UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Saudi Arabia Investigation Report
(IR) SA-81

GEOLOGY AND MINERAL DEPOSITS OF THE JABAL ASH SHUMTA QUADRANGLE KINGDOM OF SAUDI ARABIA

by

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72-177

U. S. Geological Survey
OPEN FILE REPORT 72-177
This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature

1972

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 Also on open file in that office is a large amount of material, in the form of unpublished manuscripts, maps, field notes, drill logs, annotated aerial photographs, etc., that has resulted from other previous geologic work by Saudi Arabian government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

Rocks, structures, and mineral deposits which are the result of both the older Halaban petro-tectonic cycle and the younger Najd Wrench Fault deformation are present in the Ash Shumta area. Northward-trending belts of granitic rocks and folded, layered metavolcanic and metasedimentary rocks of the Halaban Formation which they intrude represent the effects of the Halaban cycle. These older rocks are everywhere transected and deformed by northwestward- and northeastward-striking fractures and strike-slip faults and by eastward-striking fractures and fracture-controlled silicic dikes which belong to the Najd Wrench Fault deformation.

Several kinds of epigenetic mineral deposits of hydrothermal origin are present throughout the Ash Shumta area. All occur in or are closely associated with structures of the Najd Wrench Fault deformation. The mineralization which produced the deposits is thought to have taken place during the period of deformation which produced the Najd Wrench Fault structures. The hydrothermal deposits include many metalliferous quartz veins most of which occur in three mineralized areas: two major areas at Jabal Ash Shumta and Jabal El Khom in the northern half of the quadrangle and a minor area along Wadi al Boharah in the southeastern part of the quadrangle.

The metalliferous lodes possess the only economic potential in the area of the Jabal Ash Shumta quadrangle. These lodes consist mainly of gold and base metal-bearing quartz veins, some of which were mined for gold in ancient times. The mineralized area at Jabal Ash Shumta has the best of these veins. Higher temperature veins with wolframite as a major constituent and beryl as a minor one occur in a granite cupola in the eastern part of the El Khom area. These veins have altered, greissen-like wall rocks. Although the grade of the veins is low at the surface, the grade could increase at depth. The tungsten-bearing veins and El Khom area possess the greatest economic promise in the Jabal Ash Shumta quadrangle. They deserve detailed surface investigation followed if needed by exploration at depth.

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 western half of Sheet 96 of the Ministry's photomosaic map series, or the Jabal Ash Shumta quadrangle as it may be called after the prominent mountain of that name in the north-central part of the area. Jabal Ash Shumta is one of numerous semi-isolated mountains scattered throughout the area, which is otherwise nearly flat with a general elevation of about 800 meters; most of the mountains lie in the northern half of the area. All of the drainage joins Wadi al Jarir, which flows northward through the middle of the area toward Wadi ar Rimah, of which it is a major tributary.

The Ash Shumta area is most accessible from the west from Medina via Al Hanakiyah, and from Jiddah to the southwest via Afif, the nearest large town which lies about 100 km southeast of the Jabal Ash Shumta area.

The Jabal Ash Shumta 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 eolian sand of Nefud al Urayk. Independent reconnaissance mineral surveys of the area were made by Ministry geologist Abdullah O. Ankary during the periods February 24 to March 13 and May 16 to 23, 1965, and by C. L. Hummel of the U. S. Geological Survey on December 17-18, 1965. Vehicles and personnel for this field work were provided by the Ministry. The report was prepared by Hummel.

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 has been to determine the gross geologic character of the mineral deposits as the basis for guiding development of those with proven potential and for the search for others.

The methods used on the mineral survey were such that they yielded only qualitative results; no quantitative sampling or valuations were made of any of the deposits. 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 sediments from the headmost parts of numerous 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 and wet chemical methods, all of the former by C. E. Thompson of the U. S. Geological Survey and most of the latter by M. Aldugaither and I. Baradja of the Ministry.

Nearly all the wadi sediments were collected from higher standing parts of the Ash Shumta area, and so represent only the layered metavolcanic and metasedimentary rocks of the Halaban Formation which make up most of them. Only a few samples were collected from the granitic rocks which are exposed almost entirely in low-lying parts of the area and underlie more than half of the quadrangle. Thus, while the numbers and spacings (one kilometer or less) of wadi sediments and fractions of them, and the data derived from them, are adequate to establish the areal distribution and lithologic association of the metallic elements being determined as manifested in wadi sediments in these parts of the area, they are not sufficient to do the same for the entire area. Accordingly, the data available from the wadi sediments have been used only to determine mean backgrounds for the areas and rocks they represent; where applicable, these are given in the tables to provide a standard for comparing data from other samples collected in the same area, and they have been used to determine the anomalous results described in the text.

General geology

The gross aspect of the bedrock geology of the Jabal Ash Shumta quadrangle is simple but is very complicated in detail. The principal features consist of two belts of metavolcanic and metasedimentary layered rocks separated by a belt of granite rocks exposed intermittently in the lowest parts of the area along Wadi al Jarir through the center of the area. All of these features, including the wadi, have moderately to well-defined northward trends and all of the granitic rocks may belong to a single mass which is exposed sporadically throughout the area, and everywhere intrudes and underlies the layered rocks at no great depth. Both the layered rocks and the granitic rocks, and the structural trends which their exposure belts manifest, are thought to have developed during a single, great Precambrian petro-tectonic cycle; this has been named after the Halaban Formation to which all of the layered rocks are believed by the author to belong (Brown and Jackson, 1960). All the features of this period are transected by structures of the Najd Wrench Fault deformation of late Precambrian and, perhaps, early Paleozoic age. These structures comprise mainly northwestward-, northeastward-, and eastward-striking vertical fractures, strike-slip faults, and fracture-controlled dikes. The deformation is named for the great wrench fault zone which transects the entire northern Arabian Shield and passes just south of the Ash Shumta area (fig. 1). All the epigenetic mineral deposits in the area, including the metalliferous lodes which possess the greatest economic potential, occur in these structures or are closely associated with them, and they are thought to have formed at the same time.

Stratigraphy

Halaban Formation.

Most of the rocks of the Halaban Formation in the Jabal Ash Shumta quadrangle are exposed in the two belts in the eastern and northwestern parts of the area cited earlier, the only others being a few, small outliers on the large granite mass cropping out in the southwest part of the area, and a portion of an extensive schist belt which extends southward from the southwesternmost corner of the area.

Neither the base nor the top of the Halaban Formation is exposed in the Ash Shumta area. Although the contacts between it and the older granite bodies are deceptively flat, the Halaban Formation is everywhere intruded by the granitic rocks. No layered rocks of younger Precambrian age than the Halaban Formation occur in the area.

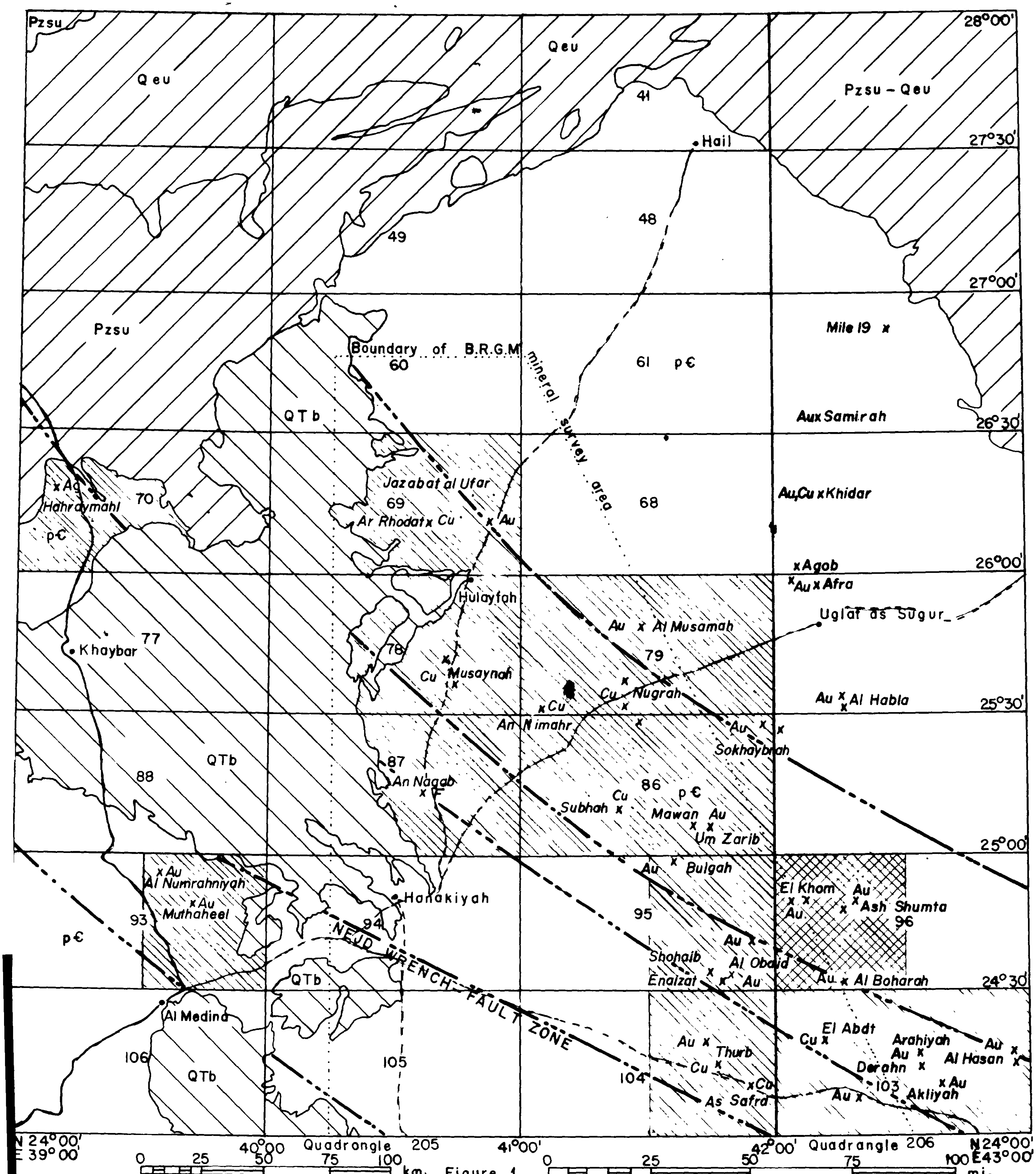


Figure 1

x Musaynah - Ancient mine

Scale 1: 2,000,000

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 — primary / - - - - - secondary } Principal access routes — 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).

Figure I 5a

The Halaban Formation is composed of irregularly interlayered and intertongued volcanic and sedimentary rocks which are metamorphosed from low to high grade; however, most of the rocks possess enough of their original character to be mapped on the basis of it rather than on metamorphic form. Where metamorphosed least, the volcanic rocks include easily recognizable derivatives of flow and pyroclastic types, and the sedimentary rocks comprise equivalents of shale, sandstone, and conglomerate. Most of the volcanic rocks are of andesitic composition although maroon, silicic-looking volcanic rocks occur at a few places.

Clastic sedimentary rocks predominate in the Halaban Formation and most of them are marine wacke types. Although moderately to well bedded, they possess the internal characteristics so diagnostic of these including poorly sorted, abrupt variations of composition vertically and laterally, angular to well-rounded pebbles and boulders of all sizes, and intraformational clasta. Much of the coarser material in the sedimentary rocks of the Halaban Formation is angular volcanic debris of the same type as the volcanic rocks which are sporadically interlayered with them and even the finest-grained sedimentary rocks are markedly tuffaceous. From this, it is clear that most of the sedimentary rocks of the Halaban Formation represent rapid accumulations under marine conditions of volcanic debris and rocks derived from concomitant volcanic activity.

No detailed petrographic studies have been made of the rocks of the Halaban Formation which have been most highly metamorphosed, but it is clear that they are closely associated with the older granitic rocks and have been intruded and altered to some extent by them. Most of the highest-grade rocks are exposed in isolated outliers resting on nearly horizontal intrusive contacts with older granitic masses in the central part of the area. Andesitic volcanic rocks and some metawacke clastic sedimentary rocks of appropriate composition have been converted to amphibolites and feldspathic amphibolites, but close inspection of most of them reveals enough of their original character to distinguish them from dioritic rocks which they strongly resemble. High-grade gneissic and schistose metasedimentary rocks along contacts with granite at several places, notably at Field Station 18670, attest to the concurrent effects of intrusion and deformation. Even moderate grade derivatives of calcareous shales and siltstones yield some of the most striking metamorphic products. In the Ash Shumta area, as at many other places on the Arabian Shield, they are now manifested by calcareous schist which contains great numbers of small, mainly accordant, quartz pods and veins; carbonate minerals are minor constituents of most of these.

The seemingly erratic mixture of volcanic and sedimentary rocks which make up the Halaban Formation in the Ash Shumta area and at many other places in the Arabian Shield is here thought to have collected in a eugeosyncline of the kind that the present Andaman-Indonesian trenches in southern Asia may be a modern counterpart. The wacke-type sedimentary rocks of the Halaban Formation formed under conditions of rapid accumulation and in great part from volcanic debris like that making up the volcanic rocks with which they intertongue and are interlayered; this attests to the strong volcanic and tectonic activity which accompanied their formation. Thereafter, they were regionally metamorphosed in varying degrees in the more deeply depressed parts of the eugeosyncline and, subsequently, invaded by granitic magmas; these latter metamorphosed the Halaban rocks along their margins to markedly higher grade than that attained by the rocks generally during regional metamorphism. Finally, the metavolcanic and metasedimentary rocks of the Halaban Formation and their associated granitic rocks were uplifted, probably by isostatic adjustments, and deeply eroded. Thus, the present geologic terrain of the Ash Shumta area represents nearly the end stage of a tectonic cycle comrpising eugeosynclinal and orogenic stages with concurrent and overlapping volcanic, metamorphic, and magmatic phases. This cycle has been appropriately characterized as the Halaban petrogenic-tectonic cycle (Brown and Jackson, 1960). It includes all the layered and plutonic rocks and all the structures in them which were produced during the cycle. In this view, the rocks of the Ash Shumta area, and indeed, much of the Arabian Shield constitute the deeply eroded and exposed roots of what must once have been a series of high-standing, northward-trending, Precambrian mountain ranges. Again, using the Andaman-Indonesian tectonic belts as modern counterparts of those of the Halaban cycle, it is possible that individual elements of the series may be progressively younger or older normal to their trend, that is eastward or westward.

Granitic rocks.

Only plutonic rocks of granitic composition occur in the Ash Shumta area. Most and perhaps all of them belong to a single large mass which crops out throughout the southwest quarter of the area, in the belt extending northward along Wadi al Jarir, and in small, sporadic exposures elsewhere. No younger granitic rocks were recognized in the area. The granitic rocks were observed at only a few places in the field and no detailed petrographic studies were made of them. Most of the granitic rocks are appreciably pink in color and some are markedly red. For the most part, they are exposed in areas having little or no relief; however, most of these contain sparse, prominent bornhardts.

The older granite mass everywhere intrudes and underlies rocks of the Halaban Formation at no great depth in the Ash Shumta area and has moderately to strogly metamorphosed adjacent parts of them. This, together with the generally flat contact between them, has led to the development of extensive but thin veneers of high-grade Halaban rocks over the granite in the north-central and south-central parts of the area. Along parts of the contact the granite has been injected lit-par-lit fashion into layered rocks of the Halaban Formation, notably at the place which has been so mapped in the center of the area. Because the relic layers of country rock are strongly metamorphosed and appear to cut both the granite and Halaban Formation, they have been mistaken for mafic dikes which they strongly resemble. However, close examination of the walls of such pseudo-dikes will usually disclose small-scale intrusive features of granite in them. This seems to be true for most of the northeastward-striking dike-like bodies in the small granite pluton located east of Jabal el Khom.

Where examined, only marginal parts of the older granite masses were prophyritic; elsewhere, they were remarkably uniformly medium-grained. Biotite is the principal mafic mineral of the older granitic rocks generally. Hornblende is a major constituent only in marginal parts of the granite masses where it occurs as prominent phenocrysts with feldspar in a fine-grained groundmass. The older granitic rocks are sheared locally, but they are not appreciably metamorphosed.

Accordant northward alignment of the elongate plutons and linear outcrop belts of the older granitic rocks and the gross grain and major folds in the Halaban rocks constitute the principal evidence for assuming that they are related tectonically. If so, the nature of that relationship depends on the following facts: everywhere, the older granitic plutons intruded the layered rocks of the Halaban Formation and metamorphosed them to a grade markedly above the regional metamorphic grade which characterizes them generally. Conversely, the granitic rocks are not more than slightly metamorphosed, if at all. This precludes any association of the older granitic rocks and the Halaban Formation during the earliest, most tectonically active, geosynclinal stage of the Halaban tectonic cycle and, instead, restricts their possible association to the orogenic stage which followed it. That the granitic magmas may have been intruded early rather than late in this stage is indicated by evidence that their thermal effects seem to have been added concurrently to those of the regional metamorphism, that is, while the rocks were still depressed into the deeper parts of the geosyncline or at least while they still retained their heat from having been so. In addition, the inclusions of invaded country rocks and injection zones attest to strong dynamic intrusive action and strongly suggest that they were being intruded and deformed at the same time, and that they had been metamorphosed to high enough grade before this so that they were only slightly affected by the still predominantly liquid magma.

Structure

Nearly all the structural features in the area of the Ash Shumta quadrangle formed during the two great periods of deformation which have affected it: 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.

Halaban petro-tectonic cycle.

Structures of the older system developed under deep-seated conditions comprising concurrent and overlapping geosynclinal sedimentation and deformation and granitic magmatic intrusive activity accompanied by thermal metamorphism. Structural features of the cycle in the Ash Shumta area include the parallel belts of granitic and metavolcanic and metasedimentary layered rocks, folds of all sizes, and metamorphic structures in the layered rocks which are largely accordant with the original primary features. The trend of all the older structures in the Ash Shumta area is strongly northward, as it is for all of those of the Halaban petro-tectonic 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.

The parallel belts of granitic and meta-layered rocks which constitute the basic grain of the Ash Shumta area are but small parts of the ones which extend far northward and southward from it. The older granitic rocks everywhere intrude the Halaban layered rocks and appear to form a single great batholith with a nearly flat upper surface. Although the upper surface has irregularities, none is needed to account for most of the exposures of granitic rocks; nearly all the exposures occur in the lowest parts of the area and at essentially the same level.

Although folds of all sizes have been found in the layered rocks throughout the Ash Shumta area, no systematic study has been made of them; accordingly, the larger geologic features to which they may belong or be related, such as anti-clinoria or synclinoria, are not known. The folds are most numerous and best preserved in the wacke metasedimentary rocks in the northeastern part of the Ash Shumta area. They vary in size from minor folds to a moderately large syncline several kilometers wide and 10 kilometers long which is the predominant structure of that part of the area. The syncline, and an anticline of similar size in the east-central part of the area, probably represent the order of magnitude of the largest individual folds in the layered rocks. The axial parts of the folds are well expressed in the present topography and many have well-defined plunges; most of these are northward and this may be the plunge of any larger tectonic feature to which they belong. Although tight, all of the folds are still open and none were observed to be overturned nor were any thrust faults identified.

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 Ash Shumta area; silicic dikes occur in all of these structures, but they are localized mainly in those which strike eastward. 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 apparent offsets on them are often much greater than the real ones.

Northwestward-striking strike-slip faults and the prominent lineaments which manifest them are the largest younger structures in the Ash Shumta area and the predominant ones in the southwest part of it; everywhere else, they are minor and the northeastward-striking features predominate. Wherever displacements could be determined, they were right-lateral on the northeastward-striking strik-slip faults and left-lateral on the northwestward-striking strike-slip faults.

Besides the silicic dikes which occur singly and as swarms in the eastward-striking, younger structures, many hydrothermal mineral deposits, including all of the metalliferous lodes in the Ash Shumta area, are localized in, or are closely associated with those structures which strike northeastward and northwestward. 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 genetically related.

All the younger northwest-, northeast-, and eastward-striking structures in the Ash Shumta area are thought to belong to the Najd Wrench Fault deformation. The deformation is named for its most prominent structure, the northwest-striking Najd Wrench Fault Zone which transects the entire northern Arabian Shield and passes just south of the Ash Shumta 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 taken place 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 Ash Shumta 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, the 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 with right-lateral movement and north-south tension. That this probably happened is borne out by prominent right-lateral displacements which have been identified on many of the northeast-striking wrench-faults in the Ash Shumta area.

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

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

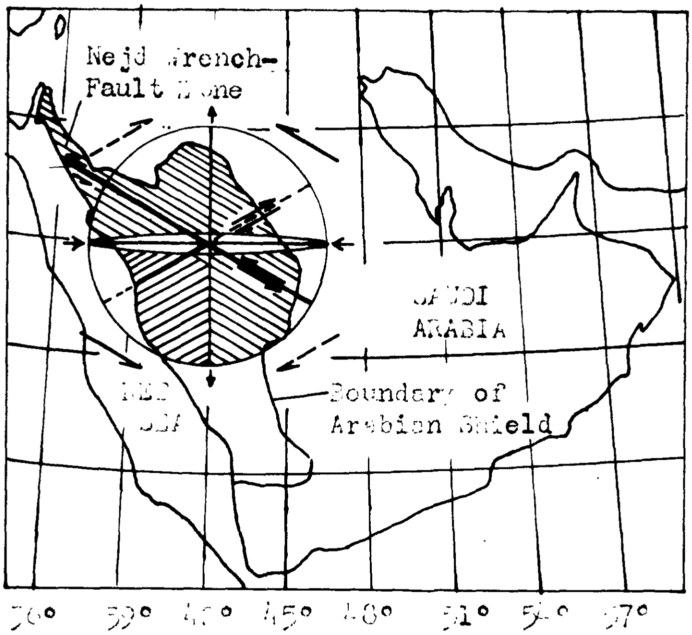


Figure 2- Stress diagram centered on Nejd Wrench Fault Zone at Latitude 24°N-Longitude 42E showing relationship of major and minor faults, fractures and dikes in north central Arabian Shield. Geologic features from Geologic Map of Arabian Peninsula: U.S. Geological Survey, Misc. Geol. Inv. Map I-270A, A.H. 1383 (A.D. 1963)

EXPLANATION

Stress Symbols

major force couple

minor force couple

principal direction of shearing

subordinate direction of shearing

direction of tension

direction of compression

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.

Fracture-controlled dikes and dike swarms are associated with all of the structures of the Najd Wrench Fault deformation, but they are most abundant in those striking eastward. This is thought to be so because this set would have been the one best conditioned by the north-south tension induced by the Najd Wrench Fault deformation to accomodate any intrusive activity concomitant with it. 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 Ash Shumta area yet.

Mineral deposits

Except for the swarm of quartz bodies of metamorphic segregation origin in the calcareous schist in the extreme southwest corner, and a few pegmatites along portions of the margins of the granite, all of the mineral deposits in the Jabal Ash Shumta quadrangle are epigenetic deposits of hydrothermal origin. Nearly all of them either occur in structures thought to belong to the Najd Wrench Fault deformation or are closely associated with them. This physical relationship strongly indicates that the deformation which produced the structures and the hydrothermal mineralization which produced the deposits are also related genetically. From this, it is concluded that all of these deposits formed during the period of Najd Wrench Fault deformation in late Precambrian time; as this deformation may have 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 Ash Shumta 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 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 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.

Most of the epigenetic mineral deposits are metalliferous quartz veins, the remainder consisting of numerous large, barren silicified breccia veins which occur in parts of northwest- and northeast-striking strike-slip faults. Most of the metalliferous deposits have ancient workings which are thought to date from 1100 to 1200 years ago (Ministry of Petroleum and Mineral Resources, 1965, p. 20), and some of them were relocated and examined in recent times. Of these, K. S. Twitchell of the Saudi Arabian Mining Syndicate (S. A. M. S.) visited deposits of the area in 1936. Since then, numerous people from the Ministry of Petroleum and Mineral Resources have revisited and resampled the same deposits, including D. F. Schaffner and G. L. McGarry in 1955-56, and H. A. Quinn in 1963.

All the known metalliferous lodes in the Ash Shumta area are filling-type quartz veins. No replacement zones like the El Abdt deposit just south of the area (fig. 1) have been found in it; however, small parts of the country rock at most of the deposits are altered and contain disseminated constituents which are the same as those in the veins. Nearly all of the metalliferous quartz veins are startlingly similar in physical character and in mineralogic and chemical composition. Many new veins were recognized during the course of the current investigation which are located at considerable distances from those known or worked previously. The practical effect of this has been to add appreciably to the part of the Ash Shumta area with some measure of mineral potential.

Whether small or large, the metalliferous quartz veins are highly fractured and more or less iron-stained. The principal internal fractures are parallel to those along which the veins are emplaced. These features with the cataclastic structure which marks most of the fractures in detail, and the repeatedly rehealed and refractured textures of all the gangue and ore minerals, attest to concurrent deformation during formation of all the deposits. The principal features produced by the concurrent fracturing and formation of the veins are abundant open cavities which could only have formed and been preserved at moderate to shallow depth. Many of the cavities are lined with euhedral quartz crystals, and most of the fracture surfaces are lined with quartz with incompletely formed crystal faces. Such quartz has been interpreted by other observers as representing successive generations of introduction of silica. It is here thought probably only to represent the effects of later metalliferous but non-siliceous hydrothermal solutions which dissolved the more finely fractured, more chemically reactive material from the original quartz vein and redeposited it essentially in situ.

The other diagnostic physical characteristic of the veins -- prominent iron stain which all but a few possess -- is derived from pyrite, the most abundant sulfide mineral which all but a few veins contain. Pyrite, and hematite pseudomorphic after it, coats the walls of the veins, the surfaces of the fractures in them, and, in addition, occurs as irregular-shaped blebs and isolated cubes throughout the quartz. In veins in granitic rocks, the distinctive stain from the pyrite/hematite is enhanced by similar occurrence of pink potash feldspar, which has probably been leached from the wall rock below and redeposited in the vein. Similarly, calcite and other carbonate gangue minerals only occur in veins in or near calcareous country rocks and, probably, these carbonate minerals have been derived from the wall rocks also.

In composition, all of the metalliferous veins of the Ash Shumta area are similar in having, besides pyrite, only a few, very sparse ore minerals composed of a very few metallic elements. No detailed mineralogy of the metalliferous lodes was done during the present investigation, but only two or three of the following metallic constituents were recognised by megascopic examination in vein material from each of the known deposits: bornite, chalcocite, chalcopyrite, galena, molybdenite, native gold, sphalerite, powellite, scheelite, and wolframite; in addition, beryl was identified from one vein. That not many, if any, more ore minerals occur in the veins is borne out by the results of emission spectrometric and wet chemical analysis of residual and dump material from most of the same deposits. These analyses showed that only 7 of 27 metallic elements determined are present in sufficiently anomalous amounts to have been introduced by hydrothermal mineralization. They are copper, lead, molybdenum, nickel, silver, tungsten, and zinc.

The Jabal Ash Shumta quadrangle contains two major and one minor center of mineralization, the former at Jabal Ash Shumta and Jabal El Khom, respectively, in the north-central and northwestern parts of the area, and the latter just east of the junction of Wadi al Boharah and Wadi al Jarir. Accordingly, the deposits in these areas are referred to by these names. The predominant fractures and faults which are present at these places and are thought to have localized the hydrothermal mineralization in them strike northwestward in the El Khom and Al Boharah areas and northeastward in the Jabal Ash Shumta area. The structures of both attitudes are thought to belong to the Najd Wrench Fault deformation.

Jabal Ash Shumta.

The Jabal Ash Shumta area contains two metalliferous quartz veins which were worked for gold in ancient times, and numerous others which were no doubt prospected but not mined. The vein with the most extensive workings and the largest village associated with it crops out across the narrow, northward-trending ridge which forms the northeast nose of Jabal Ash Shumta. It is in north-dipping, hornflesed, wacke-type sandstone and conglomerate along an intrusive contact with the older granite mass. The other vein with ancient workings crosses the north end of a small, detached ridge spur in the southwest slope of Jabal Ash Shumta. The ridge is composed of northwest-dipping, interlayered metavolcanic and metasedimentary rocks. The layered rocks at both mines, and those making up most of Jabal Ash Shumta, belong to the Halaban Formation.

The Jabal Ash Shumta area is transected and bounded by strongly developed vertical fractures and strike-slip faults which bear northeastward, but the precise relationship of these and the metalliferous veins was not determined during the present reconnaissance mineral survey. Detailed descriptions of the veins, the ancient workings on them, and previous sampling results are available elsewhere (Twitchell, 1937; Quinn 1963a), accordingly, only the general features of the deposits are discussed below.

The vein at North Ash Shumta strikes northwestward and dips about 20° southwest. It crops out for a distance of 242 m along the west side of the ridge and for 182 m in the east slope. The thickness of the vein was estimated by Twitchell to be from 0.15 m to 0.4 m. Except for moderately abundant pyrite, the vein contains only sparse primary ore minerals and weathered products of them; bornite, chalcopyrite, galena, native gold, sphalerite, and wolframite were recognized in samples of vein material. Results of emisssion spectrometric and wet chemical analyses of dump and wash material from the vein, and tailings from the village, (table 1, 18661, 18662) confirmed the presence of copper, lead, and zinc and, in addition, indicated a little silver, probably associated with the gold or galena.

Results from sampling the vein, as given by D. F. Schaffner in 1956 are as follows:

> "Twitchell took 7 grab samples of quartz on the surface of the dumps which averaged 10.0 dwt (.05 oz.) gold per ton. Twenty-six test pit samples in the tailings area averaged 2.15 dwt. gold per ton. McGarry took three grab samples of quartz on the surface in the tailings area which averaged 0.40 oz. gold per ton.
>
> "Shumta is too small to be developed by itself. If there was an operating mill within trucking distance, the grade is high enough to warrant prospecting work."

The South Ash Shumta vein also strikes northwest, but dips more steeply than the northern vein, and may be nearly vertical. However, the vein crosses the low, north nose of the ridge nearly at wadi level and little could be determined about its downward extension. The workings are about 300 m long, but veins are exposed only intermittently in them. This suggests that the workings are not a single large vein, but, rather, are on a series of small quartz bodies along a fracture or fault.

Primary ore minerals other than pyrite are very sparse in the South Ash Shumta vein, only native gold and a little copper stain having been recognized. An emission spectrometric analysis of dump material from the vein yielded slightly anomalous amounts of copper and lead (table 1, 18668). A wet chemical analysis of a wadi sediment derived from the vein gave a small tungsten anomaly (table 1, 13375A); no scheelite was present in the dump material, which indicates that tungsten, if present, is in wolframite. Finally, assays of vein material from the workings as reported by D. F. Schaffner (1956) gave the following results (sample P-1876): 0.09 oz. Au/ton; 0.28 oz. Ag/ton; tr. Cu; 1.2% Pb; 5% Zn. Assays for gold and silver were by Schaffner, and for base metals by the Ministry of Petroleum Laboratory, Jiddah.

The chief value of numerous other metalliferous quartz veins and occurrences in the Jabal Ash Shumta area which were not mined is the evidence they afford that mineralization accompanied by metallization was much more widespread than old workings alone indicate. The presently known veins are listed below with their physical character, mineralogy (in addition to pyrite), and the laboratory results obtained from them.

Field station	Attitude	Mineralogy	Anomalous metal content
13235-39	N.60°W.	secondary copper minerals galena, sphalerite	-
13366-68	n.d.	bornite, chalcopyrite	-
13369-70	N.50°E.	molybdenite, powellite	-
13373	n.d.		w.s., tungsten
13375	n.d.		w.s., tungsten

(Abbreviations: w.s. -- wadi sediment; n.d. -- not determined)

The composition and physical character of the vein at Field Stations 13235-39 are very similar to those of the main Ash Shumta vein, and so is its bearing (N.60°W. for the former, N.40°W. for the latter). Being similar and on strike with the Ash Shumta vein raises the possibility that it may be a continuation of it that is covered along most of its length by the khabra deposit between them. Detailed work should be done in the area to determine this.

The vein at F.S. 13369-70 is of particular significance because it is one of only two presently known in the Jabal Ash Shumta area which strikes northeast (N.50°E.); it may thus be localized in one of the principal mineralizing structures in the area. For the same reason, an anomalous amount of tungsten detected by wet chemical analysis in a wadi sediment sample collected at F.S. 13375 (table 1) is important because it was derived from a portion of the northeast-striking fracture lineament which transects the most strongly mineralized part of the Jabal Ash Shumta area. The tungsten anomaly obtained from a sample of wadi sediment collected at F.S. 13375 was attributed previously to the South Ash Shumta vein from which it was probably derived.

El Khom.

The other major center of mineralization in the Jabal Ash Shumta quadrangle is in the northwestern part around Jabal El Khom. The deposits of the area occur in a small, semi-detached cupola of the older granite mass which is exposed just east of the mountain and in moderately to strongly metamorphosed layered rocks of the Halaban Formation surrounding it and which it intrudes. The layered rocks consist mainly of dense, porphyritic or porphyroblastic derivatives of andesitic volcanic rocks which have been converted to amphibolites and feldspathic amphibolites, but they include reddish, silicic-looking volcanic rocks, wacke and calcareous metasedimentary rocks, and fine- to medium-grained dioritic rocks locally.

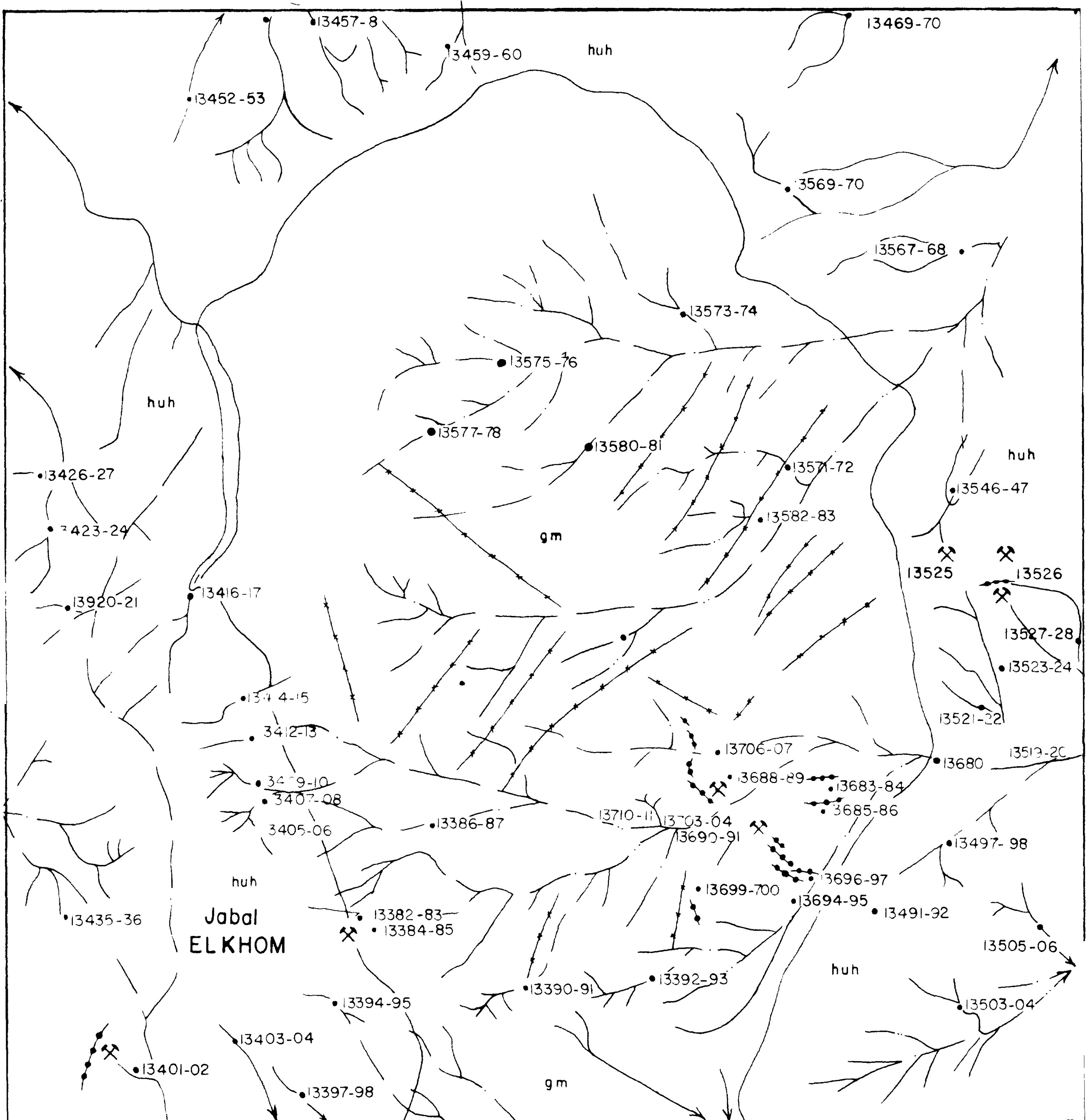
The older Halaban structures are obscure in the El Khom area, but the older granite cupola and its umbilical-like attachment to the main mass seem to lie along the crest of a large, northward-trending anticline. Younger structures are also ill-defined, but the predominant strike-slip faults, fractures, and fracture-controlled lineaments in and striking into the El Khom area bear west-northwest. These are thought to have been the major mineralizing structures of the area and to belong to the Najd Wrench Fault deformation of late Precambrian age.

The largest ancient mine of the area, just west of Jabal El Khom, was relocated by K. W. Twitchell in 1935 (Quinn, 1963b); the rest of many smaller ones were found by Abdullah O. Ankary during the course of the present mineral survey. Although all the deposits of the area are clearly related, for purposes of description they can be subdivided conveniently into those around Jabal El Khom (West El Khom) and those in and around the eastern margin of the granite cupola (East El Khom) (fig. 3).

All of the epigenetic hydrothermal deposits of both parts of the El Khom area are metalliferous, filling-type quartz veins, and all possess the general features which are characteristic of all the lodes in the Jabal Ash Shumta quadrangle. However, they include a somewhat wider range of primary ore minerals, notable wolframite, which indicates that they have formed under a correspondingly wider range of physical-chemical conditions. All the deposits which appear to represent the highest grade of hydrothermal mineralization are located in the eastern part of the El Khom area.

West El Khom:-- Metalliferous deposits and occurrences included in the West El Khom area lie in a belt 15 km long extending north of Jabal El Khom to Field Station 13457 and south of it to Field Station 18671; but most of them lie in the 5 km long central portion of the belt in and near Jabal El Khom. The kind and character of the metalliferous veins and other occurrences are summarized below:

Field station	Attitude	Mineralogy	Anomalous metal content
13386	-	-	w.s., tungsten
13390	-	-	w.s., tungsten
13407	-	-	w.s., tungsten
13412	-	-	w.s., tungsten
13414	-	-	w.s., tungsten
13457	-	-	w.s., tungsten



GEOLOGIC MAP OF EL-KHOM AREA SHOWING LOCATION OF MINES AND TUNGSTEN BEARING QUARTZ VEINS

Scale 1:50,000

0 2 3 4 Km

by Abdullah Ankary in U.S.G.S./Min of Petrol Tech Letter II

gm — gray biotite granite

huh — strongly metamorphosed layered rocks of the Haliban formation

diorite, andesite, and rhyolite dikes

tungsten-bearing quartz vein

ancient mine

•13580-81 field station and wadi sediment sample locality

geological contact

Field station	Attitude	Mineralogy	Anomalous metal content
13434	WNW, V	chalcopyrite, sphalerite?	-
13435-7	n.d.	chalcocite, chalcopyrite, galena, sphalerite	-
18671	n.d.	abundant pyrite	R/D; copper
18675	NNE.,10°W.?	primary and secondary copper minerals, native gold, sphalerite	R/D; copper
18678	WNW,V	secondary copper minerals	R/D; copper, lead, silver, zinc

(abbreviations: n.d.-- not determined; R/D-- residual or dump material; V-- vertical or steeply dipping; w.s. -- wadi sediment)

Many of these deposits have ancient workings, but those with village ruins and the most extensive workings occur at Field Stations 18675 and 18678. The former is the principal deposit of the area and the only one known and sampled before the present mineral survey. The vein lies two kilometers west of Jabal El Khom in feldspathic amphibolite country rocks which may be metamorphosed diorite. It trends northward and is exposed for a length of 470 m. Mr. D. F. Schaffner's description of the workings and results of sampling are given below.

> "The workings are 1600' in length. They are now filled with debris but appear to have been narrow and shallow. There is a small tailings dump in the village ruins area on the east side of the working, a few grinding stones are scattered among the ruins.
>
> "Twitchell's samples of quartz from the dump assayed 7.00 dwt gold per ton, of tailings 1.25 dwt. gold per ton. McGarry and Schaffner resampled the dumps this year. Eight grab samples of quartz on the surface of the dumps over a total length of 1550' averaged 0.13 oz. gold per ton.
> Coom is too low grade to be of interest."

The ancient gold mine at the east base of Jabal El Khom (F.S. 18678, 13378-85) was reported to K. S. Twitchell in 1936, but too late for him to examine it;

it was relocated by Abdullah O. Ankary during the current mineral survey. The workings consist of one pit and a stope adit; a few ruins are associated with them and their character indicates that the deposits were worked for gold. Both the pit and the stope-adit strike N.75°W. and the latter dips 65°S. Little vein material remained in either workings, and their physical character indicates that the original veins were small, discontinuous lenses. The wall rock and vein material of the stope-adit are strongly sheared and fractured.

Only sparse secondary copper minerals were observed in vein material from the workings, but laboratory analyses of dump and wash material from them showed significantly anomalous amounts of copper, lead, silver, and zinc (table 1, 18678).

The pyritiferous quartz vein at F.S. 18671 is one of many in the Ash Shumta area which resembles in appearance those worked in the ancient mines, and they are thought to have formed during the same period of hydrothermal mineralization. Besides its physical similarity to these deposits, vein material from F.S. 18671 also contained an anomalous amount of copper as detected by emission spectrometric analysis (table 1). Beyond their probable relationship to the tungsten minerals known to occur in many of the veins of the El Khom area, nothing is known about the anomalous amount of tungsten detected in wadi sediments at several localities (F.S. 13386, 13390, 13407, 13412, 13414 and 13457; table 1). However, because of this association, they should be traced to their bedrock sources during the course of any future detailed investigations of the entire area.

East El Khom: -- Like those in the West El Khom and Jabal Ash Shumta areas, the mineral deposits of East El Khom are in marginal parts of the granite and adjacent parts of the meta-layered country rocks which it intrudes; however, a greater proportion of them are in the granite than at the other places. The deposits, too, are like those everywhere else in the Ash Shumta area in being highly fractured, iron-stained quartz veins with generally sparse, primary ore minerals. The El Khom area differs somewhat from the others by having some veins which contain wolframite as a major constituent and moderately strongly altered wall rocks; both features are thought to be the result of appreciably higher-grade conditions of formation. All the known veins of this character are in the granite in the southeast quarter of the cupola (fig. 3). The most significant mineral occurrences of the East El Khom area are listed below together with some information about their physical character, mineralogy (in addition to pyrite), and chemical composition.

Field station	Attitude	Mineralogy	Anomalous metal content
13590	-	-	-
13594	-	-	-
13595	-	-	-
13687	-	wolframite	-
13690	-	-	w.s., tungsten
13692	-	powellite?	-
13693	-	beryl	-
13694	-	-	w.s., tungsten
13696	-	-	w.s., tungsten
13698	-	-	-
13699	-	-	w.s., tungsten
13701	-	secondary copper minerals	-
13702) 18680)	N.60°W.	bornite, galena, scheelite, sphalerite	R/D; copper, lead, molybdenum, silver, zinc
13703	-	-	w.s., tungsten
13706	-	-	w.s., tungsten
13708) 13493) 18679)	WNW., 30°N.	secondary copper minerals, scheelite, wolframite	-
13709	-	chalcopyrite	-
13710	-	-	w.s., tungsten
13497	-	-	w.s., tungsten
13501	-	-	w.s., tungsten
13526	E.-W., V	secondary copper minerals, galena	-
13531	-	chalcopyrite	-
13712	E.-W.	secondary copper minerals	-

(Abbreviations: n.d.- not determined; R/D - residual or dump materials; V - vertical or steeply dipping; w.s. - wadi sediment)

All but the last five localities listed above are in the small tungsten-bearing area cited previously. They include two ancient gold mines with village ruins at F.S. 13590 and 18680; in addition to the deposits which were mined at these places, numerous other veins in the East El Khom area have small workings. The largest workings at F.S. 18680 consist only of a shallow trench 100 m or so long which trends N.60°W. Besides native gold and pyrite, vein material from the dumps contained bornite, galena, scheelite, and sphalerite; and a spectrometric analysis indicated anomalous amounts of copper, lead, molybdenum, silver, and zinc (table 1, 18680).

The other veins in the tungsten-bearing area were examined by Abdullah O. Ankary who gave the following information about them. (Ankary, 1965a):

> "Quartz veins containing tungsten are located in the southeast part of the granite body. Most of them trend about N.70°W., and they occupy fractures in the dikes as well as in the granite. They range between 120 m and 900 m in length and between 0.3 m and 1 m in width. The quartz tends to be milky to translucent and is stained with hematite. Usually the tungsten minerals are found in the parts of the veins where there are well-developed crystals of quartz. In two small workings located in this area the quartz veins contain malachite and free gold.
>
> "The tungsten minerals are wolframite (ferberite-huebnerite) and scheelite. The wolframite was identified by Charles Thompson of U. S. Geological Survey. The scheelite was identified by the writer through use of an ultraviolet light in the field. The most abundant mineral is wolframite which occurs in the quartz as nodules and crystals ranging in size from about 2 millimeters to 4 centimeters. The tungsten minerals are distributed throughout the vein."

From megascopic inspection of vein material and wall rock material collected by Ankary from these localities and field examination of a few of them, the following information about the veins can be added. Pyrite and hematite pseudomorphic after it are the most abundant metallic minerals in all the veins; in addition to pyrite, only a few other primary ore minerals are present in very sparing amounts: native gold, scheelite, wolframite, and in one vein, beryl. The granite which forms the wall rocks of the veins has been altered along some of them to a greissen-like rock and the colorless mica which makes up most of the adjacent rocks also occurs as a minor constituent of the veins. Although the veins in the tungsten-bearing part of the East El Khom area are clearly like and related to the gold-base metal veins of the Ash Shumta area generally, the association in them of wolframite, beryl, and low-grade greissen-like altered granite wall rocks indicates that they formed under significantly higher-grade conditions than the others. Again, as in the West El Khom area, wadi sediments collected at a number of places in the East El Khom area were found to contain anomalous tungsten. As there, it can be assumed that they were derived from tungsten-bearing deposits like the known ones, but they should be traced to their sources to be certain.

Al Boharah.

Although the known mineral deposits of the Al Boharah area in the south-central part of the Jabal Ash Shumta quadrangle are of little economic importance, they are of considerable geological significance, for in no other part of the area are the deposits so closely and clearly associated with undoubted structures of the Najd Wrench Fault deformation. As with the others in the Ash Shumta area, and many more throughout the northern Arabian Shield, they are confusingly associated with both wrench faults and marginal parts of older granitic masses; but for those in the Al Boharah area, it is somewhat more certain that they are most closely related to wrench faults, and only incidentally, perhaps fortuitously, associated with the granite contact.

The deposits of the Al Bohara area are metalliferous quartz veins which are similar in every way to those elsewhere. They occur in intermittent groups in a belt extending southeastward from the mouth of Wadi al Boharah along and between several of the most strongly developed, northwest-striking strike-slip faults in the Ash Shumta area. However, the area has little relief and details of both the deposits and structures, and their relationship to each other are poorly exposed and known. For the present, the principal evidence for concluding that the deposits are localized along structures of the Najd Wrench Fault deformation, and that the hydrothermal mineralization which produced them may be related genetically to the deformation which produced the structures, must rest mainly on their close areal association and the presence of several prominent silicified breccia veins in the Al Boharah area until stronger evidence is developed by more detailed studies. Like the deposits elsewhere, these occur along individual strike-slip faults and have been deformed during deposition by movement on them. The silicified breccia vein at F.S. 18659 contains sparse pyrite and a slightly anomalous amount of copper both of which also occur in the Al Boharah gold mine a few kilometers east of the breccia vein (table 1).

As described above, only one small ancient gold mine occurs in the Al Boharah area and it is poorly exposed. However, it is significant that some of the quartz vein material associated with it has the fine-grained, sugary texture which is characteristic of the silicified breccia veins and parts of other metalliferous veins which have been deformed by strong movements on the structures in which they occur. Abundant pyrite and a little chalcopyrite were the only primary ore minerals recognized in vein material from the mine, but a spectrometric analysis of dump material showed that it contained an anomalous amount of nickel in addition to copper (table 1). A small vein two kilometers northwest of the Al Boharah mine at F.S. 13675 is one of many others in the same area; like that at the mine, it contained pyrite and a little chalcopyrite.

Miscellaneous mineral deposits and occurrences.

A number of other mineral deposits and occurrences are present in the Ash Shumta area which are thought to have developed or have been derived from deposits which formed during the same period of hydrothermal mineralization. They are:

Field station	Type of deposit or mineral occurrence
13266	northeast-striking, silicified breccia vein
18651	northwest-striking, silicified breccia vein
18655	northwest-striking, silicified breccia vein
18656	northwest-striking, silicified breccia vein

Field station	Type of deposit or mineral occurrence
18659	northwest-striking, silicified breccia vein
18659A	northwest-striking, silicified breccia vein
18664	pegmatitic quartz vein
18665	northeast-striking metalliferous vein
18669	aplite and pegmatite dikes
13362	wadi sediment with anomalous amount of tungsten
13597	wadi sediment with anomalous amount of tungsten
13643	wadi sediment with anomalous amount of tungsten
13645	wadi sediment with anomalous amount of tungsten
13653	abundant quartz bodies of metamorphic segregation origin

The silicified breccia zones 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 these fractures attest to concurrent and recurrent deformation and siliceous mineralization. The silicified breccia vein at F.S. 13266 is of particular geologic significance for the evidence it affords that similar kinds of movement and mineralization were taking place on both the northeast- and northwest-striking wrench faults of the Najd Wrench Fault zone at the same time.

No silicified breccia veins in the Ash Shumta area were found to be metallized except the one at F.S. 18659 described earlier, which contains pyrite/hematite and a slightly anomalous amount of copper. As a group the silified breccia veins possess no economic potential; their chief value derives from their possible genetic-structural relationship to metalliferous veins which do.

The tungsten anomalies at F.S. 13362, 13597, 13643, and 13645 belong to a group for which no source is known. Some of these have been discussed before, and like them, the others should be traced to their sources in bedrock in any future investigations. However, it should be noted that all the anomalies represent only marginally detectable amounts of tungsten by the wet chemical methods employed to determine it, and a laboratory check of the samples from which the results were obtained ought to be made before additional field work is done to locate their sources.

The swarm of quartz bodies of metamorphic segregation origin in calcareous schist in the southwest corner of the Ash Shumta area (F.S. 18653) represent the truncated northern end of a belt which extends far toward the south. They possess no economic potential and are of interest only for the confusion they cause when metalliferous lodes occur with them. Where poorly exposed, distinction between the two types of quartz is difficult because both can and do contain sparse iron and copper mineral and carbonate gangue. The metamorphic segregation quartz is thought to have been rendered out of the calcareous-siliceous sediments when they underwent desilication during regional metamorphism. The segregation quartz zones are closely associated with older granite bodies and, while they are intruded by them, it is at least possible that marginal parts of these bodies could have been desilicated too; in which case these might be appreciably more mafic than the central parts, the more so if marble or other calcareous rocks were assimilated during crystallization.

Conclusions and recommendations

Gold, base metal, and tungsten-bearing lodes are the only mineral deposits in the Ash Shumta area which possess potential for economic development. The principal gold-quartz veins of the area, and ancient workings with them, have been examined and sampled in modern times and adjudged uneconomic in size and grade; however, results of the present survey indicate that they should be re-evaluated for metallurgical and geological reasons. For the first because some, perhaps much, of the gold in the veins is in pyrite and hematite pseudomorphic after it, and so is not free milling. More elaborate treatment of the gold ores from the area may be needed to realize their full potential, and laboratory tests should be made on them to determine this and the possibility of recovering base metals as byproducts. On geological evidence, some of the gold-quartz veins seem to be much larger than the ancient workings alone indicate, notably the one which crops out at the north end of Jabal Ash Shumta and may extend much farther along strike toward the northwest than supposed previously. This could only be determined by detailed geologic investigations, including exposure of part of the vein which may be buried under a khabra deposit.

Tungsten-bearing quartz veins, together with their altered wall rocks, found during the present survey are thought to pessess the greatest economic potential in the Ash Shumta area under present conditions. Although the grade of the veins exposed at the surface is too low to be of interest, it could increase at depth; for this reason, detailed surface investigations and, if warranted, exploration at depth are recommended to determine the feasibility of mining them.

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