U. S. GEOLOGICAL SURVEY

SAUDI ARABIAN PROJECT REPORT 211

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by

Charles W. Smith, R. Ernest Anderson, and M. R. Dehlavi

ABSTRACT

The ancient Kutam mine in southwestern Saudi Arabia was discovered during the course of regional geologic mapping. Malachite coatings along fractures in the ancient workings and nearby large piles of slag indicate the mine was worked for copper.

Quartz porphyry of Precambrian age is the principal host rock of the deposit. The quartz porphyry is associated with volcanic rocks of mafic to intermediate composition. All rocks have been deformed and metamorphosed to various types of schist, of which quartz-sericite-chlorite schist is the most common.

Mineralization is thought to be controlled by the convergence of three fault patterns that strike N.60°W., N.45°W., and N.20°W., respectively, and dip steeply west to vertical. Cross faults that extend between faults of the N.45°W. pattern have influenced deposition of sulfides locally. Southeast-plunging lineation derived from two converging directions of planar schistosity also may have exerted control on sulfide deposition.

Detailed geologic mapping of surface features and geochemical and geophysical studies indicated that the deposit warranted subsurface exploration. Accordingly, eight holes were drilled that delineated possible economic-grade sulfide deposits in an area about 300 m long and which is known to continue to a depth of more than 200 m. However, drilling found copper-zinc mineralization along a strike length of 850 m. Drill findings show that copper and zinc sulfides partially replace chlorite and higher concentrations of chlorite generally define the higher-grade mineralization. The more intensely chloritized zones tend to follow the N.45°W. fracture pattern. South of drill hole KA-1, the sulfide mineralization may plunge 40° to 60° southeast.

Indicated and inferred reserves outlined by drilling total 8,056,000 metric tons, the grade of which averages 0.31 g/t Au, 6.13 g/t Ag, 1.83 percent Cu, and 0.95 percent Zn.

INTRODUCTION

The ancient Kutam mine (fig. 1) is at lat 17°35'55"N., long 43°34'10"E. in the southern part of the Asir mountains, about 23 km southeast of Zahran al Janub at an altitude of about 2100 m. It was named for the nearest village, Kutam, 7 km northwest, and is within a kilometer of the paved highway connecting Khamis Mushayt and Najran. Scheduled air service is available at Najran 90 km east, and at Khamis Mushayt 115 km northwest.

The terrain in the area is a hilly dissected upland where developed on crystalline basement rocks and flat-topped buttes and cliffs where developed on the Paleozoic Wajid sandstone. Streams have carved rugged canyons in the upland to depths of about 300 m and drainage is to the east, away from the edge of the Red Sea escarpment, about 15 km west.

During the course of geologic mapping of the Magzah quadrangle in October, 1973, Anderson (1976) discovered the ancient workings of the Kutam mine. These workings consist of shallow trenches and open pits clustered along northwest-trending shear zones in an area about 500 m long and 100 m wide. Extensive slag piles nearby testify to operations in ancient times, probably during the Abbasid Caliphate about 800 A.D., but possibly earlier and later as well.

In addition to the slag, shows of copper minerals in the ancient workings indicated that further studies might be warranted. Accordingly, late in 1973, M. R. Dehlavi began mapping the mine area at scale 1:2,000 and also began a geochemical sampling program; the surrounding area also was mapped on a scale of approximately 1:10,000 by Dehlavi and Anderson (fig. 2). A plane-table topographic map of the deposit was made by K. McLean and Murryyi bin Bunayan Almutayri. Electrical self potential, gamma-radiation, and Turam electromagnetic surveys were carried out by V. J. Flanigan and H. M. Merghelani. The results of the mapping programs, geochemical sampling, and geophysical surveys indicated that exploratory drilling was warranted. A drilling program subsequently was carried on by the Arabian Drilling Company in 1974 and 1975; eight holes totalling 1,929.2 m were drilled. Willard Puffett logged and sampled core from drill holes KA-1 and 2; Abdul Malik Helaby logged core from KA-3 and 4; Smith and Helaby logged core from KA-5, 6, 7, and 8.

During November 1974 to November 1975, H. R. Blank, H. M. Merghelani, and M. Gettings conducted induced poten-

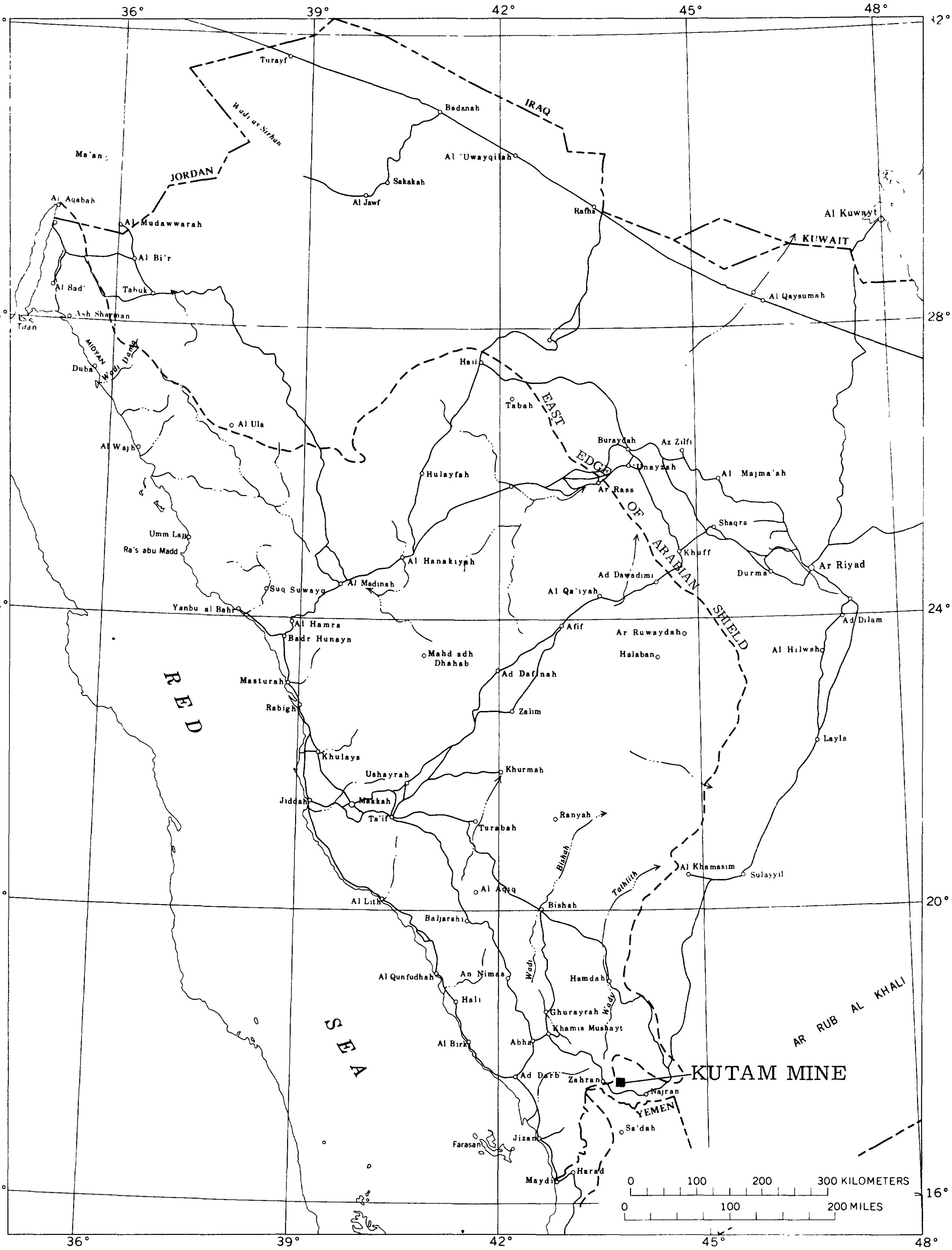

Figure 1. - Index map of western Saudi Arabia showing the location of the Kutam mine.

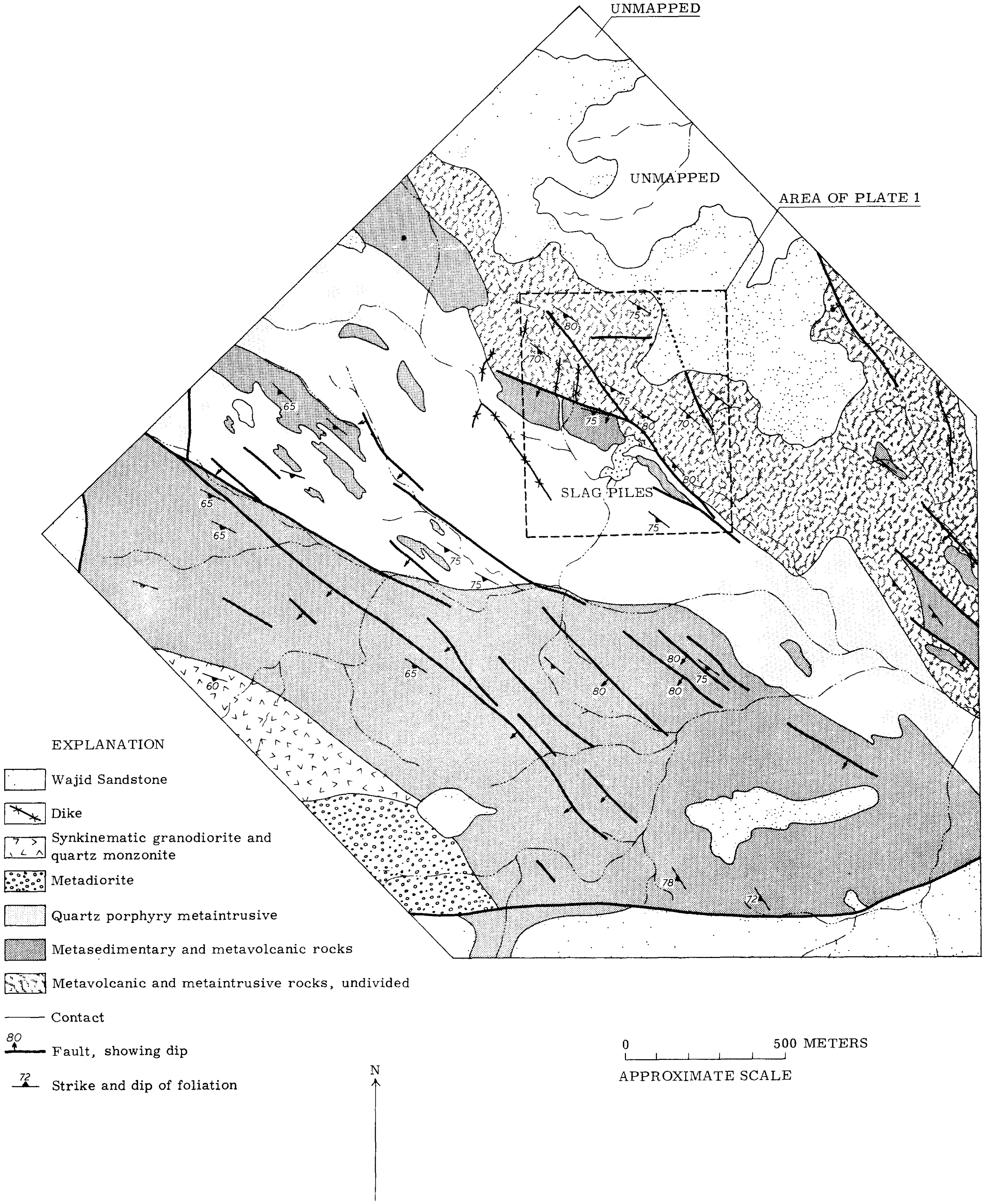

Figure 2. - Sketch map showing geology in the vicinity of the Kutam mine.

tial, ground magnetometer, and additional self potential and Turam surveys. Early in 1975 Smith extended the 1:2,000 scale mapping, revised the mapping of alteration boundaries, and mapped surface detail along the projection of the drill holes.

The present report summarizes the geology and ore deposits of the Kutam area. Anderson is responsible for the section on geology; and Smith and Anderson for sections on ore deposits and exploration. A geophysical report on the deposit, by H. R. Blank, V. J. Flanigan and others, is the subject of a separate report.

Work at the Kutam deposit is part of a series of mineral exploration investigations by the U. S. Geological Survey made in accordance to a Work Agreement with the Ministry of Petroleum and Mineral Resources, Kingdom of Saudi Arabia.

GEOLOGY

by

R. Ernest Anderson

Regional geologic setting

The Kutam prospect is near the southwest margin of a broad crescent-shaped mass of porphyritic diorite and quartz diorite that covers an area of about 70 Km^2. This pluton is one of several similar bodies that together form the complex southeast marginal zone of a very large north-trending dioritic batholith, the Wadi Tarib batholith. Along the batholith's southeast margin the porphyritic phases intrude volcanic rocks, volcanogenic clastic rocks, and sparse carbonate rocks of probable Late Precambrian age.

The batholith and associated rocks have been strongly deformed and faulted and a strong schistosity was developed which locally is distorted into kink folds and isoclinal folds. In less deformed areas the batholith is faulted and the faults are folded. In addition to deformation the batholith and adjacent country rocks were highly recrystallized to the amphibolite facies. The Kutam ancient mine is in a 2 km-wide zone of northwest-trending faults that may in part include structures that have been rotated to that trend from more regional north and northeast trends by postbatholithic deformation. The deformation and metamorphism in the

Kutam area is probably coeval with the emplacement of nearby synkinematic plutons of dioritic, granodioritic, and quartz monzonitic composition. The border of one of these plutons is about 1.5 km from the Kutam prospect (fig. 2).

Precambrian rocks in the Kutam area are partially overlain unconformably by erosional remnants of Cambrian to Ordovician age Wajid Sandstone (Brown and Jackson, 1959; Brown, 1970: Schmidt and Hadley, 1973; Anderson, written commun.). The Wajid is some 200 to 300 m thick in the area and consists principally of coarse to medium-grained marine sandstone. It is not mineralized.

The Kutam mine is near the northeast boundary of the Sadah graben (Anderson, written commun.), a broad northwest-trending zone in which the Wajid Sandstone is down dropped on normal faults with as much as 1200 m throw. Faults of that system near the prospect have displacements of a few centimeters to a few tens of meters. Part of the displacement on the system of faults predates the Sirat plateau basalts of the southern Asir area reported to be as old as 29 m.y., and part of the displacement is younger than the basalts which range to 25 m.y. (Brown, 1970).

Stratigraphy

Precambrian rocks at the Kutam mine are divided into three principal units: metasedimentary, metavolcanic, and metaintrusive, the latter of which is separated into three types (pl. 1). All rock units have been metamorphosed to the amphibolite facies. Sulfide mineralization appears to have affected all rock types. In the descriptions that follow the premetamorphic features of the rocks are emphasized, whereas the effects of metamorphism and mineralization are described later in the text. The Wajid Sandstone and surficial deposits are not described.

Metasedimentary rocks

Metasedimentary rocks are recognized in very limited zones within the Kutam mine area. A small lense of marble which has been caught up in the Kutam fault was mapped along the projection of drill hole KA-4. Drill hole KA-8 intersected graphitic schist and narrow zones of this rock also are mapped at the surface.

Metavolcanic rocks

Metavolcanic rocks at the Kutam prospect are porphyritic and nonporphyritic in texture and of mafic to intermediate composition. Their volcanic origin is indicated by ovoid quartz-rich and hornblende-rich relict amygdules a few mm to 1 cm in diameter (fig. 3). The metavolcanic rocks are part of a widespread sequence, but at the mine (pl. 1, fig. 2) they occur as large xenolithic masses so complexly invaded by quartz porphyry and related nonporphyritic dacitic rocks that many of them are not mapped separately. Most contacts dip steeply, but, gently dipping contacts are found northwest of the mine. At the contacts apophyses of quartz porphyry extend into metavolcanic rocks, and away from the contacts xenoliths of metavolcanic rocks are found in quartz porphyry.

Quartz porphyry metaintrusive

Quartz porphyry metaintrusive rock of probable quartz dioritic to trondhjemitic composition is found throughout the Kutam area as irregular-shaped masses and thin sill-like to broad tabular masses that have invaded older more mafic rocks in a complex fashion. Regionally much of the quartz porphyry is mapped as a composite unit of metavolcanic and metaintrusive rock (fig. 2), but surrounding the mine on three sides is a relatively homogeneous body of quartz porphyry that is mapped separately (pl. 1). Quartz phenocrysts are the most conspicuous feature of the rock; they are typically bluish white, are as much as 1 cm in diameter, and form up to 20 percent of the rock. The initial groundmass was probably fine grained but is now recrystallized and the rock as a whole now ranges from nonfoliated to strongly foliated.

Dikes

Within the area mapped in detail at Kutam (pl. 1), several northerly trending mafic dikes contain inconspicuous relicts of small plagioclase phenocrysts in their central parts. These dikes cut foliation within the metavolcanic and metaintrusive rocks and are judged to be the youngest intrusive rocks in the area.

Structure

The earliest known structural event in the Kutam mine area was tilting of the volcanic units. This is indicated by an inconspicuous textural layering striking N.30°W. and dipping steeply which may be relict primary layering; and by contact between porphyritic and nonporphyritic metavolcanic rocks which dips 75°W. This period of deformation either predates or coincides with the intrusion of the Wadi Tarib batholith. There is no evidence that the rocks were

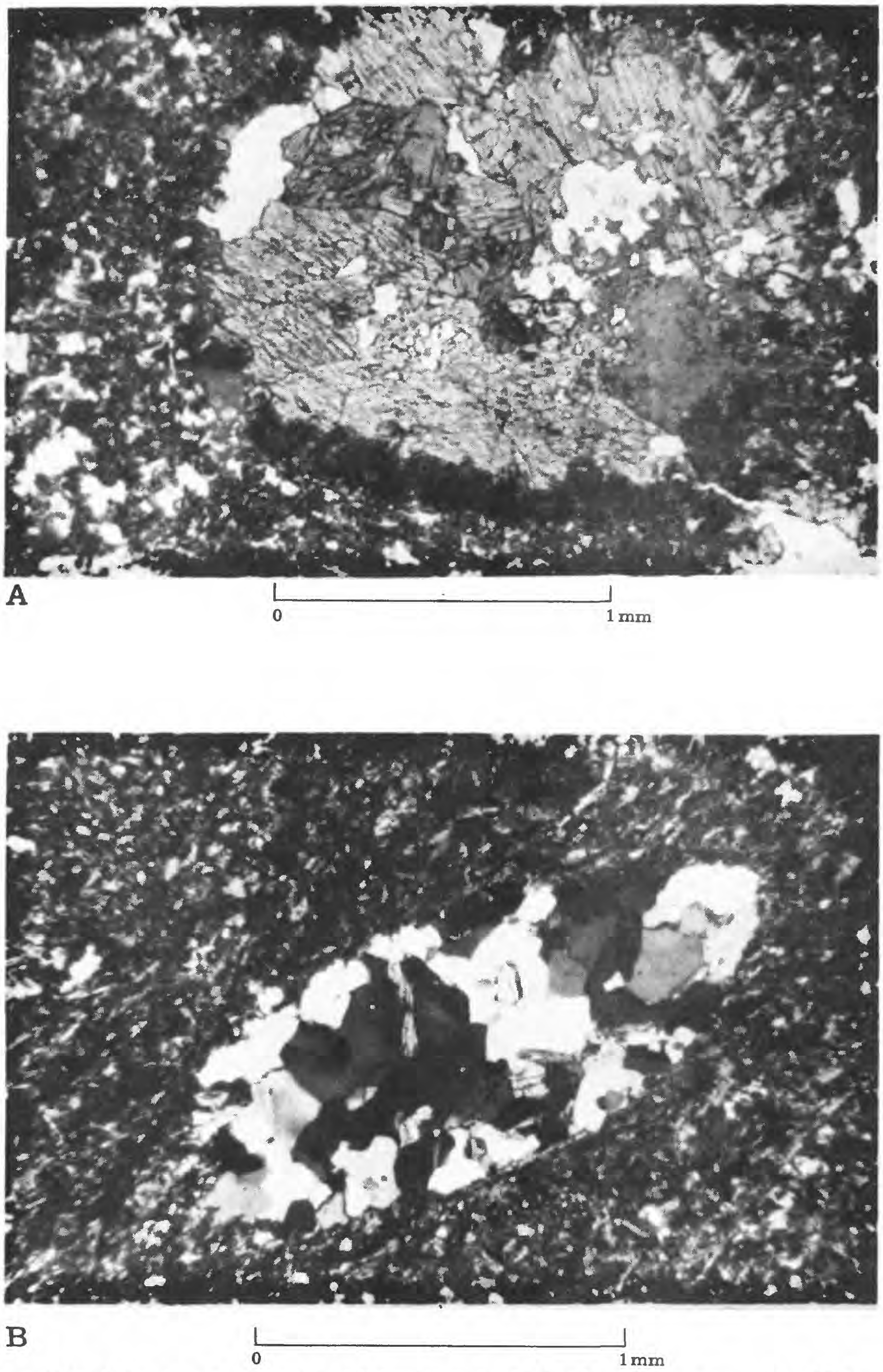

Figure 3. - Photomicrographs showing ovoid structures. A, Formed by coarse-grained quartz and hornblende rimmed by granular epidote, plane light. B, Formed by coarse-grained quartz, crossed nicols. The rocks are amphibolitic metavolcanics and the ovoid structures are interpreted as relict amygdules that survived metamorphism. From 9.4 m in drill hole KA-2.

metamorphosed or altered by the intrusion.

Subsequent regional metamorphism has imparted a pervasive foliation striking northwest and dipping steeply westerly.

The rocks in the mineralized area at Kutam are conspicuously more schistose than equivalent rocks in the surrounding area. In the northwestern part of the mine area an early, penetrative, steeply southwest-dipping schistosity is recognized trending about N.60°W. and cut by a later cleavage and schistosity with a strike of about N.45°W. and generally steep southwest dip. In the southeast part the early schistosity may have been rotated to essential parallelism with the late structures. Throughout much of the mineralized area an indistinct steeply southeast plunging lineation is formed by the intersection of the two schistosities. Though folded schistosity was observed in some intensely deformed zones near faults, it is uncommon elsewhere.

The late cleavage and schistosity is essentially parallel to and probably related to the system of northwest-trending faults shown on figure 2. In the western part of that area the angular relationship between early cleavage and late faults is the same as that between the early and late structures in the mineralized area. Throughout the area contacts are offset by small-scale slippage on the late cleavage resulting in complexly interdigitated contacts in most areas. Some of these are shown diagrammatically on plate 1.

One of the faults of the northwest-trending system forms the southwest boundary of the mineralized area and was penetrated by drill holes KA-1, 2, 4, and 5. This fault, named the Kutam fault zone, is well exposed north, northeast, and east of drill hole KA-1 where it is marked by a zone of intensely schistose, brecciated, and bleached rock about 20 m wide. A wide variety of rock types including massive quartz, ferruginous quartz, talc, marble, actinolite schist, and sericite schist are found in the fault zone, some as isolated lenses and breccia blocks and others as boudined layers. Minor structures in the fault zone suggest predominantly lateral separation.

Regional metamorphism

The Kutam mine is in a 200 km^2 area where rocks of the Wadi Tarib batholith and older rocks have been metamorphosed to the amphibolite facies. The host rocks of the mineral deposit are structurally, mineralogically, and chemically different from those adjacent to the mineralized deposit and these differences are the result of metamorphic processes.

Metamorphic textures in rocks adjacent to the Kutam mine are mostly granoblastic and poikiloblastic although in many rocks these are superposed on earlier nematoblastic and less commonly on lipidoblastic textures. In some rocks, however, the second-stage crystals define a second foliation or lineation that transects the first foliation at a low angle. Primary phenocrysts or their partially replaced relicts are visible in many rocks, and they generally show little or no cataclasis.

Some highly recrystallized metavolcanic rocks consist of hornblende, calcic andesine, and garnet (all with strongly poikiloblastic textures formed from quartz inclusions) and granoblastic quartz. Highly recrystallized intrusive rocks commonly contain needle-like randomly oriented and interpenetrating hornblende grains in a granoblastic matrix of quartz and oligoclase or quartz and andesite. Epidote, an essential mineral in many of these rocks, appears to have been a stable phase during the recrystallization. The textures are hornfelsic and suggestive of contact metamorphism, but they are distributed regionally.

Near contacts with quartz porphyry the rocks in the metavolcanic xenoliths are coarsely crystalline; as for example hornblendite grains that are several centimeters in length. Although these contact relationships resemble hornfels it seems unlikely that a prophyritic intrusive with a fine-grained groundmass could produce such extensive recrystallization in country rocks that are more mafic than the intrusive. Instead, the recrystallization at and near the contacts appears to be part of the widespread episode of relatively static recrystallization. In strong support of this suggestion is the fact that the mafic dikes that cut quartz porphyry at and in the vicinity of the prospect are also conspicuously more coarsely crystalline at their contacts than in their interiors. Thin sections cut across contacts of metavolcanic rock intruded by quartz porphyry and quartz porphyry intruded by dike rock show static hornfels-like recrystallization textures on both sides of the contacts.

The hornfelsic textures and hornfels-like contact relationships record a widespread thermal event that occurred under conditions of little or no differential stress. The presence of calcic andesine as a metamorphic mineral in these rocks suggests that temperatures during recrystallization were in excess of 550°C if moderate pressure is assumed (Liou and others, 1974).

Some conspicuously porphyritic metavolcanic rocks contain veins, layers, and clast-like masses that appear to lack phenocrysts. In thin section, however, shadowy outlines of plagioclase phenocrysts that have been extensively replaced by granoblastic quartz and oligoclase can be seen, thus suggesting that the features formed by silicification. The silicification probably occurred early in the metamorphic history as the clast-like masses tend to be jacketed by schistose rock and tend to form augen-like structures. The silicification may reflect incipient silica segregation rather than silica introduction. The silicified areas are commonly weakly pyritiferous.

Small amounts of fracture- and fault-controlled secondary quartz, calcite, chlorite, sericite, albite, and epidote are found in many exposures surrounding the mineralized area, but there is no suggestion of a regional greenschist facies retrograde metamorphic event.

ORE DEPOSITS AND EXPLORATION

by

Charles W. Smith and R. Ernest Anderson

Ancient workings

Ancient workings at the Kutam mine are in a zone 500 m long and 100 m wide on a northwest-trending ridge. The flanks of the ridge are partly covered by mined waste. The workings consist of trenches ranging in width from .5 to 5 m, some of which extend to 15 m depth, and open pits that are now mostly caved. Slag piles estimated to gross about 50,000 tons lie on the southwest flank of the ridge and in the adjacent valley.

Rock surfaces in the workings are commonly stained by iron oxide and partially coated by malachite. Streaks and wisps of malachite and veinlets of limonite are seen on freshly broken surfaces. No sulfide minerals were observed in rocks in the mine dumps, indicating either that the early miners did not reach the sulfide zone or that they ceased mining when they reached it.

Geology of the mine area

The rocks in the mineralized area have been complexly sheared, recyrstallized, and pervasively altered. In part these processes began during deformation and metamorphism, but continued through ore formation as well. The rocks in the ore zone include chlorite-quartz schist, chlorite-sericite-quartz schist, sericite-quartz schist, chlorite schist, massive quartz, and talc schist. The chlorite-bearing rocks are commonly garnetiferous. Relicts of quartz phenocrysts are visible at many places and attest not only to the igneous origin of the rocks but to their equivalence with rocks adjacent to the mineralized area. The quartz porphyry, for example, occurs in all stages of silicification ranging from mild to a rock composed of at least 80 and possibly 95 percent quartz. Also, based on study of surface exposures, the talc schist probably was derived from metamorphic hornblendite. Their common parentage notwithstanding, rocks in the mineralized area differ in many respects from those in the adjacent areas: 1) they are more micaceous and therefore more schistose, 2) they are, on the average, far more siliceous, 3) hornblende, epidote, and plagioclase, all essential minerals in adjacent rocks, generally are absent, 4) they show evidence of more intense metamorphic segregation and 5) they contain a more diverse assortment of metamorphic minerals. All of these differences have resulted from metamorphic or hydrothermal processes.

Smith feels that the intrusive nature of the quartz porphyry within the Kutam mine area is in question because of the lack of direct evidence of intrusive features and the presence of features which suggest layering. In some of the outlying areas quartz porphyry may be found in conformable contact to layered rocks, although layering in the porphyry is absent. About 0.5 km southwest of the mine one locality shows the layered sequence to be as follows: massive unlayered quartz porphyry with large blue quartz phenocrysts in conformable contact to a gray-green fine grained quartz-feldspar-biotite rock; quartz porphyry with clear quartz phenocrysts to 3 mm in diameter containing cherty layers; graphitic schist a few meters width; and mafic metavolcanic rocks. Another exposure in Wadi Kutam south of the mine shows quartz porphyry in conformable contact to layered siliceous rock containing cobbles and thin layers of graphitic schist.

East of the mine one locality shows a zone of rounded quartz porphyry cobbles within quartz porphyry which is in contact with amphibolite, indicating the possibility of a fossil weathered surface rubble.

Metamorphism and cataclasis have masked original textures of the quartz porphyry to such an extent that blue quartz phenocrysts are the only remaining feature of the original rock, consequently diminishing the value of petrographic studies in the determination of primary rock type.

Structure of the mine area

Cleavage, faulting, lineation, and jointing

Flow-shear cleavage is the most striking characteristic of the Kutam deposit. The entire deposit is in rocks that show intense flow and shear cleavage. Sharp contacts demark the mineralized zone from the regionally metamorphosed rock (pl. 1).

Three major fault systems, intimately related to the shear cleavage, join at the Kutam mine. The three systems strike N.45°W., N.20°W., and N.60°W. and all dip steeply west or vertical (fig. 4). Away from the immediate area of the faulted zones cleavage directions are parallel or semiparallel to the faults and where two or three different fault sets join or intersect, cleavages may be found superimposed. This is true especially in the northwestern part of the mapped area where N.60°W. cleavage is superimposed on both N.50°W. and N.20°W. cleavage. Strong N.60°W. foliation is predominant in the northwest corner of the mapped area and crosses the N.20°W. set on the projection of drill hole KA-3, and the N.50°W. set on the projection of drill holes KA-2,5, and 1. South of KA-1 it weakens perceptably. Foliation associated with the N.20°W. fractures appears to be only local. The N.50°W. set is predominant in the area southeast of KA-2, but within the mined area foliation-cleavage associated with the faulting is locally varied. All of the flow cleavages dip steeply west or vertical.

Fracturing in the N.45°W. direction is thought to have occurred first, and this system must have been active over a long period, for some of the faults are generally defined by silicification which has been brecciated and re-sealed by silica. In places the brecciated, siliceous zones carry chlorite pods and lenses, signifiying repeated brecciation and alteration to chlorite. After much of the silica had been deposited it was faulted off by the N.20°W. set and also by one east-west fault mapped in the north part of the mine.

The shear-faulting and cleavage of the N.60°W. set is thought to be the youngest, since it crosses the N.20°W.

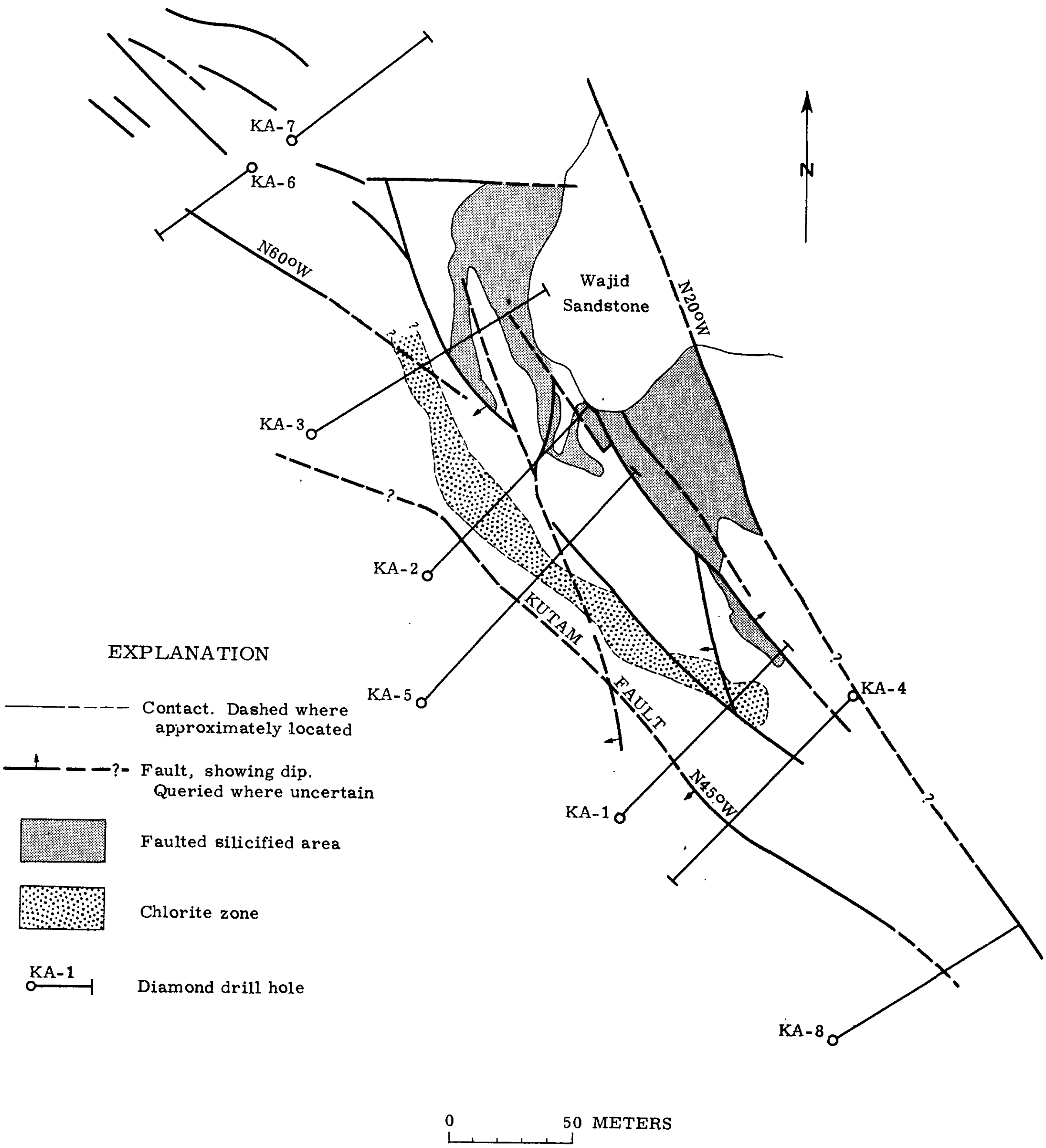

Figure 4. - Map of the Kutam mine showing principal faults, faulted silicified area, chlorite zone, and diamond drill holes.

sets and cuts silicification in the area of drill hole KA-3. Cross faults between members of the N.45°W. set strike N.12°W. and N.8°E. They are believed to be formed as the result of differential movement within the N.45°W. system.

Generally, the absolute movement on these faults cannot be determined. Judging from the relative position of foliation on both sides of a few cross fractures, the horizontal component of movement was left lateral, but both left and right lateral movements were mapped in the area to the south of the workings. Slickensides plunging about 75°S. were measured along faults of the N.45°W. set.

A lineation resulting from two cleavage directions may be measured in many places at the mine. Plunge of the lineation ranges from 35° to 80° to the southeast and is very prominent within the walls of workings.

Joints which dip gently to the southeast were mapped in some of the workings in the southern part of the mined area. The joints are spaced about one meter apart and are mineralized in places.

Localization of ore bodies

The ore bodies at the Kutam mine are localized in northwest-trending shear zones. These shear zones initially were controlled by previously developed schistosity, and subsequently served as channelways for movement of silica and later for ore-forming solutions.

Detailed surface and drill core studies show correlation between fracture systems mapped at the surface and mineralized zones intersected by drilling. Also, correlation of mineralized intervals from drill hole to drill hole is good when based on the projection of fracture systems. Judging from surface mapping and drill hole intercepts, the shape of the sulfide bodies is roughly tabular and dip is steeply to the southwest.

Along the N.45°W. system, fractures appearing in the walls of trenches are roughly parallel to foliation, but cross fractures at an oblique angle to schistosity also are mineralized and were stoped locally between major fractures. The workings also are seen to take abrupt turns where miners followed mineralization. Some of the more extensive, higher grade ore bodies may occur where cross fractures join the N.45°W. system. For example, drill holes KA-1, 2, and 5 cut mineralization along the projected intersection of these fracture systems. Also, the most intensive mining activity was centered at two of these areas. Sparse mineralization was found in hole KA-4, which penetrated the mineral zone parallel to hole KA-1, 65 m southeast, at approximately 90 m depth. Surface mapping along the projection of this drill hole revealed fracturing along the N.45°W. system parallel to schistosity. Shallow excavations were made along the fractured zone by the ancient miners. No other fracturing was mapped along this projection, in contrast to the main pit area above hole KA-1, where at least two fracture sets join.

Drill hole KA-3, positioned 110 m northeast of hole KA-2, found minor mineralization along fractures which belong wholly or partially to the N.20°W. set. This fracture set, explored by one long trench and four other workings, projects very well to sparse mineral intercepts in the drill hole. No cross fracturing was noted during mapping along the surface projections of the drill hole.

The Kutam fault was found to be sparsely mineralized in holes KA-1, KA-4, and KA-5. Drill hole KA-2 intersected sphalerite-bearing schist at the contact of amphibolite and quartz porphyry on the projection of the Kutam fault. Two other sphalerite-bearing zones found in the footwall of the deposit in hole KA-2 make this area of special interest since surface mapping indicates shearing and faulting to tbe aligned in both N.45°W. and N.60°W. directions. Drill holes KA-3 and KA-7 penetrated the Kutam fault but both intersections are barren of copper or zinc.

A chlorite zone is shown on plate 1 and figure 4. This zone contains a significant amount of chlorite in pods, lenses, and as fracture fillings associated with a quartz-sericite-chlorite schist (fig. 5). The chloritized masses contain euhedral garnet, brown biotite, white mica and talc and in places may have been derived from alteration of mafic dikes. It is considered to be generally derived from metasomatism and metamorphic segregation within a shear zone, resulting in the isolation of chloritic masses and giving the zone a weakly brecciated appearance. The same features were noted in drill core where, with few exceptions, sphalerite and chalcopyrite are found replacing the chloritic material. The zone trends along the southwest edge of the deposit and terminates south of the large open pit between KA-1 and KA-4. To the north, it disappears under mine waste but was intersected in hole KA-3. Its lateral extent generally defines the higher grade mineralized bodies intercepted in drill holes. All of the zone is not mineralized, but some of the higher grade material intersected in holes

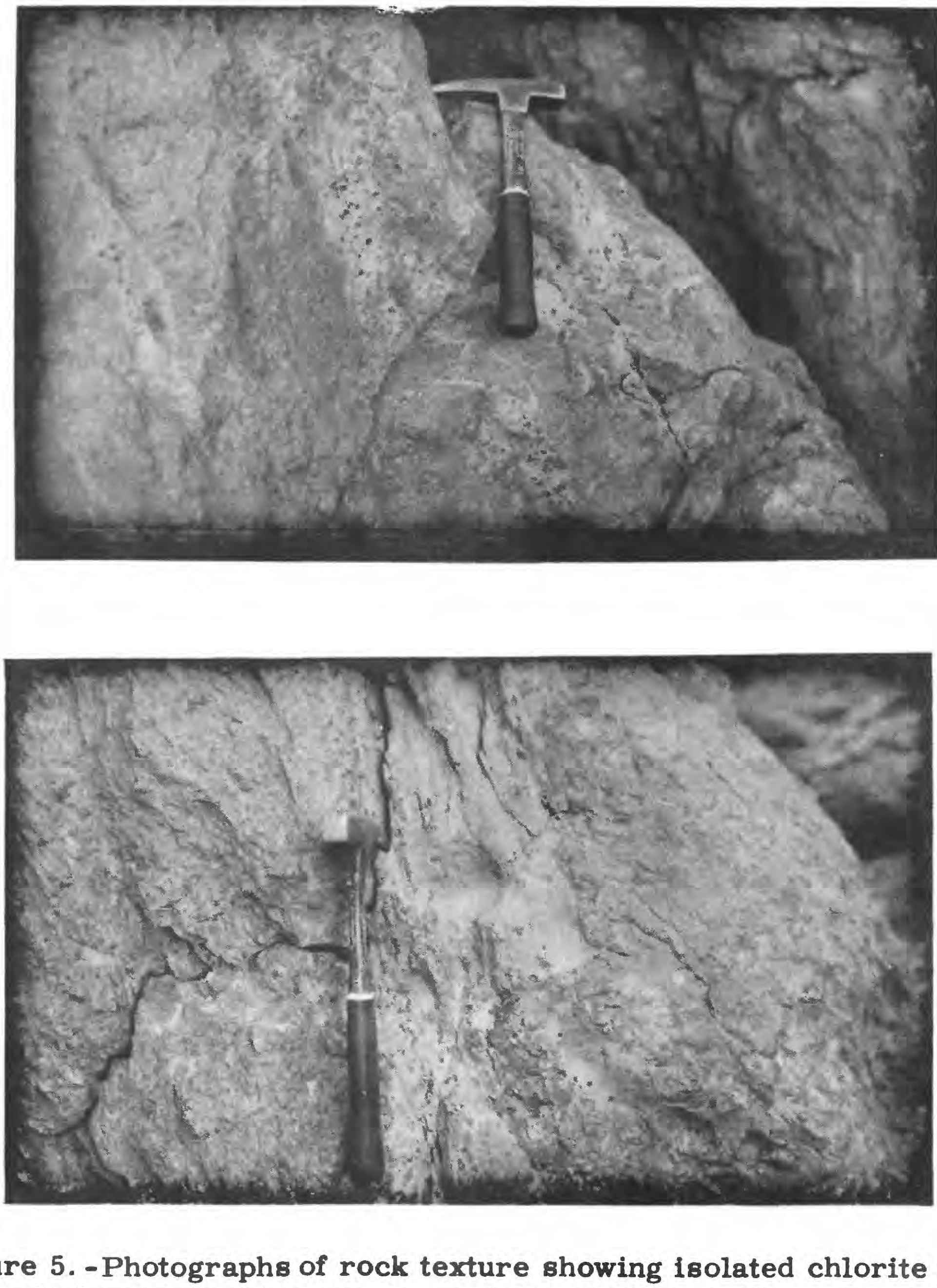

Figure 5. - Photographs of rock texture showing isolated chlorite with euhedral garnet within quartz-sericite-chlorite schist. Irregular lighter colored areas are mainly chlorite; dark spots are garnet.

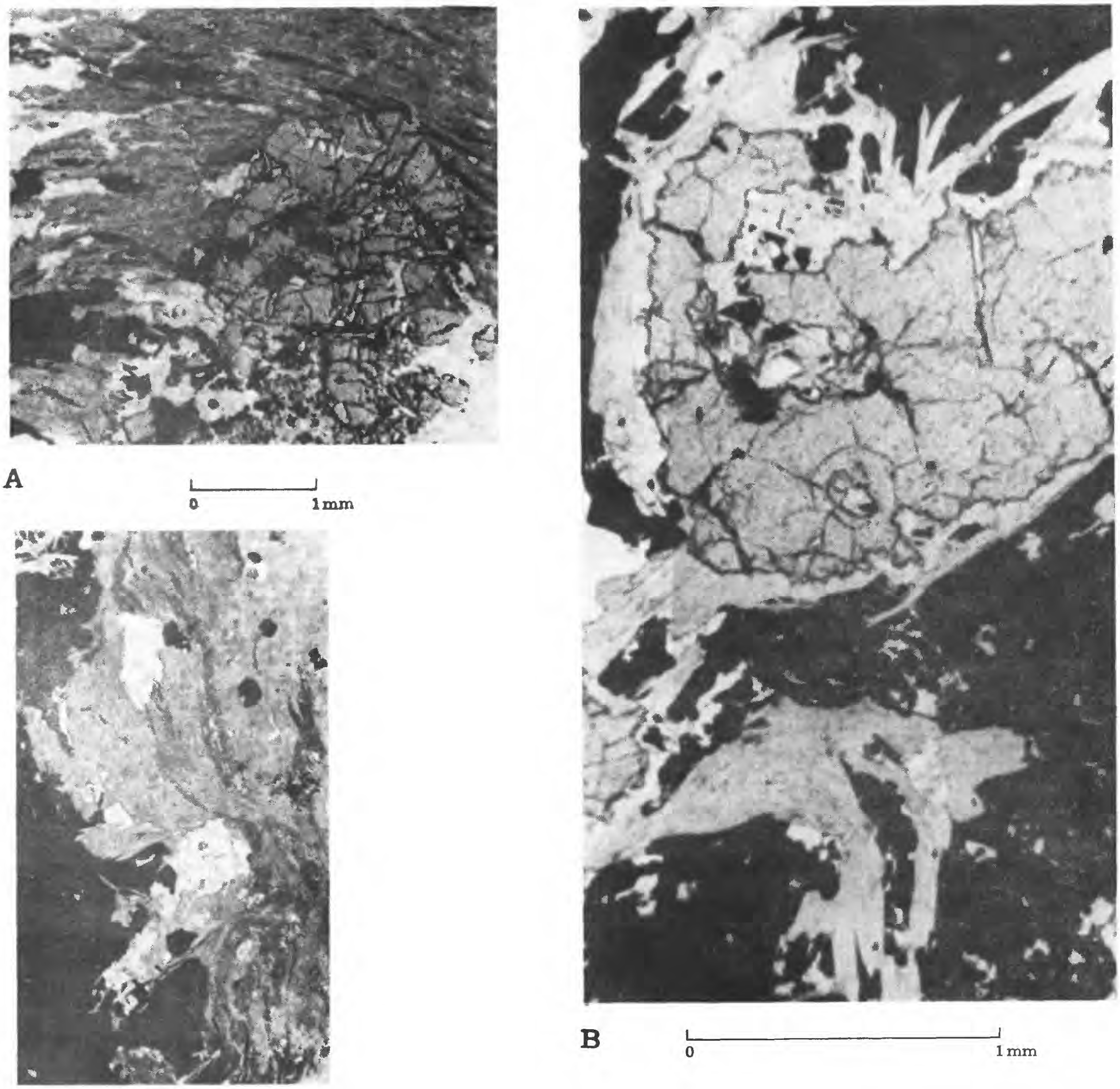

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Figure 6. - Photomicrographs showing replacement textures in main ore zone. A, Porphyroblast of garnet partially replaced by chalcopyrite (black) and sericite (white); from 93.25 m in drill hole KA-4. B, Garnet porphyroblast with an incomplete sheath of coarse-grained chlorite partially replaced by ore and very fine-grained chlorite, c. The lower part of the view shows a fold nose of coarse-grained chlorite isolated in massive nondeformed chalcopyrite; the coarse-grained chlorite in the sheath and fold nose is probably pseudomorphouse after biotite that crystallized with garnet, whereas the fine-grained chlorite is a product of hydrothermal replacement; from 131.9 m in drill hole KA-1. C, Massive ore has here replaced fine-grained schist. Thin plates of ripidolite are imbedded in ore in the upper left and bottom of the view; from 131.35 m in drill hole KA-1.

KA-1, 2, and 5 is found within it. Correlation of the chlorite zone between surface and drill hole findings is reasonably good although the zone appears to be folded or faulted in the area of hole KA-1.

Generally, as drill holes penetrate beyond the chlorite zone, the rocks become gradually more silicified and faulted. The faulted zones are marked by brecciated siliceous quartz porphyry associated with chloritic material. Here again mineralization is found replacing chloritic material. These fault zones were mapped on the surface and are recognized in drill core as fractures controlling mineralization. They can be seen on the surface especially within walls of trenches, in the strongly silicified area on the northeast edge of the mineralized zone. These fracture systems also localized the mafic feldspar porphyry dikes which are associated with massive chlorite and are mineralized both in drill cores and on the surface. The mineralization associated with the dikes is not extensive, however, and KA-5 was the only drill hole to intersect mineable grade sulfides associated with this rock.

In some areas the ore bodies worked by the ancient miners were formed at the intersection of two cleavages. These cleavages were developed by shearing that trends N.60°-70° and N.30°W.; the intersection forms a lineation that plunges 35°-60°SE. This southeast plunge may account for the differences in metallization between two adjacent drill holes KA-1 and KA-4. Although high copper-zinc values were found in KA-1, only low grade material was found in KA-4. The steep plunge may cause the ore bodies intersected in hole KA-1 to project beneath the area explored by hole KA-4.

Mineralogy

Gangue Minerals

Quartz.--Quartz began to separate early in the metamorphic process and continued to form during the hydrothermal period of the deposit. In the southeastern half of the mineralized area richly garnetiferous chlorite-quartz schist forms concordant sheaths around lensoid and podiform quartz-rich masses a few centimeters to more than 1 m in length. Garnet porphyroblasts in these rocks are as large as 1 cm and locally comprise 10 percent of the rock. Such high concentrations of garnet are very atypical in the region and are suggestive of metamorphic segregation. The quartz-rich masses are interpreted as boudined segregations in a matrix of garnet-chlorite-quartz schist. Early segregation of quartz also is indicated in rocks adjacent to the mineralized area.

The large silicified area shown on the geologic map probably formed mostly by replacement. Although relict quartz phenocrysts were not identified with certainty from the main mass, phenocrysts of undeformed, unstrained quartz (some showing the effects of resorption) are clearly visible in thin sections of nearby silicified rocks that consist of 70-80 percent quartz. This intensely silicified rock and bodies of massive quartz appear to be barren of significant concentrations of ore minerals.

Brecciated silicified zones healed by later quartz are common in mineralized zones and indicate the migration of silica during late stages of pre-ore silicification.

Garnet.--Garnet in the host rock is pink to red and probably almandine. The euhedral porphyroblasts in the mineralized rocks tend to be ragged in appearance owing to their alteration and partial replacement by chlorite and in some cases by fracturing and introduction of sulfide minerals (fig. 6). Foliation surfaces are commonly truncated sharply by the porphyroblasts and not deflected around them. Some garnets contain sparse aligned inclusions of sphene similar to garnets found in chlorite schist adjacent to the deposit. These fabrics indicate that garnet growth took place under conditions of relatively static differential stress, following the formation of schistosity. The garnets probably are coeval with poikiloblastic garnets in rocks adjacent to the Kutam deposit.

Apatite.--Clusters of apatite crystals with zonally arranged minute inclusions are found in garnetiferous chlorite schist of the mineralized zone. Grain-boundary relationships indicate that apatite crystallized with chlorite and is considered to be of hydrothermal origin.

Tourmaline.--Needles of green tourmaline were found in drill core from the Kutam fault zone and pink tourmaline was found in samples of float along the fault (K. Branscome, oral commun., 1975).

Gahnite.--Green gahnite, a zinc-bearing spinel, was found as surface float and in garnetiferous chlorite-muscovite schist in drill hole KA-1. Its presence suggests that concentrations of zinc in the schist date back at least to regional thermal metamorphism.

In core from hole KA-1., gahnite is idiomorphic where bounded against or included within massive quartz (fig. 7, a, b) but otherwise tends to have ragged boundaries resulting

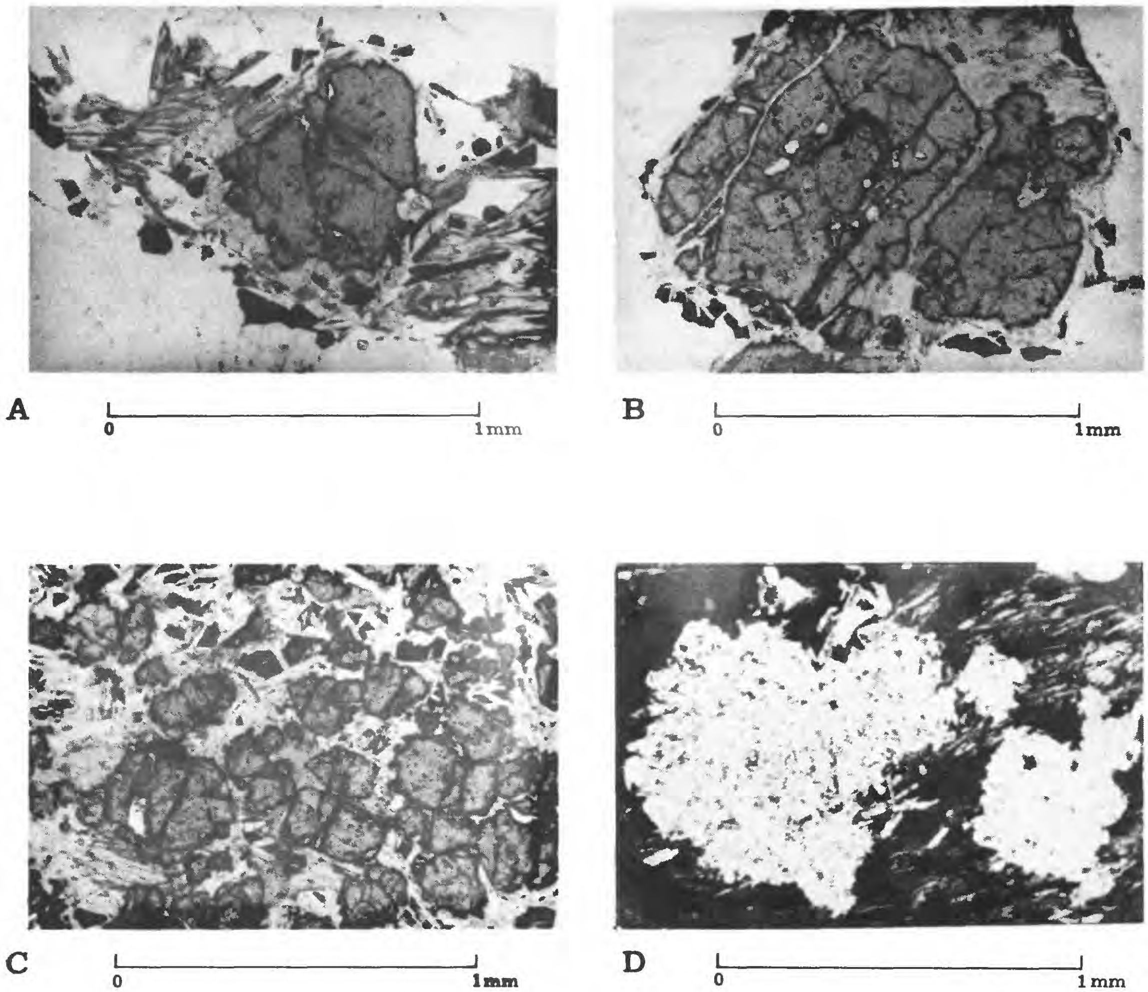

Figure 7. - Photomicrographs of gahnite porphyroblasts in core from drill hole KA-1. A, B, and C are plane-light views of a mineralized garnetiferous chlorite-sericite-quartz schist at 134.5 m. A, Shows relationship of the gahnite to the chlorite that forms the schistosity; white field is quartz, black is sphalerite, gray is very fine-grained secondary sericite that partially replaces gahnite. Part of an original crystal face is seen where the gahnite is in contact with quartz along the top part of the grain. B, Similar to A but shows distribution of sphalerite peripheral to gahnite, suggesting that it formed as a residue during partial replacement of gahnite (also seen in A). C, Shows a cluster of partially replaced gahnite grains that were probably mostly a single large euhedral grain prior to partial replacement by sericite and sphalerite. D, From a similar rock in a nonmineralized zone 24.3 m higher in the hole than A, B, and C, but the view is with crossed nicols. The fine-grained matted sericite (light areas) in chlorite is interpreted as completely replaced gahnite euhedra.

from partial replacement (fig. 7, a, b, c). Gahnite was noted at 179 m in drill hole KA-1, and completely replaced grains are inferred at 110.3 m (fig. 7d). Initial grains probably were well-formed euhedra, and there is no tendency for foliation surfaces to deflect around them. Gahnite probably crystallized with garnet under relatively static stress conditions.

Gahnite alters to poorly crystalline white mica and sphalerite (fig. 7 a, b, c) and in come cases the matted white mica passes outward away from a central grain of gahnite to an outer rim in which sphalerite is between well-formed white mica. Where it has formed by replacement sphalerite is not found in contact with gahnite.

The occurrences of gahnite in association with massive quartz indicates concentrations of zinc in a contact metasomatic environment (Deer, Howie, and Zussman, 1966). At Kutam, however, the contact metamorphic aspect is in doubt because of regional hornfelsic textures.

Mica.--In the mineralized area at Kutam micas take the place of hornblende, epidote, and plagioclase found in equivalent rocks adjacent to the area. The earliest micas generally are those of fine grain size that form the first schistosity. Chlorite and white mica are the chief types. Preliminary X-ray and petrographic data indicate that the chlorite is ripidolite which is monoclinic with $\beta = 97°$ and that the white mica is similar to the 2M polymorph of muscovite, which is monoclinic with $\beta = 95°$. The data are not, however, definitive as to whether the white mica is muscovite or pyrophyllite for both minerals have similar optical properties and hkl reflections. Chemical data are needed.

Garnet is common in chlorite schist, and it is tempting to assume that the chlorite is pseudomorphous after biotite that was stable before or during garnet growth. There is, however, no compelling evidence that this is so. If all or most of what is now chlorite had been biotite at an earlier stage a perplexing relationship exists with regard to the activity of potassium. Also, if all of the white mica is muscovite, the perplexity is compounded. Petrographic studies of volcanic, sedimentary, and plutonic rocks in the region surrounding the Kutam prospect indicate that the rocks are deficient in potassium-bearing minerals. Although data are insufficient to formulate mass-balance equations it seems likely that potassium would have had to have been introduced into the rocks in large quantities during the formation of the "early" biotite and muscovite. Potassium feldspar should have been produced during the subsequent chloritization of the biotite according to the following reaction:

$$2(OH)_2KFe_3^{+2}AlSi_3O_{10}+2H_2O \rightarrow (OH)_8Fe_5^{+2}Fe^{+3}AlSi_3O_{10}+KAlSi_3O_8+K.$$

The absence of potassium feldspar in rocks at the Kutam prospect would indicate that if large quantities of biotite were chloritized the potassium released was either systematically removed from the system or was used in the formation of some mineral other than potassium feldspar. The first possibility involves a complex history of potassium migration (vis. early introduction during biotite formation and removal during chloritization) and thus lacks favor. Muscovite could have formed instead of potassium feldspar according to the second possibility (the Al needed for its formation could have come from the breakdown of epidote in a system open to the removal of calcium). However, large masses of chlorite schist exist without significant quantites of white mica and the explanation therefore loses favor. Alternatively, the large amounts of chlorite in the prospect could have formed directly from metamorphic replacement of actinolitic hornblende and epidote. Tilley (1938, cited by Deer and others, 1962, p. 153) gave clear evidence that chlorite forms from actinolite hornblende and epidote in a reaction of the following types:

Actinolitic hornblende + epidote$\rightarrow$chlorite (an Al-rich ripidolite) + SiO_2 + CaO. This alternative explanation would require that ripidolite was the stable ferrian phyllosilicate during the thermal metasomatic episode when garnet and gahnite were stable and that it remained stable throughout most of the subsequent hydrothermal event. Chlorite at Kutam is of the IIb-type polymorph and Bailey and Brown (1962) have noted that this polymorph is stable in medium and high temperature ore deposits. That ripidolitic chlorite was stable during the hydrothermal episode is suggested by the common occurrence of late chlorite that cuts the schistosity of the earlier ripidolitic chlorite (fig. 8). The coarser-grained later chlorite tends to follow along fracture zones and to be replaced by sulfide ore minerals. As such it is considered to be the product of pre-ore propylitic alteration. Sparse brown biotite also cuts schistosity of the early ripidolitic chlorite.

Ore minerals

Pyrrhotite, pyrite, chalcopyrite, and sphalerite are the principal primary sulfide minerals penetrated by the drill holes. They form concentrations ranging from wisps and streaks less than 1 mm wide that generally parallel the schistosity (fig. 6a and 8c) to massive chalcopyrite-rich veins 2 m or more in width. The veins are irregularly spaced at distances ranging from a few centimeters to several meters and tend to form families of veins separated by relatively unveined rock.

A minor proportion of the sulfides are small euhedral disseminated crystals. In the veins chalcopyrite and sphalerite are medium to coarse grained and occur individually or intergrown. In places, inclusions of chalcopyrite in sphalerite suggest exsolution texture. A sample of ore that contained high silver values was determined by X-ray analysis to contain silver-bearing tetrahedrite. Sparse amounts of galena also were noted.

Locally, the deposition of disseminated chalcopyrite is clearly later than the event in which the schistosity was crenulated (fig. 9). Commonly, folded chlorite is replaced by massive undeformed chalcopyrite (fig. 6b). Even the earlier metamorphic minerals are replaced by later sulfides, as shown by the garnet (fig. 6a). Examination of drill core and microscopic studies indicate that most of the sulfide minerals are post-shearing and occupy fractures that do not parallel primary foliation. Close inspection of the massive sulfides show the bodies to have selectively replaced the coarser-grained chlorite that is presumed to have formed by propylytic alteration.

Zones of massive quartz and intensely silicified schist are less mineralized than zones of chlorite schist. The highest concentrations of sphalerite occur in drill core taken from the Kutam fault zone and from the hanging wall section of the mineral deposit. The fault transects and deforms early schistosity, which is further evidence that the epoch of sulfide mineralization is later than most of the geologic processes that affect the Kutam deposit.

Secondary minerals

Malachite is the predominant copper oxide, although sparse amounts of azurite were noted. Chrysocolla has not been positively identified, nor have any of the oxidized zinc minerals that would be expected to be found.

Iron oxides in the form of hematite and goethite form stockworks locally, but are not conspicuous in the mine area. In the northern part of the mapped area in the vicinity of holes KA-6 and 7 iron oxides which are probably mostly hematite are seen as fracture fillings and as aureoles around cubic voids giving the rocks a rust red color. These

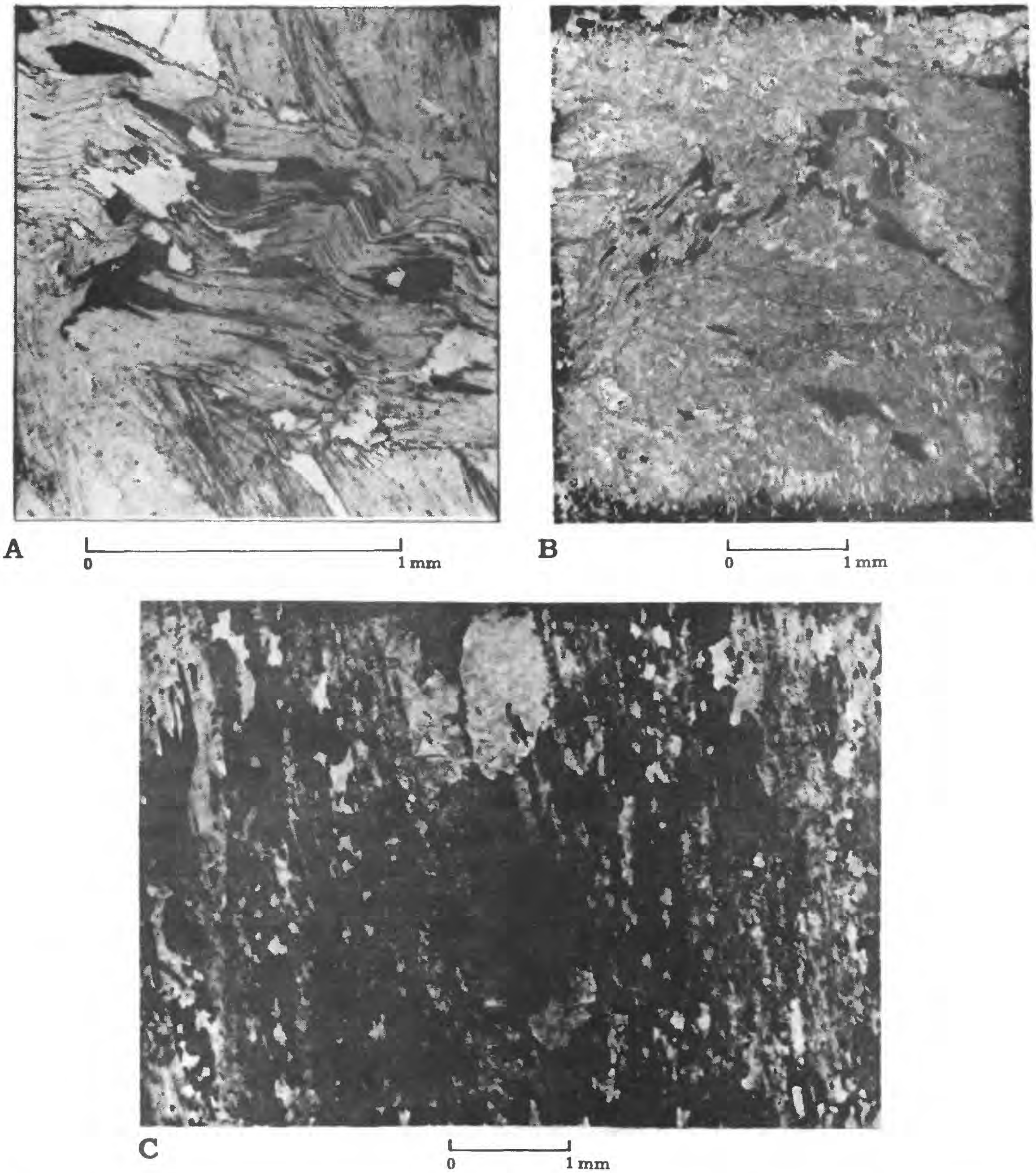

Figure 8. - Photomicrographs showing the general preference for ore to be associated with relatively coarse-grained late metamorphic minerals that tended to crystallize under conditions of low or no differential stress. A coarse grain of late chlorite that cuts early schistosity-forming chlorite is seen at different scales in A and B. Chalcopyrite (black) shows a preference for the coarse grain and is kinked along with the cleavage traces of its host; garnetiferous quartz-chlorite schist with chalcopyrite and sphalerite from main ore zone. In C chalcopyrite resides in streaks and bands of coarsely crystalline quartz and chlorite. Cleavage traces of the late chlorite (vaguely visable in center of view) lie at a high angle to schistosity. Rock is a garnetiferous quartz-chlorite schist from main ore zone in drill hole KA-4.

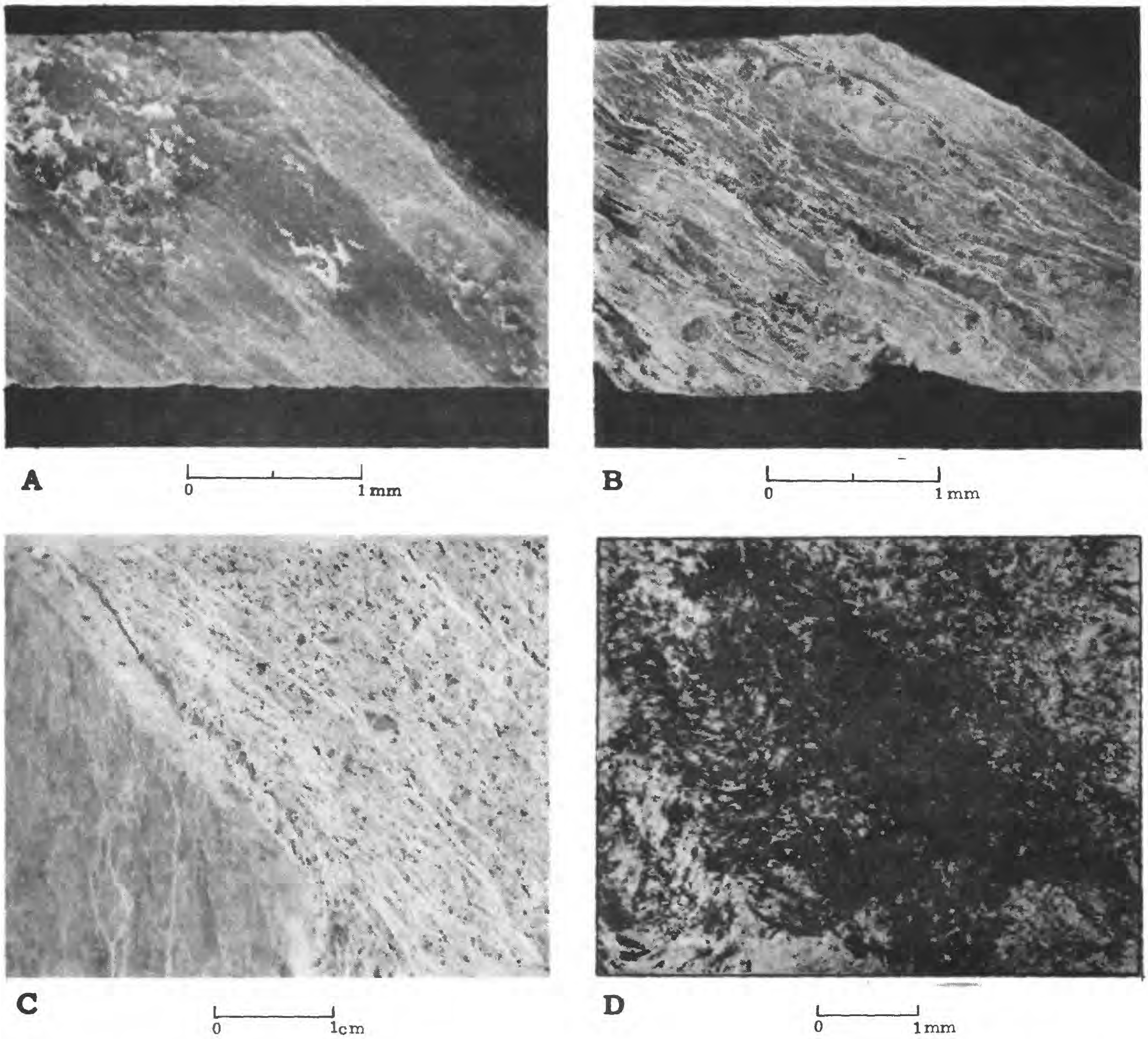

Figure 9. - Photographs of textures in rocks containing ore. A, Polished section of drill core from hole KA-4; sericite schist shows chalcopyrite (white) restricted to irregular-shaped areas of coarse recrystallization that transect early schistosity. B, Shows distribution of chalcopyrite (dark) in a polished drill core of garnetiferous chlorite schist from 93.2 m in hole KA-4. C, Shows disseminated chalcopyrite (black specks) restricted to upper half of a piece of polished drill core of sericite schist from 190.4 m in hole KA-1. The boundary between the nonmineralized and mineralized parts separates planar schistosity in the lower part from crenulated schistosity in the upper part. D, Photomicrograph of a thin section cut across that contact. It also shows the chalcopyrite granules (black) restricted to the part with crenulated schistosity. Although the contact transects the planar schistosity the schistosity is not offset by slippage along the contact. Therefore, the crenulated schistosity clearly served to localize the ore. The ore-bearing part of C exhibits a postore third cleavage that is almost parallel to the contact.

iron oxides were probably derived from pyrite, and drilling in this area disclosed disseminated pyrite below the outcrop.

Iron oxides extend about 150 m southeast of the mineralized ridge and from there on to the south they are scattered sparsely. Drill hole KA-8 cut minor pyrite and 1 m of 2.2 percent zinc within localized shears, which correlate well with surface shears exhibiting minor iron oxides.

Oxidation has not penetrated deeply at Kutam and Sulfides were found in drill holes only a few meters from the surface. In all of the holes oxidation of the sulfides is minor and only a few centimeters of the sulfide-bearing rock are coated with copper oxides. Supergene mineralization was not seen in drill cores; it seems probable that not enough pyrite was present in the mine area to accomplish leaching of sulfides and redeposition at depth as secondary copper and zinc minerals.

Zonation of metals

A definite zonation of copper and zinc is apparent at the Kutam deposit and drill holes KA-1 through KA-5 encountered higher zinc-copper ratios in the hanging wall zone than in the footwall zone. In holes KA-2 and KA-5 mineralization high in sphalerite was found within the Kutam fault but elsewhere the Kutam fault was found to be only weakly mineralized although the zinc-copper ratio remained high. In hole KA-1 the strong zinc mineralization is generally associated with the Kutam fault zone but also occurs deeper in the hole, in the hanging wall of the mineralized deposit. Drilling invariably found progressively diminishing amounts of zinc toward the footwall of the deposit.

Correlation coefficients for Au, Ag, Cu, Pb, and Zn

Table 1 shows linear correlation coefficients for Au, Ag, Cu, Pb, and Zn. Data are taken from drill core assays of mineralized sections in drill holes KA-1, 2, 3, 4, and 5. These data are not related to depth of hole. All drill holes obtained higher zinc values in the hanging wall of the deposit in contrast to higher copper content in the footwall. Silver and zinc have the strongest correlations in holes KA-1 and KA-2; silver and copper in KA-3; and lead and copper in KA-4 and KA-5. Gold-copper have strong negative correlations in holes KA-1, KA-2, KA-3, and KA-5, indicating that these metals are disassociated in the formation.

The high silver-zinc correlation and absence of lead in holes KA-1 and KA-2 probably indicate association and zoning of these metals at least in the hanging wall portion of the

Table 1. Correlation coefficients for Au, Ag, Cu, Pb, and Zn based on drill core assays

KA-1 - 238 samples

	Au	Ag	Cu	Zn
Au	1.000	0.0015	-0.0987	0.0179
Ag	0.0015	1.0000	0.4500	0.7207
Cu	-0.0987	0.4500	1.0000	0.2790
Zn	0.0179	0.7207	0.2790	1.0000

KA-2 - 201 samples

Au	1.0000	0.3015	-0.0107	0.3487
Ag	0.3015	1.0000	0.6559	0.8457
Cu	-0.0107	0.6559	1.0000	0.2803
Zn	0.3487	0.8457	0.2803	1.0000

KA-3 - 65 samples

	Au	Ag	Cu	Pb	Zn
Au	1.0000	-0.4381	-0.5615	0.0246	-0.2405
Ag	-0.4381	1.0000	0.8239	-0.0549	0.1082
Cu	-0.5615	0.8239	1.0000	-0.1016	0.0370
Pb	0.0246	-0.0549	-0.1016	1.0000	-0.0233
Zn	-0.2405	0.1082	0.0370	-0.0233	1.0000

KA-4 - 47 samples

Au	1.000	0.4197	0.4565	0.1177	0.0837
Ag	0.4197	1.0000	0.3361	0.3643	0.1221
Cu	0.4565	0.3361	1.0000	0.7598	0.4689
Pb	0.1177	0.3643	0.7598	1.0000	0.4772
Zn	0.0837	0.1220	0.4689	0.4772	1.0000

KA-5 - 71 samples

Au	1.0000	-0.7497	-0.3543	-0.5321	0.0759
Ag	-0.7479	1.0000	0.7271	0.8878	-0.0231
Cu	-0.3543	0.7271	1.0000	0.9173	0.0898
Pb	-0.5321	0.8878	0.9173	1.0000	0.1903
Zn	0.0759	-0.0231	0.0898	0.1903	1.0000

NOTE: Pb values in drill holes KA-1 and KA-2 were negligible and not put into computer.

mineralized zone. Lead-silver has moderate correlation in hole KA-4 and strong correlation in KA-5, but the amounts of lead and silver found in all drill holes were so small that no mineral samples were available for laboratory work to test this association.

More detailed studies of metal pairs and their relative position in respect to the entire mineralized body is needed in order to better understand the geometry of the zonal arrangement of the elements.

Exploration program

Eight holes were drilled at the Kutam deposit during the period September 1974 to August 1975. Locations of the holes are shown on plate 1 and figure 4. Each hole was logged in detail and reduced versions of the logs are enclosed in the pocket at the rear of this report. Originals of the logs are on file at the U. S. Geological Survey Saudi Arabian Project office, Jiddah, and copies of the logs are available at offices of the Directorate General of Mineral Resources, Ministry of Petroleum and Mineral Resources, Jiddah.

Drilling was successful in delineating a sulfide deposit enriched principally in copper but also containing zinc and lesser amounts of gold and silver. The deposit is considered to be large enough and of sufficient grade to be mined at current costs and prices.

Drill hole KA-1

Hole KA-1 was sited to intersect the downward projection of the most intensively worked area which coincides with a self potential anomaly outlined by geophysical studies (pl. 1, fig. 10). The upper portion of the hole passed through quartz porphyry and amphibolite containing sparsely disseminated pyrite and chalcopyrite. At 75.90 m the hole intersected the probable projection of the Kutam fault where an abrupt change in rock alteration from strongly chloritic to sericitic with tremolite accompanied by sparse disseminated chalcopyrite, sphalerite, and galena delineates the fault zone. The next significant mineralized zone was cut at 105.50 m where sphalerite replacing chlorite is found in strongly schistose zones. Sphalerite with minor chalcopyrite continues to 121.55 m; it accompanies quartz veins, replaces chlorite in brecciated zones, and replaces quartz-sericite-chlorite schist along foliation. At 105.50 m a 0.4 m interval of core assayed 0.14 g/t Au, 13.0 g/t Ag, 1.5% Cu, and 7.55% Zn. The interval 111.80 m to 121.55 m averaged 0.10 g/t Au, 7.71 g/t Ag, 0.94% Cu, and 3.02% Zn. The 0.4 m interval of zinc ore

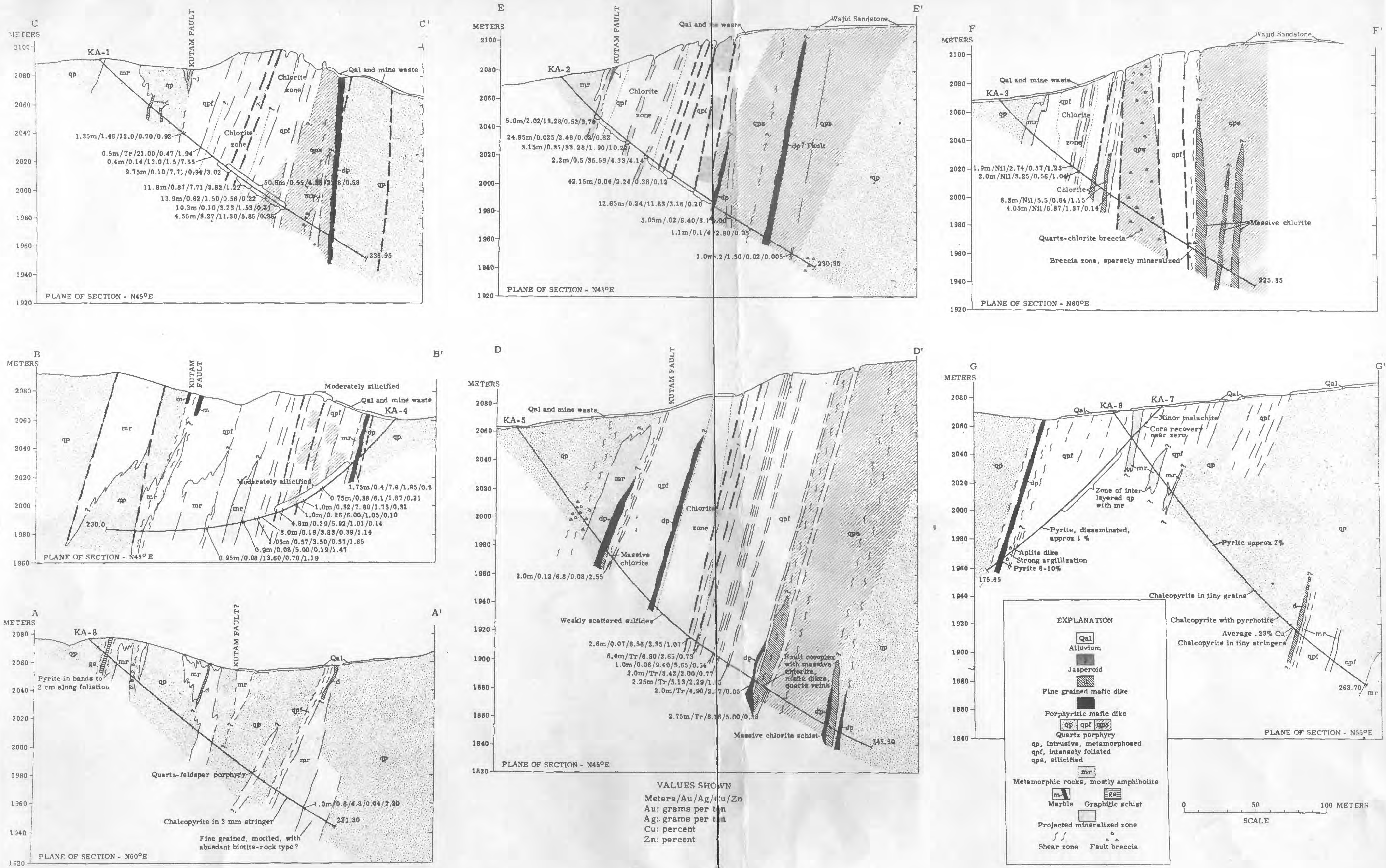

Figure 10. - Vertical sections through diamond drill holes KA-1, KA-2, KA-3, KA-4, KA-5, KA-6, KA-7, and KA-8, Kutam mine.

projects very well to a line of shallow, debris covered workings situated at the edge of the steep slope rising northeast from the Kutam fault zone, but the wider zone cited could not be correlated with surface exposures because of cover.

Beginning at 127.80 m chalcopyrite occurs in veins and stringers which cross cut foliation and also replaces chlorite along foliation. The chalcopyrite is distributed erratically to 139.60 m but chlorite diminishes and the rocks become more siliceous with increasing depth. This zone, which averages 0.87 g/t Au, 7.71 g/t Ag, 3.82% Cu, and 1.22% Zn for 11.8 m, may project to the area just west of the large open pit where, narrow workings on a N.10°W. fracture extend to depth. In the interval between 139.60 m to 163.80 m the rock becomes intermittently but increasingly siliceous down hole with the intervening zones displaying sericitic alteration. Sulfide mineralization is relatively sparse within this zone; one interval of 0.55 m at 158.45 m, however, assayed 14.25% Cu. Abundant sulfide minerals were again intersected throughout 4.55 m extending from 163.80 m to 168.35 m where an average assay of 3.27 g/t Au, 11.3 g/t Ag, 5.85% Cu, and 0.35% Zn was obtained. Within this zone the highly silicified rock appears to have been fractured in places with massive chalcopyrite coming in along clean fractures not necessarily parallel to foliation. This interval of strong copper sulfide mineralization projects upward to the large open pit worked by the ancient miners (fig. 11).

Below 168.35 m sparse chalcopyrite occurs as narrow veinlets and disseminations in highly quartzose rock. From 187.0 m to 196.0 m the hole penetrated a brecciated fault zone containing gouge up to 10 cm wide. The quartzose rock terminates at the faulted zone and the hole then penetrated a lens of amphibolite from 191.0 m to 198.0 m and a mafic feldspar porphyry dike from 211 m to 217 m. This entire zone of some 30 m probably represents the extension of a N.45°W. fault zone which projects up to deep trenches mapped 50 m north of the drill hole. The hole terminated at 236.95 m in chloritized quartz porphyry containing numerous large garnets and sparse chalcopyrite, pyrrhotite, and pyrite.

The projection of the chlorite zone in the drill hole to the surface does not project parallel to the foliation and is apparently folded or faulted within this area.

Drill hole KA-2

Drill hole KA-2 was laid out to test the northern end of a self potential anomaly and to cut projected mineralized bodies worked intensively in a series of open cuts (pl. 1, figs. 10 and 12).

Figure 11. - Photograph of ancient workings looking toward large open pit. Drill hole KA-1 intersected projected mineralized bodies at an average depth of 90 m below the workings.

Figure 12. - Photograph of ancient workings looking northwest. Drill hole KA-5 passed beneath area in the foreground. Drill hole KA-2 intersected projected mineralized bodies worked in ancient pits in the background approximately 100 m below the surface.

Hole KA-2 began in amphibolite and continued in this rock to 35.90 m where an intense shear zone was intersected. This shear zone consisting of sericite, muscovite, tremolite, garnet, talc, and biotite and boudins of quartz is stained by malachite and goethite and contains sphalerite and minor chalcopyrite layers parallel to cleavage and as disseminations. The interval 36.00 m to 41.00 m averaged 2.02 g/t Au, 13.28 g/t Ag, 0.52% Cu, 3.79% Zn, and is considered to represent the northern extension of the Kutam fault as projected from drill holes KA-1, KA-4, and KA-5, and as mapped on the surface. After passing through a sparsely mineralized chloritic zone containing quartz phenocrysts, the drill hole again intersected sulfide mineralization in the interval 65.85 m to 69.00 m where assays averaged 0.37 g/t Au, 33.28 g/t Ag, 1.90% Cu, and 10.22% Zn. The mineralization occurs as thin layers and massive replacement zones along shear cleavage; and the zone projects upward at 75° to a series of deep workings within the chlorite zone. An essentially barren zone was then cut, after which sulfide mineralization was encountered in a 2.2 m interval beginning at 81.50 m which averaged 0.50 g/t Au, 35.59 g/t Ag, 4.33% Cu, and 4.14% Zn. This zone is accompanied by a marked change in rock type from chloritized quartz porphyry to a fine grained sericite-chlorite schist with tremolite and projects at a 75° dip to a narrow line of workings on the hillside. An interval of 42.15 m was then cut which averaged 0.04 g/t Au, 2.24 g/t Ag, 0.38% Cu, and 0.12% Zn. These values represent sparse sulfide mineralization within rocks which becomes less chloritic and more sericitic and silicic down hole. This zone is down dip from the ancient workings, as projected from drill hole intercepts on the projection of the drill hole. Beginning at 125.85 m, sulfide mineralization averaged 0.24 g/t Au, 11.83 g/t Ag, 3.16% Cu, and 0.20% Zn over a 12.65 m interval. The mineralization consists of chalcopyrite with lesser amounts of sphalerite replacing chlorite within brecciated zones in silicified quartz porphyry. This zone also projects at a steep dip to major workings where silicification extends to the northeast (fig. 12). After passing through another sparsely mineralized siliceous zone, mineralization averaging 0.2 g/t Au, 6.4 g/t Ag, 3.17% Cu, and 0.06% Zn, occurs in a 5.05 m interval beginning at 156.95 m. The chalcopyrite is localized within fault breccia. If projected vertically to the surface, this zone correlates with a vertical cross-fracture in a trench.

The remainder of the drill hole passed through siliceous rock containing masses of chlorite which, in part, are replaced by pyrite and chalcopyrite. The interval 174.80 m to 175.90 m assayed 0.10 g/t Au, 4.80 g/t Ag, 2.80% Cu, and 0.05% Zn after which sulfides become progressively sparse. At 189.0 m the hole intersected a fault bordering a mafic dike. Minerals in the fault are oxidized. The fault apparently is the projection of a fracture zone marked by a series of workings on the eastern edge of the mineralized hilltop. The hole bottomed at 230.95 m in silicified material which had been brecciated and resealed by silica.

Drill hole KA-3

Because of the excellent findings in holes KA-1 and 2, drill hole KA-3 was set well to the northwest to test the continuation of the mineralized zone (pl. 1, fig. 10).

Hole KA-3 was collared in quartz porphyry and intersected amphibolite from 26.55 m to 35.90 m. The quartz porphyry in the upper part of the hole is characterized by chloritized zones containing brown biotite and garnet, alternating with quartz-sericite-chlorite schist layers. The rock has not undergone shearing like that found in the upper part of KA-2 and the Kutam fault is less evident here.

The upper part of the hole contains sparse pyrite and beginning at 68.80 m sphalerite occurs as narrow wisps along schistosity. The interval 68.80 m to 70.70 m averaged nil Au, 2.74 g/t Ag, 0.57 Cu, and 1.23% Zn, and from 75.70 m to 77.70 m averaged nil Au, 3.25 g/t Ag, 0.56% Cu, and 1.04% Zn. This mineralization may be associated with the shear zone that extends N.60°W. across hole KA-7. At about 80.0 m the rock becomes more siliceous and contains sparse sulfides.

Beginning at 92.0 m, an 8.3 m zone averaged nil Au, 5.5 g/t Ag, 0.74% Cu, and 1.15% Zn. Below this zone at 102.30 m a 4.05 m zone averaged nil Au, 6.87 g/t Ag, 1.37% Cu, 0.14% Zn. These mineralized intervals project at a dip of 75° to 80° to deep trenches on the surface. The mineralization consists of wisps and streaks of chalcopyrite and sphalerite replacing chlorite. At 113.80 m the drill hole penetrated a complex of brecciated siliceous zones intermingled with seams and pods of chlorite-garnet-biotite schist and remained in this rock to 154 m depth. This zone is sparsely mineralized and projects to a sparsely mineralized zone on the surface. The brecciated material projects with a very steep easterly dips, opposite to most other dips mapped within the area.

Down hole from the brecciated zone several intervals of massive chlorite, sericite-chlorite-talc, and narrower brecciated, siliceous intervals were encountered, but this portion of the hole projected at 75° to the surface is covered by a thin layer of Wajid Sandstone. Most of this zone carries sparse pyritic mineralization with sparse chalcopyrite. The hole bottomed at 225.35 m.

Drill hole KA-4

Hole KA-4 was positioned to test the southeast extension of the mineralization found in KA-1 and was drilled in an opposite direction from all other holes to test the footwall of the deposit and the intensely silicified zone. The hole flattened with depth however, and crossed the mineralized interval at a higher elevation than had been expected (fig. 10).

The hole was collared in quartz porphyry; the upper part passed through metavolcanic rocks belonging to the older metamorphic series, many of which appear to be layered. At 35.75 m the drill cut serpentinized fault breccia with associated gouge. The faulted zone continues to 47.10 m and consists of alternating brecciated and mylonitized rock associated with mafic feldspar porphyry dikes and amphibolite. This interval coincides with the faulted zone intersected near the end of KA-1 and also with the fault trace passing through some of the large workings to the northwest.

At 41.75 to 43.50 m chalcopyrite occurs as intergrowths with pyrrhotite and as 1-5 mm wide stringers along cleavage planes within mafic metamorphic rocks. This interval assayed 0.4 g/t Au, 7.6 g/t Ag, 1.95% Cu, and 0.3% Zn. The hole then entered siliceous quartz porphyry at 47.10 m, where the rock is sericite-garnet quartz chlorite schist. This rock is interbedded with sericite-quartz-chlorite schist; zones of stronger silicification and chlorite-garnet schist in drill holes KA-1, 2, 3, and 5 to the north are found only within narrow intervals in KA-4. The high grade mineralized sections found in drill hole KA-1 were not encountered in this hole. Instead, much sparser copper-zinc mineralization was found paralleling schistosity as replacement material, and locally associated with clear quartz gangue. This type of mineralization was found within the interval 47.10 m to 140.0 m, with the higher grade sections averaging as follows: 104.65-109.45 m, 0.29 g/t Au, 5.92 g/t Ag, 1.01% Cu, and 0.14% Zn. From 117.20 m to 120.20 m the material averaged 0.19 g/t Au, 3.83 g/t Ag, 0.39% Cu, and 1.14% Zn. Other intervals on the cross section show the copper-zinc content to be low grade with values averaging less than 2 percent copper. The hole cut several amphibolite zones beginning at 135.50 m and passed into nonmineralized siliceous quartz porphyry at 203.55 m. The Kutam fault at the surface along the projection of the drill hole is characterized by lenses of medium-gray marble found together with amphibolite within a strong shear zone. Shallow workings suggest that the zone is mineralized and indeed, copper and iron oxides are found here. The intersection of the Kutam fault is placed at the amphibolite-quartz porphyry contact at 203.50 m, and projects at approximately 70° dip to the surface trace of the fault. Drill core, however, is essentially barren with only widely scattered pyrite and pyrrhotite grains. The hole was terminated at 230.0 m in siliceous quartz porphyry.

Drill hole KA-5

Hole KA-5 was drilled at a steeper angle than previous holes and positioned further from the Kutam deposit in order to test the mineralized zone at greater depths (pl. 1, fig. 10). The hole also tested an induced potential anomaly found during geophysical investigations.

Hole KA-5 was collared in quartz porphyry and continued in porphyry to a depth of 86.20 m after passing through brecciated and sheared zones that contain sparsely disseminated pyrite with scattered grains of chalcopyrite. At 86.20 m the hole passed into amphibolitic rocks and then into a complex series of fractured mafic dikes, chlorite zones, mafic feldspar porphyry, and quartz veins which extend to 108 m. This zone contains only minor disseminated chalcopyrite and pyrite. Between 108.0 and 122.0 the hole intersected quartz porphyry that is intensely sheared and metamorphosed to sericite-chlorite-garnet schist which grades into quartz-sericite schist containing masses of chlorite, brown biotite, garnet, muscovite, and talc. The projected Kutam fault was intersected in the interval 114.0 to 118.50 m. Sulfide mineralization in the interval consists of narrow stringers of sphalerite and chalcopyrite which locally replace chlorite parallel to schistosity. From 114.50 to 116.50 assays averaged 0.12 g/t Au, 6.8 g/t Ag, 0.08% Cu, and 2.55% Zn. This zone projects at 70° to the Kutam fault trace mapped at the surface.

The interval 122.0 to 155.85 consists of interlayered sericite and quartz-sericite-chlorite schist units of the quartz porphyry and are sparsely mineralized. A massive fine-grained mafic dike was cut from 155.85 m to 158.55 m after which brecciated, quartz porphyry was encountered; the porphyry contains masses of chlorite, brown biotite, garnet, and muscovite with sparse chalcopyrite and sphalerite. The sulfides are found locally in quartz stringers, but more commonly they replace chlorite throughout a wide interval extending to 192.50 m. This interval projected to the surface at approximately 75° includes much of the area mapped as chlorite zone.

From 192.50 m to 264.0 m chalcopyrite and sphalerite occur in veins, stringers and disseminations in fractured rock. Within the interval the rock changes from a quartz-sericite-chlorite schist to highly quartzose schist. The silicified rock is fractured and partly replaced by chlorite. At 250.0 m massive sulfide mineralization is associated with massive chlorite adjacent to mafic feldspar porphyry dikes. Several copper-enriched zones were intersected in this interval as shown in the enclosed drill log. Among the more important mineralized intercepts are 192.50-195.10, 2.6 m, 0.07 g/t Au, 8.58 g/t Ag, 3.35% Cu, 1.07% Zn; 199.0-205.40, 6.4 m, Tr Au, 6.90 g/t Ag, 2.65% Cu, 0.73% Zn; 215.75-216.75, 1.00 m 0.08 g/t Au, 9.40 g/t Ag, 3.65% Cu, 0.54% Zn; 226.75-229.00, 2.25 m, Tr Au, 5.13 g/t Ag, 2.29% Cu, 1.55% Zn; 250.00-252.00, 2.0 m Tr Au, 4.9 g/t Ag, 2.27% Cu, 0.05% Zn; 261.25-264.00, 2.75 m, Tr Au, 8.16 g/t Ag, 5.00% Cu, 0.38% Zn. Within the last interval cited an assay of 0.78 g/t Au, 20.0 g/t Ag, 12.50% Cu, and 1.14% Zn was obtained within an interval of 0.87 m starting at 261.25 m.

Figure 10 shows the mineralized intervals and their respective grades. Even though the mineralization found in the drill is projected 200 m to the surface, correlation of subsurface and surface shows is good. The first interval beginning at 192.50 m projects to fractures in workings. The central part, with narrow, mineralized intercepts projects to a zone of cross fractures and splits which control mineralization. The deepest mineralized interval associated with feldspar porphyry dikes and massive chlorite bodies projects to the easternmost line of large workings where similar dikes were mapped within open-cut walls. The hole bottomed at 345.30 m in quartz porphyry.

Drill hole KA-6

Hole KA-6 tested a moderate induced potential anomaly found by geophysical investigations and cut the extension of the mineralized zone where high geochemical values in copper and extensive iron oxides were found at the surface.

The hole was collared in quartz porphyry and intersected several zones of amphibolite and mafic dike rocks within the interval 0-70 m (fig. 10). Beginning at 70.0 m pyrite content begins to increase and reaches about 2 percent at 115.0 m, after which it diminishes to approximately 1 percent. The rock is mostly a moderately siliceous, garnetized quartz porphyry. At 160.0 m the rock changes to a chloritized, garnetized porphyry containing tiny wisps of chalcopyrite intergrown with pyrrhotite. This rock continues to 202.0 m. The interval 195.40 to 202.40 m averaged 0.23 percent copper with 1 m of this interval assaying 0.40 percent copper. From 202.0 to 209.0 m the rock is a complex of chloritized dikes and amphibolite where copper values decrease markedly. From 209.0 m to the end of the hole at 263.70 m the rock is chloritized-garnetized quartz porphyry interspersed with narrow zones of amphibolite and mafic dikes. Very fine disseminations of chalcopyrite and pyrrhotite assay as high as 0.31 percent copper at 216.40 m but copper values diminish to trace amounts from 237.40m to the end of the hole.

Drill hole KA-7

Hole KA-7 was positioned to intersect a shear zone containing iron oxides which coincides with anomalous zinc values found in geochemical grid sampling and also with an anomalous area outlined by the Turam survey. The hole was drilled in the same plane as hole KA-6 and in the opposite direction, but from a point 40 m to the northeast so that the two holes wculd explore the rocks beneath to a depth of about 20 m (fig. 10).

The hole was collared in quartz porphyry, but numerous zones of layered schistose rock were encountered throughout. Sparse malachite associated with a quartz vein was found at 15.90 m. Between 19.4 m and 25.0 m core recovery dropped sharply and the drillers recorded a cavity within this interval. The few pebbles recovered here contain iron oxides and at 27.40 m a pale green mineral which may be turquoise was found. The findings indicate old workings but none were seen at the surface. Within the interval 30.0 m to 100.0 m different rock types were encountered, some of which appear to be layered flow breccias of probable andesitic composition. Hornblende needles are found in layers parallel to schistosity within this zone but only minor amounts of scattered pyrite was found. At 128.65 m the disseminated pyrite content increased to about 1 percent and at 140.0 m again increased to about 2 percent, after which it decreased to less than 1 percent at 148.0 m and remained at approximately that percentage to 160.0 m. At 144.0 m a mafic rock with saussuritized feldspars was intersected and this rock type continues to 147.80 m. Dikes of probable aplitic composition were cut at 148 m and 155 m. The dikes are adjacent to an intensely brecciated zone exhibiting strong fault gouge and argillic alteration. This zone correlates with a shear zone mapped at the surface dipping about 70°SW. Within the fractured zone, disseminated pyrite increases to 6-10 percent of the rock volume. The Turam anomaly found in this area probably reflected the pyrite mineralization and the shear zone. At 162.72 meters the hole passed into unsheared, nonmineralized quartz porphyry and was terminated at 175.65 m.

Drill hole KA-8

Hole KA-8 was placed to intersect the extension of the Kutam fault and a Turam anomaly found by geophysical investigations (fig. 10).

KA-8 was collared in quartz porphyry and intersected pyritic graphite schist from 15.90 m to 19.65 m. The graphitic zone was mapped at the surface and extends through the projection of the drill hole at a trend of N.55°W. At 29.70 m the drill hole intersected a zone of siliceous, fine-grained rock alternating with dense, fine grained, graphitic material carrying less than 1 percent pyrite along fractures and folia planes. The graphitic material continued to 44.30 m where siliceous quartz porphyry was again encountered in a shear zone which has been resealed by silica. Below this point quartz porphyry with siliceous garnet-biotite schist with very sparsely disseminated pyrite continued to approximately 102.0 m. Amphibolite was intersected within the interval 102.0 m. to 114.50 m, after which quartz porphyry continued to 151.75 m where a medium-grained, quartz-feldspar porphyry dike was cut. Sulfides are sparse within these intervals also, and pyrrhotite intergrown with chalcopyrite is even rarer. Between 155.75 m and 168.50 m the quartz porphyry becomes more chloritic and chalcopyrite intergrown with pyrrhotite becomes a little stronger, but only approximates 0.1 percent of rock volume. At 168.50 m intense shearing within a chloritized zone containing chalcopyrite-pyrrhotite was noted along the contact with amphibolite. These rocks contain chalcopyrite in stringers as much as 3 mm wide but the sulfide content does not exceed 0.1 percent. Amphibolite continues down to 196.15 m after which a fine grained biotite schist extending to 214.30 m was intersected. Chalcopyrite and pyrite in thin wisps along cleavage planes make up about 2 percent of rock volume for 0.5 m at 197.15 m and sphalerite together with pyrite was also found in a 4 cm layer along foliation together with quartz at 196.85 m. From 196.50 to 197.50 the core assayed 0.8 g/t Au, 4.8 g/t Ag, 0.04 Cu, 0.14% Pb, and 2.20% Zn. At 214.30 m barren quartz porphyry was again encountered and the drill hole stayed within this rock type to the end of the hole at 221.30 m.

The sheared zone and amphibolite project at a 67° dip to the surface where a shear zone and mafic dike were mapped; it is believed that the Turam anomaly which coincides with this zone was fully tested.

Ore reserves

The calculation of ore reserves was based on mineral intercepts in drill holes, KA-1, KA-2, KA-3, and KA-5, using weighted averages for continuous sample intervals along the hole. A cutoff grade of 2 percent was used for both copper and zinc which resulted in separate copper and zinc ore reserve blocks. Where ore blocks averaged higher than 2 percent in both copper and zinc the block was put in copper reserves. There is no definite economic basis for using the 2 percent cutoff grade, since there are altogether too many unknown factors when figuring costs of a mining operation in Saudi Arabia. The 2 percent, or higher, classification does, however, include all higher grade and more easily mineable material, leaving only scattered, lower grade bodies that are considered in a following section on lower-grade reserves.

Two standard classifications of "indicated" and "inferred" reserves are used, defined as follows: "indicated reserves"--ore for which tonnage and grade are computed partly from specific measurements and partly from projection for a reasonable distance on geologic evidence; and "inferred reserves"--ore for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few if any samples or measurements (Howell, J. V., 1957).

Indicated reserve blocks are calculated as follows: the depth of block is determined by projecting to the deepest ore grade intercept in the drill hole. The angle of projection of the block to the surface is determined by geology and location of old workings, otherwise a dip of 75 degrees was used (fig. 13). Ore blocks are projected only to within 20 m of the surface to allow for stoping of ore by the ancients and leaching of the sulfides. The lateral limits of an ore block is determined by "influence of drill hole" to extend half way to adjoining holes and an equal distance to the other side if no hole is present there.

Inferred ore blocks are calculated as having the same lateral limits but only one half of the height of the indicated ore block and are projected below the deepest ore interval intersected in the drill hole. They contain the same average grade as the corresponding indicated reserve block above.

Forty-nine specific gravity determinations were made on samples from the mineralized interval of KA-1; these determinations averaged 2.9. The metric tonnage was then calculated by multiplying this factor times the cubic meters in the ore blocks. Individual ore blocks are shown projected to the 2,000 m level plan (fig. 14) and in longitudinal section (fig. 15). The 2,000 m level was chosen because drill holes KA-1, KA-2, and KA-3 penetrated the mineralized zone at approximately the 2,000 m elevation. The projected level is about 120 m above the deepest mineralized interval intersected in hole KA-5. The individual ore blocks and grade were weighted for gold, silver, copper, and zinc; no interval of less than 1.0 meter along hole was put into

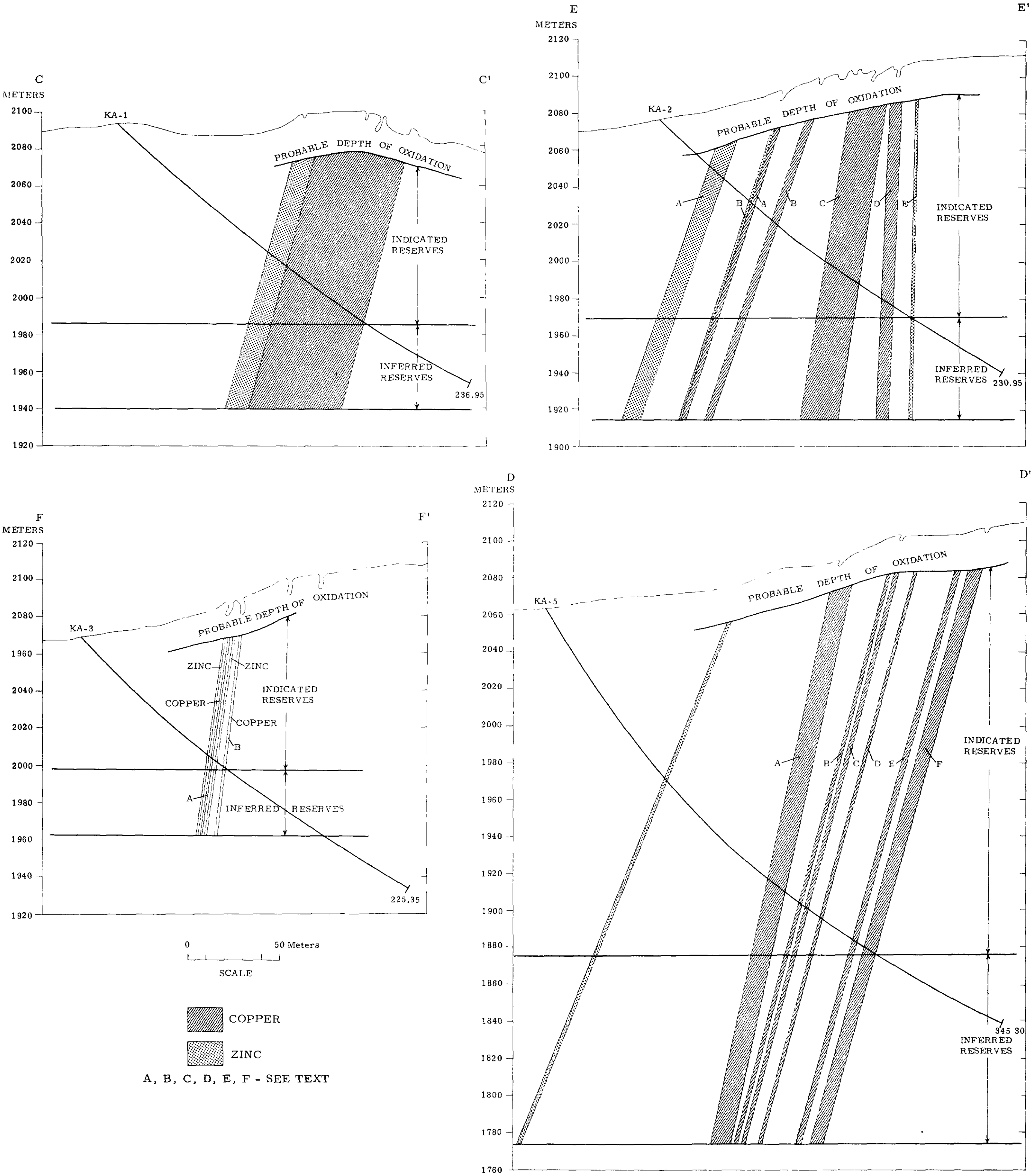

Figure 13.--Vertical sections through drill holes KA-1, KA-2, KA-3, and KA-5, showing copper and zinc ore reserve blocks

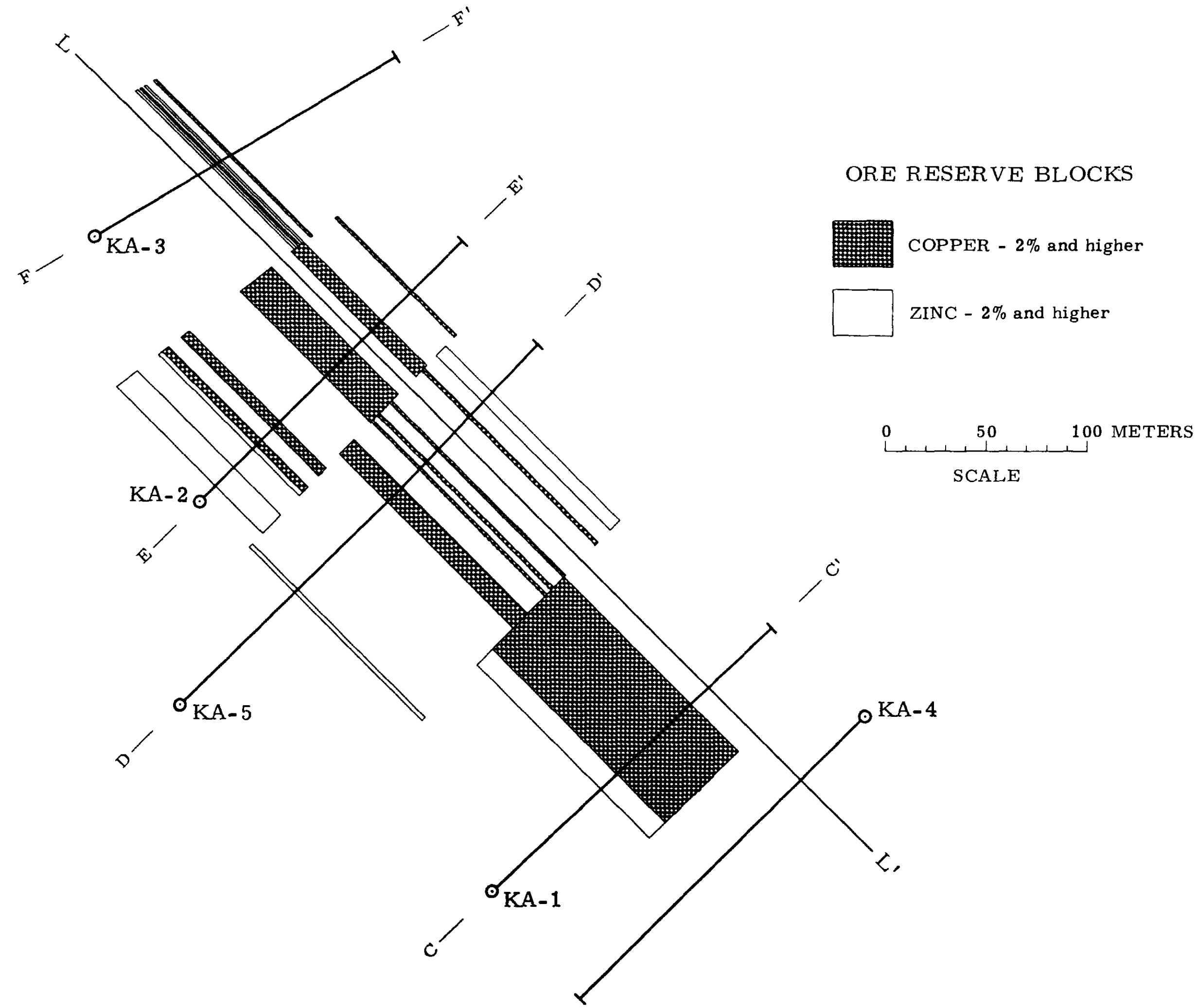

Figure 14. - Plan of 2000 meter level, Kutam mine, showing copper and zinc ore reserve blocks.

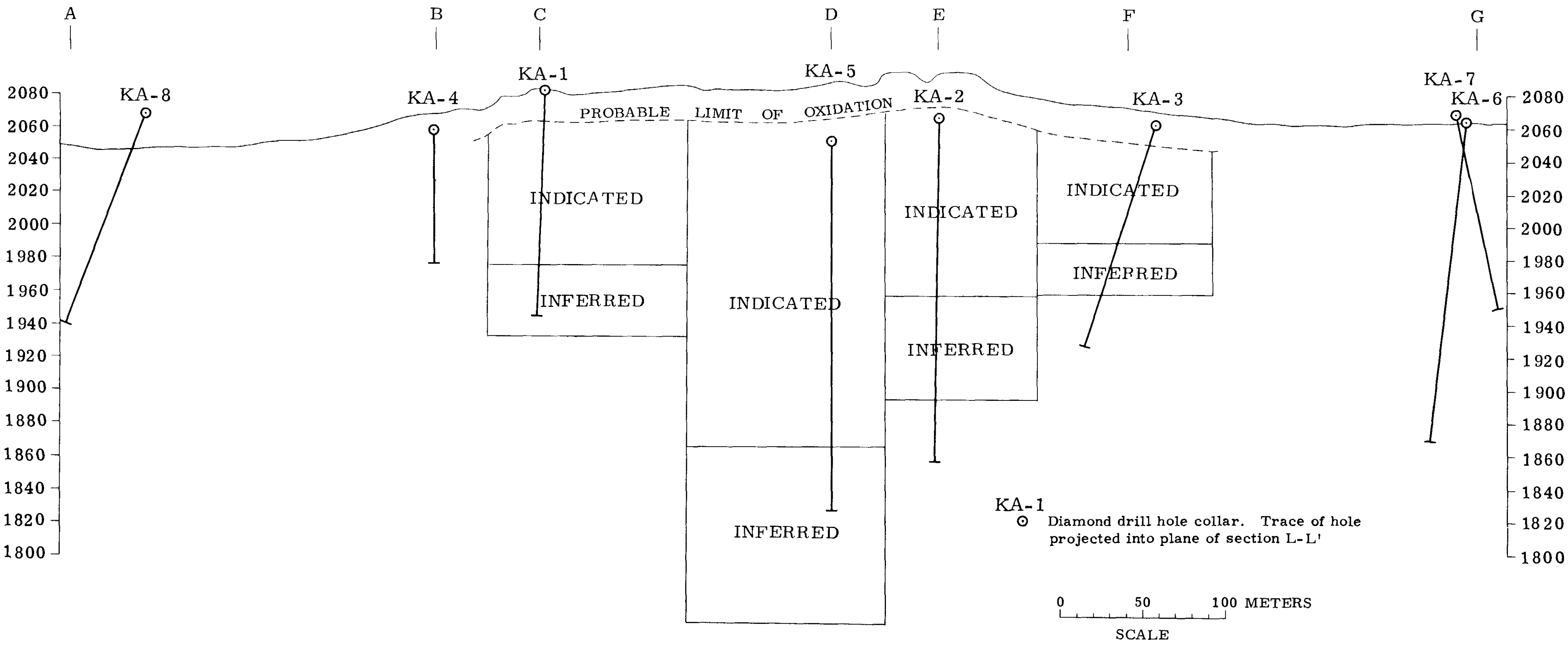

Figure 15. - Longitudinal section L-L' looking S45°W, Kutam mine, showing ore reserve blocks.

the reserves. No dilution factor was used as such calculations are premature at this stage. The 1.0 m interval of 2.2 percent zinc intersected in KA-8 was not put in reserves because of the long projections required.

Details of tonnages are compiled in tables 2 and 3.

Lower-grade reserves

Indicated reserves were also calculated for copper and zinc intervals grading between 1 and 2 percent. This grade of metal was found mainly in KA-4, but drill holes KA-2, KA-3, and KA-5 also contributed to tonnage. Much of this grade material is found as isolated intervals of about one meter within essentially barren rock so costs in recovering may be prohibitive.

Compilation of all intervals of 1 m or more along the drill hole gave the following results:

Tons	Au g/t	Ag g/t	Cu %	Zn %
Copper Reserves Grading 1.0-1.99%				
492,000	.052	5.02	1.32	0.35
Zinc Reserves Grading 1.0-1.99%				
382,000	.049	3.30	0.23	1.25

Sampling and assaying

A total of 1060 samples from drill core splits were analyzed at the DGMR-USGS laboratories in Jiddah, where atomic absorption methods were used to assay for gold, silver, copper, lead, and zinc. Semiquantitative spectrographic analysis was also used for comparative studies of these metals in addition to giving semiquantitative information for Fe, Mg, Ca, Ti, Mn, As, B, Ba, Be, Bi, Cd, Co, Cr, La, Mo, Nb, Ni, Sb, Sc, Sn, Sr, and V. Every sample was scanned for these elements with the results for Fe, Mg, Ca, and Ti given in percentages the remaining elements in ppm.

One half of the split core and all unsampled core is stored in Jiddah for future reference.

Four mineralized samples were sent to the U. S. Geological Survey Isotope Laboratories, Denver, Colorado, for studies of lead-isotope ratios for comparison with other deposits in the Kingdom.

Table 2.--Kutam-indicated and inferred ore reserves: Copper

INDICATED ORE RESERVES

Drill hole	Block	Average grade for block				Average grade for drill hole				Metric tons		
		Au g/t	Ag g/t	Cu %	Zn %	Au g/t	Ag g/t	Cu %	Zn %	Total for ore block	Total for drill hole	Total
KA-1						0.55	4.38	2.08	0.58		1,554,800	
KA-2	A	0.42	41.90	2.41	12.09					72,400		
	B	0.32	20.00	2.36	2.20					123,600		
	C	0.097	7.62	2.00	0.13					606,800		
	D	0.13	4.46	2.16	0.04					195,700		
	E	0.10	4.80	2.80	0.05					31,600		
						0.15	10.83	2.13	1.20		1,030,100	
KA-3	A	Nil	15.4	2.13	0.35					19,500		
	B	0.18	8,4	2.00	0.25					22,200		
						0.096	11.67	2.06	0.30		41,700	
KA-5	A	0.01	5.40	2.05	0.62					862,700		
	B	0.08	9.40	3.65	0.54					70,600		
	C	Tr	3.42	2.00	0.77					141,500		
	D	Tr	5.13	2.29	1.35					158,500		
	E	Tr	4.90	2.27	0.05					142,500		
	F	Tr	3.68	2.00	0.15					515,600		
						.01	4.87	2.13	0.52		1,891,400	

4,518,000 tons

Au g/t	Ag g/t	Cu %	Zn %
0.23	6.12	2.11	0.69

Table 2.--Kutam-indicated and inferred ore reserves: Copper - cont'd.

INFERRED ORE RESERVES

			Metric tons		Au g/t	Ag g/t	Cu %	Zn %
KA-1	Block		777,400		0.55	4.38	2.08	0.58
KA-2	Block		515,100		0.15	10.83	2.13	1.20
KA-3	Block		20,800		0.006	11.67	2.06	0.30
KA-5	Block		945,700		0.01	4.87	2.13	0.52
		Total	2,259,000	Average grade	0.23	6.12	2.11	0.69

TOTAL COPPER RESERVES
INDICATED PLUS INFERRED

6,777,000	0.23	6.12	2.11	0.69

Table 3.--Kutam-indicated and inferred ore reserves: Zinc

INDICATED ORE RESERVES												
Drill hole	Block	Average grade for block				Average grade for drill hole				Metric tons		
		Au g/t	Ag g/t	Cu %	Zn %	Au g/t	Ag g/t	Cu %	Zn %	Total for ore block	Total for drill hole	Total
KA-1						0.89	5.20	0.46	2.23		368,000	
KA-2	A	1.07	8.31	0.26	2.46					282,100		
	B	0.08	2.77	0.16	2.25					44,300		
						0.93	7.56	0.25	2.43		326,400	
KA-3	A	Nil	3.0	0.40	2.02					26,000		
	B	Nil	2.0	0.02	3.12					20,100		
						Nil	2.56	0.23	2.50		46,100	
KA-5						0.12	6.80	0.08	2.55		112,500	

853,000 tons

Au g/t	Ag g/t	Cu %	Zn %
0.75	6.17	0.32	2.36

Table 3.--Kutam-indicated and inferred ore reserves: Zinc - continued

INFERRED ORE RESERVES

			Metric tons		Au g/t	Ag g/t	Cu %	Zn %
KA-1	Block		183,800		0.89	5.20	0.46	2.23
KA-2	Block		163,100		0.93	7.56	0.25	2.43
KA-3	Block		23,000		Nil	2.56	0.23	2.50
KA-5	Block		56,100		0.12	6.80	0.08	2.55
		Total	426,000	Average grade	0.75	6.17	0.32	2.36

TOTAL RESERVES
INDICATED PLUS INFERRED
ZINC

	Au g/t	Ag g/t	Cu %	Zn %
1,279,000	0.75	6.17	0.32	2.36

Surface geochemical study

As part of the initial study of the deposit, prior to drilling, a total of 459 chip samples from exposed bedrock and 47 composite grab samples of alluvium, mined waste, and slag were collected from sites variously spaced 10, 20, and 40 m apart. The sample sites were located from a Brunton and tape grid, at intercepts spaced at 40 m. The samples were analyzed for Au, Ag, Cu, Pb, and Zn by the atomic absorption spectrographic method. Samples enriched in copper and zinc are shown on plate 2.

Copper

Sample analysis indicates that background value of copper is 80 ppm and samples containing more than 1000 ppm copper are shown on plate 2. Concentrations of copper greater than 1000 ppm are found in a 400 m-long zone in the mine area (plate 2). Higher values drop off sharply in all directions from the central area leaving only two small, isolated anomalies of greater than 1000 ppm Cu which are along a N.20°W. fracture that passes beneath the Wajid Sandstone.

To the north a zone of 351 to 700 ppm Cu lies on strike with the central area (not shown) and again the grouping appears within a halo of surrounding samples running just above background in copper.

Zinc

The background value of zinc is 70 ppm and samples containing more than 700 ppm zinc are shown on plate 2. Values in zinc of greater than 700 ppm are offset to the southwest from the higher copper values and trend approximately N.45°W. Zinc values are much lower than copper and the moderate zinc content is distributed less uniformly over a wider area. The zinc zone follows the surface trace of the Kutam fault, more or less above zinc-enriched zones intersected in the drill holes. Higher zinc values are found on one sample line which crosses the projected surface trace of hole KA-2. Samples from this drill hole also contain higher zinc values. Scattered high zinc values found to the north did not correlate with findings in drill core since drilling in this area revealed very small amounts of zinc.

Drilling

A total of 1929.20 m were diamond drilled at Kutam by the Arabian Drilling Company using a Longyear 58 rig.

All holes were drilled at an angle ranging from 43 to 55 degrees at the beginning and all tended to flatten. Hole KA-4, for example, flattened from a minus 45° at the beginning of the hole to zero degrees at 230 m, but this was exceptional and most of the holes flattened approximately 15°. All holes also deviated to the north by as much as 8°. Tropari measurements were taken for bearing and inclination at approximately 50 m intervals.

Drilling began September, 1974, and finished July 23, 1975; two shifts averaged 8.65 m drilling per day. Drilling conditions were good and core recovery throughout mineralized zones was good, although grinding of massive chalcopyrite was noted in hole KA-5 at 201.0 and 228.0 m where core runs of 60 percent recovery were obtained. All holes were started NXM sizes and later reduced to BXM, and AXM, if necessary. No attempt was made to catch sludges for assay because of the good recovery in mineralized zones.

Drill logs with all pertinent drilling data are in a pocket at the rear of this report.

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