppb; Fe, Mg, Ca, Ti in percent. All other elements in ppm. L = element detected, but below limit of determination; N = not detected.]

	1 Silicified Siltstone	2 Ferruginous Slip	3 Broken Siltstone	4 Barren Quartz Vein	5 Argillized Gouge	6 Analytical Method
Fe	5	5	7	0.15	5	SES
Mg	2	1	1	L	1	SES
Ca	5	3	1.5	0.05	1	SES
Ti	0.5	0.7	0.7	0.002	1.0	SES
Mn	500	500	700	10	500	SES
Ba	500	300	300	N	300	SES
Sr	163	134	145	13	138	XRF
Rb	87	139	154	16	123	XRF
W	N	30	30	10	2	COL
Sn	N	N	N	N	N	SES
Mo	5	10	15	4	9	AA
Bi	N	1	N	N	N	AA
Zr	110	120	134	23	133	XRF
Au	400	800	500	320	107	AA
As	184	20109	4210	280	1534	XRF
Sb	30	30	50	15	30	AA
Ag	L	0.35	0.4	0.12	0.2	AA
Cu	53	70	98	3	56	AA
Pb	10	18	8	9	7	AA
Zn	92	82	108	3	77	AA
Co	5	L	5	L	5	SES
Ni	50	30	50	N	30	SES
Cr	100	300	300	100	150	SES
V	150	300	300	10	300	SES

1. Sample No. 214774
2. Sample No. 214775
3. Sample No. 214776
4. Sample No. 214777
5. Sample No. 214778
6. AA = Atomic absorption; COL = Colorimetry; SES = Semiquantitative emission spectrography; XRF = X-Ray fluorescence

Table 5.--Average chemistry of folded, stockwork, and barren quartz veins.

[Au in ppb; Fe, Mg, Ca, Ti in percent. All other elements in ppm. L = element detected, but below limit of determination; N = not detected.]

	1 Folded Quartz Veins Ave. (4)	2 Stockwork Quartz Veins Ave. (2)	3 Barren Quartz Veins Ave (4)	4 Analytical Method
Fe	0.7	0.02	0.2	SES
Mg	0.2	0.01	L	SES
Ca	5.4	0.6	0.03	SES
Ti	0.03	0.003	L	SES
Mn	158	20	8	SES
Ba	48	N	N	SES
Sr	212	42	9	XRF
Rb	23	N	6	XRF
W	15	30	14	COL
Sn	N	N	N	SES
Mo	13	315	12	AA
Bi	1	N	0	AA
Zr	27	28	22	XRF
Au	19	17	15	AA
As	74	31	35	XRF
Sb	2	N	1	AA
Ag	N	N	N	AA
Cu	10	4	8	AA
Pb	2	2	1	AA
Zn	12	2	2	AA
Co	N	N	N	SES
Ni	N	N	N	SES
Cr	113	85	98	SES
V	5	10	L	SES

1. Average of samples 214786-214789 (Appendix No. 3)
2. Average of samples 214761 and 214762 (Appendix No. 3)
3. Average of samples 214779, 214781, 214782, and 214785 (Appendix No. 3)
4. AA = Atomic absorption; COL = Colorimetry; SES = Semiquantitative emission spectrography; XRF = X-ray fluorescence

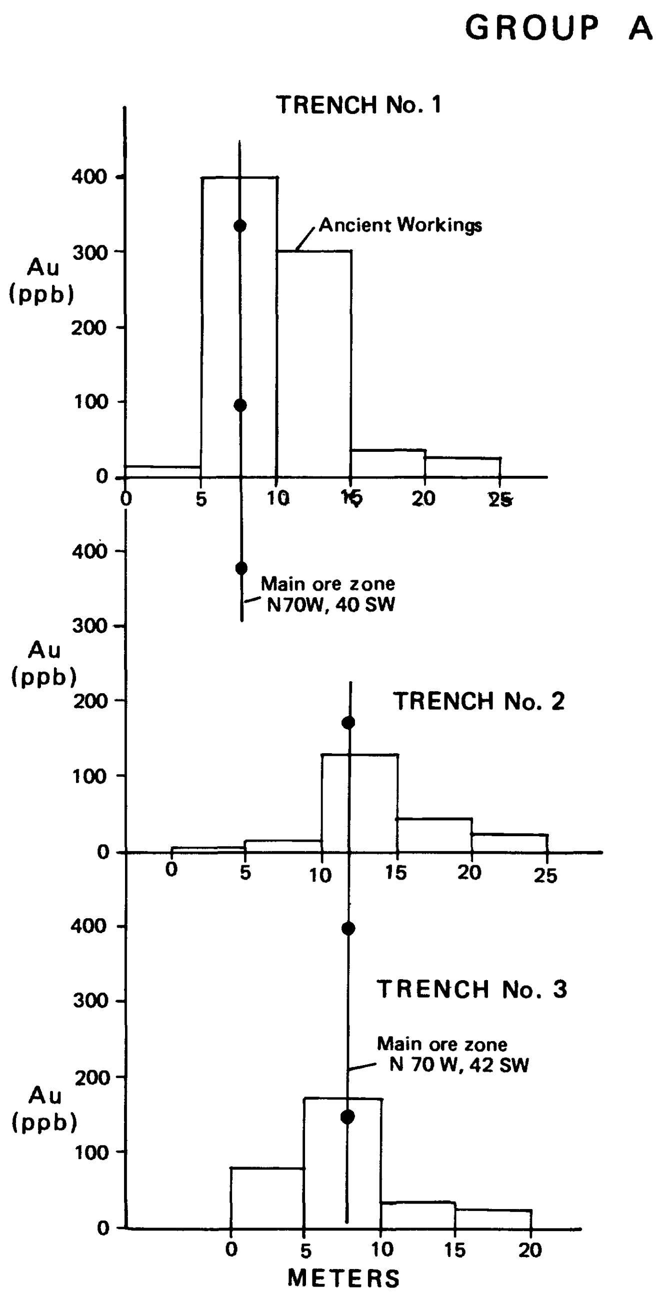

Figure 5.--*Bar graph showing gold values of trench samples in Group A. Graph alignment is based on mapped intersection of main ore zone with north rib of each trench.*

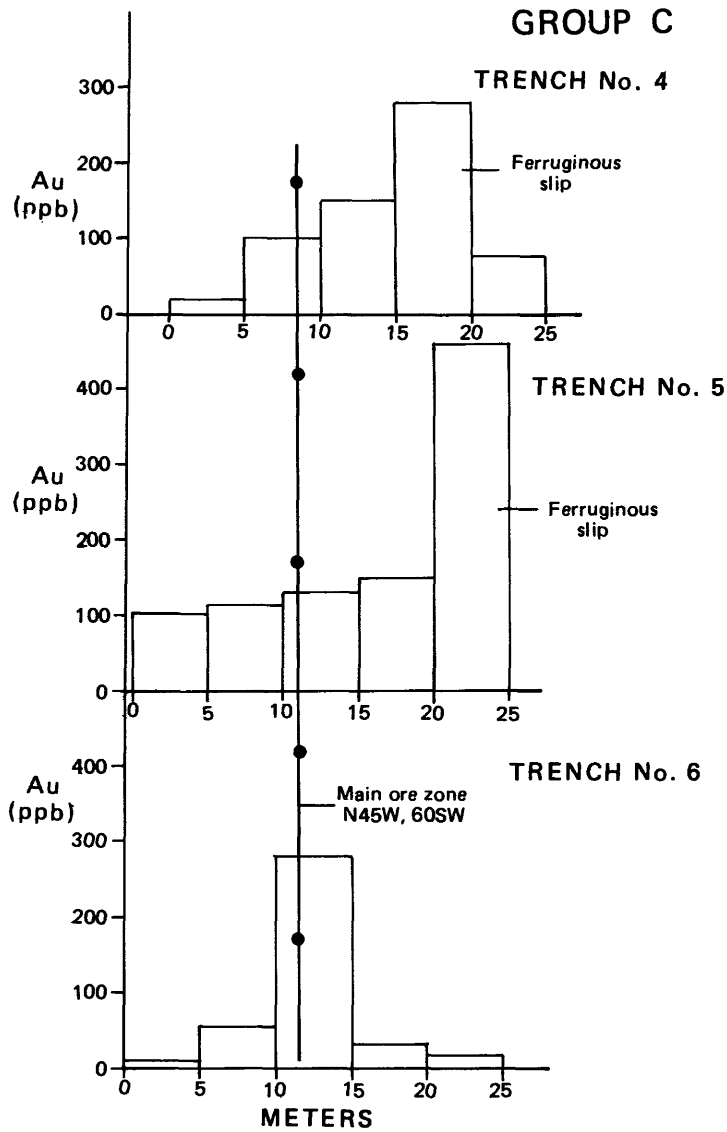

Figure 6.--*Bar graph showing gold values of trench samples in Group C. Graph alignment is based on mapped intersection of main ore zone with north rib of each trench.*

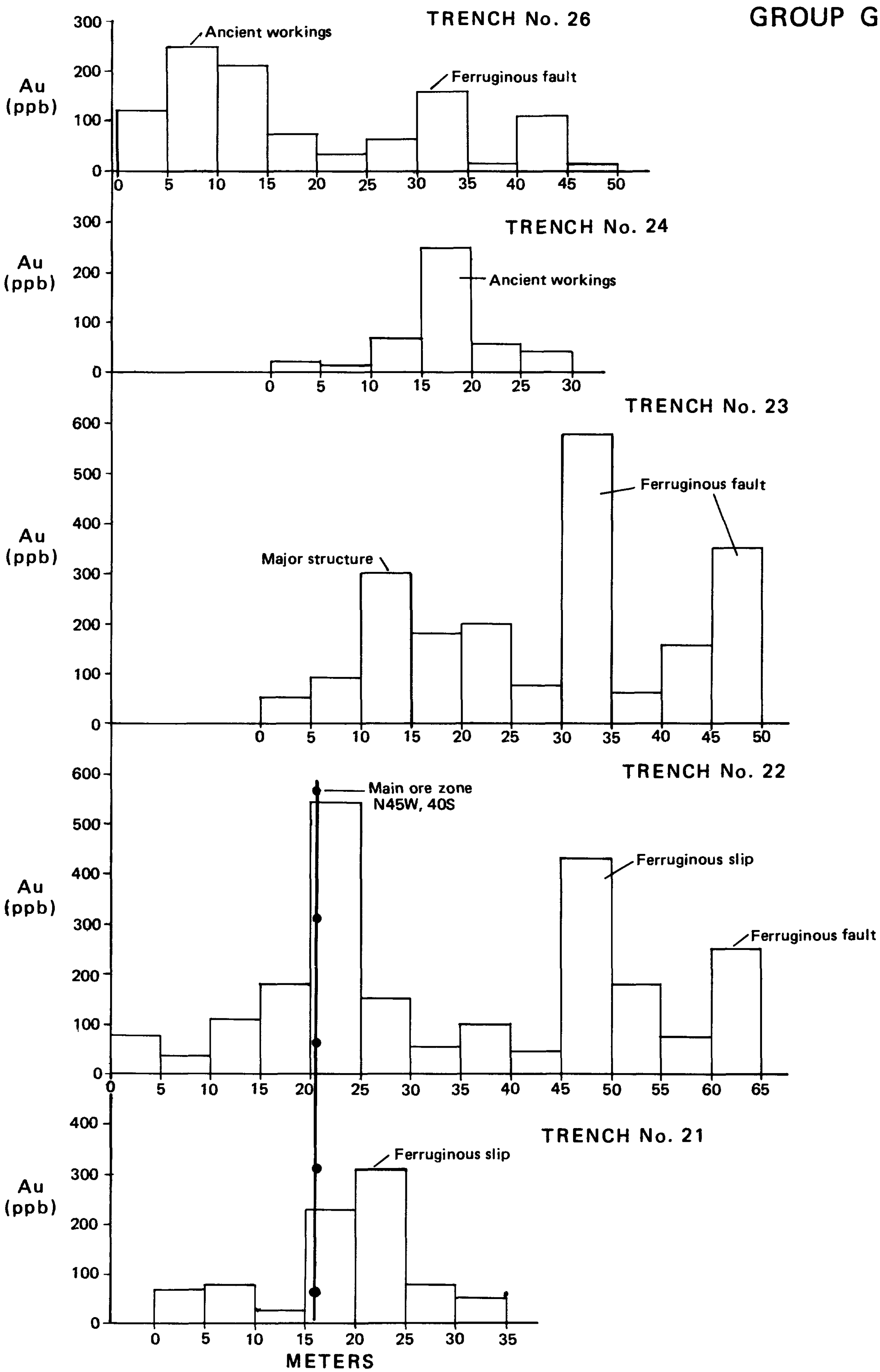

Figure 7.--*Bar graph showing gold values of trench samples in Group G. Graph alignment is based on mapped position of trenches.*

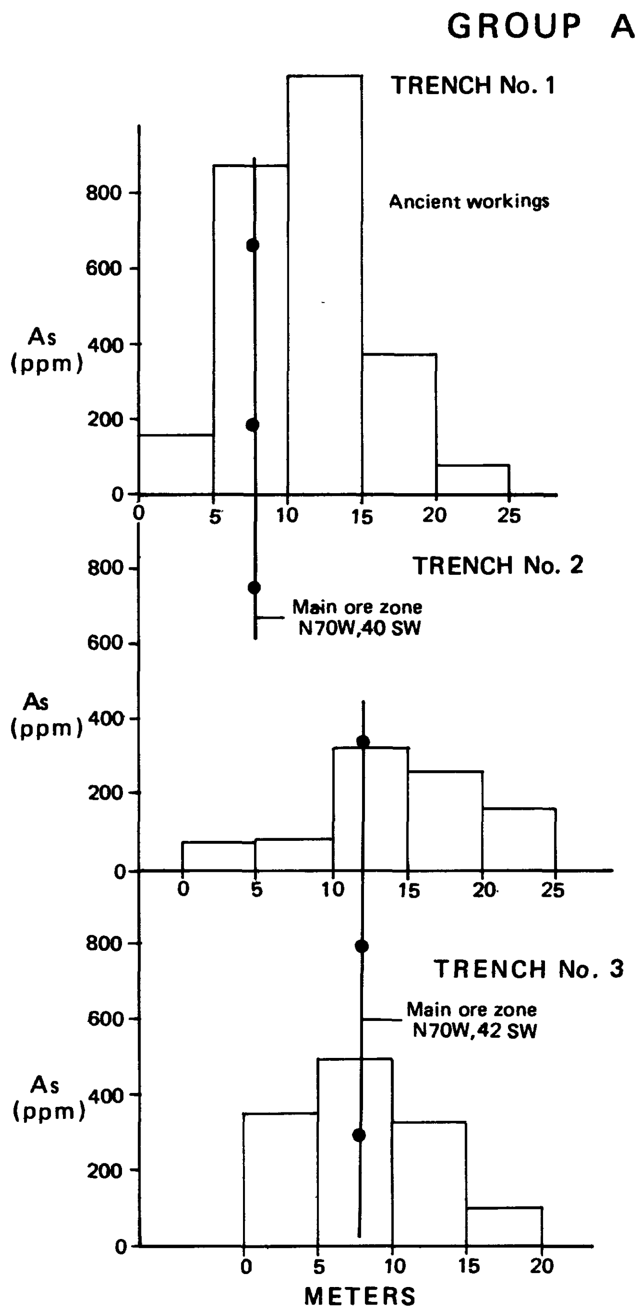

Figure 8.--*Bar graph showing arsenic values of trench samples in Group A.*

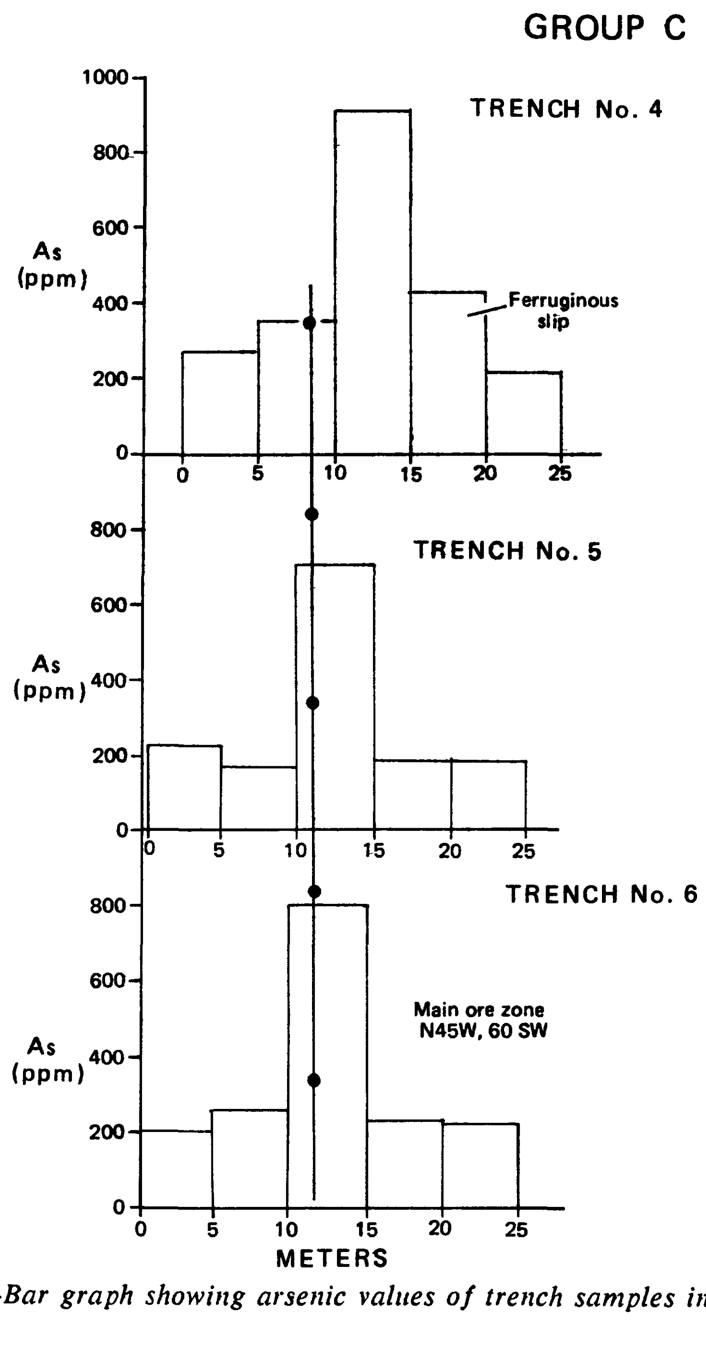

Figure 9.--*Bar graph showing arsenic values of trench samples in Group C.*

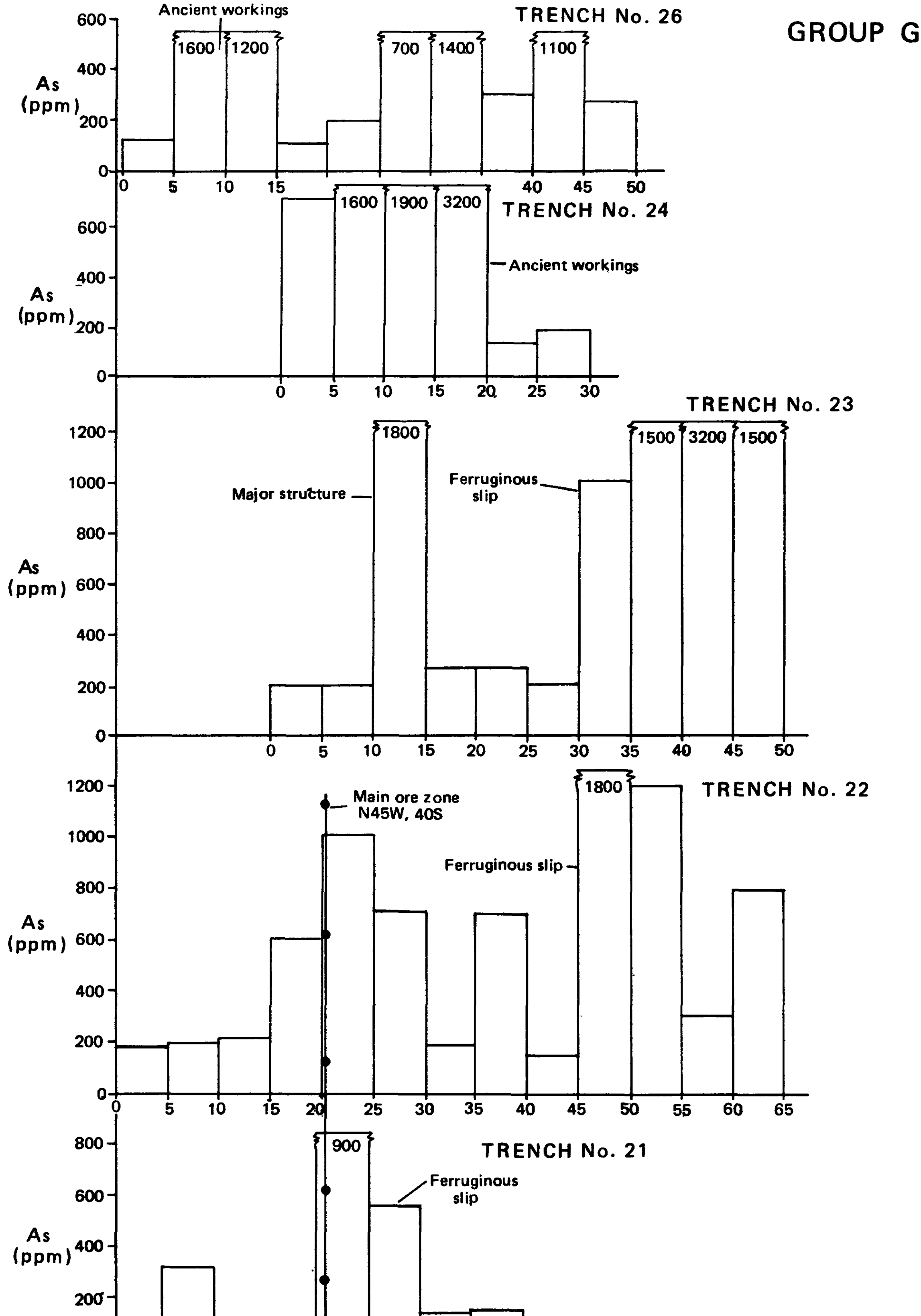

Figure 10.--*Bar graph showing arsenic values of trench samples in Group G.*

VEINS

CHARACTER

Folded quartz veins of the metasedimentary rocks

Folded quartz veins of the metasedimentary rocks occur only in the Murdama siltstone, where they invariably parallel the bedding. If bedding is deformed, the enclosed quartz veins are also deformed, such that veins are thickest on the crests of folds and thinnest on the flanks. On strike, veins pinch, swell, and locally form segmented boudins. Contacts of veins appear sharp, but are actually zones of thinly interlaminated quartz and wall rock.

Quartz within veins is commonly laced with red iron oxide and coated with black manganese. No sulfides were observed within veins, and no alteration halos occur in the adjacent siltstone. Average vein thickness is 5 cm, but widths as small as 0.5 mm and as large as 8 cm are locally present.

Folded quartz veins, which preceeded Murdama folding, represent the oldest quartz vein event at Ar Rahail. They are thought to have originated during the early stages of the metamorphic-tectonic episode that produced the folding. The widespread veins are the primary source for the quartz lag deposits so abundant in the surrounding region (du Bray, 1983, p. 9; Williams, 1983, p. 10, 22).

Stockwork quartz veins of the Rahail stock

Stockwork quartz veins of the Rahail stock are so named because they form "stockworks" of numerous intersecting vein trends in the Rahail cupola, west dike, east dike, and local areas of adjacent siltstone (pl. 1). Individual veins are sharply bounded, linear, continuous over at least several meters, and slightly tapered on strike. No ferruginous alteration halos are present in adjoining porphyry or siltstone country rock. Most veins are locally vuggy, barren white quartz, but traces of orange iron oxide and rare pseudomorphs of pyrite occur along some parting surfaces. Molybdenite rosettes as much as 2 mm in diameter are present in veins of the cupola.

Stockwork quartz veins are most abundant and largest within the Rahail cupola. Veins less than 1 cm wide average 12 per 30-cm interval near contacts, but 20 per 30-cm interval in the interior. Veins greater than 1 cm wide are rare near contacts, but reach 4 per 30 cm in the interior. The average thickness of the greater-than-1 cm-wide veins is 3 cm. Vein trends are variable, but strikes of N. 20° E. and N. 30° W. are typical.

Visible molybdenite occurs only in veins wider than 4 cm. The average molybdenite-bearing vein is 20 cm wide, and the largest is 45 cm. Most of the large veins are restricted to the interior of the cupola, where they strike west-northwest and dip northeast.

In dikes, the average stockwork-vein density is 6 per 30-cm interval and the average width is less than 1 mm. Vein density and width are greatest in the wider portions of the dikes and both decrease towards the narrower southern dike extensions. No dominant vein trend was observed.

In the Murdama siltstone, stockwork veins transect bedding as much as 9 m from the cupola contact and 13 m from the contact with the larger portions of the west dike. Stockwork veins cut the contact between porphyry and siltstone, and where observed, are generally normal to it. Most stockwork veins in the Murdama are 1 or 2 cm wide.

The undeformed stockwork quartz veins post date the folded quartz veins of the metasedimentary rocks, but are cut by the barren quartz veins of the ore zones of the ancients. The localization of stockwork veins within and adjacent to intrusive masses strongly suggests that the veins were produced by a mineralizing event associated with crystallization of the magma.

Barren quartz veins in the ore zones of the ancients and subsidiary structures

Barren quartz veins occur within the ore zones of the ancients and subsidiary ferruginous structures. Larger veins, which range in width from 20 to 60 cm, and are typical of the main ore zones, are white, and contain contact-paralleling fractures coated with red iron oxide. Crack-seal textures, a common indication of multiple injection, however, are lacking (Colvine and others, 1984, p. 14). Most veins are devoid of sulfides, although trace stibnite was observed in one sample.

Smaller veins, which range in width from 1 mm to 5 cm, and are present in the subsidiary ferruginous structures, are either white or gray, and commonly show red-iron-oxide or black-manganese staining. Vugs as much as 5 cm long, larger than in the stockwork vein type, are characterized by inward penetrating gray quartz crystals, coatings of yellow-brown iron oxide, and local carbonate. Iron-oxide pseudomorphs of pyrite are present locally, but fresh pyrite is rare.

Both large and small veins pinch and swell on strike, generally varying directly with the size of the enclosing structure and ferruginous alteration halo. Measurement and analysis of 173 of the smaller quartz veins shows no systematic change in density or width with proximity to outcrops of either the dikes or cupola of the Rahail stock. Smaller quartz veins average 1.6 per 10 meters in trench exposures throughout the area.

Barren quartz veins in the ore zones of the ancients transect and locally displace stockwork quartz veins, but are cut by veins of carbonate.

Carbonate Veins

Brown carbonate veins, generally less than 2 mm in width, follow joints, ferruginous slips, and the boundaries of stockwork type quartz veins in the Murdama siltstone. Carbonate veins that occur within ferruginous structures commonly parallel, and locally crosscut the enclosed quartz veins. They represent the youngest episode of veining at Ar Rahail, and are probably a result of near surface weathering.

FLUID INCLUSIONS

Fluid inclusions in four quartz vein samples from Ar Rahail were studied by Kamilli (written commun., 1986). One stockwork quartz vein from the Rahail stock has abundant inclusions of micron and sub-micron size. Although direct measurements could not be made, high filling temperatures are suggested by the presence of large vapor bubbles in liquid-rich inclusions.

Twenty one measurements on three samples of barren quartz veins from the ore zones of the ancients yield mean filling temperatures of 287^{o} C on two-phase CO_2-bearing liquid-rich inclusions, and mean filling temperatures of 302^{o} C on three-phase CH_4 and liquid CO_2-bearing liquid-rich inclusions. The range of temperatures is 261^{o} to 319^{o} C and the average is 295^{o} C. Measurements on six inclusions from one sample yield a mean salinity of 1.0 NaCl equivalent weight percent. According to Kamilli, the inclusions upon which these measurements were made "are probably representative of the hydrothermal fluids that formed the veins which contain them" (Kamilli, written commun., 1986).

Younger episodes of quartz veining, evident in thin section, are indicated by 1-mm-wide drusy quartz veins that cut the stockwork vein type and by 1-mm-wide vuggy, fluid inclusion-poor quartz veins that cut the barren veins of the ore zones of the ancients. The mean of five measurements on the drusy veins gives a filling temperature of 210^{o} C, whereas a mean of three measurements on the vuggy variety gives 276^{o} C. These episodes of quartz veining are thought to represent only minor, late injections of possibly remobilized silica, but they do attest to the presence of additional complexities on a microscopic scale.

CHEMISTRY

The chemistry of the quartz veins, based on samples selected to include only veins and no wallrock, show that the folded quartz veins contain more iron, manganese, calcium, barium, strontium, rubidium, and zinc, than other vein types; that the stockwork quartz veins contain high molybdenum, but little barium, strontium, rubidium, and zinc; and that the barren quartz veins lack significant quantities of any reported element (table 5) (Appendix 3). The contrasting chemistry confirms the uniqueness of each event and suggests different sources for the contained elements.

The iron and calcium of the folded quartz veins are elements that might be expected in the mafic constituents of Murdama rocks (Cole, 1985, p. 21) and manganese, barium, strontium, rubidium, and zinc are typically high in shales worldwide (table 3). Their occurrence in the folded quartz veins suggests either the presence of minute shale inclusions in the selected quartz samples, or the incorporation of these elements in the metamorphogenic fluids that are thought to have produced the quartz veins. Anomalous molybdenum, unique to the stockwork veins, probably originated in the magma that produced the Rahail stock.

STRUCTURE

The large-scale structural elements at Ar Rahail include, from oldest to youngest: 1) a minor northwest-plunging fold in Murdama metasedimentary rocks, 2) northwest-oriented tension fractures along which mafic dikes were emplaced, 3) northeast-oriented fractures along which granodiorite porphyry dikes were injected, 4) minor northwest-trending fractures that may offset porphyry dikes, and 5) the northwest-trending faults that contain the ore zones of the ancients (pl. 1). The most significant of these, with respect to gold mineralization, are the faults that contain the ore zones of the ancients.

Although the ore-zone faults show ample evidence of compression-caused movement in the form of broken zones and argillized gouge, in no place do main gold-bearing structures intersect or displace dikes of the Rahail stock. This holds true even where major ore structures project across the dikes, as at the ancient workings of Group G (pl. 1). Perhaps the northwest-trending faults, which developed in a compressional tectonic regime, were later opened by a tensional event, such as doming caused by emplacement of the Rahail stock. The faults would then have become open features, ready to accept the subsequent injection of the gold-bearing fluids that produced the ancient ore zones.

GEOPHYSICS

Telluric-electric (TE) profiles were made on four east-west traverses 500-750 m long and one north-south traverse 1250 m long across the crest of the hill at Ar Rahail by C. Zablocki (personal commun., 2/19/85) according to the method outlined by Flanigan and Zablocki (1984). These measurements, confirmed by Audio-magnetotelluric (AMT) soundings, define a northeast-trending anomaly 380 m long and 150 m wide that is believed to outline the subsurface configuration of the main mass of the Rahail stock, the top of which is about 50 m deep (pl. 1) (Zablocki, personal commun., 1985).

The ancient ore zones of Group G, located above and immediately adjacent to the southern end of the subsurface main mass, as outlined by geophysics, contain the highest gold and arsenic values of any ancient ore zone at Ar Rahail. These ore zones also contain the widest ore structures, thickest quartz veins, and the only occurrence of structure-related silicified siltstone in the map area. Perhaps the zones of Group G overlie an unexposed high on the main mass of the Rahail stock, and, if so, further imply a close genetic relationship between intrusive and gold-bearing quartz veins.

GOLD QUANTITY AND DISTRIBUTION

The highest gold content of any ancient ore zone at Ar Rahail is 4200 ppb across 0.7 m (Trench #21, table 6) (pl. 2). Gold values between 1000 ppb and 2000 ppb occur in three additional zones across intervals as wide as 0.5 m, but these are exceptional (Trenches #1, #3, #9, #10, table 6). The average gold content of the ancient ore zones is 384 ppb (table 3).

The maximum average gold content of any ancient mine group, derived from the five-meter trench samples, is 125 ppb (Group C, table 7). The average of all 250 trench samples is 86 ppb. If the averages of trench samples are calculated by reducing all gold values over 100 ppb to 100 ppb in order to eliminate spurious highs, the averages show a general decrease in gold away from outcops of the Rahail cupola (Figs. 11 and 12) (pl. 2). Although the distribution of other elements, such as As, Ba, and Zn were also plotted, only gold shows a systematic variation.

The structures with the highest gold content and the trenches with the highest average grade occur in Groups A, C, D, and G.

Table 6.--Gold content of selected samples from ancient ore zones with gold values greater than 1000 ppb.

Sample No.	Trench	Group	Sample Interval (m)	Au (ppb)	Comments
214408	1	A	0.3	1600	main ore zone
214409	1	A	0.5	1700	adjacent to main ore zone
214420	3	A	0.3	1040	adjacent to main ore zone
214421	3	A	0.4	1030	main ore zone
214467	9	D	0.4	1200	main ore zone
214473	10	D	0.3	1330	main ore zone
214587	21	G	0.7	4200	adjacent to main ore zone

Table 7.--Average gold content of each trench group.

Trench Group	Average Au (ppb)	Trench Group	Average Au (ppb)
A	91	F	35
B	51	G	113
C	125	H	45
D	121	I	74
E	91	J	33

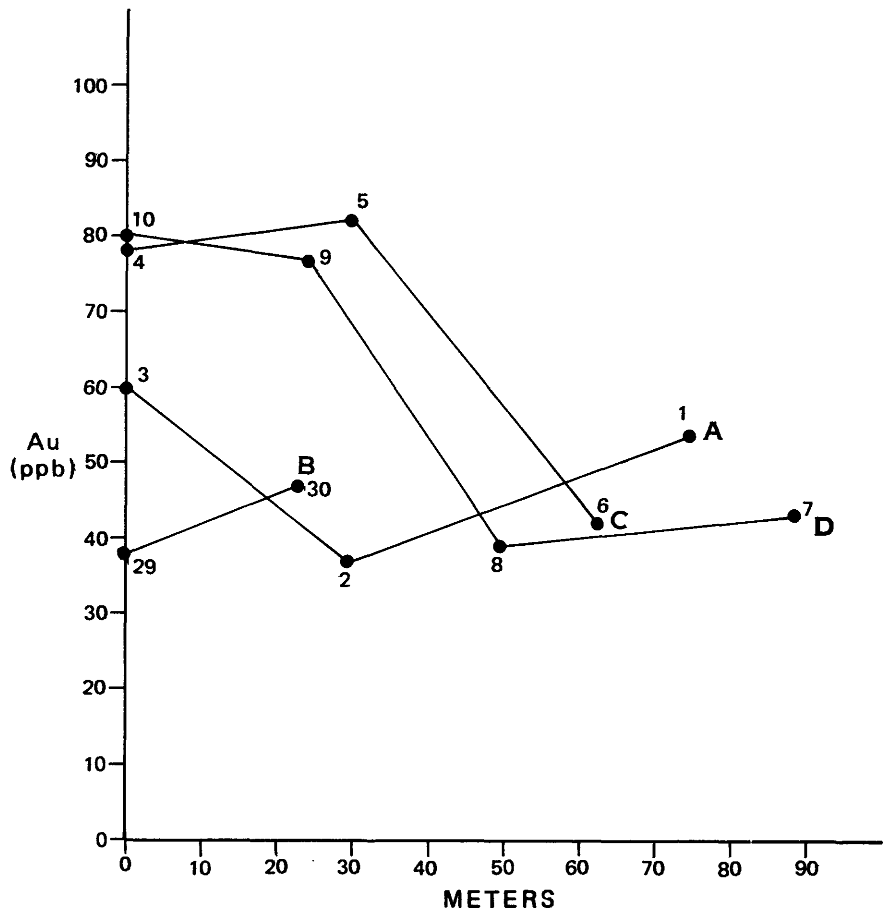

Figure 11.--*Graph showing the average amount of gold within each trench in Groups A through D versus distance away from the trench nearest the cupola in each group. Values over 100 ppb are considered as 100 ppb to eliminate spurious high values.*

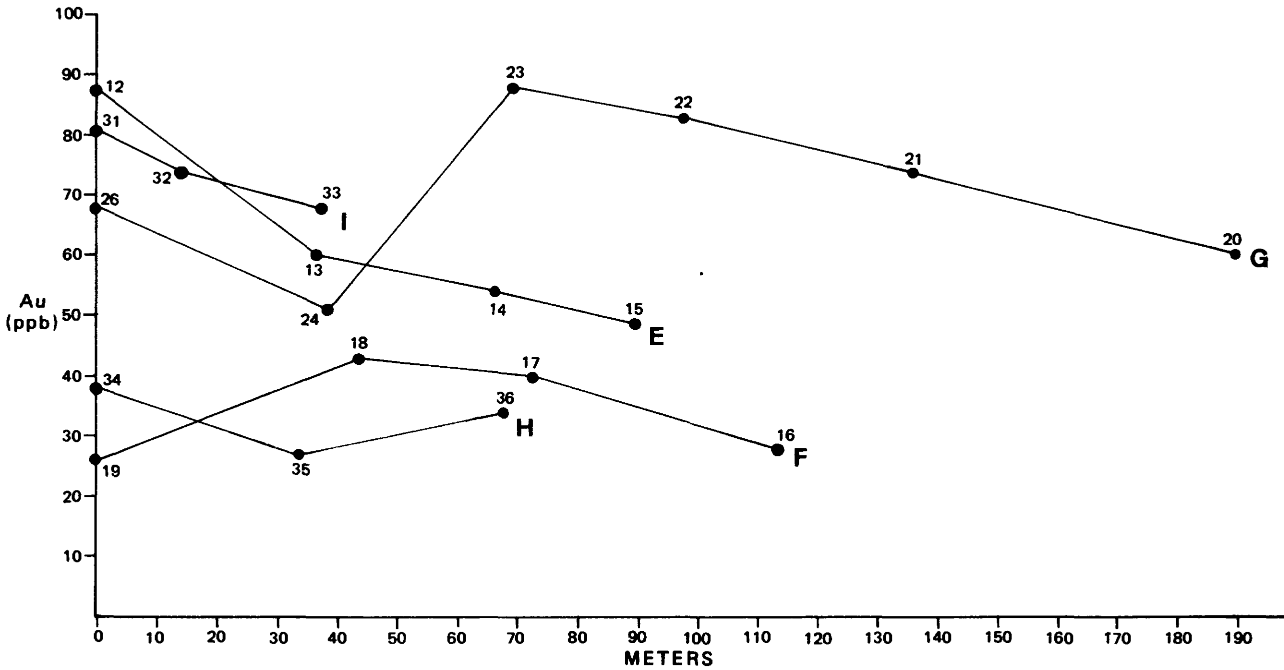

Figure 12.--*Graph showing the average amount of gold within each trench in Groups E through I versus distance away from the trench nearest the cupola in each group. Values over 100 ppb are considered as 100 ppb to eliminate spurious high values.*

SUMMARY AND CONCLUSIONS

SEQUENCE OF EVENTS

In summary, field relationships indicate the following sequence of events.

1. Deformation of the Murdama producing northwest-trending folds and contemporaneous metamorphogenic fluids that precipitated to form the folded quartz veins of the metasedimentary rocks.

2. Development of northwest-trending tension fractures along which mafic dikes were injected.

3. Formation of northeast-trending fractures.

4. Emplacement of dikes and cupola of the Rahail stock with concomittent stockwork quartz veining and hydrothermal alteration.

5. Formation of minor northwest-trending fractures that may locally displace the dikes.

6. Precipitation of gold, as well as barren quartz veins, in the ore zones of the ancients and subsidiary ferruginous slips.

7. Development of late carbonate veining, probably through near-surface weathering.

ORIGIN OF FLUIDS

The clustering of ancient ore zones within a stock-centered area of fluid movement, as defined by the alteration zones, suggests that gold precipitated from fluids that circulated in response to the heat of the intrusive. The younger age of the ancient ore zones, compared to the stock-related molybdenum-producing hydrothermal event, suggests that the gold-bearing fluids originated outside the stock.

In addition, the chlorite and sericite zones at Ar Rahail contain the same mineral assemblages as the propylitic and phyllic zones associated with porphyry copper deposits of southwestern North America (Titley and Beane, 1981, p. 238-239). The most widely accepted model for the origin of alteration zones around these deposits is the two-fluid model proposed by Shepard and others (1969) (Beane and Titley, 1981, p. 249). According to this concept the high salinity, high K/H fluids generated from the magma produce the inner potassic alteration zone, but low salinity, low K/H fluids, believed to have originated as formation water, form the outer propylitic and phyllic zones. By analogy, we suggest that the chlorite and sericite zones at Ar Rahail may also have been caused by the passage of heated formation water.

SOURCE OF GOLD

The origin of the gold at Ar Rahail remains in question. The localization of gold-bearing structures adjacent to the Rahail stock, the systematic decrease in the average gold content of these structures away from the cupola, and the concentration of maximum gold values above an unexposed, geophysically-defined part of the stock, strongly suggest a genetic link between the gold and the intrusive. The nature of this link, however, is less certain. The gold may have originated in the magma and passed into the ancient ore zones via cupola-produced hydrothermal fluids, or the gold may have existed in the adjacent Murdama country rocks and have been leached by cells of circulating formation water generated by the heat of the stock. That the cupola was a volatile collection area and a source of mineralizing fluids is amply demonstrated by the presence of crenulate quartz veins and micrographic textures, as well as the relative concentration, size, and abundance of stockwork quartz veins contained within it. The evidence for cells of circulating formation water in the form of propylitic and phyllic alteration zones is equally compelling.

Trace-element chemistry is not definitive. Arsenic, highly anomalous in the gold-bearing structures, is typical of many gold deposits throughout the world, regardless of origin (Boyle, 1979, p. 143-144), and cannot be used to verify a magmatic source. Molybdenum, highly anomalous in the stockwork veins, might be considered a signature for magmatic source and as it is depleted in the ancient ore zones suggest that elements of the ore zones had no magmatic component. An alternative, however, is that the same hydrothermal event that produced hypogene molybdenite at the source cupola could have developed epigenetic gold at a greater distance.

The observation by Cole (1984, p. 10) that gold-bearing veins in the Murdama are spatially associated with plutons of varying composition is the most telling indication that the intrusives acted only as sources of heat and not of gold. However, the possibility of gold originating in the magma, at least in part, cannot be ruled out at Ar Rahail.

ORE-FORMING PROCESS

The ore-forming process at Ar Rahail began with emplacement of the Rahail stock. Initial injection of granodiorite porphyry dikes, mostly along *en echelon* northeast-trending fractures striking sub-parallel to bedding of the Murdama siltstone, was followed by crystallization and volatile concentration that produced indigenous stockwork quartz veins within and immediately adjacent to the dikes. Areas of greater dike size developed larger and more abundant veins.

Dike injection was followed by emplacement of the main mass of the Rahail stock, outlined by geophysics to be present within 50 m beneath the present erosion surface, but exposed only as a small cupola of monzogranite porphyry. Crystallization of the main mass produced late magmatic interstitial potassium feldspar, and later volatile concentration that developed micrographic textures, apatite-bearing crenulate quartz layers, probable hydrofracturing, and molybdenite-bearing stockwork quartz veins in the cupola. In addition, the emplacement of the main mass may have opened pre-existing northwest-trending faults normal to the bedding of the Murdama siltstone.

The heat of the intrusion may have generated formation water-fed convection cells that altered the earlier dike rocks creating an inner sericite zone, nearest the cupola, and a chlorite zone farther out. In the sericite zone, oligoclase altered to albite, and mafic minerals to white mica and sericite. In the chlorite zone, oligoclase altered to albite, but hornblende changed to secondary biotite and chlorite, and primary biotite to white mica. Pyrite was distributed throughout the sericite zone, and locally in the chlorite zone.

The silica-bearing fluids, with mean temperatures of 295^{o} C, passed through the Murdama siltstone, and possibly leached constituents, principally gold and arsenic, although the possiblity of a magmatic contribution for some of these elements cannot be ruled out. Fluids were concentrated in the highly permeable open fractures where they precipitated quartz in the central portions and gold, arsenic, iron, and other elements in the adjacent gouge and fractured rock of the fault zones. Gold also formed in minor fractures along contacts between siltstone and intrusive rocks and probably in rare fractures within the margins of the intrusions.

Minor episodes of fluid injection may be recorded by a few parting surfaces in the larger quartz veins, and by rare microscopoic cross-cutting veinlets, but the absence of megascopic crack-seal textures suggests that widely disparate ages of major quartz veining are not present and that the formation of the ore zone of the ancients was essentially one event. The relative decrease in gold content with increasing distance from the cupola may reflect temperature gradients generated by the main mass of the Rahail stock.

ECONOMIC POTENTIAL

The individual ore zones of the ancients at Ar Rahail are not, in themselves, mineable. Assuming that the structure with the highest grade (Trench #21) maintained that grade over its maximum width of 1.2 m, strike length of 40 m, and depth of 100 m, the structure would contain 12,960 tonnes averaging 4.2 g/t, or only 54 kg of gold. The longest, most persistent structure, which has a maximum width of 0.4 m, strike length of 90 m, and depth of 100 m, would have

9720 tonnes averaging 1.3 g/t, or about 13 kg of gold. Structures containing less than 100 kg of gold include 58 percent of the gold occurrences in Saudi Arabia, (Boyle and others, 1984, p. 57). The above calculations assume a density factor of 2.7.

The ancient ore zones are clustered in Murdama siltstone around the edges of an exposed cupola. Presuming that this spatial association indicates a genetic relationship, it seems reasonable to assume that, if the flanks of this cupola dip gently beneath the surface, the siltstone between the top of the intrusive and the surface might contain sufficient gold between structures to warrant bulk mining. The data clearly indicate, however, that the structures defined by the ancients contain most of the gold. Samples from trenches that were placed in areas of ancient workings probably give an artifically high value for the bulk of the rock, but even the overall average of these samples is only 0.086 g/t (86 ppb), far below that considered by most miners for bulk mining (Mining Journal, 1983, p.201).

There is no evidence to suggest that the gold quantity or grade at surface should increase with depth. No further work is recommended.

DATA STORAGE

DATA FILE

A Data-File (USGS-DF-06-07) that contains trench maps, petrographic descriptions, fluid inclusion information, analytical data, field notes, and thin sections has been established in the Jeddah office of the U.S. Geological Survey Saudi Arabian Mission.

MINERAL OCCURRENCE DOCUMENTATION SYSTEM

The existing MODS file on the Ar Rahail mineral occurrence (MODS 03272) was updated in December, 1986.

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APPENDIX No. 1.--Analytical data for the ore zones of the ancients

[Au in ppb; Fe, Mg, Ca, Ti in percent; all other elements in ppb). AA = atomic absorption; COL = colorimetry; SES = Semiquantitative emission spectrography. G = greater than value shown; L = element detected, but below limit of determination or below value shown. N = not detected].

SAMPLE NO.	TRENCH	SAMPLE WIDTH (M)	SES Fe	SES Mg	SES Ca	SES Ti	SES Mn	SES Ba	SES Sr	COL W	SES Sn	SES Mo	AA Bi	SES Zr	AA Au	AA As	AA Sb	AA Ag	AA Cu	AA Pb	AA Zn	SES Co	SES Ni	SES Cr	SES V
214408	1	0.5	5	1	1	0.2	500	500	200	20	N	20	12	100	1600	1400	9	0.2	26	18	66	10	50	200	200
214409	1	0.5	5	0.7	1	0.2	500	300	200	15	N	N	1	100	1700	4000	9	L(.1)	21	13	30	10	20	100	200
214415	2	0.5	5	1	3	0.2	300	500	500	6	N	N	3	100	180	1000	12	L(.1)	17	14	50	5	30	150	150
214420	3	0.3	5	1	2	0.2	700	500	150	4	N	N	N	100	1040	850	12	N	86	9	107	10	50	200	200
214421	3	0.4	5	1	1	0.2	500	500	150	20	N	10	N	100	1030	4000	16	0.18	40	25	67	10	50	150	300
214450	4	0.2	5	2	2	0.1	500	500	100	1	N	N	N	100	140	2200	15	N	42	12	65	10	100	300	200
214451	4	0.1	5	0.7	2	0.1	500	500	100	N	N	10	N	50	240	1300	12	N	76	8	50	10	50	500	100
214452	5	0.03	5	2	2	0.2	500	700	200	7	N	L	N	100	120	1600	22	0.11	45	9	70	30	70	300	200
214453	6	0.2	5	0.7	3	0.2	500	500	100	11	N	L	N	70	700	2300	30	0.12	36	15	50	5	30	200	100
214454	6	0.5	10	1	5	0.15	1500	1000	200	N	N	10	N	150	140	2200	42	L(.1)	61	57	160	20	70	100	100
214455	7	0.06	5	2	2	0.2	500	500	200	50	N	L	N	100	950	2200	20	L(.1)	52	13	60	10	100	200	200
214456	7	3.0	3	2	7	0.2	500	500	500	N	N	15	N	70	270	250	5	N	34	7	45	5	30	300	100
214457	8	0.1	5	2	7	0.2	500	500	150	N	N	L	N	70	110	800	15	L(.1)	44	12	85	5	70	200	150
214458	8	0.1	5	3	3	0.2	500	500	150	N	N	N	N	100	22	1100	L(5)	N	40	6	45	10	50	500	100
214465	9	0.2	5	2	7	0.3	500	500	200	N	N	N	N	100	59	2000	8	N	40	9	85	10	50	500	200
214466	9	0.1	2	1	7	0.2	500	500	200	N	N	N	N	30	110	200	N	N	20	6	35	5	20	300	100
214467	9	0.4	5	1	7	0.3	500	500	L	N	N	N	N	50	1200	2000	6	.14	41	10	62	7	30	200	150
214472	10	0.3	5	0.5	7	0.2	500	500	L	N	N	N	N	30	400	250	10	0.2	12	80	47	N	10	500	300
214473	10	0.3	7	3	7	0.5	500	700	300	N	N	N	N	100	1330	150	N	L(.1)	50	8	90	20	70	500	300
214483	11	0.1	5	1	5	0.2	500	500	150	N	N	L	N	70	130	2000	17	0.16	22	10	50	5	20	200	200
214484	11	0.1	5	5	1.5	0.2	500	500	200	N	N	N	N	70	6	150	N	0.11	30	5	50	10	30	150	200
214504	13	0.05	0.5	0.07	0.2	0.01	150	70	N	N	N	15	N	100	79	250	L(1)	0.15	6	2	5	N	10	100	10
214405	13	0.3	2	0.5	0.5	0.1	500	70	N	N	N	15	N	50	88	116	N	L(.1)	9	1	25	N	20	150	30
214506	13	0.1	5	1	5	0.05	700	500	150	N	N	40	N	100	130	1200	9	N	35	8	70	15	50	200	150
214507	13	0.1	5	0.1	1	0.02	200	70	N	N	N	10	3	20	20	330	N	0.2	8	50	15	N	70	100	20
214522	14	0.05	2	0.5	0.7	0.1	200	200	N	N	N	10	N	50	120	170	N	L(.1)	9	7	15	5	20	200	100
214523	14	0.1	5	2	5	0.15	1000	500	500	2	N	50	N	50	81	1000	N	L(.1)	170	6	250	30	50	200	150
214535	15	0.5	1	1	1.5	0.02	200	150	N	N	N	L	N	10	25	570	N	L(.1)	5	8	9	N	10	200	10
214543	16	0.1	5	0.5	1	0.1	500	200	N	N	N	10	N	50	61	160	L(1)	0.2	44	7	32	10	30	200	150
214544	17	0.1	2	0.5	1	0.1	500	200	N	N	N	5	N	30	99	500	N	0.15	19	5	23	5	30	300	100
214555	17	0.2	5	1	1	0.15	500	200	N	N	N	20	N	50	65	200	L(1)	L(.1)	48	22	70	10	30	200	200
214556	17	5.0	5	0.7	2	0.1	500	200	100	N	N	7	N	30	37	1600	6	L(.1)	15	15	26	5	30	300	200
214557	17	0.5	5	0.7	0.5	0.1	200	150	N	N	N	15	N	50	19	140	N	L(.1)	43	5	45	5	20	100	100
214570	18	0.05	5	0.5	1	0.2	300	200	100	N	N	35	N	100	111	2100	N	0.1	22	8	40	5	20	100	200
214571	18	0.2	5	2	2	0.2	500	500	500	N	N	10	N	100	7	60	N	L(.1)	22	4	33	10	50	100	150
214572	18	0.2	1	0.2	0.5	0.02	300	150	N	N	N	20	N	15	68	430	N	L(.1	6	4	7	N	10	100	30
214579	19	0.6	2	0.5	1.5	0.05	500	150	N	N	N	30	N	30	160	1400	L(1)	0.1	15	3	16	5	20	200	70
214580	20	0.1	5	1	2	0.05	500	200	L	N	N	5	N	20	104	400	L(1)	0.1	52	7	41	10	50	200	100
214587	21	0.7	5	0.2	0.5	0.2	100	100	N	N	N	20	N	10	4200	1000	13	0.25	11	34	13	N	50	200	50
214595	22	0.1	2	1	7	0.2	500	150	100	N	N	10	N	50	22	50	N	L(.1)	20	4	37	N	30	200	50

APPENDIX No. 1.--Analytical data for the ore zones of the ancients--Continued

SAMPLE NO.	TRENCH	SAMPLE WIDTH (M)	SES Fe	SES Mg	SES Ca	SES Ti	SES Mn	SES Ba	SES Sr	COL W	SES Sn	SES Mo	AA Bi	SES Zr	AA Au	AA As	AA Sb	AA Ag	AA Cu	AA Pb	AA Zn	SES Co	SES Ni	SES Cr	SES V
214596	22	0.6	0.7	0.2	0.5	0.02	500	70	N	N	N	10	N	10	230	1200	L(1)	0.4	80	17	8	N	L	100	20
214635	22	0.3	5	0.7	7	0.5	1000	200	L	N	N	5	N	70	600	1100	7	N	30	5	72	5	30	150	150
214610	23	1.0	1	0.2	1.5	.015	100	100	100	N	N	20	N	N	90	1000	3	L(.1)	5	3	5	N	7	150	30
214611	23	0.2	3	0.7	2	.03	1500	150	L	N	N	N	N	20	20	260	3	L(.1)	47	3	80	N	10	100	100
214622	24	0.2	3	0.2	0.7	0.5	1000	150	L	N	N	7	8	50	290	900	5	N	43	4	43	N	20	70	150
214623	24	0.1	3	0.2	0.7	0.15	300	150	L	N	N	N	N	20	300	270	4	L(.1)	41	4	20	N	10	70	100
214638	26	0.1	5	3	7	.3	700	500	100	N	N	5	N	150	290	600	3	L(.1)	48	7	77	15	50	100	150
214639	26	0.3	7	3	1	.5	1000	300	L	N	N	8	N	150	400	650	4	L(.1)	6	2	12	15	50	70	150
214640	26	0.5	5	7	1.5	.3	700	300	150	N	N	5	N	100	960	1400	24	L(.1)	5	50	12	15	50	150	150
214636	27	0.1	0.5	0.7	.07	.7	150	150	L	N	N	N	2	N	180	290	6	0.2	4	22	10	N	N	70	15
214637	28	0.3	L	.05	.5	.01	100	N	L	N	N	N	2	N	700	700	8	L(.1)	4	10	5	N	N	70	10
214677	32	0.1	3	.5	1.5	.2	200	150	200	50	N	5	N	30	290	270	91	L(.1)	35	9	91	N	10	100	200
214682	33	0.05	.2	.05	.2	.01	20	N	200	N	N	5	N	N	71	65	5	L(.1)	4	10	5	N	N	100	10
214689	34	0.2	3	.7	5	.2	500	200	100	N	N	5	1	N	50	220	34	L(.1)	40	6	34	N	N	50	50
214693	35	0.2	3	.15	20	.07	1500	150	150	N	N	10	N	20	6	170	35	L(.1)	23	6	35	10	20	500	70
214703	36	0.1	2	.3	5	.15	1000	300	150	7	N	10	N	20	27	95	40	L(.1)	21	6	40	10	30	700	70

APPENDIX No. 2.--Analytical data for trench samples.

[Au in ppb; Fe, Mg, Ca, Ti in percent; all other elements in ppm. AA = atomic absorption; COL = colorimetry; SES = Semiquantitative emission spectrography. G = greater than value shown; L = element detected, but below limit of determination or below value shown, N = not detected, ND = no data.]

ANALYTICAL METHOD			SES	SES	SES	SES	SES	SES	SES	COL	SES	SES	AA	SES	AA	AA	COL	AA	AA	AA	AA	AA	SES	SES	SES	SES
SAMPLE NO.	TRENCH NO.	TRENCH INTERVAL (m)	Fe	Mg	Ca	Ti	Mn	Ba	Sr	W	Sn	Mo	Bi	Zr	Au	As	As	Sb	Ag	Cu	Pb	Zn	Co	Ni	Cr	V
214403	1	0-5	5	3	2	0.2	500	300	200	3	N	N	N	100	12	-	155	L(5)	0.16	57	8	56	10	50	100	150
214404	1	5-10	5	1	2	0.2	500	700	200	15	N	5	4	150	400	850	-	7	0.16	62	21	115	10	50	100	200
214405	1	10-15	5	1	3	0.2	500	500	300	18	N	10	N	101	300	1100	-	15	L(.1)	44	14	77	10	50	100	200
214406	1	15-20	3	2	5	0.2	500	300	150	3	N	N	3	100	36	-	360	6	L(.1)	43	7	85	10	50	100	150
214407	1	20-25	3	3	5	0.2	500	500	700	7	N	N	N	100	24	-	60	L(5)	N	49	10	100	10	50	100	150
214410	2	0-5	5	3	1	0.2	500	500	300	N	N	N	2	100	7	-	75	L(5)	N	46	8	88	10	50	200	150
214411	2	5-10	5	3	1	0.2	500	500	500	N	N	N	2	100	14	-	80	5	N	43	6	90	10	50	200	150
214412	2	10-15	5	3	1	0.5	500	900	500	8	N	N	2	200	130	200	-	5	N	38	8	95	15	50	300	150
214413	2	15-20	5	2	1	0.5	300	500	200	5	N	N	N	100	43	-	260	5	0.1	40	12	107	10	50	100	150
214414	2	20-25	3	3	2	0.5	500	500	200	2	N	N	N	100	21	-	160	L(5)	L(.1)	52	8	106	10	50	150	150
214416	3	0-5	5	3	2	0.2	500	500	300	3	N	N	N	100	78	350	-	L(5)	N	50	7	100	20	50	200	200
214417	3	5-10	5	3	1	1	500	500	150	4	N	N	2	100	170	500	-	9	N	52	7	100	15	50	500	150
214418	3	10-15	5	3	1.5	ND	500	500	150	1	N	N	N	100	34	-	330	7	L(.1)	47	6	90	15	50	200	200
214419	3	15-20	5	3	1	0.2	500	500	150	19	N	10	N	100	27	-	105	L(5)	L(.1)	55	7	95	15	50	200	200
214422	4	10-15	5	3	2	0.2	700	500	200	N	N	N	N	100	19	-	270	5	N	29	7	75	10	50	150	200
214423	4	5-10	5	3	5	0.2	500	700	500	N	N	N	N	150	99	-	350	12	L(.1)	36	9	86	20	50	200	200
214424	4	10-15	5	3	1.5	0.2	500	500	300	2	N	N	N	200	150	900	700	10	L(.1)	50	11	85	20	50	200	200
214425	4	15-20	5	3	1	0.2	300	500	200	1	N	N	N	200	280	425	320	7	L(.1)	60	8	86	10	50	200	200
214426	4	20-25	5	5	1.5	0.3	500	1000	300	1	N	N	N	200	76	-	210	5	N	43	8	85	10	70	200	200
214427	5	0-5	5	3	1.5	0.3	500	700	200	2	N	N	L(1)	150	11	-	235	8	N	52	13	100	15	70	150	200
214428	5	5-10	5	3	1	0.3	500	500	200	2	N	N	6	150	115	-	175	6	L(.1)	54	7	85	10	50	100	200
214429	5	10-15	5	2	1	0.3	500	500	100	3	N	N	5	100	130	700	600	16	0.1	55	15	87	5	50	100	200
214430	5	15-20	5	5	1.5	0.3	500	500	200	1	N	N	N	100	150	-	185	8	N	46	7	85	10	50	200	200
214431	5	20-25	5	3	1	0.2	500	500	300	N	N	N	N	100	460	-	185	9	N	52	7	92	10	50	100	200
214432	6	0-5	5	3	1.5	0.3	500	500	300	N	N	N	N	100	10	-	230	7	L(.1)	44	9	70	10	50	150	200
214433	6	5-10	5	3	1	0.3	500	200	200	N	N	N	N	100	55	-	250	10	L(.1)	45	9	85	10	50	100	200
214434	6	10-15	5	2	5	0.3	500	500	200	N	N	N	N	70	280	800	600	14	L(.1)	50	11	75	15	50	100	200
214435	6	15-20	5	3	2	0.2	500	200	200	N	N	N	N	70	33	-	230	6	N	37	7	55	10	50	150	150
214436	6	20-25	5	3	2	0.3	500	500	300	4	N	N	N	100	14	-	225	9	N	45	10	65	10	50	200	200
214437	7	0-5	5	3	5	0.2	500	500	500	6	N	N	L(1)	100	50	-	320	5	N	46	7	80	20	50	200	200
214438	7	5-10	5	5	2	0.7	500	700	200	5	N	N	5	70	320	-	175	8	L(.1)	48	9	90	7	50	200	200
214439	7	10-15	5	2	1	0.7	500	500	300	3	N	N	4	100	370	-	70	6	L(.1)	48	8	90	7	50	100	300
214440	7	15-20	5	3	5	0.5	500	200	300	N	N	N	5	50	26	-	55	5	N	38	6	95	7	50	200	300
214441	7	10-25	5	3	5	0.3	500	500	200	5	N	N	6	100	5	-	75	5	N	37	6	80	5	50	100	200
214442	7	25-30	5	3	5	0.3	500	500	500	N	N	N	6	100	6	-	200	N	N	38	6	70	10	50	150	200
214443	7	30-35	5	3	3	0.2	500	500	200	1	N	N	N	100	14	100	-	10	N	35	6	75	10	50	200	100
214444	8	0-5	5	3	1	0.3	500	300	200	N	N	N	N	100	24	120	-	2	N	55	9	105	10	100	200	100
214445	8	5-10	5	3	5	0.3	500	700	100	2	N	N	N	150	19	200	-	15	N	45	15	115	10	70	200	150
214446	8	10-15	5	3	5	0.3	500	500	150	4	N	N	N	150	60	200	-	12	N	42	17	105	10	70	200	150

APPENDIX No. 2.— Analytical data for trench samples.—Continued

ANALYTICAL METHOD			SES	SES	SES	SES	SES	SES	SES	COL	SES	SES	AA	SES	AA	AA	COL	AA	AA	AA	AA	AA	SES	SES	SES	SES
SAMPLE NO.	TRENCH NO.	TRENCH INTERVAL (m)	Fe	Mg	Ca	Ti	Mn	Ba	Sr	W	Sn	Mo	Bi	Zr	Au	As	As	Sb	Ag	Cu	Pb	Zn	Co	Ni	Cr	V
214447	8	15-20	5	3	2	0.5	500	500	150	5	N	N	N	100	240	200	–	5	L(1.)	58	7	75	10	100	200	100
214448	8	25-30	5	3	2	0.2	700	500	300		N	N	N	100	29	150	–	6	N	46	6	85	10	100	200	150
214449	8	25-30	5	3	2	0.2	700	700	300	2	N	N	N	100	8	150	–	45	N	48	8	85	15	70	200	150
214459	9	0-5	5	3	5	0.2	500	700	500	2	N	L	N	100	300	200	–	N	N	30	8	65	20	50	300	100
214460	9	5-10	5	3	7	0.2	500	700	700	5	N	N	N	200	56	270	–	N	N	50	14	80	15	100	200	100
214461	9	10-15	5	3	5	0.2	500	700	500	9	N	N	N	100	630	2000	–	L(5)	N	54	9	90	10	70	500	100
214462	9	15-20	5	3	5	0.2	500	700	300	2	N	N	N	100	130	300	–	N	L(.1)	41	8	70	15	50	300	100
214463	9	20-25	3	3	5	0.2	500	500	500	2	N	N	N	100	90	300	–	N	N	43	9	85	10	50	200	200
214464	9	25-30	7	3	3	0.5	500	500	150	3	N	N	N	150	13	1000	–	6	N	50	9	85	30	70	500	200
214468	10	0-5	7	5	7	0.5	700	500	500	3	N	N	N	100	130	1400	–	N	1	52	8	90	7	50	200	200
214469	10	5-10	7	5	5	1	500	500	300	2	N	N	N	100	170	260	–	N	L(.1)	46	9	80	10	50	200	300
214470	10	10-15	5	3	7	0.5	500	700	500	N	N	N	N	100	230	1500	–	8	L(.1)	50	11	100	10	50	500	300
214471	10	15-20	5	3	7	0.5	500	500	300	1	N	N	N	100	21	250	–	N	N	38	7	80	N	50	700	300
214474	11	0-5	10	5	5	0.5	500	700	300	2	N	N	N	70	39	150	–	N	N	43	7	87	10	50	500	200
214475	11	5-10	5	5	1	0.2	500	300	150	N	N	N	N	50	45	150	–	N	N	44	5	90	5	20	300	150
214476	11	10-15	5	3	5	0.5	500	500	200	4	N	N	N	100	10	1500	–	L(5)	L(.1)	32	9	72	10	30	200	200
214477	11	15-20	5	3	5	0.5	500	500	150	1	N	N	N	70	9	270	–	N	L(.1)	43	9	86	10	50	200	200
214478	11	20-25	7	5	5	0.3	500	500	200	N	N	N	N	100	80	270	–	N	N	50	6	90	10	50	200	150
214479	11	25-30	5	5	7	0.3	500	500	150	2	N	N	N	50	360	1000	–	L(5)	N	40	10	80	10	30	300	200
214480	11	30-35	7	3	5	0.5	500	500	150	1	N	N	N	100	76	250	–	N	N	44	8	90	10	30	200	200
214481	11	35-40	5	5	7	0.7	500	500	500	2	N	N	N	100	21	200	–	N	N	50	7	90	10	50	300	200
214482	11	40-45	5	3	2	0.5	500	500	100	1	N	L	N	100	110	220	–	N	0.25	46	7	90	10	50	100	200
214485	12	0-5	1	0.2	1	0.05	100	200	100	2	N	20	N	50	80	300	–	N	0.1	5	12	12	N	5	200	30
214486	12	5-10	1	0.2	1	0.05	100	500	100	2	N	20	N	100	37	300	–	N	L(.1)	2	15	9	N	L	150	15
214487	12	10-15	2	0.7	2	0.2	200	500	300	4	N	30	N	70	290	350	–	L(5)	0.14	4	6	19	N	10	200	50
214488	12	15-20	5	3	2	0.5	300	700	200	3	N	30	N	70	95	350	–	L(5)	0.12	40	7	77	10	30	200	200
214489	12	20-35	5	2	1	0.5	200	500	200	3	N	20	N	100	820	310	–	L(5)	L(.1)	40	8	90	10	30	200	200
214490	12	25-30	1	0.5	1	0.2	100	500	100	N	N	15	N	50	37	260	–	L(5)	0.1	8	9	25	N	10	200	70
214491	12	30-35	5	2	5	0.2	500	200	500	5	N	30	N	50	92	290	–	N	L(.1)	21	5	67	10	30	500	100
214492	12	35-40	3	1	1	0.2	500	200	500	2	N	30	N	70	20	250	–	N	L(.1)	18	5	50	5	30	300	70
214493	13	0-5	5	1	2	0.2	500	300	500	1	N	N	N	70	18	200	–	5	L(.1)	30	ND	66	10	30	100	200
214494	13	5-10	5	2	1	0.2	500	500	500	5	N	10	N	70	105	250	–	N	0.1	26	7	63	10	30	200	200
214495	13	10-15	3	2	2	0.2	500	500	500	4	N	10	N	100	25	200	–	L(5))	L(.1)	30	7	77	10	20	100	200
214496	13	15-20	2	1	1	0.2	200	700	200	N	N	20	N	100	81	1100	–	N	L(.1)	21	12	50	N	10	200	200
214497	13	20-35	5	3	2	0.5	500	700	500	6	N	20	N	100	44	400	–	L(5)	N	42	9	95	10	50	300	200
214498	13	25-30	5	2	1	0.5	500	700	500	2	N	20	N	70	150	350	–	L(5)	N	34	6	73	5	20	300	100
214499	13	30-35	2	0.5	2	0.05	150	500	150	1	N	10	N	70	69	350	–	N	N	ND	10	25	N	N	100	20
214500	13	35-40	5	2	2	0.5	200	700	200	1	N	20	N	100	43	350	–	N	N	36	14	90	7	30	150	200
214501	13	40-45	5	3	2	0.5	500	500	200	N	N	15	N	100	32	200	–	L(1)	L(.1)	42	9	85	15	70	100	200
214502	13	45-50	5	3	2	0.5	500	500	300	N	N	7	N	100	53	330	–	L(1)	L(.1)	50	6	100	15	70	100	200

APPENDIX No. 2.--Analytical data for trench samples--Continued

ANALYTICAL METHOD			SES	SES	SES	SES	SES	SES	SES	COL	SES	SES	AA	SES	AA	AA	COL	AA	AA	AA	AA	AA	SES	SES	SES	SES
SAMPLE NO.	TRENCH NO.	TRENCH INTERVAL (m)	Fe	Mg	Ca	Ti	Mn	Ba	Sr	W	Sn	Mo	Bi	Zr	Au	As	As	Sb	Ag	Cu	Pb	Zn	Co	Ni	C	V
214503	13	50-55	5	3	1	0.3	500	70	150	N	N	10	N	100	89	170	-	L(1)	L(.1)	42	5	70	10	50	150	200
214508	14	0-5	5	3	2	0.3	700	500	500	1	N	10	N	100	23	120	-	N	N	47	14	100	10	70	100	200
214509	14	5-10	5	5	5	0.5	500	500	500	6	N	10	N	100	39	90	-	N	L(.1)	43	10	110	7	50	100	200
214510	14	10-15	5	2	0.7	0.5	200	300	300	3	N	15	N	100	42	95	-	N	L(.1)	33	8	73	6	30	150	200
214511	14	15-20	5	2	1	0.2	200	300	150	4	N	10	N	100	27	200	-	N	N	35	10	75	10	50	100	200
214512	14	20-25	5	3	1	0.2	200	500	150	4	N	5	N	100	94	280	-	N	N	37	12	82	5	50	100	150
214513	14	25-30	5	3	1	0.3	500	200	200	N	N	5	N	100	55	240	-	N	N	42	6	105	10	50	100	200
214514	14	30-35	5	3	1	0.5	500	300	200	N	N	L	N	100	32	280	-	N	L(.1)	47	7	110	10	50	150	200
214515	14	35-40	5	3	1	0.5	200	200	200	1	N	L	N	100	120	750	-	L(1)	L(.1)	53	7	80	10	50	100	200
214516	14	40-45	5	3	5	0.5	700	500	500	1	N	10	N	100	118	340	-	L(1)	N	41	6	95	10	50	100	150
214517	14	45-50	5	3	1	0.2	500	500	L	1	N	10	N	100	102	450	-	N	L(.1)	42	8	76	5	50	100	200
214518	14	50-55	5	3	2	0.2	700	500	200	2	N	5	N	100	41	340	-	N	N	53	8	115	20	70	100	200
214519	14	55-60	5	3	5	0.2	500	300	500	1	N	N	N	100	30	290	-	L(1)	N	35	6	72	10	50	70	150
214520	14	60-65	5	3	5	0.2	500	500	200	N	N	N	N	30	40	100	-	N	N	41	5	86	10	50	100	200
214521	14	65-70	5	3	2	0.2	500	500	500	N	N	N	N	100	27	250	-	L(1)	N	60	7	100	20	50	150	200
214524	15	0-5	5	3	2	0.2	500	300	500	7	N	5	N	150	28	130	-	N	N	36	6	83	50	50	300	200
214525	15	5-10	5	3	2	0.2	700	300	500	N	N	N	N	100	33	160	-	N	N	38	8	90	20	50	100	100
214526	15	10-15	5	3	2	0.2	700	500	200	N	N	N	N	100	210	660	-	N	N	37	11	65	30	50	100	200
214527	15	15-20	5	3	2	0.2	1000	500	200	4	N	10	N	150	35	520	-	N	N	57	12	145	30	50	100	200
214528	15	20-25	5	3	2	0.2	500	500	200	N	N	15	N	200	42	650	-	N	L(.1)	42	16	140	30	50	100	200
214529	15	25-30	5	3	0.7	0.2	200	700	200	2	N	L	N	200	68	300	-	N	L(.1)	45	17	110	20	50	200	200
214530	15	30-35	5	3	2	0.2	500	700	300	2	N	10	N	150	54	240	-	L(1)	N	40	13	100	20	50	150	200
214531	15	35-40	5	5	5	0.7	200	700	500	3	N	10	N	200	63	300	-	L(1)	N	41	12	95	10	30	200	300
214532	15	40-45	5	5	2	0.5	500	500	150	6	N	5	N	150	18	260	-	L(1)	N	45	12	105	7	50	100	300
214533	15	45-50	5	5	2	0.5	500	500	200	23	N	N	N	200	79	300	-	L(1)	N	47	11	100	7	50	100	300
214534	15	50-55	5	5	1.5	0.7	300	500	200	1	N	N	N	200	10	180	-	N	N	46	12	95	10	50	100	300
214536	16	0-5	5	3	2	0.2	500	200	200	N	N	N	N	200	53	160	-	L(1)	N	31	6	70	10	50	100	100
214537	16	5-10	5	3	2	0.2	500	300	150	1	N	N	N	150	50	380	-	L(1)	N	45	10	85	10	70	100	200
214538	16	10-15	5	3	5	0.2	500	700	500	N	N	N	N	150	27	290	-	L(1)	L(.1)	42	10	85	10	50	100	200
214539	16	15-20	5	3	1	0.3	500	500	N	N	N	N	N	N	31	260	-	N	L(.1	50	12	95	15	70	150	200
214540	16	20-25	5	3	1	0.3	500	500	150	1	N	N	N	150	10	150	-	L(1)	N	45	9	107	15	70	100	200
214541	16	25-30	5	3	1	0.2	500	500	100	2	N	10	N	150	10	190	-	L(1)	0.15	40	10	72	15	70	200	200
214542	16	30-35	5	3	1	0.2	500	500	100	5	N	10	N	100	15	150	-	N	0.15	42	10	90	10	50	500	200
214545	17	0-5	2	3	2	0.2	500	300	200	4	N	N	N	70	126	890	-	N	N	17	6	70	5	30	100	100
214546	17	5-10	5	3	2	0.2	500	500	200	5	N	N	N	100	31	350	-	11	L(.1)	38	5	75	15	70	100	200
214547	17	10-15	5	3	5	0.2	500	500	300	N	N	N	N	70	47	260	-	N	L(.1)	41	8	76	10	50	100	200
214548	17	15-20	5	3	2	0.2	500	300	200	2	N	N	N	70	43	450	-	N	L(.1)	45	8	85	10	50	100	200
214549	17	20-25	3	3	2	0.15	500	200	200	N	N	N	N	50	24	170	-	N	L(.1)	53	7	82	5	20	100	100
214550	17	25-30	5	3	2	0.2	500	500	200	2	N	10	N	100	20	175	-	N	0.1	64	8	70	10	50	100	200
214551	17	30-35	5	3	2	0.2	500	500	300	N	N	N	N	150	8	140	-	L(1)	L(.1)	41	6	70	10	50	100	200

APPENDIX No. 2.-- Analytical data for trench samples--Continued

ANALYTICAL METHOD			SES	SES	SES	SES	SES	SES	SES	COL	SES	SES	AA	SES	AA	AA	COL	AA	AA	AA	AA	AA	SES	SES	SES	SES
SAMPLE NO.	TRENCH NO.	TRENCH INTERVAL (m)	Fe	Mg	Ca	Ti	Mn	Ba	Sr	W	Sn	Mo	Bi	Zr	Au	As	As	Sb	Ag	Cu	Pb	Zn	Co	Ni	Cr	V
214552	17	35-40	5	3	2	0.2	500	500	100	N	N	10	N	150	25	300	-	L(1)	L(.1)	56	11	92	10	70	150	200
214553	17	40-45	5	3	1	0.2	500	500	100	N	N	N	N	100	89	410	-	5	L(.1)	63	10	95	10	70	150	200
214554	17	45-50	5	3	2	0.2	500	500	300	N	N	10	N	100	14	85	-	L(1)	L(.1)	50	10	77	10	70	300	200
214558	18	0-5	5	3	1	0.2	500	500	300	N	N	15	N	150	29	450	-	N	L(.1)	42	10	105	15	70	100	200
214559	18	5-10	5	3	2	0.2	500	500	300	6	N	10	N	150	67	1300	-	L(1)	L(.1)	38	11	92	15	50	100	200
214560	18	10-15	5	3	1.5	0.2	300	500	200	5	N	10	N	100	35	240	-	N	L(.1)	45	10	86	10	50	100	150
214561	18	15-20	5	3	1	0.2	300	500	150	2	N	10	N	100	53	200	-	L(1)	0.15	45	13	103	10	50	150	200
214562	18	20-25	5	2	1.5	0.2	500	500	200	3	N	15	N	100	20	180	-	N	L(.1)	44	7	88	10	50	200	200
214563	18	25-30	5	3	5	0.3	500	700	500	1	N	15	N	100	16	120	-	L(1)	L(.1)	51	8	76	10	50	200	200
214564	18	30-35	5	3	2	0.2	500	700	500	N	N	10	N	150	34	110	-		L(.1)	46	ND	ND	10	50	150	150
214565	18	35-40	5	3	3	0.2	500	500	300	N	N	10	N	100	7	90	-	L(1)	0.1	45	8	72	10	50	100	200
214566	18	40-45	5	2	3	0.2	500	300	300	2	N	15	N	100	91	290	-	L(1)	L(.1)	50	8	67	10	50	100	200
214567	18	45-50	5	3	2	0.3	500	700	300	N	N	15	N	150	62	400	-	6	L(.1)	46	10	86	10	50	100	200
214568	18	50-55	5	2	3	0.2	500	700	300	1	N	N	N	100	99	750	-	N	L(.1)	53	11	90	10	50	100	200
214569	18	55-60	5	3	3	0.2	500	500	500	N	N	15	N	150	20	160	-	6	L(.1)	45	7	77	10	50	150	150
214573	19	0-5	5	2	3	0.2	500	700	500	3	N	5	N	100	21	370	-	N	L(.1)	37	10	83	10	50	100	200
214574	19	5-10	5	3	3	0.2	500	500	500	1	N	10	N	100	36	300	-	N	L(.1)	40	7	84	20	70	200	200
214575	19	10-25	5	2	2	0.2	500	500	300	N	N	10	N	200	14	170	-	L(1)	L(.1)	34	5	74	10	50	200	150
214576	19	15-20	5	2	1.5	0.3	200	500	300	2	N	10	N	200	48	420	-	N	0.1	40	14	90	10	50	200	200
214577	19	20-25	5	3	2	0.3	500	700	300	2	N	10	N	150	12	120	-	N	L(.1)	37	9	90	50	70	100	200
214578	19	25-30	5	3	2	0.3	200	500	300	N	N	5	N	150	23	130	-	N	0.1	50	8	127	10	50	100	200
214581	20	0-5	5	3	1	0.2	500	500	150	N	N	5	N	100	8	130	-	L(1)	L(.1)	50	8	75	15	50	200	100
214582	20	5-10	5	5	1	0.2	500	500	150	N	N	5	N	150	15	100	-	L(1)	L(.1)	53	9	85	15	50	150	100
214583	20	10-15	5	3	1	0.2	500	500	100	N	N	5	N	100	34	150	-	L(1)	L(.1)	47	8	85	15	50	200	100
214584	20	15-20	5	3	1	0.2	500	500	100	N	N	15	N	100	120	450	-	L(1)	0.1	52	8	75	15	50	300	100
214585	20	20-25	5	3	2	0.2	500	500	150	N	N	15	N	100	130	700	-	L(1)	L(.1)	50	7	82	15	50	300	100
214586	20	25-30	5	3	2	0.02	500	300	150	N	N	20	N	100	110	190	-	L(1)	L(.1)	35	10	75	15	50	300	100
214588	21	0-5	5	3	2	0.2	500	500	300	1	N	N	N	100	70	330	-	N	L(.1)	47	9	87	10	50	100	100
214589	21	5-10	5	5	2	0.2	500	500	300	3	N	N	N	150	80	120	-	N	L(.1)	52	7	75	15	50	150	150
214590	21	10-15	5	5	1.5	0.2	500	500	300	1	N	10	N	70	28	120	-	N	0.1	46	7	52	10	50	150	100
214591	21	15-20	5	2	2	0.5	500	500	150	N	N	15	N	100	230	900	-	20	L(.1)	47	9	60	15	50	200	150
214592	21	20-25	5	2	1	0.3	500	500	150	N	N	20	N	100	310	560	-	6	L(.1)	50	10	60	15	50	200	150
214593	21	25-30	7	7	5	0.2	500	700	150	1	N	N	N	100	81	150	-	N	L(.1)	60	10	92	15	70	200	150
214594	21	30-35	5	5	7	0.2	500	500	150	N	N	N	N	100	56	160	-	N	L(.1)	43	7	63	10	30	200	100
214597	22	0-5	5	3	2	0.03	300	200	L	5	N	10	N	50	76	190	-	L	L(.1)	35	5	55	7	50	500	50
214598	22	5-10	7	3	5	0.5	300	700	200	N	N	10	1.0	150	34	200	-	2	N	46	11	67	15	50	100	300
214599	22	10-15	7	3	7	0.5	700	700	200	N	N	L	1.0	100	110	220	-	3	N	36	6	84	15	30	150	150
214600	22	15-20	5	3	5	0.3	700	500	150	N	N	5	1.0	70	180	600	-	8	L(.1)	46	11	74	15	30	70	150
214601	22	20-25	5	3	1.5	0.3	300	300	150	2	N	5	N	70	540	1000	-	11	L(.1)	37	10	65	10	30	100	150
214602	22	25-30	5	3	1.5	0.3	700	300	200	N	N	5	1.0	70	150	700	-	4	N	45	7	88	15	30	100	150

APPENDIX No. 2.— Analytical data for trench samples.--Continued

SAMPLE NO.	TRENCH NO.	TRENCH INTERVAL (m)	Fe	Mg	Ca	Ti	Mn	Ba	Sr	W	Sn	Mo	Bi	Zr	Au	As	As	Sb	Ag	Cu	Pb	Zn	Co	Ni	Cr	V
ANALYTICAL METHOD			SES	SES	SES	SES	SES	SES	SES	COL	SES	SES	AA	SES	AA	AA	COL	AA	AA	AA	AA	AA	SES	SES	SES	SES
214603	22	30-35	5	3	7	0.5	700	500	100	N	N	5	1.0	70	52	190	-	5	N	44	8	75	15	50	100	150
214604	22	35-40	5	3	7	0.5	700	700	150	23	N	L	N	70	100	700	-	3	N	34	8	62	15	50	70	150
214605	22	40-45	5	7	7	0.5	500	700	200	N	N	5	N	100	46	150	-	1	N	52	8	86	15	70	100	150
214606	22	45-50	5	3	7	0.3	700	300	300	N	N	5	N	70	430	1800	-	7	N	37	6	71	15	50	150	150
214607	22	50-55	5	5	5	0.3	700	700	500	N	N	10	N	100	180	1200	-	6	L(.1)	51	10	106	15	50	100	300
214608	22	55-60	7	5	5	0.5	700	200	200	7	N	L	N	100	72	300	-	10	N	43	6	85	15	70	150	150
214609	22	60-65	5	3	10	0.5	700	700	200	N	N	L	N	70	250	800	-	6	N	27	6	60	15	70	150	150
214612	23	0-5	5	5	2	0.5	500	500	200	N	N	L	N	100	56	210	-	2	N	41	7	77	10	50	70	150
214613	23	5-10	5	5	3	0.3	700	500	500	1	N	5	N	70	90	280	-	4	N	35	6	90	10	70	150	150
214614	23	10-15	3	1.5	2	0.2	700	500	200	1	N	5	N	70	300	1800	-	18	L(.1)	29	7	76	15	50	150	150
214615	23	15-20	7	3	2	0.3	500	700	300	N	N	5	N	100	180	270	-	4	N	51	9	96	15	70	150	150
214616	23	20-25	5	5	2	0.3	700	500	150	N	N	5	N	100	200	270	-	6	N	45	7	90	15	70	150	150
214617	23	25-30	5	5	3	0.3	300	500	200	N	N	L	N	100	78	210	-	4	N	52	8	80	10	30	70	150
214618	23	30-35	5	5	1.5	0.5	700	200	100	2	N	LK	2	70	580	1000	-	12	N	45	7	95	10	50	100	150
214619	23	35-40	5	3	0.7	1	500	300	L	N	N	L	1	100	64	1500	-	4	L(.1)	47	11	97	10	30	100	300
214620	23	40-45	7	3	3	G(1)	700	700	L	4	N	L	2	100	160	3200	-	21	N	61	11	92	10	50	100	300
214621	23	45-50	7	1.5	7	0.7	1500	300	L	N	N	L	1	70	350	1500	-	15	N	55	10	102	10	50	150	200
214624	24	0-5	5	7	5	0.7	1000	300	100	N	N	N	1	70	20	700	-	4	L(.1)	41	6	184	5	30	150	200
214625	24	5-10	5	5	2	G(1)	1000	300	L	N	N	L	N	100	14	1600	-	5	L(.1)	41	10	100	10	30	150	500
214626	24	10-15	5	3	1	G(1)	500	500	L	N	N	L	N	100	71	1900	-	11	L(.1)	45	9	135	5	30	100	700
214627	24	15-20	7	3	1.5	G(1)	700	500	L	N	N	L	1	70	250	3200	-	20	L(.1)	46	19	75	10	50	300	300
214628	24	20-45	7	2	2	0.7	700	500	L	N	N	L	1	20	56	140	-	7	L(.1)	29	6	56	N	20	70	150
214629	24	25-30	3	0.7	1.5	0.2	3000	700	L	N	N	L	1	70	43	190	-	2	L(.1)	11	9	26	N	15	70	70
214630	25	0-5	3	7	5	0.7	1500	300	L	N	N	L	1	70	47	250	-	4	L(.1)	49	8	82	15	50	70	200
214631	25	5-10	5	7	3	0.7	1000	500	L	N	N	L	N	50	40	190	-	4	L(.1)	50	6	78	5	30	70	150
214632	25	10-15	5	7	7	0.7	1000	300	L	N	N	L	1	70	24	700	-	3	L(.1)	39	6	68	5	30	70	200
214633	25	15-20	5	3	7	0.7	2000	700	L	N	N	L	1	50	29	200	-	5	L(.1)	23	7	126	N	20	70	150
214634	26	0-5	1	0.7	2	0.15	200	300	L	N	N	L	1	50	85	700	-	2	N	8	9	22	N	N	50	30
214641	26	0-5	5	3	1.5	0.3	700	700	100	N	N	10	1	100	120	1350	-	13	L.1	49	10	87	20	50	100	150
214642	26	5-10	5	3	1.5	0.5	500	500	L	1	N	L	N	150	250	1600	-	10	1.44	52	160	205	15	50	70	150
214643	26	10-15	3	0.5	0.7	0.15	700	200	N	3	N	L	N	50	210	1200	-	7	L(.1)	45	16	102	5	15	150	100
214644	26	15-20	2	0.5	0.7	0.1	500	150	N	5	N	N	N	20	73	110	-	1	L(.1)	50	10	102	L	15	150	100
214645	26	20-25	5	3	7	0.3	700	300	300	N	N	L	N	100	34	190	-	5	L(.1)	37	7	72	15	50	150	150
214646	26	25-30	5	5	5	0.3	700	500	100	1	N	L	N	100	62	700	-	8	L(.1)	45	11	90	15	50	150	150
214647	26	30-35	3	5	7	0.2	700	500	300	N	N	L	N	70	160	1400	-	12	L(.1)	45	19	90	10	30	70	100
214648	26	35-40	7	7	5	0.5	700	300	200	18	N	L	N	100	14	290	-	2	L(.1)	26	6	80	20	70	150	150
214649	26	40-45	5	5	5	0.5	700	300	200	8	N	5	1	70	110	1100	-	4	L(.1)	41	6	86	15	50	100	150
214650	26	45-50	5	5	3	0.3	300	300	150	27	N	7	1	100	1.3	260	-	6	N	44	7	82	15	50	100	150
214651	27	0-5	5	7	3	0.3	500	500	300	1	N	N	N	100	17	260	-	3	N	41	5	84	20	30	100	150
214652	27	5-10	5	5	3	0.5	500	700	100	3	N	L	1	150	39	260	-	4	L(.1)	44	7	125	15	70	150	150

APPENDIX No. 2.— Analytical data for trench samples.--Continued

ANALYTICAL METHOD			SES	SES	SES	SES	SES	SES	SES	COL	SES	SES	AA	SES	AA	AA	COL	AA	AA	AA	AA	AA	SES	SES	SES	SES
SAMPLE NO.	TRENCH NO.	TRENCH INTERVAL (m)	Fe	Mg	Ca	Ti	Mn	Ba	Sr	W	Sn	Mo	Bi	Zr	Au	As	As	Sb	Ag	Cu	Pb	Zn	Co	Ni	Cr	V
214653	27	10-15	5	3	1	0.3	500	300	L	1	N	N	N	100	39	140	-	2	L(.1)	45	6	80	15	50	70	150
214654	27	15-20	3	5	5	0.15	500	500	300	9	N	N	1	70	55	700	-	3	L(.1)	4	12	30	10	30	70	100
214655	27	20-25	3	0.7	1	0.15	700	300	L	3	N	10	N	50	15	5200	-	15	L(.1)	35	11	55	5	30	100	100
214656	28	0-5	3	0.5	5	0.15	700	200	L	N	N	L	1	50	39	210	-	3	L(.1)	64	5	70	5	20	150	100
214657	28	5-10	3	0.5	0.5	0.07	200	150	L	12	N	10	N	20	85	300	-	2	L(.1)	62	9	100	5	15	70	70
214658	28	10-15	5	2	1	0.7	300	300	L	11	N	L	N	100	43	150	-	4	0.1	45	4	66	10	30	200	300
214659	28	15-20	5	3	1.5	0.7	700	300	L	7	N	L	1	90	15	230	-	3	0.11	47	8	95	15	50	100	300
214660	28	20-25	5	3	1.5	0.7	200	200	L	4	N	L	1	70	11	300	-	1	0.1	54	9	104	10	30	150	200
214661	29	0-5	5	5	0.7	1	300	300	L	3	N	L	N	100	23	240	-	5	0.1	51	12	115	10	30	150	300
214662	29	5-10	5	5	0.7	1	300	700	L	4	N	10	N	100	66	210	-	3	0.1	50	12	120	10	30	70	300
214663	29	10-15	7	5	0.7	G(1)	700	700	L	1	N	L	N	100	34	80	-	1	L(.1)	4	9	30	5	50	70	500
214664	29	15-20	7	5	0.7	1	300	700	L	N	N	5	N	150	35	140	-	2	L(.1)	3	9	27	15	70	100	700
214665	30	0-5	1	0.5	0.7	0.05	300	700	200	N	N	L	N	50	30	160	-	2	L(.1)	4	8	22	N	N	50	20
214666	30	5-10	1	0.5	0.5	0.05	150	700	200	2	N	N	N	50	40	130	-	1	L(.1)	3	5	22	N	N	70	15
214667	30	10-15	1	0.5	0.5	0.05	150	300	150	1	N	N	N	50	70	100	-	1	L(.1)	4	8	24	N	N	70	15
214668	30	15-20	1	0.5	0.7	0.05	150	500	300	N	N	L	N	70	22	120	-	2	L(.1)	3	7	20	N	N	20	15
214669	30	20-25	0.7	0.5	0.7	0.05	150	500	300	N	N	N	N	50	23	260	-	7	L(.1)	50	8	92	N	N	20	20
214670	30	25-30	0.7	0.5	0.3	0.05	100	700	200	1	N	N	N	50	47	1700	-	9	0.14	36	8	56	N	N	30	15
214671	30	30-35	5	2	5	1	700	700	200	17	N	N	2	100	44	210	-	6	0.11	37	6	60	10	30	70	300
214672	30	35-40	5	0.7	7	0.5	500	1000	150	10	N	L	1	70	220	600	-	9	0.11	50	15	125	5	20	70	300
214673	31	0-5	3	1	3	0.7	500	150	L	9	N	L	1	70	73	800	-	3	L(.1)	21	11	43	L	30	100	150
214674	31	5-10	7	2	3	0.7	700	700	L	20	N	5	1	100	73	1700	-	3	0.1	9	28	36	10	50	150	300
214675	31	10-15	3	0.7	1.5	0.5	300	700	300	10	N	L	1	100	77	1300	-	4	0.1	50	6	110	N	N	70	150
214676	31	15-20	3	0.7	1.5	0.5	150	700	L	40	N	L	N	70	130	260	-	2	L(.1)	17	9	65	N	N	50	70
214678	32	0-5	3	0.5	1.5	0.5	200	700	300	7	N	N	1	100	68	270	-	2	L(.1)	15	9	62	N	N	70	100
214679	32	5-10	5	1	2	0.7	200	500	100	3	N	N	N	70	55	210	-	5	L(.1)	34	9	93	N	10	100	150
214680	32	10-15	5	3	0.7	0.7	200	300	L	22	N	N	1	70	74	700	-	5	L(.1)	48	9	77	N	20	50	200
214681	32	15-20	3	1	1	0.7	300	300	100	10	N	N	2	50	110	750	-	7	L(.1)	50	10	95	N	15	70	200
214683	33	0-5	5	3	1.5	G(1)	200	500	100	12	N	N	N	100	25	60	-	1	L(.1)	42	10	90	N	20	100	200
214684	33	5-10	2	0.7	2	0.7	150	500	100	3	N	N	1	50	78	900	-	4	L(.1)	14	12	70	N	N	50	50
214685	33	10-15	3	0.5	1.5	0.7	150	700	100	14	N	L	N	50	92	1100	-	4	L(.1)	12	10	55	N	N	70	50
214686	33	15-20	5	0.7	2	0.7	300	700	300	3	N	N	1	70	79	1100	-	7	L(.1)	17	10	65	N	10	70	100
214687	33	20-25	3	0.7	1.5	0.7	150	500	100	14	N	L	1	70	230	900	-	5	0.24	11	51	72	N	N	70	100
214688	33	25-30	7	3	3	1	700	300	100	28	N	N	1	50	35	140	-	2	L(.1)	51	10	98	N	30	100	300
214690	34	0-5	5	3	5	G(1)	300	300	100	18	N	N	1	70	14	100	-	3	L(.1)	43	7	73	N	30	100	300
214691	34	5-10	7	3	2	G(1)	300	700	100	5	N	N	2	70	35	200	-	6	L(.1)	49	9	80	N	30	150	300
214692	34	10-15	7	3	5	G(1)	700	500	200	4	N	N	1	50	22	90	-	2	L(.1)	45	7	87	N	30	150	300
214693	34	15-20	5	2	2	0.7	500	200	100	5	N	N	1	50	40	90	-	8	L(.1)	62	9	83	N	30	70	150
214694	34	20-25	3	3	7	0.7	700	300	100	12	N	N	1	100	120	900	-	9	L(.1)	39	10	76	N	30	150	150
214695	34	25-30	5	3	1.5	0.7	700	200	100	22	N	N	N	70	14	35	-	1	L(.1)	56	7	94	N	30	100	150

APPENDIX No. 2.— Analytical data for trench samples. Continued

ANALYTICAL METHOD			SES	SES	SES	SES	SES	SES	SES	COL	SES	SES	AA	SES	AA	AA	COL	AA	AA	AA	AA	AA	SES	SES	SES	SES
SAMPLE NO.	TRENCH NO.	TRENCH INTERVAL (m)	Fe	Mg	Ca	Ti	Mn	Ba	Sr	W	Sn	Mo	Bi	Zr	Au	As	As	Sb	Ag	Cu	Pb	Zn	Co	Ni	Cr	V
214697	35	0-5	7	1.5	2	0.5	300	1500	100	N	ND	10	-	100	8	170	-	L5	L(.1)	53	10	115	15	50	300	300
214698	35	5-10	3	1.5	5	0.3	500	1500	100	N	ND	10	-	70	52	145	-	15	L(.1)	43	9	75	15	50	300	200
214699	35	10-15	3	0.7	15	0.15	1500	1500	150	N	ND	10	-	20	28	100	-	15	L(.1)	37	9	56	10	30	500	100
214700	35	15-20	3	1.5	3	0.3	700	1500	200	14	ND	L	-	30	14	250	-	6	L(.1)	30	6	48	15	50	300	100
214701	35	20-25	7	2	3	0.5	700	1500	300	34	ND	5	-	50	39	160	-	L5	L(.1)	47	14	88	15	70	700	200
214702	35	25-30	3	1.5	5	0.3	1500	1500	300	19	ND	L	-	30	19	200	-	L5	L(.1)	55	8	76	15	50	700	150
214704	36	0-5	2	0.7	10	0.15	700	150	200	4	ND	10	-	30	3	90	-	5	L(.1)	25	7	42	10	20	700	150
214705	36	5-10	5	2	G(20)	0.5	1000	300	200	87	ND	L	-	50	7	170	-	L5	N	35	6	62	15	50	1000	300
214706	36	10-15	5	2	0.7	0.3	700	1500	100	2	ND	L	-	50	260	160	-	L5	N	50	10	78	15	50	700	300
214707	36	15-20	5	2	3	0.3	1000	1500	200	N	ND	L	-	30	57	120	-	L5	N	50	9	88	15	50	700	300
214708	36	20-25	3	1.5	3	0.3	500	1500	300	N	ND	5	-	30	4	90	-	7	N	48	8	72	15	50	700	150

APPENDIX No. 3.--Analytical data for folded, stockwork, and barren quartz veins.

[Au in ppb; Fe, Mg, Cu, Ti in percent; all other elements in ppm. AA = atomic absorption; COL = colorimetry; SES = semiquantitative emission spectrography; XRF = X-ray fluorescence]

ANALYTICAL METHOD SAMPLE NO.	VEIN TYPE	SES Fe	SES Mg	SES Ca	SES Ti	SES Mn	SES Ba	XRF Sr	XRF Rb	COL W	SES Sn	AA Mo	AA Bi	XRF Zr	AA Au	XRF As	AA Sb	AA Ag	AA Cu	AA Pb	AA Zn	SES Co	SES Ni	SES Cr	SES V
214761	Stockwork	0.2	.02	9.5	0.003	30	N	39.3	N	30	N	330	N	26.1	26	30	N	N	4	2	2	N	N	100	10
214762	Stockwork	0.2	L	0.7	0.002	10	N	45.2	N	30	N	330	N	29.4	8	33	N	N	4	2	1	N	N	70	10
214779	Barren	0.1	L	L	L	L	N	9.4	8.6	20	N	N	N	21.8	13	23	N	N	14	1	3	N	N	70	L
214781	Barren	0.3	L	L	L	30	N	9.7	8.8	20	N	32	N	21.8	22	57	2	N	3	2	1	N	N	70	L
214782	Barren	0.07	L	0.05	L	L	N	9.4	-	5	N	3	N	22.7	12	19	2	N	9	14	4	N	N	50	L
214785	Barren	0.3	L	0.05	L	L	N	9.0	8.1	10	N	12	1	23.4	14	39	N	N	4	12	1	N	N	200	L
214786	Folded	0.3	.05	1.5	L	30	20	82.3	10.1	5	N	8	1	24.7	15	52	2	N	8	1	5	N	N	100	L
214787	Folded	1	.3	3	0.1	200	70	91.3	50.6	25	N	32	N	35.1	24	152	3	L	11	2	17	N	N	100	10
214788	Folded	0.7	.07	0.002	0.002	200	30	304.8	12.8	20	N	10	N	22.4	21	67	2	L	9	2	11	N	N	150	L
214789	Folded	0.7	.07	0.02	0.02	200	70	370.8	19.0	10	N	3	2	26.0	17	24	N	N	12	3	16	N	N	100	10