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MINERAL EXPLORATION: MAHD ADH DHAHAB DISTRICT

KINGDOM OF SAUDI ARABIA

by

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U.S. Geological Survey
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ABSTRACT

Mahd adh Dhahab is the largest of numerous ancient gold mines scattered through the Precambrian shield of Saudi Arabia and the only one with recent production. During the period 1939-54, 765,768 fine ounces of gold and 1,002,029 ounces of silver were produced from the mines by the Saudi Arabian Mining Syndicate.

Ore minerals at Mahd adh Dhahab include free gold and silver, tellurides, sphalerite, and chalcopyrite in and associated with a system of north-trending quartz veins and quartz veinlet stockworks. Pyrite is a common sulfide gangue mineral. Country rocks are a north dipping sequence of pyroclastic and transported pyroclastic rocks of the Hulayfah Group that are locally highly silicified and potassium-feldspathized.

The prime target for this exploration program was a north-trending zone of quartz veins and breccias, faults, alteration, and metalization approximately 400 m wide and 1000 m long. The ancient and recent mine workings are located in the northern part of this zone. Although the quartz veins and alteration cut all lithologies, the major metalization is confined to the intersection of veins and agglomerate. Ten holes were diamond drilled to explore geochemical, geological, and geo-physical targets in the area.

A significant new zone of metalization was discovered 700 m south of the ancient and recent mine workings and within the same major zone of quartz veins, alteration, and faults. Metalization in this southern mineralized zone is at the intersection of the quartz veins and a distinctive and highly altered agglomerate. The total zone of vein and agglomerate intercept is potentially metalized and comprises a block of ground 40 m thick and 400 m wide along the strike of the agglomerate and projected downdip 250 m. Tonnage of this block is 17.2 million tons. The explored zone, approximately 25 percent of the potentially metalized rock, has a potential resource of 1.1 million tons containing 27 g/t gold and 73 g/t silver.

INTRODUCTION

Location and description

Mahd adh Dhahab, situated 250 km north of At Ta'if and 170 km southeast of Al Madinah at lat 23°30'N.; and long 40°53'E. (fig. 1), is an ancient and recent gold mining site. Access to the area is by unimproved tracks across playas and low rolling rocky hills north from the At Ta'if-Riyad surfaced highway and south from the Al Madinah-Suwaydurah highway. During the later part of 1975 construction of a new road from Mahd adh Dhahab to Al Madinah was initiated.

The village of Mahd adh Dhahab, a local trade center, lies just north of Jabal Mahd adh Dhahab and the ancient and recent mining site situated along the eastern flank of the Jabal. The Mahd adh Dhahab area has been a center of mining activity throughout the recorded history of Arabia. Besides gold mining,

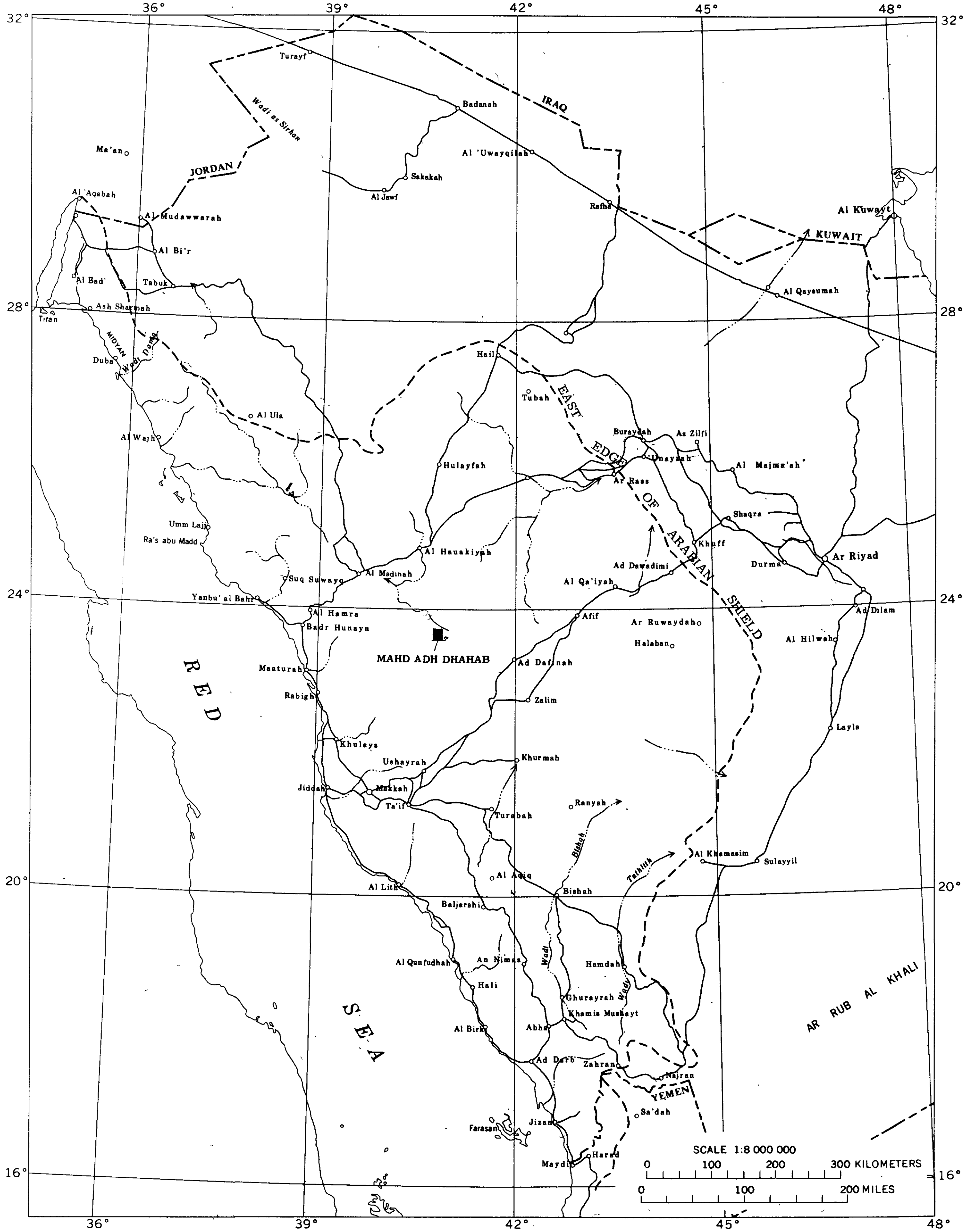

Figure 1. - Index map showing the location of the Mahd adh Dhahab district.

which may date back to 950 B.C. (Luce and others, 197~~6~~4, p. 2), the area was a central point along trade routes and the inland pilgrim routes between Mecca, Al Madinah, and the Moslem countries to the north. The caravan and pilgrim trails followed a natural route along easily-traveled terrain between wells and springs situated along the eastern front of the Harrat Rahat (Tertiary plateau basalts). The ease of access and abundance of nearby water was probably an important factor in making this a major mining center in ancient times.

Previous investigations

Ancient mining activity in the area is indicated by numerous narrow workings that extend to a depth of 85 m along major veins, several thousand tons of slag left from crude smelting operations, and a largely destroyed tell with attendant ruins and artifacts. These operations occurred during two periods, possibly about 950 B.C. and during the Abbasiad Caliphate about 800 A.D. (Luce and others, 1976, p. 1). These dates are based upon C^{14} dating of charcoal found in slag and from scanty mention in historical journals. No evidence of mining activity between about 1000 A.D. and the twentieth century has been found. In recent times (1931) the Mahd adh Dhahab mine was recognized as part of a major mining district by geologists and engineers retained by the Saudi Arabian government. A concession for development of the Mahd adh Dhahab mine was granted the Saudi Arabian Mining Syndicate (SAMS) in 1936, and production of gold began in 1939. SAMS will be used throughout to designate the Saudi Arabian Mining

Syndicate mining operations at Mahd adh Dhahab. During the period 1939-54, 765,768 fine ounces gold and 1,002,029 ounces of silver were produced from the mine by SAMS. Ancient gold production probably equaled recent production. During the SAMS operation of the general mine area, all mine workings and diamond drill core were mapped and studied in detail. The geologic maps and sections from this period are largely the work of Dirom (1947) with modifications and additions by succeeding mine geologists.

Geologists of the U.S. Geological Survey (USGS) mission and the Saudi Arabian Directorate General of Mineral Resources (DGMR) covered the general region in the early to middle 1960s doing 1:500,000 scale mapping of the Precambrian shield (Brown and others, 1963) and by more detailed (1:50,000) regional studies in the Mahd adh Dhahab area (Goldsmith and Kouther, 1971). During this period the USGS drilled two exploration holes in an altered zone that contains anomalous molybdenum values, at the western edge of Jabal Mahd adh Dhahab approximately 1 km southwest of the SAMS mine shaft (Theobald and others, 1977).

Geologists of the French Bureau de Recherches Geologiques et Minieres (BRGM) mapped and studied at a scale of 1:100,000 the Jabal Sayid quadrangle (Aguttes and Duhamel, 1971) and the Sufaynah quadrangle (Lefevre, 1969, and Dottin, 1974). Mahd adh Dhahab lies close to the boundary line between these two quadrangles. BRGM geologists have undertaken extensive studies in the vicinity of Jabal Sayid, a major copper occurrence, 40 km to the north. The regional geology was being analyzed and synthesized as part of a 1:250,000 scale mapping program by BRGM geologists in 1976.

Present investigations

The United States Geological Survey, in accordance with a work agreement with the Ministry of Petroleum and Mineral Resources, Kingdom of Saudi Arabia, has been studying and evaluating mineral deposits in the Mahd adh Dhahab district (23°30'N.; 40°53'E.). The first phases of the study included geologic mapping at a scale of 1:2,500 (Luce and others, 1976), geochemical investigations (Roberts and others, 1978), and placer gold investigations (Bagdady and others, 1978). The second phase of the study, reported here, included extensive diamond drilling, detailed mapping at a scale of 1:1000, limited surface geochemical investigations, and synthesis and evaluation of SAMS geological data.

U.S. Geological Survey drill holes are designated throughout this report by the symbol MD- and the drill hole number; i.e. MD-5. Saudi Arabian Mining Syndicate drill holes are designated by SAMS- and the drill hole number; i.e. SAMS-5.

Plates 1 and 3 and figures 9 through 16 and the northern portion of plate 2 are modified and simplified after Dirom (1947). Modifications to Dirom's maps and sections were minor and involved only lithologic reinterpretations based upon fieldwork and examination by the author of representative core samples from the SAMS drilling program. Samples (5 cm split core chips) from the 13 SAMS diamond drill holes were discovered late in the spring of 1975, beneath a pile of rubble within the village of Mahd adh Dhahab. Unfortunately the bulk of the SAMS drill core was unusable as it had been dumped into one rubble pile some time after mining operations ceased. Many representative lithologic core samples however, could be accurately positioned with respect to hole number and depth and afford a direct connection between surface rocks, USGS drill core, SAMS drill core, and subsurface mine mapping and also provided fresh samples for petrologic and petrographic studies. Incomplete drill logs and assay data are available for the SAMS drill holes, but were not in suitable shape to use in this report. The 1" to 40' scale maps and cross sections of Dirom (1947) contain a wealth of data that could not be transferred to the author's 1:1000 scale working maps.

Three horizontal controls are included on plates 1, 2 and 3; the SAMS mine grid, in feet; latitude and longitude; and a 50-meter square grid set by the USGS and used for 1:1000 scale mapping and sampling and geophysical studies. The SAMS mine grid is included for correlation. Several of the maps and sections used were poor paper copies that have not held scale, thus correlations between some plates is not exact. Transfer of data from one control system to another was based on distance from the southwest corner of the main shaft.

Acknowledgements

Acknowledgement is due the Minister of Petroleum and Mineral Resources of the Kingdom of Saudi Arabia and the Directorate General of Mineral Resources for providing the support that made the study possible.

The guidance and discussion concerning this study by T.H. Kiilsgaard, Project Chief, and R.J. Roberts of the USGS are gratefully acknowledged. Abdulaziz Bagdady contributed to the synthesis of the SAMS data and general geologic knowledge of the area. Ziad Al Kolak logged core from drill hole MD-9 and is responsible for geologic interpretation of that core. Roy Nixon and Charles Robins laid out the 50-meter square grid that served as base for detailed mapping and for geophysical work. Geologists too numerous to mention, from the USGS, DGMR, BRGM, and private industry have contributed by discussion of the area.

GEOLOGIC SETTING

Regional geology

The Mahd adh Dhahab district is underlain by a complex of Precambrian pyroclastic, volcanic, and clastic rocks overlying a large body of diorite to granodiorite (Goldsmith and Kouther, 1971, pl. 1). Regional correlations of this largely pyroclastic sequence, the Mahd adh Dhahab series, is not in agreement among previous investigators. The rocks have been assigned to the Hulayfah Group (Halaban Group) (Aquttes and Duhamel, 1971; Delfour, 1975), the Halaban Group and Fatima Formation (Brown and others, 1963), an intraformational agglomerate above the Halaban (Lefevre, 1969), the Fatima and Murdama Formations (Goldsmith and Kouther, 1971) and to the Murdama Group (Luce and others, 1976; Dottin, 1975). The author concurs with assignment to the Hulayfah Group. This sequence rests upon granitic rocks of the type that intrude pre-Hulayfah Group rocks elsewhere in the region and in turn is overlain by relatively nonmetamorphosed volcanic flow rocks and breccia of the Murdama Group (Brown and others, 1963). The Mahd adh Dhahab series in the vicinity of the Mahd adh Dhahab mine is described by Aguttes and Duhamel (1971, p. 17) as predominantly "rhyolitic pyroclastites" with interstratified andesite, fine-grained sedimentary rocks, "ignimbrite", and silicic tuff, none of which has regional extent except the "ignimbrite". They consider the Mahd adh Dhahab series in the mine area as a succession of lenses several meters to 40 m thick and limited in areal extent by numerous facies changes. Towards the west the Mahd adh Dhahab series grades by intertonguing and facies changes to a predominantly tuff and dolomite sequence (Aguttes and Duhamel, 1971, p. 18). Alkalic granite and rhyolite cut the sequence north of Mahd adh Dhahab and andesite dikes and sills cut it throughout its exposures.

The Mahd adh Dhahab area is in a zone of strong regional northeast-trending faults and folds (Goldsmith, 1971, p. 36). Within the study area (pl. 2), however, north-trending structures dominate with subordinate northeast and northwest-trending structures. The southwestern edge of the northwest-trending Najd fault system is only a few kilometers northeast.

Lithologies and alteration

Rocks of the Mahd adh Dhahab series exposed in the study area (pl. 2) are composed of an intimate mixture of pyroclastic and transported pyroclastic and clastic detrital material. Volcanic flow rocks, welded tuff, and breccia are subordinate. Grain size and related parameters of sorting, grading, and bedding vary much more than lithic, pyroclastic, and mineral composition, which is relatively consistent through most units mapped. Most of the medium- to fine-grained rocks are bedded, and commonly graded. The rocks exposed range from coarse agglomerate to very fine-grained tuff. Lithic and pyroclastic fragments in order of decreasing abundance are andesite to rhyodacite volcanic rock, silicic tuff, and chert, with locally abundant broken feldspar grains, diorite, pumice, and glass shards. The common minerals are chlorite, plagioclase, potassium-feldspar, and quartz, with locally abundant epidote and minor amphibole. The rocks are not regionally metamorphosed, but are hydrothermally altered. The original mafic minerals have altered to chlorite and magnetite. Much of the plagioclase has been altered to either masses of sericite and quartz or to saussurite aggregates.

Two types of post-depositional alteration have affected these rocks: 1) hydrothermal alteration, mainly silicification, pyritization, and propylitization centered on the quartz vein zone and 2) more widespread and pervasive potassium-feldspathization. The relationship between the two is not documented, but the potassium-feldspathization seems to be in part contemporaneous with early quartz veining. Three types of potassium-feldspar are found: disseminated crystals, as a replacement of plagioclase, and as a minor vein mineral. All three types are similar optically and X-ray diffraction patterns suggest they are compositionally similar, nearly maximum microcline.

Randomly disseminated potassium-feldspar crystals occur in all map units indiscriminately throughout the groundmass and in lithic and pyroclastic fragments of all types. The subhedral potassium-feldspar crystals commonly cut grain boundaries of metamorphic minerals. Fragmental plagioclase in crystal-lithic tuff of the upper and lower agglomerates are partially to totally replaced by potassium-feldspar; plagioclase cores with potassium-feldspar rims are common. Potassium-feldspar occurs as an early vein mineral in banded veins and as monomineralogic veinlets, mostly in the mine area.

The lithologic sequence of Luce and others (1976), in decreasing age of lower agglomerate, lower tuff, upper agglomerate and upper tuff, with further breakdown of the units is retained in this report. The lower agglomerate has been subdivided by the author into lower, middle, and upper units on the basis of drill core information. The subdivision is recognizable at the surface, but is not readily discernible on the scree-covered outcrops. The lower unit is mainly andesite tuff and lapilli tuff and is distinctive from the middle and upper units. The middle and upper units, both mafic-lapilli tuff to agglomerate, appear similar but the upper unit has a mostly siliceous gray groundmass while the middle unit has a chlorite and epidote-rich groundmass. In addition, the middle unit has locally abundant chert and siliceous tuff fragments not present in the upper unit. The three units also differ geochemically as discussed in this report under the section on geochemistry. The contact of the lower agglomerate and lower tuff is gradational across a wide zone of intercalated lapilli tuff, agglomerate, and massive tuff. The upper contact of the lower tuff with the upper agglomerate is sharp with no gradation or intercalation of the two lithologies.

Rocks considered by previous investigators to be rhyolite (Dirom, 1947; Luce and others, 1976) are considered by the author to be potassium-feldspathized tuff, wacke, and sandstone and are probably metasomatized equivalents of part of the lower tuff. Rocks of the two units are similar in texture, composition, and mineralogy, with the exception of the locally abundant potassium-feldspar crystals and zones of sericitization(?) in the metasomatized rock. The gradation from unaltered to altered rock can be observed in core from drill holes MD-6, 9, and 10 and SAMS-1, 4, 5, and 13.

The upper agglomerate is here divided into two units, crystal-lithic tuff to agglomerate and gray agglomerate. The crystal-lithic tuff conformably overlies the lower tuff. The lower few meters are primarily a mafic pyroclastic rock and contains an abundance of flattened lapilli and possible shards. The remainder of the crystal-lithic tuff and agglomerate is generally bedded and commonly graded. The gray agglomerate seems to be unconformable to the crystal-lithic tuff and agglomerate, as its outcrop pattern transects layering in the underlying crystal-lithic tuff and agglomerate and in some areas it directly overlies potassium-feldspathized tuff and sediments. The gray agglomerate is characterized by subrounded chert, tuff, and volcanic rock fragments set in a siliceous gray groundmass. Layering is not common but is present in a few finer-grained zones.

The upper tuff is largely agglomerate-conglomerate with a relatively thin unit of argillite and carbonate-bearing tuff at the base. It is in unconformable contact with the underlying upper agglomerate. Where penetrated by drill or mine workings the contact is a bedding plane fault, parallel to bedding in the upper tuff. The nature of this contact is important as the quartz veins terminate upward against it. If the contact is a fault plane with major offset, the vein system may continue northward from the faulted offset whereas if it is primarily an unconformity it may represent the northward terminus of the vein system. The vein system may predate the unconformity and be truncated by that structure, or the veins may have terminated upwards against the unconformity because of the overlying incompetent tuff. Whereas the more competent underlying agglomerate would fracture and subsequently fill with vein forming material the less competent tuff would absorb the fracturing stress and open fractures would not develop. The argillite and carbonate-bearing tuff of the upper tuff are finely bedded, waterlain and differ distinctly from the lower tuff. The overlying agglomerate-conglomerate portion is characterized by an abundance of pale-green dacite fragments and well-rounded red chert fragments, and local fragmental quartz.

Structure

The Mahd adh Dhahab series, aside from the upper tuff, is highly fractured and cut by numerous faults, joints, and quartz veins, but the rocks are not highly sheared and primary textures, bedding, and lithologic layering may be seen in most outcrops. Schistosity or other metamorphic penetrative surfaces are not well developed. Deformation of the rocks other than the upper tuff was brittle rather than plastic, and more typical of near surface fracturing than deep-seated thermal dynamic metamorphism.

The most obvious structural feature within the study area (pl. 2) is the zone of north to N45°E trending quartz veins, andesite dikes, and faults. There is also an important, but less obvious because of lack of contained quartz veining, fault system that trends N45°W to west. Several periods of faulting and quartz vein and andesite dike emplacement along the north to northeast trending systems and to a lesser extent the northwest to west system are evident (Luce and others, 1976). The latest faulting was along the northwest to west trending system, although lateral offset in the map area (pl. 2) is minor. The low angle thrust faults in the northern part of the area (pl. 2) are nearly parallel to layering in the crystal-lithic tuff-agglomerate unit of the upper agglomerate. These are local features related to folding, and are not of regional significance.

A major northeast-trending right lateral fault system bounds the map area on the southeast (Goldsmith and Kouther, 1971, pl. 1; also pl. 1 of this report). Although not exposed, the individual zones of alteration associated with this fault system are well delineated by SP and EM geophysical anomalies in the alluvial covered valley just to the east of the study area (Mark Gettings, personal communication, 1975). The anomalies associated with these faults are offset and truncated by northwest to west trending faults. A segment of a major northeast-trending fault was penetrated by drill hole MD-10. This was the only fault zone penetrated in the USGS diamond drilling characterized by an abundance of clay-rich gouge, vugs, and complete water loss during drilling. The other intersected fault zones were characterized by minor sericite mylonitic shears, or thin seams of gouge and granulated rock.

A nearly horizontal joint system cuts all rock types and in some places minor offset of quartz veins along this system can be seen. In drill core these joints are generally open and often lined with fine drusy quartz and are nearly penetrative surfaces in some sections of core. The significance of this system is unknown.

Structure of the Mahd adh Dhahab Series is defined by primary sedimentary or volcanic bedding and lithologic layering in most units. Only the agglomerates lack measurable bedding or other primary layering features. Foliation and other metamorphic penetrative planar structures are not well developed, and where present are generally parallel to bedding or to an adjacent major shear zone. Minor fold axes and other measurable linear penetrative structures are lacking. Folds in the Mahd adh Dhahab series are broad, open flexural types; shear folds and flow folds common in higher metamorphic grade rocks of the Arabian Precambrian shield were not seen.

Main strike direction of bedding and layering is east-west with north dips. Structural analysis of measured attitudes available from all sources (unpublished SAMS data; Dirom, 1947; Goldsmith and Kouther, 1971; Luce and others, 1976; this report) defined areas of broad open folds (pl. 1). Poles to bedding attitudes were plotted on the lower hemisphere of a Schmidt equal-area net to define structurally homogeneous subareas I through VI (pl. 1). Fold models shown by curvilinear strike and dip symbols within each subarea are based upon the distribution of poles to bedding on the corresponding stereonet. Structure in most of the map area, and in subareas I and V (pl. 1), is a slightly folded homocline. In structural subareas II, III, and IV, structure is open flexural folding around a north-plunging axis, while in the subarea VI the folding is around an east-plunging axis. Relationship of folding in subareas II, III, and IV to regional structure is unknown, but these folds are probably subsidiary folds on the flanks of large regional-scale features. Variation in attitude of axis of folding between subareas, and variation of poles to bedding away from the best-fit great circle within subareas is the result of post-folding block faulting. Note that most subarea boundaries are along major faults. The structures defined in subarea VI are probably the result of drag folding along the major northeast-trending fault system just to the east and are not of regional significance. There is no evidence in any of the subareas for multiple episodes of folding.

Special mention must be made of structural subarea III as the structure defined in this subarea is the basis for the structural interpretation in cross-section A-A' (fig. 2), which shows that metasomatized tuff is continuous with and is an altered portion of the lower tuff. Data in this subarea includes attitudes noted as flow-banding in rhyolite on the SAMS 300' level geologic map (Dirom, 1947). The poles to bedding have relatively wide scatter around the defined great circle, but there is little question that this area is structurally homogeneous. This supports the premise that the lower tuff is continuous into the metasomatized rock.

Mineralization

Mineralization at Mahd adh Dhahab consists of gold, silver, copper, and zinc metalization in or associated with quartz veins. Although quartz veins occur throughout Jabal Mahd Dhahab they are most abundant in a north-trending zone 400 m wide and approximately 1000 m in length along the eastern edge of the jabal. This zone of faulting, veining, and metalization is the prime exploration target of this study and contains the SAMS mine and most ancient workings.

The quartz veins range in width from 1 mm to as much as 5 m for some composite veins, but most individual veins are 10 to 50 cm in width. Vein material is generally space filling of fractures, open breccias, and fissures and commonly earlier vein material is brecciated and healed by later quartz. The larger veins are invariably brecciated composite veins composed of quartz-healed breccias of previous vein material and wall rock

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fragments and sheeted veins in the 10 to 50 cm width range. Veins 10 to 50 cm wide are typified by banding, crystal-lined vugs, cockade structure, and comb structure of inwardly terminated zoned quartz crystals. The veins are mostly quartz with subordinate bands of pyrite, sphalerite, chalcopyrite, and chlorite. Chalcendonic quartz and carbonate are late constituents in some veins. In a few sections of core dark-gray quartz-sulfide veinlets cut all other quartz. Potassium feldspar is locally abundant, especially in the SAMS mine area, as bands in the veins and as veinlets in altered wall rock. Metalization is highest where quartz veining is most intense, but all such zones are not metalized.

Luce and others (1976) recognized four types of quartz veins. Their breakdown was not readily apparent in drill core, although two or three distinct generations of quartz deposition was evident and mm veinlets of drusy quartz and carbonate lining a nearly horizontal joint system are common throughout. Post-mineral (quartz vein) shears and faults occur within and along the edge of most of the major veins.

Sulfides present in the veins are pyrite, chalcopyrite, at least two generations of sphalerite, minor galena, tetrahedrite, and argentite. Native gold and silver accompany the major sulfides. Preliminary petrologic and mineralogic studies of the USGS drill core indicate that much of the gold, and presumably also the silver, in the southern mineralized zone as outlined by drill holes MD-3, 7, and 8, is in the form of tellurides. BRGM geologists have recognized hessite, empressite, and rare altaite and pezite in ore samples from Mahd adh Dhahab (Delfour, 1975, p. 24). An occasional gold grain or wire can be found in quartz from the dumps or outwash plain. Visible gold was seen in only one core sample, from drill hole MD-6. According to studies by Luce and others (1976) "Silver is distributed throughout the specimen (study sample) in galena and tetrahedrite, but gold is mainly in selvage zones".

The degree of wall rock alteration is variable. Most of the core is pyritized and propylitized(?) while some zones are intensely silicified and other zones are potassium-feldspathized, as shown by veinlets of potassium-feldspar and pyroclastic fragments and plagioclase replaced by potassium-feldspar. Highly fractured rock with a pervasive stockwork of 1 cm sized veinlets is the most strongly altered. Alteration at the contact of the larger veins sometimes consists of a thin zone of dark-green chlorite, although there is generally no contact alteration.

GEOCHEMISTRY

Sampling plan

Three types of samples were collected for geochemical analysis; split core, character core, and surface samples. The split core was analyzed to test for metalization while the character core was used to determine the geochemistry of the host rocks. Surface samples were taken to check the distribution of metals in and along quartz veins through rocks of different lithologies. All analyses were performed by the DGMR-USGS laboratory in Jiddah. Analytical results are stored in the RASS system. Split core samples have sample (RASS) numbers 97,000-97,499, 97,628-97,749, 97,900-97,999, 105,100-105,999, and

110,100-110,356; character core samples have sample (RASS) numbers 97,500-97,628; and surface character samples have numbers (RASS) 105,700-105,999.

The entire diamond drill core obtained, with the exception of sections of drill holes MD-5, MD-6, and MD-7, was split, with one-half being retained and stored, the other half being submitted for analyses. Sampled intervals were generally 1 or 2 m lengths of core. The split core samples were analyzed for gold, silver, copper, and zinc by atomic absorption methods. The results are part of the permanent core record on file with the USGS project, Jiddah. Only the logs and analyses for holes MD-7, 8, and 3 are included with this report (Appendix B). Every tenth sample from part of the drill core was further analyzed by semiquantitative spectrographic methods. The results of the spectrographic analyses are listed in Appendix A.

One hundred twenty-eight lithologic character samples from diamond drill holes MD-1, -2, -3, and -4 were taken according to a nested hierarchical sampling plan. The purpose was to test element concentration variation within and between lithologic units. These 20-30 gram samples were taken before the core was split by sawing out a 1 to 2 cm disk. Since this size is the equivalent of a chemical split, no variation in analytical results was introduced by sample splitting or sample preparation. The total sample was used in the analysis. An attempt was made to include only wall rock in the sample disk, but in some sample zones the wall rock contained a pervasive network of mm-sized quartz veinlets that could not be avoided.

Analyses performed on the lithologic character samples included gold, silver, copper, lead, zinc, bismuth, cadmium, cobalt, manganese, sodium, potassium, SiO_2, aluminium, and calcium by atomic absorption methods and molybdenum, tungsten, arsenic, and antimony by colorimetric methods. Values for molybdenum, tungsten, arsenic, antimony, and bismuth were generally low, at or below detection levels. Values for copper, lead, and zinc were erratic and generally corresponded to values obtained from the split core samples. Mean, variance, and standard deviation of each element grouped as to lithologic unit within the lower agglomerate are given in table 1.

A suite of surface geochemical samples were taken to test metal distribution within and along veins in several lithologies. Sample locations are shown on plate 2, and sample description and anlytical results are listed in Appendix A. Gold, silver, copper, and zinc were determined by atomic absorption methods. Each sample was composed of numerous 1 to 3 cm sized chips taken from outcrop along the length of the sample zone which varied with each sample (Appendix A). The total weight of sample varied with sample length; a 1 m sample contained approximately 2 kg of rock chips.

Discussion of results

Metal values in split core samples from drill holes MD-3, -7, and -8 indicate a major body of metalization within the lower agglomerate in the southern part of the zone of quartz veins, alteration, and faults. Surface expression of this mineralized zone is shown by anomalous gold geochemical values

Table 1.--Summary of analytical results and specific gravity determinations of 128 character core samples from diamond drill holes MD-1, 2, 3, and 4.

I Upper unit of lower agglomerate - 32 samples

Element	Mean	Standard deviation	Range in values
K	0.36	0.42	0.02-1.50
SiO_2	75.69	13.70	50.38-94.16
Na	0.66	1.13	0.01-3.40
Al	3.72	2.42	0.50-9.40
Ca	0.49	0.51	0.05-2.22
Mg	2.53	1.79	0.16-5.98
Mn	.11	.08	0.01-0.25
Sp Gr	2.70	0.12	2.41-3.13
Ag	13.10	43.7	1.00-245.00
Au(-)	0.14	0.10	0.04-0.40
Au	1.25	5.19	0.04-29.44
Cu	0.09	0.13	0.002-.58
Zn	0.38	0.41	0.03-1.65

II Middle unit of lower agglomerate - 80 samples

Element	Mean	Standard deviation	Range in values
K	2.90	1.68	0.04-5.81
SiO_2	70.25	9.93	45.70-93.02
Na	0.84	1.40	0.01-8.00
Al	4.22	2.10	0.30-7.60
Ca	0.43	0.36	0.01-1.18
Mg	2.35	1.43	0.58-5.80
Mn	.15	.07	0.03-.34
Sp Gr	2.68	.08	2.28-2.89
Ag	1.98	5.50	0.10-47.10
Au(-)	0.08	0.08	0.02-0.50
Au	0.20	0.62	0.02-4.80
Cu	0.05	0.15	0.001-.95
Zn	.17	.21	0.008-1.12

III Lower zone of lower agglomerate - 16 samples

Element	Mean	Standard deviation	Range in values
K	1.72	1.3	0.30-3.45
SiO_2	63.38	20.87	42.06-95.78
Na	2.30	2.17	0.06-5.90
Al	6.07	3.58	0.30-9.80
Ca	1.56	1.16	0.06-3.00
Mg	2.48	1.30	0.24-4.16
Mn	0.16	0.08	0.04-0.25
Sp Gr	2.77	0.08	2.65-2.86
Ag	1.57	0.92	0.60-4.70
Au	0.06	0.05	0.02-0.16
Cu	0.02	0.008	0.003-0.03
Zn	0.22	0.52	0.009-2.14

(pl. 2, and Roberts and others, 1978, pl. 1). High metal values in the core are in altered and quartz veinlet zones next to major veins, or within major quartz veinlet stockworks. More importantly all of the high gold and silver values and most of the high copper and zinc values are restricted to a distinct stratigraphic horizon; the upper unit of the lower agglomerate. The high values from surface samples also occur within this unit. The distinction of units within the lower agglomerate was made first by examination of the drill core, but later was recognized on the surface. Although similar in hand specimen lithology, units 1 and 2 of the lower agglomerate differ markedly geochemically (see for example table 1). Unit 1 is distinctly lower in K and possibly lower in SiO_2 and Al than unit 2. Metal values are higher in unit 1, even when the few anomalously high values are removed from consideration.

The variance of element concentration values within each unit is high for most elements (table 1); too high to allow direct comparison of element concentration between units. Assuming that any one element within a lithologic unit has a single and evenly distributed origin the analytical determinations for that element will be from a single population, and will have a normal or lognormal distribution. Something other than normal or lognormal distribution and especially distributions with more than one mode (high), suggests that more than one population was being sampled. In this case it suggests that the element being analyzed had either more than one origin, or that it was not evenly distributed at the time of formation of the unit being sampled. Of the elements listed in table 1, only the values for specific gravity and background metals have normal or lognormal distribution; the others are mostly bimodal or trimodal. The lack of normal distributions, reflected in the high variance values (table 1), makes comparison of chemistry between the units difficult. Only the differences in K values between the upper unit and the other two units has statistical significance. The mode of individual populations within the obviously bimodal or trimodal distribution curves can be approximated. For example, using SiO_2 values from the upper unit three populations with approximate mode values of 48 percent, 67 percent, and 90 percent can be differentiated (fig. 3). This was done by visually fitting curves to a histogram of the SiO_2 values. The 90 percent SiO_2 population is slightly greater in abundance than the 67; the 50 percent is relatively minor. Using SiO_2 values from the lower unit (fig. 3), the same three populations can be recognized, only here the 45 percent SiO_2 population is dominant and the 68 percent and 92 percent SiO_2 populations are less, but still significant. Only two populations can be seen in the SiO_2 histogram for the middle unit; a very dominant 67 percent SiO_2 population and a minor 90 percent SiO_2 population (fig. 1). The modes for all significant elements were determined in this manner and are listed in table 2.

The trimodal nature of element value distribution reflects the genetic history of the lower agglomerate. Using the modes listed in table 2 and petrography as a guideline it can be inferred that the source of elements for the lower agglomerate

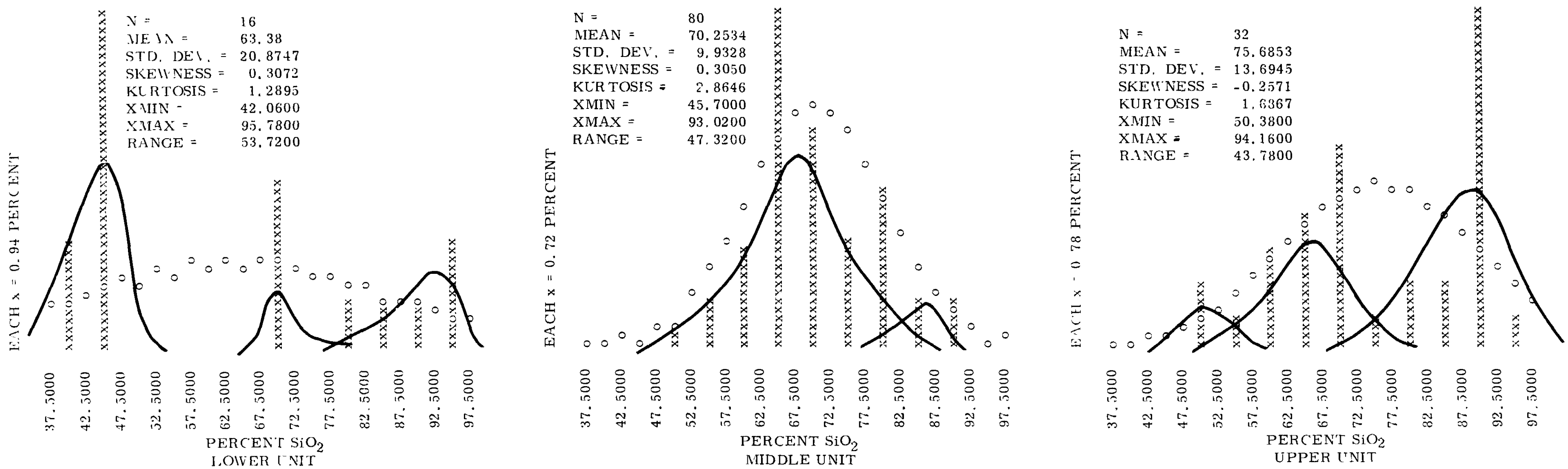


Figure 3. - Histograms and computer derived (∘∘∘∘) and visually derived (——) smooth curves for SiO_2 distribution in the upper, middle, and lower units of the lower agglomerate.

Table 2.--High, medium, and low population mode values determined by visual inspection of bimodal and trimodal distribution curves. Value representing dominant population is underlined.

Element		Upper unit	Middle unit	Lower unit
K %	h		4.00	3.50
	m		1.75	2.00
	l	.50	.50	.25
SiO_2 %	h	90	87	92
	m	67	67	68
	l	48		45
Na %	h	3.8		4.5
	m	1.5	2.2	2.2
	l	.50	.25	.50
Al %	h	9.0	7.00	9.50
	m	5.5	4.75	4.25
	l	1.25	1.00	1.25
Ca %	h	2.1		2.8
	m	.9	.9	.9
	l	.3	.3	.3
Mg %	h	5.7	5.5	
	m	3.2	3.8	3.5
	l	.4	1.2	.75
Mn ppm	h	2400	3200	2400
	m	1400		1800
	l	400	800	700
Au ppm	h			
	m	.35		
	l	.1	.02	.02

was in part andesite volcanic rock and in part diorite to granodiorite plutonic rock and dacite to rhyodacite volcanic rock. This is consistent with the geologic history of the region. Imposed upon the agglomerate were later metamorphic and hydrothermal alterations reflected by the high K, high SiO_2, high Na, low Al, high Mg(?), and high metal modes. The modes (table 2) suggest that the upper unit is more highly altered than either the middle or lower unit. If the upper unit was originally composed largely of andesitic component, similar to the lower unit, alteration involved the introduction of SiO_2 and metals and removal or dilution of Ca, Mn, Al, and Mg. If the upper unit was originally composed largely of diorite-dacite component, similar to the middle unit, alteration involved the introduction of SiO_2 and metals and removal or dilution of K, and possibly Al, and Mg. In conclusion, the chemical differences including the higher metal content of the upper unit were introduced by post-depositional alteration rather than being a primary feature.

EXPLORATION PROGRAM

Introduction

The USGS exploration project at Mahd adh Dhahab was initiated in 1972. The area of Jabal Mahd adh Dhahab was mapped at a scale of 1:2500 and the petrology and genesis of the gold deposits studied (Luce and others, 1976). An extensive traverse and grid geochemical sampling program in parts of Jabal Mahd adh Dhahab outlined several areas containing anomalous metals and also provided information on the genetic relationships of the metals present (Roberts and others, 1978). The placer potential of the gravels surrounding the mine area was also investigated (Bagdady and others, 1978). The diamond drilling program was based upon results of work by Luce, Roberts, and Bagdady. An extensive geophysical survey was done under contract to ARGAS during July and August of 1975.

Three target areas were tested: the southern mineralized zone, the SAMS mine area, and a geophysical anomaly between the mine area and the southern mineralized zone. The main objective of the diamond drilling program was to prove existence of metalization, not to outline size, shape, and tonnage of ore bodies. The drill holes were located in a manner to obtain the maximum geologic information in addition to testing potential metalized zones. Targets were picked on the basis of geology, geochemistry, and undergound maps and data of the SAMS operation. Geophysical data were utilized in the placement of drill hole 10.

Diamond drilling was by the Arabian Drilling Company during the period November 11, 1973 to June 28, 1975. A total of 10 holes with an aggregate length of 3720 m were drilled into the selected targets. Core logs containing drilling information, core recovery, structure, lithology and mineralization of core sample, and sample interval and anlytical results are on permanent file with the USGS project, Jiddah. Appendix B contains complete logs for drill holes MD-3, 7, and 8, and summary logs of the other drill holes. Metalized zones are listed in table 3 and drill-hole information in table 4.

Table 3.--Zones of metalization in core from diamond drill holes MD-1 through 10

Core interval (m)	Length (m)	Au g/ton	Ag g/ton	Cu %	Zn %	Au/Ag	Cu/Zn
MD-1							
292-303.6	11.6			.25			
MD-2							
nothing							
MD-3							
16-18	2			.12			
62-74	12			.25			
106-120	14			.42	.81	.52	
124-140	16			.30			
148-158	10			.23	.27	.85	
166-190	24			.50	1.19	.42	
(includes)							
174-190	16	17.1	84.9			.20	
174-182	8	32.8	164.0			.20	
176-182	6	42.4	207.0			.20	
178-182	4	60.9	200.5			.30	
214-230	16			.45			
MD-4							
40-46	6	3.8	30.1	.20		.13	
64-86	12			.32			
118-122	4			.62			
156-168	12			.51			
194-198	4			.23			
MD-5							
351-379	28	.20	.30	.30	.40	.67	.75

Table 3.--Zones of metalization in core from diamond drill holes MD-1 through 10 (cont'd.)

Core interval	Length	Au g/ton	Ag g/ton	Cu %	Zn %	Au/Ag	Cu/Zn
MD-6							
218.02-219.10	1.02	.96	19.5	.63	5.00	.05	.13
247.00-250.00	3.00	.18	9.5	1.35	.51	.02	2.65
303.05-304.70	1.65	.04	8.1	1.56	.93	.004	1.68
332.40-335.25	2.85	.04	4.8	.91	.17	.01	5.36
353.00-355.00	2.00	.04	9.4	.92	.70	.004	1.31
366.35-368.45	2.10	.08	65.0	2.80	2.00	.001	1.40
403.40-404.45	1.05	16.40	.3	-	-	.55	
MD-7							
121.00-125.50	4.50	4.1	26.7	.24	.90	.15	.27
129.50-139.50	10.00	5.7	28.6	.26	1.40	.15	.18
(includes) 133.50-135-50	2.00	15.0	64.0	.47	3.45	.23	.14
149.90-151.20	1.30	20.8	140.0	2.15	12.50	.15	.17
174.50-175.65	1.15	4.3	79.5	1.92	4.97	.05	.39
185.90-186.70	.80	7.2	27.0	.78	2.10	.27	.37
198.80-200.63	1.83	1.40	10.0	.70	.22	.14	3.18
248.25-256.00	7.75	1.48	20.19	1.57	4.10	.07	.38
262.00-267.00	5.0		4.2	1.45			
271.00-276.00	5.0	.14	5.05	.87	1.02	.03	.87
289.30-289.80	.50	.14	13.70	4.05	2.90	.01	1.40
299.15-299.30	.15	-	3.40	8.65	.07	-	123.6
MD-8							
72-78	6	12	12	.40	.70	1	
78-81	3	81.4	169	.70	1.40	.48	
81-87	6	12.8	56.2	.60	1.50	.23	
87-90	3	97.3	249	.60	4.30	.39	
90-94	4	3.2	20.4	.40	.50	.16	
94-97	3	31.8	170	1.20	3.00	.19	
97-112	15	5.0	31.7	1.20	2.90	.16	
112-122	10	.21	4.43	.20	.97	.05	
122-123	1	10.2	1.0	-	-	.10	
123-130	7	.30	6.53	.20	.90	.05	
130-132	2	9.2	30	.20	.30	.31	
132-133	1	190.0	240	.45	2.30	.79	
133-135	2	10.0	19.0	.20	.70	.53	
135-148	13	.33	2.68	.16	.30	.12	

Table 3.--Zones of metalization in core from diamond drill holes MD-1 through 10 (cont'd.)

Core interval	Length m	Au ppm	Ag ppm	Cu %	Zn %	Au/Ag	Cu/Zn
MD-8 (cont'd.)							
148-156	8	.88	7.18	.72	1.35	.01	
277-280	3		2.0		.84		
295-296	1	.09	1.63	.53	.55	.06	
353-355	2		3.12	.88	.13		
358-359	1	.20	16	1.98	.80	.01	
72-90	25	32	90	.60	1.63	.36	.37
97-112	15	5	32	1.20	2.90	.16	.41
112-130	18	.8	5	.20	.92	.16	.22
130-135	5	46	68	.30	.90	.68	.33
135-156	21	.5	5	.37	.70	.10	.53
72-112	40	22	68	.30	.90	.32	.33
72-156	84	14	39	.55	1.43	.36	.38
MD-9							
nothing							
MD-10							
84-88	4	.15	2.78	.10	.30	1.05	.33
88-90	2	.15	5.80	.80	2.25	2.03	.36
90-92	2	.10	2.65	.18	.20	1.04	.90
92-97	5	.15	3.52	.25	1.21	2.04	.21
97-99	2	.10	1.50	-	.39	1	
119-121	2	2.44	42.00	-	.64	1.06	
122-123	1	-	2.06	.50	2.70	2	.19
133-139	3	.23	8.00	.57	.41	1.03	1.39
171.43-171.70	.27	-	7.00	2.88	-	2	

Table 4.--Length, azimuth, inclination and location of diamond drill holes MD-1 through 10

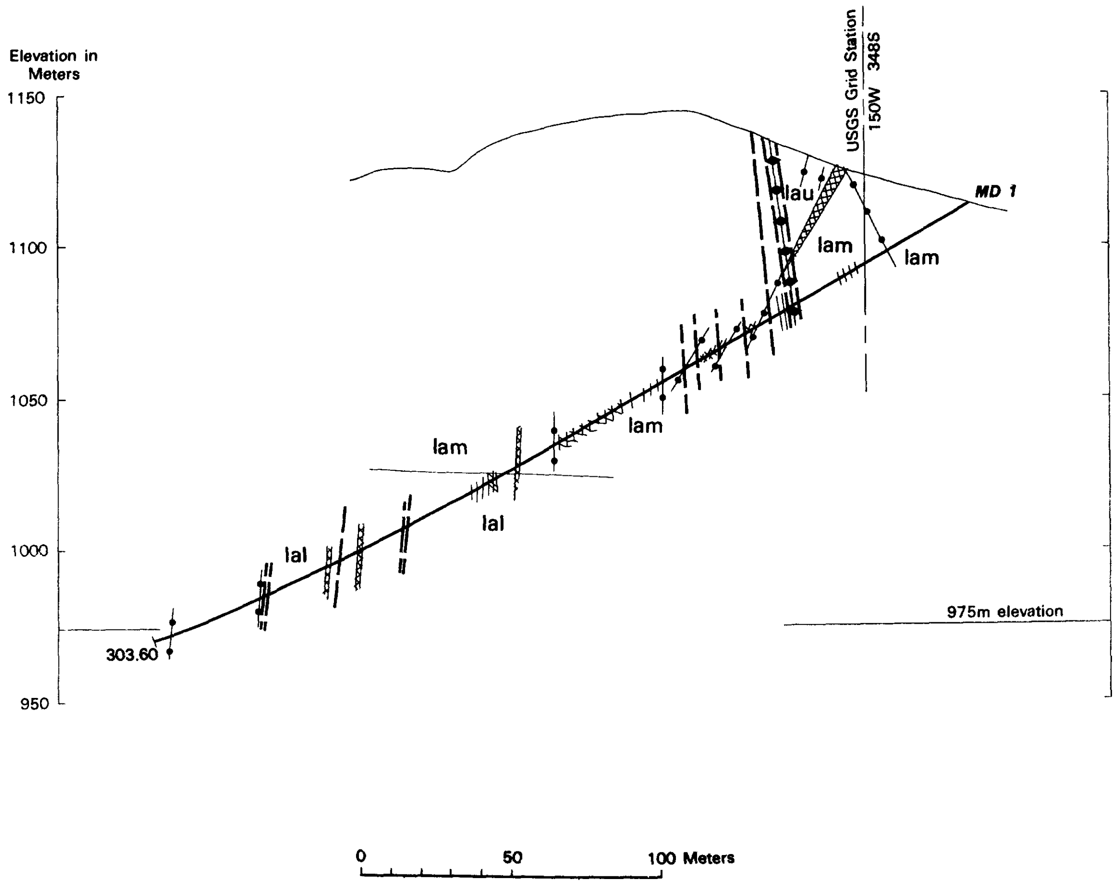
Hole #	Length	Azimuth	Inclination	Map Coordinates	
USGS					
MD-1	303.60	265°	30°	346S	116W
MD-2	321.45	305°	40°	346S	116W
MD-3	251.85	300°	35°	286S	12E
MD-4	223.60	115°	50°	344S	114W
MD-5	601.80	100°	45°	662N	298W
MD-6	450.05	157°	50°	608N	91E
MD-7	300.30	300°	35°	244S	36E
MD-8	445.65	300°	50°	303S	38E
MD-9	582.45	112°	70°	444N	251W
MD-10	249.70	90°	50°	000N	207E

Drill targets

Southern mineralized zone

The southern mineralized zone occurs at the intersection of the north-trending zone of faults, alteration, and quartz veins and the east-striking, north-dipping, upper unit of the lower agglomerate (pl. 2). Metalization is mainly gold and silver, but copper and zinc are also important constituents. Although metals are most abundant next to the major quartz veins, anomalous gold and silver occur throughout the intervein areas penetrated by drilling. The entire zone of quartz vein-upper unit intersection can be considered as potentially metalized. As surface exposures are poor the outcrop pattern of the metalized zone is not exactly defined (pl. 2). The surface expression is best shown by the distribution of samples containing anomalous gold (pl. 2).

Diamond drill holes MD-1, 2, 3, 4, 7, and 8 (figs. 4-8) explored the southern mineralized zone. Several major veins cut the agglomerate and the rock is sufficiently fractured and filled with quartz veins and veinlets to constitute a stockwork in many areas. Large areas of rock near and around the veins are highly silicified. Ancient people mined along many of these veins and faults by means of shallow pits and trenches. Most importantly, surface rock samples indicate a large area with anomalous concentrations of gold, silver, copper, lead, and zinc (Roberts and others, 1978, and pl. 2) that coincides with the major vein systems. All drill holes in this zone were designed to intersect numerous veins and still remain within the lower agglomerate.



EXPLANATION

LOWER AGGLOMERATE

lau	Upper Unit
lam	Middle Unit
lal	Lower Unit

CONTACT

FAULT ZONE

MAJOR AND SIGNIFICANT QUARTZ VEINS

NUMEROUS TO ABUNDANT QUARTZ VEINS

ANDESITE DIKE

MD 1 DIAMOND DRILL HOLE TRACE

Figure 4. Geologic cross section through diamond drill hole MD 1

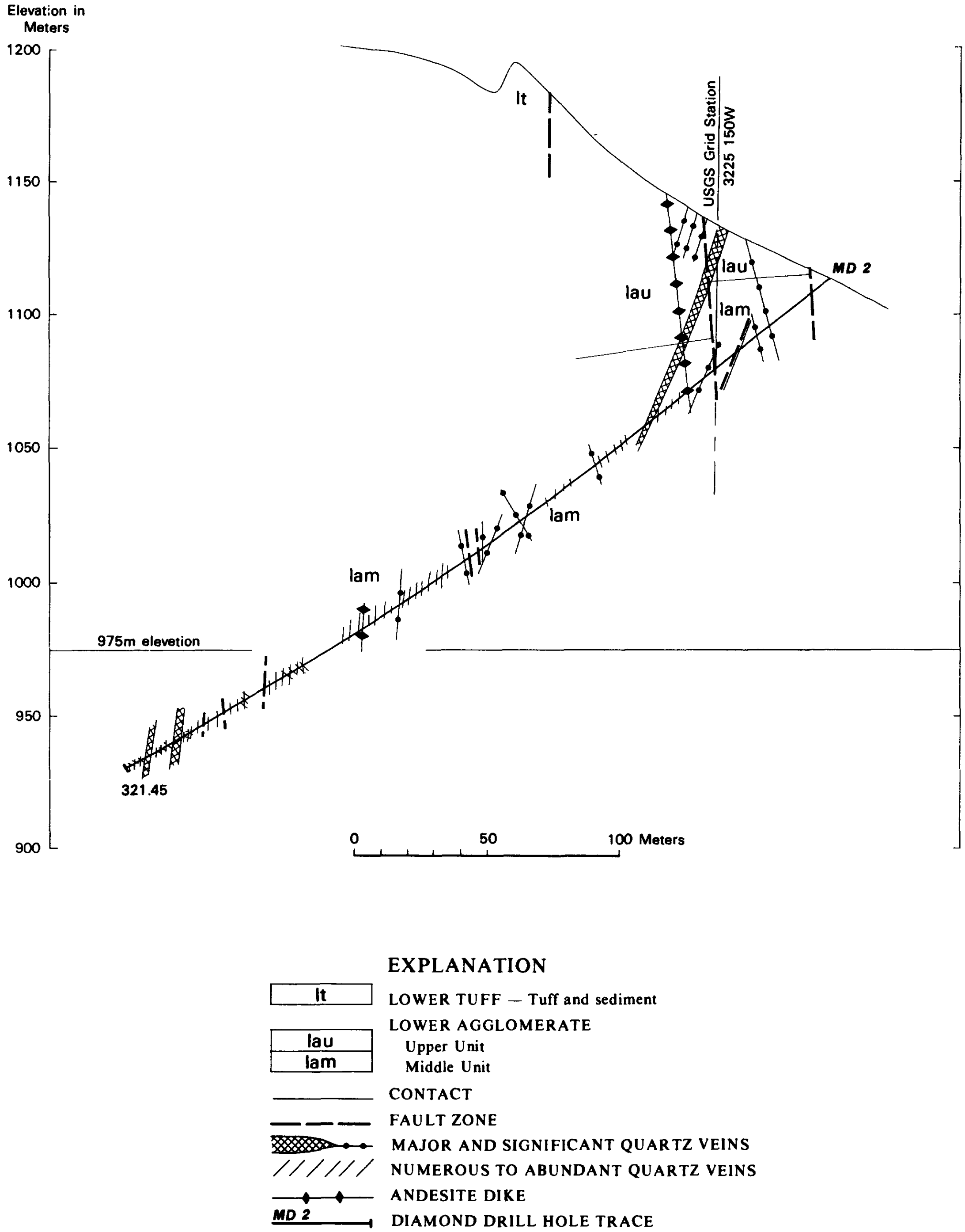


Figure 5. Geologic cross section through diamond drill hole MD 2

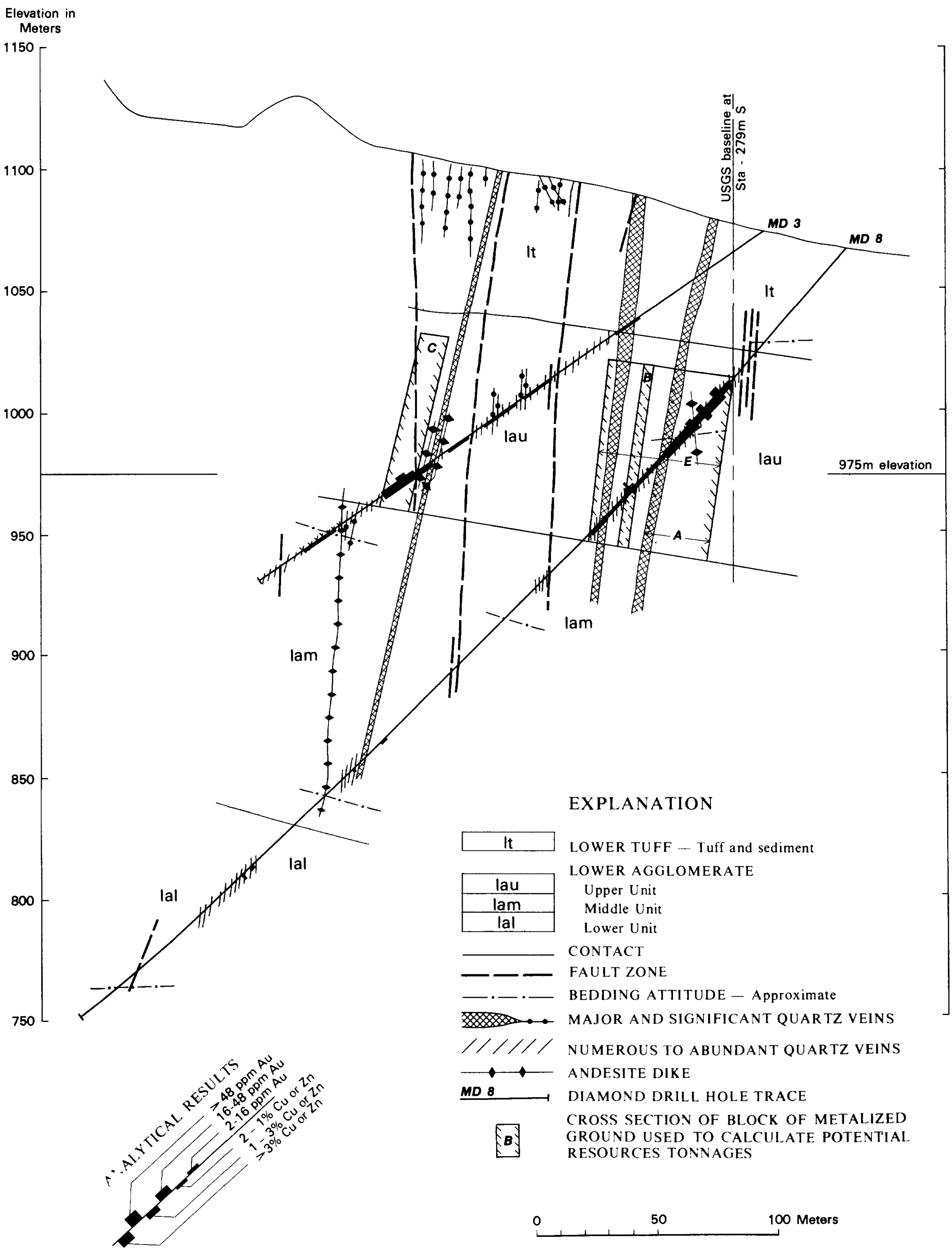
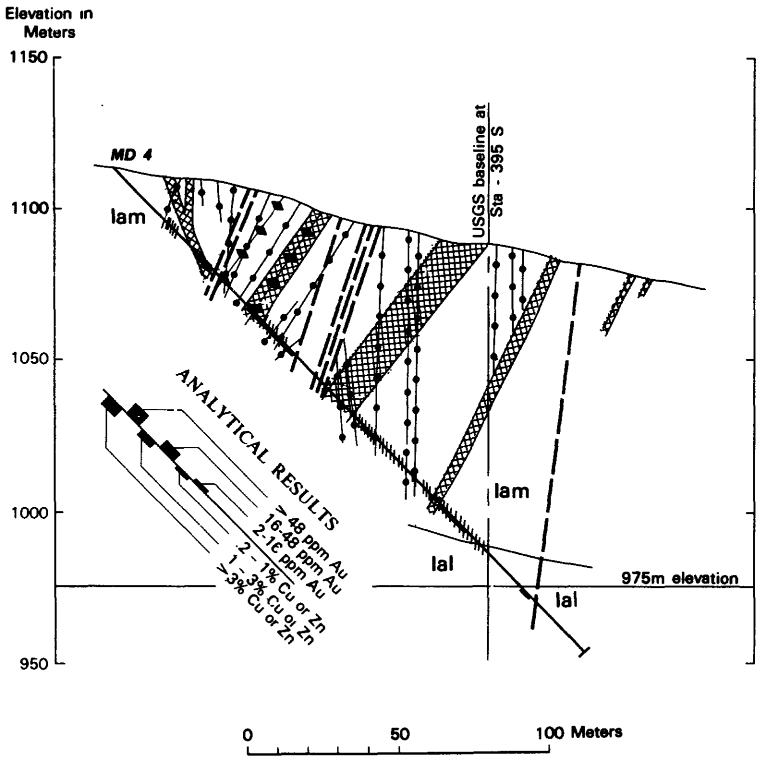


Figure 6. Geologic cross section through diamond drill holes MD 3 and 8



EXPLANATION

LOWER AGGLOMERATE

lam	Middle Unit
lal	Lower Unit

CONTACT

FAULT ZONE

MAJOR AND SIGNIFICANT QUARTZ VEINS

NUMEROUS TO ABUNDANT QUARTZ VEINS

ANDESITE DIKE

MD 4 DIAMOND DRILL HOLE TRACE

Figure 7. Geologic cross section through diamond drill hole MD 4

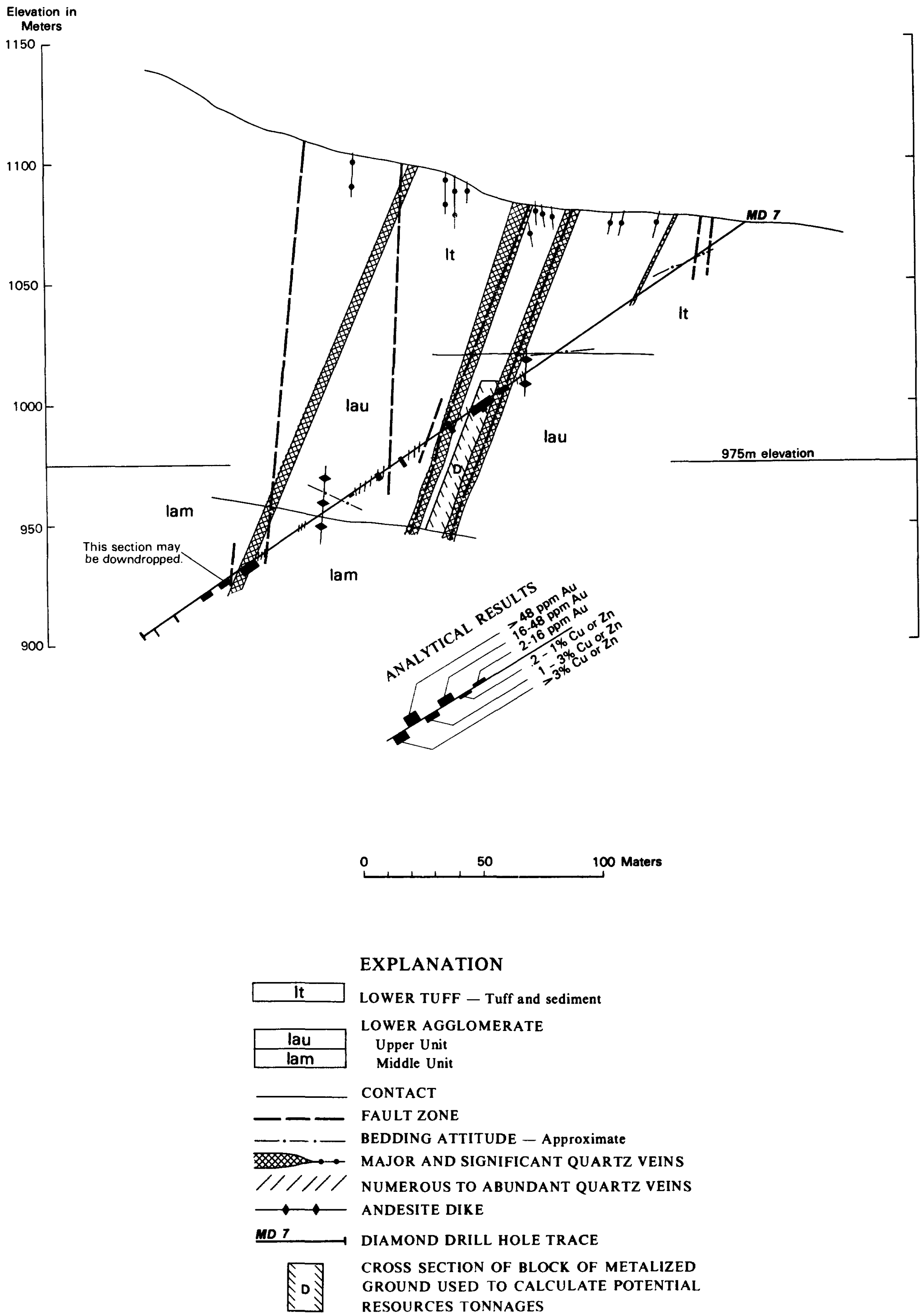


Figure 8. Geologic cross section through diamond drill hole MD 7

Drill holes MD-1, 2, and 4 (figs. 4, 5, and 7) penetrated mainly the lower and middle units of the lower agglomerate. Core from these drill holes was generally barren of metals. Drill holes MD-3, 8, and 7 (figs. 6 and 8) penetrated mainly the upper unit of the lower agglomerate. Core from these three holes contain extensive lengths of anomalous to very high-grade metalized rock. This zone of metalization, is thought to be a major orebody and worthy of more extensive exploratory investigations.

Tonnages and grades given in this report are not reserve calculations, but are estimates of potential resources. Only geologic presence and perspective of metalization is given in this report. Determination of size, distribution, and grade of ore bodies must await development work. The following assumptions are placed upon the estimates of potential resources:

a. Metalization is confined to a 40-m thick section of the upper unit of the lower agglomerate.

b. Metalization is parallel to the major quartz veins.

c. The size, shape, and grade of any one metalized block is consistent and continuous from surface to a point 50 m downdip from deepest drill penetration. This point is 250 m downdip and 160 m vertically below surface.

d. Core interval, totaling 254 m, from MD-3, 7, and 8 is representative of that zone of vein-upper unit intersection.

e. Specific gravity averages 2.7.

f. No assumption is made about metallurgical properties or recoverability of the metals.

The potentially metalized rock includes all of the upper unit of the lower agglomerate within the zone of faults, alteration, and quartz veins. The exposed width of the vein zone is approximately 300 m, but an additional 100 m of width under wadi fill to the east of the exposures can be inferred by southward projection of veins from the mine areas (pl. 2). The potentially metalized rock can be visualized as a north-dipping tabular sheet 40 m thick, 250 m wide (downdip of upper unit), and 400 m long (along strike of upper unit). North, northwest, and west-trending faults break this block into wedges that are slightly offset from one another. This block contains 17,210,000 tons of potentially metalized rock.

Drill holes MD-3, 8, and 7 (figs. 6 and 8) tested approximately 150 m of the possible 400 m length of vein-upper unit intersection. The block of ground tested by drilling, a north-dipping tabular sheet 40 m thick, 250 m wide (downdip), and 150 m long (along strike), contains 4,050,000 metric tons. Average grade of this block, as determined from analyses of all split core from the upper unit of the lower agglomerate, is 6 g/t gold and 22 g/t silver.

Five blocks of higher-grade metalization can be defined within the zone tested by drilling. Cross-sections of the higher-grade blocks are noted on figures 6 and 8. Each block is 40 m thick, 250 m wide (downdip) and of the length (along strike) shown on the cross-sections. The size and grade of each of the five blocks is given in table 5. Various combinations of the high-grade blocks are used to calculate estimated potential resources, also given in table 5. The potential resources compare favorably in grade to the grade determined from production figures of the SAMS operation. Approximately 585,000 metric tons of underground ore containing an average of 37 g/t gold and 58 g/t silver were produced during the SAMS operation. The southern mineralized zone has a potential resource of 783,000 metric tons of 31 g/t gold and 68 g/t silver ore or 1,107,000 metric tons of 27 g/t gold and 73 g/t silver ore. Because only 150 m of the possible 400 m width of vein-upper unit intersection has been explored, it is tempting to increase all potential resource figures 2.7 times. However, the geologic perspective does not warrant this; much of the untested zone is not exposed and is inferred to begin with, and metalization along the untested veins is unproved.

The SAMS mine area

The SAMS mine area was the center of most ancient mining and all recent mining. Ancient mining was from surface pits and narrow stopes and shafts as much as 50 m deep. The SAMS operation was from a quarry and from 150', 300', 450', and 600' levels of the mine (figs. 9-17). Most ore came from four major vein systems, numbers 1, 4, 8, and 14. Approximately 600,000 tons of ore averaging 1 oz of gold were taken from underground workings during the SAMS operation.

The number 1 vein system (pls. 2 and 3), the easternmost of the productive veins, is a north-trending system that was mined from surface to the 450' level. It was most productive

Table 5.--Potential resource grades and tonnages (metric) of the southern mineralized zone

Block	Size (meters)	Tonnage (metric)	Grade Gold g/ton	Silver g/ton
Total potential metalized rock	40x250x400	17,210,000		
Total metalized rock tested by drilling program	40x250x150	4,050,000	6	22
A 1/	40x250x40	675,000	28	68
B	40x250x04	108,000	47	68
C	40x250x12	324,000	17	84
D	40x250x07	189,000	11	57
E (includes A,B, and intervening rock)	40x250x50	1,350,000	13	38
Potential Resources				
C, D, and E		1,863,000	13.5	48
A and B		783,000	31	68
A, B, and C		1,107,000	27	73

1/ Outline of blocks A-E shown on figures 5 and 6.

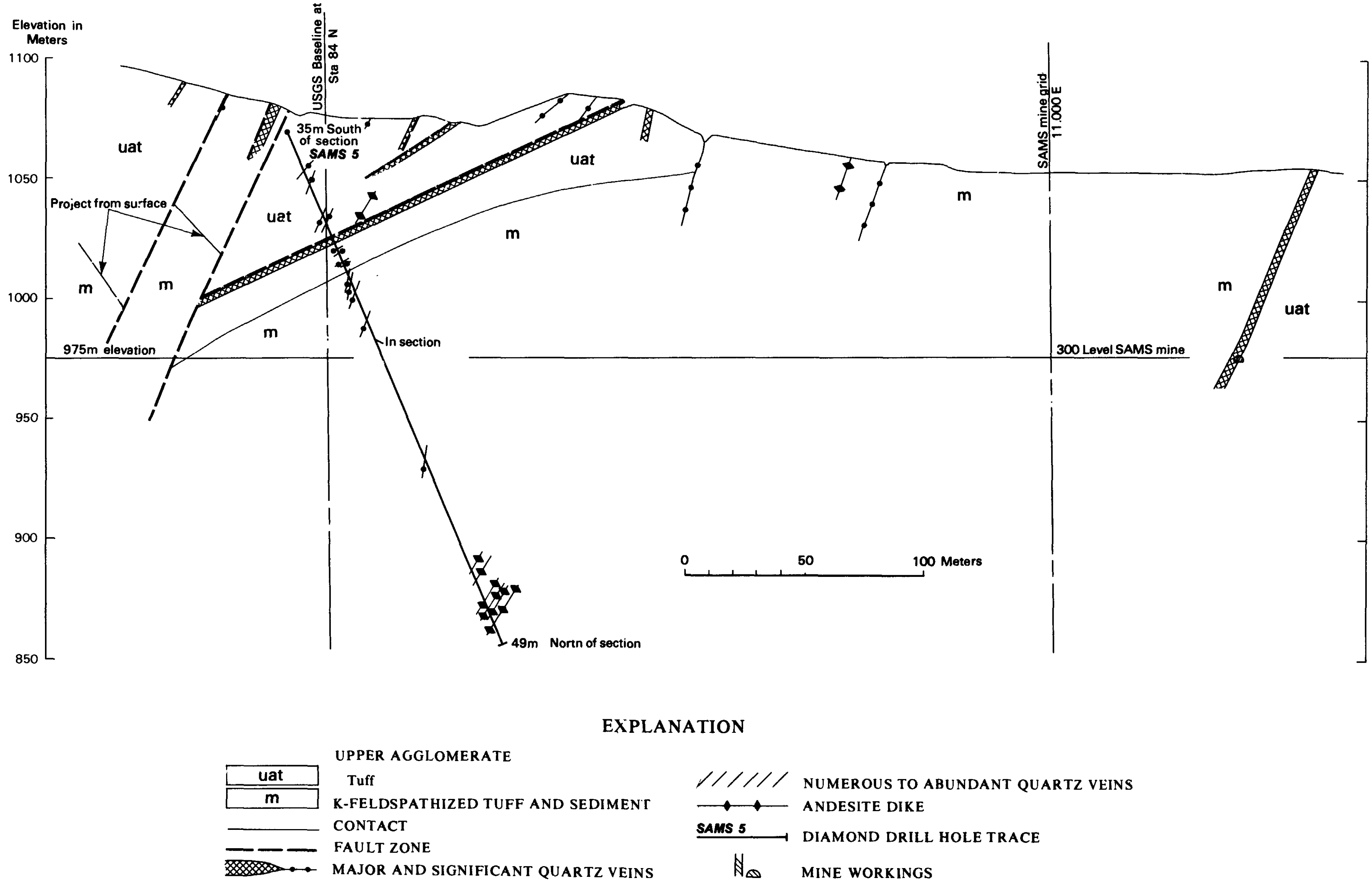


Figure 9. Geologic cross section along SAMS mine coordinate 8000 north

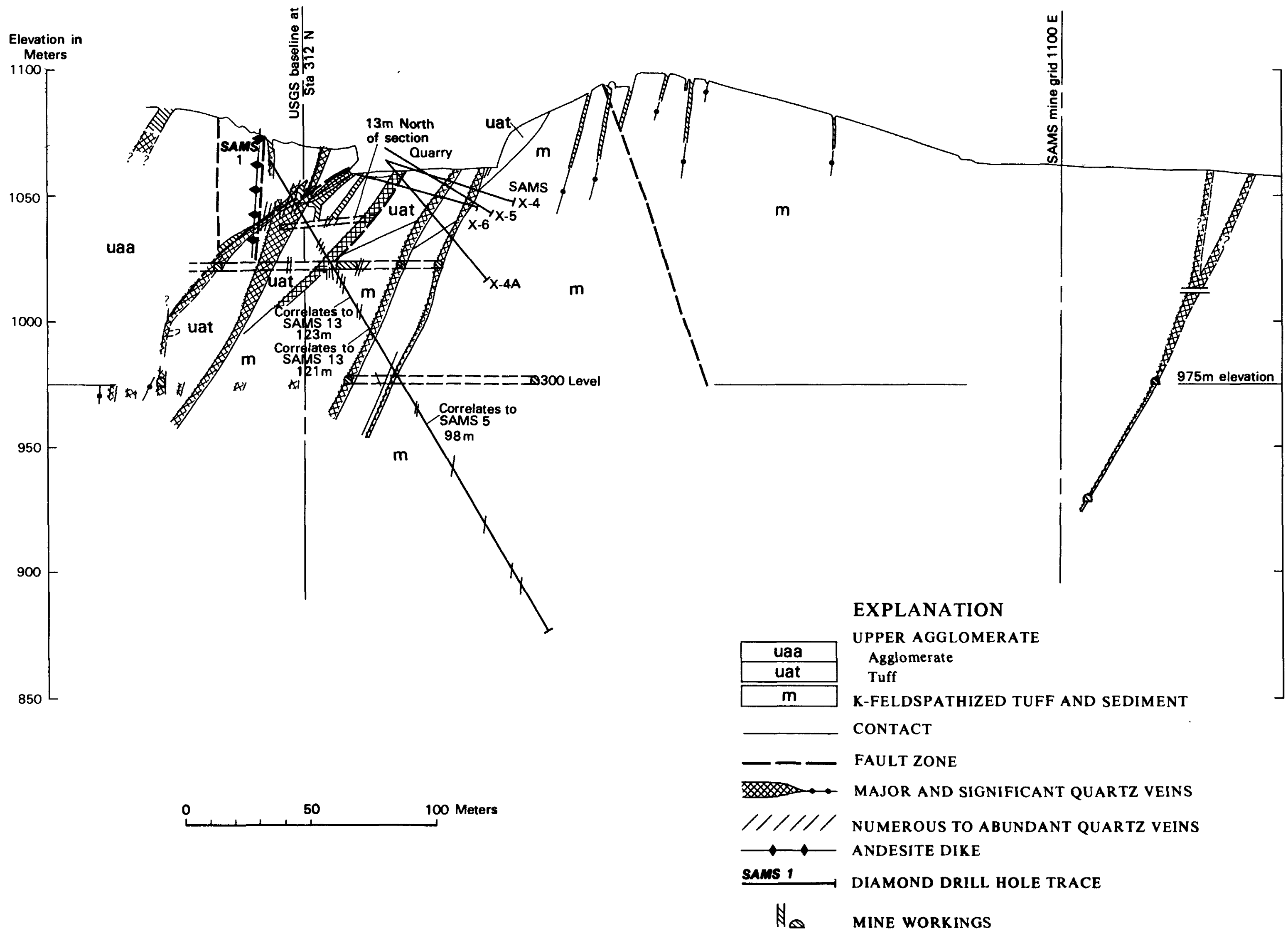


Figure 10. Geologic cross section through diamond drill hole SAMS 1

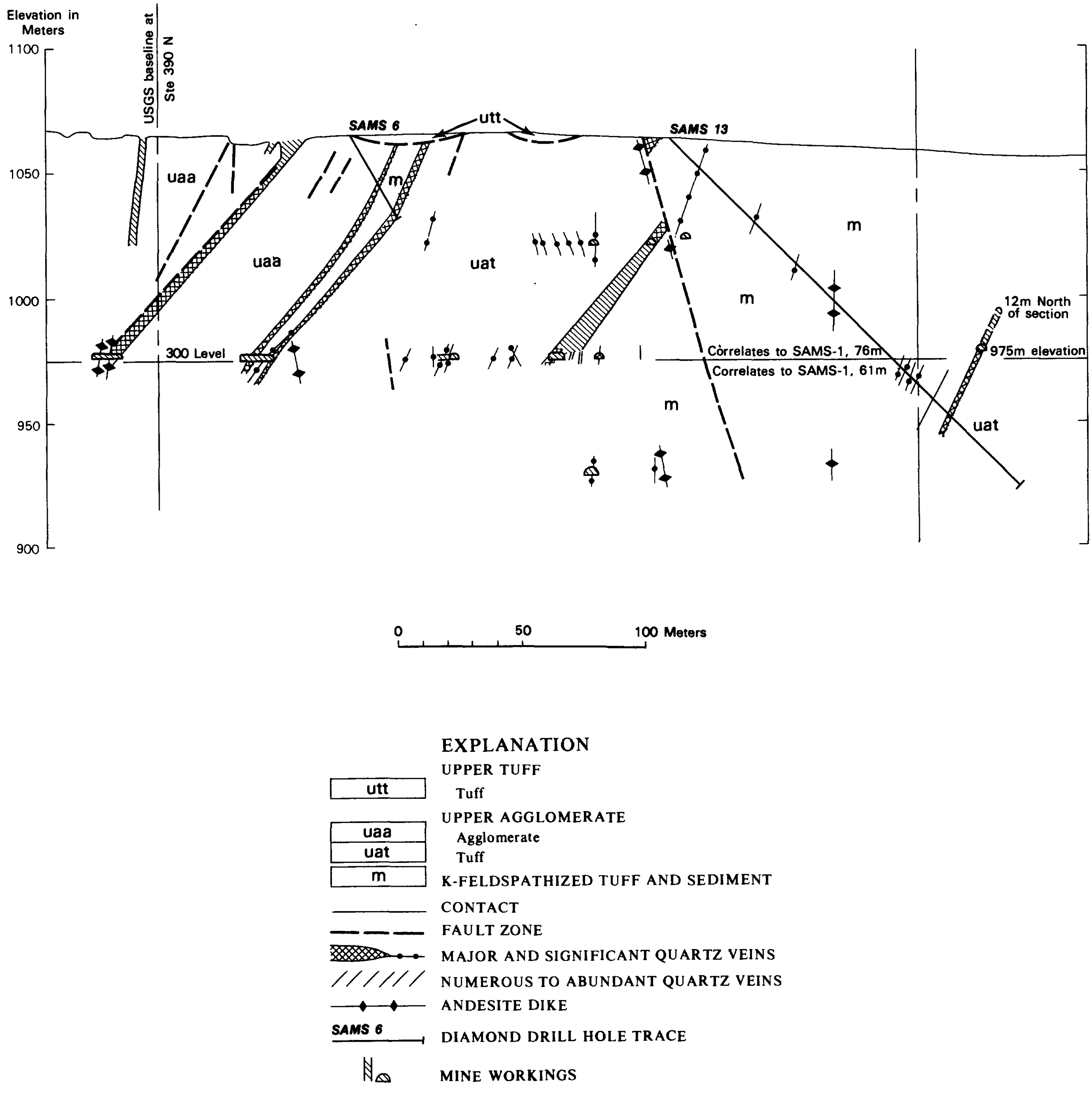


Figure 11. Geologic cross section through diamond drill holes SAMS 6 and 13

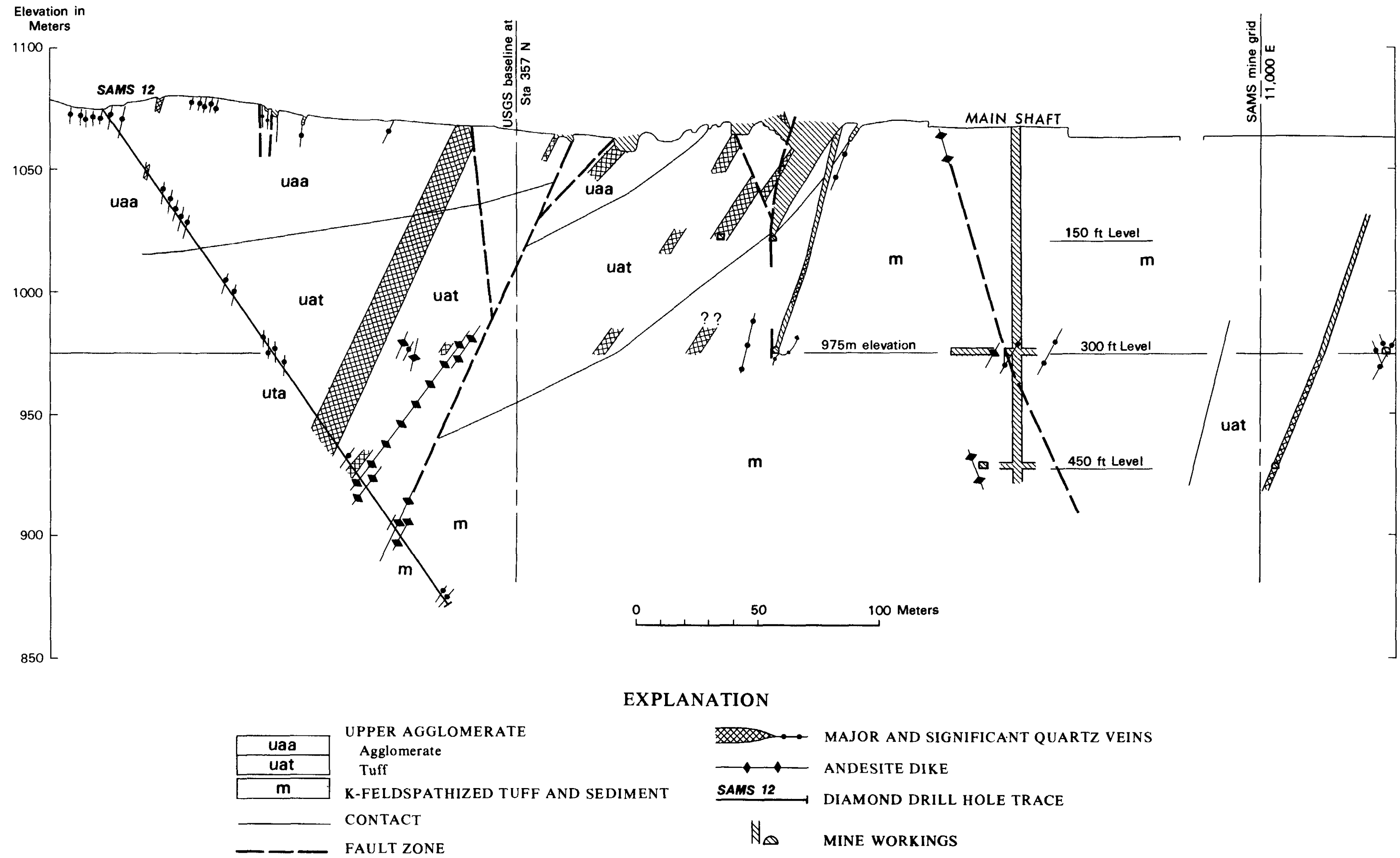


Figure 12. Geologic cross section through diamond drill hole SAMS 12

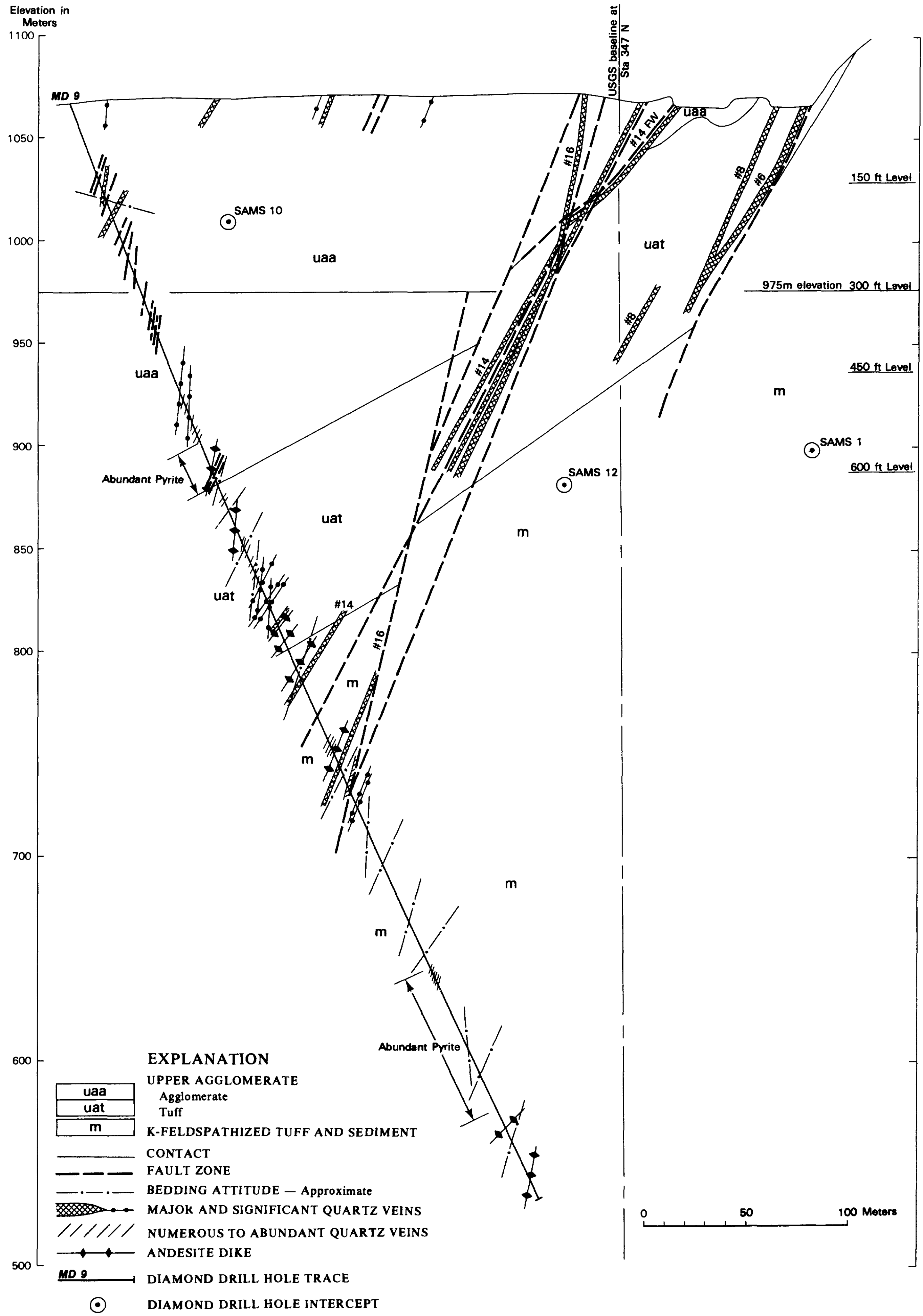


Figure 13. Geologic cross section through diamond drill hole MD 9

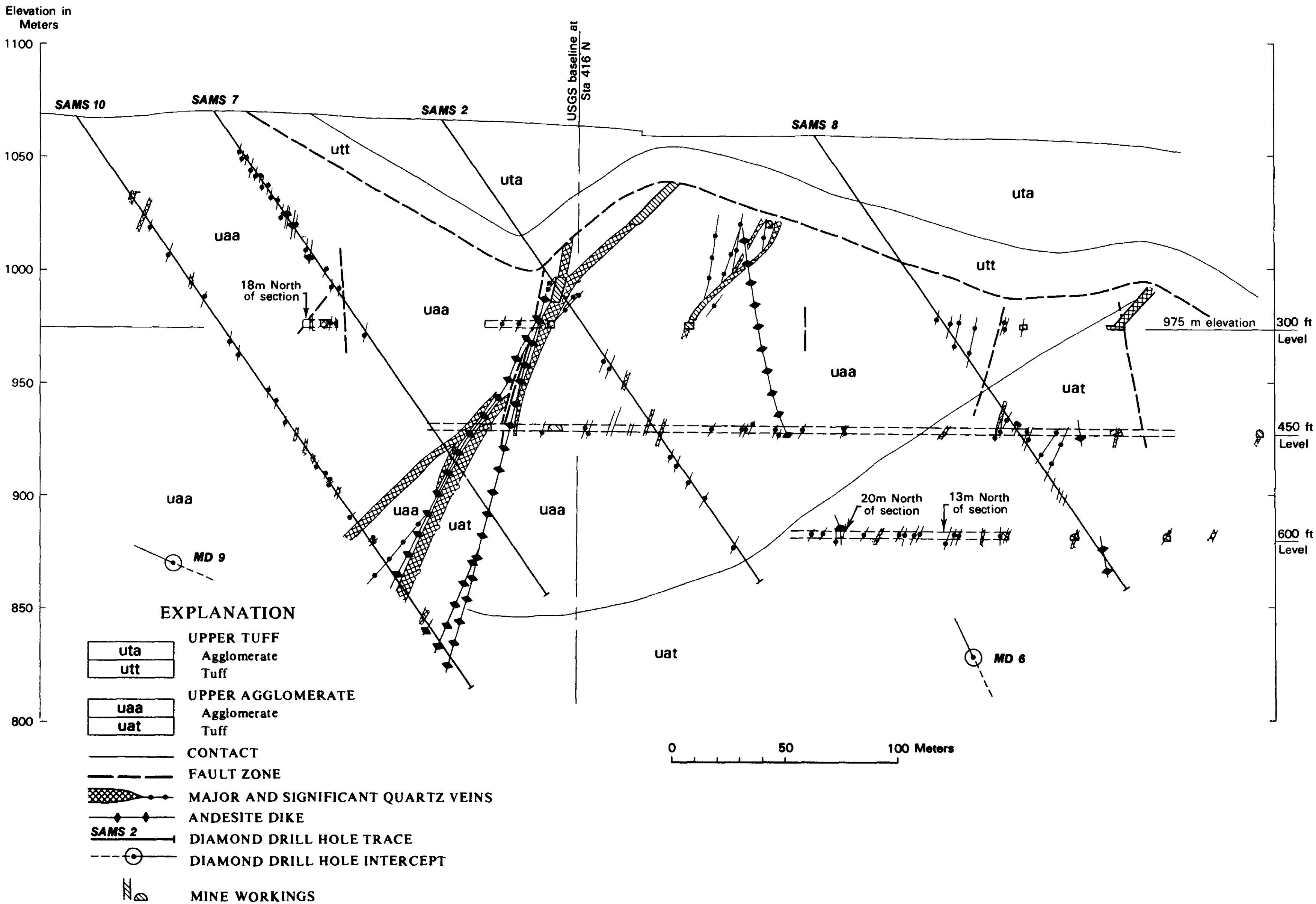


Figure 14. Geologic cross section through diamond drill holes SAMS 2, 7, 8, and 10

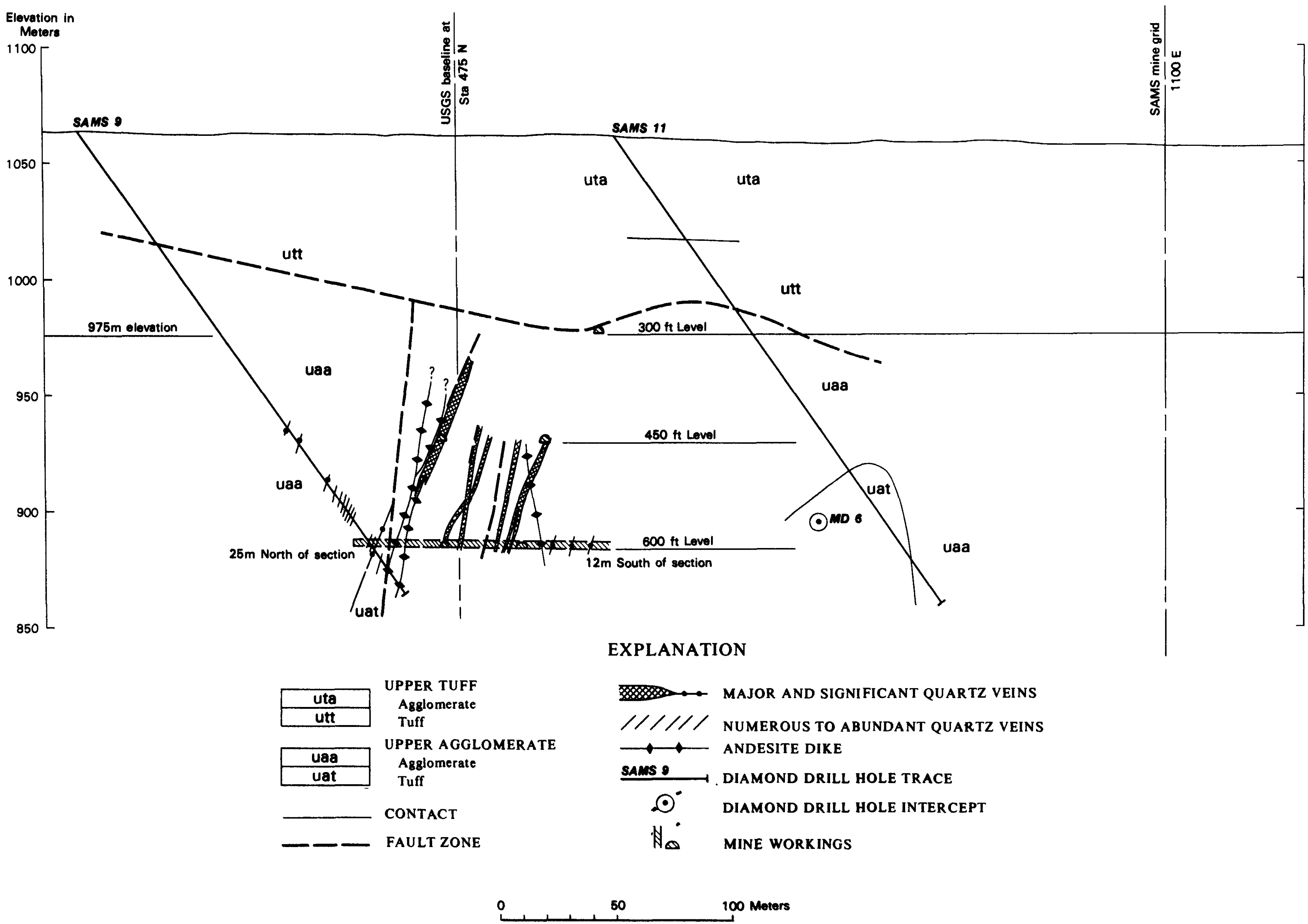


Figure 15. Geologic cross section through diamond drill holes SAMS 9 and 11

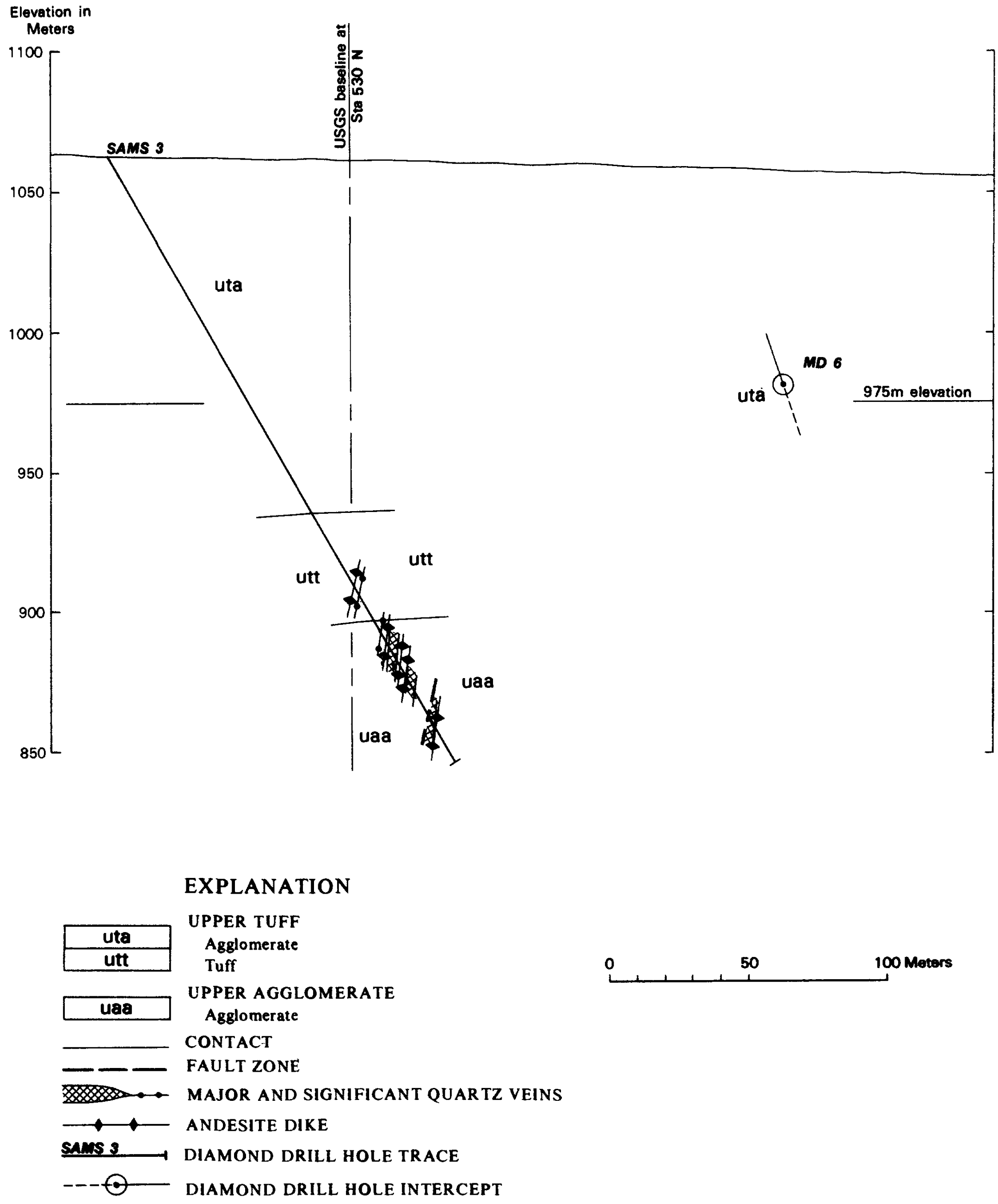


Figure 16. Geologic cross section through diamond drill holes SAMS 3

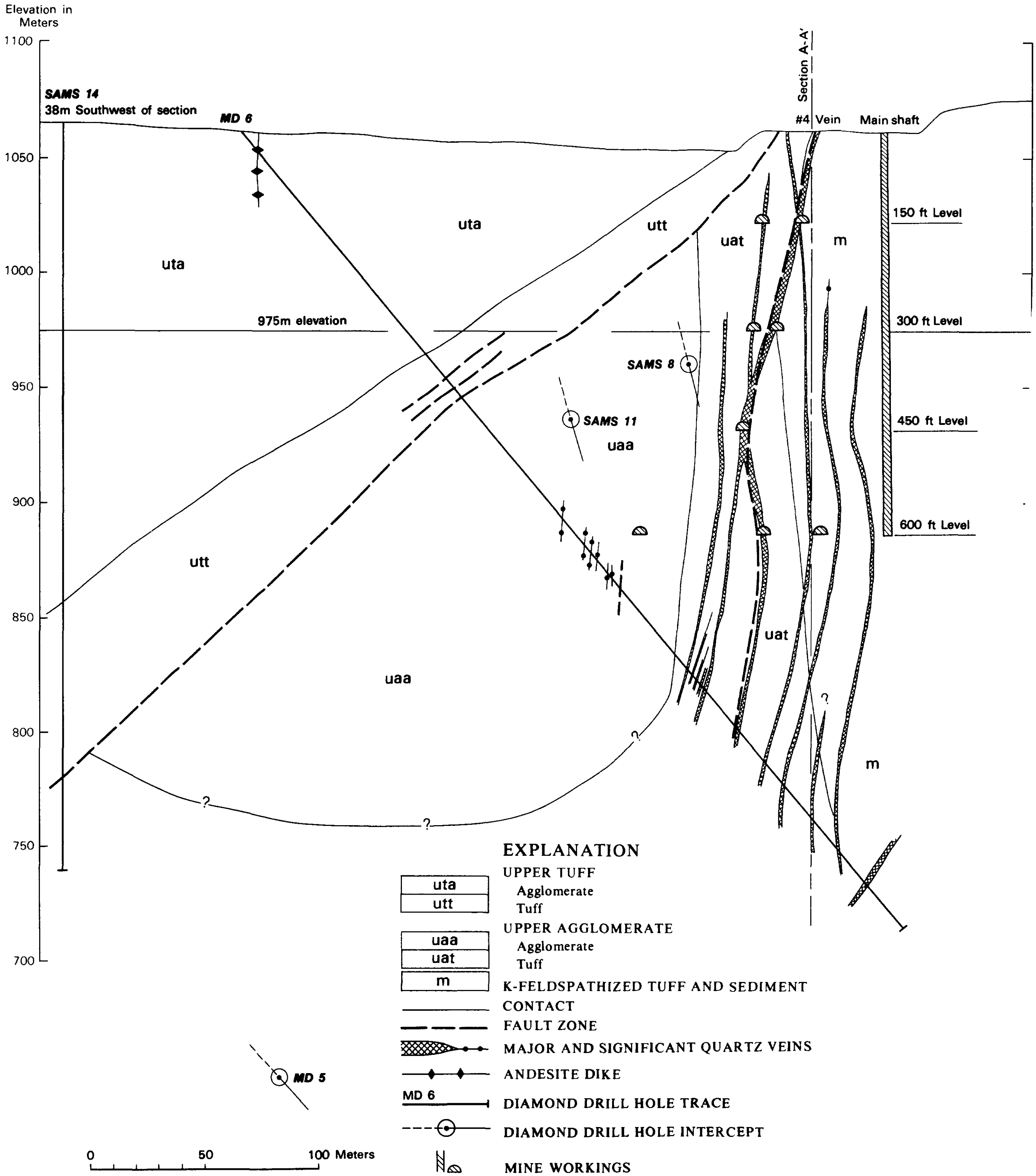


Figure 17. Geologic cross section through diamond drill holes MD 6 and SAMS 14.

on and above the 300' level where 250 m of vein length in 3 ore shoots was stoped. Only 107 m of vein length in one ore shoot was stoped on the 450' level and there was no mining attempted on the 600' level because only narrow widths of low-grade ore were indicated by exploratory diamond drilling.

The number 4 is a northeast-trending vein system that was the early major producer for the SAMS operation. Towards the southwest the number 4 system turns southward and joins the north-trending number 8 vein system (pl. 2). Excellent ore was mined above the 300' level from one ore shoot 165 m long; the same ore shoot on the 450' level was 130 m long, but was of very low grade. Only minor ore was taken from the number 4 vein on the 600' level. The south-trending portion of the number 4 vein system, before it joins the number 8 system, was a major producer at the surface but yielded no ore below the 150' level.

The number 8 vein system was the focus of extensive ancient near-surface mining. That portion of the number 8 system north of the intersection with the number 4 vein was also a major SAMS producer. Above the 300' level one ore shoot approximately 100 m long was stoped to the surface. On the 450' level this ore shoot was only 30 m long and it did not extend to the 600' level. South of the intersection with the number 4 vein the number 8 system splits into a multitude of minor mineralized fractures. One stope in this zone mined from 300' to 150' level produced ore of very erratic grade and low average gold content.

The number 14 vein system consists of two major veins, the 14 footwall (14 FW) and the 14 hanging wall (14 HW) veins (pls. 2

and 3). Only the number 14 footwall vein has produced ore. The number 14 hanging wall is a post-ore barren quartz vein. The nature of the number 14 footwall vein is not well documented. Based on some mine reports and maps the vein seems to steepen abruptly in dip at the 300' level from 45° above to 90° below. Other mine reports and maps suggest that there are actually two veins, a 45° dipping vein that is cut off by a later nearly vertical vein. Surface indications support this concept, as throughout the study area (pl. 2) earlier shallow dipping veins are cut by later nearly vertical veins, faults, and dikes. According to mining records several stopes along the number 14 footwall vein stopped abruptly against faults, mafic dikes, or barren quartz veins of north-trend and nearly vertical attitude. The number 14 hanging wall vein is within and along a major shear zone that extends the length of the map area (pl. 2), and the number 14 footwall vein is broken and offset as it approaches this zone. Two major ore shoots were mined along the number 14 footwall vein; a southern ore shoot approximately 100 m in length was stoped from the surface to the 300' level and a northern ore shoot approximately 100 m in length was stoped from the 300' level to the 600' level.

The ore shoots mined by the SAMS operation are all within 200 m of the contact of the upper agglomerate and the overlying upper tuff and occur only in the upper agglomerate. Fracturing and subsequent vein filling was post folding; the veins are not folded. The number 4 vein system and the number 14 footwall vein probably represent vein filling of fractures developed along the contact of the metasomatized tuffs and sediments and the overlying upper agglomerate at the time of folding.

Although much of the mine data suggests that metalization does not extend below the 450' level of the mine there is evidence to the contrary. Most of the ore shoots mined quit with depth; but this seems to be more a function of distance from the overlying upper tuff contact than from actual depth. The southern ore shoots along the number 8 and north-trending portion of number 4 veins were productive only near the surface. The bulk of these ore shoots were probably removed by erosion with only the lower tail left. The north ore shoot along the number 8 vein was productive from the surface, or the contact with the overlying upper tuff to the 450' level. The southern ore shoot along the number 14 footwall vein was productive from the surface to the 300' level while the northern ore shoot was productive from the upper tuff contact to the 600' level. Also a blind ore body that extends to depth in the number 10 vein, was discovered in the northwesternmost workings of the 600' level, shortly before mining operations ceased.

In summary, there were three controlling factors in ore formation: the distance below the overlying upper tuff, the presence of upper agglomerate wallrock, and the metal-bearing quartz veins. Any zone, no matter the depth, where all three criteria are met--short distance below the upper tuff, upper agglomerate wallrock, and metal-bearing quartz-veins--is a prime target area. Three such targets were explored by diamond drill holes MD-5, 6, and 9 (figs. 18, 17, and 13).

Diamond drill hole MD-5 (fig. 18) was designed to test the extensions of vein systems 8 and 14 and 10 northward from the mine area. Metalization in the mine area is confined to a zone directly below the tuff, that rakes approximately 50° north more or less parallel to the northward dip of the upper tuff. MD-5 intersected veins thought to be extensions of vein systems 14 and 8 just below the overlying tuff in the down rake extension of the mined ore bodies. The intersections were in the projected target area. The drill penetrated 60 m of silicified agglomerate containing abundant quartz veins and stockworks of veinlets, but the core contains only trace amounts of gold, .08 to 1.6 g/t, throughout. The best zone of metalization, 28 cm of core length, contains an average .20 g/t gold, .30 g/t silver, .30 percent copper, and .40 percent zinc (table 3).

Although quartz veining does continue northward from the mine under the overlying tuff cover, the low metal values detected in the split drill core do not justify further investigations.

Diamond drill hole MD-6 (fig. 17) was designed to test vein system number 4 below the 600' level of the SAMS mine and to test for possible parallel vein systems to the north. SAMS data and maps indicate that the number 4 vein system was a major producer from all mine levels, except the 600' level, and that ore on the 600' level was confined to that section of vein within agglomerate. Drill hole MD-6 intersected several veins of the number 4 system within agglomerate and one vein within fine-grained rocks (fig. 8). Most contain anomalous concentrations of copper, zinc, or silver, but only one has significant gold

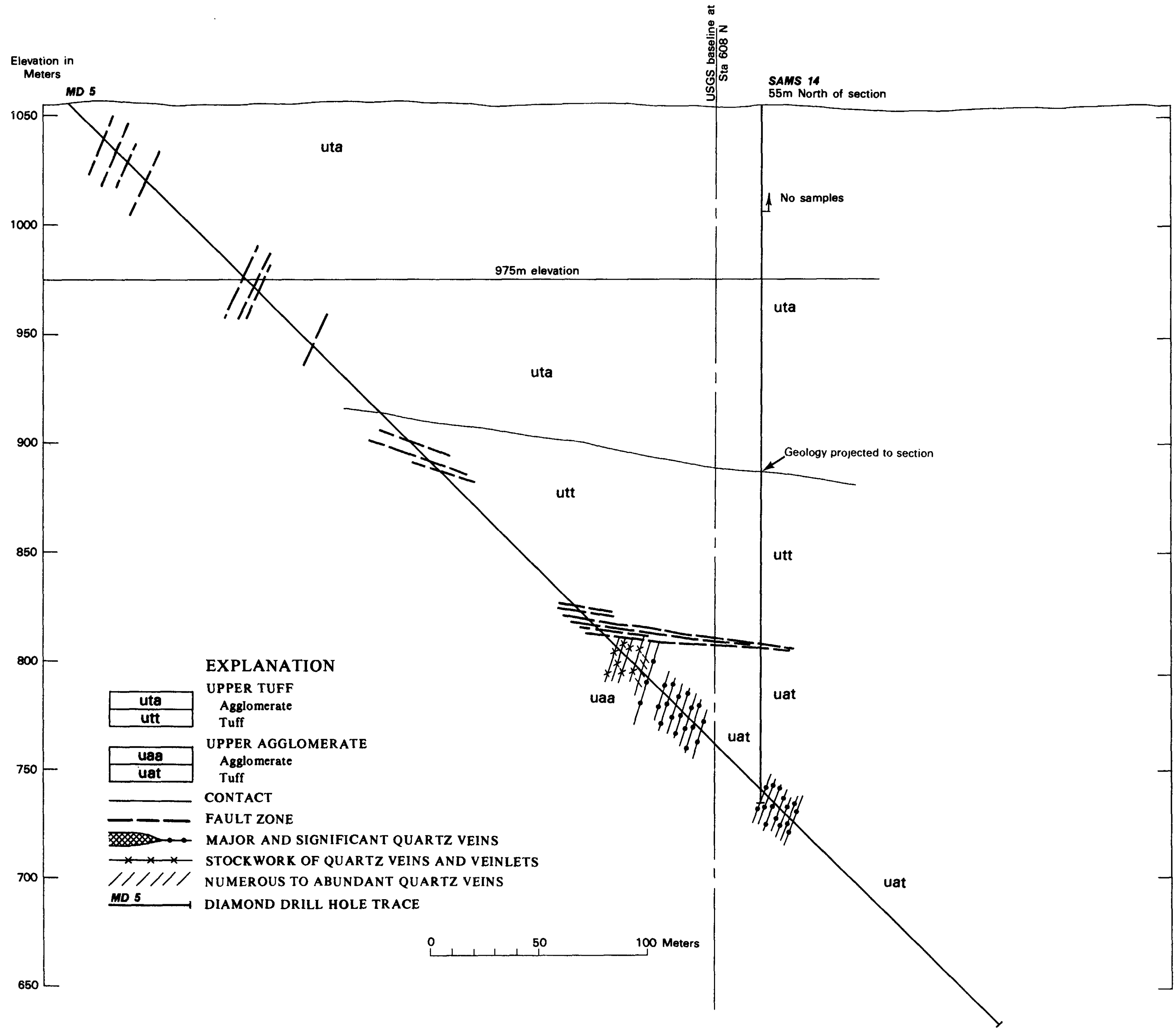


Figure 18. Geologic cross section through diamond drill hole MD 5 and SAMS 14

(table 3 and fig. 17). Although not encouraging, the results of drill hole MD-6 indicate that the number 4 vein system and some metalization does extend to depth and that most of the veins remain within agglomerate at depth.

Diamond drill hole MD-9 (fig. 13) was designed as a test of vein system 16, a possible westward extension of the flat dipping number 14 footwall vein and also to test the interior of what was presumed to be an altered and possibly mineralized rhyolite stock. This drill hole was completed before the abandoned SAMS drill core samples were discovered. Instead of rhyolite, the drill intersected fine-grained tuff and metasediment, locally potassium-feldspathized. Following examination of the SAMS drill core samples it was determined that the rock intersected in drill hole MD-9 was the relatively unaltered equivalent of the rock mapped at the surface as rhyolite. Rather than rhyolite the rock is considered to be potassium-feldspathized tuff and metasediment. The drill penetrated only minor veins and vein systems (fig. 13) that may be the extensions of veins 14 and 16. Faults paralleling vein systems 8, 14, and 16 are major structures, and it is possible that the drill intersected a zone where the vein systems had been faulted out.

The results of MD-9 indicate little potential for metalization at depth immediately below the 600' level; the veins diminish in size, the grade of mineralized material decreases, and the country rock is crytal-lithic tuff, a poor host for metalization.

Geophysical target

Ground IP and SP geophysical surveys outlined several geophysical anomalies east of the main zone of shearing, veining and alteration in an area of alluvial cover (Habib M. Merghelani, personal commun., 1975). One northeast-trending zone of coincident IP and SP anomalies occurs just east and south of the abandoned SAMS mill. Diamond drill hole MD-10 (fig. 19) was designed to test the highest of these anomalies. The anomalies undoubtedly outline alteration associated with major faults; but the purpose of the drilling was to ascertain the presence of metalized veins within or parallel the fault. The drill penetrated several quartz veins and quartz veinlet stockworks and a major fault system. Several intervals of core contained anomalous but not high metal values (table 3). The metalization potential below the trace of drill hole MD-10 is not considered favorable as the veins pass into fine-grained tuffs and metasediments with depth. However, this is a newly recognized gold-bearing quartz vein and by tracing this vein northward or southward to areas of favorable agglomerate host rock significant ore bodies may be found.

CONCLUSIONS AND RECOMMENDATIONS

The main target investigated at Mahd adh Dhahab is a north-trending zone of quartz veins, faults, alteration, and related metalization that is exposed in an area approximately 400 m wide and 1000 m long. The eastern and southern boundaries of the quartz vein zone are covered by alluvium. The quartz vein zone cuts a sequence of volcanic, volcanic-sedimentary, and sedimentary

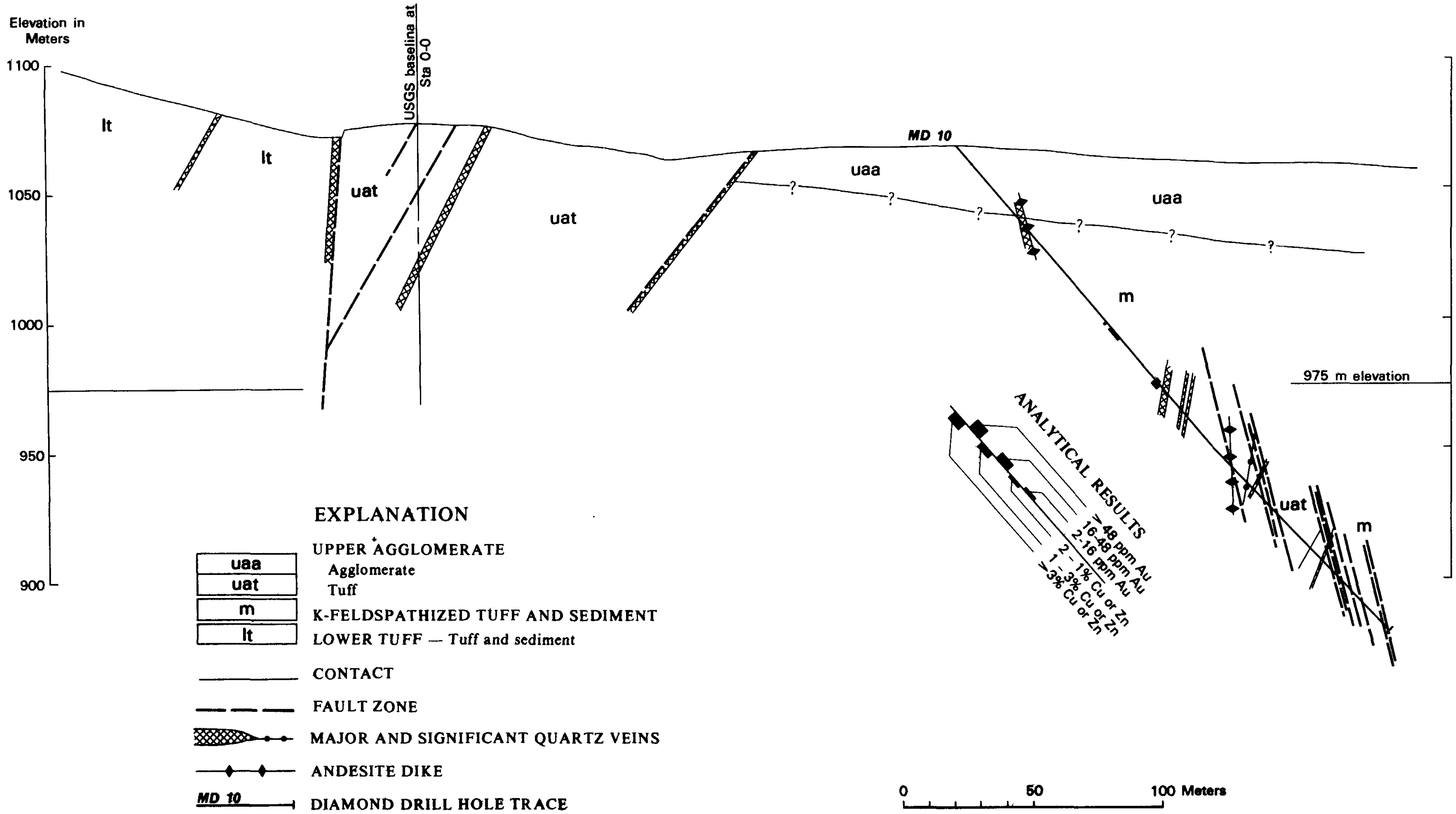


Figure 19. Geologic cross section through diamond drill hole MD 10

rocks of the Mahd adh Dhahab Series, which may be correlated regionally to the Hulayfah Group. Most of the rock types exposed at Mahd adh Dhahab, from coarse-grained agglomerate to very fine-grained tuff, are of mixed clastic, pyroclastic, and transported pyroclastic origin. Low-grade metamorphism has not obliterated original textures of the rock, nor has alteration, shearing, and large scale brecciation within the vein zone. Host rocks within the quartz vein zone are generally propylitized and locally silicified. A more widespread potassium-feldspathization has affected all rock types, but is most intense in the vicinity of the SAMS mine.

Anomalous metal values occur within or next to quartz veins throughout the length of their exposure within all rock types. Significant concentrations of gold and silver, however, occur only where the quartz vein zone intersects agglomerate. The SAMS mine ore bodies occur along the quartz vein zone-upper agglomerate intersection, and the southern metalized zone occurs along the quartz vein zone-lower agglomerate intersection. In both metalized zones the agglomerate is propylitized, highly silicified, and locally highly pyritized, with fragments in the agglomerate replaced by pyrite. Quartz veins through the agglomerates are larger and have extensive stockworks of veinlets extending out from them that are not present where the veins cut finer-grained rocks.

The southern metalized zone at the intersection of quartz vein zone and the upper unit of the lower agglomerate contains approximately 4 million metric tons of potentially metalized rock. Size of this block is 40 m thick, 250 m downdip, and 150 m along strike of the lower agglomerate. Average grade of the block explored by three diamond drill holes is 6 g/t gold and 22 g/t silver. Unexplored portions of the zone of quartz vein-upper unit intersection contain an additional 13 million metric tons of potentially metalized rock. Three higher grade blocks within the explored block contain 1.1 million metric tons containing an average 27 g/t gold and 73 g/t silver.

The potential for additional ore in the SAMS mine area lies in zones directly below the upper tuff where metal-bearing quartz veins cut agglomerate. Several of these zones were tested by diamond drilling with little success. The down-rake extension of vein systems 8, 10, and 14 below the upper tuff were tested by drill hole MD-5. The possibility of metal-bearing veins north of and parallel to the number 4 vein system and the extension of the number 4 vein system to depth was tested by drill hole MD-6. The number 16 vein system and the possibility of a westward extension of the shallow dipping number 14 footwall vein were tested by drill hole MD-9.

Two targets remain untested in the SAMS mine area: the possibility of metalization in the lower agglomerate below the potassium-feldspathized tuffs and sediments and the north and northeast extensions of the number 1 and number 4 vein systems. Thickness of the lower tuff is estimated to be 150 to 200 m. Depth to the contact in the vicinity of the southern portions of vein systems 8 and 14 should be 250 to 300 m. However the depth to the contact will increase rapidly north, west, and south, as the structure is a northwest-plunging antiform.

The extensions of the number 4 and number 1 vein systems to the north and east are thought to have the best potential for undiscovered metalization. Neither the northward and down-rake extension of vein system number 1, nor the eastward and down-rake extension of vein system number 4 have been adequately tested. Both systems have been traced underground to their terminations against the overlying upper tuff, but their extensions under the tuff were not checked. The favorable host-rock agglomerates extend to depth in this area.

The potential of hidden quartz veins and zones of metalization under alluvial cover in the wadi to the east of the map area (pl. 2) is unknown. A few poor outcrops of veins can be seen, but the configuration of the favorable agglomerates is unknown as extensive faulting along north and northeast trends makes projection from the mapped area difficult. A series of drill holes in a panel extending eastward in the plane of drill holes MD-3, 7, and 8 is needed to define the eastern limit of the vein zone-lower agglomerate intersection. Planning of other drill holes in this area should be based on geophysical surveys.

The quartz veins and related metalization occupy north and northeast-trending fractures that are thought to be tear faults associated with major northeast-trending right lateral faulting. The metals were deposited largely in the agglomerates because the agglomerate was a "chemical" and "physical" receptive host and in part because poorly developed fractures in the tight lower and upper tuffs restricted fluid movement, thus trapping metal-bearing fluids in the underlying agglomerates. The setting of quartz vein emplacement and metalization in the geologic history of the region is uncertain. Quartz veins in the surrounding area are genetically and physically related to a series of rhyodacite to rhyolite dikes. Although not exposed in the map area, similar dike rock occurs on the SAMS mine dump, suggesting that dikes were intersected underground. These dikes terminate in flow rocks and breccia of the Murdama Group (Brown and others, 1963) exposed a few kilometers north of the mine area, and are probably feeder dikes to that volcanic sequence. All intrusive rocks in the region including the alkaline granites are cut by the dike swarms that may be a late phase of alkaline granite igneous activity. It is thought that both the potassium-feldspathization and the quartz veining and metalization are related to alkaline igneous activity, best represented by the intrusive bodies at Jabal Sayid and Jabal Hadh'b Daheen, north and northeast of the mine area, and the series of dikes. The potassium-feldspathization took place during emplacement of the plutonic bodies, dikeswarms, and volcanic rocks, and the quartz veining and metalization during late-stage dike and vein formation.

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APPENDIX A

Analytical results

The list that follows contains sample descriptions and analytical values for geochemical surface samples and semi-quantitative spectrographic analysis results of split core samples. Locations of the geochemical surface samples are given on plate 2.

Appendix A-1. Geochemical surface sample descriptions and analytical values

Map[1/] Location	Au ppm	Ag ppm	Cu ppm	Zn ppm	Au/Ag	Sample number	Interval meters	Description
033N 027E	-	.75	100	90		105700	1.2	Country rock, no quartz
038N 027E	.95	3.30	2650	2750		701	2.0	Quartz breccia on east edge main zone
032N 020E	-	1.50	240	175		702	.90	Comb quartz vein on west edge of main zone
031N 022E	.18	2.80	2500	2000		703	.30	Copper-stained sheared Cr on edge main vein zone
015N 030E	-	8.40	240	110		704	.60	Quartz breccia from center main vein zone
001S 028E	6.20	24.00	2500	3875	.26	705	.40	Quartz breccia from center main vein zone
002S 030E	8.00	20.00	3050	6750	.40	706	.30	Sheared and brecciated Cr on east edge main vein zone
002S 025E	3.00	11.50	3000	4300	.26	707	.60	Stringy quartz veinlet zone on west edge main vein
012N 008E	-	.30	90	1500		708	.15	Comb quartz vein, west-trend
004S 001E	.40	6.40	2950	650		709	dump	Quartz breccia
019S 002W	.12	2.00	425	350		710	2.4	Intercalated wall rock from stringy quartz veinlet zone
019S 002W	-	-	85	325		711	2.4	Quartz only from above zone
003S 024W	-	1.30	6250	-		712	2.0	Sheared, granular quartz breccia, east edge main zone
						713 through 717		Continuous sequence from east to west across zone
023S 023W	-	.40	500	90		713	1.2	Quartz breccia on east edge main vein zone
023S 024W	-	.80	600	-		714	.9	Massive quartz breccia, minor WR
024S 025W	-	1.30	700	90		715	1.2	Massive quartz
024S 026W	-	2.50	1700	450		716	.8	Chlorite-rich quartz veinlets in andesite tuff
024S 027W	1.60	2.30	7750	700	.70	717	2.9	Massive to slightly veined andesite tuff
031S 044W	-	.70	500	425		718	.20	Comb quartz vein, 25° trend
043S 090W	-	.50	650	925		719	.50	Stringy comb quartz vein
034S 085W	.08	1.30	3900	1150		720	1.0	Stringy quartz breccia vein, 50% WR, copper stain
030S 080W	-	.80	1325	750		721	1.0	Stringy quartz breccia vein
027S 075W	-	.80	3550	600		722	.80	Composite, comb and breccia vein, local copper stain
007S 010E	-	.80	310	-		723	1.0	Lense of quartz breccia in stringy comb quartz vein zone
025S 003E	-	240	600	325		724	1.0	Quartz breccia on edge of large comb quartz vein
032S 006W	-	.50	135	1000		725	.60	Massive comb quartz
						726 through 728		Continuous sequence from west to east across zone
051S 024W	-	1.00	1225	475		726	.70	Slightly sheared and altered purple tuff
051S 023W	-	1.00	1375	450		727	.90	Sheared and altered tuff with abundant green chlorite
051S 022W	-	.50	325	150		728	1.0	White quartz breccia vein
051S 015W	-	.70	1025	150		729	1.0	Slightly veined and sheared breccia

1/ Map coordinates occur as field number card 3 in RASS system: columns 1-5 meters north or south; column 6-letter N or S; column 7-blank; colums 8-12 meters east or west; column 13, letter E or W.

Appendix A-2. Geochemical surface sample descriptions and analytical values (cont'd.)

Map Location	Au ppm	Ag ppm	Cu ppm	Zn ppm	Au/Ag	Sample number	Interval meters	Description
						730 through 732		Continuous sequence from west to east
052S 012W	.05	2.30	7500	225			.80	Quartz breccia on west edge vein, copper stained
052S 011W	-	.70	600	90		105731	1.0	Mainly massive quartz
052S 010W	-	.80	340	150		732	1.0	Massive quartz
016S 018E	.20	1.80	875	125		734	.60	Comb quartz vein, some copper-stain
018S 026E	-	-	235	150		735	1.2	Quartz and Cr breccia
030S 025E	-	-	80	110		736	.50	Comb quartz, 30% Cr
037S 030E	-	-	80	100		737	1.0	Stringy quartz breccia
050S 035E	-	-	350	100		738	.30	Banded comb quartz
025S 050E	-	.70	350	1000		739	.50	Silicified zone along edge of fault
022S 065E	.65	.70	1700	250		740	.40	Stringy comb quartz vein, low west dip
022S 065E	2.00	1.50	1250	1875	1.33	741	.40	Granular quartz breccia, east edge vein, Cu stained
002N 090E	2.10	7.00	1000	2375	.30	742	2.0	Stringy comb quartz veins
040N 130E	.16	2.30	6375	1075	.41	743	Dump	Quartz breccia, copper-stained
031S 130E	6.20	15.00	1845	3500		744	1.2	Banded stringy veins
034S 112E	.16	4.00	1500	2375		745	1.3	Diffuse stringy vein
056S 132E	.14	1.30	1325	475		746	.80	Quartz breccia, along low west dipping litho contact
080S 140E	.35	.50	975	700		747	.60	Quartz breccia, low west dip, Mn and Fe oxides
074S 139E	.06	1.50	825	550		748	1.0	Altered Cr breccia. Fe oxides
053S 090E	.06	.70	110	60		749	1.0	Silicified breccia zone
068S 026E	.06	-	360	50		750	.60	Comb quartz vein
107S 146E	.44	.50	750	375		751	.90	Veined and altered zone, low west dip, Cu stained
120S 148E	1.10	.80	18000	450	1.4	752	.90	Veined and altered zone along post-altered fault
124S 143E	-	.40	150	90		753	.90	Altered breccia in Wadi
118S 132E	-	.80	360	90		754	1.20	Comb quartz vein
109S 125E	-	.40	300	150		755	.50	Brecciated comb quartz
093S 101E	.40	.80	1225	300		756	.30	Comb quartz
101S 097E	.24	.60	1125	650		757	1.0	Breccia, comb quartz with 40% Cr
104S 070E	.08	.40	260	250		758	.90	Stringy comb quartz veins, 50%
086S 060E	.34	.40	525	150		759	Dump	Quartz breccia
098E 050E	.34	.40	175	150		760	.80	Stringy comb quartz

Appendix A-3. Geochemical surface sample descriptions and analytical values (cont'd.)

Map Location	Au ppm	Ag ppm	Cu ppm	Zn ppm	Au/Ag	Sample number	Interval meters	Description
						761 through 766		Continuous sequence from east to west across zone
100S 020W	.12	.50	3925	350		105761	1.0	Comb quartz
100S 21W	-	.50	700	175		762	1.1	Granular quartz breccia
100S 22W	.06	1.30	1750	500		763	1.0	Same
100S 23W	.12	.80	750	210		764	1.8	Same
100S 25W	.12	1.00	425	175		765	1.5	Massive to comb quartz
100S 26W	.14	1.00	600	210		766	.60	Granular quartz breccia
101S 33W	.24	1.00	1700	2500		767	.65	Quartz breccia, Mn oxides
095S 50W	4.00	4.50	3250	2750	.9	768	.90	Stringy banded vein, abundant chlorite, Cu stained
092S 52W	.32	1.00	3125	3000		769	.70	Same
						770 through 772		Continuous sequence from east to west across zone
094S 81W	.08	1.00	750	425		770	.90	String quartz breccia
094S 82W	.04	1.60	900	510		771	1.2	Granulated breccia of quartz and Cr
094S 83W	1.10	2.10	875	700	.52	772	.80	Stringy quartz breccia
095S 89W	.28	3.20	1225	2250		773	.90	Brecciated comb quartz
095S 90W	-	1.00	425	1475		774	.80	Veined and altered zone on west edge vein. Cu stained
091S 104W	-	1.00	260	950		775	.60	Stringy comb quartz
071S 83W	.12	3.30	300	1100		776	.40	Fault breccia, mixed quartz and Cr
061S 76W	.12	2.80	750	700		777	.30	Brecciated comb quartz
097S 02W	-	.40	300	225		778	.20	Comb quartz
103S 11E	.14	2.10	1800	950		779	.50	Brecciated comb quartz
103S 12E	-	1.00	875	1225		780	.30	Chlorite-rich breccia on edge of vein
104S 028E	.12	.50	2025	520		781	.60	Stringy comb quartz
134S 121W	-	.50	975	400		782	1.3	Brecciated comb quartz
134S 128W	-	.80	100	925		783	1.0	Granulated fault breccia
133S 105W	.04	.70	260	600		784	.40	Brecciated comb quartz
137S 098W	.14	1.00	1075	975		785	.35	Stringy comb quartz, east trend
137S 093W	.72	1.90	1700	925		786	1.1	Vuggy breccia, 60% Cr
148S 092W	.12	1.60	600	1200		787	.20	Stringy quartz breccia
148S 083W	.18	1.60	2825	650		788	.35	Same
154S 076W	3.00	5.30	24500	2175	.57	789	.50	Granulated quartz breccia, Cu stain
150S 060W	.14	1.10	1500	750		790	.80	Altered and shear Cr and quartz along fault

Appendix A-4. Geochemical surface sample descriptions and analytical values (cont'd.)

Map Location		Au ppm	Ag ppm	Cu ppm	Zn ppm	Au/Ag	Sample number	Interval meters	Description
147S	051W	.88	.50	600	575		105791	.40	Brecciated comb quartz
142S	037W	.40	.70	2125	425		792	.75	Stringy comb quartz
							792 through 796		Continuous sequence from west to east across zone
142S	034W	-	.50	700	600		793	1.5	Fine-grained tuffaceous sandstone
142S	033W	.18	1.00	700	425		794	1.0	Fault breccia, knots of quartz
142S	032W	-	1.10	575	225		795	1.4	Same
142S	031W	-	.80	1635	520		796	2.0	Slightly sheared and altered country rock
							797 through 800		Continuous sequence from west to east across zone
144S	023W	.08	2.10	825	350		797	.60	Stringy veinlet zone on west edge main vein
144S	022W	.08	.80	575	300		798	1.0	Brecciated comb quartz
144S	021W	.08	1.10	1425	175		799	1.0	Granulated quartz breccia, Fe oxides
144S	020W	.08	.80	1500	175		800	.9	Same, Cu stained
143S	014W	1.24	3.70	500	200	.34	801	.75	Comb quartz
154S	019W	-	.50	270	50		802	.55	Brecciated zone on east edge vein
150S	001W	-	.20	370	300		803	.65	Comb quartz, combined with minor Cr
146S	021W	-	.80	1600	825		804	1.3	Granulated quartz and Cr breccia
147S	024W	.84	.90	825	50		805	1.0	Same
							806 through 811		Continuous sequence from west to east across zone
156S	041E	1.98	3.50	2575	250	.57	806	.7	Granulated quartz breccia, Fe oxides
156S	042E	.08	2.20	285	75		807	.6	Comb quartz
156S	043E	.20	2.60	825	125		808	.7	Stringy comb quartz
156S	044E	.22	3.20	2250	450		809	.9	Granulated quartz breccia, abundant chlorite
156S	045E	.60	2.70	1800	325		810	1.2	Same
156S	046E	-	0.90	190	75		811	1.3	Comb quartz
125S	080E	-	.80	2400	400		812	.60	Brecciated comb quartz
118S	083E	.32	1.10	33000	1150		813	.25	Altered fault zone, copper-stained
129S	044E	.14	.60	500	75		814	Dump	Quartz breccia, Fe oxides
157S	066E	.05	.50	380	70		815	.60	Slightly brecciated comb quartz
200S	070E	.08	.50	575	225		816	.35	Quartz breccia, Fe oxides
196S	069E	-	.50	575	550		817	.90	Coarse breccia, mostly comb quartz
152S	100W	3.10	2.00	825	1875	1.55	818	.70	Stringy quartz breccia
160S	095W	4.90	7.20	3075	460	.68	819	.45	Banded chlorite quartz vein, Cu stained
175S	70W	.27	4.20	38000	9259		820	.40	Granulated quartz breccia in bedding plane fault

Appendix A-5. Geochemical surface sample descriptions and analytical values (cont'd.)

Map Location	Au ppm	Ag ppm	Cu ppm	Zn ppm	Au/Ag	Sample number	Interval meters	Description
184S 70W	.12	1.30	1200	123		105821	.20	Bleached and altered tuff on west edge vein
184S 69W	-	1.40	1250	145		822	.60	Vuggy, dursy stringy vein
175S 40W	.05	.70	1100	760		823	.65	Same
***						825 through	838	Continuous sequence from west to east
182S 26W	-	.90	650	1100		825	.50	Granular, rounded quartz breccia on edge vein
182S 25W	-	.80	575	300		826	1.0	Quartz breccia, abundant small angular fragments
182S 24W	-	.80	1200	138		827	.80	Vuggy, stringy veins, Fe oxides
182S 23W	.08	1.80	41000	500		828	.90	Quartz breccia, granulated, Cu stained
191S 13E	-	.40	400	525		829	.35	Stringy vein, Fe oxides
192S 29E	.08	.90	425	325		830	.45	Comb quartz
192S 30E	-	3.50	150	48		831	.50	Comb quartz
191S 34E	-	.80	475	300		832	.70	Stringy quartz breccia, rounded to angular fragments
196S 49E	-	.80	415	225		833	.40	Comb quartz copper-stained
197S 50E	-	.80	850	475		834	.70	Same
198S 51E	-	.60	455	275		835	.50	Stringy comb quartz, 30% Cr
197S 64E	-	.80	260	40		836	.70	Comb quartz
182S 120W	.38	.84	3000	1800		837	.50	Brecciated comb quartz, local vugs
187S 119W	.12	1.40	335	625		838	.45	Breccia from fault zone
206S 107W	.12	1.70	425	2250		839	.50	Brecciated and altered rock next to fault zone
204S 103W	.12	1.60	800	300		840	.35	Banded comb quartz vein
202S 100W	.05	1.60	375	550		841	.20	Comb quartz
178S 95W	.05	1.40	4000	2250		842	1.0	Coarse breccia, minor quartz cement, Cu stain
185S 92W	.14	5.00	1650	1625		843	.70	Quartz breccia, Fe oxides and Cu stain
204S 91W	-	2.10	480	950		844	.85	Comb quartz with chlorite banding
204S 91W	-	3.50	75	350		845	.85	Country rock from same zone as 844
						846 through	848	Continuous sequence from west to east
205S 87W	-	1.50	700	1875		846	.50	Quartz and wall rock breccia, locally granulated
205S 86W	.46	2.30	900	850		847	.50	Same
205S 85W	.17	1.40	600	350		848	.50	Same
217S 54W	-	1.10	1150	250		849	.70	Quartz breccia, Fe oxides, minor Cu stain
218S 46W	-	1.70	265	103		850	.20	Banded comb quartz
***								
172S 26W	-	.40	250	125		824	.30	Comb quartz, east-trending vein

Appendix A-6. Geochemical surface sample descriptions and analytical values (cont'd.)

Map Location	Au ppm	Ag ppm	Cu ppm	Zn ppm	Au/Ag	Sample number	Interval meters	Description
218S 43W	-	2.70	365	108		105851	2.5	Coarse quartz and wall rock breccia
218S 41W	-	1.70	600	135		852	.55	Breccia on east edge vein, mostly Cr with granular quartz
						853 through 863		Continuous sequence from west to east
239S 129W	3.30	2.80	2700	126	1.18	853	1.0	Massive healed quartz breccia
239S 128W	1.60	7.30	520	100	.22	854	1.0	Sheared Cr with numerous 1-2 cm quartz veinlets
239S 127W	3.80	25.00	2400	1000	.15	855	1.0	Vuggy banded quartz vein
239S 126W	.18	3.60	1000	410		856	1.0	Slightly sheared and vein Cr
239S 125W	.28	4.50	1500	145		857	1.0	Same
239S 124W	.35	4.25	1350	145		858	1.0	Same with several banded veinlets
239S 123W	.72	3.25	625	350		859	.50	Major fracture zone, brecciated quartz and Cr
239S 122W	.58	8.50	485	300		860	1.0	Lacy banded vein systems in sheared Cr
239S 121W	.17	1.56	850	875		861	1.0	Lacy banded vein and veinlet system in sheared Cr
239S 120W	.17	2.75	950	625		862	1.0	Same
239S 119W	.15	3.35	580	550		863	1.0	Same
245S 116W	1.50	3.90	700	975	.38	864	.55	Granulated quartz breccia
244S 113W	.12	2.21	1375	250		865	1.0	Stringy veins of granulated and brecciated quartz
240S 111W	.12	2.40	750	750		866	.45	Banded and locally granulated vein
250S 111W	.17	1.10	450	300		867	.60	Stringy veins of brecciated quartz
246S 101W	.12	2.10	1150	500		868	.45	Same 30% Sr
248S 98W	.20	.75	1150	130		869	.35	Quartz breccia, granulated
254S 90W	.25	1.75	1150	1375		870	.30	Stringy veins
248S 85W	.02	1.00	1250	560		871	.70	Horsetail zone of larger vein
233S 60W	.17	1.20	465	126		872	.45	Banded, vuggy quartz carbonate vein, Cu stain
235S 56W	.15	.75	1150	350		873	.70	Same
233S 47W	.05	.51	520	325		874	.40	Granulated quartz breccia, Fe oxides
233S 35W	.05	.75	110	74		875	.70	Quartz breccia, angular fragments
235S 34W	.12	1.25	350	350		876	1.4	Brecciated and silicified WR on east edge vein
313S 140W	6.50	32.50	21500	8000	.20	877	Dump	Quartz breccia, Fe oxides, Cu stained
308S 120W	3.50	21.20	1800	775	.17	878	1.0	Quartz breccia, chlorite-rich
299S 150W	-	1.20	900	300		879	.80	Quartz breccia, may not be in place
295S 160W	.17	1.65	485	970		880	.40	Stringy comb quartz veins

Appendix A-7. Geochemical surface sample descriptions and analytical values (cont'd.)

Map Location		Au ppm	Ag ppm	Cu ppm	Zn ppm	Au/Ag	Sample number	Interval meters	Description
287S	158W	.10	2.75	500	1500		105881	.75	Altered WR between vein and andesite dike
273S	141W	.65	3.25	2125	840		882	.60	Stringy comb quartz veins
270S	135W	.72	10.00	1450	1250		883	1.0	Same
268S	125W	.72	1.85	1100	1750		884	.70	Brecciated CR from fault zone
265S	123W	.20	2.25	450	190		885	.20	Comb quartz
265S	113W	.97	2.75	950	450		886	1.5	Quartz breccia, angular to rounded fragments
264S	115W	.42	3.00	1200	1375		887	.70	Quartz and WR breccia along edge of major vein
262S	108W	.20	1.65	1125	1250		888	1.0	Brecciated and altered country rock
273S	73W	.10	.51	475	450		889	1.0	Stringy veins of brecciated quartz, 50% WR
351S	174W	2.50	18.00	7500	7000	.14	890	1.0	Stringy comb quartz, Cu stain
352S	169W	7.80	75.00	2300	650	.10	891	1.0	Coarse breccia of quartz and silifified WR
							892 through 894		Continuous sequence from west to east
353S	160W	31.00	47.50	61000	7800	.65	892	1.0	Sheared, altered veinlet zone, Cu stained
353S	159W	1.70	17.50	2200	2500	.10	893	1.0	Vuggy quartz breccia, rounded fragments
353S	158W	27.50	31.50	8500	7800	.87	894	1.0	Same
343S	148W	35.00	33.50	1450	1625	1.04	895	.40	Quartz breccia, with abundant chlorite-rich fragments
							896 through 900		Continuous sequence from west to east
316S	75W	.15	8.50	675	1700		896	1.0	Granulated quartz breccia
316S	74W	.15	1.85	1200	67000		897	1.0	Quartz breccia, with post mieral shearing
316S	73W	2.50	22.50	1725	1150	.11	898	1.0	Same
316S	72W	1.80	56.00	2200	1575	.03	899	1.0	Stringy breccia zone, boudins of older quartz
316S	71W	1.80	32.50	975	790	.06	900	.80	Same
316S	64W	.12	6.50	475	575		901	.75	Granulated quartz vein, banding
320S	63W	.66	13.50	1725	2900		902	1.0	Same
322S	61W	2.40	15.00	6875	3450	.16	903	.50	Comb quartz, copper-stained
320S	59W	.55	6.50	4625	2825		904	.80	Altered breccia zone on east edge vein
322S	46W	.95	38.50	1250	465		905	1.0	Stringy vein zone, abundant chlorite
323S	42W	.17	3.80	825	500		906	.80	Brecciated comb quartz
							907 through 910		Continuous sequence from west to east
325S	36W	.25	4.75	250	910		907	1.0	Quartz breccia
325S	35W	.62	15.00	11500	450		908	1.0	Same
325S	34W	.92	37.50	20000	31000		909	1.0	Same, abundant copper stain
325S	33W	2.20	9.00	5625	5400	.24	910	1.0	Altered Cr on east edge of vein

Appendix A-8 Geochemical surface samples descriptions and analytical values (cont'd.)

Map Location		Au ppm	Ag ppm	Cu ppm	Zn ppm	Au/Ag	Sample number	Interval meters	Description
326W	27W	9.00	5.00	475	279	1.80	105911	.70	Quartz WR breccia
326S	24W	1.32	2.50	375	225		912	1.2	Stringy banded veins, Fe oxides, post mineral shears
297S	11W	.10	1.10	625	90		913	.60	Massive quartz
266S	21W	.10	2.70	325	80		914	.50	Quartz breccia
264S	20W	.15	4.00	1725	700		915	1.0	Altered tuff on east edge of vein
265S	26W	.26	21.20	1450	1550		916	.50	Veined and altered Cr, along NW trend
285S	30W	.15	1.00	375	510		917	1.0	Bleached and altered zone
							918 through 920		Continuous sequence from west to east
345S	19W	2.20	38.50	325	250	.06	918	.80	Altered and sheared zone, 50% WR
345S	18W	2.24	37.50	250	60	.06	919	.50	Granulated quartz breccia
345S	17W	24.00	100.00	375	120	.24	920	.70	Altered and veined zone, 30% WR
347S	04W	3.60	24.00	2700	1550	.15	921	.65	Granulated quartz breccia, slight banding
348S	01W	1.72	18.50	1550	715	.09	922	1.0	Stringy quartz veins
350S	06W	.11	-	675	75	3.0	923	.45	Massive comb quartz
350S	22E	3.30	1.10	625	75		924	.40	Banded comb quartz
338S	109W	.14	5.00	500	390		925	.30	Same
342S	91W	.05	2.20	675	465		926	1.10	Granulated quartz breccia with comb quartz along edges
345S	90W	.30	5.00	1500	6200		927	.55	Quartz breccia, abundant chlorite
350S	78W	.87	18.50	625	2520		928	.50	Stringy quartz veins
354S	80W	.25	5.00	625	585		929	.85	Stringy quartz veins, 50% WR
358S	76W	.10	1.77	675	500		930	.45	Vuggy quartz breccia, abundant Fe oxide
359S	75W	.20	2.15	1700	1000		931	.50	Altered Cr on east edge of vein
358S	66W	.25	3.60	325	490		932	1.3	Lacy breccia with banded quartz
360S	63W	.12	4.60	575	465		933	.40	Granulated quartz breccia
362S	62W	.05	1.77	1500	1700		934	.20	Bleached and altered WR on edge of vein
364S	60W	-	3.30	1350	850		935	.55	Boudin of older quartz, brecciated
365S	56W	.22	2.10	875	510		936	1.0	Altered and veined WR, 30% vein
367S	54W	.22	5.50	675	365		937	.60	Vuggy, open drusy veins carbonate(?), Cu stained
368S	52W	.60	3.30	13750	5100		938	1.0	Granulated quartz breccia
369S	50W	2.24	7.50	13750	2900		939	.60	Altered WR, Fe oxides, Cu stained
370S	49W	.02	5.00	375	250	.30	340	.60	Breccia of WR and granulated quartz

Appendix A-9. Geochemical surface sample descriptions and analytical values (cont'd.)

Map Location	Au ppm	Ag ppm	Cu ppm	Zn ppm	Au/Ag	Sample number	Interval meters	Description
365S 43W	.02	3.30	775	620		105941	.75	Altered shear zone, Fe oxides
366S 34W	.07	3.14	1250	860		942	.75	Same
365S 27W	.14	3.70	675	465		943	1.6	Granulated quartz breccia
359S 21W	.85	7.00	775	1800		944	1.3	Quartz breccia, fragments of older quartz
372S 23W	.20	6.50	375	690		945	1.2	Granulated quartz, chlorite banding
370S 18W	1.28	5.00	775	3050	.26	946	1.1	Same
374S 16W	7.52	75.00	1600	850	.10	947	1.1	Quartz breccia, abundant chlorite and older quartz frags
363S 11W	.60	6.50	675	730		948	.25	Banded comb quartz
369S 08W	7.24	11.00	825	600	.66	949	.50	Quartz breccia with later comb quartz in center
380S 06W	3.60	5.00	25250	9550	.72	950	.50	Same, Cu stained
372S 01E	.30	.85	1451	245		951	.30	Banded comb quartz
374S 06E	.06	.50	160	475		952	1.1	Silicified breccia, tuff and chert fragments
370S 11E	.20	.95	675	345		953	.30	Comb quartz
376S 11E	3.30	.65	2525	790	5.08	954	.25	Comb quartz with Cu stain
375S 16E	.24	1.35	450	690		955	.40	Stringy veins
384S 25E	.16	1.65	450	730		956	.40	Banded and crustified vein with granular quartz
396S 23E	.32	.65	1250	675		957	.60	Same, but by later comb
398S 35E	1.48	2.40	9250	1875	.62	958	.60	Stringy banded veins, Cu stained
396S 41E	.10	.80	500	325		959	.40	Massive brown chert
406S 40E	.16	.65	925	2650		960	.75	Massive white quartz
397S 48E	.16	1.10	475	1675		961	.60	Banded and crustified quartz veins
398S 61E	.26	1.35	500	760		962	.85	Massive white quartz, minor banding
400S 80E	.12	.50	195	175		963	.25	Milky white quartz with scattered clear quartz
437S 36W	.10	1.20	238	760		964	.70	Quartz breccia, fragments of older, cut by comb quartz
438S 38W	.22	.85	625	730		965	1.4	Vuggy quartz breccia, may crosscut 964
425S 30W	.24	2.00	1250	140		966	.60	Stringy veins, Cu stain
432S 36W	-	.30	125	500		967	.65	Breccia, quartz and WR fragments
441S 48W	23.00	6.50	4875	725	6.54	968	1.0	Breccia, rounded to angular fragments quartz and WR
440S 50W	.02	1.10	275	190		969	1.0	Same to west
432S 19W	-	1.20	325	860		970	.45	Quartz breccia
430S 10W	.35	1.00	575	565		971	.85	Quartz breccia, some chlorite banding, cut by comb quartz
410S 01E	1.00	.85	1050	2100		972	1.0	Quartz breccia with fragments of older, cut by comb quartz
400S 17W	.20	1.35	1175	650		973	1.0	Granulated quartz breccia
409S 24W	.17	1.00	190	1950		974	1.0	Quartz breccia, older quartz frags set in milky quartz matrix
404S 33W	-	.65	185	530		975	.80	Breccia of WR and comb quartz fragments

Appendix A-10. Geochemical surface sample descriptions and analytical values (cont'd.)

Map Location	Au ppm	Ag ppm	Cu ppm	Zn ppm	Au/Ag	Sample number	Interval meters	Description
401S 39W	.10	2.0	825	220		105976	1.0	Granulated quartz breccia, abundant chlorite
404S 52W	2.70	1.00	675	520	2.70	977	.80	Same with cross-cutting comb quartz veinlets
401S 65W	.08	.85	475	110		978	.90	White massive quartz, Cu stain
395S 104W	.80	1.45	675	1100		979	.60	Stringy banded vein
401S 120W	.16	2.50	475	875		980	.35	Faulted continuation of 979
458S 72W	.08	1.10	7250	155		981	.70	Stringy comb quartz, Cu stained
473S 54W	-	.80	1075	875		982	.60	Same with 50% altered andesite
470S 46W	1.00	2.60	1075	230	.38	983	.85	Chlorite fragments in quartz breccia
480S 30W	.06	1.10	1306	640		984	.35	Breccia, quartz and andesite

Appendix A-11. Semiquantitative spectrographic analyses of 2-meter split core. Other elements analyzed for include: As, B, Be, Bi, Cd, Co, Cr, La, Mo, Nb, Ni, Sb, Sc, Sn, Sr, W. and Y. Their values were generally at or below detection levels.

Sample number	Fe %	Mg %	Ca %	Ti %	Mn ppm	Ba ppm	V ppm	Zr ppm
97181	3	.5	.3	.7	300	5000	150	50
97191	3	2	.3	.5	1000	3000	150	30
97201	3	2	.5	.7	1000	G5000	70	30
97211	2	1	.3	.5	1500	3000	150	30
97221	2	.5	.3	.5	700	2000	70	20
97231	2	.7	.05	.3	1000	1500	70	50
97241	3	1.5	.5	.5	1000	3000	150	30
97251	2	1	1.5	.3	1000	2000	150	30
97261	5	1.5	2	1	1500	1500	1000	70
97271	3	1.5	.3	.7	700	1500	700	50
97281	3	1	.5	.3	700	5000	300	30
97291	5	1.5	2	.7	1500	2000	700	30
97301	3	1.5	.5	.3	1000	1500	200	30
97311	5	2	.7	.7	1500	50	300	30
97321	3	3	.3	.7	1500	2000	70	100
97331	3		.3	.7	1500	1500	50	100
97341	2	3	.05	.5	1500	500	50	100
97351	3	1	.05	.7	70	2000	70	100
97361	5	2	.1	.7	1000	5000	700	100
97371	2	2	.1	.5	500	700	50	50
97381	2	2	.7	.5	1000	2000	70	100
97391	3	3	.3	.5	1000	2000	100	100
97401	3	5	.3	.5	5000	G5000	150	50
97411	3	3	.7	.7	5000	3000	300	100
97421	3	5	2	.7	5000	2000	300	100
97431	1	1.5	.1	.15	700	700	50	150
97441	2	2	.1	.2	1000	300	50	150
97451	3	2	.05	.2	1000	500	50	50
97461	5	3	.3	.5	1500	200	100	70
97471	5	5	.2	.5	2000	150	100	300
97481	2	2	.3	.2	1000	1500	50	100
97491	2	2	.7	.2	1000	1000	50	100
97631	5	2	3	.5	1500	200	150	50
97641	5	2	.5	.5	1500	700	70	50
97651	5	2	.3	.5	1500	1000	100	100
97661	2	.5	.2	.1	500	500	30	50
97671	3	3	.7	.7	1000	1000	100	500

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APPENDIX B

Core logs

The section that follows includes summary geologic logs for drill holes MD-1, 2, 4, 5, 6, 9, and 10 and photo reductions of complete drilling and geologic logs for drill holes MD-3, 7, and 8. The complete logs (similar to those included here for holes MD-3, 7, and 8) are on permanent file with the U.S. Geological Survey Mission, Jiddah, Saudi Arabia.

Appendix B.--Summary geologic logs of diamond drill core from MD-1, 2, 4, 5, 6, 9, and 10

B-1

Summary log MD-1

From	To	Description
0	31.05	Weathered agglomerate
31.05	34.50	Quartz vein
34.50	65.00	Intercalated lithic tuff and agglomerate
65.00	108.30	Intercalated lithic tuff and agglomerate Several gougy fault zones Several quartz veins Numerous to abundant quartz veinlets
108.30	118.30	Agglomerate
118.30	158.38	Intercalated lithic tuff and agglomerate Numerous quartz veinlets
158.38	180.80	Agglomerate
180.80	303.60	Andesitic tuff
214.15	216.40	Fault zone, gouge
265.20	266.40	Fault zone gouge

Summary log MD-2

0	47.10	Agglomerate
47.10	60.20	Agglomerate, numerous quartz veinlets and several quartz veins
60.20	66.05	Agglomerate
66.05	67.20	Andesite dike

Summary log MD-2 (continued)

B-2

From	To	Description
67.20	69.80	Fault, gouge
69.80	111.25	Intercalated tuff and agglomerate, numerous quartz veinlets and several quartz veins
111.25	120.30	Andesite tuff
120.30	143.94	Intercalated agglomerate and lithic tuff, numerous quartz veinlets
143.94	167.95	Intercalated agglomerate and lithic tuff, numerous quartz veinlets and several quartz veins
167.95	170.30	Andesite dike
170.30	171.48	Fault zone
171.48	179.40	Agglomerate
179.40	218.33	Agglomerate, numerous quartz veinlets
218.33	219.25	Andesite dike
219.25	244.00	Andesitic tuff
244.00	321.45	Andesitic tuff to agglomerate, numerous to abundant quartz veinlets, several small faults

Summary log MD-4

0	39.50	Agglomerate
39.50	40.75	Quartz vein
40.75	86.00	Intercalated lithic tuff and agglomerate, several fault zones, gouge. Numerous large quartz healed breccias
86.00	96.40	Agglomerate
96.40	99.80	Fault zone, gouge
99.80	113.72	Quartz healed breccia
113.72	180.00	Agglomerate, numerous quartz veinlets

Summary log MD-4 (continued)

B-3

From	To	Description
180.00	191.00	Intercalated agglomerate and andesitic tuff, numerous quartz veinlets
191.00	196.35	Andesitic tuff
196.35	199.60	Fault zone, gouge, vein quartz fragments
199.60	223.60	Andesitic tuff

Summary log MD-5

0	37.70	Weathered agglomerate
37.70	38.98	Fault zone
38.98	71.58	Massive tuff
71.58	118.40	Intercalated lapilli to massive tuff and agglomerate
118.40	121.45	Fault zone, gouge
121.45	152.53	Intercalated mafic agglomerate and cherty tuff
152.53	200.05	Mafic agglomerate
200.05	216.36	Carbonate-bearing tuff
216.36	218.90	Fault zone
218.90	230.55	Talc, massive
230.55	233.85	Fault zone, gouge
233.85	332.00	Intercalated argillite, carbonate and talc bearing tuff and volcanic conglomerate
332.00	359.90	Numerous fault zones, gouge
359.90	376.00	Agglomerate gray, silicified, abundant quartz veinlets and stockworks

Summary log MD-5 (continued)

B-4

From	To	Description
376.00	542.20	Lithic to crystal tuff intercalatea with mafic agglomerate
542.20	547.07	Andesite dike
547.07	590.25	Mafic agglomerate
590.25	601.80	Massive tuff

Summary log MD-6

0	38.25	Weathered agglomerate
38.25	88.00	Agglomerate, to lithic tuff
88.00	119.40	Intercalated agglomerate lapilli tuff, lithic tuff and carbonate-bearing tuff
119.40	140.60	Carbonate-bearing tuff
140.60	146.90	Fault zone
146.90	260.45	Agglomerate, gray, several 50 cm quartz veins and abundant quartz veinlets from 218.08 to 253.42
260.45	296.70	Agglomerate, mafic
296.70	298.60	Fault zone
298.60	418.20	Crystal tuff to lapilli tuff, abundant K-feldspar, numerous quartz veinlets 300.30 to 315.30, 331.70 to 339.85, 351.00 to 355.00, 366.35 to 368.45
418.20	450.05	Tuff, massive to well bedded, numerous quartz veinlets

Summary log MD-9

0	31.85	Weathered agglomerate
31.85	36.80	Andesite dike
36.80	39.10	Fault zone

Summary log MD-9 (continued)
B-5

From	To	Description
39.10	100.00	Agglomerate, gray scattered quartz veins
100.00	106.50	Stockwork of quartz veins
106.50	192.80	Agglomerate, gray, scattered quartz veins
192.80	194.30	Fault zone
194.30	207.20	Lithic to crystal tuff, generally bedded
207.20	211.20	Quartz vein, minor sulfides
211.20	296.80	Lithic to crystal tuff, scattered quartz veins
296.80	306.20	Stockwork of quartz veins and veinlets
306.20	342.40	Andesitic tuff intercalated with agglomerate and lapilli tuff
322.55	322.80	Shear zone
342.40	343.80	Stockwork of quartz veins
343.80	355.00	Agglomerate intercalated with lithic tuff
355.00	356.30	Stockwork of quartz veinlets
356.30	364.80	Intercalated agglomerate and lithic tuff
364.80	365.20	Shear zone
365.20	371.60	Andesitic tuff, generally bedded
371.60	376.00	Stockwork of quartz veins and veinlets
376.00	431.85	Intercalated andesitic tuff, lapilli tuff and agglomerate
431.85	580.45	Massive to well bedded andesitic tuff, local mafic lapilli

Summary log MD-10

B-6

From	To	Description
0	23.25	Weathered agglomerate
23.25	23.85	Fault zone
23.85	38.95	Agglomerate, gray
38.95	40.35	Andesite dike
40.35	85.40	Intercalated agglomerate, andesitic tuff, lapilli tuff and crystal tuff, generally layered
85.40	110.00	Andesitic tuff and tuff breccia, numerous to abundant quartz veins and veinlets
110.00	122.10	Andesitic tuff
122.10	125.20	Quartz breccia vein, minor sulfides
125.20	148.30	Intercalated andesitic tuff to agglomerate, layered, several 20 cm quartz veins and numerous quartz veinlets
148.30	160.10	Agglomerate
160.10	165.80	Andesite dike
165.80	193.75	Intercalated andesitic tuff to agglomerate
182.15	187.00	Sheared zone
193.75	198.80	Agglomerate with abundant pyrite and pyrite-rich fragments
198.80	249.70	Intercalated andesitic tuff, crystal tuff and lithic tuff
219.50	238.95	Fault zone, gouge and shear planes
247.75	249.70	Fault zone

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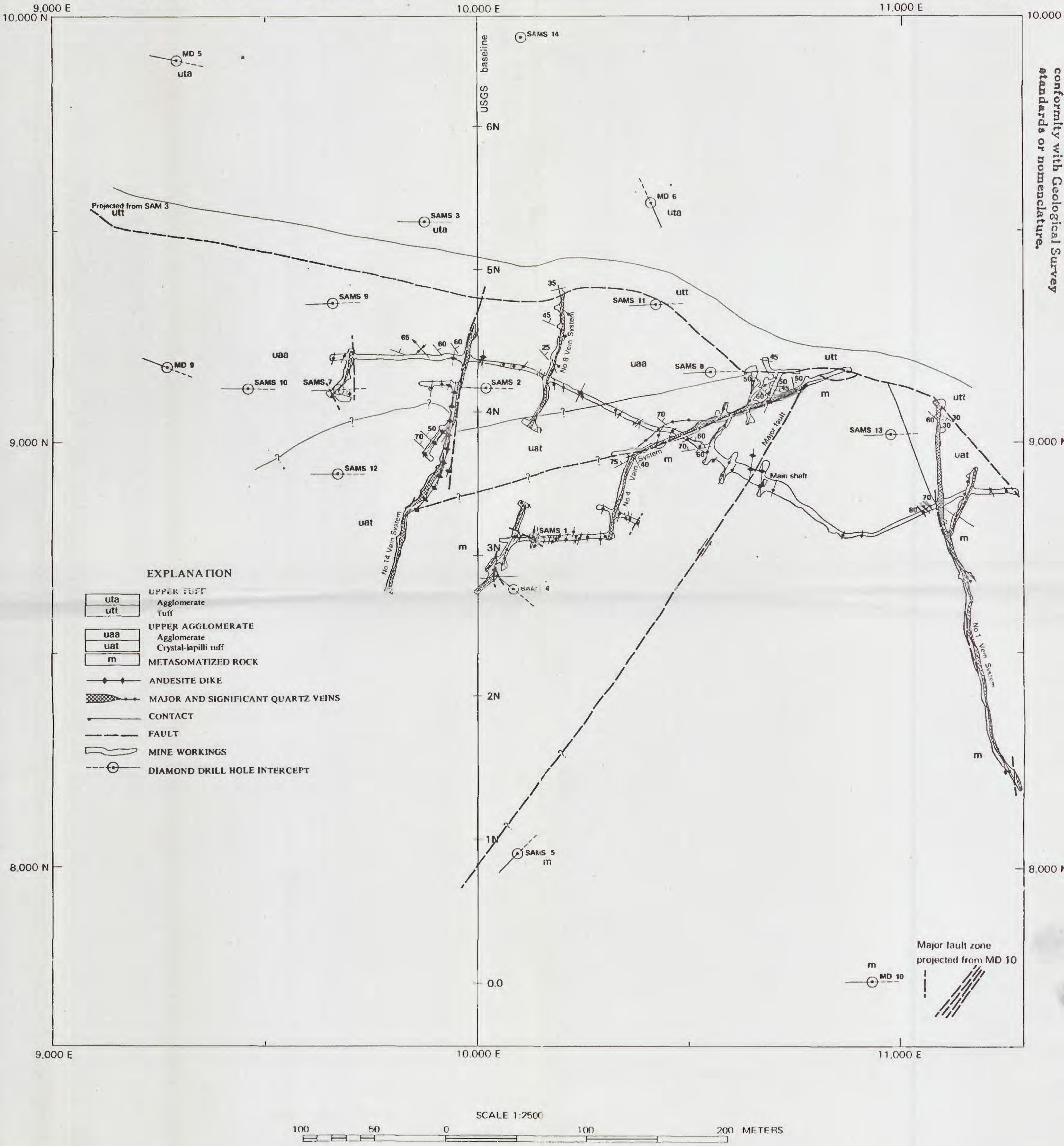
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DIRECTORATE GENERAL OF MINERAL RESOURCES

KINGDOM OF SAUDI ARABIA

SA (IR) 233
PLATE 3

U. S. Geological Survey
OPEN FILE REPORT-78-1073
This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.



GEOLOGY OF THE 300 FT LEVEL OF THE MAHD ADH DHAHAB MINE

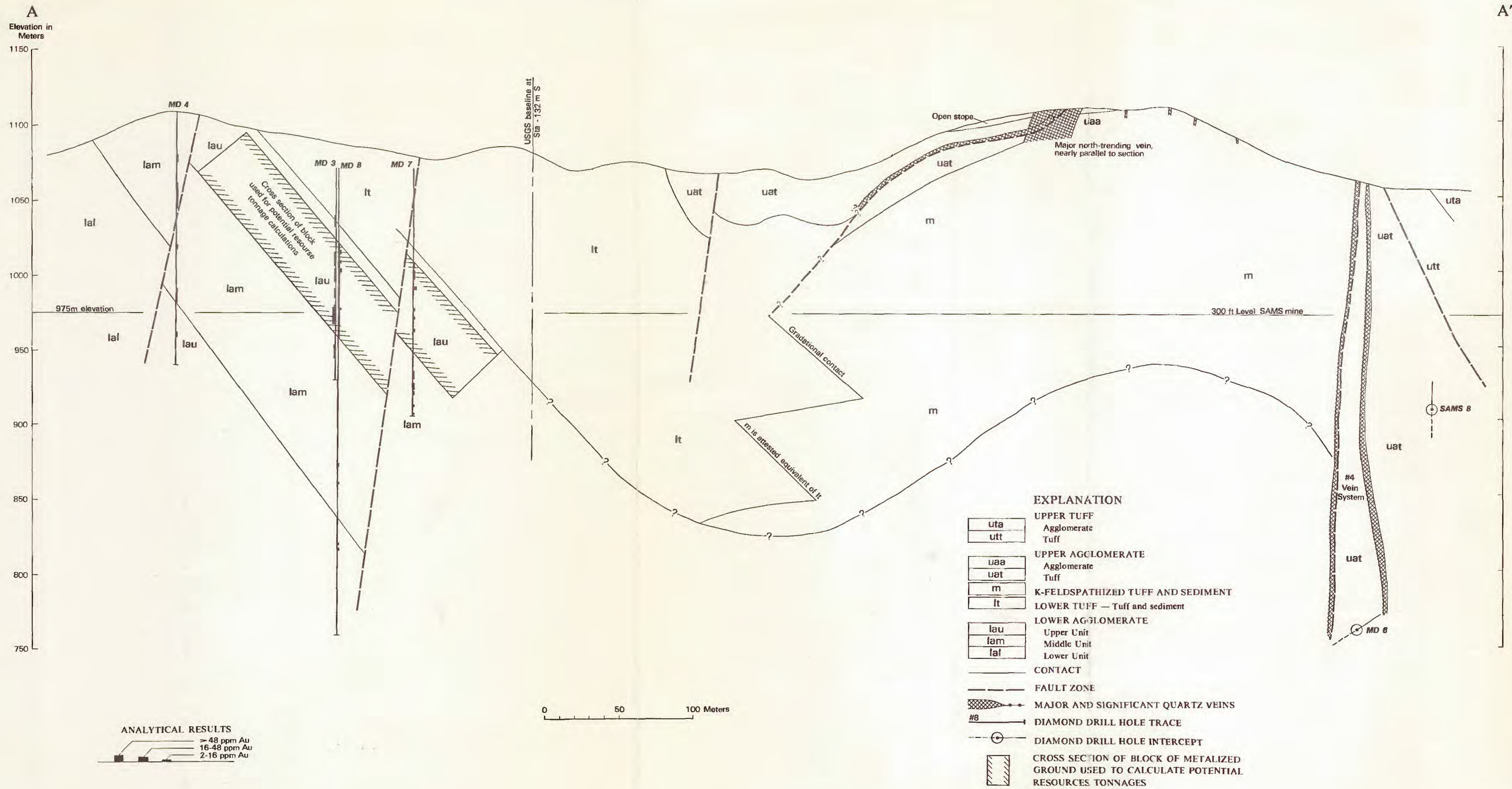


Figure 2. Geologic cross section along line A-A′

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KINGDOM OF SAUDI ARABIA
Ministry of Petroleum and Mineral Resources
Directorate General of Mineral Resources

U S Geological Survey

Mineral Occurrence

Mahd adh Dhahab

Drill Hole Number: **MD 8**

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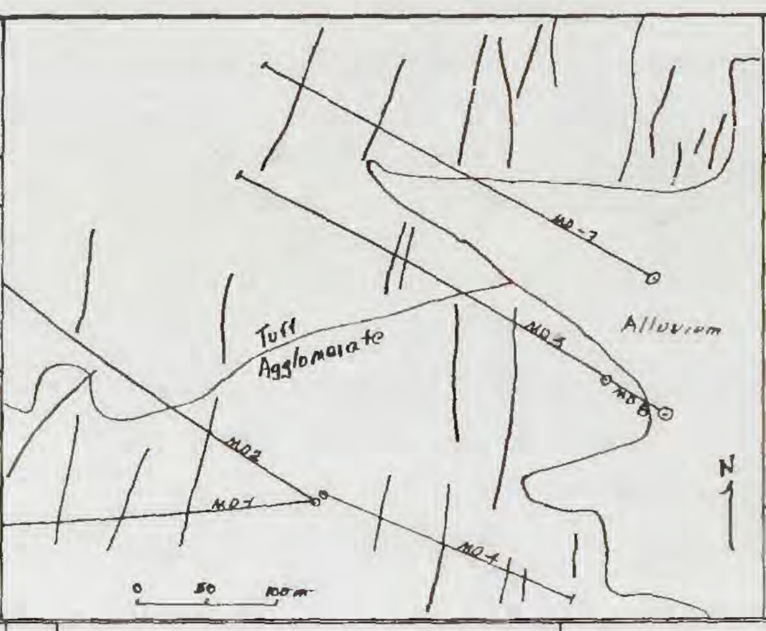
APPENDIX B



Date started: January 11, 1975
Date completed: March 2, 1975
Driller: ADC

Hole size: Nx-83.70, Bx-325.50, Ax-445.65

Survey Data

Collar Coords: Lat 23°49'53" Long 41°51'47"

Subsurface Depth	Inclination (Tropari)	Azimuth
Collar	50°	300°
50 m	50	298
150	45	296
250	44	294
325	43	292
440	41	288

Logged by: Ronald G. Worl

CORE RECOVERY	STRUCTURE	INTERSECTION ANGLE CORE AXIS	LOG SCALE 1/200	DEPTH	LITHOLOGY	MINERALIZATION
					Sand	
973				9.50		Qtz fragments
				14.45		
1622		25, 20			Fragments of tuff, gray to green, siliceous, conglomerate, angular, and quartzite	
1319		30, 45, 50, 35				
1408	Weak shear zone, 68.00 - 66.50	(50)		66.00	Lapilli tuff to Agglomerate, chlorite-rich, stretched lapilli, fragments of glass, andesite, tuff, local rounded sulfide-rich; siliceous pyrite rich groundmass	Abundant 1mm to 30cm quartz veins in stockwork, banded, locally veggy, chlorite-rich, core 60-80% quartz. Local quartz bleeding away from veins into agglomerate with sulfide rims around some fragments. Numerous late quartz-carbonate veinlets, open drusy from 68.8 meters
3980		(70), 35		91.00	Fine-grained Andesite tuff	
				92.75		Numerous quartz veins as above core 40-60% quartz
466		(30), 45			Lapilli tuff and Agglomerate as above	
567				111.60		Quartz vein, chlorite-rich
472		35		117.20		
583						Numerous quartz veins in stockwork, 30-40% quartz, 1mm to 4cm, minor sulfides
1465		(0, 40, 60), 40			Agglomerate, gray to green, fragments of red, gray-black chert, abundant andesite, diorite, granite, pink K feldspar, locally abundant pyrite-rich fragments, intercalated tuff, locally epidote-rich	
73	Broken zone, gouge, slickensides, 144.10 - 146.95			146.95		
450		(50, 30), (10, 40)		148.50, 151.30		Massive quartz vein
650		(60, 85)				Abundant 1-10 cm quartz sulfide veins, core 60-70% quartz
28		(45)		157.25, 161.20		
						Scattered veggy quartz veins, local carbonate
	Broken zone, 179.50 - 179.70					
2535	Several shear planes with gouge, 15° to axis, 181.15 - 187.15	40		189.15	Lithologic description on sheet 2	

SAMPLE DATA

DEPTH	LENGTH	SAMPLE NUMBER	Au g/t	Ag g/t	Cu %	Pb %	Zn %
0.00	9.60	105208	.18	2.40	.07	-	.06
9.50	5.35	105209	.10	1.72	.03	-	.09
14.45	4.75	105210	-	.86	.02	-	.03
19.20	5.80	105211	.12	.84	.06	-	.18
25.00	2.00	105212	-	.80	.08	-	.12
27	2	105213	-	.72	.02	-	.31
29	2	105214	.18	1.44	-	-	.04
31	2	105215	-	.48	.01	-	.06
33	2	105216	-	.60	-	.01	.10
35	2	105217	-	.40	-	.01	.11
37	2	105218	.07	1.24	.04	-	.37
39	2	105219	-	1.50	.01	-	.17
41	2	105220	-	1.72	-	-	.50
43	2	105221	-	1.24	-	-	.30
45	2	105222	-	1.20	-	-	.25
47	2	105223	-	1.82	-	-	.02
49	2	105224	-	1.60	-	-	.08
51	2	105225	-	1.32	-	-	.02
53	2	105226	-	1.72	-	.01	.01
55	2	105227	.03	1.82	-	.01	.01
57	2	105228	-	1.60	-	-	.01
59	2	105229	-	1.72	-		.01
61	2	105230	-	1.72	-		.04
63	2	105231		1.12	.01	.01	.04
65	2	105232	-	1.44	.01	.01	.07
67	1.5	105233	-	1.32	.01		.05
68.50	1.5	105234	.24	9.87	.15	.02	.06
70	1	105235	-	1.88	.39	-	.06
71	1	105236	-	2.08	.38	.01	.14
72	1	105237	.88	23.8	1.50	.07	.80
73	1	105238	.12	5.8	.30	.08	.30
74	1	105239	.16	9.5	.41	.06	.65
75	1	105240	.26	2.88	.13	.03	.76
76	1	105241	9.70	11.00	.10	.04	1.25
77	1	105242	2.20	13.00	.20	.07	.58
78	1	105243	85.60	360.0	.61	.30	7.50
79	1	105244	18.24	40.0	.39	.06	1.70
80	1	105245	40.00	167.00	1.20	.26	1.82
81	1	105246	21.20	104.00	.52	.07	2.30
82	1	105247	28.00	127.00	.80	.07	1.00
83	1	105248	1.32	13.0	.31	.06	1.50
84	1	105249	18.80	28.60	1.50	.05	3.70
85	1	105250	.71	3.84	.73	.08	.38
86	1	105251	6.88	31.00	.25	.07	.45
87	1	105252	50.40	280.0	.67	.07	6.30
88	1	105253	83.60	328.0	.30	.20	3.70
89	1	105254	48.00	160.0	.76	.12	3.20
90	1	105255	3.28	23.0	.52	.05	.57
91	1.7	105256	.82	3.24	.73	.01	.36
92.70	1.3	105257	7.00	41.00	.54	.01	.64
94	1	105258	17.80	118.00	.80	.02	1.08
95	1	105259	38.00	217.00	4.10	.06	4.25
96	1	105260	39.60	180.0	.97	.03	3.70
97	1	105261	1.76	12.60	.38	.21	1.20
98		105262	1.70	9.90	.48	.06	1.10
99		105263	2.04	66.60	.34	.07	1.76
100		105264	2.86	35.00	.54	.03	2.76
101		105265	4.28	24.00	1.50	.02	1.50
102		105266	3.10	21.80	.65	.01	2.36
103		105267	3.20	31.00	1.20	.01	4.80
104		105268	7.82	4.08	1.11		7.15
105		105269	11.44	194.00	4.00	.03	9.00
106		105270	9.48	78.00	3.00	-	6.50
107		105271	1.62	48.00	.87	-	1.50
108		105272	.39	3.84	.30	-	.62
109		105273	.92	17.00	.75	.01	9.00
110		105274	.58	3.98	.27	.05	1.80
111		105275	16.80	21.20	.87	.10	3.40
112		105276	.74	24.00	.80	.04	1.80
113		105277	.26	6.68	.30	.10	1.80
114		105278	.50	5.18	.19	.18	1.50
115		105279	-	2.40	.28	.19	.90
116		105280	.14	3.20	.17	.29	1.50
117		105281	-	1.40	.03	.03	.30
118		105282	-	.70	.02	-	.15
119	1	105283	-	1.20	.12	-	.20
120		105284	.10	1.00	.15	-	.61
121		105285	.19	.90	.02	-	.11
122		105286	.06	1.00	.05	-	.05
123		105287	.19	2.20	.18	-	1.80
124		105288	.30	7.90	.06	.03	1.60
125		105289	.26	2.20	.32	.03	1.20
126		105290	.10	12.00	.25	.03	.94
127		105291	.33	1.00	.65	.02	.07
128		105292	.56	.68	.06	.02	.15
129		105293	.99	4.12	.17	-	.52
130		105294	8.80	32.40	.25	-	.15
131		105295	9.52	24.00	.15	-	.97
132		105296	190.40	285.00	.05	-	2.30
133		105297	16.72	34.00	.40	-	1.00
134		105298	9.20	4.12	.02	.01	.32
135		105299	.22	1.00	.06	-	.20
136		105300	.38	2.20	.12	-	.35
137		105301	.16	1.72	.09	-	.30
138		105302	1.00	11.40	.51	-	.76
139		105303	.16	1.36	.02	-	.15
140		105304	.45	7.60	.44		.31
141		105305	.18	4.75	.11		.19
142		105306	.06	1.00	.04		.32
143		105307	.05	1.60	.05		.43
144		105308	.09	1.25	.03		.34
145		105309	.11	1.20	.06		.35
146		105310	.09	1.00	.09		.31
147		105311	.38	3.00	.25		.43
148		105312	.56	3.16	.34		.47
149		105313	.86	8.65	.40		1.75
150		105314	1.48	14.00	.41		2.02
151		105315	.26	4.48	1.80		.71
152		105316	.35	4.40	.45		.50
153		105317	1.66	9.00	.72		2.38
154		105318	1.36	11.00	1.75		1.42
155		105319	.77	2.70	.16		1.03
156		105320	.10	1.30	.07		.22
157		105321	.27	3.80	.09		.27
158		105322	.05	2.40	.07		.85
159		105323	.05	1.40	.02		.38
160		105324	.05	1.05	.09		.11
161		105325	.05	1.20	.02		.12
162		105326	-	1.66	-		.11
163		105327	.09	1.75	.10		.18
164	2	105328	-	1.00	.01		.09
166	2	105329	-	1.20	-		-
168	2	105330	-	.90	.02		.02
170	2	105331	.04	1.00	.01		.01
172	2	105332	.04	1.00	-		.09
174	2	105333	.04	1.40	-		.10
176	2	105334	.04	1.00	-		.15
178	2	105335	.04	1.40	-		.10
180	2	105336	.06	1.50	.01		.09
182	2	105337	.04	1.50	.03		.11
184	2	105338	.04	1.65	.03		.10
186	2	105339	.04	1.50	.07		.16
188	2	105340	.04	1.50	.04		.17
190	2	105341	.05	1.50	.01		.15

1 meter samples (142–162)

AVERAGES

6.0% Cu, 14.3% Zn (72–97 m)

12.3% Cu, 2.96% Zn (97–111 m)

3.0% Cu, .90% Zn (130–135 m)

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KINGDOM OF SAUDI ARABIA
Ministry of Petroleum and Mineral Resources
Directorate General of Mineral Resources

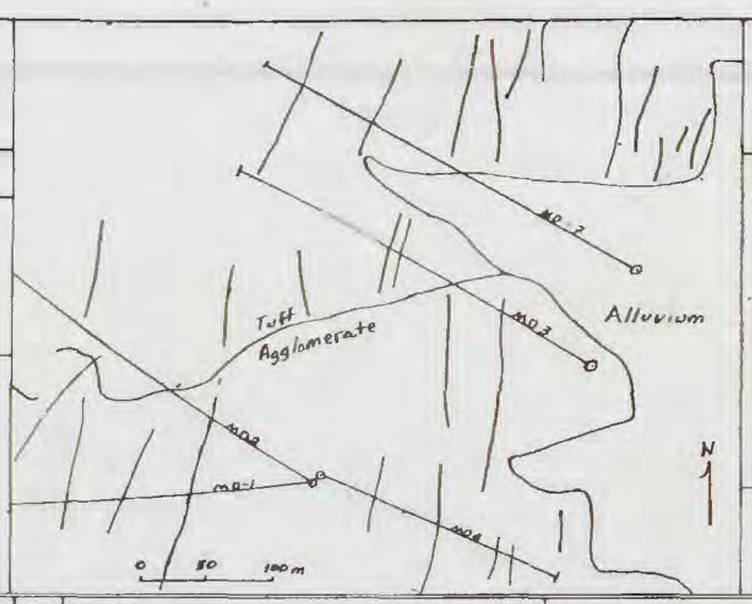
U S Geological Survey

Mineral Occurrence

Mahd adh Dhahab
Drill Hole Number:
MD 7

SA(IR) 233

APPENDIX B



Date started: November 14, 1974 — Hole size: Nx— 71.15
Date completed: January 9, 1975 — Bx— 300.30
Driller: ADC — Ax—

Survey Data

Collar Coords: Lat 23° 49' 54" Long 41° 51' 47"
Subsurface

Depth	Inclination	Azimuth
Collar	300°	35°
(Tropari)		
50 m	298°	35°
100	298	35
200	298	35
300	299	31

Logged by: Ronald G Worl

CORE RECOVERY (LENGTH, %) | STRUCTURE | INTERSECTION ANGLE WITH CORE AXIS | LOG SCALE 1/200 | DEPTH | LITHOLOGY | MINERALIZATION | SAMPLE DATA | AVERAGES

Structure and lithology notes (by depth):

- Sand
- Fragments of lithic tuffs, greenish, fine to medium-grained, and sandstone, reddish, fine-grained
- Broken zone 17.24 - 21.60
- Tuff, green to brown, locally agglomeratic, intercalated agglomerate, pale green siliceous gray groundmass, red chert fragments and quartz fragments.
- veins (60)
- Tuff, green, finely banded, locally abundant carbonate in bedding, minor disseminated pyrite
- Quartz healed breccia 92.11 - 93.61
- Quartz healed breccia 97.00 - 98.48
- Broken zone, gouge 122.00 - 123.38
- Agglomerate, medium grained, large andesite fragments, locally massive sulfide as sulfide with fragments, K-feldspar dissemination and veinlets, intercalated carbonate-bearing tuff
- Broken zone/gouge 153.80 - 155.00
- Broken zone, gouge 160.40 - 162.00 and 163.30 - 165.20
- Broken zone 180.05 - 181.25
- Lithology described on sheet 2
- Agglomerate, coarse to medium-grained, epidote-rich groundmass, locally brecciated and K-feldspar, fragments of gray chert, tuff, andesite, rhyolite and granite (?), local disseminated pyrite
- Andesite
- Slightly brecciated zone 241.45 - 248.30
- Agglomerate, fragments of dark red gray chert, andesite, pyrite, carbonate-rich matrix, abundant pink K-feldspar
- Broken zone, gouge 260.30 - 260.85
- Agglomerate, coarse-grained, large andesite fragments, interbedded tuff

Sample Data

Mineralization	Depth	Length	Sample number	Au g/t	Ag g/t	Cu %	Pb %	Zn %	Averages
Vein quartz fragments	0	4.5	97969	.40	7.10	.09		.08	
	4.5	1.9	97970	.06	1.60	.07		.15	
	6.4	1.8	97971	.06	2.10	.07		.01	
	8.2	1.8	97972	–	1.70	.08		.17	
	10	2	97973	.06	1.50	.17		.13	
Vein quartz fragments	12	2	97974	.06	1.25	.07		.12	
	14	2	97975	–	1.4	.10		.37	
	16	3	97976	–	2.0	.29		.57	
	19	3	97977	–	1.8	.15		.30	
	22	2	97978	–	1.8	.12		.11	
	24	3	97979	–	1.9	.20		.15	
	27	2.65	97980	–	1.8	.12		.16	
	29.65	1.45	97981	–	1.5	.07		.16	
Vein quartz fragments	31	2	97982	–	1.9	.07		.09	
	33	2	97983	–	1.5	.11		.04	
	35	2	97984	–	1.5	.21		.03	
Abundant quartz veins 5% quartz	37	2	97985	.09	1.15	.30		.14	
	39	2	97986	.11	2.00	.06		.15	
	41	2	97987	–	1.50	.31		.06	
	43	2	97988	.11	1.25	.16		.07	
	45	2	97989	–	1.5	.18		.09	
Scattered quartz veins	47	2	97990	–	1.0	.02		.06	
	49	2	97991	–	1.2	.02		.07	
	51	2	97992	–	1.2	.03		.09	
	53	2	97993	–	1.0	.02		.17	
	56	2	97994	–	1.5	.17		.12	
massive quartz vein	57	2	97995	–	1.4	.12		.07	
Numerous 1-3 cm quartz veins	59	2	97996	–	1.7	.10		.05	
	61	2	97997	–	1.5	.03		.08	
	63	2	97998	–	2.6	.02		.06	
	65	2	97999	–	1.7	.01		.05	
	67	2	105100	.05	1.4	.01		.02	
	69	2	105101	.05	1.2	–		.05	
	71	2	105102	.05	1.2	–		.04	
	73	2	105103	.08	1.2	–		.06	
	75	2	105104	.04	1.0	–		.03	
	77	2	105105	–	1.4	–		.03	
	79	2	105106	–	1.4	–		.03	
Scattered quartz-carbonate veinlets	81	2	105107	–	1.2	–		.03	
	83	2	105108	–	1.5	–		.02	
Disseminated pyrite	85	2	105109	.05	1.2	.05		.03	
	87	2	105110	–	1.2	–		–	
	89	2	105111	–	1.0	–		–	
	91	2.17	105112	–	1.2	–		–	
Quartz-filled breccia, sulfides	92.17	1.03	105113	–	1.0	–		–	
	93.20	.80	105114	.04	1.2	–		–	
	94	1	105115	.04	1.2	–		–	
	95	2	105116	–	1.5	.06		–	
Quartz-filled breccia, sulfides	97	2	105117	–	1.2	–		–	
	99	2	105118	–	1.8	–		–	
	101	2	105119	.04	1.5	.02		.02	
	103	2	105120	–	1.8	–		.01	
Scattered quartz-carbonate veinlets locally with sulfides	105	2	105121	.28	3.4	–		.13	
	107	2	105122	.10	2.0	.05		.06	
	109	2	105123	.05	1.5	–		.07	
	111	2	105124	.05	1.3	–		–	
	113	2	105125	.05	1.5	–		.03	
	115	1.70	105126	.18	2.5	.06		–	
	116.7	4	105127	.48	8.0	.15		.02	
Quartz-sulfide vein	117.1	1.7	105128	.05	2.1	.04		.03	
Abundant drusy quartz veinlets	118.7	[illegible]	105129	.30	3.10	.07		.14	
	121.0	1	105130	7.6	45.0	.20		.90	
Quartz-sulfide vein, stockwork 80% qtz	122	1	105131	1.50	12.50	.18		1.0	
	123	1.35	105132	1.82	25.0	.42		.70	
Abundant 2-5 cm quartz veins	124.35	1.15	105133	6.00	25.0	.16		.10	
	125.50	2	105134	.20	2.7	.05		1.25	
Scattered quartz veinlets	127.50	2	105135	.05	2.0	.06		.01	
	129.50	2	105136	.40	14.5	.09		.49	
	131.50	2	105137	.92	7.9	.13		.41	
	133.50	2	105138	15.0	64.0	.46		3.45	
Abundant 1mm to 2 cm drusy quartz veins locally abundant sulfides	135.50	2	105139	.32	10.0	.27		.72	
	137.50	2	105140	1.60	41.0	.33		1.80	
	139.50	2	105141	[illegible]	[illegible]			.53	
	141.50	2	105142	[illegible]	[illegible]	[illegible]		[illegible]	
	143.50	2	105143	.10	3.9	.01		.17	
	145.50	2	105144	[illegible]	5.0	.15		.80	
Numerous 1 cm quartz veins	147.50	2.40	105145	[illegible]	2.9	.09		.11	
	149.90	1.3	105146	20.80	180.00	2.15		12.60	
Quartz vein	151.20	2	105147	[illegible]	8.90	.15		.12	
	153.20	2	105148	.10	1.80	.12		.25	
	155.20	2	105149	.25	2.70	.20		.09	
	157.20	2	105150	3.80	15.00	.12		.75	
Numerous 1mm to 5cm quartz-carbonate-sulfide veins and gray quartz veinlets, locally abundant pink K-feldspar in wall rock	159.20	2.20	105151	[illegible]	5.00	.01		.07	
	161.40	1.30	105152	.90	3.80	.10		.10	
	162.70	2	105153	.10	1.90	.10		.08	
	164.70	2	105154	.54	5.20	.20		1.25	
	166.70	2	105155	–	2.50	.04		.09	
	168.70	2	105156	–	1.25	–		–	
	170.70	2	105157	–	1.80	.08		.05	
	172.70	1.80	105158	.16	2.30	.09		.03	
Massive quartz vein	174.50	.50	105159	5.00	145.00	3.50		4.36	
	175.00	.65	105160	5.20	29.00	.78		5.37	
	175.65	2.07	105161	[illegible]	2.50	.06		.04	
	177.72	2	105162	–	1.20	–		.04	
	179.72	1.03	105163	–	1.45	.02		.04	
	180.75	.50	105164	–	1.25	–		.04	
Abundant 1-10 cm quartz veins, locally abundant sulfides	181.25	2	105165	–	1.25	.01		.04	
	183.25	2	105166	.09	1.00	.02		.04	
	185.25	.65	105167	–	1.80	.12		.03	
	185.90	.80	105168	7.20	27.00	.78		2.05	
	186.70	2	105169	.16	2.50	.09		.13	
	188.70	2	105170	.44	2.80	.07		.44	
	190.70	2.20	105171	.09	1.90	.07		.02	
cont. of abundant quartz veins									
	197.50	.85	105172	.06	1.26	.08		.05	
	198.80	.83	105173	1.40	10.00	.70		.22	
	200.65	.55	105174	.04	1.50	–		.03	
Massive quartz vein	203.09	.80	105175	.04	.92	–		.02	
Scattered quartz veins									
Abundant 1cm quartz-sulfide veins	222.95	1.55	105176	.09	2.2	.05		.03	
	224.50	1.25	105177	.20	5.0	.57		.02	
Scattered white quartz veinlets									
	241.45	2.00	105178	.17	4.60	.97		.34	
Numerous quartz-sulfide veinlets	243.45	1.75	105179	.16	4.50	.47		1.03	
	247.00	1.25	105180	.14	3.10	.21		.26	
	248.25	1.00	105181	.90	17.40	1.52		5.05	
	249.25	1.00	105182	.76	17.50	2.88		3.00	
	250.25	1.00	105183	1.50	37.50	2.02		8.70	
	251.25	1.00	105184	.22	6.60	.69		1.80	
Abundant 50mm to 1cm quartz-sulfide veins	252.25	1.00	105185	2.00	15.50	1.25		2.70	
	253.25	1.00	105186	.54	12.00	1.02		3.60	
	254.25	.75	105187	.30	12.70	1.95		2.60	
	255.00	[illegible]	105188	5.40	40.00	1.30		4.90	
	258.00	1.00	105189	.12	2.87	.16		.32	
Numerous tape-like drusy quartz veinlets in stockwork, minor sulfides	[illegible]	[illegible]	105190	[illegible]	[illegible]	[illegible]		[illegible]	
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	
Sulfide-rich vein	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		.07	

Averages (marginal notes): 2.9% Cu, 1.0% Zn; 4.1 ppm Au, 24 ppm Ag (121.00–125.50); 2.0% Cu, 1.2% Zn; 3.7 ppm Au, 28 ppm Ag (129.50–141.50); 1.5% Cu, 4.0% Zn; 1.5 ppm Au, 20 ppm Ag (248.25–258.00)

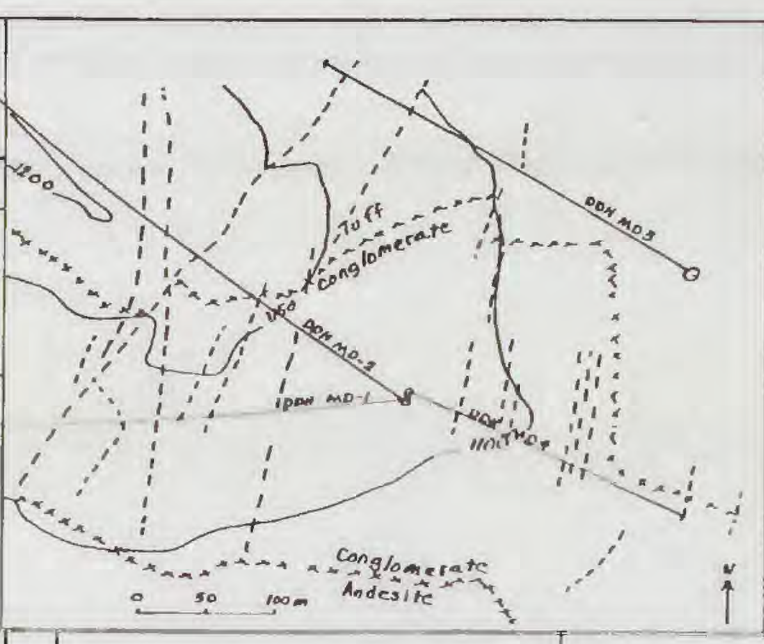
KINGDOM OF SAUDI ARABIA
Ministry of Petroleum and Mineral Resources
Directorate General of Mineral Resources

U S Geological Survey

Mineral Occurrence
Mahd adh Dhahab
Drill Hole Number: **MD 3**

SA (IR) 233

APPENDIX B



Date started: March 21, 1974 — Hole size: Nx – 79.85
Date completed: May 26, 1974 — Bx – 177.35
Driller: ADC — Ax – 251.85

Survey Data

Collar Coords: Lat 23°49'53" Long 40°51'47"

Subsurface

Depth	Inclination	Azimuth
Collar	35°	300°
(Tropari)		
50m	36°	301°
100	35	297
150	35	296
250	34	294

Logged by: Ronald G Worl

CORE RECOVERY (LENGTH, %) | STRUCTURE | INTERSECTION ANGLE WITH CORE AXIS | LOG SCALE 1/200 | DEPTH | LITHOLOGY | MINERALIZATION

Thin Sections

Structure / Lithology / Mineralization (by depth, m)

- ~35: Fragments ... fragments — Mineralization: Fragments of vein Qtz
- ~46–50: Lithic tuff, Andesite and feldspar (crystal) fragments 97825, 97826
- 64: Qtz healed breccia, 66.45 – 67.00 — Massive fine grained grey dike rock — Mineralization: Qtz breccia
- 68: Qtz healed breccia, 69.10 – 70.70 — Mineralization: Qtz breccia
- 80: Agglomerate, intercalated clastic and pyroclastic and fine- and coarse-grained tuffs, no carbonate, generally siliceous, partly silicified — Mineralization: Numerous Qtz veins, 2cm to 10cm; Diss pyrite
- 102: Bkn zone, 102.85 – 102.90 — Lithic tuff, andesite and feldspar fragments. 97827
- 106: Bkn zone, 106.35 – 106.45 — Cont. as above with addition of Andesite(?) and vesicular glass fragments in Agglomerate — Mineralization: Abundant Qtz veins, 20-50% Qtz, locally abundant pink K-feldspar veins, locally abundant sulfides, Diss pyrite, locally abundant
- 118: Massive Qtz
- 122: Cont. of abundant Qtz veins etc.
- 128: Agglomerate, Siliceous, with large diffuse siliceous fragments
- 132: Felted texture, feldspar fragments 97828 — Mineralization: Massive Qtz; 5% sulfides
- 146: Bkn zone, 145.36 – 145.55 — Lithic tuff, andesite and sericitized feldspar fragments 97829; Agglomerate, medium grained, angular fragments, much pink K-feldspar, locally silicified — Mineralization: Abundant Qtz veins, 50-80% Qtz, minor sulfides; locally abundant pink K-feldspar veinlets
- 164: Massive fine grained green dike rock 97830; Massive fine grained green dike rock — Mineralization: Massive Qtz
- 174: Bkn zone, Fe stain, 174.10 – 176.60 — Intercalated fine grained siliceous tuff and medium grained conglomerate agglomerate — Mineralization: Qtz stockwork, 1m to 9cm veins, 70% Qtz, abundant pyrite, numerous pink K-feldspar veinlets
- 194: Lithic tuff, Andesite and Dacite fragments, may be some diorite fragments 97831 — Mineralization: Numerous quartz veins
- 208: Quartz vein
- 212: Andesite dike, with Qtz vein in center
- 220: Intercalated fine grained siliceous tuff and medium grained conglomerate agglomerate 97832; Lithic tuff, Andesite and Dacite fragments; qtz-sericite stringers — Mineralization: Qtz stockwork, 20-30% Qtz, sulfides and veinlets, minor carbonate
- 240: Bkn zone 240.25 – 241.90 — Mineralization: Numerous Qtz carbonate veinlets, diss pyrite

SAMPLE DATA

DEPTH	LENGTH	SAMPLE NUMBER	Au g/t	Ag g/t	Cu %	Pb %	Zn %	AVERAGES
0	8m	97427	.30	4.2	.06			
8	2m	97428	.06	.6	.04			
10	2	97429	.06	.6	.04			
12	2	97430	.09	.5	.03			
14	2	97431	-	-	.05			
16	2	97432	.07	.6	.12			
18	2	97433	.08	.5	.04			
20	2	97434	L.04	.6	-			
22	2	97435	L.04	.4	-			
26	2	97436	L.04	1.2	.02			
28	2	97437	L.04	1.4	-			
30	5m	97438	L.04	3.1	.05			
35	5m	97439	L.04	.6	.03			
40	2m	97440	L.04	1.2	.02			
42		97441	-	-	.03			
44		97442	L.04	.5	.03			
46		97443	L.04	.6	.03			
48		97444	L.04	.9	.03			
50		97445	L.04	.6	.03			
52		97446	L.04	1.3	.04			
54	All samples 2m interval	97447	L.09	.9	.07			
56		97448	L.04	.9	.07			
58		97449	L.04	.7	.01			
60		97450	L.04	1.2	.12			
62		97451	-	1	.66			
64		97452	L.04	1.0	.12			.25% Cu (62–74)
66		97453	L.04	1.6	.19			
68		97454	.11	3.1	.20			
70		97455		5.8	.18			
72		97456	.15	4.7	.16			
74		97457		4.1	-			
76		97458	.19	4.1	.04		.33	
78		97459		1.6	.03		.16	
80		97460	.04	1.3	.02		.33	
82		97461	.04	1.3	.01		.12	
84		97462	.07	1.6	.09		.12	
86		97463	.04	1.5	.07		.08	
88		97464	.10	1.0	.01		.05	
90		97465	.15	1.6	.02		.10	
92		97466	-	.7	.02		.21	
94		97467	.04	.6	.01		.03	
96		97468	.10	1.2	.03		.04	
98		97469	.07	1.0	.01		.02	
100		97470	.04	.9	.01		.03	
102		97471		1.3	-		.03	
104		97472	.10	8.0	.01		.20	
106		97473		8.2	.49		1.12	.42% Cu, .81% Zn (106–118)
108		97474		2.8	.36		.44	
110		97475	.07	3.0	.20		.32	
112		97476	.07	4.6	.52		1.40	
114		97477	.07	3.8	.37		1.48	
116		97478	.07	1.7	.15		.37	
118		97479	.27	4.0	.36		1.32	
120		97480	.07	1.6	.05		.25	
122		97481	L.04	.5	.01		.03	
124		97482	L.04	1.7	.12		.11	.30% Cu (124–138)
126		97483	L.04	3.4	.61		.10	
128		97484	L.04	5.2	.68		.08	
130		97485	L.04	1.3	-		.05	
132		97486	L.04	2.6	.14		.31	
134		97487	.07	2.2	.24		.65	
136		97488	.07	2.3	.11		.37	
138		97489	L.04	3.6	.28		.94	
140		97490	.07	1.0	.06		.11	
142		97491	.07	1.6	.10		.34	
144		97492	.04	1.6	.07		.80	
146		97493	L.04	1.3	.05		.31	.58% Cu, .27% Zn (146–156)
148		97494	.11	2.5	.20		.50	
150		97495	.19	4.6	.36		.62	
152		97496	.13	3.1	.26		.09	
154		97497	.10	2.2	.18		.03	
156		97498	.09	1.3	.16		.13	
158		97499	.07	1.3	.03		.20	
160		97628	L.04	.4	.01		.05	
162		97629	L.04	.4	.01		.07	
164		97630	L.04	1.1	.04		.24	
166		97631	.19	2.8	.09		5.10	
168		97632	.31	3.4	.13		1.84	
170		97633		3.3	.17		.92	
172		97634	.23	2.6	.22		.04	
174		97635	3.92	35.0	.35		.54	.80% Cu, 1.19% Zn; 17.1 ppm Au, 84.0 ppm Ag (174–188)
176		97636	6.98	230.0	.53		2.00	
178		97637	75.8	230.0	1.37		.92	
180		97638	46.0	171.0	.41		.88	
182		97639	.09	2.0	.03		.04	
184		97640	1.66	8.7	.37		.86	
186		97641	.15	3.4	.27		.16	
188		97642	3.42	5.7	.17		.25	
190		97643	.10	1.3	.02		.04	
190	2m	97643	.10	1.3	.02		.03	
192		97644	.06	1.3	.02		.03	
194		97645	.04	1.0	.01		.03	
196		97646	.06	1.0	.01		.04	
198		97647	.06	1.0	.01		.05	
200		97648	1.48	5.1	.06		9.40	
202		97649	.06	1.0	.01		.03	
204		97650	.06	.9	.01		.03	
206		97651	.21	1.7	.08		.09	
208		97652	.04	1.8	.11		.18	
210	All samples 2m interval	97653	.10	1.2	.02		.02	
212		97654	.07	1.4	.03		.09	
214		97655	.04	1.2	.16		.39	
216		97656	.05	2.2	.33		.09	
218		97657	.33	1.8	.14		.19	.45% Cu (218–224)
220		97658	.14	4.0	.4		.58	
222		97659	.04	2.7	.50		.11	
224		97660	L.04	2.7	.63		.08	
226		97661	.10	1.1	.18		.06	
228		97662	.05	2.9	.55		.02	
230		97663	L.04	1.1	.26		.07	
232		97664	L.04	.8	-		-	
234		97665	L.04	1.1	.03		.39	
236		97666	.10	1.3	.04		.07	
238		97667	L.04	.9	.04		.06	
240		97668	.07	1.2	.07		.59	
242		97669	L.04	1.4	.09		.06	
244		97670	.31	1.6	.07		.13	
246		97671	L.04	.8	.01		.04	
248		97672	L.04	1.9	.16		.03	
250	2m	97673	[illegible]	[illegible]				

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KINGDOM OF SAUDI ARABIA
Ministry of Petroleum and Mineral Resources
Directorate General of Mineral Resources

U S Geological Survey

Mineral Occurrence

Drill Hole Number: **MD8 Sheet 2**

SA(IR) 233

APPENDIX B

Date started: | Hole size: Nx– Bx– Ax–
Date completed:
Driller: ADC

Survey Data
Collar Coords: Lat Long
Subsurface
Depth Inclination Azimuth
Collar
(Tropari)

Logged by:

CORE RECOVERY (LENGTH, %) | STRUCTURE | INTERSECTION ANGLE CORE AXIS | LOG SCALE 1/200 | DEPTH | LITHOLOGY | MINERALIZATION | SAMPLE DATA | AVERAGES

Core recovery: 1555; 260; 3323; 533; 16932

Intersection angles: 60, (35 / 15), (60), (25), (35), (30 / 50), (55), (30), (35), (20), (30), (20), (10), (20), (25), (25), (60), 60, (40), (35), 40, (40)

Depths: 211.46; 216.62; 234.00; 236.65; 259.00; 276.35; 287.50; 288.00; 302.43; 307.93; 309.50; 311.45; 325.25; 333.29; 350.15; 357.80; 383.60; 430.38; 445.45 EOH

Structure

Several broken zones, and shear surfaces, 40° ∠ axis, 234.05 - 236.65

= Fault zone, gouge, 315.75 - 316.00

= Fault zone, gouge, 35° ∠ axis, 325.00 - 325.25

Sheared zone, mylonite, 375.75 - 383.40

= Broken zone, gouge, 35° ∠ axis, 416.10 - 416.30

Lithology

Intercalated crystal to lithic tuff, gray, abundant pink K-feldspar; fine-grained gray siliceous tuff; and amygdaloidal andesite.

Tuff, andesitic, fine-grained, epidote-rich

Agglomerate, fragments of vesicular glass, abundant andesite, volcanic rhyolite, abundant feldspar grains. Contains reddish chalcedonic cement

Tuff, andesitic, abundant carbonate lined vugs, fine-grained, disseminated pyrite. Intercalated lapilli tuff and agglomerate

Andesite, fine grained

Tuff, as above, 276.35 - 307.60

Lapilli tuff to agglomerate, generally massive, epidote rich; locally abundant carbonate in veinlets and vugs, disseminated pyrite, locally abundant, Intercalated fine-grained tuff with zones of disseminated K feldspar

Lapilli tuff to agglomerate, generally massive, epidote rich, locally abundant carbonate in veinlets and vugs, disseminated pyrite, locally abundant. Intercalated fine-grained tuff with zones of disseminated K-feldspar

Mineralization

Scattered 2 cm quartz-carbonate veins, local sulfides

Scattered vuggy and drusy mm veinlets and massive 8 cm veins, minor sulfides

Scattered quartz-carbonate veinlets, locally abundant vugs lined with carbonate, minor amounts of sulfides.

= Massive quartz-sulfide vein

Numerous quartz sulfide veins

Scattered vuggy and drusy quartz-carbonate veinlets 1 mm to 1 cm

Abundant quartz veins and locally abundant sulfides

Numerous quartz veins, minor sulfides, and quartz-carbonate veinlets

Cont. & numerous veins and veinlets

Scattered stockworks & veins, locally abundant sulfides.

SAMPLE DATA — ANALYSES

Depth	Length	Sample Number	A1	A2	A3	A4	A5
190	2	105341	.05	1.50	.01		.15
192	2	105342	.06	2.35	.13		.67
194	2	105343	.06	2.00	.09		.26
196	2	105344	.04	1.30	.03		.16
198	2	105345	.04	1.50	.02		.47
200	2	105346	.04	1.60	.03		.07
202	2	105347	.06	1.55	.02		.21
204	1	105348	.04	1.50	.02		.09
205	2	105349	.06	1.50	.01		.56
207	2	105350	.09	1.80	–		.13
209	2	105351	.09	1.35	.01		.15
211	2	105352	.07	2.70	.09		.29
213	2	105353	.07	1.85	.05		.50
215	2	105354	.09	3.00	.01		.68
217	2	105355	.06	1.35	.02		.10
219	1	105356	.06	1.60	.02		.05
220	1	105357	.05	1.80	.03		.09
221	2	105358	.05	1.50	.02		.15
223	2	105359	.05	1.80	.08		.11
225	2	105360	–	1.35	.01		.06
227	2	105361	.04	1.40	.04		.06
229	2	105362	.04	2.10	.11		.19
231	2	105363	.06	1.55	.01		.21
233	2	105364	.02	1.40	–		.03
235	2	105365	.05	.70	–		.05
237	2	105366	.05	.75	–		.03
239	1	105367	.07	.80	–		.04
240	2	105368	.10	1.26	.01		.15
242	2	105369	.06	.90	–		.09
244	2	105370	.05	.85	–		.03
246	2	105371	.09	.72	–		.03
248	2	105372	.05	.80	.04		.04
250	1	105373	.05	.46	–		.02
251	1	105374	.05	1.22	.02		.17
252	1	105375	.05	1.48	.11		.27
253	1	105376	.07	1.64	.11		.36
254	1	105377	.07	1.28	.02		.10
255	1	105378	.05	.72	–		.02
256	1	105379	.03	1.00	–		.09
257	1	105380	.05	.80	–		.02
258	1	105381	.04	.80	–		.02
259	2	105382	.05	.80	–		.02
261	2	105383	.05	.72	–		.03
263	2	105384	.05	.72	–		.02
265	2	105385	.07	1.22	.02		.11
267	2	105386	.39	2.16	.02		.18
269	2	105387	–	1.00	.01		.18
271	2	105388	–	.80	–		.03
273	2	105389	–	.60	–		.02
275	2	105390	.09	1.22	.03		.18
277	1	105391	.09	2.88	.11		1.25
278	1	105392	.09	2.00	.06		.90
279	1	105393	.09	1.14	.03		.37
280	2	105394	.12	1.40	–		.16
282	2	105395	.08	1.20	–		.03
284	2	105396	.08	1.00	–		.03
286	2	105397	.10	2.16	.20		.28
288	2	105398	.10	1.55	.03		.10
290	2	105399	.06	1.20	–		.08
292	2	105400	.06	1.10	–		.02
294	1	105401	.08	1.35	.06		.42
295	1	105402	.09	1.65	.53		.55
296	2	105403	.08	2.05	.10		.23
298	2	105404	.04	1.60	.12		.45
300	2	105405	.04	1.40	.03		.55
302	2	105406	.04	1.10	–		.03
304	2	105407	.04	1.10	–		.44
306	2	105408	.06	1.40	–		.03
308	1	105409	.06	1.20	–		.03
309	2	105410	.05	1.33	–		.02
311	2	105411	–	1.40	–		.01
313	2	105412	.04	1.90	–		.03
315	2	105413	.04	1.40	.01		.03
317	2	105414	.04	1.00	.01		.02
319	2	105415	.04	1.10	.01		.02
321	2	105416	.04	1.10	–		.03
323	3	105417	–	1.25	.02		.02
326	2	105418	.10	1.25	–		.03
328	2	105419	–	1.40	–		.02
330	2	105420	.10	1.00	–		.02
332	2	105421	–	1.00	–		.17
334	2	105422	–	1.10	–		.02
336	2	105423	–	1.63	–		.06
338	2	105424	–	1.70	–		.04
340	2	105425	.07	1.55	–		.07
342	1	105426	.04	1.05	–		.02
343	1	105427	.45	1.40	–		.02
344	1	105428	–	1.55	–		.62
345	1	105429	–	1.10	–		.11
346	1	105430	–	1.10	–		.02
347	1	105431	–	.78	–		.08
348	2	105432	–	1.40	–		.02
350	1	105433	–	1.48	.02		.04
351	1	105434	–	1.48	.01		.03
352	1	105435	.04	1.85	–		.03
353	1	105436	–	2.55	.45		.11
354	1	105437	–	3.70	1.30		.15
355	1	105438	–	2.55	.20		.45
356	1	105439	–	1.70	.15		.06
357	1	105440	–	1.10	.07		.11
358	1	105441	.20	16.00	1.98		.80
359	1	105442	.05	1.25	.04		.19
360	1	105443	.05	1.20	.01		.06
361	1	105444	.04	1.00	.02		.05
362	1	105445	.04	1.00	.02		.03
363	1	105446	.05	1.55	–		.07
364	1	105447	.05	1.25	.01		.17
365	2	105448	.06	1.85	.02		.06
367	2	105449	–	1.48	.01		.62
369	2	105450	.04	1.40	.03		.06
371	2	105451	.04	1.25	–		.03
373	2	105452	.10	7.00	.57		.23
375	2	105453	.10	7.00	.08		.17
377	2	105454	.00	4.23	.53		.14
379	2	105455	.07	2.40	.12		.04
381	2	105456	1.00	5.20	.25		.28
383	2	105457	.06	2.70	.10		.13
385	2	105458	.06	3.70	.50		.09
387	2	105459	.04	2.40	.05		.04
389	2	105460	.05	2.25	.03		.05
391	2	105461	.04	2.00	.01		.04
393	2	105462	.04	1.88	.02		.06
395	2	105463	.04	1.38	.01		.02
397	2	105464	.04	1.70	–		.03
399	2	105465	.06	1.60	–		.04
401	2	105466	.08	1.25	–		.03
403	2	105467	.08	1.25	–		.03
405	2	105468	.08	.95	–		.06
407	2	105469	.09	2.15	.10		.46
409	2	105470	.05	.88	–		.03
411	2	105471	.06	1.00	–		.02
413	2	105472	.06	1.00	.01		.04
415	2	105473	.05	1.00	–		.03
417	2	105474	.06	1.25	–		.13
419	2	105475	.05	1.35	–		.04
421	2	105476	.04	1.25	–		.05
423	2	105477	.07	1.25	.01		.05
425	2	105478	.08	1.25	.02		.05
427	2	105479	.08	1.25	–		.04
429	2	105480	.04	1.65	–		.06
431	2	105481	.07	2.25	.01		.06
433	2	105482	.05	2.05	.02		.06
435	2	105483	.06	2.05	–		.06
437	2	105484	.09	2.15	.11		.04
439	2	105485	–	1.86	.02		.19
441	2	105486	–	1.46	.05		.02
443	2	105487	.04	1.78	.02		.03
445	.65	105488	.04	1.60	.01		.03