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GEOLOGY AND MINERAL DEPOSITS OF THE WADI AN NUQUMI QUADRANGLE KINGDOM OF SAUDI ARABIA

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PREFACE

In 1963, in response to a request from the Ministry of Petroleum and Mineral Resources, the Saudi Arabian Government and the U. S. Geological Survey, U. S. Department of the Interior, with the approval of the U. S. Department of State, undertook a joint and cooperative effort to map and evaluate the mineral potential of central and western Saudi Arabia. The results of this program are being released in USGS open files in the United States and are also available in the Library of the Ministry of Petroleum and Mineral Resources. Also on open file in that office is a large amount of material, in the form of unpublished manuscripts, maps, field notes, drill logs, annotated aerial photographs, etc., that has resulted from other previous geologic work by Saudi Arabian government agencies. The Government of Saudi Arabia makes this information available to interested persons, and has set up a liberal mining code which is included in "Mineral Resources of Saudi Arabia, a Guide for Investment and Development," published in 1965 as Bulletin 1 of the Ministry of Petroleum and Mineral Resources, Directorate General of Mineral Resources, Jiddah, Saudi Arabia.

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Abstract

The rocks, structures, and mineral deposits of the Wadi an Nuqumi quadrangle were formed during three periods of deformation, two of Precambrian age and one of Tertiary and Recent age. The older Precambrian Halaban cycle produced the thick eugeosynclinal suite of interlayered metasedimentary and metavolcanic rocks comprising the Halaban Formation, the numerous synorogenic granitic masses which intrude the layered rocks, and the northward-trending tectonic, plutonic, and metamorphic features of all these rocks which constitute the basic grain of the area. The older Halaban features are everywhere strongly transected, but only slightly deformed and offset, by many eastward-, northeastward-, and northwestward-striking fractures and strike-slip faults. Silicic dikes are emplaced in these fractures, and several kinds of barren and metalliferous veins are closely associated with them. All these features are here thought to have formed during a period of deformation of late Precambrian age which produced the Najd Wrench Fault Zone; therefore, these features are named for it. Sporadic remnants of once far more extensive basaltic lava fields and the north-northwestward-striking vertical fractures which occur in them and contain volcanic vents from which they were extruded are the youngest rocks and structures in the Wadi an Nuqumi area. They are thought to have formed during the period of tectonic and volcanic activity which also produced the Red Sea graben.

The principal mineral deposits of the Wadi an Nuqumi area are silicified-carbonate breccia veins which occur in structures of the Najd Wrench Fault deformation and metalliferous quartz veins which are closely associated with them. Only the latter possesses any economic potential, the most promising being the gold and silver-bearing quartz-base metal veins of the Al Numrahniyah and Mutha-heel ancient mines.

Introduction

This report is a product of a joint reconnaissance mineral survey of the Arabian Shield by the Saudi Arabia Ministry of Petroleum and Mineral Resources and the United States Geological Survey. It presents the results of the survey

obtained in the portion of the Shield exposed in the eastern half of Sheet 93 of the Ministry's photomosaic map series, or the Wadi an Nuqumi quadrangle as it may be called after the prominent wadi which flows southward through the middle of the area. The Wadi an Nuqumi area is most accessible from the south through Medina, and from the road from Medina to Tabuk through the central part.

The Wadi an Nuqumi quadrangle encompasses a total area of 2,700 sq. km. Precambrian rocks of the Arabian Shield are exposed everywhere in it except along the eastern margin where they are covered by basaltic lava flows of the Harrat al Khaybar. Field work for the present reconnaissance mineral survey of the area was done during March 1966. Vehicles and personnel for the field work were provided by the Ministry.

The immediate objective of the mineral survey was to examine all parts of the area for mineral deposits which possessed either present or longer range potential for economic exploitation, and for other geologic features related to them. The long-range objective of the survey was to determine the gross geologic character of the mineral deposits found by the survey as the basis for guiding development of those with proven potential and the search for others. The methods used on the mineral survey were such that they yielded only qualitative results. No quantitative sampling or valuation was made of any of the deposits found by the survey, nor were systematic studies made of either the geology or geochemistry of the area. However, geochemical prospecting techniques were used to test specific geologic features. For this purpose, samples of sediment from the headmost parts of wadis were collected and analyzed in the Ministry laboratory in Jiddah by methods designed to detect very small (trace) amounts of many metallic elements. Most of these determinations were made by emission spectrometric methods by C. E. Thompson of the U. S. Geological Survey.

General geology

The geology of the Wadi an Nuqumi quadrangle includes the same major elements as are represented throughout the northern Arabian Shield -- rocks, structures, and mineral deposits derived from the older Halaban petro-tectonic cycle and the

younger Najd Wrench Fault deformation, -- both mainly of Precambrian age -- and, in addition, structures and basaltic lava flows which are the result of epirogenic activity of Tertiary to Recent age, which produced the Red Sea graben. Although it is somewhat more obscured by high relief than elsewhere, the basic grain of the area comprises the same features produced during the Halaban cycle: northward-trending belts of older granitic rocks and folded, layered metavolcanic and metasedimentary rocks of the Halaban Formation. In the An Nuqumi area, these are manifested mainly by the northward-aligned, intermittent exposures of older granite bodies along the western margin, northward-trending folds in the layered rocks east of these, and, physiographically, by the northward-trending wadis which flow southward through the middle of the area.

The older features produced by the Halaban cycle are everywhere transected and deformed by structures of the Najd Wrench Fault deformation, mainly northwestward- and northeastward-striking, vertical fractures and strike-slip faults. Silicic, principally rhyolitic, dikes occur in many of these structures, and they are here thought to have been intruded during the same period of deformation which produced the structures.

Only two small granite bodies of younger Precambrian age were identified in the An Nuqumi area. Both are located along the western margin and possess the distinctive features of most of the younger granitic rocks -- ring, or in this case, crescent-shaped small stocks with steeply dipping contacts.

Basaltic lava flows are present sporadically throughout the area, at all heights, and are clearly remnants of much more extensive lava fields which once covered the entire area. The lava flows have been extruded during and since Tertiary time and are still being extruded as the flow of historical age just south of the airport in the south-central part of the area indicates. Prominent lineaments in the older flows strike north-northwestward, as do many weakly developed vertical fractures in the bedrock in the east-central part of the area. Modern volcanoes are localized along these structures at many places just south of the lower edge of the quadrangle, notably a series of four about 10 km west of Medina. The structures and volcanic features are thought to be related. Both are probably effects of the epirogenic activity which produced the Red Sea graben.

Stratigraphy.

All of the metasedimentary rocks and layered metavolcanic rocks in the An Nuqumi quadrangle are thought by the writer to belong to a single stratigraphic unit -- the Halaban Formation. No rocks of younger Precambrian age than the Halaban Formation have been recognized. Accordingly, the character of the upper contact is not known; otherwise, it is overlain sporadically with great unconformity by basaltic lavas of Tertiary and Quaternary age.

The lower contact of the Halaban Formation may be exposed at several places both north and south of the Qassim road about 30 km east of Medina. At two localities where it could be observed well (field stations 18704 and 18710) andesitic agglomerate lay directly, and apparently unconformably, on meta-dioritic rocks. Neither diagnostic erosional or depositional features nor intrusive igneous features were recognized at either place. However, the metadiorite was markedly more metamorphosed than the volcanic rocks, and this constituted the principal field evidence of unconformity. Both the metadioritic and volcanic rocks were epidotized. The metadiorite strongly resembled similar rocks mapped as "dg" in the northwestern-most corner of Quadrangle 210 (Brown and others, 1962), on which clastic and calcareous metasedimentary rocks and marble of the Halaban Formation rest unconformably in Jabal Athelith, about 100 km east of Afif.

The Halaban Formation is made up of slightly to strongly metamorphosed volcanic and sedimentary rocks representing a considerable range of original physical and chemical character. The volcanic rocks include flow and fragmental pyroclastic rocks of andesitic and more silicic composition. More mafic types predominate generally, but silicic types, including rhyolitic rocks, are abundant locally, notably in Jabal Uhud, just north of Medina, and east of the head of Wadi Qana. Although neither chemical analyses nor detailed petrographic data were obtained from the volcanic rocks of the Halaban Formation, the impression is strong that they comprise a complete range of composition between andesitic and rhyolitic extremes.

The volcanic rocks occur as massive, lenticular bodies which are irregularly interlayered with sedimentary rocks, usually coarser clastic types of similar gross physical character. Dark, greenish colors are dominant where the rocks are andesitic, and light, reddish colors where they are rhyolitic.

Sedimentary rocks in the Halaban Formation vary from the metamorphic equivalents of thin and very thin bedded calcareous, tuffaceous, and siliceous shale and impure limestone to massive, thick-bedded sandstone and conglomerate. Dark-colored, greenish-gray, undifferentiated metawacke-type sandstone and conglomerate predominate. Although all kinds occur with the volcanic rocks, the coarser clastic types are usually associated with them. Clearly the coarser clastic rocks have been derived from the volcanic units in great part, as have the finer-grained slates and argillites which grade away from the coarser clastics, often within a few kilometers laterally. Generally, the coarser clastic metasedimentary rocks and the metavolcanic flow and fragmental rocks are so integrally interlayered and associated that they cannot be mapped separately, at least at 1:100,000 or smaller scales.

Besides varying in dynamic metamorphic character because of lithologic differences, rocks of the Halaban Formation also vary in thermal metamorphic grade. All of the latter are associated with exposed and buried granitic plutons, and the highest grade rocks occur over or around these, and as isolated outliers and septa on and in them. The highest-grade rocks observed anywhere in the An Nuqumi area occur along the contact of the Halaban Formation and the older granite body north of the Al Numrahniyah mine.

The Halaban Formation is conceived here to represent the combined results of volcanic and sedimentary activity in a great eugeosyncline, followed by folding and regional metamorphism. Thereafter, rocks of the Halaban Formation were invaded and metamorphosed additionally but locally by synorogenically intruded granitic plutons.

Igneous rocks.

Non-volcanic igneous rocks in the western part of Quadrangle 205 comprise older and younger granitic plutons, and rhyolitic and andesitic dikes. All of

the granitic rocks are here thought to intrude the Halaban Formation which comprises the only layered rocks recognized in the An Nuqumi quadrangle. Eastward-, northeastward-, and northwestward-striking rhyolitic dikes and dike swarms may belong to the Najd Wrench Fault deformation. At least some of the mafic dikes in some of the granitic plutons may be thin sheets of meta-andesitic volcanic rocks which were intruded lit-par-lit fashion by the granite and were retained in the granite with little change of physical appearance.

Older granitic rocks: -- With the exception of the large pluton which lies north of the Al Numrahniyah mine, all the older granitic masses in the An Nuqumi area are so similar in field character that no distinctions have been made among them. Further, since all are intrusive except the dioritic rocks along the eastern edge of the sheet, and only into rocks of the Halaban Formation, no differences of age have been determined on field evidence. The older granite bodies have irregular outlines which are due to high relief and the manner of exposure of the moderately sloping intrusive contacts which characterize the older granitic bodies. By far the greatest proportion of all the older plutons consists of pinkish-white, non-porphyritic, medium to low coarse-grained granite in which biotite is the predominant mafic constituent. The marginal portions of the more homogeneous masses tend to be relatively pinker and more porphyritic, both being the result of abundant and prominent pink, potash feldspar phenocrysts. Cupolas and other small exposed parts of the larger plutons are entirely of this character.

Round to sub-angular xenoliths as large as a meter or so across are sparse to very abundant in the older granite masses. More angular shapes of xenoliths predominate. Weathering dislodges the xenoliths, yielding a strongly pitted habit which is distinctive feature of most of the older granite masses. Nearly all the xenoliths are dark-colored, amphibole-bearing rocks which resemble strongly the more highly metamorphosed andesitic volcanic rocks of the Halaban Formation which the granites intrude.

Some of the older granite plutons contain from a few to swarms of what appear to be mafic dikes, but which may be layers of metavolcanic rock which the granite intruded lit-par-lit fashion and retained as relic, dike-like septa or screens.

In detail, many of them have been intruded by the granite on a small scale, and strongly resemble the most abundant xenoliths in composition. In such cases, continuity of the mafic dikes or septa into the country rocks does not settle the matter of their field relationships with these or with the granite.

The contacts of the older granite bodies and the Halaban country rocks are characterized by moderate slope, moderately to strongly metamorphosed country rocks, and sparse to numerous apophyses and aplitic and pegmatitic dikes. Although many parts of the contacts are accordant with the country rocks and contain little evidence of intrusion, features attesting to a very strong dynamic intrusive activity are present locally: small to moderate-scale piecemeal, magmatic stoping, and large-scale, lit-par-lit injection. Effects of this latter style of intrusion were found only around the granite body in the southwest corner of the An Nuqumi quadrangle.

All the older granitic rocks are thought to be sufficiently similar in character and composition to belong to a single sequence of magmatic activity. Although this activity manifestly occurred long after the geosynclinal phase of the Halaban tectonic cycle, many features of the older granite plutons and their relations with the Halaban country rocks indicate strongly that they were emplaced during the subsequent, orogenic phase of the cycle.

Only a small part of the older granite pluton which differs somewhat from all the others in An Nuqumi area is exposed in the quadrangle; it crops out just north of the Al Numrahniyah mine. This pluton differs from the other older granitic plutons in being much more uniformly and markedly reddish in color, much more uniformly medium-grained and non-porphyritic in texture, and in containing hornblende as the principal mafic constituent throughout. Like the others, it contains sparse to moderately abundant dark-colored xenoliths. However, only in marginal parts of the pluton are these xenoliths of comparable size and angular shape to those in other older granite masses. In the interior of the mass the xenoliths are much smaller -- generally less than 5 cm across, more rounded, and more altered than those in other bodies. Again, like the other older plutons, this one has a shallow sloping

intrusive contact with the Halaban country rocks, and these are metamorphosed and cut by numerous small apophyses from the granite and by sparse aplitic and pegmatitic dikes. However, at many places the country rocks are much more strongly altered and resemble dioritic and granitic rocks. This unusual older pluton contains a great number of vertical, dark-colored, mafic, dike-like sheets which, in detail, are intruded on a small scale by granite. Instead of being dikes, these sheets are thought to be relict, altered layers of country rock which have been retained as pseudo-dikes.

These apparent differences between the pluton at Al Numrahniyah and other older granite masses are only minor, and all the differences can be readily accounted for by assuming a somewhat more fluid magma and a correspondingly higher temperature of intrusion for the pluton at Al Numrahniyah. Accordingly, it is thought to have been intruded during the same period of synorogenic magmatic activity which produced all of the older granite masses in the An Nuqumi area.

Rhyolite dikes:-- Reddish, porphyritic rhyolite dikes are abundant in the An Nuqumi area. They cut the Halaban Formation and all the older granitic plutons, but are, themselves intruded by the younger granitic rocks. The dikes are vertical and strike eastward, northeastward, and northwestward in and along fractures and faults of the Najd Wrench Fault deformation. They occur as single and sparse dikes and in intermittent swarms throughout the length of the quadrangle. Although they are intruded by younger granite bodies, both are of late Precambrian age and could have formed during the same general period of silicic magmatic activity.

Younger granitic rocks:-- Only two small younger granite plutons were recognized in the An Nuqumi area, both cropping out along the west side of the quadrangle. They are composed of reddish, medium-grained biotite granite. Like other younger granite masses, they are crescent-shaped with subcircular outlines, and have steeply dipping, nearly vertical, intrusive contacts along which only small zones of the country rocks are contact metamorphosed. These bodies are of considerable importance geologically for the relative age relationships which they afford: they clearly intrude rocks of the Halaban Formation, and the red rhyolite dikes which cut the Halaban and all the older granite masses. The sequence, from

oldest to youngest is thus: Halaban Formation, older granite, rhyolite dikes, younger (gp) granite.

Structural geology

Nearly all the structural features in the An Nuqumi area formed during the two great periods of deformation which affected it during Precambrian time: the older Halaban petro-tectonic cycle described earlier and a younger one of which the Najd Wrench Fault Zone is the main feature and, so is called the Najd Wrench Fault deformation. In addition to these, and superimposed on them, are weakly developed structures which formed during the volcanic-epirogenic activity which produced the Red Sea graben in Tertiary and Recent time.

Halaban petro-tectonic cycle:-- Structures of the older system developed under deep-seated conditions comprising concurrent and overlapping eugeosynclinal vulcanism sedimentation, and deformation, and granitic magmatic intrusive activity accompanied by thermal metamorphism. Structural features of the system in the An Nuqumi area include ill-defined belts of granitic and metavolcanic and metasedimentary layered rocks, folds of all sizes, and metamorphic structures in the layered rock which are largely accordant with the original primary features. The trend of all the older structures in the An Nuqumi area, and of the trunk channels of the major wadi systems which manifest them physiographically, is strongly northward, as it is for all of those of the Halaban cycle everywhere on the Arabian Shield. It is safe to assume that the trend of the tectonic belt, or succession of belts, in which these features formed was also northward and that it was at least as long as the present Arabian Peninsula and as wide as the Arabian Shield.

All the older structures are thought to have developed under deep-seated conditions during the Halaban petro-tectonic cycle and to be the effects of both the earlier geosynclinal and later orogenic stages of it. They probably developed in a large, northward-trending tectonic belt or succession of belts in Precambrian time. The folds and regional metamorphic effects formed during the earlier geosynclinal stages, whereas the granitic rocks and the thermal metamorphic effects

associated with them may have started to form in the earlier stage, but are mainly the results of the later orogenic stage.

Younger structures of the Najd Wrench Fault deformation:-- Northeastward- and northwestward-striking fractures and strike-slip faults, and eastward-striking fractures are the principal younger structures in the An Nuqumi area. Silicic dikes occur in all these structures, but they are localized mainly in those which strike northeastward and northwestward. The younger structures everywhere transect and deform the older Halaban features. Displacements on individual faults are generally small; however, their physiographic influence is considerable, with the result that they are often marked by strong lineaments in the topography which are many kilometers long.

Northwestward-striking strike-slip faults and the prominent lineaments which manifest them are the largest younger structures and the predominant ones in the western half of the An Nuqumi area, whereas northeastward-striking ones predominate in the eastern half. Their combined effect, together with the northward-trending wadis through the middle of the area, produces a remarkably tree-like pattern to the area as a whole. The only displacement which could be determined was a left-lateral one on the fault in the southwest corner of the area.

Besides the silicic dikes which occur singly and as swarms in the northeastward- and northwestward-striking younger structures, many hydrothermal mineral deposits, including all of the metalliferous lodes in the An Nuqumi area, are localized in, or are closely associated with the same structures. Most of these are brecciated and contain internal fractures with the same attitude as the structures in which they occur. From this, it is clear that formation of the deposits and movements on the structures took place at the same time. Accordingly, the hydrothermal mineralization which produced the mineral deposits and the deformation which produced the structures are thought to be related genetically.

All the younger northwest-, northeast-, and eastward-striking structures in the An Nuqumi area are thought to belong to the Najd Wrench Fault deformation, named for its most prominent structure, the northwest-striking Najd Wrench Fault Zone

which transects the entire northern Arabian Shield and passes just north of the An Nuqumi area (fig. 1). The zone is made up of many parallel and en echelon, vertical fractures and left-lateral, strike-slip faults. Only small movements have occurred on individual faults, but similar and cumulative movements on many of them have yielded displacements as much as 20 km across the zone at places. Other wrench fault zones like the Najd Wrench Fault Zone, and many fractures and strike-slip faults between them with the same attitude and relative movement, are the predominant younger structures throughout the northern Arabian Shield, including those of the An Nuqumi area.

The same forces which produced the Najd Wrench Fault Zone, and others like it, could also have produced the eastward- and northeastward-striking structures which are everywhere associated with them. As illustrated in Figure 2, a stress system which could have produced the northwest-striking, left-lateral, strike-slip faults would have induced an alternate but subordinate direction of shearing which could have produced northeast-striking, strike-slip faults, and north-south tension which might have developed the westward-striking fractures.

From evidence elsewhere in the northern Arabian Shield, the structures of the Najd Wrench Fault deformation are known to be of late Precambrian and early Paleozoic age, but no evidence to confirm this has been determined in the An Nuqumi area yet.

Mineral deposits

Only a few kinds of mineral deposits have been found in the An Nuqumi area; they include a few pegmatites and numerous epigenetic veins of hydrothermal origin. The latter consists of siliceous-carbonate breccia veins and metalliferous quartz veins. Some of the latter have been worked as ancient mines.

The pegmatites, and aplites closely associated with them, are present only in the strongly metamorphosed country rocks along contacts with older granite masses, and have clearly been derived from the older granites. All the pegmatites are small. Most are simple, unzoned aggregates of quartz and pink feldspar, but a few

have finer-grained, feldspar-rich margins and coarse quartz cores. Some of both types contain a little hematite, but no constituents of economic value were recognized.

All of the hydrothermal veins are closely associated with structures of the Najd Wrench Fault deformation, and some are localized in them, notably the siliceous-carbonate breccia veins which owe their character to movement on the structures concurrent with their formation. All the hydrothermal deposits are thought to be related, and, in turn, to have been produced by mineralization which accompanied the deformation which produced the structures of the Najd Wrench Fault deformation.

Only the metalliferous quartz veins in the An Nuqumi area possess potential for economic development. All the known deposits are in two small areas in the northwesternmost part of the quadrangle. Both areas have ancient workings and are named for the largest wadis nearest them, respectively, Al Numrahniyah to the west, and Muthaheel to the east.

Al Numrahniyah mine:-- Al Numrahniyah mine is on Wadi Al Numrahniyah just north of its confluence with Wadi al Farshah and at a point 14 km eastward, thence 5 km east-southeastward from the place where the road between Medina and Tabuk crosses the wadi about 75 km north of Medina. A sizeable mine village is located on the north side of the wadi while the main workings are on the south slope of the mountains about 2 km northwest of it. Moderately recent professional samples had been collected from the tailings at the village but no channel cuts or reasonably fresh broken rock were found at the mine workings; it is possible that they had not been visited previously. The physical character and effects of the village -- grinding stones, etc.-- make it clear that native gold was the commodity sought at the mine, but a little slag is present and an attempt may have been made to recover sliver, copper being much too sparse to be likely.

The areal setting of the Al Numrahniyah mine includes the same baffling combination of geologic elements which characterizes many of the ancient mines in Quadrangle 205 and the southwest part of Quadrangle 206. The deposits are in

highly metamorphosed, in part granitized, volcanic and sedimentary rocks of the Halaban Formation along the southern contact of a large, older granite pluton. The granite has intruded and, to a marked degree, contact metamorphosed the country rocks above the grade to which they had been regionally metamorphosed previously. Northwest- and westnorthwest-striking, vertical faults and fractures cut both the granite and metamorphosed country rocks. These faults are the principal structures of the area and the main deposits of Al Numrahniyah mine are on a west-northwest-striking vein which lies midway between two strong wadi lineaments with the same trend, Wadi al Numrahniyah being the southern one.

Most of the lode workings of the mine consist of stopes and open pits which are located intermittently along a vertical, compound quartz vein. The vein strikes N.50°- 55°W. and is exposed for 2 km along the south slope of the mountain in which it is located. The vein is strikingly similar in character to most of the other gold-quartz veins in Quadrangle 205, consisting of more and less fractured and rehealed, open-textured, vuggy, iron-stained quartz. Horses and inclusions of country rock in the vein have been more or less silicified or replaced by sulfide minerals. Obviously, movement on the fault or fracture along which the vein was forming continued through the period of hydrothermal mineralization.

Pyrite is by far the most abundant metalliferous constituent of the Al Numrahniyah gold-quartz vein and accounts for the strong iron stain. In comparison, sphalerite, bornite, chalcopyrite, and galena are minor constituents. Quartz is the only gangue mineral. A spectrometric analysis of tailings and crushings from many places in the mine village (F.S. 18767, table 1) confirms the presence of the copper, lead, and zinc to be expected from the mineralogy; in addition, it shows the presence of anomalous amounts of silver and molybdenum. Minerals composed of the latter metals were not found. At least for silver, none may be present, and the silver may be associated instead with gold or in the galena. A little slag in the village area indicates that an attempt was made to smelt some of the ore for silver or copper.

Evidence to indicate the areal extent of the mineralization centering on the Al Numrahniyah mine consists of several mineral occurrences around the mine including the Muthaheel mine 15 km east-southeast along the same structures. The closest mineral occurrence consists of two mineralized fractures located just north of the main Al Numrahniyah vein which, with somewhat more northerly strikes, intersect the east end of it. Small quartz veins with secondary copper minerals and abundant pyrite like that of the main vein can be seen in place at the heads and along the valley walls of both fracture-controlled wadis. Wash material from one of these (F.S. 18768, table 1) contained anomalous amounts of copper and zinc as determined by emission spectrometric analysis.

An eastward-striking network of quartz veinlets and silicified breccia is exposed at F.S. 18769 and quartz occurs at F.S. 18766 along the prominent lineament which marks the course of Wadi al Numrahniyah. Only the first of these was sampled, but both appear to be barren (table 1).

Finally, a small pyritiferous quartz vein a few meters long and a meter or so wide crops out exactly on the contact of a small, older granite mass 8 km due south of the Al Numrahniyah mine (F.S. 18774). Although much smaller, the vein is strikingly similar in appearance and geologic setting to the main Numrahniyah vein. Besides pyrite the vein contains a little scheelite and material from it yielded anomalous amounts silver, molybdenum, lead and tin.

Muthaheel mine:-- The Muthaheel ancient mines are located 15 km east-southeast of the Al Numrahniyah mine, and 5 km west of Wadi Muthaheel. The smaller of two small villages and their nearby deposits lies 2 km northwest of the larger one. At the latter, called Muthaheel East, only gold was mined but at the other, Muthaheel West, a little slag in conjunction with the grinding stones indicates that, besides gold, silver was smelted there.

Deposits at both places occur in south- and southeast-dipping metavolcanic and metasedimentary rocks of the Halaban Formation along the contact of a moderately large, older granite mass; the granite is intrusive and is partially covered by lava.

The country rock throughout the mine area is meta-andesitic greenstone.

The workings at both mines are small and little could be seen to determine the character of the original deposits. Those at Muthaheel East are located on the tops of the mountains north and south of the village. The pit on the former is about 100 or 150 m long and trends northward. The one on the mountain to the south is a little longer and trends N.60°W., approximately parallel to the strike of the major wrench-fault lineaments of the area.

Almost no vein material could be found in place or on the dump of the workings at Muthaheel West, and only a very little on those at Muthaheel East. That at the latter strongly resembled material from the Al Numrahniyah vein deposit in being strongly iron-stained and containing abundant pyrite and sparse chalcopyrite and bornite. Spectrometric analyses of dump and tailing material indicates a great difference of composition between the deposits of the two mines. Those from Muthaheel West (F.S. 18759, F.S. 18760) contain major amounts of lead and zinc and minor amounts of silver, bismuth, and copper (table 1), whereas those from Muthaheel East (F.S. 18761, F.S. 18762) contain small amounts of only copper and lead (table 1). As in the Al Numrahniyah mine, it seems likely that the silver was present in galena and that this was smelted for it. Gold occurred free in the deposits at both places and was recovered by crushing, grinding, and washing.

Silicified breccia veins:-- The silicified breccia veins vary from a few meters to a few tens of meters wide and from a few hundreds of meters to several kilometers long. They are composed of varying proportions of highly fractured, open-textured, granular and recrystallized quartz, and strongly brecciated and silicified inclusions of country rock. Portions of country rock along the veins and horses of it in them are fractured and contain irregular networks of small quartz veins. All of these features attest to concurrent and recurrent deformation and siliceous mineralization.

Although slightly iron-stained, no megascopic evidence of metallization was observed in the siliceous-carbonate breccia veins in the An Nuqumi area, nor did

the spectrometric analysis of residual material from the one at F.S. 18755 show anomalous amounts of any metals (table 1). Accordingly, they possess no economic potential and their chief importance derives from their possible genetic-structural relationship to the metalliferous lodes which do.

All the hydrothermal deposits in the area, including the metalliferous lodes worked in ancient mines, isolated veins of the same physical character and composition outside these districts, and the silicified breccia veins either occur in or are closely associated with structures which could belong to the Najd Wrench Fault deformation. From this, it is concluded that all of these deposits formed during the period of Najd Wrench Fault deformation in late Precambrian times; since this continued into early Paleozoic time, so also may the mineralization.

On empirical evidence based on spatial relationship, another interpretation concerning the genesis of the metalliferous lodes of the An Nuqumi area is possible. All of them are sufficiently closely associated with the older granitic rocks to suggest possible genetic relationship. While by no means certain for all of the deposits, most of them are clearly associated with younger structures which transect and offset features of the older Halaban cycle, including the northward-trending belts and elongate plutons along which many occur. The actual relationship between the metalliferous lodes and the older granitic rocks, instead, is here thought to be a fortuitous structural one. In this view, differential effects of deformation during the Najd Wrench Fault deformation between the homogeneous, more competent granite masses together with adjacent higher-grade parts of the country rock which they intrude and the less metamorphosed, less competent layered rocks were such as to localize the effects of the hydrothermal mineralization accompanying the deformation at places where the younger structures intersected appropriately conditioned parts of the older features of the Halaban cycle.

Conclusions and recommendations

Only the metalliferous lodes of the Wadi an Nuqumi area possess any mineral potential. The best of these deposits were worked in the Al Numrahniyah and Muthaheel ancient mines. The gold-base metal-quartz veins at Al Numrahniyah are

the most promising deposits. These veins, the strongly developed structures of the Najd Wrench Fault deformation with which they are associated, and the area containi them deserve to be investigated in sufficient detail to determine their economic potential.

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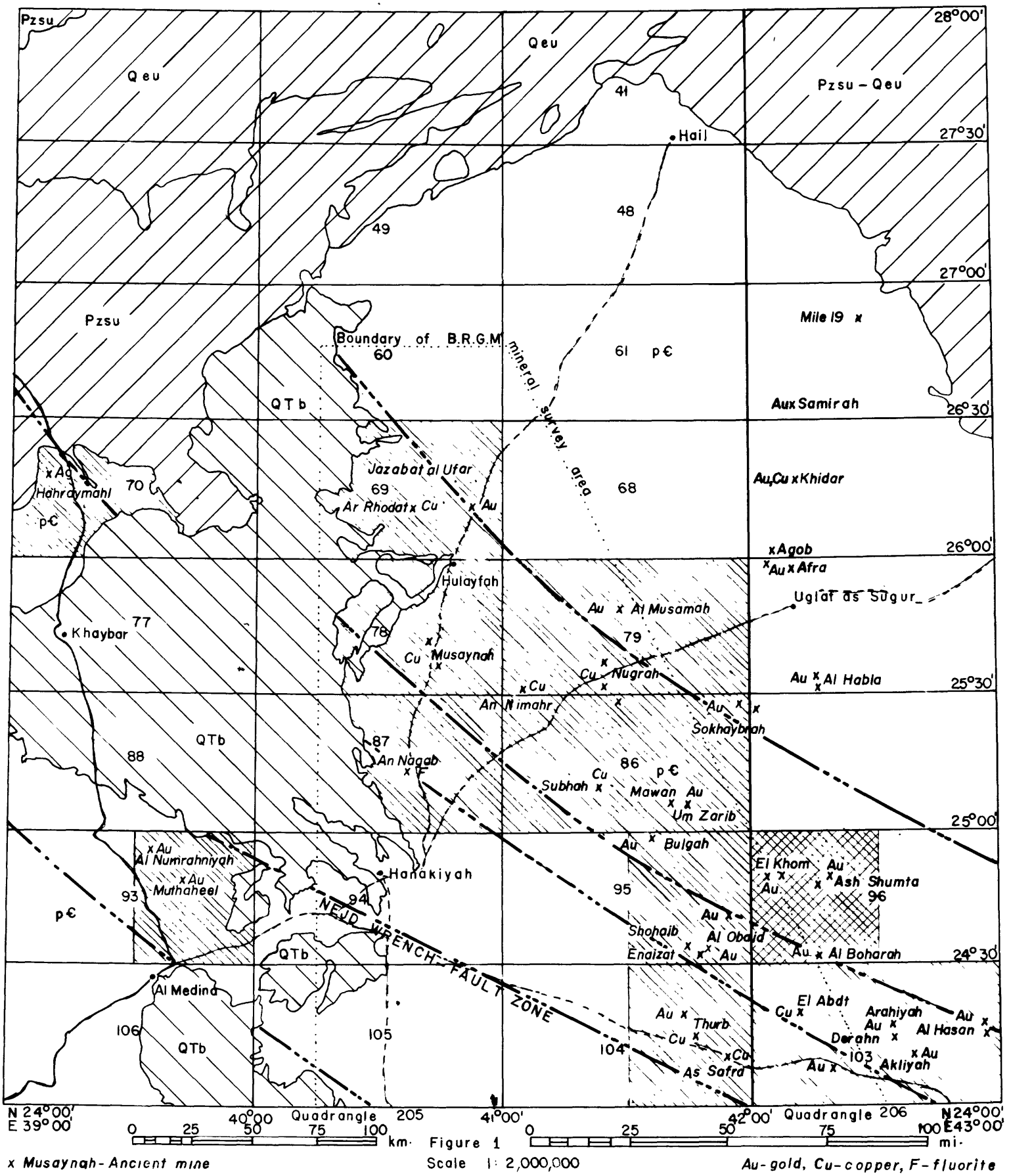


Figure 1

Scale 1: 2,000,000

x Musaynah - Ancient mine

Au - gold, Cu - copper, F - fluorite

NORTHEASTERN HIJAZ QUADRANGLE 205 AND WESTERN PART OF WADI AR RIMAH QUADRANGLE 206

areas recommended for detailed mineral surveys

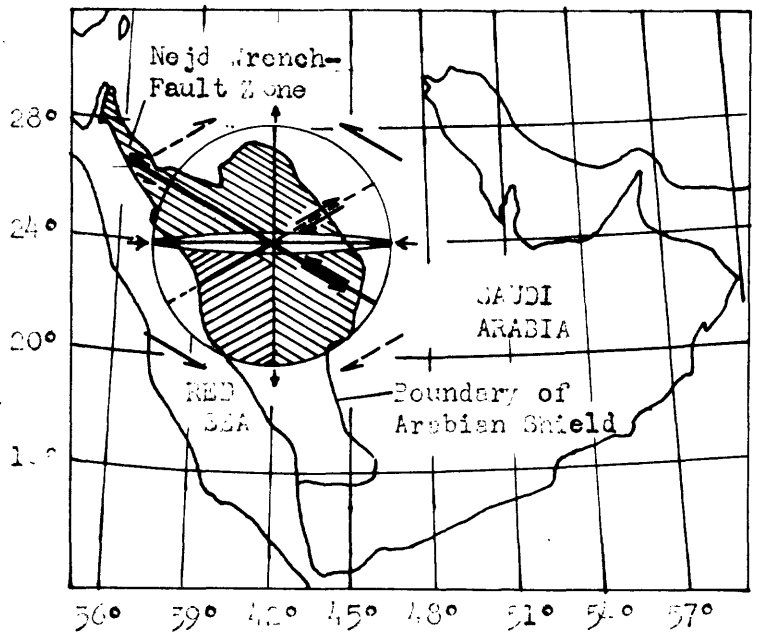
Principal access routes: ——— primary, ------ secondary

approximate center lines of wrench-fault zones

Qeu Quaternary eolian/alluvial deposits, undivided - Pzsu - paleozoic sedimentary rocks, undivided
QTb - Quaternary-Tertiary basaltic lava (harrat) p€ - Precambrian rocks, undivided (Arabian Shield).

STRUCTURES OF THE NEJD WRENCH-FAULT SYSTEM IN THE NORTH CENTRAL ARABIAN SHIELD, KINGDOM OF SAUDI ARABIA

C.L. Hummel, U.S. Geological Survey



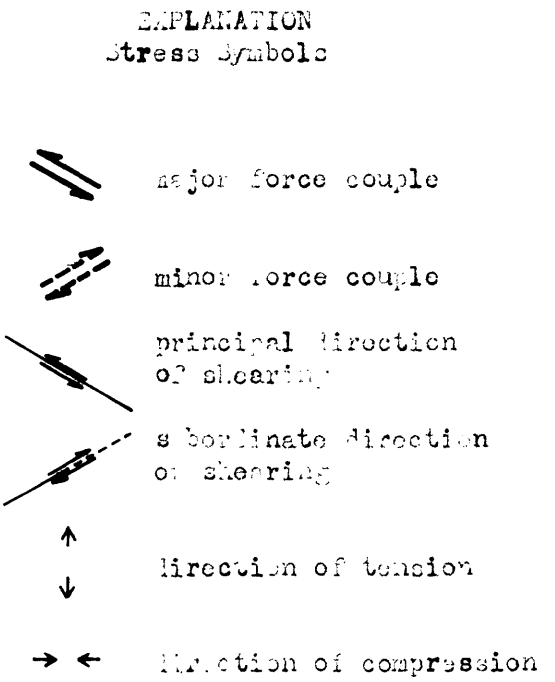
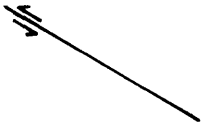


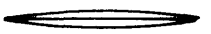
Figure 2- Stress diagram centered on Nejd Wrench Fault Zone at Latitude 24°N-Longitude 42E showing relationship of major and minor faults, fractures and dikes in north central Arabian Shield. Geologic features from Geologic Map of Arabian Peninsula: U.S. Geological Survey, Misc. Geol. Inv. Map I-270A, A.H. 1385 (A.D. 1965)

Structures and Dikes

All faults, fractures, and dikes are vertical or nearly vertical



Nejd Wrench-Fault Zone



diagrammatic representation of tensional effects and eastward-striking rhyolite dikes and dike swarms.

parts of northern Arabian Shield where northwest-striking fractures, and left-lateral, strike-slip faults predominate.

parts of northern Arabian Shield where northeast-striking fractures, and right-lateral, strike-slip faults predominate.

SAMPLE DATA

CONTENT† OF ELEMENTS (ppm) IN SAMPLES FROM QUADRANGLE 205 PHOTOMOSAIC SHEET 93

Number	Type"	Size°	Ag	As	Au	B	Ba	Be	Bi	Cd	Co	Cr	Cu	Ga	Ge	Hg	La	Mn	Mo	Nb	Ni	Pb	Sb	Sc	Sn	Sr	Te	Ti	U	V	W	Y	Zn	Zr
Min. detect. content'			1			10	20	2	20	50	5	5	10	10	20		20	20	2	50	5	10	200	10	10	50		20		20	50	10	100	20
18720						50	200				20	100	20	20				700	2		20	15		10	10	150		3000		70		15		70
18725						15	700				20	70	20	20				700			20	15		10		100		3000		70		10		50
18728						15	700				15	100	20	20				700			20	10		10		100		3000		50		20		70
18729						15	500				15	150	20	20				700			20	10		10		100		3000		50		20		70
18731						15	500				15	70	20	20				700			20	10		10		100		3000		50		20		70
18734						20	700				20	50	20	20				700			20	10		10		150		3000		70		15		50
18735						20	300				20	200	20	20				700	2		30	10		10		200		5000		70		20		50
18736						10	70				20	100	20	20			20	700	2		20	10		10		200		5000		100		20		70
18737						10	1000				10	50	10	20				300			7	10		10		200		2000		30		10		30
18739						10	200	5			15	50	10	50			50	1000	2	70	7	50			15	200		2000		30		150		2000
18740						10	700				15	70	10	20			30	500			20	20		10		200		2000		30		10		70
18746						10	500				20	100	20	20				700			20	10		10		200		3000		30		20		100
18755						20	300				20	150	20	20				700	2		30	15	200	10		200		5000		70		15		70
18759			70			30	3000		20		20	100	200	20				7000	2		20	>10000		10		150		2000		100		15		30
18760			50			30	200				20	200	200	20				3000	2		30	>10000		10		200		3000		100		15		30
18761						20	300				20	100	150	20				500	2		20	20		10		157		3000		70		15		50
18762						20	500				20	100	150	20				500	2		20	>50		10		200		3000		70		15		50
18767			70			20	200				20	100	200	20				700	10			5000		10		200		3000		70		15		50
18768						20	200				20	150	50	20				700	2		30	20		15		200		7000		70		15		50
18769						20	500				20	70	15	20				500	2		200	200		10		150		5000		70		20		50
18771						10	100				20	100	15	20			30	300			20	10		15		200		2000		50		15		50
18774						20	200				10	70	20	20				500	5		7	100		10	10	200		3000		50		15		50
18775						10	700				15	100	20	20			20	700	2		20	10		10		300		3000		50		20		70
18776						20	300				20	150	20	20				700	2		50	15		10		200		5000		70		20		70
18845			<1			10	500	<2	<20	<50	15	150	15	20	<10		<20	1000	3	<50	50	10	<100	10	<10	150		10000		150	<50	15	300	30
18859						10	700				15	150	15	20				300			50	10		15		200		3000		50		15		100
18860						10	1000				20	70	15	30			200	300			20	10		15		200		3000		50		15		70
18861						10	1000				10	50	10	20			50	300			20	15		15		200		2000		30		10		100
18862						10	1000				10	150	10	20			20	300			15	10		15		300		2000		30		15		50
Background																																		

† All determinations by emission spectrometry (Analyst: C.E. Thompson) unless indicated otherwise: a-assay (☒ Au, Ag >.01 oz/ton), at-atomic absorption, f-fluorescence; r-radiometric; x-X-ray spectrometry; w-wet chemical methods; v-vapor detection.

" R-rock; RA-altered rock; RP-pegmatite; RV-vein material; S-soil sample; R/W-residual and wash material; AD-dump and pit material from ancient mine; AT-tailings from ancient mine; AS-slag; HWS-head wadi or fan sediment; WS-wadi sediment; K-khabra sediment. Letters after the foregoing indicate magnetite (M), panned concentrate (P).

° Screen sizes: 32 mesh (.0195 in., .495 mm.); 80 mesh (.0069 in., .175mm.). > -greater than; < -less than. ' Minimum detectable content of element by method.