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Alteration Zones: Are They a Good Target for Gold Deposits in Egypt?

Abstract: Extensive rock alterations are a clearly visible characteristic of most Egyptian gold deposits and occurrences. The alterations occur either surrounding the auriferous quartz veins and/or structurally controlled by specific structural features, such as fractures and shear surfaces.

Some samples of these alteration zones have proved to be anomalously enriched in gold while others are completely barren. Accordingly there is a controversy on the merit of alteration zones as a good lead to gold. Here, the various types of wall-rock alterations are reviewed with a discussion on the possible reactions that could have generated them. It is concluded that two main styles of alterations could be recognized in the field. The first results during the liberation of gold from the source rocks, and is characterized by being widely distributed and spatial relation to major structures. The second style, however, is related to the deposition of gold and is recognizable only within a few meters of the auriferous quartz veins. The potentiality of each style is discussed and some applications of the concept are offered.

In general, alterations accompanying the liberation of gold are not completely devoid of gold, but may still retain some gold depending on the mineralogical siting of gold in the source rocks. Moreover, this type of alteration is a good criterion for the presence of gold in nearby sites. Alterations accompanying deposition of gold, on the other hand, constitute a good target for gold, particularly the portions that are dissected by minor quartz veins, veinlets and stockworks (silicification) where gold is believed to migrate to such sites with silica liberated during the different types of alterations.

The presence of some efficient precipitants, such as sulphides, carbonates, clay minerals, sericite, iron oxides, chlorite and graphite in the alteration zones is a good indicator of the potentiality of the alteration zone.

Keywords: Egypt, alteration zones, geology, rock, gold deposits.

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هل تعتبر صخور الجدار المتغايرة مكمناً جيداً لرواسب الذهب في مصر؟

ناجي شوقي بطرس

المستخلص: تعتبر صخور الجدار المتغايرة (نطاقات التغاير) و المصاحبة لقرارات الذهب في مصر، من أهم مميزات تلك القرارات، و تتواجد إما حول عروق المرو أو مرتبطة بمناطق الضعف أو كلاهما ، ويتراوح سمك نطاقات التغاير من عدة سنتيمترات إلي بضع كيلومترات . من الملاحظ لا أنة عند تحليل عينات صخور الجدار المتغايرة، خاصة المحيطة بعروق المرو: أن نسبة الذهب تتفاوت من عينة إلى أخرى، حتى في المنطقة الواحدة و في نفس نوع التغاير؛ الوضع الذي يتطلب دراسة جدوى هذه النطاقات و بيان سبب هذا التفاوت في نسبة الذهب. يتناول البحث نوعين من نطاقات التغاير. الأول يحيط بعروق المرو، و يشمل أنواع التغاير المعروفة، مثل السر ستة؛ الكلورة و الكربنة. أوضح البحث بمعادلات كيمائية عديدة، أن كل هذه العمليات طاردة للسليكا، و التي يعتقد أنها توجد في حالة غروية و مختلطة بغرويات من أكاسيد الحديد المائي، مما يعكس شحنة التكهرب للسليكا من شحنة سالبة إلي شحنة موجبة. و هذا يؤدى بدورة إلي جذب غرويات الذهب و معقدات الذهب، و التي تحمل شحنة سالبة. و تنتقل السليكا بما تحمل من الذهب إلي مناطق الانفصام (البتر) الفرعية داخل نطاقات التغاير ذاتها، حيث تتبلور علي هيئة عريقات ثانوية للمرو حاملة للذهب. عليه يتضح أن أجزاء معينة من نطاقات التغاير، وهى التي تحتوى علي عريقات المرو الثانوية، تعتبر مكمناً جيداً للذهب أكثر من غيرها . ركز البحث على أهمية وجود بعض المعادن في نطاقات تغاير النوع الأول، مثل معادن الكبرتيدات ؛الكربونات ؛معادن الطين ؛ أكاسيد الحديد؛الكلوريت و الجرافيت، حيث أن وجود هذه المعادن يوحي بزيادة ملحوظة في نسبة الذهب في نطاقات التغاير المحيطة بعروق المرو.

اما النوع الثاني من نطاقات التغاير، يتميز بالانتشار الواسع و المرتبط بنطاقات التكسير الضخمة، حيث يتم شطف الذهب من بعض الصخور أثناء عملية التغاير (مثل عملية الكربنة للصخور الفوق مافية)؛ وبالتالي فان احتمالية وجود الذهب في هذا النوع ، تتوقف على مدى ملائمة الذهب للشطف من عدمه في هذه الصخور.

كلمات مدخلية: مصر، جيولوجيا، نطاقات التغاير ، صخور، ذهب، رواسب.

Introduction

More than 95 localities for gold deposits and occurrences are known in Egypt. Most of these have been worked out since Pharaonic and Roman times. In most of these deposits, quartz veins constituted the main target for gold. Recently, wall-rock alterations (alteration zones) surrounding the quartz veins have been taken into consideration as a target for gold (Botros, 1993b) where the gold contents in these zones may be reasonably high (Osman and Dardir, 1986, and Takla *et.al.* 1989). However, sampling of alteration zones is more troublesome where the gold content ranges widely from sample to sample and any review in recent papers reveals that some of these alteration zones are anomalously enriched in gold in some sites while others are depleted or barren of gold even in the same district. For example, Oweis and Khalid, (1991), mentioned that group II contains gold up to 6g/ton and group III contains gold from 2 to 5 gram/ton in Um Qareiyat gold deposit whereas group I in the same mine, with the same alterations, has gold values of less than 0.1g/ton. Also, Khalaf and Oweiss, (1993) stated that beresite zone (Zone 8) in Sukkari gold deposit contains gold in amounts varying from 0. 001g/ton to 15g/ton.

Although the author is aware that gold cannot be uniformally distributed in any medium, the wide range of variability of gold values in alteration zones gives rise to many questions. Do alteration zones actually constitute a good "pathfinder" for gold mineralization in any exploration program in the Eastern Desert? Do we have to sample and check any alteration zone for its gold content? Are there any alterations that should be taken into consideration if we deal with different types of alterations?

The present paper discusses the controversy about the potentiality of alteration zones. The paper reviews the definition of wall-rock alterations and their characteristics and then proceeds to discuss the chemical reactions that are responsible for these alterations. An attempt is made to classify these alterations according to their relative importance in exploration.

Types of Wall-Rock Alterations in the Gold Deposits of Egypt and their Chemistry

Wall-rock alterations (alteration zones) occur either surrounding the auriferous quartz veins (Fig. 1) and/or are structurally controlled by tectonic disturbances (Botros, 1991) of local (Fig. 2) and regional extent. The most common types of wall-rock alterations in the Egyptian gold deposits and occurrences are sericitization, beresitization, alunitization, silicification, ferrugination, carbonatization, listwaenitization, chloritization, propylitization and kaolinitization. A brief review of these alterations and their chemistry is given hereafter.

Fig. 1: Alteration zones surrounding auriferous quartz vein.Um Balad gold prospect.depleted, transitional and anomalous zones in any lateral section of alteration zone surrounding an auriferous quartz vein.

Fig. 2: Wall-rock alteration along shears in granite. Um Monqul gold prospect.

1-Sericitization. This alteration is the most common type of wall-rock alteration in gold deposits. It is developed mainly in acidic rocks; however, occurrence of such alteration in intermediate and mafic rocks is not uncommon (Boyle, 1979). This is clear in the Egyptian gold deposits where such alteration is encountered in felsite and felsite porphyries of Fatiri and gabbroic rocks of Um Tenedba (Botros, 1991 and Takla *et al.* 1989).

Sericitization involves the development of sericite as a result of the hydration of feldspar or from the rearrangement of K, Al, and SiO_2 within the intensively altered wall rocks (Maclean and Barret, 1993) (Fig. 3). Chemically, sericitization embraces introduction of K and H_2O and sometimes CO_2 into the rock undergoing alteration and there is a removal of some SiO_2 and Na (Boyle, 1979, Colvine *et al.* 1988). Some possible reactions that could generate sericite are provided below. These reactions are consistent with the observed geochemical-mass balances for altered rocks (Colvine *et al.* 1988).

$NaAlSi_3O_8 + K^+ + 2H^+ \rightarrow KAl_3Si_3O_{10}(OH)_2 + \mathbf{6\ SiO_2} + 3Na^+$

Albite Sericite **Quartz** ------ (1)

$4(N,K)AlSi_3O_8 + 2H^+ \rightarrow NaAlSi_3O_8 + KAl_3Si_3O_{10}(OH)_2 + \mathbf{6SiO_2} + 2Na^+$

Alkali-feldspar Albite Sericite **Quartz** ---- (2)

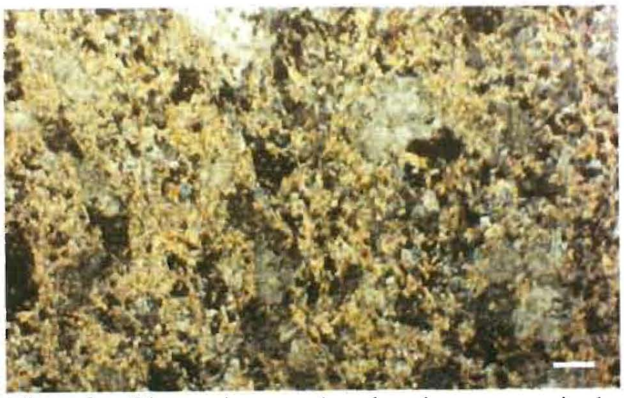

Fig. 3: Photomicrograph showing extensively sericitized (Ser.) feldspars in felsites. Fatiri gold mine. Plane polarized light, crossed nicols. Bar length represents 1mm.

From these possible reactions one can notice that silica is generally liberated , and may crystallize as quartz in the alteration zone or be transferred to the veins or other dilitant zones (Boyle, 1979) (Fig. 4).

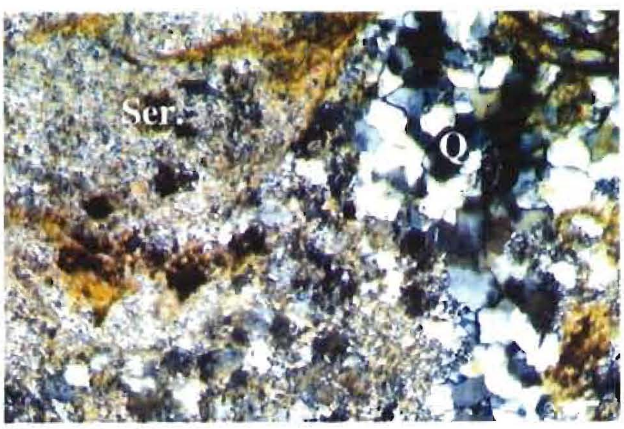

Fig. 4: Photomicrograph showing secondary quartz (Q) accompanying extensive sericitization (Ser.) of feldspars of granite. Abu Marawat gold prospect. Plane polarized light, crossed nicols. Bar length represents 0.39 mm.

2-Beresitization. The beresitized wall-rocks are also common in many gold deposits and occurrences and in the Egyptian gold deposits. This alteration is exemplified by the beresitized zones along fractures in Sukkari plagiogranite (Hassaan et al., 1990). The process involves introduction of K, CO_2, and H_2O with a depletion of Fe^{+}+, Al^{+}+ and SiO_2 (Boyle, 1979). The resultant SiO_2 crystallizes as quartz veinlets in the beresitized zone. This is evident by the observation of Khalaf and Oweiss (1993) that the beresitized zone of Sukkari gold deposit is characterized by enclosing numerous quartz veinlets of different thicknesses (1mm to 30cm) arranged parallel to the main auriferous quartz vein.

3-Alunitization. This type of alteration involves the development of alunite $KA_{13}(SO_4)_2(OH)_6$ which is usually accompanied by a series of minerals that are typified by an abundance of sulphur, both as sulphates and sulphides (Bonham, 1989). In south Um Monqul gold prospect dacite and rhyodacite porphyry are extensively altered to alunite and pyrophyllite (Botros, 1999) (Fig. 5).

Chemically, alunitization involves introduction

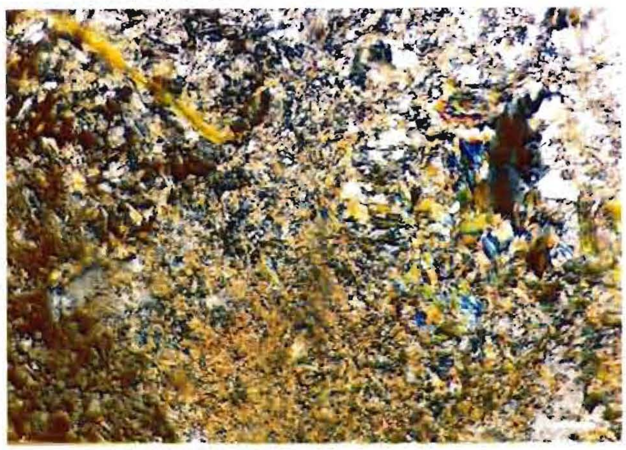

Fig 5: Photomicrograph showing aggregates of alunite in granite porphyry, Um Monqul gold prospect. Plane polarized light, crossed nicols. Bar length represents 0.39 mm.

of S and H_2O and removal of SiO_2 (Boyle, 1979), where the liberated silica migrates to subsidiary fractures and crystallizes as quartz veinlets.

4-Silicification. This type of alteration may be defined as an increase in the proportion of quartz (Troop, 1986). Chemically, the process of silicification involves redistribution of SiO_2 within the host rocks; i.e., leached in one place and added in another (Boyle, 1979). The most common examples of silicification in gold deposits and occurrences of Egypt are represented by silicification of ultramafic rocks in the Hutite gold deposit (Takla *et al.* 1989) and silicification of volcanic rocks in the Hamash area (Hilmy and Osman, 1989).

5-Ferrugination. Ferrugination is a general term that is used to refer to the growth of iron-bearing minerals along fractures (Fig. 6). It may include pyritization (Colvine *et al.* 1984) and arsenopyritization (Bullis, 1987). Examples of ferrugination are the pyritized granites of the Atalla deposit (Sabet and Bordonosove, 1984) and the pyritized felsite in the Fatiri area (Botros, 1991). In both localities pyritization of the wall rocks is of great importance as a large proportion of the gold is hosted in pyrite.

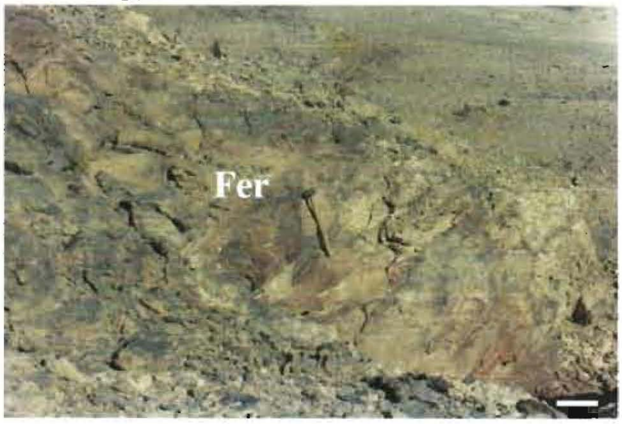

Fig. 6: Ferrugination (Fer.) along a major shear in granite. Atall gold mine.

6-Carbonatization. This process is one of the most common alterations in the Egyptian gold deposits and occurrences (e.g. Barramiya, Hutite, El Sid, Abu Marawat). The process involves the formation of carbonates in the affected host rocks (Fig. 7). It may include the formation of calcite and/or dolomite (Colvine *et al.* 1988).

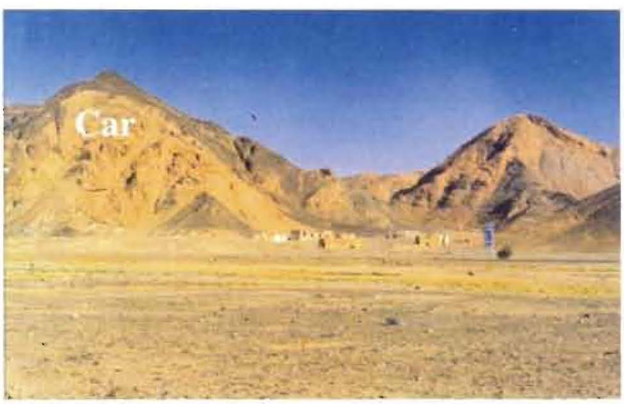

Fig. 7: Carbonated rocks (Car.) associated with serpetinites. Barramiya gold mine.

In the following, some possible reactions that lead to the formation of calcite and dolomite are given (Colvine *et al.* 1988):

$$3Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2 + 2Ca_2Al_3Si_3O_{12}(OH) + 10\,CO_2 + 8H_2O \longrightarrow$$

Actinolite Epidote

$$3(Mg,Fe)_5Al_2Si_3O_{10}(OH)_8 + 10\,CaCO_3 + \mathbf{21\,SiO_2}$$

Chlorite Calcite **Quartz** ——— (5)

From the previous equations, it is clear that carbonatization is accompanied by talc formation, and is marked also by a loss of silica, which is probably transferred to crystallize as quartz in veins or minor quartz veinlets in the dilatant zones of the alteration zones (Fig. 8).

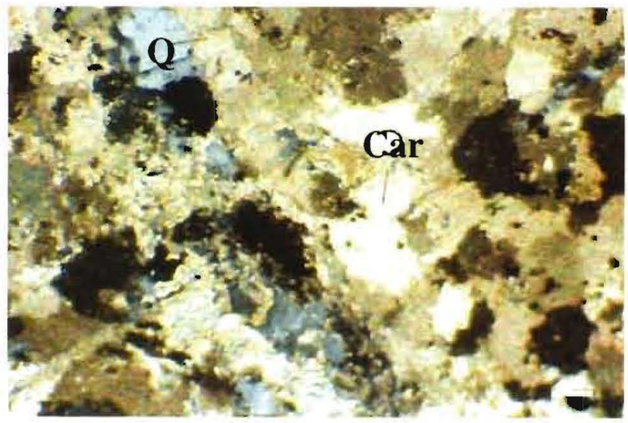

Fig. 8: Photomicrograph showing quartz aggregates (Q)-associating carbonatization (Car.) of serpetinites. Abu Marawat gold prospect. Plane polarized light, crossed nicols. Bar length represents 1mm.

7-Listwaenitization. This alteration is a special type of carbonatization where the mafic and ultramafic rocks are heavily carbonated (Buisson and Leblance, 1986). The listwaenite is generally located along tectonic contacts and grades laterally into the serpentinized ultramafic rocks through a talc carbonate zone (Buisson and Leblance, 1986). The most characteristic feature of listwaenites is their relative resistance against weathering, if compared with the surrounding rocks; accordingly, they stand out forming prominent topographic ridges (Fig. 8). Chemically, listwaenitization involves an introduction of K, Ca, Al, CO_2 and H2O and an abstraction of SiO_2 (Boyle, 1979). The most common examples of listwaenites are encountered at Barramiya gold deposit (Fig. 9) (Sabet and Bordonosove, 1984), Sukkari, Um Ud and Samut (Hassaan *et al.* 1990) and Abu Marawat (Botros, 1991).

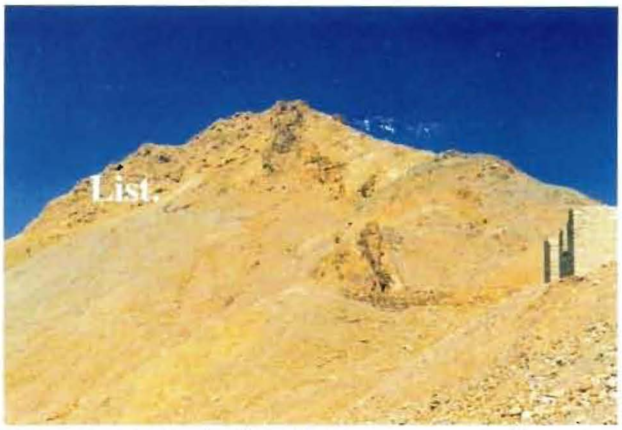

Fig. 9: Listwaenite (List.) ridge surrounded by talc-carbonates on both sides. Barramiya gold mine.

8-Chloritization. Chloritization is one of the most common types of alterations in areas of gold deposits and occurrences. It is usually associated with carbonatization (Neall and Phillips1987). During these alterations H_2O and CO_2 are introduced and some SiO_2 is removed (Maclean and Barret, 1993). Secondary pyrite and arsenopyrite may develop in this type of alteration, on condition that iron is fixed and S and As are introduced to the host rocks (Boyle, 1979).

A possible equation in the mafic rocks that can lead to formation of chloritized zones is given (Colvine *et al.* 1988):

$3Ca_2(Mg,Fe)_5\ Si_8O_{22}(OH)_2+6CO_2+2H_2O \longrightarrow 5(Mg,Fe)3Si_4O_{10}(OH)_2+6CaCO_3$

Tremolite Talc Calcite

+4 SiO2

Quartz ——————————————(3)

$Mg_3Si_4O_{10}(OH)_2 + 3CaCO_3 + 3CO_2 \rightarrow 3CaMg(CO_3)_2+$

Talc Calcite Dolomite

$4SiO_2$ $+H_2O$

Quartz ——————————————(4)

From this equation of alteration, it is clear that there is a removal of SiO_2 and carbonatization may accompany chloritization of mafic rocks.

Examples from Egypt of hydrothermally chloritized rocks are encountered at Hanglia (Osman and Dardir, 1989), Um Monqul (Botros, 1991) and Um Rus gold mine (Harraz and El Dahhar, 1994).

9-Propylitization. This alteration is commonly associated with mafic rocks and is manifested by the development of secondary minerals of green colors as chlorite, epidote, actinolite, uralite and prehnite. Most commonly the process of propylitization is associated with chloritization,carbonatization, pyritization and silicification. Boyle (1979) believes that all these alterations require the introduction of much water, CO_2, S and As. SiO_2 is usually liberated and may crystallize as quartz in the alteration zone or be transferred to the veins or other diltant zones.

Examples of propylitization in Egypt are encountered in Hamash (Hilmy and Osman, 1989), Atud and Sabahia (Osman and Dardir, 1989) and Um Balad (Botros, 1991).

10-Kaolinitization. This type of alteration consists of the development of clay minerals in the wall rocks of the altered rocks. The process seems to include essentially introduction of H_2O and a removal of some SiO_2 (Fig. 10). Examples of kaolinitization are observed in Hangalia (Osman and Dardir,1989).

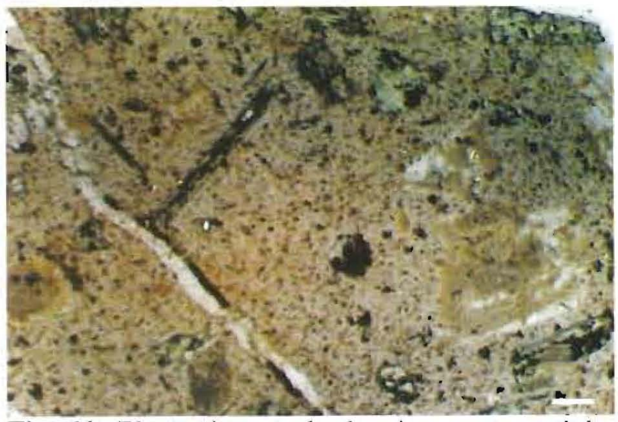

Fig. 10: Photomicrograph showing quartz veinlet (Q) accompanying kaolinitization (Kaol.) of plagioclase in granites. Fawakhir gold mine. Plane polarized light, crossed nicols. Bar length represents 1.22 mm.

Discussion

This review reveals ten different types of wall-rock alterations in the gold deposits and occurrences in Egypt. In spite of the diversity of these alterations and the variety of the host rocks that are affected, they all share a common feature of silica release from the rock undergoing these alterations.

Where does the liberated silica go? It is believed that the silica liberated in most reactions migrates to subsidiary fractures in the affected rocks where it crystallizes as quartz veinlets or lenses in the alteration zones themselves (Figs.4, 8, 10). The liberated silica is usually colloidal and carries a negative charge (Boyle, 1979). On the other hand, (gold–chloride) and (gold-bisulphide) complexes, as well as colloidal gold, have a negative charge. Stabilization of these negative charges is accomplished by numerous compounds, the most common of them being colloidal silica.

Theoretically, liberated silica with its negative charge should repeal and disperse the colloidal gold and the anionic gold complexes (negative charge). In nature, however, the theory does not in general apply (Boyle, 1979), for we find the ultimate association of gold and silica in all gold deposits and occurrences. The reason for this lies in the fact that silica gel is seldom found in a pure state. Most is highly contaminated by hydrous ferric oxide and alumina gels. This contamination reverses the charge of colloidal silica from negative to positive (Boyle, 1979) and accordingly colloidal gold and gold complexes (negative charges) are adsorbed to this contaminated silica. This may explain why most of the quartz veinlets distributed in the alteration zones of the Egyptian gold deposits are ferruginated and not existing in a pure state (Osman and Dardir,1989; Harraz and El-Dahhar,1994) .

Colloidal gold and gold complexes adsorbed to the liberated silica migrate together to the quartz veins of the main shear and/or its adjacent parts where subsidiary shear zones and other structural locales or openings that are usually parallel to the main shear are dominated.

To sum up, in any alteration zone surrounding a quartz vein of the main shear (main lode), it is expected to find: (1) a depleted zone, (2) a slightly auriferous zone and (3) a relatively anomalous zone, depending on the presence or absence of shears which act as channels for the passage of the liberated silica. In general, the portions of the alteration zones that are far from the main shear, i.e. the near border of the alteration zone, are usually barren due to the liberation of silica (and gold) during alteration (i.e. desilicified zones) and the deficiency of subsidiary shears (Fig. 11 C). As the quartz vein of the main lode is approached, quartz veinlets, stringers and stockworks of the liberated silica are common in this highly sheared zone (Fig. 11 C) and the possibility of finding an anomalous alteration zone can exist. This zone is usually describe as wall-rock silicification. Between the two extremes all gradations can occur (Fig. 11 B). The possibility that liberated silica and associated gold migrate to the main shear (main quartz vein) only, and consequently, any sample taken from the alteration zones will be barren, is not excluded.

Figure (12) is a typical numerical example, where some host rocks of metavolcanics and volcaniclastics at Abu Marawat area were subjected to two types of alterations viz, ferrugination (F) and carbonatization (C).Gold contents in samples taken by the author from these alterations were 1.37 ppm and 1.71 ppm, respectively. (Botros,1991). Liberated silica was migrated to nearby sites ,where shears are dominated, forming a silicified zone (S) where gold values reached up to 11.29 ppm in such sites (Botros, 1991).

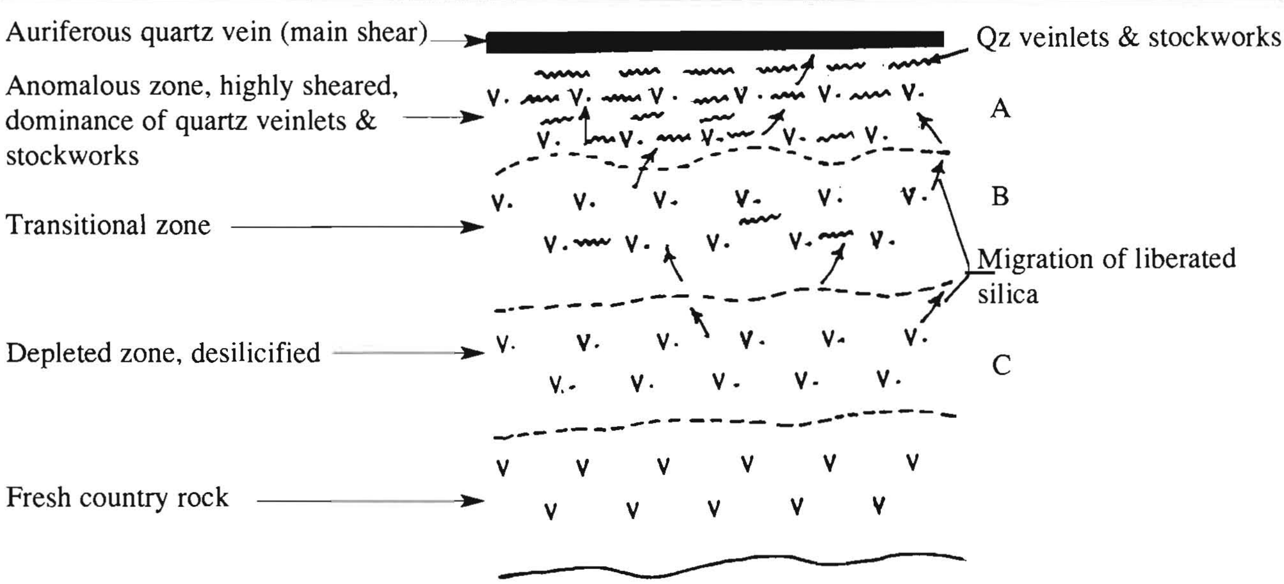

Fig. 11: Sketch showing the relative position of depleted, transitional and anomalous zones in any lateral section of alteration zone surrounding an auriferous quartz vein.

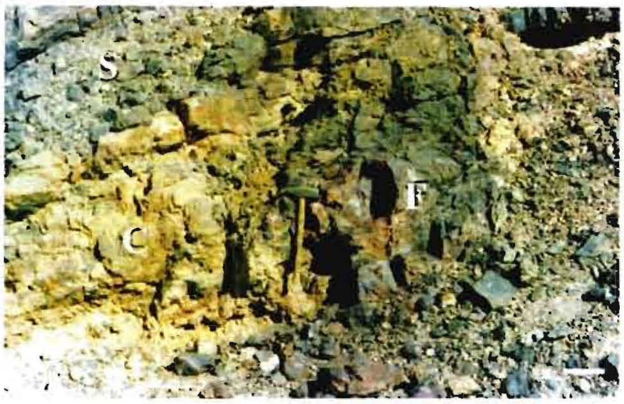

Fig. 12: Photo showing ferrugination (F), carbonatization (C) and silicification (S) of metavolcanics and metavolcaniclastic, Abu Marawat area.

Another important factor that influences the variation of gold values in alteration zones, even in the same locality, is the constituent minerals of the alteration zones. It is well known that one of the most common mechanisms in which gold may be precipitated is the reaction between gold–bearing fluids and host rocks with the consequent alteration of these rocks. The reactions cause a shift in pH of the auriferous fluid. Acidic auriferous fluids containing gold-chloride complex coming into contact with country rocks cannot precipitate their gold till a group of minerals, like carbonates for example (i.e., a reducing medium), are formed in the resultant alteration zone. Accordingly, presence of carbonate minerals among the constituent minerals of the alteration zone (in this example) is of prime importance for precipitating gold from the acidic auriferous fluids.

Similarly, auriferous alkaline fluids containing gold-bisulphide complex will precipitate their gold when such fluids come into contact with wall rocks and reactions such as sericitization, and albitization are formed. In this case, the alkaline mineralizing solution will lose alkalis such as K, Na ,etc. Hence, the pH of that solution is shifted toward the acid range. Consequently, the bi-sulphide complex will decompose and gold is precipitated. In this example also, the presence of sericite and secondary albite are of importance, being good precipitants for gold in alkaline fluids. This is indicated in Um Rus gold mine where the appearance of sericite in silica-carbonates-chlorite assemblage is concomitant with an increase in gold values from 1.5 ppm to 28 ppm (Harraz and El-Dahhar, 1994). Likewise, removal of S from the auriferous alkaline fluids, as a result of sulphidation alteration, leads to the break down of the gold-bisulphide complex and the consequent precipitation of gold, usually with sulphides (Seward, 1984).

Briefly, the most efficient precipitants in any alteration zone are sulphides, carbonates, clay minerals, sericite, iron oxides, chlorite and graphite. The presence of such minerals within alteration zones is necessary to increase the potentiality of alteration zones.

In closing such discussion, it should be pointed out that the review in this work was focussed mainly on alteration zones surrounding quartz veins, usually not exceeding some meters in the most promising localities (Hussein, 1990). These alterations differ markedly from the alterations that accompany leaching of gold from any probable source rocks. During the process of leaching of available gold from source rocks, enormous tonnage of these source rocks are altered. The liberated gold and associated elements migrate to sites,certainly of lower temperature,where another reaction takes place resulting in the precipitation of gold, most commonly, in the form of auriferous quartz veins and adjacent wall-rock alterations.

It is clear that two styles of alterations can be encountered in the field. One forms a relatively limited zone surrounding the auriferous quartz veins (favorable sites of deposition) and this type of alteration is termed here as alterations accompanying deposition of gold. The other style of alteration, on the other hand, is of relatively regional extent, where enormous tonnage of any source rock for gold is altered during the liberation of gold from that source. In such regional alterations, there is a major loss of silica (Boyle, 1979). This silica is transferred to the dilitant sites in the great shear zone or to similar sites in subsidiary shear zones and faults, where it is precipitated mainly as quartz. It is also probable that much of the gold and other metallic elements present in rocks affected by this regional alteration migrate

laterally and vertically to "second-degree low pressure dilitant sites" (Boyle, 1979). Many examples of such regional alterations in different parts of the world are mentioned in the literature. For example, Roslyakova *et al.* (1970), noticed that the highly altered zones of carbonatization and sericitization constituted negative gold haloes. That is, gold in these zones appeared to have been extracted.

In Egypt, ophiolitic serpentinites have been proposed as probable source rocks for gold (Botros, 1991, and Takla and Surour, 1996) The conversion of ophiolitic serpentinites to carbonates is accompanied by a liberation of gold (Viljoen, 1984). Hence, the resultant carbonated ultramafics are relatively poor in their gold content (but not exactly barren, see below). Similarly, Takla *et al.* (1990), have also noted a relationship between gold mineralization and fresh gabbros (younger gabbro) in Um Eleiga area, announcing that these gabbros are favorable source rocks for gold because of their intrinsically elevated gold abundance, high above the average background. They added that "the altered gabbro is devoid of gold as it is completely altered to chlorite-kaolinite and both oxides and sulphides are completely oxidized to goethite and limonite and it appears that all its gold content was leached and mobilized during alteration". Once again, Basta *et al.* (1996) observed alteration-accompanying leaching of gold in Semna gold deposits where values of gold were reduced from 710 ppb in fresh gabbro to 200 ppb in altered gabbro. In all these examples, liberated gold and associated elements migrate to subsidiary shears, if compared with the major shear along which alterations accompanying liberation of gold took place. In such subsidiary shears, fluids laden with gold and other elements are deposited as quartz veins and adjacent wall-rock alterations (i.e. alterations accompanying deposition of gold).

The question is still remaining, do alterations accompanying liberation of gold from any "source rock"represent a useless target for gold? In fact, the author believes that answer to such question depends on the mineralogical siting of gold in the source rocks. According to Keays and Scott (1976), gold hosted in sulphides can easily be leached, where as gold hosted in silicate or oxide is not readily accessible to leaching fluids. Accordingly, it is axiomatic to state that the potentiality of alterations accompanying leaching of gold depends on the presence of available gold in the source rocks. This may explain why some carbonated ultramafics are barren (due to the pressence of available gold in original ultramafics), whereas others are auriferous (due to the presence of gold hosted in sites that can not easily be leached by the fluids).

Fig.13 is a sketch illustrating the development of alterations accompanying leaching of gold (style 1 of alterations) and alterations accompanying deposition of gold and quartz as quartz veins and adjacent wall-rock alterations (style 2 of alterations).

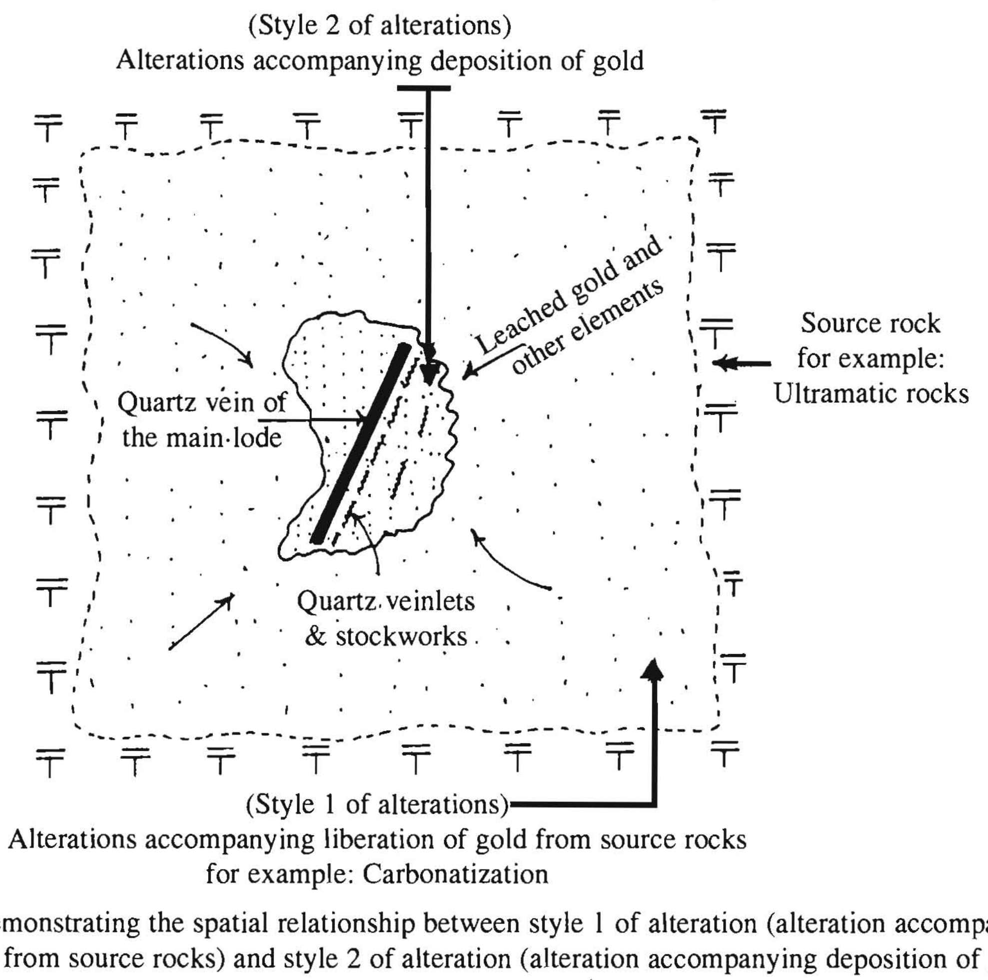

Fig 13: Sketch demonstrating the spatial relationship between style 1 of alteration (alteration accompanying liberation of gold from source rocks) and style 2 of alteration (alteration accompanying deposition of gold).

Conclusions

Intense and extensive rock alterations are an easily observed characteristic of most gold deposits and occurrences in Egypt. Two main styles of alterations can be recognized in the field. The first is where alterations are of relatively regional scale and take place during the liberation of gold from "source rocks". Attention must be given to this style, as it represents a good criterion for the presence of gold in nearby sites. Some of gold may still remain in this style of alteration, depending on the mineralogical siting of gold in the "source rocks". The second style of alteration, on the other hand, is manifested by alterations related to deposition of gold and is discernible only within a few meters of the auriferous quartz veins. Top priority must be given to this style of alterations, particularly the portions that are dissected by minor quartz veins, veinlets and stockworks (silicification), where gold is believed to have migrated to such sites with silica liberated during the different types of alterations.

The presence of some efficient precipitants such as sulphides, carbonates, clay minerals, sericite, iron oxides, chlorite and graphite in the alteration zones is a good indicator of the potentiality of the alteration zones.

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