Sulfide Assemblages and Metamorphic Episodes at Mahd Adh Dhahab Gold Mine, Kingdom of Saudi Arabia

HASHEM D. HAKIM and OMAR R. EL-MAHDY
Faculty of Earth Sciences, King Abdulaziz University, Jeddah, Saudi Arabia

ABSTRACT. The Mahd Adh Dhahab gold mine is located in the west central part of the Arabian Shield and has been the most productive gold mine in Saudi Arabia in both ancient and recent times. Textural and mineralogical features observed in the ore deposits at Mahd Adh Dhahab indicate that the deposits have been subjected to metamorphism.

Three main effects were recognized. Recrystallization of the ores during regional metamorphism resulted in changes mainly in the fabrics, but also in the mineralogy, of the ores. With increasing metamorphism: a) there is a general increase in grain size, b) growth of pyrite as porphyroblasts, and c) presence of triple junction point texture. Deformational effects present varied from none, through brittle cataclasis to ductile deformation. The features observed include: a) fracturing, brecciation and mylonitization of fine-grained sulfides and porphyroblasts, b) deformation twinning, c) folding and disruption of cleavage traces, d) rotation of pyrite crystals, and e) stretching and elongation of soft sulfides. Remobilization produced irregular bodies of vein quartz and ore minerals, either within the deposits or in their immediate country rocks. The remobilization distances are limited, either within parent body or in restricted halo surrounding it (up to some tens of meters). The remobilization is selective and proceeded by creep or fluid-phase transport. The apparent order of decreasing mobility is: galena, chalcopyrite, sphalerite, pyrite. Certain replacement phenomena observed between the euhedral-subhedral pyrite grains and the base metal sulfides could be ascribed to metamorphism.

At Mahd Adh Dhahab area, successive episodes of low grade metamorphism prevailed during a long time span. Intermittent with such pervasive regional metamorphism, the ores were subjected to short periods of essentially dynamic and thermal metamorphism.
Introduction

The Mahd Adh Dhahab gold mine is located in the west central part of the Arabian Shield (Fig. 1) about 275 km northeast of Jedda (23°30'N and 40°32'E). The mine is

Fig. 1. Location map of Mahd Adh Dhahab.
situated at the northern part of an isolated hill, Jabal Al-Mahd, covering an area of about 2.2 km² at an altitude of 1238 m which is the highest peak in the area.

The Mahd Adh Dihahb mine in the Mine Hill area has had by far the largest production of any gold mine in the Arabian Shield. It has also been the most productive mine in Saudi Arabia in both ancient and recent times. At present, the mine is reopened and an exploratory decline has been completed and consists of about 1100 meters of adits and crosscuts.

Ancient mining and smelting in the area is evidenced by intricate workings that extend to a depth of 85 meters along major veins and by several thousands tons of waste and artifacts and ruins.

**Previous Work**

A program of detailed mapping and geochemical sampling was carried out from 1974 to 1977 (Loe et al., 1975, 1979; Roberts et al., 1978; and Wold 1978, 1979). This led to the discovery of the southern mineralized zone (SMZ) 700 meters south of the ancient workings. Diamond drilling in the SMZ intercepted wide veins that averaged as much as 60 gm per ton (Wold 1978). Reserves in the Southern Ore Zone are estimated at 1.1 million tons of approximately 1 oz. of gold per ton (Doebrich and Le Anderson 1984 and Hilpert et al. 1984).

**Geology**

The country rocks belong to the Upper Proterozoic (800-780 Ma) Mahd Group and consist of a thick-layered succession of volcanic and sedimentary rocks unconformably overlying granite and granodiorite (Fig. 2). From base to top, the local stratigraphic sequence is composed of andesite, andesitic tuff, lower argilolaterite, lower tuff, lithic crystal tuff, and upper tuff (Hakim 1978). The layered rocks are cut by two generations of intrusives. The earliest consists of plugs or domes of porphyritic rhyolite, and the latter of andesite dikes. The porphyritic rhyolitic outcrops in the northeast part of Jabal Al-Mahd. A series of andesite dikes occupy northeastly and northwesterly faults in the Mine Hill area. The dikes cut and displace the mineralized veins.

**Structure**

The layered rocks dip mostly to the north except locally in the northeast part of Jabal Al-Mahd where the rocks have been folded by the rhyolite intrusion. The dips in the southern part of the Jabal are 35 to 40° N and generally steepen northward to 60-80° N. This monocline is cut by several fracture systems (Hakim 1978 and Hilpert et al. 1984). These are N139W to N30W, dipping 25-45° W; N45-75°E, dipping 45-60°W; N10W to N20°E; dipping steeply westward; N30W dipping steeply to the west or southwest; N45E dipping steeply to the west, and N30W, vertical. The north or northwesterly-trending faults belong to the older Hijaz Variscan Cycle, while the northwest-trending faults belong to the younger Najd Fault System.
Ore Deposits

Gold mineralization occurs as disseminations, quartz veins, and stockworks. Thus far, none of the gold production came from the quartz veins. There are two separate ore zones; the northern zone includes ancient workings at the northeastern part of Jabal Al-Mahd; and the southern zone along the southern side of the Jabal.

The quartz veins cut across the steeply dipping layered rocks and the rhyolite. The veins strike N10W to N20E, and N30E to N70E and are essentially vertical. The veins are divided into four types, three are metal-bearing and the fourth is barren.

The metal bearing quartz veins are divided as follows:

1 – Milky Quartz Veins

These are sharp walled veins of white, milky, fine- to medium-grained quartz. Comb structure is common. A thin film of chlorite envelopes the quartz crystals and, near vein margins. Patches of calcite are randomly distributed in the fine-grained quartz. Sphalerite, chalcopyrite and galena are dispersed along the vein margins. These veins are 1/2 to one meter thick.

2 – Crystallized Milky Quartz Veins

These are medium-grained quartz veins 5 cm to one meter thick with crystallized bands of galena, chalcopyrite, sphalerite and chlorite alternating with chaledony.

3 – Quartz-Cemented Breccia Veins

This type contains breccia fragments mostly of chert, rhyolite, and quartz. Quartz cement makes up about 40% of the veins. Sphalerite and galena are the common sulfide phases in these veins.

The stockwork mineralization occurs as intricate, thin, crosscutting veinlets of quartz traversing the chloritized and silicified country rocks. They form irregular patches and contain thin veins and disseminations of sulfides. Disseminated pyrite occurs in the wall rocks particularly in the northern area.

Ore Minerals

The primary ore minerals include, in order of abundance, pyrite, sphalerite, chalcopyrite, galena, hespide, altaite, argentite, pyrrhotite, pybysite, petzite, tetrahydrite, tellurohematite, calaverite, gold, electrum and specular hematite. Secondary minerals include covellite, chalcocite, neodiginite, bournie, malachite, azurite, specular hematite, geothite, lepidocrocite, and amorphous hydrated ferric oxides.

Metamorphic Features

The ore deposit at Mahd Adh Dhahab exhibits a number of textural and mineralogical features which indicate that the deposit has been subjected to effects of
low grade metamorphism. The metamorphic features described in this work are mainly concerned with the smaller-scale, predominantly microscopic effects. The pervasiveness of metamorphism in terms of sulfide mineral re-equilibration often inhibited determination of the original ore mineral paragenesis.

The metamorphic effects observed in the sulfides at Mahd Adh Dhabab generally resemble those that can be observed in the enclosing rocks (pumpeebellie facies). Bareon and Skinner (1979) discussed the tendency of ore minerals to re-equilibrate at various temperatures. They demonstrated that the respond threshold for ore minerals corresponds, in general, with bond strength and hardness. Thus minerals such as pyrite, magnesite and arsenopyrite have the greatest tendencies to retain their original texture and composition during mild metamorphism. If, however, these minerals are re-equilibrated during the metamorphism, they are also more likely to preserve some record of the metamorphic peak rather than totally re-equilibrating during the subsequent retrograde metamorphism. On the other hand, soft sulfides (e.g. chalcopyrite, galena) and native metals (e.g. gold, electrum, bismuth), may readily re-equilibrate during the thermal rise to the metamorphic maximum and during the retrograde cooling, and hence may retain little or no evidence of their origin. Sphalerite behaves in a different way because although it is soft, it is sufficiently refractory to retain original growth features through mild metamorphism, and to retain metamorphically equilibrated compositions through retrograde cooling periods.

The metamorphic features observed at Mahd Adh Dhabab are related to: (i) thermal or contact, (ii) dynamic or stress, and (iii) dynamothermal of regional effects. All the ore minerals reveal effects of regional metamorphism; contact and stress effects are present but have commonly been overprinted by regional effects.

Megascopic Ore Textures

The principal megascopic effects are increase in grain size, and injections of the plastic sulfides into crosscutting apophyses. The pyrite- and sphalerite-rich veins may contain nearly undistributed primary sulfide banding with inclusions of undeformed volcanoclastic fragments. They may also display thorough destruction of the original texture. During plastic deformation of the soft sulfides, included layers and even portions of the wall rocks, which are more brittle, are broken and rotated in the sulfide matrix. Chalcopyrite, sphalerite and galena are commonly injected into fractures and cleavages of the accompanying silicates. Mobilization of chalcopyrite is suggested by its common presence in cross cutting features and its concentration along grain boundaries of, and fractures in, large pyrite crystals. Part of the texture observed in chalcopyrite may result from its precipitation last in the paragenetic sequence and replacement of pre-existing minerals.

The degree of homogenization and recrystallization varies greatly from one vein to the other and even in the same vein. The grain size of pyrite averages approximately 1 mm but over a distance of few cm it may vary from 0.1 mm to 3 cm. In places, pyrite
has grown into cubes 2 cm across that are intermixed with pyrite crystals barely 0.1 cm in size.

Microscopic appearance

Pyrite

Pyrite is the most abundant ore mineral. The behavior of pyrite during metamorphism is determined by its abundance and its strong form of crystallization. Pyrite locally displays considerable cataclasis on account of its brittleness. The effects range from slight to intense fracturing (Fig. 3) culminating in pronounced brecciation and mylonitization (Fig. 4). Rectangular sections of pyrite cubes are common.

Fig. 3. Photograph illustrating moderate to intense fracturing in pyrite. Incident light, × 300, oil.

Fig. 4. Photograph illustrating brecciation of pyrite crystals. Incident light, × 300, oil.
in polished sections (Fig. 5). Tertiary shadows were also observed. The develop-
ment of porphyroblasts of pyrite is quite common at Mahd Adh Dhitab. The crys-
tals may reach more than 2 cm across. Several types of porphyroblasts are distin-
guished based on morphology, texture and types of inclusions present. They prob-
ably represent porphyroblasts developed at several stages during successive periods of
metamorphism. Types of porphyroblasts observed are:

1. - Euhedral to subhedral pyrite with very low microporosity. The porphyro-
blasts are either unfractured or very slightly fractured with the fractures vacant or fil-
led by gangue (Fig. 5).

2. - Subhedral porphyroblasts with relatively high microporosity. The core of the
crystal is often occupied by unfractured subhedral quartz (Fig. 6). Fracturing is slight
to absent.

Fig. 5. Photomicrograph showing euhedral vesicles and rectangular sections of pyrite, incident light × 100.

Fig. 6. Photomicrograph of subhedral to euhedral pyrite porphyroblasts with cores occupied by subhedral quartz, incident light, × 100, oil.
3. Anhedral, rounded and rotated pyrite porphyroblasts. In some crystals the rounding is almost perfect, and few exhibit "tails" or curved inclusion trails depicting effects of rotation. Syntectonic growth of rotating pyrite porphyroblasts with curved inclusion-trails was first described by Carstens (1944). Randohr (1969) emphasized that such inclusions, still retaining the orientation and grain size they had before being captured, offer most valuable information regarding the metamorphic history of ore bodies. The porphyroblasts are commonly traversed by veinlets of chalcopyrite and sphalerite. The crystals may be devoid of inclusions, or contain varying amounts of small rounded, curved or irregularly shaped inclusions of base metal sulfides. These inclusions are usually restricted to the core of the porphyroblast, but in some instances they may delineate part of the growth pattern of the pyrite (Fig. 7).

Another type of inclusions present are those of acicular crystals of specularite that are usually aligned parallel to the growth lines of the growing pyritic porphyroblast (Fig. 9). Some of the pyritic porphyroblasts are strained causing slight anomalous anisotropism.

Under thermal metamorphism, pyrite recrystallizes with the development of 120 triple junctions characteristic of equilibrated annealed textures (Fig. 9). Minute films of chalcopyrite tend to collect along such junctions and/or spread along pyritic interfaces. The recrystallization effects are also apparent where the growth of pyritic grains during metamorphism has trapped base metal sulfide grains (Fig. 10).

Growth textures, probably reflecting metamorphic development, are abundant in pyrite but usually requires etching to be made readily visible. Many pyrite crystals, with or without discernible growth zoning, possess a polycrystalline internal texture (brought about by etching) in spite of their external appearance as single crystals. Initially polycrystalline aggregates are unlikely to have grown into a form which possessed the external morphology of a single crystal (Craig 1983). Thus the polycrystalline
nature may be due to recrystallization at the metamorphic maximum.

Pyrite sometimes occurs as aggregates of fine cubes < 50 \mu m in size, whereas in other instances, it occurs as single grains of a larger size. The differences in size could be explained in terms of the rate of nucleation and precipitation. It is also a function of temperature and cooling rate. When the rates of precipitation were high, this resulted in rapid deposition of globular to spheroidal masses of FeS, which subsequently recrystallized to form the present fine-grained aggregates. On the other hand when the temperature is high, the nucleation rate is low and the result is the growth of fewer and larger single crystals. These changes in rates of pyrite precipitation and crystallization probably also reflect intermittent discharge of the hydrothermal solutions.
Spheroidization (i.e., attainment of near-minimum surface area in order to minimize surface free energy) is also noticed in pyrite grains embedded in quartz grains. The pyrite also form botryoidal or colloform bunch up to few mm in length (Fig. 11). This texture is similar to what Ramanathan (1969) calls bird’s eye structure formed by alteration of pyrhotite along (1101) to produce fine-grained pyrite + martinite.

Fig. 11. Photomicrograph showing colloform banding in pyrite. Incident light, × 300, oil.

Sphalerite

Sphalerite is the most abundant of the base-metal sulfides at Mahd Adh Dhahab deposit, and generally ranges between 1 to 15 volume% of all vein sulfides but may locally reach up to 70%. Although sphalerite is known as one of the more refractory
sulfide minerals (Barton and Skinner 1979), some of the sphalerite at Mahid Ath Dhuahab has recrystallized and homogenized during metamorphism. Electron microprobe traverses across sphalerite reveal homogeneous Fe contents within the same grain averaging 0.60%. However, the Fe content of sphalerite varies from 0.00 to 2.65%. Highly rounded blebs of sphalerite in chalcopyrite or isolated in pyrite crystals are very common in the deposit. Many of the sphalerites contain randomly disseminated or aligned blebs of chalcopyrite (Fig. 12), similar to Barton’s (1987) “chal-

Fig. 12. Photomicrograph of randomly oriented blebs of chalcopyrite in sphalerite. Note the rim of fine-grained chalcopyrite enclosing lower and coarse chalcopyrite. Incident light, × 300, col.

copyrite disease.” These chalcopyrite grains, once thought to be the result of exsolution, are now interpreted as replacement or epitaxial features; the solubility of Cu in sphalerite is not sufficient for exsolution to be responsible for its development (Wiggins and Craig 1980; Hutchinson and Scott 1981). During metamorphism, the chalcopyrite has commonly migrated from the interiors of the individual sphalerite grains to grain boundaries or to the periphery of the sphalerite aggregate where it remains as rims as shown in Fig. 13.

The grains of sphalerite differ in the intensity of development and patterns of distribution of chalcopyrite intergrowths. The following are some examples of the patterns observed:

1 – A “ring” of fine-grained chalcopyrite enclosing a core of sphalerite containing a central zone of coarse, vermicular chalcopyrite (Fig. 12).

2 – Unusually coarse and anhedral chalcopyrite in the outer periphery of sphalerite passing gradually into much finer chalcopyrite in the core (Fig. 14).

3 – Chalcopyrite aggregates showing strong resemblance to myrmekitic intergrowths.

4 – Fine anhedral, irregularly shaped blebs of chalcopyrite that show parallel alignment within the same sphalerite crystal.

5 – Fine acicular plates that are arranged along one or more directions.
Sphalerite with no chalcopyrite intergrowths can be found encrusting chalcopyrite-diseased sphalerite as well as other clasts containing chalcopyrite. Clear (and undiseased) sphalerite also overgrows (Fig. 15) and fills cracks in diseased sphalerite. The chalcopyrite-free areas may be due to annealing which locally drove the chalcopyrite inclusions out of the sphalerite. Also some of the apparently undiseased sphalerite may contain submicroscopic chalcopyrite disease that is only apparent in transmitted light. Some zones within sphalerite are more strongly diseased than others. The chalcopyrite disease has not been observed in any mineral other than sphalerite.

Several processes may be considered to explain the development of chalcopyrite disease in sphalerite:
(1) Textural phenomena: This is unlikely because it was shown experimentally that coalescence is not a viable mechanism (Hutchinson 1978; Eldridge et al. 1985).

(2) Physical segregation of remnants of a prismatic stage of ore formation (Yee 1983). This process implies that sphalerite and chalcopyrite formed contemporaneously as small (<1 μm) blebs and that sphalerite grew into present grain size (up to 3 mm) while pushing and squeezing the small chalcopyrite blebs to grain boundaries. Though some co-precipitated sphalerite and chalcopyrite intergrowths are observed, this process is incapable of explaining the vast majority of the textures.

(3) Supergene phenomena (De Waal and Johnson 1981). This process is inapplicable since the discolor show no relationship to covellite, bornite or any other possible supergene mineral.

(4) The breakdown of a metastable Cu-Zn-Fe-S phase such as that found by Claeck (1970) in the supergene enrichment zone of a porphyry copper deposit. This possibility entails growth of a metastable Cu-Zn-Fe-S mineral which will breakdown to yield CuFeS₂ + ZnS.

(5) Interaction of sphalerite with later ore forming fluids (Eldridge et al. 1983; Barton 1987). One of the possible mechanisms (Eldridge et al. 1983) involves removal of Cu originally dissolved in sphalerite by interaction with fluids of higher sulphur fugacity such as:

\[ Zn_{0.04}Fe_{0.15}Cu_{0.85}S + 0.04S = Zn_{0.04}Fe_{0.15}Cu_{0.85}S + 0.04CuFeS_2. \]

The initial Cu content of sphalerite is the limiting factor of the extent of the change. However, the initial sphalerite is unlikely to have contained sufficient Cu to form chalcopyrite.

Another mechanism suggested by Eldridge et al. (1983) is the reaction between sphalerite and Cu-bearing fluids. It may begin as a replacement of the FeS component of sphalerite in reactions such as:
Metamorphic recrystallization: This involves the action of metamorphic re-mobilization and re-equilibration. During the low-grade metamorphism to which the deposit and encasing country rocks were subjected, Ca-bearing solutions were generated and move along microfractures. These solutions replaced the FeS and ZnS components in sphalerite. This process occurred at several episodes during the metamorphism of the deposit with the result that there are multiple stages of chalcopyrite disease superimposed on each other. In other words, the chalcopyrite disease was a series of repeated events occurring during successive periods of metamorphism. During the slow and intermittent percolation of such solutions within sphalerite, they developed a multitude of nucleation centers around which plates of chalcopyrite were formed. It must be noted, however, that examples of the disease process going to complete replacement of sphalerite have not been found. Only examples of intensely disced sphalerite have been observed. It is conceivable that the chalcopyrite disease represents a part of the processes that caused the whole-site replacement of the other sulfides by chalcopyrite.

Localized effects of dynamic metamorphism are evident through the presence of intensely fractured and/or mylonitized sphalerite (Fig. 16). In addition, deformation along faults or shear zones has locally lead to ductile flow of the softer sulfides (sphalerite, galena, and chalcopyrite). Such deformation products are recognized by an extremely deformed fabric unless later modified by annealing. Thus sphalerite commonly forms stretched and irregularly elongated patches that occupy microfractures or line cavities and spaces between gangue minerals. The elongation of sphalerite has been ascribed to twin gliding during deformation.

With increasing depth, sphalerite becomes coarser and more euhedral. It is com-

![Fig. 16. Photomicrograph illustrating intensely fractured sphalerite. Incident lighe, x 308, oil.](image-url)
monly seen as subhedral to euhedral crystals lining former cavities or as crystal fragments. Etching reveals that the largest sphalerite grains (up to 3 mm) consist of clusters of smaller subgrains. Crystals may grow together to form semilunar to curved bands. Sphalerite crystals at Mahd Adh Dahab do not show any discernible growth banding on close examination of doubly polished thin sections. This is attributable to recrystallization during metamorphism. Few examples of frambooidal sphalerite were observed in the upper parts of the deposit. Three processes make it very difficult to correlate growth stratigraphy of one sphalerite crystal to another:

1. Coarse-grained sphalerite crystals may have been broken and mixed with other mineral fragments. Homogeneous aggregates of crystals were also recrystallized by late sulfides or gangue minerals.

2. Hydrothermal dissolution may have removed part of the growth history of sphalerite, creating a microkarst texture (Barton 1987) similar to those described in sphalerite from Mississippi Valley-type deposits and vein deposits.

3. Partial replacement of sphalerite by chalcopyrite (chalcopyrite disease) masks the initial character of much of the sphalerite.

**Chalcopyrite**

Chalcopyrite is the second most abundant base metal sulfide in the veins. It occurs as disseminated anhedral grains or irregular patches interstitial to pyrite and siliicates. In contrast to the other sulfides, the chalcopyrite is nearly always massive and anhedral. Chalcopyrite increases in abundance from the top of the ore downward. With increasing abundance, its boundaries with the other sulfides become increasingly cuspathe (Fig. 17). Associated with the increased rounding of other sulfides against chalcopyrite is an increase in the porosity. The migration of chalcopyrite to low pressure areas during metasomatism is evidenced by its abundant occurrence in fractures and cracks in pyrite grains and in the siliicates included within, and
peripheral to the ore deposit. Chalcopyrite also commonly occurs as randomly, or
aligned disseminated grains and rods dispersed within sphalerite.

The typical textural relationships between chalcopyrite and the other base metal
sulfides in the deposit can be summarized as follows:

1) Chalcopyrite fills gaps in the outer shell of pyrite cubes and often penetrates to
   the interior of cubes to form atoll texture;

2) Chalcopyrite encloses small rounded islands separate from peninsulas or scal-
   leped masses of sphalerite, pyrite or galena (Fig. 18).

![Fig. 18: Photomicrograph of chalcopyrite encasing islands of base metal sulfides. Incident light, x 308.](image)

3) Chalcopyrite surrounds highly rounded crystals of pyrite, sphalerite and galena
   (Fig. 19).

![Fig. 19: Photomicrograph showing round pyrite surrounded by chalcopyrite. Incident light, x 308. oil.](image)
4) Chalcopyrite forms the chalcopirite disease in sphalerite; and
5) Chalcopyrite appears in some cases to have superimposed in minor amounts with the other sulfides either in small "tules" along growth horizons or as patches with mutual boundaries.

Deformation twinning is commonly developed in patches of interlaced to subbedular chalcopyrite (Fig. 20). Slight to moderate fracturing are observed occasionally and reflect effects of dynamic metamorphism.

Fine lamellae of bornite are often observed in some chalcopyrite grains, particularly along fractures and cracks. They are probably the result of weathering of chalcopyrite.

**Galena**

Galena is the least abundant of the sulfides. It occurs as disseminated grains and in cross cutting veined. It also forms anhedral to subbedular beds and irregularly shaped patches. These forms are typically tightly intergrown with sphalerite and pyrite. Galena is found occasionally as large and irregularly shaped patches that are abundantly intergrown with sphalerite and pyrite. There is multiplicity in the direction of elongation in these patches, indicating that several individual crystals may be contained in each galena mass.

Galena is often crosscut by and enclosed in chalcopyrite indicating that the majority of the galena formed before chalcopyrite. However, small quantities of galena formed after chalcopyrite, as indicated by the occurrence of galena encrusting on or filling cracks in clasts of ore containing chalcopyrite. As the weathers the grain size and chalcopyrite content increase with depth, the abundance of galena decreases, and the abundance of rounded galena inclusions in chalcopyrite increases. In rela-
Tellurides

Minerals of the telluride group are less abundant than galena. The tellurides have poorly developed crystal outlines and typically occur as irregularly shaped patches intergrown with the sulfides described above. Small islands of tellurides surrounded by chalcopyrite are very common (Fig. 22).

Precious metals

The behavior of the precious metal-bearing metamorphosis is not well understood. Gold is present almost entirely as disseminated fine-grained ore in close association with chalcopyrite, sphalerite, galena, and quartz. Substantial Au occurs as pyrite, Ag, Au, Te, (Atf. 1990). It also occurs as very thin irregular streaks and veining that have irregular mutual boundaries with the associated sulfides and gangue. Due to the unique physical and chemical characteristics of gold (e.g., extreme softness, low power of crystallization, and resistance to chemical reactions) it is difficult to assess effects of metamorphism on gold. Mobilization of gold usually occurs at high metamorphic grade. However, it is reasonable to assume that at least part of the
originally disseminated gold has been renobilized during metamorphism. This would probably involve coalescence of the fine-grained gold into irregular patches, or its physical migration into elongated streaks within microfractures in the associated sulfides.

Summary and Conclusions

Textural and mineralogical features observed in the ore deposits at Mahd Adh Dhabab indicate that the deposits have been subjected to metamorphism.

Three main effects were recognized: Recrystallization of the ores during regional metamorphism resulted in changes mainly in the fabric of the ores. With increasing metamorphism: a) there is a general increase in grain size; b) growth of pyrite as porphyroblasts; c) presence of triple junction point texture and d) sulfidation of iron-bearing minerals.

Deformational effects present varied from none, through brittle cataclasis to ductile deformation. The features observed include: a) fracturing, brecciation and mylonitization of fine-grained sulfides and porphyroblasts, b) deformation twinning, c) replacement, d) folding and disruption of cleavage traces, e) rotation of pyrite crystals, and f) stretching and elongation of soft sulfides.

Renobilization produced irregular bodies of vein quartz and ore minerals, either within the deposits or in their immediate country rocks. The renobilization distances are limited, either within parent body or in restricted halo surrounding it (up to some tens of meters). The renobilization is selective and proceeded by creep or fluid-phase transport. The apparent order of increasing mobility is: most mobile (galena and chalcopyrite), mobile (sphalerite), least mobile (pyrite). Certain replacement phenomena observed between the cuenfidal-subcuenfidal pyrite grains and the base metal sulfides could be ascribed to metamorphism.
The multitude of metamorphic features observed and their varied nature suggest that the ores at Mahd Adh-Dhabah area were subjected to polytextural episodes. Successive episodes of low grade metamorphism prevailed during a long time span. Intermediate with such pervasive regional metamorphism, the ores were subjected to short periods of essentially dynamic and thermal metamorphism.

References


بحسب الكسنيدات وآراء التحول في منهج المهد الذهبي

للملكة العربية السعودية

الخطب: يفيد منهج المهد الذهبي في وضع الحرم العربي وغيره في منهج المهد الذهبي في المملكة العربية السعودية، حيث يركز على التعليم الذي يجب أن تقوم بتوجيهه في الامتحان على أن يكون الأخلاقيات تغطي أدوات ادوات المباني.

تتبع هناك عدة أنواع من حضور الحضور في إعادة التجهيز والتحديث وفترة المهد.

تتبع عن إعادة شكل الحرم الذهبي في الأسلوب، وكذلك في عناوين الحصن،

وهو نتاج من التحول أوامر الاحترام في حماية الحصين، ب- نمو البروتين على هيئة نموذج، و- حذف الخطاط النقدي، أما المذكرة النائية عن الشروع في التنوير من أساس، إلى نموذج آخر إلى نموذج آخر، و- ج- تقنية، وتغفيت الكشفات ذات الجودة الحديثة والبروتينات، ب- نموذج شرارة، و- د- نموذج ضبط الإitating، و- إدراك إنتاج البروتين، و- ه- تقنية، و- وضع واسطةكربريات الشفيرة.

تتبع عن إعادة ترك الحرم الذهبي على أساس مبدأ منطقية الأخلاق كي يجري الرؤية والعمل.

الهواج: إذا ما يكون الحرم الألمني من الصحوة الخلاقة، فهناك ترك الحرم الألمني في حضور الحضور، الذي ي 输入 بشكل جيد يمكن أن يكمل من حيث الفهامة والходимية.

التحول يدخل من خلال ذلك إلى الحضور، يدخل واضحاً في إدراك البروتين الشفيرة، والتحويلا، وكثيراً ما يكون من خلال الشفيرة على الميدان.

تتبع عن إعادة نموذج المهد الذهبي إلى الشفيرة. لكي يكون نموذج القلائد

الأخلاقي المثبتر على مدار نموذج أفقية طويلة من الميثاق الخلاق، فإن مثبتر نموذج النحات

الديني، والتحول الحاوي.