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Acid-Sulphate Alteration Type at South Um Monqul, North Eastern Desert, Egypt

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ABSTRACT. Acid-sulphate alteration comprising of argillic and advanced argillic alteration is common in South Um Monqul area, North Eastern Desert, Egypt. The alteration is exclusively hosted by NE-SW and NW-SE sheared volcanic rocks (dacite and rhyodacite porphyry) as well as intrusions (sub-porphyritic biotite granite and granite porphyry). Argillic alteration is dominated by clay minerals that are usually associated with phyllic alteration. Advanced argillic alteration, on the other hand, comprises quartz, alunite, clay minerals, pyrophyllite and specularite. Mineralization linked to advanced argillic alteration is represented by gold with the high sulphidation minerals enargite, calcocite and covellite. The high sulphur content of acid sulfate alteration is further emphasized by the common presence of barite veins in the examined area.

It is envisaged that volatiles rich in SO_2 degassed from the nearsurface intrusions, which were unable to re-equilibrate with the country rocks along their relatively short path of ascent. As a result, the SO_2 produced sulphuric acid in conjunction with meteoric water. The interaction of the sulphuric acid solution with the wall rock resulted in the advanced argillic alteration.

The recognition of such alteration in the Eastern Desert is of prime importance where it can be used, as a shallow level indicator of a possible deeper porphyry system, in any exploration program.

Intense and extensive rock alteration is a highly visible characteristic of most Egyptian gold deposits and occurrences. The alterations are either surrounding the

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auriferous quartz veins and/or structurally controlled by tectonic disturbances (Botros 1991, 1993). In the Egyptian gold deposits and prospects several wall-rock alterations are recognized. the most common types of which are sericitization (*e.g.* Sukkari gold deposit, Hassaan *et al.* 1990), silicification (*e.g.* Hamash gold occurrence, Hilmy and Osman 1989), ferrugination (*e.g.* Um Hutite gold mine, Takla *et al.* 1989), carbonatization (*e.g.* Barramiya gold deposit, Osman and Dardir 1990), Listwaenitization (*e.g.* Barramiya gold deposit, Sabet and Bordonosove 1984' Abu Marawat gold occurrence, Botros 1991), chloritization (*e.g.* Hangalia deposit, Osman and Dardir 1990) and kaolinitization (*e.g.* Wadi EL Urf gold occurrence, Shalaby 1989).

In the present paper, another type of alteration, acid sulphate alteration, is studied and as far as the author is aware, the present paper represents the first record of this type of alteration. The alteration occurs in South Um Monqul gold occurrence, North Eastern Desert, Egypt.

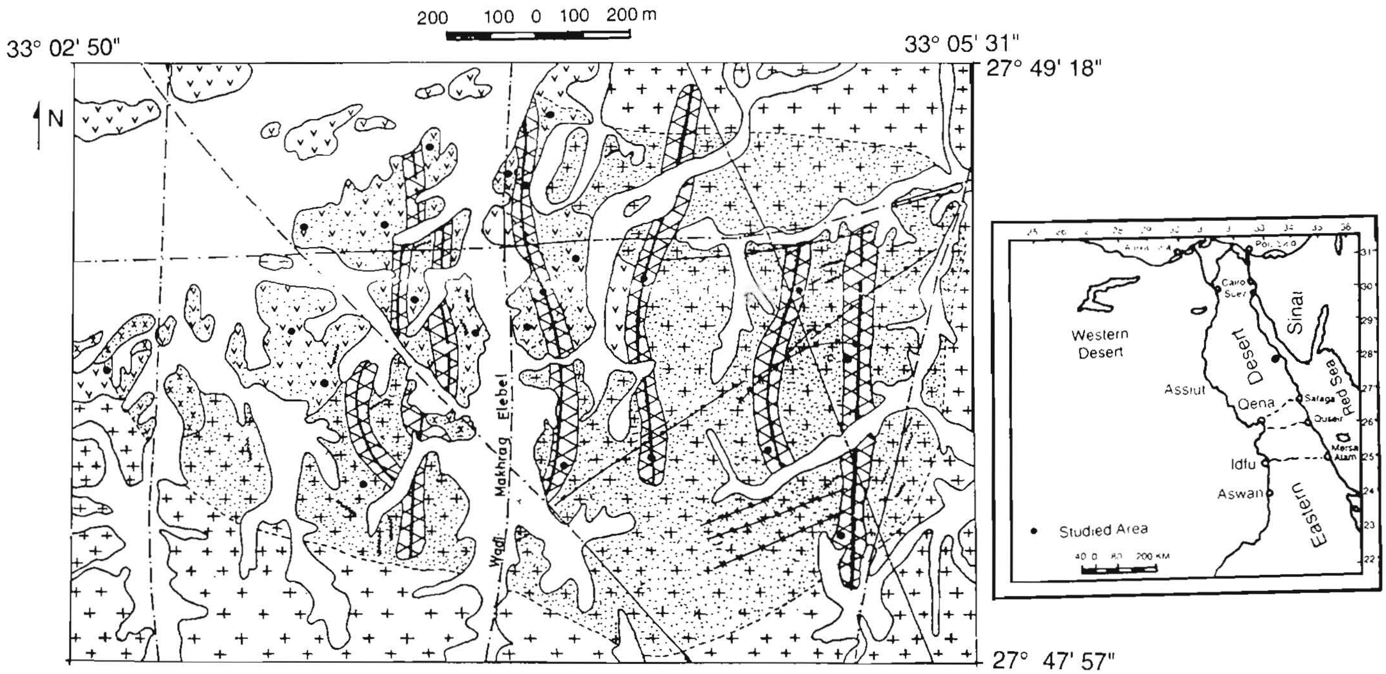
The present paper describes the characteristic features of this alteration is South Um Monqul prospect including nature of host rocks, mineralogical composition and genesis of such alteration.

Geology of South Um Monqul Gold Prospect

The simplified surface geology of South Um Monqul is shown in Fig. (1). The area consists of a Pan-African assemblage comprising intrusive rocks which are contemporaneous with their surface manifestation *i.e.* the volcanic rocks of the Dokhan type (El Gaby *et al.* 1988).

Volcanic rocks

The volcanic rocks of Um Monqul area are represented by dacite and rhyodacite porphyry. These volcanic rocks belong to the Dokhan volcanics which are calc-alkaline and of Andean-type erupted along active continental margins (Basta *et al.* 1980). In the field, these volcanic rocks form moderate to high reliefs of successive sheets exhibiting crude stratification and are sheared in NE-SW and NW-SE directions where hydrothermal alterations are dominant. Megascopically, these volcanics vary in colour from black to grey with various shades of purple and brown. Microscopically, they exhibit a porphyritic texture where phenocrysts of plagioclase (oligoclase-andesine) are embedded in a fine-grained groundmass



- Areas of acid - sulfate alterations
- Porphyry - style alterations
- Faults (a): definit (b) infered
- Bimodal dykes
- Basic dykes
- Acidic dykes
- Quartz veins
- Dacite and rhyodacite porphyry
- Granite porphyry
- Biotite Granite
- Granodiorite
- Hornblende gabbro

Fig. 1. Geological Map of South Um Monqul Area.

composed of feldspars, quartz and biotite (Fig. 2). Opaques are represented by martitized magnetite and minor amounts of pyrite and chalcopyrite.

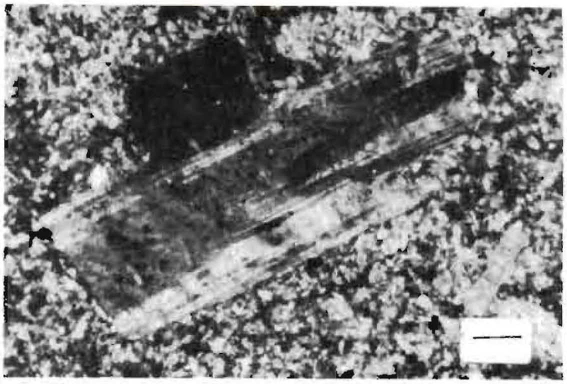


Fig. 2. Photomicrograph of rhyodacite porphyry from South Um Monqul area showing phenocryst of plagioclase embedded in fine - grained groundmass composed of feldspars, quartz and biotite. Cross Nicols. Bar length represents 1.22 mm.

Intrusive rocks

The intrusive rocks of the study area are typified by hornblende gabbro, granodiorite, biotite granite and granite porphyry.

Hornblende gabbro forms lands of moderate relief. In hand specimen, hornblende gabbro is greyish green in colour on weathered surface and sometimes shows porphyritic texture even in the scope of hand specimen. Microscopically, hornblende gabbro is composd of plagioclase (An 48-54) and hornblende. The accessories are opaque minerals (4-6%) which are dominated by martitized magnetite and to a lesser extent ilmenite and sulphides (chalcopyrite and pyrite).

Granodiorite is the dominant rock type among the intrusive rocks of South Um Monqul prospect. It is comparable to G-1 granites (subduction-related calc-alkaline granites) of Hussein *et al.* (1982) classification for the Egyptian granites. Two sets of fractures are noticed in this rock variety; NE and NW. Microscopically granodiorite is composed of plagioclase (An 30-45), quartz, potash feldspar, hornblende and minor biotite. Sometimes plagioclase and hornblende form the phenocrysts of the porphyritic varieties of granodiorite (Fig. 3). Sericite, kaolinite, chlorite and calcite represent the secondary phase minerals. Accessory minerals are represented by apatite,sphene and opaques .The latter constitute about 2-4% of the rock and are dominated by martitized magnetite and minor pyrite and chalcopyrite.

Biotite granite occurs as sheet like bodies traversing the grandodiorite (Fig. 4) and trending in a N-S direction and dipping to east with angles ranging from 15° to

25°. Microscopically this variety has a sub- porphyritic texture where biotite forms phenocrysts (Fig. 5) that are embedded in a matrix composed of potash feldspar, oligoclase, quartz and biotite of relatively smaller size. Sericite, hydrothermal

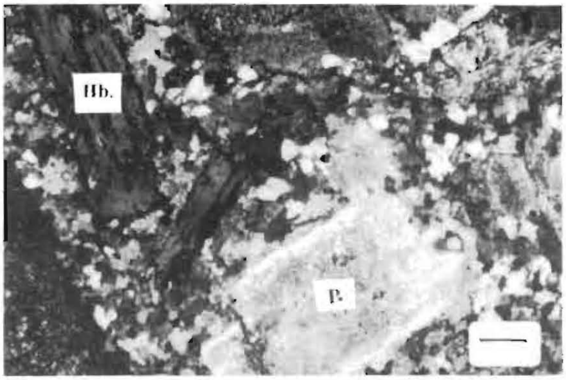


Fig. 3. Photomicrograph of granodiorite from S. Um Monqul area illustrating porphyritic texture represented by plagioclase (P.) and hornblende (Hb.) phenocrysts embedded in fine - grained groundmass. Cross Nicols. Bar length represents 0.185 mm.

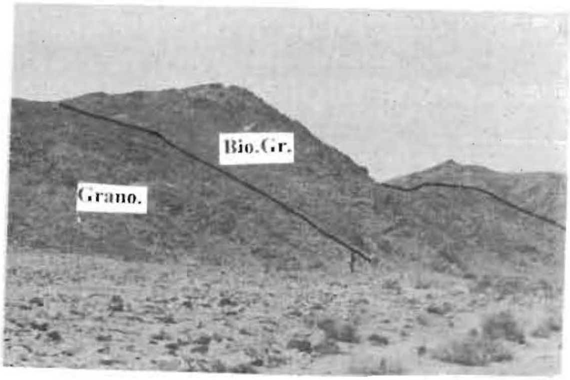


Fig. 4. Sheet - like body of biotite granite (Bio. Gr.) traversing granodiorite (Grano.). South Um Monqul area.

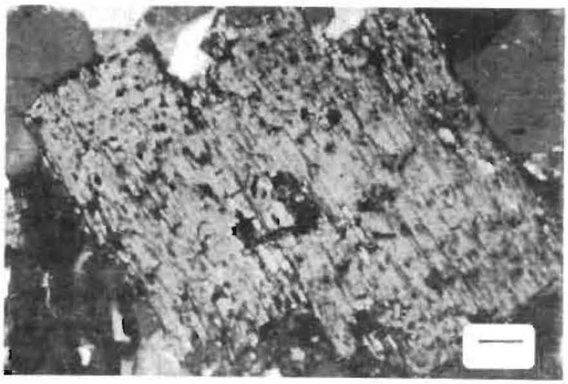


Fig. 5. Photomicrograph of biotite granite from S. Um Monqul area showing sub-porphyritic texture exhibited by biotite. Notice the presence of the other constituents in a relatively smaller size. Cross Nicols. Bar length represents 0.185 mm.

biotite, kaolinite, chlorite epidote and carbonates are the alteration products of the primary minerals. Opaques constitute about 7% of the rock components and are represented by martitized magnetite hosting specks of gold, pyrite and chalcopyrite.

Granite porphyry occurs as a dyke-like body trending in a N to NNE direction and dipping to the east with angles varying from 20° to 30°. In hand specimen, the rock is reddish white in colour, extensively altered and stained along fractures by malachite. Phenocrysts in the porphyry are repesented by potash feldspar and quartz. The groundmass is composed of quartz, feldspar, biotite and rarely hornblende. The granite porphyry is characterized by a high ratio of opaques (up to 10%) that are dominated by martitized magnetite, pyrite and chalcopyrite. Minor gold, as well as, bornite are observed in some examined polished surfaces. The granite porphyry and biotite granite were the sites of old workings carried out by the old prospectors in South Um Monqul. It is the belief of the author that old prospectors collected and crushed the auriferous quartz stockworks that are dispersed in these rocks searching for gold.

Later dykes and veins

This suite traverses all the previously mentioned country rocks and is represented by quartz veins, dolerite, felsite and bimodal dykes.

The previously mentioned rock assemblages correlate excellently with those of continental margin orogenic belts (El Gaby *et al.* 1988) which are dominated by gabbro-diorite-tonalite-granodiorite and granite, as well as, their surface equivalents in the type locality Andean Cordillera of South America (Wilson 1989).

Wall-Rock Alteration at the South Um Monqul Prospect

South Um Monqul prospect was long known as a district for gold since Pharaonic times. Recently, the area is subjected to intensive study for the hydrothermal alterations (Botros and Wetait 1997). The preliminary results indicate that the rocks at South Um Monqul are variably altered over an area of about 16 km^2. Studies of hydrothermal alterations have resulted in the recognition of four main alteration assemblags, viz a hydrothermal biotite (potassic), quartz-sericite-pyrite (phyllic), sericite-clay (phyllic-argillic) and chlorite-carbonates-epidote (propylitic) assemblages. These alterations characterize a porphyry-style mineralization (Botros and Wetait 1997). In addition to the previously mentioned alteration, acid-sulphate alteration was also recognized. By definition, acid-sulphate alteration is typified by an abundance of sulphur, both as sulphate and sulphide, distinct suite of ore minerals characterized by a high sulphidation state, and distinctive alteration mineral assemblages (Ashley 1982, Bonham and Giles 1983, Bonham 1984, 1989, Walthier and Proano 1985).

Acid-Sulphate Alteration of South Um Monqul Prospect

Figure 1 shows the locations of acid-sulphate alteration in the investigated area. In most examined thin sections, acid sulphate alteration is superimposed on the alteration assemblages characteristic of the porphyry-style mineralization (Botros and Wetait 1997). This is in agreement with studies carried out by many workers for classical porphyry copper deposits (*e.g.* Sillitoe and Gappe 1984, Bonham 1986, Sillitoe *et al.* 1990).

Intensive field studies supported by microscopic investigations revealed that acid-sulfate alteration in the examined area has unique features that include characteristic host rocks and also ore, gangue and alterations mineral assemblages. These features are discussed below.

Host-rocks

Acid-sulphate alteration of the examined area is exclusively hosted by dacite and rhyodacite porphyry, as well as, intrusive biotite granite and granite porphyry. Thus the host rocks for this alteration essentially display a porphyritic texture (Figs. 2, 3, 5) and it is worth mentioning that the primary host rocks for acid-sulphate alteration in the type locality (Goldfield in Nevada and Summitvile in Colorado) are almost exclusively rhyodacite and also commonly porphyritic (Heald *et al.* 1987). In general, the alteration in the examined area is facilitated and controlled by minor fractures (out-side the scale of present mapping) trending in NE-SW and NW-SE direction.

It should be mentioned that the Egyptian Basement is dominated by two structural trends; NW-SE to NNW-SSE and NE-SW to ENE-WSW (EL Gaby *et al.* 1988). The first trend is characterized by the trends of major folds, thrust faults and geanticlines. The primary NW trend is rotated to become NE-SW and ENE-WSW (El Gaby *et al.* 1988). This trend is believed to mark a major shear along which the north Eastern Desert (where the examined area is located) and Sinai were uplifted during the Pan-African orogeny (El Gaby *et al.* 1988).

Mineralogy

Acid-sulphate alteration of South Um Monqul consists of argillic and advanced argillic assemblages. In this paper, it is to be noted that the term clay here is used to cover several mineral species of the clay group. The very small sizes of these minerals and the small patches in which they occure make it impossible positively to distinguish the different species of the clay group. Consequently, X-ray is highly recommended for the further studies. However, kaolinite and illite were the only clay minerals that were identified under high magnification. Optically the kaolinite was readily identified by its weak birefringence (gray and white interference colours) and indices of refraction approximating those of quartz. Illite was readily distinguished, under crossed nicols, from kaolinite by its slightly higher birefringence (first-order yellow), and indices of refraction above Canada balsam.

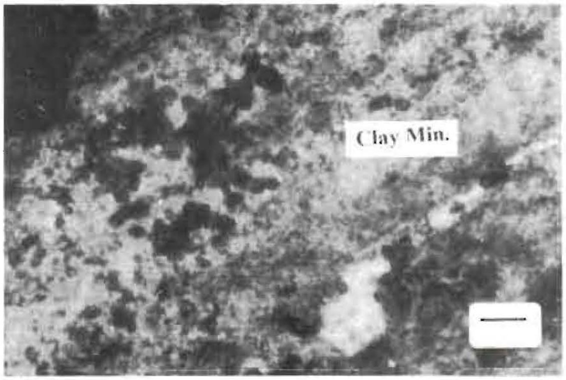


Fig. 6. Photomicrograph of rhyodacite from S. Um Monqul area showing argillic alteration where plagioclase is completely altered to clay minerals (Clay Min). Plane Polarized. Bar length represents 0.39 mm.

Most of the feldspars in host rocks are extensively altered to clay minerals (Fig. 6) in such way that original twining is completely obliterated. The argillic alteration is usually intermixed with phyllic alteration and in most examined outcrops argillic alteration passes imperceptibly to advanced argillic alteration.

The advanced argillic assemblage comprises various combinations of quartz, alunite, pyrophyllite, barite and specularite. It is interesting to mention that advanced argillic alteration in South Um Monqul may contain all the previously mentioned minerals in one location or only few of them. Which ones develop depends upon intensity of leaching, total sulphur concentration and concentration of alkalies (Na^+, K^+) in the hydrothermal solution (Ashely 1982).

A crude pattern of zonation can be noticed in the advanced argillic alteration. The width of each zone varies from few centimeters to some meters rarely exceeding 30m. Alunite is usually accompanied by silicification. The assemblage *i.e.* quartz-alunite assemblage grades to clay-alunite assemblage and usually clay-sericite assemblage. Prophylitized rocks represented by chlorite-epidote-carbonates assemblage are located at the outer most part of the altered zones. Pyrophyllite, barite and specularite are randomly distributed and there is no preferable assemblage for these minerals.

Vuggy silica alteration which results from the intense leaching of all the primary rock-forming minerals except quartz and which commonly occurs in areas affected by this alteration (Ashley 1982), is not observed in South Um Monqul prospect. This may be attributed to the possibility that this alteration was formed and then removed by erosion.

Generally speaking, alunite occurs either as subparallel veinlets with a characteristic comb structure traversing all the constituents of the rocks (Fig. 7) or as bladed or lath like crystals replacing the feldspars. Pyrophyllite occurs either as large crystals traversing all constituents (Fig. 8) indicating a late stage of alteration or as small fibrous crystals replacing the plagioclase (Fig. 9). Barite occurs principally in the form of barite specularite- quartz veins (Fig. 10). Interstitial crystals in host rocks are not uncommon feature (Fig. 11). Sometimes specularite occurs as rod-like crystals (Fig. 12) disseminated in the quartz veins that are associated with the advanced argillic alteration.

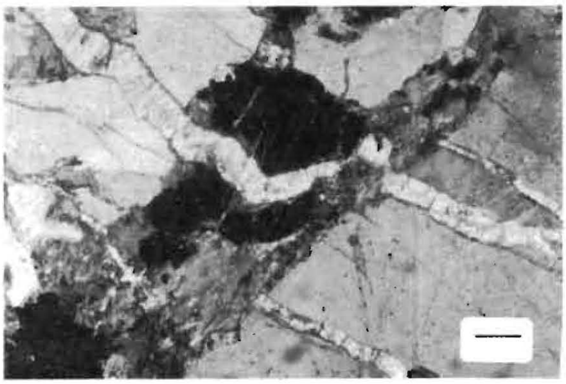


Fig. 7. Photomicrograph of biotite granite from S. Um Monqul area showing sub-paralle veinlets of aluninte traversing the rock. Cross Nicols Bar length represents 0.39 mm.

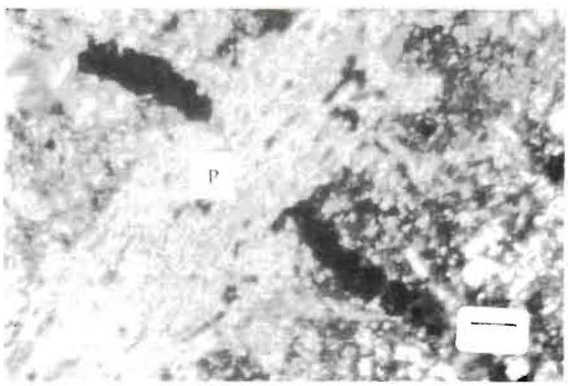


Fig. 8. Photomicrograph of rhyodacite porphyry from S. Um Monqul area showing large crystal of pyrophyllite (P) traversing the other contituents of the rock. Cross Nicols. Bar length represents 0.39 mm.

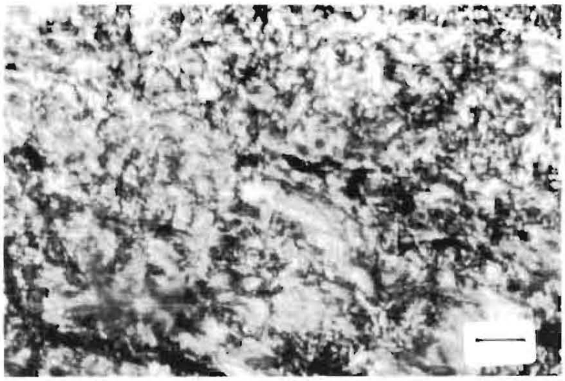


Fig. 9. Photomicrograph of dacite from S. Um Monqul area showing fibrous crystals of pyrophyllite replacing plagioclase. Cross Nicols. Bar length represents 0.196 mm.

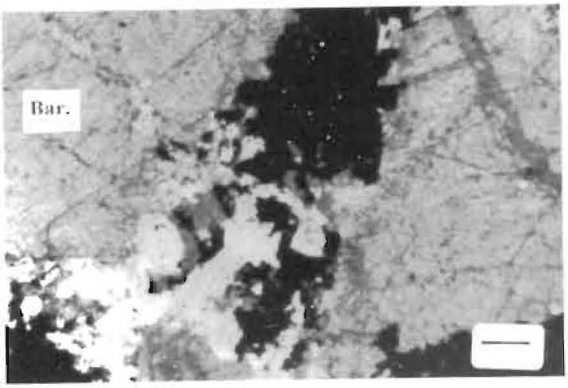


Fig. 10. Photomicrograph of barite-specularite-quartz vein from S. Um Monqul showing barite (Bar.), interstitial specularite (black) and quartz (white). Plane Polarized. Bar length represents 1.22 mm.

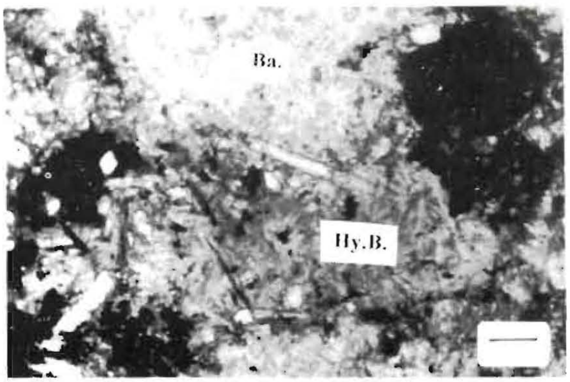


Fig. 11. Photomicrograph of dacite porphyry from S. Um Monqul showing interstitial barite (Ba) and hydrothermal biotite (Hy.B.) Plane Polarized. Bar length represents 0.39 mm.

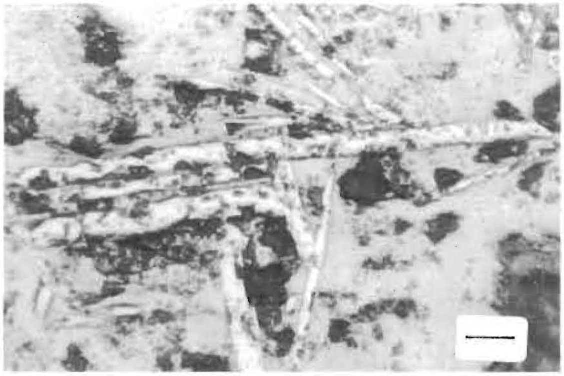


Fig. 12. Photomicrograph of quartz from S. Um Monqul area showing rod-like crystals of specularite disseminated in quartz. Reflected light. Bar length represents 0.196 mm.

Gold mineralization connected with acid-sulphate alteration is typified by some specks that are disseminated either in the host rocks that are affected by this alteration (Fig. 13) and/or in quartz veins (Botros 1991). Barite-specularite-quartz veins are also gold-bearing. In addition to gold mineralization, ore mineralogy connected with acid-sulphate alteration includes the high sulphidation minerals enargite (Fig. 14), chalcocite, bornite and covellite.

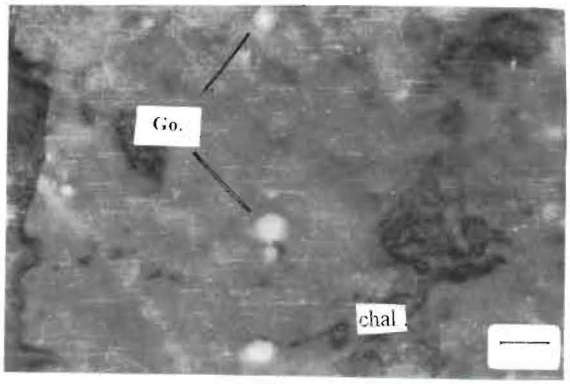


Fig. 13. Photomicrograph of altered rhyodacite from S. Um Monqul area showing disseminations of gold (Go.) and chalcopyrite (chal.). Reflected Light. Bar length represents 0.06 mm.

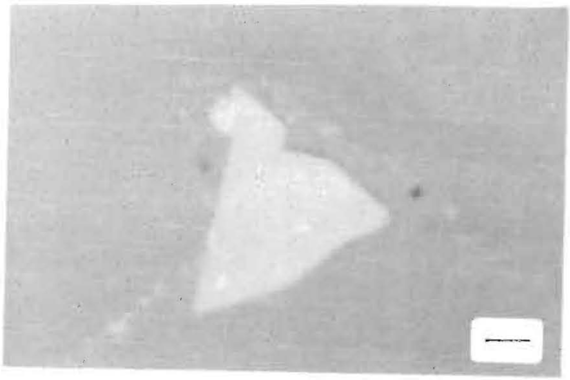


Fig. 14. Photomicrograph of granite porphyry from S. Um Monqul area showing dessiminated crystal of enargite. Reflected Light. Bar length represents 0.05 mm.

No data about the age of acid-sulphate alteration and accompained mineralization is available at the present time. However, Heald *et al.* (1987) believe that such alterations and accompanied mineralization in their type locality (*e.g.* Goldfield and Summitvile) has followed very closely (< 0.5 m.y.) the emplacement of the host rocks suggesting a genetic relationship. Taking in consideration that intrusive biotite granite and granite porphyry, as well as, dacite and rhyodacite prophyry are the main hosts for this alteration and accompanied mineralization, and that all these rocks were contemporaneous and members of the pronounced calc-alkaline magmatic activity that took place at about 680-570 Ma ago (El Gaby *et al.* 1988), we believe that acid-sulphate alteration and ore deposition accompanied with it took place more or less at this interval.

Fluid Chemistry of Acid Sulphate Alteration

Defining the geochemical environment of acid-sulphate alteration in South Um Monqul is limited by the current lack of fluid inclusion studies and isotope data. However, a useful tool for limiting the conditions of alteration and mineralization parameters such as temperature of mineral deposition, chemical composition of the fluids can be recognized from the mineralogy of the alteration and ore assemblage. Hydrothermal and ore mineralogy are good indicators of fluid chemistry and temperature (White and Hedenquist 1990). The presence of alunite, enargite and usually covellite indicates an environment at relatively high sulphur fugacity (Heald *et al.* 1987). On the other hand, the common appearance of pyrophyllite indicates that temperatures during acid-sulphate alteration exceeded 270° - 300 °C (Hemely *et al.* 1980, Ashley 1982). Since ore depositian always occurs late in the evolution of these alterations, prevailing temperatures may well be less than 270 °C during ore formation (Ashley 1982).

Genesis of Acid-Sulphate Alteration in South Um Monqul Prospect

In the light of the field and petrographic investigations, it is clear that a high level of emplacement of the studied intrusive rocks is favoured by the occurrence of dacite and rhydodacite porphyry and the dominance of porphyritic texture in the intrusive rocks.

Volatiles and gases derived from these magmatic bodies generate acidity (Hedenquist 1987). As a result of the high level of emplacement of these intrusive bodies, the acid volatiles and gases have no chance to be neutralized by interaction with country rocks along their relatively short path of ascent. It is believed, therefore, that SO_2 is derived from a near-surface magma and is transported upward in a vapour plume (Rye *et al.* 1992) consisting predominantly of water vapour. Disproportionation of SO_2 becomes important at temperature below 400 °C in the presence of water (Holland 1967, Saki and Matsubaya 1977, Rye *et al.* 1992). SO_2 disproportionates into H_2SO_4 and H_2S according to the reaction:

$$4\ SO_2 + 4\ H_2O \Leftrightarrow 3H_2SO_4 + H_2S$$

This equation indicates that meteoric water is necessary for disproportionation of SO_2 and formation of H_2SO_4. This gives rise to the indication that SO_4 vapour plume condenses into and mixes with the surrounding meteoric water or meteoric water may encroach the country rocks and mix with the vapour plume during its ascent (Rye *et al.* 1992).

The interaction of the sulphuric acid solutions with wall rocks produces the advanced argillic alteration. The deposition of minerals in these conditions is governed by the relatively prevailing pH conditions *e.g.* pyrophyllite is formed from low pH fluids (Leach *et al.* 1985) where as continuous neutralization of these acidic fluids-result in the depositions of other minerals of acid-sulphate alteration assemblage. The author is, thus, inclined to the belief that a vertical change in ore minerals connected with advanced argillic alteration could exist on the basis that there is an upward increase in oxidation state and dissolved sulphur content and upward decrease in temperature (Stoffregen 1987). Accordingly, it is believed that barite veins in the examined area may represent the topmost level of a mineralization connected with acid-sulphate alteration.

Conclusions

The results of field mapping and petrographical investigations can be summarized as follows:

(1) Host rocks are represented by a suite of intrusive rocks, as well as, volcanic rocks. These rock assemblages correlate strongly with those of active continental margins typified by Andean Cordillera.

(2) Acid-Sulphate alteration of South Um Monqul area is characterized by the following:

a) It is facilitated and controlled by minor shear zones trending NE-SW and NW-SE.

b) It is exclusively hosted by dacite and rhyodacite porphyry, although intrusive biotite granite (sub-porphyritic texture) are not uncommon hosts. This reflects that porphyritic texture is a unique feature to the hosts of the alteration.

c) Argillic alteration assemblage is composed of different minerals of clay group, whereas advanced argillic alteration assemblage comprises various combinations of quartz, alunite, pyrophyllite, barite and specularite. A crude pattern of zonation for advanced argillic alteration assemblage can be noticed in the studied area.

d) Mineralization linked to advanced argillic alteration is represented by gold with the high sulphidation minerals; enargite, chalcocite and covellite. The high sulphur content of acid-sulphate alteration is further emphasized by the common presence of barite veins in the examined area.

3) Petrographical studies of alteration minerals dominated in acid-sulphate alteration at Um Monqul, suggest that this alteration is similar to those characterizing high sulphur (Bonham 1986), high sulphidation (Hedenquist 1987), acid-sulphate (Heald *et al.* 1987) and kaolinite-alunite (Berger and Henley 1989) types of epithermal gold deposits.

(4) The proposed genesis for this alteration is that acid volatiles and gases derived from high-level magmatic bodies have no chance to be neutralized by interaction with country rocks along their relatively short-path of ascent.

(5) It is obvious from the proposed genesis that fluids were dervied from intrusive rocks that are emplaced at a relatively high levels, accordingly porphyritic and sub-porphyritic textures are unique features to these intrusives. On the other hand, porphyry mineralization is also connected with such environment, *i.e.* near-surface intrusive bodies and their surface equivalents. This relation between acid-sulphate alteration and porphyry mineralization is well documented in many prophyry copper deposits (Ashley 1982, Sillitoe and Gapp 1984, Bonham 1986, Sillitoe *et al.* 1990), indicating that such alteration may be shallow level indicator of deeper porphyry systems.

It is highly recommended that explorationsts should take care of such alteration in the field taking into consideration that acid-sulphate alteration can occur above and peripheral to some porphyry copper deposits. Moreover, such alteration may be potentially significant for gold mineralization. On the other hand shallow drilling and induced polarization survey are highly recommended to achieve a better understanding about the mineralization in the studied area.

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تغاير من النوع الحامضي الكبريتي في منطقة أم منجول بشمال الصحراء الشرقية بمصر

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ينتشر التغاير الحامضي الكبريتي في منطقة أم منجول التي تضم أحد مناجم الذهب بشمال الصحراء الشرقية بمصر وهو نوعان طيني وطيني متطور .

يتميز التغاير الحامضي الكبريتي بارتباطه بالصخور البركانية (الداسيت والداسيت البورفيري) والصخور الجرانيتية ذات النسيج البورفيري وتحت البورفيري . ومن الملاحظ أن هذا النوع من التغاير يكون مرتبطاً بنطاقات الضعف (التكسير) في الصخور وخاصة تلك النطاقات التي تتجه شمال الشرق وشمال الغرب .

أظهرت الدراسة البتروجرافية أن التغاير الطيني يتميز بوفرة معادن الطين المختلفة بينما يشتمل الطيني المتطور على معادن الطين إلى جانب الألونيت و الكوارتز والبيروفيليت والإسبيكولوريت والباريت .

ومن أهم مميزات التغاير الطيني المتطور في منطقة الدراسة ارتباطه بتركيزات الذهب والتي غالباً ما تصاحب معادن عالية الكبرتة مثل الانيرجيت

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والكالكوسيت والبورنيت والكوفيليت مما يوحي بمحتوى عالٍ من الكبريت في التغاير الطيني المتطور . وهذا المحتوى العالي من الكبريت يمكن الاستدلال عليه أيضاً من وفرة عروق الباريت في المنطقة المذكورة .

ويعتقد المؤلف أن التغاير الحامضي الكبريتي قد نتج من تفاعل المواد الطيارة الحامضية والغازات المصاحبة للطور النهائي من تباور الصخور الجرانيتية البورفيرية وتحت البورفيرية مع صخور الإقليم بمنطقة الدراسة مع الأخذ في الاعتبار بأن قرب تلك الصخور الجرانيتية من السطح وقت تداخلها قد قلل من فرصة تغير التركيب الحامضي لهذه المواد الطيارة والغازات . وبناء على الاعتقاد السابق فإن المؤلف يرى أن غاز ثاني أكسيد الكبريت يتميأ في وجود الماء السطحي إلى حامض الكبريتيك وغاز كبريتيد الهيدروجين وبتفاعل حامض الكبريتيك مع صخور الإقليم بمنطقة الدراسة تتكون معادن التغاير الحامضي الكبريتي المختلفة والذي يحكم تكونها تغير معامل الأس الهيدروجيني للمحلول الحامضي وتفاوت درجات الحرارة وحالة التأكسد ونسبة الكبريت الذائب في المحلول .

وتتبع أهمية هذا النوع من التغاير من في أنه يمكن أحياناً اعتباره مرشداً سطحياً لخام النحاس البورفيري العميق وغير الظاهر على السطح .