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A new classification of the gold deposits of Egypt

Nagy Shawky Botros*

Egyptian Geological Survey, Cairo, Egypt

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Abstract

Gold deposits and occurrences located in the Nubian Shield have been known in Egypt since Predynastic times. Despite the fact that these deposits were long under exploitation and investigated many times, they are still insufficiently classified in harmony with the crustal evolution models suggested for the evolution of the Nubian Shield. Several plate tectonic models were proposed for the development of the Nubian Shield and the present classification relies heavily on the model that implies collision of arc-inferred continent through subduction and obduction of oceanic lithosphere. A three-fold classification of gold deposits of Egypt is offered here in harmony with this evolutionary model. These are stratabound deposits and non-stratabound deposits hosted in igneous and metamorphic rocks, as well as placer gold deposits.

The stratabound deposits are hosted in island arc volcanic and volcaniclastic rocks of comparable composition formed in ensimatic island arcs. They are thought to have formed by exhalative hydrothermal processes during the waning phases of sub-marine volcanic activity. Stratabound deposits are sub-divided into three main types: gold-bearing Algoma-type Banded Iron Formation, gold-bearing tuffaceous sediments and gold-bearing volcanogenic massive sulphide deposits.

Non-stratabound deposits occur in a wide range of igneous and metamorphic rocks. They were formed during orogenic and post-cratonization periods by mineralizing fluids of different sources. Non-stratabound deposits are divided into vein-type mineralization, which constituted the main target for gold in Egypt since Pharaonic times, and disseminated-type mineralization hosted in hydrothermally altered rocks (alteration zones) which are taken recently into consideration as a new target for gold in Egypt.

Placer gold deposits are divided into modern placers and lithified placers. The former are sub-divided into alluvial placers and beach placers. Conglomerates occurring on or near ancient eroded surfaces represent lithified placers.

Keywords: Nubian Shield; Upper Proterozoic; Egypt; Eastern Desert; Classification; Gold deposits

1. Introduction

The Eastern Desert of Egypt is well known as a gold-mining area since ancient times and more than 90 gold deposits and occurrences are spread over the whole area covered by the basement rocks of Precambrian age (Fig. 1). Records of mining for gold range back to predynastic times and mining activity continued at different periods. In most mines, the ancient Egyptians extracted gold from quartz veins of various dimensions in open-pits and underground workings. At present, there is no production and activities are

* Present address: Abtal El Faloga Street, Mit Ghamr No. 35611, Dakahlia, Egypt.

E-mail address: nagyshawky35611@yahoo.com (N.S. Botros).

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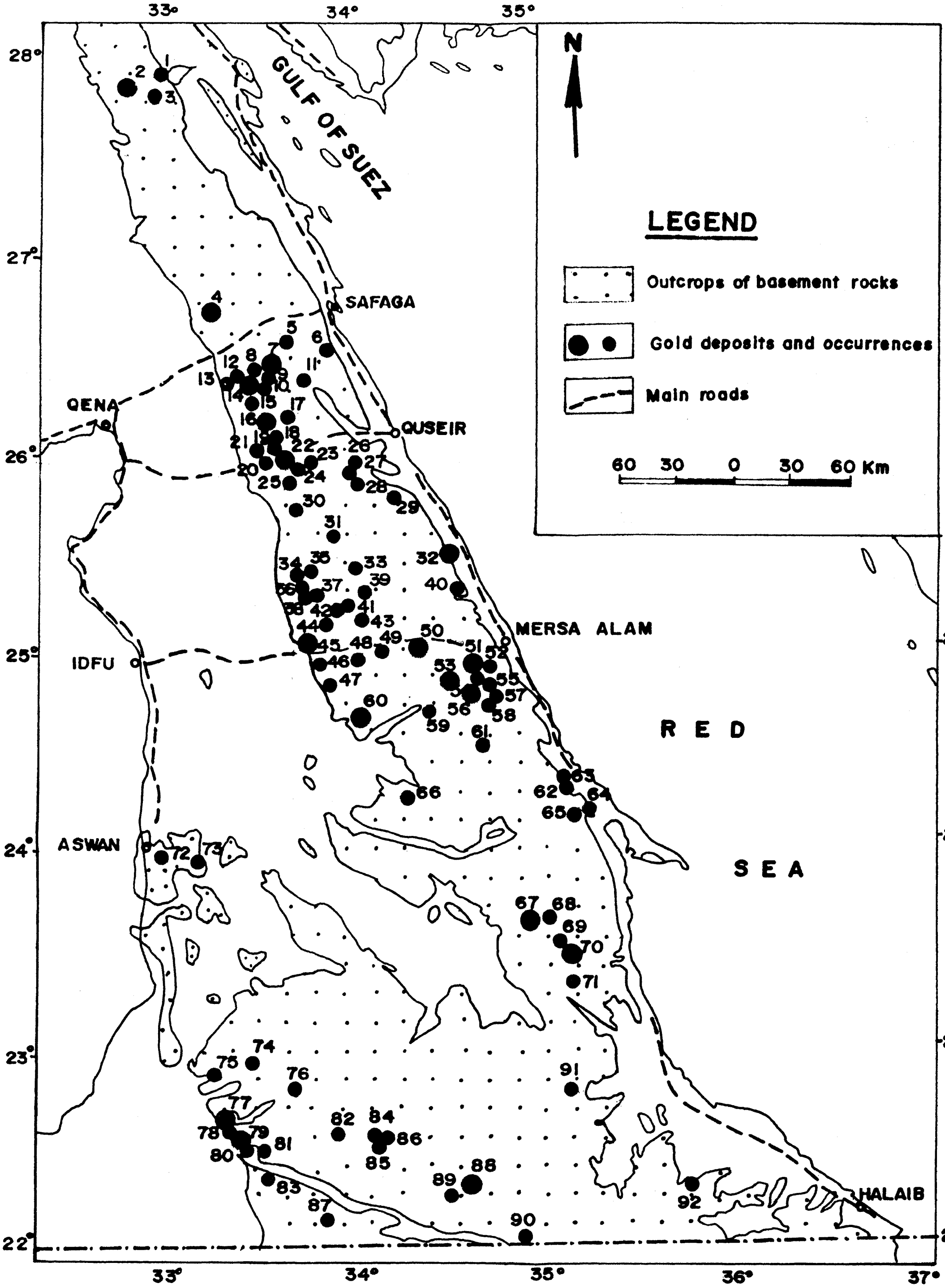
GULF OF SUEZ
SAFAGA
QENA
QUSEIR
IDFU
MERSA ALAM
ASWAN
HALAIB
RED
SEA
N
LEGEND
Outcrops of basement rocks
Gold deposits and occurrences
Main roads
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33°
34°
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25°
24°
23°
22°

concentrated on the evaluation of the old gold mines and tailings.

Gold, although rare in quantity, is nevertheless a widely distributed element and may be associated with diverse geological terranes (Antweiler and Campbell, 1982). In Egypt, in addition to the auriferous quartz veins, which constituted the main target for gold since ancient times, gold is associated with some other ore deposit types. It occurs in some Algoma-type Banded Iron Formation deposits such as at Abu Marawat (Botros, 1991, 1993b, 1995a) and in the Um Nar area (Dardir and Elshimi, 1992). Minor concentrations of gold occur also in the volcanogenic Zn–Cu–Pb massive sulphide deposits of Um Samuki area (Searle et al., 1976). Minor quantities of gold occur also with possible porphyry copper deposit in the South Um Monqul prospect (Botros and Wetait, 1997; Botros, 1999). Relatively high concentrations of gold occur in alteration zones (Botros, 1993b; Osman and Dardir, 1989). As a consequence, this presentation addresses the need for a new classification of gold deposits of Egypt to serve as a framework for the detailed study of these deposits and to facilitate their correlation with worldwide deposits.

In Egypt, Kochine and Bassuni (1968) classified gold deposits, according to the mode of occurrence and the nature of mineralization, into three types: dyke-type, vein-type and placer-type. Upon close inspection of this classification, it becomes clear that there is no sharp boundary between dyke-type and vein-type. For example, in dyke-type mineralization of Fatiri area, gold in these dykes is hosted in irregular veinlets of quartz veins traversing the whole mass of the dyke rocks (Botros, 1991). Sabet and Bordonosov (1984) classified gold deposits in Egypt into three formations namely gold-sulphide formation, skarn gold-ferruginous quartzite formation and gold quartz formation. Although this classification is the first actual attempt at classifying gold deposits in Egypt, it ignores the tectonic setting of host rocks, as well as the source of the mineralizing fluids.

The well-known spatial and temporal relationship of gold mineralization to tectonic structures in the Nubian Shield (Loizenbauer and Neumayr, 1996), combined with the recent recognition of the importance of plate tectonic processes in the Precambrian (Dardir and Greiling, 1987; Dardir et al., 1990; Greiling et al., 1994; Greiling and Rashwan, 1994) raises the important question of how gold mineralization fits into the plate tectonic evolution of the Nubian Shield. The author believes that in any proposed classification, it is essential to consider the formation of gold deposits in terms of the tectonic, magmatic and metamorphic history of the Nubian Shield.

Several plate tectonic models were proposed for the development of the Nubian Shield and the present classification relies heavily on the model that implies collision of arc-inferred continent through subduction and obduction of oceanic lithosphere.

2. Overview of the basement geology

The Precambrian basement complex of Egypt comprises about 10% of the total area of the country. It is exposed mainly in the Eastern Desert along the Red Sea, and sporadic ones located in the Western Desert at Gebel Oweinat. A considerable part also covers the southern portion of Sinai (Fig. 2). In the Eastern Desert, the basement rocks extend as a belt parallel to the Red Sea coast for a distance of about 800 km.

Fig. 1. Gold deposits and occurrences in the Eastern Desert of Egypt (compiled from Kochine and Bassuni, 1968). (1) Umm Mongul; (2) Umm Balad; (3) Wadi Dib; (4) Fatira; (5) Abu Marawat; (6) Wadi Gasus; (7) Semma; (8) Gebel Semna; (9) Abu Qarahish; (10) Kab Amiri; (11) Sagi; (12) Gidami; (13) Hamana; (14) Erediya; (15) Abu Had; (16) Atalla; (17) Rebshi; (18) Umm Esh; (19) Fawakhir; (20) Hammamat; (21) Umm Had; (22) El Sid; (23) Umm Selimat; (24) Hammuda; (25) El Nur; (26) Kareim; (27) Kab El Abyad; (28) Tarfawi; (29) Sherm El Bahaari; (30) Zeidum; (31) Wadi Zeidum; (32) Umm Rus; (33) Sigdit; (34) Talat Gadalla; (35) Abu Muawaad; (36) Daghbag; (37) El Hisimat; (38) Bokari; (39) Umm Samra; (40) Abu Dabbad; (41) Abu Qaria; (42) Umm Saltit; (43) Bezah; (44) Umm Selim; (45) Barramiya; (46) Dungash; (47) Samut; (48) Umm Hugab; (49) Urf El Fahid; (50) Atud; (51) Sukkari; (52) Umm Tundeba; (53) Hanglaliya; (54) Kurdeman; (55) Sabahia; (56) Umm Ud; (57) Allawi; (58) Lewewi; (59) Dweig; (60) Hamash; (61) Geli; (62) Qulan; (63) Kab El Rayan; (64) Sheialik; (65) Abu Rahaya; (66) Wadi Khashb; (67) Umm Eleiga; (68) Betan; (69) Qurga Rayan; (70) Hutit; (71) Kalib; (72) Kurtunos; (73) El Hudi; (74) Hariari; (75) Um Shira; (76) Neqib; (77) Haimur; (78) The Nile Valley (Block E); (79) Umm Garaiart; (80) Marahib; (81) Atshani; (82) Murra; (83) Filat; (84) Seiga I; (85) Seiga II; (86) Umm Shashoba; (87) Abu Fass; (88) Umm Tuyur; (89) Betam; (90) Umm Egat; (91) Kurbiai; (92) Romit.

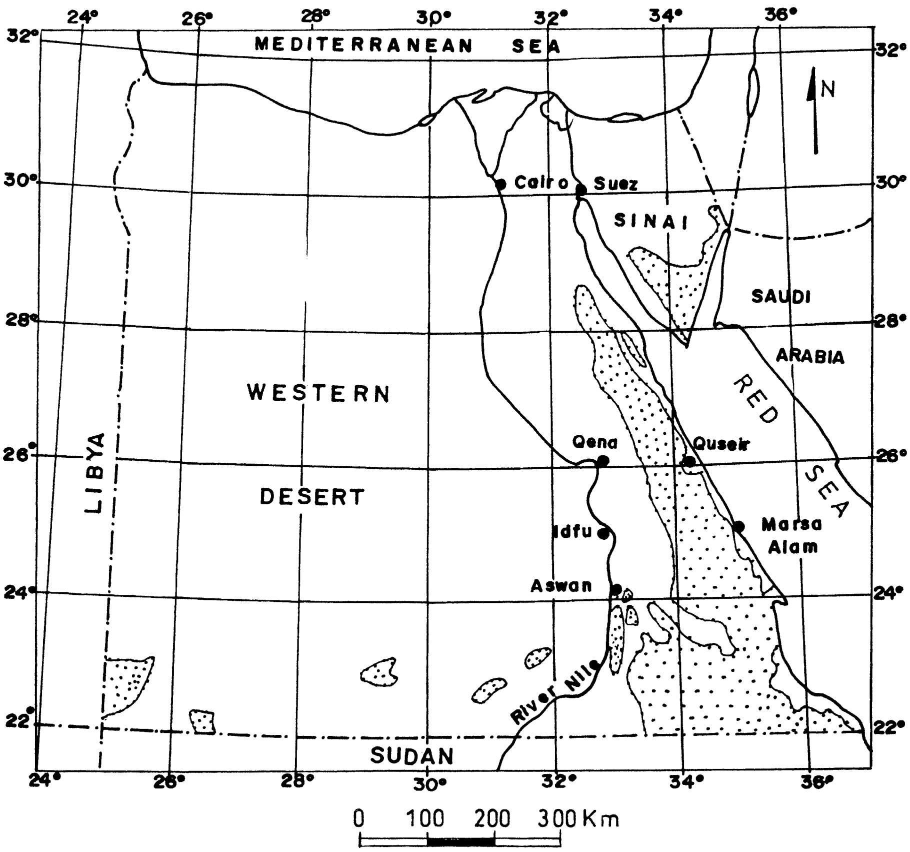


Fig. 2. Distribution of basement outcrops in Egypt. ▭ Younger sedimentary formations. ▭ Precambrian basement rocks.

The basement rocks of the Eastern Desert of Egypt constitute the Nubian Shield that formed a contiguous part of the Arabian shield in the Arabian Peninsula before the opening of the Red Sea. It is generally accepted that the basement of the Nubian Shield was cratonized during the Pan-African orogeny around 570 Ma ago (El Gaby et al., 1988).

The term "Pan-African" was introduced by Kennedy (1964) to define an "important and widespread tectonic and thermal event" which affected the African continent during the Late Precambrian and Early Paleozoic, some 500 ± 100 Ma ago. However, the term was later used by Gaas (1977) to describe the whole process of cratonization of ocean arc complexes and their collision and welding to the older African craton during the time period 1200–450 Ma.

The western edge of the basement exposures, changes west of the Nile into a series of high-grade migmatitic gneisses, migmatites and partly granulites with intercalated high grade supracrustal rocks like marbles, calc-silicates and amphibolites (Schandelmeier et al., 1988). There is considerable evidence that these rocks belong to an older sialic continental plate (Abdel Monem and Hurley, 1979; Harris et al., 1984; Beranu et al., 1987). This continental plate was named Nile Craton (Rocci, 1965; referring to the Uweinat inlier) or East Sahara Craton (Kroner, 1979; referring to the area between Hoggar and Arabian–Nubian Shield).

In the light of available radiometric age data, Greiling et al. (1994) suggested that the boundary between the East Sahara Craton and the Pan-African belt occurs as a north–south trending line just to the western limit of the basement exposures (Fig. 3). Moreover, El Gaby et al. (1988), from a synthesis of available geological, geochemical and

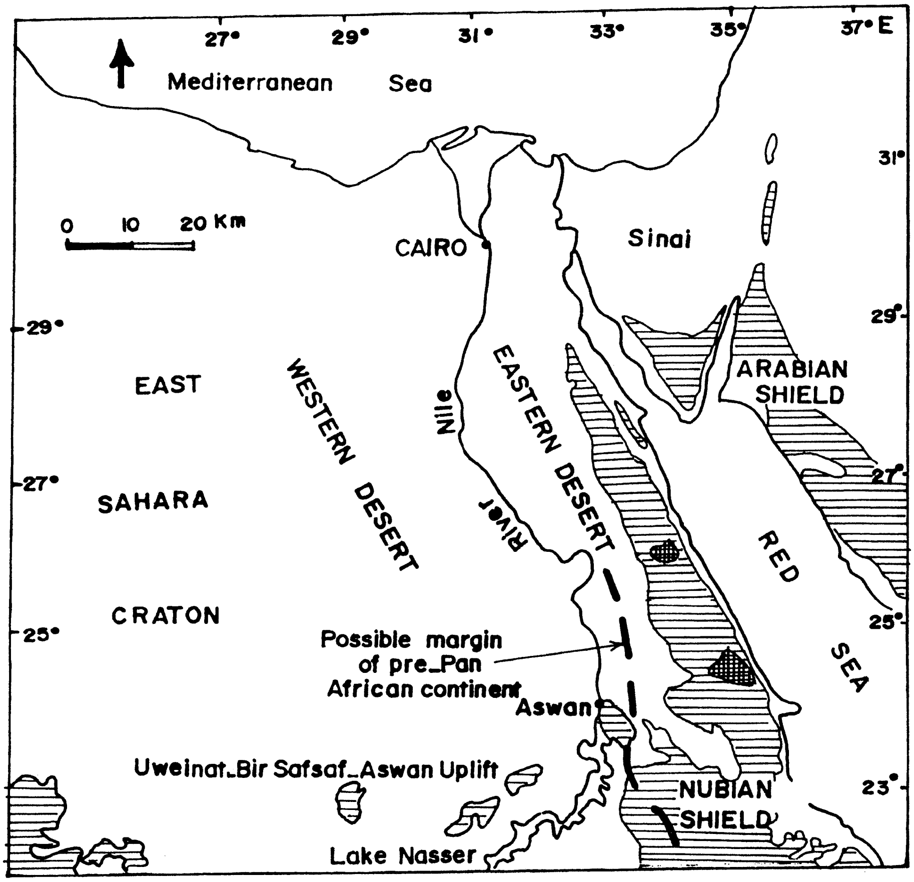


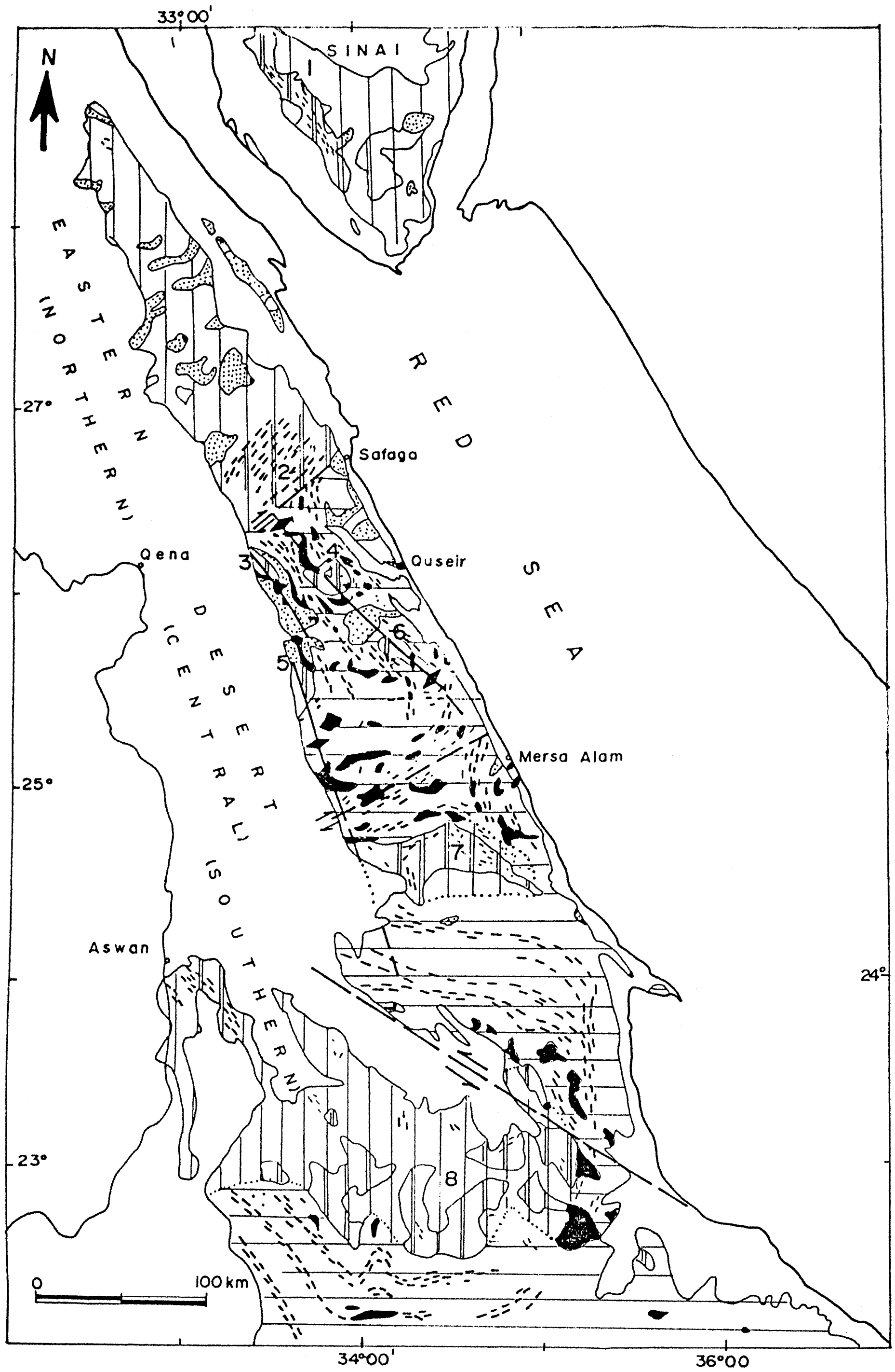
Fig. 3. The possible boundary between the East Sahara craton and the rocks of the Pan-African belt and the tectonic windows. (Compiled from El Gaby et al., 1988; Greiling et al., 1994). ▤ Rocks of the Pan African belt. ▦ Windows.

radiometric age data, came to a conclusion that the continental craton crust extends eastward into the Eastern Desert underneath the Pan-African cover and now is exposed in several tectonic windows (Fig. 3).

The presence of continental crust underneath the Pan-African rocks can be indirectly inferred, as El Gaby et al. (1988) mentioned from: (1) the presence of molasse-type sediments, which characterizes the continental margin orogenic belts (Windley, 1984, p.267), (2) the abundance of granitoid intrusions which do not form by partial melting of subducted oceanic crust or of upper mantle, but originate through interaction of subduction-related magmas with continental crust at depth (Wyllie, 1983).

Generally speaking, there are two major lithological associations in the Eastern Desert (Shackleton et al., 1980; Ries et al., 1983; El Gaby et al., 1988; Al Filali et al., 1993; Neumayr et al., 1996; Mansour et al., 1999). These are: (1) Pre-Pan-African rocks (infrastructure), which comprises gneisses, migmatites and amphibolites and occur as small windows, (2) Pan-African assemblage (suprastructure), which comprises ophiolites, island-arc volcanic and volcaniclastic rocks. The latter are metamorphosed to greenschist-amphibolite facies, and are intruded by syn- to late-tectonic calc-alkaline granites.

The boundary between the two major lithological associations is tectonic (Abdel Khalek et al., 1992; Hamimi et al., 1994) and has been produced by low-angle thrusting (Al Filali et al., 1993; Kroner et al., 1987). Ophiolites are commonly located along the major thrust faults (El Gaby, 1983; El Gaby et al., 1988, 1990) and particularly along the decollement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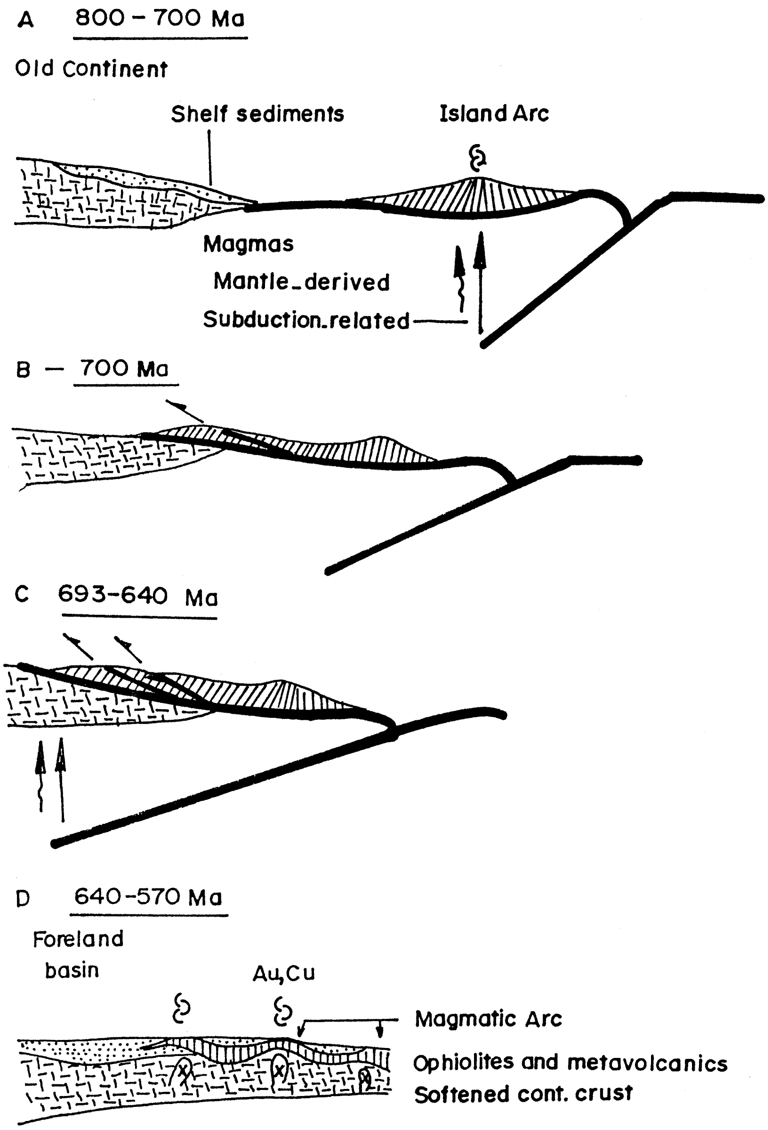

Fig. 5. Carton illustrating the tectonic evolution of the Eastern Desert of Egypt (simplified from El Gaby et al., 1988). (A) Island arc change. (B) Overthrusting of back-arc ophiolites and island arc volcanic and volcaniclastic rocks over the old continental margin. (C) Cordilleran Stage. (D) A sketch profile during the Cordilleran stage.

surface between the obducted Pan-African belt (suprastructure) and the underlying old continental margin (infrastructure) (Fig. 4).

Three tectonic–magmatic stages could be recognized in the evolution of the Nubian Shield in Late Proterozoic times. These are island-arc stage, orogenic

Fig. 4. The main structural features and the distribution of the major lithostratigraphic units in the Pan-African belt (compiled from El Gaby, 1983; El Gaby et al., 1998). ▭ Phanerozoic. ▭ Molasse-type Hammamat clastic sediments and penecontemporaneous Dokhan volcanic rocks. ▭ Island arc volcanic and volcanistic rocks. ■ Ophiolitic serpentinite. ▭ Gneiss and mylonite (1,2,3…). ▭ Infrastructure in general. Geanticline. Major shear zone. Trend lines. (1) Ferian; (2) Barud; (3) Um Had; (4) Meatiq; (5) El Shalul; (6) Sibai; (7) Hafafit; (8) Aswan-Nigrub.

stage and the cratonization stage. During the island-arc stage, an intra-oceanic island arc was formed as a result of subduction between two converging plates of oceanic lithosphere (Gaas, 1982). The volcanic rocks of this stage are represented by basalts, basaltic andesites and dacites (El Ramly et al., 1998). The volcaniclastic rocks, which accumulated in intra-arc basins, include tuffs and volcanogenic wackes that are often banded and graded bedded. Ophiolites were formed in back-arc basins during the island-arc stage in the Upper Proterozoic (Stern, 1981).

During the orogenic stage (Pan-African orogeny) that gave the Egyptian basement its present-day configuration (Gaas, 1977), the island arc was swept against the old continent, thereby thrusting back-arc ophiolites and the island-arc volcanic and volcaniclastic rocks onto the margins of the old continent. Thrusting was in a NNW direction over the pre-Pan-African continental margin (Shackleton et al., 1980; Ries et al., 1983; Habib et al., 1985) The Pan-African belt then acquired a Cordilleran character (El Gaby et al., 1988) (Fig. 5). The whole succession of the ophiolites and island arc association is dissected by many listric thrust faults causing repetitions, tectonic mixing (El Gaby et al., 1988) and disruption of the oceanic lithosphere in the form of dismembered phiolitic components (Akaad et al., 1996). Ries et al. (1983) believe that the metasediments, metavolcanics, serpentinites and metagabbros are all components of an ophiolitic melange.

Subduction was active under the continent while the process of overthrusting was operative along the thrust planes (Gaas, 1982). A pronounced phase of cal-alkaline magmatic activity, represented by the emplacement of G-1 and G-2 granites (Hussein et al., 1982) and the eruption of their volcanic equivalents (Dokhan volcanics) took place (El Gaby et al., 1988, 1990). G-1 granites (older granites) are subduction-related I-type magnetite-series granites, formed in old Benioff zones by partial fusion of the mantle wedge with little or no crustal melt contribution. G-2 granites (younger granites), on the other hand, are suture-related granites formed in the thickened crust due to folding and thrusting. They are characterized by being S-type, ilmenite series granites (Hussein et al., 1982).

The compressional deformation event that characterized the orogenic stage was also synchronous with the regional metamorphism to greenschist-amphibolite facies. Obducted Pan-African ophiolites and island arc volcaniclastic rocks were metamorphosed to talc carbonates and actinolite schist, respectively (El Gaby et al., 1988). Extensional shear fractures reflected in brittle–ductile shear zones were broadly contemporaneous with the intense compressional tectonic regime. These fractures opened spaces in which mineralizing fluids penetrated (Loizenbauer and Neumayr, 1996). At the orogenic stage or slightly later, coarse terrigenous molasse-type sediments (Hammamat sediments) were deposited in a non-marine intermontane basins (Grothaus et al., 1979).

During the prolonged period of plutonism that constituted the cratonization stage, igneous bodies represented by ultramafic–mafic rocks (younger gabbros) were intruded. These rocks occur as small, frequently layered intrusions and sills. The latest stage in the formation of the continental crust was dominated by a number of subalkaline to peralkaline A-type granite bodies.

3. Classification of gold deposits

According to the previously mentioned tectonic–magmatic evolution of the Nubian shield, a three-fold classification of gold deposits in Egypt is offered. These are stratabound deposits, non-stratabound deposits and placer deposits. The stratabound deposits are further subdivided into three-main types: gold-bearing Algoma-type Banded Iron Formation, gold-bearing tuffaceous sediments and gold-bearing volcanogenic massive sulphide deposits. Non-stratabound deposits are divided into two main types: vein-type mineralization hosted in a wide range of rocks and disseminated-type mineralization hosted in hydrothermally altered rocks (alteration zones). Placer deposits are divided into modern placers and lithified placers.

3.1. Stratabound gold deposits

These deposits are hosted in island arc volcanic and volcaniclastic rocks that are equivalent to younger metavolcanics (YMV) of Stern (1981), Shadli metavolcanics (El Ramly, 1972) and ophiolitic melange (Shackleton et al., 1980; Ries et al., 1983). Volcanic

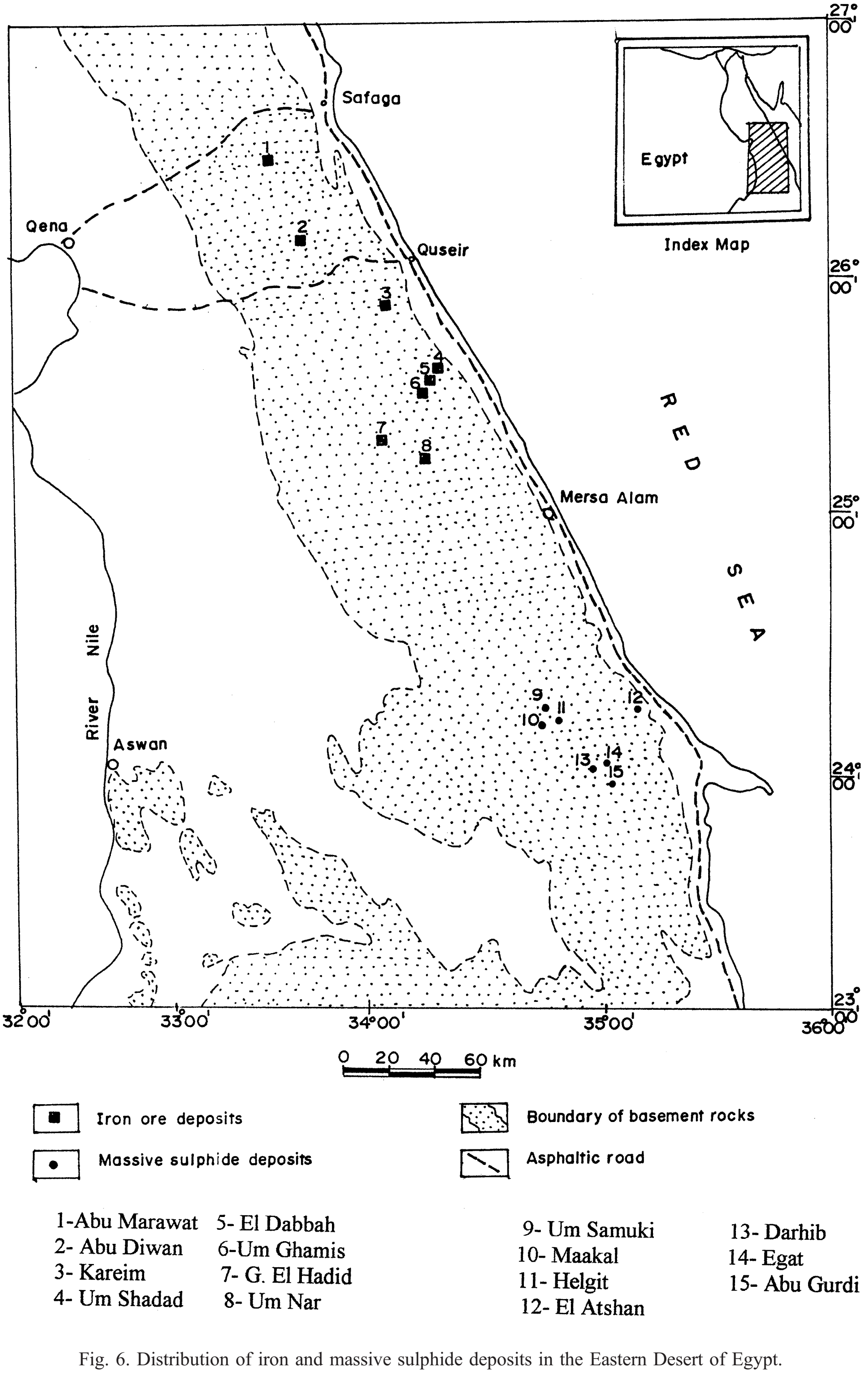

Fig. 6. Distribution of iron and massive sulphide deposits in the Eastern Desert of Egypt.

rocks are represented mainly by basalts, basaltic andesites and dacites. The volcaniclastic rocks, which accumulated in intra-arc basins are frequently intercalated with Banded Iron Formation (BIF) of Algoma-type particularly in the central part of the Eastern Desert and associated further to the south with massive sulphide deposits similar in many respects to the massive sulphide deposits (Fig. 6) of the Canadian shield (Hussein et al., 1977).

Geochemically, basalts and basaltic andesites show tholeiitic affinity, whereas andesites and dacites show calc-alkaline affinity (Botros, 1991; El Ramly et al., 1998). The mineral assemblage of these volcanic and volcaniclastic rocks indicates that they are metamorphosed in the greenschist to epidote-amphibolite facies transition. The metamorphism was synchronous with the compressional deformation events that happened during the Pan-African orogeny (El Gaby et al., 1988; El Ramly et al., 1998).

Stratabound gold deposits are classified into three main types. These are shown below.

3.1.1. Gold-bearing Algoma-type banded iron formation (BIF)

BIF in the Eastern Desert (Fig. 6) occurs as well-defined stratigraphic unit within the Pan-African layered volcanic and volcaniclastic rocks. At present, it is well established that BIF in the Eastern Desert resembles those found in Archaean and younger volcanic assemblages and belongs to the class of Algoma-type deposits which are related in time and space to volcanic activity (Sims and James, 1984; Botros, 1995a; Khalil, 2001).

The majority of BIF in the Eastern Desert belong to the oxide facies where hematite and magnetite occur in bands alternating with silica-rich bands (Fig. 7). However, carbonate and sulphide facies are also encountered in some localities (Aly et al., 1992; El Gaby et al., 1994).

Recently, gold mineralization associated with oxide facies of BIF at Abu Marawat gold prospect (Botros, 1991, 1995a) and Um Nar area (Dardir and Elshimi, 1992) was recorded. In this study, Abu Marawat BIF is taken as an example for gold-bearing oxide facies in Algoma-type BIF (Fig. 8). At Abu Marawat area, BIF is located the upper parts of Abu Marawat mountain as sharply defined horizon within volcano-sedimentary succession (Fig. 9). Pillowed basalts (Fig. 10) that show a characteristic variolitic texture under the microscope (Fig. 11) dominate volcanic rocks. They were formed during the early stages of arc development (immature island arc) (Botros, 1991). Sedimentary rocks at Abu Marawat gold prospect are represented by graywacke, laminated and pebbly mudstone and polymict conglomerate. The volcano-sedimentary succession is regionally metamorphosed into greenschist facies.

Gold occurs up to 2.15 ppm in the formation (Botros, 1991), either enclosed in the flaky hematite crystals of the hematite mesoband (Fig. 12) and/or as fine inclusions in the gangue constituents of the magnetite mesoband (Fig. 13).

The genesis of the auriferous BIF in Abu Marawat gold prospect was attributed to interaction between volcanically derived fluids (hot brines) and seawater. The hot brines were capable of leaching iron, silica, gold and other associated elements from basaltic andesites and basalts of tholeiitic affinity that characterized the early stage of the island arc volcanicity (immature arc). When these brines mixed with seawater, auriferous BIF was deposited as chemical sediments (Botros, 1991).

At Um Nar area, gold in the BIF varies from 0.41 to 1.24 ppm with an average of 0.82 ppm and the hematitic bands of the iron formation are slightly

Fig. 7. Photo showing a boulder of BIF with rhythmic alternation of iron oxide-rich bands (dark) and silica-rich bands (light), Abu Marawat area (from Botros, 1991).

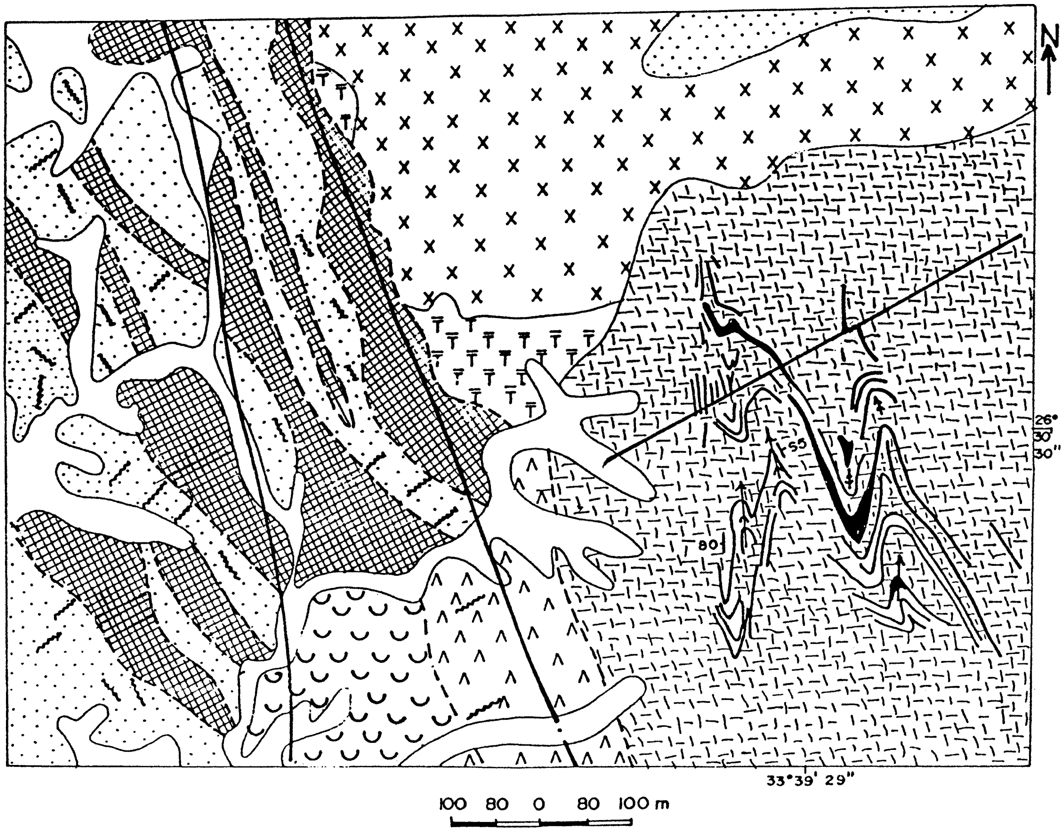

Fig. 8. Geologic map of Abu Marawat area, Eastern Desert, Egypt (after Botros, 1991 with some modifications). Wadi deposits. Diorite-tonalite. Metagraywacke, metamudstone and their schists. Algona-type Banded Iron Formation (BIF). Metalapilli tuffs, pebbly metamudstone and polymictic metaconglomerate. Pillowed metabasalt. Metabasaltic andesite. Serpentinized ultramafic rocks. Mineralized zones. Quartz veins. Faults Axis (1) anticline, (2) syncline. 55 Attitude. Contacts (1) sharp, (2) gradational.

richer in gold than magnetite ones (Dardir and Elshimi, 1992).

BIF in the Eastern Desert of Egypt satisfies the initial criteria for syngenesis in that it is stratiform and confined to particular lithologies (layered volcaniclastic rocks and intercalated lava flows). Other criteria are: (1) the constituent minerals participated in all deformation and metamorphic events recorded in the adjacent rocks. They are metamorphosed to greenschist facies, with the development of chlorite, sericite and the iron silicate stilpnomelane; (2) mineralization is not restricted to specific folds or fault structures or zones of fracturing; (3) wall rock alterations are not recorded (Botros, 2002a).

3.1.2. Gold bearing tuffaceous sediments

Tuffaceous sediments, which are often banded, graded bedded and intercalated with BIF are usually gold bearing (Botros, 1993b). This style of mineralization is localized in areas where volcanic and volcaniclastic rocks are intimately intercalated with each other. Botros (2002a) believes that this style of gold mineralization in the Eastern desert of Egypt may represent a break or termination within the volcanic stratigraphy, and in areas occupied by island arc volcanic and volcaniclastic rocks, such breaks are confirmed by the occurrence of BIF which is also considered to be a chemical sediment precipitated during breaks of volcanic activity (Sims and James, 1984). The anomalous gold in

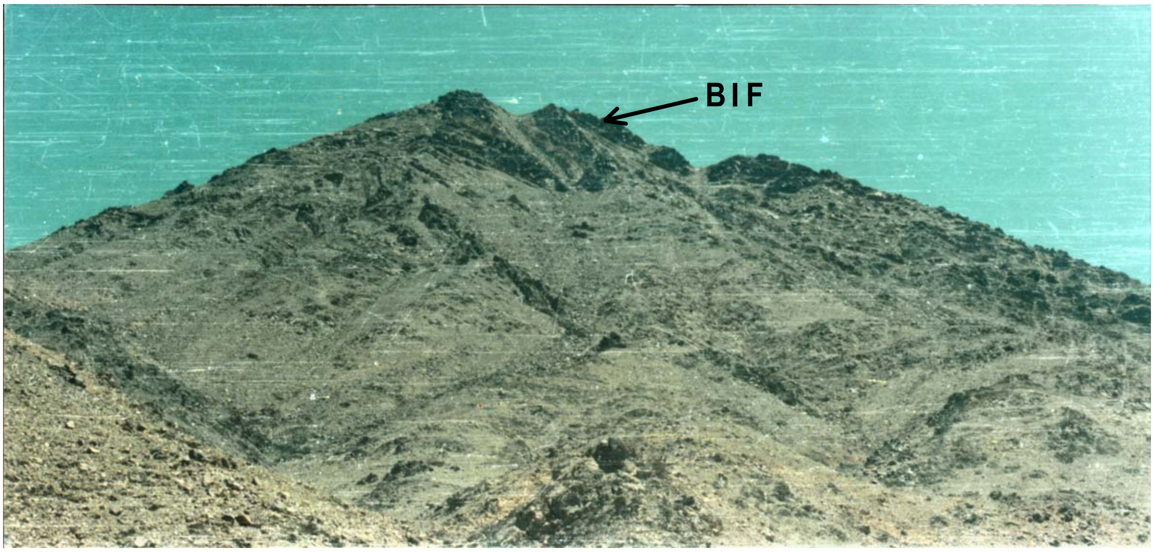

Fig. 9. Algoma-type Banded Iron Formation (BIF) occurring as sharply defined stratigraphic unit within the Pan-African layered basaltic andesites, basalts, tuffs and volcanogenic wackes, Abu Marawat area, Eastern Desert of Egypt.

the auriferous tuffaceous sediments (up to 11.62 ppm in Abu Marawat area, Botros, 1991) can be considered as a type of exhalative deposits analogous to present day hot springs or fumarolic discharges. Viljoen (1984) has made reference to this phenomenon.

Fig. 10. Close view of pillowed metabasalts at Abu Marawat area, Eastern Desert, Egypt.

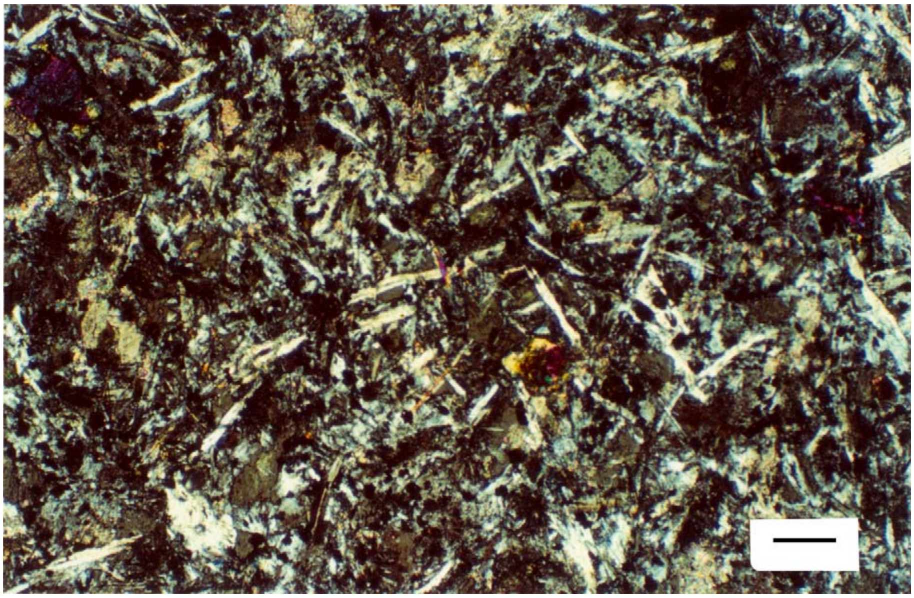

Fig. 11. Photomicrograph showing variolitic texture exhibited by the divergent laths of plagioclase, Abu Marawat area. Plane polarized light, crossed nicols, bar length represents 1.22 mm (from Botros, 1991).

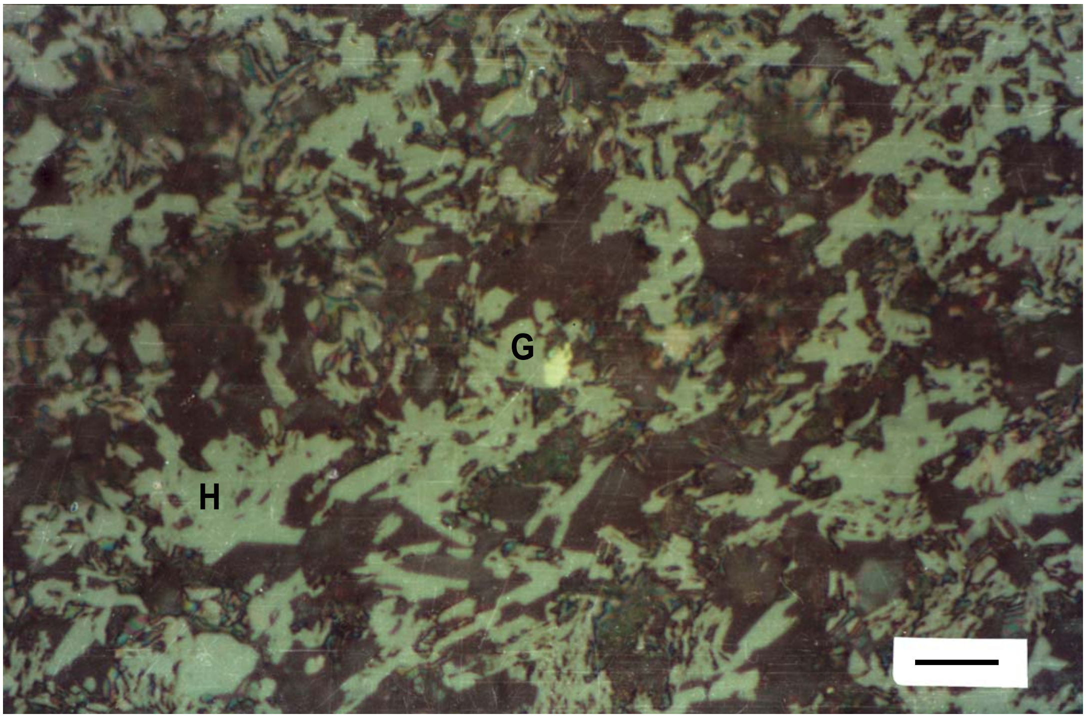

Fig. 12. Photomicrograph of Algoma-type BIF showing minute gold speck (G) enclosed in the hematic flake (H). Abu Marawat area, Eastern Desert, Egypt. R.L., Bar length represents 0.02 mm (from Botros, 1991).

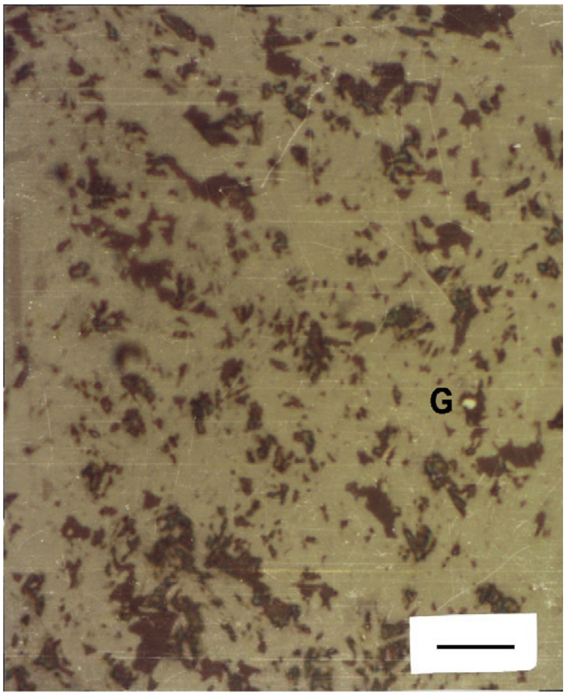

Fig. 13. Photomicrograph of Algoma-type (BIF) showing minute gold speck (G) enclosed in the gangue minerals, Abu Marawat gold prospect, Eastern Desert, of Egypt. Bar length represents 0.02 mm (from Botros, 1991).

3.1.3. Gold bearing volcanogenic massive sulphide deposits

Volcanic hosted massive sulphide (VHMS) deposit in the Eastern Desert include Um Samuki, Helgit, Maakal, Darhib, Abu Gurdi, Egat and El Atshan (Fig. 6). Some of these deposits (e.g. Darhib and El Atshan) have been identified as talc mines (Hussein, 1990). Most studies on VHMS deposits in Egypt are concentrated mainly on the Um Samuki deposit, which is the largest in the reserves and the best in ore grade.

Um Samuki is a Zn–Cu–Pb sulphide deposit in an area of very rugged topography amidst the belt of island arc volcanic rocks. For that area, Searle et al. (1976) divided Shadli volcanic rocks (island-arc volcanic rocks) into the older Wadi Um Samuki volcanic rocks and a younger Hamamid assemblage (Table 1). The Wadi Um Samuki volcanic rocks are a thick succession of submarine cyclic basic and acid volcanics with minor intercalated banded tuff and chert beds. The Abu Hamamid group includes two distinct cycles of volcanism. Each cycle starts with pillowed basalt and terminates with thick beds of rhyolitic volcaniclastic rocks. Vent complexes are recorded in the area and are thought to be the centers of eruption for the acidic phase of the first volcanic cycle. The massive sulphide body is confined to the coarse acid pyroclastic rocks of the first cycle of Abu Hamamid group (Searle et al., 1976). The body occurs along a specific stratigraphic horizon, which separates the brecciated rhyolite and vent facies on one hand, and the banded graded bedded tuffs on the other hand. The ore minerals of Um Samuki orebody are represented mainly by sphalerite, chalcopyrite, pyrite, marcasite and minor galena. Secondary minerals include covellite, bornite, marcasite and occasional neodigenite (Deyab, 1986).

The upper contacts of the massive sulphide body at Um Samuki are sharp and well defined; while on the footwall side, an extensive pipe or funnel of alteration is present. Here, the alteration zone beneath the orebody at Um Samuki area is characterized by septechlorite and talc, associated with

Table 1
Stratigraphical succession of the Shadli volcanic rocks (island-arc volcanic rocks) in Um Samiuki area, Eastern Desert, Egypt (after Searle et al., 1976)

Shadli volcanic rocks		
	Hammid assemblage	Dolerite
		Upper banded tuffs and cherts
Cycle 2	Acid-lava phase	Volcanic breccias
		Dacite and related intrusions
		Volcanic breccias and turbidites
	Basic lava phase	Upper pillow lavas and hyaloclastic
		Basic vent breccias and lava
		Lower banded tuffs and cherts
Cycle 1	Acid-lava phase	Acid vent rocks and mineralization
	Basic-lava phase	Micro-diorite
		Lower pillow lavas
Wadi Umm Samiuki volcanic rocks		Basic and intermediate lavas with rhyolites and acid. Volcaniclastic rocks

variable amounts of carbonates and tremolite (Rasmy et al., 1983).

Two distinct spatial and mineralogical associations of gold mineralization could be identified in the volcanogenic massive sulphide deposits and their footwall alterations (the keel zone) in the Eastern Desert of Egypt (Botros, 2003):

(1) Gold–silver–zinc association: Here gold grades are very low (generally in the range 0.3–0.4 ppm) and silver is anomalous, averaging 109.25 ppm in the Um Samuki VHMS deposit. This association occurs typically in the upper levels of the deposit where low-temperature sulphides are abundant. This association deposited in the initial stage of the massive sulphide body development where gold was transported as thio-complex Au (HS_2) with significant amounts of lead, zinc and silver, usually in the range 150–250 °C. The most plausible interpretation for the deposition of gold is the mixing that took place between the ascending hot brines and the sulphate-rich seawater. This process led to a decreasing in the H_2S with concomitant increasing in the SO_4/H_2S ratio. The upper levels of Um Samuki sulphide body represent this association.

(2) Gold–copper association: This association typically occurs in the footwall rock alteration zone (the keel zone) and the lowest parts of the massive sulphide body. Gold grades reach up to 5.54 ppm but average is 1 ppm. Silver is very low, usually in the range 4–10 ppm. Lead usually, but not always, accompanies gold in this association. This association deposited in the later stages where gold and copper were transported as chloride complexes, in relatively high-temperature fluids (>300 °C) with low pH (<4.5), low H_2S concentration, high salinity (greater than that of seawater) and moderate to high oxygen fugacity. Deposition took place due to decreasing of temperature and/or increasing pH conditions. The keel zones at Darhib, Abu Gurdi, El Atshan, Um Selimat, Nikhira and Egat talc mines represent this association.

The twofold gold association observed in the volcanogenic massive sulphides and their footwall alterations, in the Eastern Desert of Egypt is also displayed in other volcanogenic massive sulphide provinces such as Kurko, Canadian and Australian deposits (Hannington and Scott, 1989).

3.2. Non-stratabound gold deposits

These deposits are hosted in a wide range of rocks that were formed in different tectonic environments. Non-stratabound gold deposits are divided into vein-type mineralization, which has constituted the main target for gold in Egypt since Pharaonic times, and disseminated-type mineralization hosted in hydrothermally altered rocks (alteration zones)which have recently been recognized as a new target for gold in Egypt. Mineralizing fluids of different sources are suggested for the formation of these deposits.

3.2.1. Vein-type mineralization: this in turn is subdivided into

3.2.1.1. Vein-type mineralization hosted in metavolcano-sedimentary assemblage and/or the granitic rocks surrounding them. This style of vein-type mineralization constituted the main target for gold since ancient times, where ancient Egyptians extracted gold from these veins in open-pit and underground workings. The style is confined to the metamorphosed island arc volcanic and volcaniclastic rocks and/or the older (syn-tectonic) granatic rocks surrounding them (Fig. 14) and is analogous to the vein-type gold deposits mentioned by Kochine and Bassuni (1968) and El Ramly et al. (1970).

Vein-type gold deposits of this environment have been formed during the Pan-African orogeny (Botros, 2002a) synchronous with the regional metamorphism (greenschist to amphibolite-facies) and attendant upon calc-alkaline I-type granites that are widely distributed in this environment. It seems that metamorphic grade is important because most auriferous quartz veins are hosted rocks which have been metamorphosed at conditions below the amphibolite-greenschist boundary (Botros, 1995b).

This style type of vein-type mineralization occurs in the hinge zones of first generation of folding, especially the anticlinal folds (Elshimi, 1996; Nasr et al., 1998), and may arrange as a series of en echelon veins with pinches and swells. Parallel veinlets and stringers that form ore zone of considerable thickness as compared to the main veins always accompany the main veins. The mineralized veins consist dominantly of quartz and carbonates, with subordinate amounts of sulphide minerals. Pyrite is the dominant sulphide mineral, commonly accompanied by minor chalcopyrite and one arsenopyrite and one or more of sphalerite, tetrahyrdrite, galena, pyrrhotite and pyrrhotite. The sulphide minerals occur as disseminations and fracture fillings in the quartz. Native gold occurs in most cases as minute specks and discrete scattered flakes within the quartz vein or as small inclusions in sulphides particularly pyrite and arsenopyrite.

Table 2 gives the character features of some vein-type gold deposits and occurrences hosted in the metavolcano-sedimentary assemblage and/or the surrounding granitic rocks.

The only available fluid inclusion study, conducted on quartz veins traversing metavolcano-sedimentary assemblage in the Pan-African belt (El Kazzaz, 1996) is summarized in Table 3. It is clear that the auriferous fluids are characterized by: (1) ubiquitous content of CO_2 in the inclusions, and (2) high salinity (25.00 equiv. wt.% NaCl). Through observations of many gold deposits in the world, a general consensus exists that mineralizing fluids of metamorphic origin are H_2O-CO_2 rich, low salinity (commonly less than 6 equivalent wt.% of NaCl) fluids (Foster, 1989; Groves et al., 1989; Peters and Golding, 1989; Goldfarb et al., 1989). Comparing the ideal metamorphic fluids with our available data, it becomes clear that these data do not suggest a unique origin for the fluids that leached gold from source rocks. It is here suggested that parent fluids were mainly of metamorphic origin, and the relatively observed high salinity in some fluid inclusion studies could be attributed to mixing of these metamorphic fluids with magmatic fluids connected with the I-type granites that are dominated in this environment. This belief is supported by oxygen and hydrogen isotopic study carried out on quartz from Atshani old gold workings (El Kazzaz, 1996). The $\delta^{18}O$ values range from 7.8‰ to 15.6‰, whereas δD values range from -89‰ to -71‰. On the diagram of Taylor (1974), the data plots overlap the fields of metamorphic and magmatic waters (El Kazzaz, 1996).

The mixed metamorphic–magmatic fluids reacted with enormous masses of rocks during their passage resulting in their alteration, with liberation of "available gold" in rocks affected by alteration, and then fluids moved down a temperature gradient away from the amphibolite-greenschist transition at depth to a lower temperature regime in the upper levels where gold-quartz veins were deposited in structural traps (Fig. 15).

The ultimate source of the gold in this style of vein-type mineralization is a matter of discussion. The author is inclined to the belief that gold could be derived from various lithologies and up till now, no one has clearly identified a volumetrically significant group of rocks of sufficiently high gold content to be identified as source rocks (Keays, 1984). The absolute gold content in any lithology appears not to be the critical factor in determining whether this lithology is potential source rock (Viljoen, 1984) but that the mineralogical siting of gold (i.e. accessible to leaching or not) would seem to be the most important parameter (Anhaeusser et al., 1975; Keays and Scott, 1976; Keays, 1984; Viljoen, 1984). One or more of the following targets could be considered as possible sources for gold in the vein-type gold deposits hosted in the island arc volcanic and volcaniclastic rocks and/or the granitic rocks surrounding them:

(1) Metabasalts and metabasaltic andesites connected with island-arc volcanic activity (Botros, 1991, 1995b; Suror et al., 1999).
(2) Sulphide-facies of Algoma-type BIF and auriferous tuffaceous sediments (Botros, 1993b).
(3) The massive sulphide deposits connected with the sub-marine volcanic activity (Botros, 1993b).
(4) Ophiolitic serpentinites (Dardir and Elshimi, 1992; Takla and Suror, 1996) that are embedded in the metavolcano-sedimentary matrix.
(5) I-type granites that are abundant in this environment of vein-type mineralization. This is indicated by the presence of Mo, Sn in some auriferous quartz veins (El Ramly et al., 1970; Botros, 1991).

3.2.1.2. Vein-type mineralization hosted in sheared ophiolitic ultramafic rocks. The vein-type mineralization hosted in the sheared ophiolitic serpentinites is another style of vein-type mineralization connected with the Pan-African orogeny. In this style, linear zones of ophiolitic serpentinites show extreme alter-

Table 2
Characteristic features of some vein-type gold deposits and occurrences hosted in the metavolcano-sedimentary assemblage and/or the surrounding older (syn-tectonic) granitic rocks, Eastern Desert, Egypt

Deposit	Host rocks	Lode type	Alteration assemblage	Ore minerals in quartz veins	Gold content in the veins
Abu Marawat	Volcano-sedimentary rocks intruded by diorite-tonalite	Shear zone vein arrays	Ch + Q + I	g + py + cpy + sl	1.37–73.48 g/t with an average of 6.9 g/t
Erediya	Tonalite-granodiorite association	Shear-zone vein arrays	Q + Carb + Ser + Ch + I	g + py	13.2–29.76 g/t
Dungash	Metavolcanic and metapyroclastic Rocks	Shear-zone vein arrays	List + Carb + Ser	g + py + apy ± cpy ± po ± sl ± gers	3.87 g/t on average
Umm Ud	Metaandesite, metabasalt and their tuffs intruded by schistose diorites. Both are crossed by quartz veins and veinlers	Quartz veins in brittle–ductile shear zone°	Car-Q	No data	Up to 15 g/t with an average of 3 g/t
Sukkari	Schist; granodiorite	Shear zone vein arrays	Ber-List	g + py + apy ± sl ± cpy ± gn	6.1–29.45 g/t with an average of 18.19 g/t
Umm Egat	Schistosed volcano-sedimentary rocks; tonalite	Hinge zones of first generation anticlinal folding	I	g + py +	From 0.3 to 40 g/t
Umm Garaiart	Metaandesitic tuffs	Steeply dipping veins	Ser-Q-Carb	g + py + cpy	7.75–155.5 g/t
Seiga	Metaandesite and their pyroclastic rocks	The mineralized vein is enclosed in subsidiary brittle–ductile shear zone	Ser-Q-Carb-I	g + py	No reliable data
Atshani	Porphyritic metabasalt	Hinge zones of first generation anticlinal folding	Ser-Q-Carb-I	g + py + cpy	No reliable data
Negib	Foliated metaandesite	Brittle–ductile shear zone genetically related to the first generation synclinal folding	Ser-Q-I	No data	No reliable data
Umm Tuyur	Schistosed metasediments intruded by tonalite-granodiorite	Shear zones parallel to the schistosity of the metasediments	Q-Ser-Ch-Carb-I	No data	29.25 g/t on average
Haimur	Metabasalt and their related chlorite-quartz-carbonate schist	Extensional shear fracture in association with the hinge zones of first generation anticlinal folding	Q-Ser-Ch-Carb	Gold + pyrite + chalcopyrite	No reliable data
Abu Fass	Porphyritic metaandesite	The mineralized vein is enclosed in brittle–ductile shear zone concordant with the foliation of the host rocks	No data	No data	No reliable data
Marahib	Close to extrusive contacts of porphyritic metaandesite and metadacite with complete restriction to the metaandesite domain	Quartz veins in brittle–ductile shear zone of pinch and swell structure in association with the hinge zones of first generation anticlinal folding	Q-Ser-Carb-I	Gold + pyrite + chalcopyrite	No reliable data
Betam	Schistosed metasediments intruded by tonalite-granodiorite (GI)	Shear zone vein arrays	Q-Ser-Ch-Carb-I	No data	2.0–11.07 g/t
Hariari	Foliated Diorite	Quartz veins in brittle–ductile shear zone of pinch and swell structure	Ser-Carb	g + py	No reliable data

Data from Ahmed et al. (2001), Arslan et al. (2000), Botros (1995a,b), Elshimi (1996), Helmy (2000), Khalil et al. (2000), Kochine and Bassuni (1968), and Nasr et al. (1998).

Q—quartz, Carb—carbonate, Ch—chlorite, Ser—seircite, Ber—bersite, List—listawenite, I—iron minerals, apy—arsenopyrite, cpy—chalcopyrite, gers—gersdorffite, gn—galena, po—pyrrhotite, py—pyrite, sl—sphalerite, g—gold.

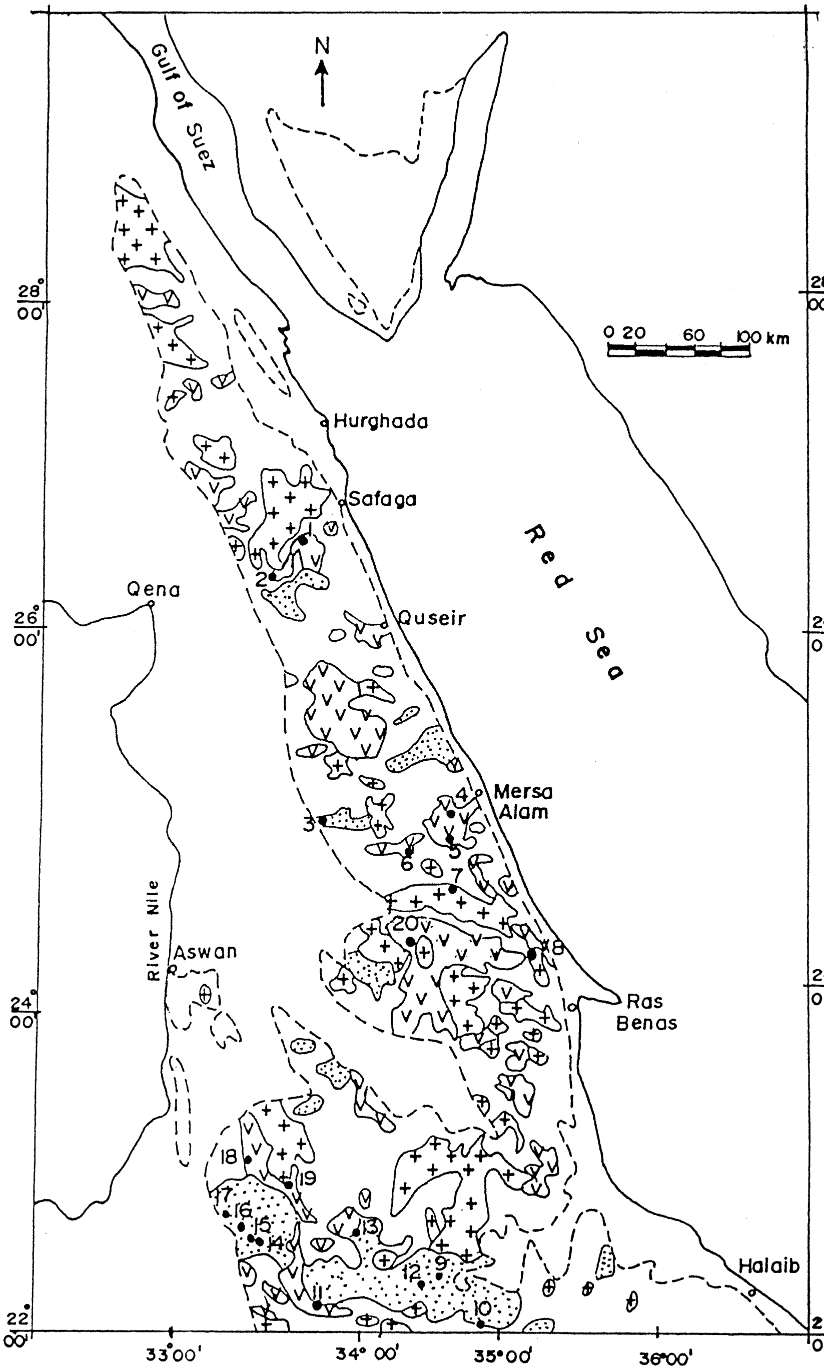

Fig. 14. Distribution of some vein-type gold deposits in metavolcano-sedimentary assemblage and/or the older (syn-tectonic) granites surrounding them, Eastern Desert. [+ +] Syn-tectonic granite. [⋯] Metasediments. [V V] Meta volcanic rocks. [⁄⁄] Boundary of basement rocks. [•] Location of gold deposits. 1—Abu Marawat; 2—Erediya; 3—Dungash; 4—Sukkari; 5—Umm Ud; 6—Dweig; 7—Geli; 8—Abu Rahaya; 9—Umm Tuyur; 10—Umm Egat; 11—Abu Faas; 12—Betam; 13—Seiga; 14—Atshani; 15—Marahib; 16—Umm Garaiart; 17—Haimur; 18—Hariari; 19—Neqib; 20—Wadi Khashb.

Table 3
Summary of fluid inclusion microthermometric data for vein-type gold deposits hosted in metavolcano-sedimentary assemblage and/or the granitic rocks surrounding them, Eastern Desert, Egypt

Deposit or area (Reference)	Fluid inclusion data	Host of the quartz veins
Atshani old gold workings (El Kazzaz, 1996)	Size: < 15 μm Genetic class: primary and secondary Shape: oblate, cylindrical, and irregular forms Types of inclusions: liquid-rich, vapour-rich Salinity: 25 equiv. wt. percent NaCl CO2: ubiquitous content Homogenization temp.: 280–320 °C Trapping pressure: 2 kbars	Metavolcanic, metavolcaniclastic rocks and granites

ations along thrusts and shear zones with the development of a range of talc, talc-carbonate and reddish brown quartz-carbonate rock (listwaenite). Listwaenite is frequently mineralized with gold (Botros, 1991; Oweiss et al., 2001). The most characteristic feature of listwaenite is its relative resistance against weathering, if compared with the surrounding rocks; accordingly, it stands out forming prominent topographic ridges (Fig. 16). Examples for this style of mineralization in the Eastern Desert are encountered in Barramiya, El Sid and Hutite (Table 4). Much field studies and geochemical exploration programs were carried out by the Egyptian Geological Survey (EGS) (1977, 1978) around Barramiya gold deposit, and in the Egyptian literature this deposit is taken as an example for the vein-type mineralization hosted in sheared ophiolitic ultramafic rocks.

The Barramiya deposit is located in the central Eastern Desert of Egypt, midway between the Nile valley and Red Sea coast. The country rocks around the mine are made up principally of ophiolitic melange that covers about 75% of the exposed rocks in the mine area (Fig. 17). The melange is composed of allochthonous dismembered blocks and clasts of serpentinite (after dunite and harzburgit) incorporated and intermixed within an intensively deformed matrix of actinolite and graphite schist. The contacts of blocks toward the enclosing matrix are tectonic. Small dyke-like bodies of tonalite and granodiorite intrude the ophiolitic melange and in places, some quartz veinlets traverse these felsic bodies (Kochine and Bassuni, 1968). The melange occurs in the core of a synclinal fold that turns into an anticlinal fold in the eastern part of the mine area (Fig. 17). The axis of the syncline is trending E–W and along this axis, the main gold-quartz lode occurs. The actinolite and graphite schists are intensively deformed and foliated and the direction of folia is parallel to the trend of the main lode, i.e. E–W. Micro-fractures filled with quartz veinlets characterize these schists, particularly the graphite schist.

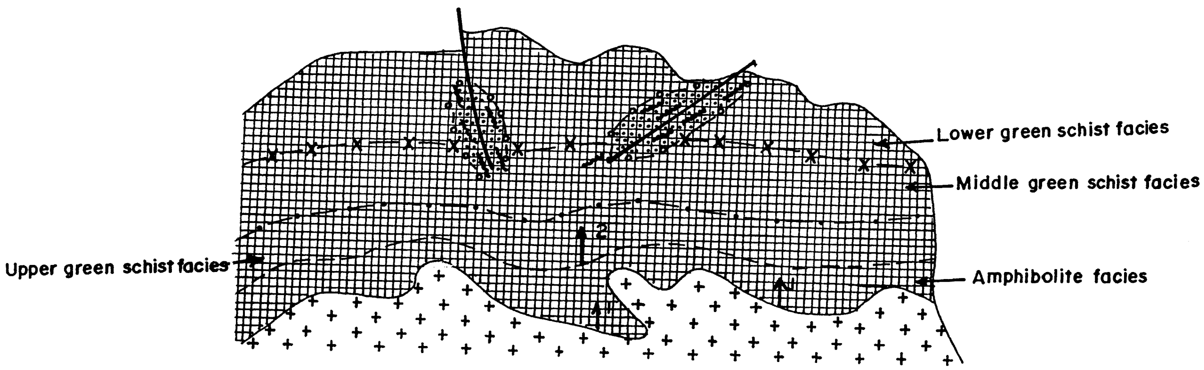

Fig. 15. Sketch diagram showing leaching of available gold from island arc volcanic and volcaniclastic rocks by mixed metamorphic–magmatic fluids and formation of vein-type gold mineralization in structural traps in the upper levels of the volcanic and volcaniclastic pile. Structural trap. Boundaries of facies of metamorphism. Fluids (1) Magmatically derived fluids; (2) Metamorphically derived fluids. Wall-rock alterations surrounding the quartz veins. Quartz veins. Island arc volcanic and vocaniclastic rocks. Calc-alkaline I-type granites (syntectonic granites).

Table 4
Characteristic features of some important gold deposits hosted in sheared, linear zones of altered ultramafic rocks, Eastern Desert, Egypt

Deposit	Host rock	Lode type	Trend of quartz veins	Alteration assemblage	Ore minerals
Hutite	Sheared serpentinite traversed by a series of dykes	Brecciated quartz vein	NW–SE, NE–SW	Q-Carb	g + gn
El Sid	Sheared serpentinite intruded by granite	Quartz veins in extensional joint system cutting across the granite-serpentinite contact	E–W	Car-T	g + py + apy + sl + gn
Barramiya	Graphitic and calcareous schists associated with serpentinite. Quartz-diorite dikes (20 m thick) were reported from the underground workings	Steeply dipping veins; parallel veinlets and stringers; lenticular veins arranged en echelon	E–W (main) N–S, NE–SW, NNE–SSW	Car-T	g + py + cpy

Data from Hussein (1990), Loizenbauer and Neumayr (1996), and Takla et al. (1995).
Q—quartz, Carb—carbonate, T—talc, Apy—arsenopyrite, cpy—chalcopyrite, gn—galena, py—pyrite, sl—sphalerite, g—gold.

The known length of the main quartz lode is about 800 m, but the exploitation has been concentrated mainly within an interval of 300 m in its western part. The thickness of the main lode varies from 0.15 to 1.40 m, averaging 1 m. Strike of the lode is nearly E–W and dips high angle (77–85°) to north. The vein shows pinching and swelling along its extension. Ore minerals in the quartz vein are represented by pyrite, arsenopyrite, and chacopyrite. Visible gold is recorded.

The mineralized zone is represented by intensively mylonitized graphite schist, yellowish brown cavernous talc-carbonate rocks containing bodies of listwaenite (quartz-carbonate rock) and quartz veins and veinlets. Gold concentrations were recorded in both the quartz veins (main lode) and in the surrounding rocks away from the main lode (Table 5). From the table, it is clear that sulphidized graphite schist, intensively cut by quartz veinlets, has the highest gold value in the mineralized zone of Barramiya gold deposit. It seems that graphite played an important role in localizing gold in this variety of schist. This is further indicated by the noticeable amount of gold recorded in actinolite schist, which has minor content of graphite.

It is interesting to mention that in the close vicinity of Barramiya gold deposit, a number of gold occurrences (Umm Saltit; Umm Selim; Abu Qaria; beza and Umm Hugab) are located within the same belt of the ophiolitic serpentinite (i.e. Barramiya–Um Saltit belt) (Fig. 18). Sometimes, the intrusion of granite within these ophiolitic serpentinites plays an important role in localizing the mineralization in such way that the difference in the competency between the granitic body with a brittle deformational characteristics and the surrounding ultramafic serpentinites with a ductile response to stress, can lead to the development of a more extensive fracture pattern in the intrusion. This is clearly seen in Umm Saltit and Abu Quaraya gold occurrences.

Another feature of the Barramiya–Um Saltit serpentinite belt is the presence of antimonite-bearing mineralized zone (length is 30 m and thickness is 0.6 m) within tremolite-carbonate schist just to the west of

Table 5
Gold concentrations in the different constituents of the mineralized zone, Barramiya gold deposit, Eastern Desert

Host of mineralization	Number of analysed samples	Average of gold[a] (ppm)
Sulphidized graphite schist, intensively cut by microfractures, filled with quartz veinlets	190	2.74
Quartz veins	42	1.59
Listwaenite	129	1.37
Dykes of granite porphyry and granodiorite traversed by veinlets of quartz	90	0.93
Talc carbonate	57	0.80
Actinolite schist with minor content of graphite	33	0.63

Reference: Egyptian Geological Survey (EGS) (1978).
[a] Gold is analysed by fire-assay method.

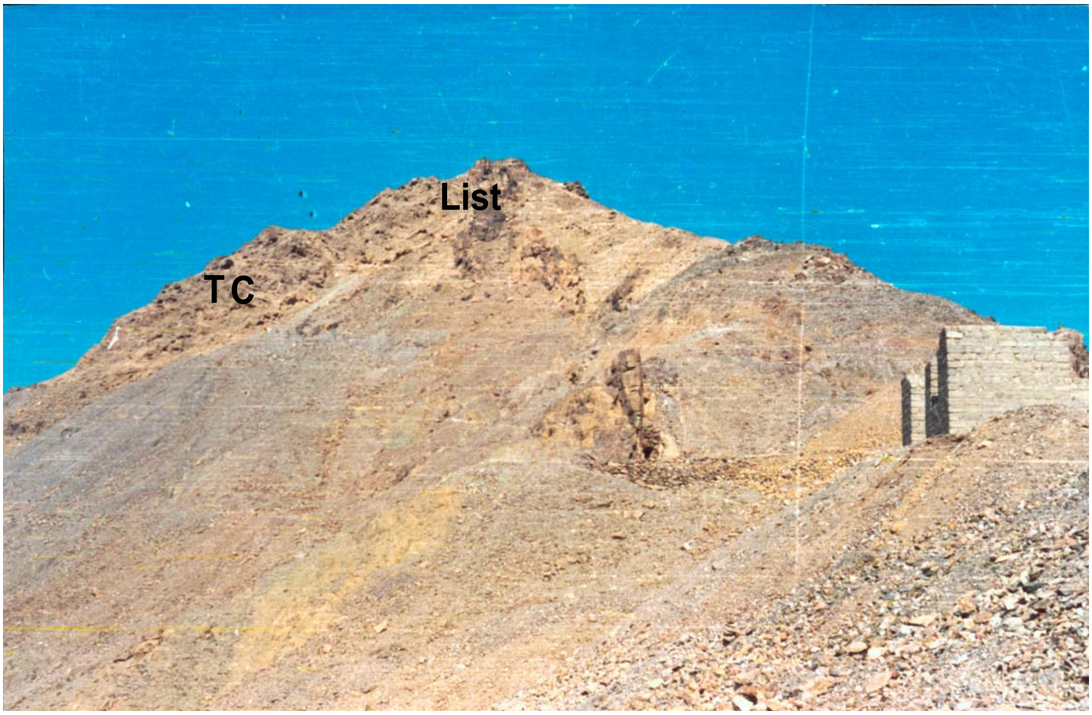

Fig. 16. Listwaenite (List.) ridge (site of old mining operations) surrounded by talc-carbonates (TC) on both sides. Barramiya gold mine. Eastern Desert of Egypt.

Um Salim gold occurrence (Egyptian Geological Survey (EGS), 1978). The antimony content ranges from 0.06% to 6.0%. The presence of antimony mineralization within the carbonated ophiolitic melange in the Eastern Desert, could make them similar to the Antimony Line rocks of the Murchison greenstone belt, southern Africa, which are considered as regional zones of talc-carbonate and siliceous-carbonate rocks hosting important antimony-gold deposits (Viljoen, 1979, 1984).

The available fluid inclusion studies for the vein-type mineralization hosted in sheared ophiolitic serpentinites are those of El Sid gold deposit (Harraz et al., 1992; Loizenbauer and Neumayer, 1996) (Table 6). From the table, it is clear that the auriferous fluids responsible for this style of mineralization are characterized by: (1) ubiquitous content of CO_2 in the inclusions (29–75mol.% CO_2); (2) wide range of salinity (5.00 to 19.4) equiv. wt. percent NaCl.

Isotopic analyses of oxygen and hydrogen were performed on separated quartz and calcite minerals

Table 6
Summary of fluid inclusion microthermometric data for the vein-type mineralization hosted in sheared ophiolitic ultramafic rocks, Eastern Desert, Egypt

Deposit (reference)	Fluid inclusion data
El Sid gold deposit (Harraz et al., 1992)	Size: 10 to 20 μm Genetic class: primary and pseudoprimary Shape: rounded shapes Types of inclusions: liquid-rich, vapour-rich Salinity: 10.2–19.4 equiv. wt.% NaCl CO_2: 29–62 mol% Homogenization temp.: 241–405 °C
El Sid-gold deposit (Loizenbauer and Neumayr, 1996)	Size: 5 to 50 μm Genetic class: secondary and pseudosecondary Shape: slightly rounded to irregular shapes Types of inclusions: liquid-rich, vapour-rich, and mixed CO_2–H_2O fluid Salinity: 5 equiv. wt.% NaCl CO_2: 65–75 mol% Homogenization temp.: 300–350 °C Trapping pressure: 1.8–2.3 kbars

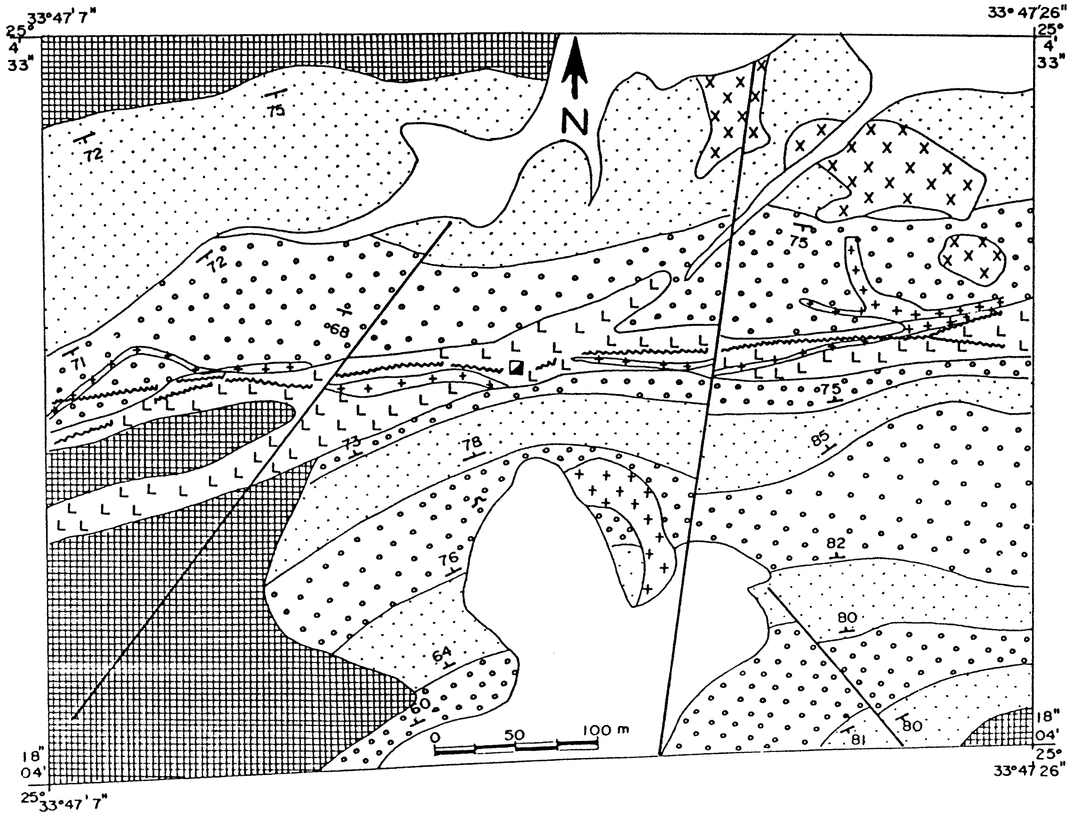

Fig. 17. Geologic map of Barramiya gold mine. ▭ Wadi deposits. ▭ Quartz veins. ▭ Quartz-carbonate rock (listwaenite). ▭ Post-tectonic granite. ▭ Syn-tectonic tonalite-granodiorite. ▭ Graphite schist. ▭ Actinolite schist. ▦ Talc-carbonate rock after serpentinite. / Faults. 85 Strike and dip of foliation. Adit. ◪ Shaft.

from El Sid gold mine (Harraz et al., 1992). The $\delta^{18}O$ values of the quartz samples range from 10.63 to 14.50 per mil, while δO values of calcite samples range from 8.2 to 18.80 per mil. On the other hand, δD values of quartz range from −127 to −81 per mil, while δD values of calcite range from −105 to −42 per mil. It is apparent that both oxygen and hydrogen isotopic data show a rather wide range of values which overlap the range of metamorphic and magmatic fluids. Harraz et al. (1992) attributed such discrepancy to progressive mixing between meteoric and magmatic-metamorphic waters.

During the Pan-African orogeny, the infrastructural rocks were highly affected by the Pan-African thermal event. A dynamic metamorphism is evidenced along the decollement surface between the Pan-African supracrustal rocks and the infrastructure, leading to the formation of mylonites. At deeper levels, on the other hand, the infrastructures were subjected to migmatisation and granitization (El Gaby et al., 1988) leading to and concomitant with the development of calc-alkaline I-type granites (G-1 granites). Under such conditions, serpentinites were metamorphosed to the epidote-amphibolite facies (Ghoneim et al., 1986). H_2O-CO_2 rich fluids continuously released within the greenschist facies and at the greenschist-amphibolite transition, moved upward along thrusts and shear zones and reacted with the serpentinized ultrafamic rocks,which are avid for carbonization if compared with any member of the dismembered ophiolitic sequence located within the Pan-African belt (Botros, 2002a). Reactions resulted in the transformation of the ophiolitic serpentinites into carbo-

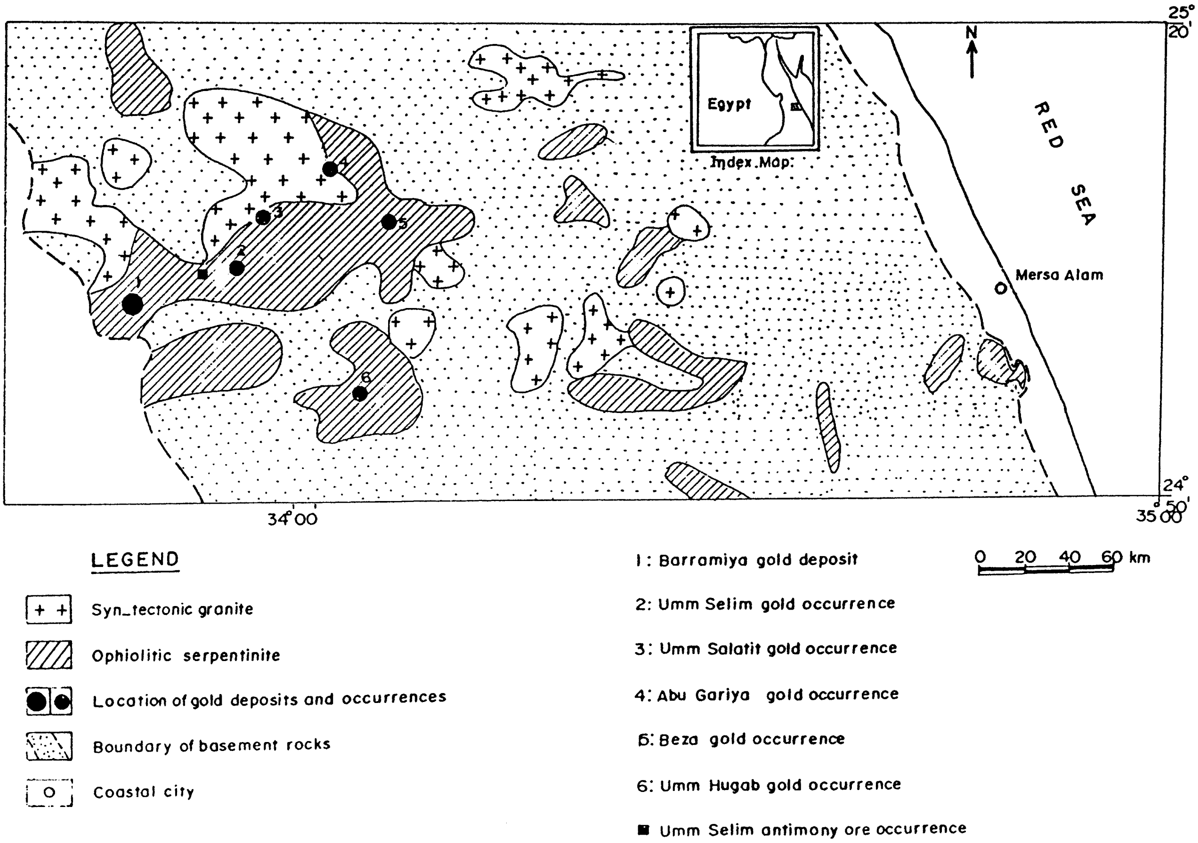

Fig. 18. Distribution of some gold occurrences within the Barramiya–Um Saltit serpentinite belt, Eastern Desert.

nates and quartz or talc and carbonates depending on temperature (Winkler, 1976):

$$1 \text{ Serpentine} + 3CO_2 \rightarrow 3 \text{ magnesite} + 2\text{Quartz} + 2H_2O \text{ at} P(\text{fluid}) = 2000 \text{ bars and temperature below } 350\ ^\circ\text{C} \quad (1)$$

$$2 \text{ Serpentine} + 3CO_2 \rightarrow 1 \text{ talc} + 3\text{magnesite} + 3H_2O \textit{ at } P(\text{fluid}) = 2000 \text{ bars and temperature between } 350 \text{ and } 500\ ^\circ\text{C} \quad (2)$$

Recently, Takla and Suror (1996) showed that some ophiolitic serpentinites from the Pan-African belt contain some Ni-sulphides and Ni-arsenides. Moreover, they suggested that serpentinized ultramafics might represent an important parent lithology for gold, where microprobe analyses of nickel sulphides showed that they carry Au up to 0.64 wt.% and some of the Ni-arsenides contain traces of Au up to 0.031 wt. Here, it is believed that liberation of "available gold" from the gold-bearing sulphides and arsenides in ultramafic serpentinites took place concomitant with these transformations of these ultramafic serpentinites (Boyle, 1961; Fyon et al., 1982; Viljoen, 1984) and attendant upon the syn-tectonic granitoids. For El Sid gold deposit, Wetait and Botros (in press) suggested that the leached gold was transported as thio complex. However, for Barramiya gold deposit, the possibility that the leached gold in the hydrothermal solutions was transported as thioarsenite complex (Seward, 1984) is not excluded. This is supported by the coincidence of the primary geochemical dispersion haloes of both gold and arsenic in

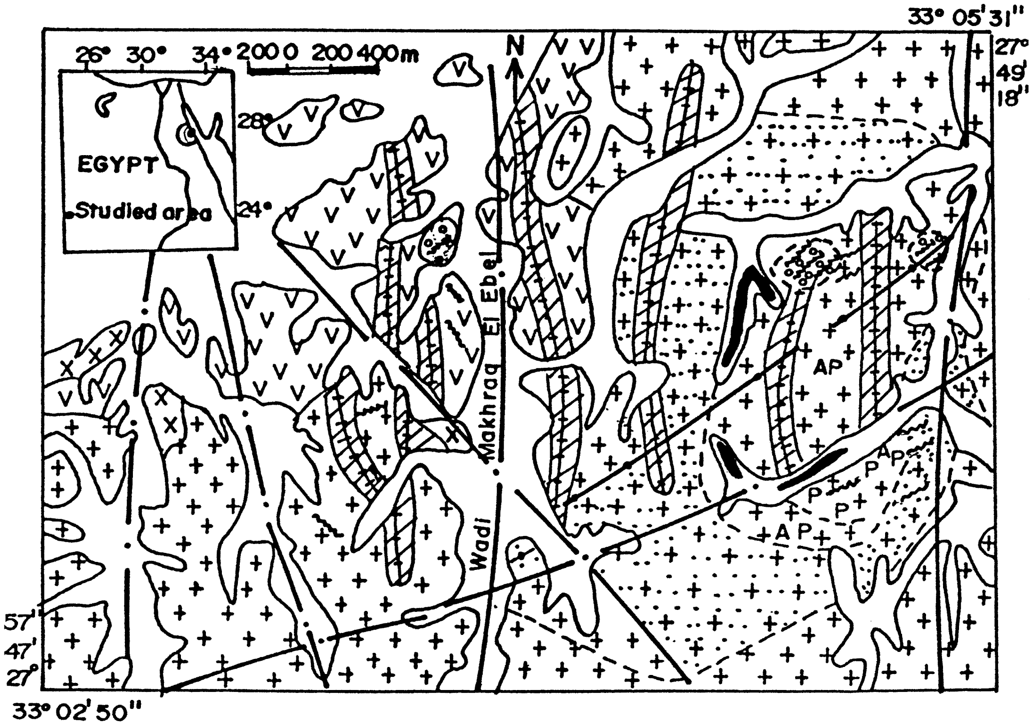

Fig. 19. Geologic map of South Um Monqul gold prospect. Wadi deposits. Faults. Dykes. Quartz veins. Granite porphyry. Biotite granite. Granodiorite. Gabbro. Dacite–rhyodacite porphyry. Potassic alteration. Phyllic alteration. Argillic–phyllic alteration. Propylitic alteration. Zones of anomalous gold in alluvium.

Barramiya gold deposit (Egyptian Geological Survey (EGS), 1977). By the same token, Elshimi (1996) mentioned that during the regional metamorphism, the ophiolitic serpentinites at Wadi Allaqi gold district were extensively carbonated into talc-carbonates and this process was associated with the break down of the sulphides–arsenides bearing gold in serpentinites and the release of Au, As, and S which transferred into the metamorphic fluids.

Generally speaking, the leached gold moves away from the heat source to mother sites at lower temperature regime, where it is deposited in fractures and shears in any suitable nearby host. The latter may be the competent granites itself and/or the volcanic and volcaniclastic rocks that form the matrix of the ophiolitic melange.

The previously mentioned model is in agreement with the broad lines of the model proposed by Viljoen (1984) for gold deposits connected with carbonated komatiitic volcanics in Southern Africa.

3.2.1.3. Vein-type mineralization connected with porphyry copper deposits. South Um Monqul prospect located in the Eastern Desert of Egypt is known as a district for gold mineralization since Pharaonic times. Rocks of the prospect are Upper Proterozoic in age and include intrusive rocks with a porphyry phase among the intrusives that are spatially and temporally associated with volcanic rocks. These rock assemblages correlate most strongly with those of active continental margins. Country rocks of the prospect are hydrothermally altered and four main alteration assemblages are recognized; (1) hydrothermal biotite (potassic), (2) quartz–sericite–pyrite (phyllic), (3) sericite–clay (phyllic–argillic) and (4) chlorite–carbonates–epidote (propylitic) assemblage (Fig. 19). Botros and Wetait (1997) suggested that the South

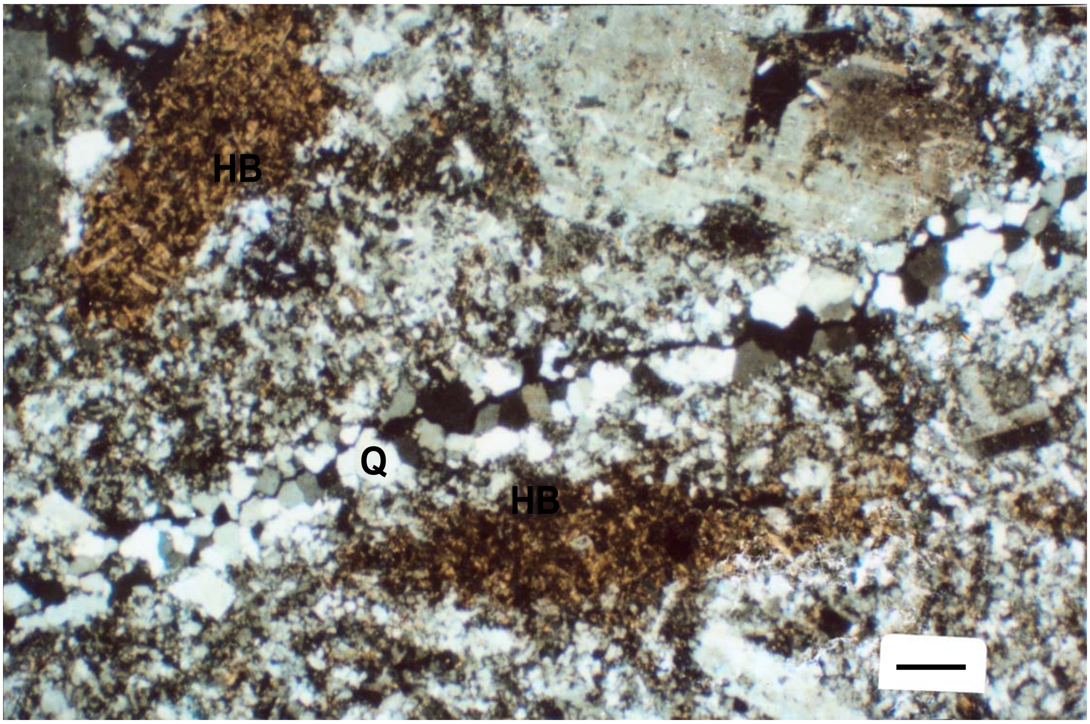

Fig. 20. Photomicrograph showing secondary quartz (Q) veintlet associated with hydrothermal biotite (HB) in the potassic zones of gold-porphyry copper mineralization, South Um Monqul gold prospect, Eastern Desert of Egypt. Bar length represents 1.22 mm.

Um Monqul gold prospect has many features in common with other porphyry copper systems in the world. The presence of acid-sulphate alteration (Botros, 1999), which is a common feature in porphyry deposits (Sillitoe and Angeles, 1985; Silliitoe et al., 1990), also validated this suggestion.

Gold mineralization connected with porphyry copper in South Um Monqul is observed in:

(1) Secondary quartz veinlets associated with the potassic zone (Fig. 20). Gold concentrations recorded in these veinlets varied from 0.6 to 2.39 ppm, with an average of 1.3 ppm. On the other hand, the anomalous values of copper are centered on the potassic zone hosting these veinlets. The latter were the sites of intensive and active mining operations carried out by the old prospectors (Botros, 1998).
(2) Barite–specularite veins linked to acid-sulphate alteration. In these veins, gold is associated with the high-sulfidation minerals enargite, bornite and chalcopyrite.
(3) Minor specks dispersed in the magnetite (Fig. 21), particularly when granite porphyry is the host rock (Botros and Wetait, 1997).

It was suggested that magma forming the granite porphyry at South Um Monqul provided both heat and chemical constituents including copper, potassium, and gold (Botros and Wetait, 1997).

3.2.1.4. Vein-type mineralization localized at contacts between younger gabbros and granites. This style of vein-type mineralization is localized at the contacts between younger gabbros and granites. Younger gabbros (Basta and Takla, 1974) represent relatively small layered intrusive bodies comprising troctolites, olivine gabbro, and hornblende gabbro and leuco gabbro. Generally speaking, younger gabbros are entirely unmetamorphosed and they represent intra-

Fig. 21. Photomicrograph showing gold speck (Au) hosted in magnetite (Mt) host, Um Monqul gold prospect, Eastern Desert, Egypt. Reflected light, bar length represents 0.05 mm (from Botros and Wetait, 1997).

plate magmatism that followed molasse-type sediments (Takla, 2002).

Younger gabbros were studied in Um Eliga, Umm Tenedba, Atalla and Semma gold deposits (Takla et al., 1990, 1995; Basta et al., 1996). In these localities, it was suggested that gabbros are favorable source rocks for gold, because of their intrinsically elevated gold concentrations. Gold in these rocks has average concentration of 85 ppb in the heavy mineral concentrates of gabbro-norite in Um Eleiga area (Takla et al., 1990), 25 ppb in the heavy concentrates of hornblende gabbro-norite of Um Tenedba (Takla et al., 1995), 510 to 710 ppb in gabbros of Atalla (Basta et al., 1996), and 360 to 710 ppb in gabbro of Semma gold deposit (Basta et al., 1996).

Recently, detailed field mapping, ore microscopic study and electron-microprobe analyses of younger gabbros from Atud gold deposit were carried out (Takla et al., 1998). Accordingly, Atud gold mine is taken as a good example for this style of vein-type mineralization. Field mapping (Fig. 22) revealed that gabbros of Atud gold mine can be classified into fresh olivine gabbro, altered gabbro and quartz-injected gabbro. The latter two varieties are abundant in the deeper levels of the shafts of the old gold mine where subsurface granite occurs and felsic stockworks at Atud gold mine increase downward (Takla et al., 1998).

Ore microscopy of the different varieties of gabbro at Atud gold deposit revealed variation in sulphide mineralogy. Fresh olivine gabbro is characterized by the presence of pentlandite, chalcopyrite and pyrrhotite, whereas altered gabbro and quartz-injected gabbro, near the granite contacts, are dominated by pyrite and arsenopyrite. Electron microprobe analyses (Table 7) revealed that all sulphides of fresh olivine gabbro are auriferous and Ag bearing. The highest Ag in sulphides is more concentrated in pyrrhotite in which Ag ranges from 100 to 680 ppm. The three auriferous sulphides of the fresh olivine gabbro contain appreciable contents of As and Sb which is not always common in mafic rocks (Takla et al., 1998). Highest As is recorded in exsolved chalcopyrite (up to 5720 ppm) which is positively correlated with the highest Au content of 710 ppm. Homogenous pyrrhotite contains the highest Sb (300–310 ppm).

Pyrite and arsenopyrite recorded in both the altered and quartz-injected gabbro are also auriferous and Ag bearing (Table 8). It is evident that pyrite is cryptically zoned with respect to Au, Ag, As and Sb. Gold content at the rim of pyrite from altered gabbro is the highest (790 ppm) whereas the highest As (9690 ppm) characterizes the pyrite rim in quartz-injected gabbro. The altered gabbro contains the highest Ag (670 ppm). Arsenopyrite composition also indicates cryptic zoning in which the As increases from core to rim. Following the same manner, Au and Ag increased toward the rim (up to 760 ppm Au and 660 ppm Ag). Sb is more concentrated at the cores of arsenopyrite (1040–1890 ppm) from quartz-injected gabbro.

On the other hand, the following features are noticed in the deeper levels of the shaft in Atud mine near the subsurface granite (Takla et al., 1998): (a) injected quartz increases in the gabbro; (b) original primary silicate mineralogy of gabbro is greatly obliterated; (c) recrystallization of pyrite and introduction of As to the system (to form arsenopyrite); (d) pyrite

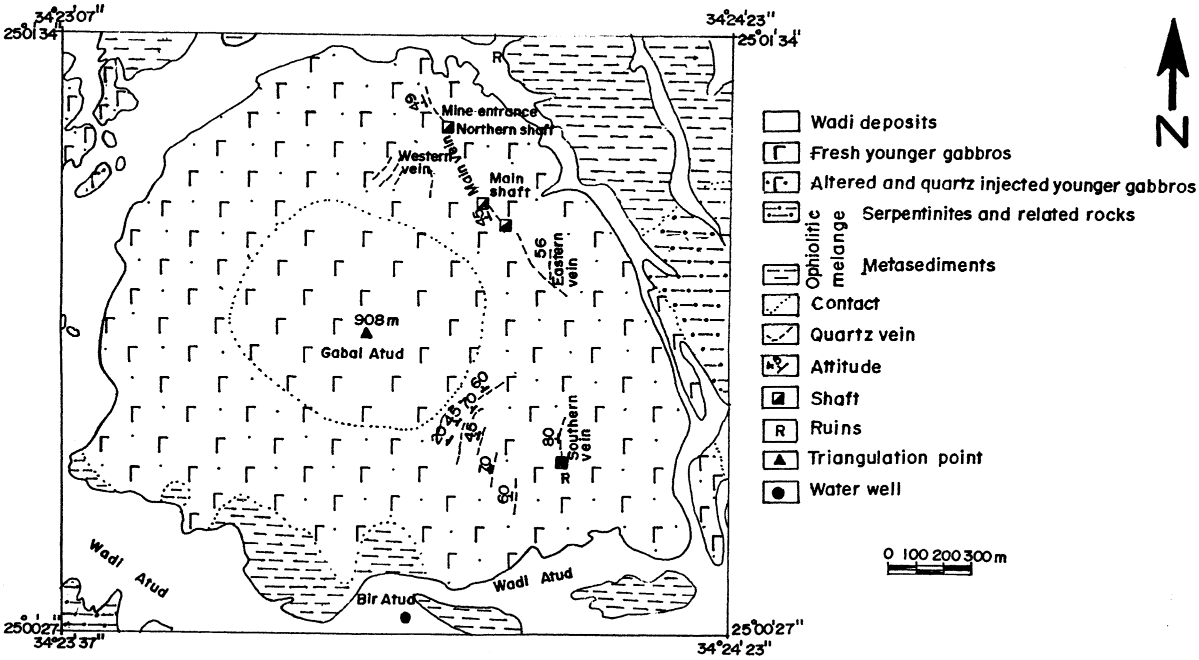

Fig. 22. Geologic map of Atud gold mine (compiled from Takla et al., 1998).

Table 7
Electron microprobe analyses (ppm) of the fresh gabbro from Atud gold mine, Eastern Desert, Egypt

Mineral	Au (ppm)	Ag (ppm)	As (ppm)	Sb (ppm)
Pyrrhotite				
Homogenous crystal	150–170	190–200	–	300–310
Host for chalcopyrite	40–560	380–680	1290–1840	40–181
Host for pentlandite	340–430	100–140	1290–3520	30–270
Host for chalcopyrite-pentlandite	140–200	150–480	115–1720	0–130
Chalcopyrite				
Exsolved crystal in pyrrhotite	90–710	0–390	200–5720	30–210
Pentlandite				
Exsolved crystal in pyrrhotite	370–670	0–110	1420–3720	0–170

Data from Takla et al. (1998).

shows the highest As (up to 9690 ppm) and Sb (up to 550 ppm).

The mechanism adopted for the genesis of quartz veins located at the contacts between younger gabbro and granite relies on the assumption that the granite intrusion acts as heat engine and as a metal

Table 8
Electron microprobe analyses (ppm) of the altered and quartz-injected gabbro from Atud gold mine, Eastern Desert, Egypt

	Au (ppm)	Ag (ppm)	As (ppm)	Sb (ppm)
Altered gabbro				
Pyrite				
Core	50	340	1370	0
Intermediate zone	120	340	2500	350
Rim	790	670	4710	400
Quartz-injected gabbro				
Pyrite				
Core	120	60	4710	70
Rim	410	380	9690	550
Arsenopyrite				
Core	100–120	20–70	4000–4200	1040–1890
Rim	470–760	110–660	4000–4400	500–570

Data from Takla et al. (1998).

Table 9
Characteristic features of some important gold deposits located in and adjacent to gabbro-granite contacts from the Eastern Desert, Egypt

Deposit	Host rock	Lode type	Alteration assemblage	Ore minerals
Atud	Contacts between the gabbro and granite	Quartz veins enclosed in shear zones of pinch and swell structure; en echelon lenticular bodies of quartz; parallel veins and offshoots of quartz	Ch-Q-Ser-Carb-py	g + py
Um Tenedba (Kalib)	Gabbro and granite	Discontinuous quartz veins	Ser-Q-carb-Ch-Ep-py	g ± gn
Umm Rus	Veins are enclosed mainly within the granodiorite and pinch out in gabbro	Shear-zone vein arrays; quartz veins arranged en echelon	Ser-Epi-Carb Ch-Q	g + py + apy ± sl ± gn ± cpy ± tet

Data from Kamel et al. (1998), Shazly et al. (1998), Takla et al. (1995), and Takla et al. (1998).
Q—quartz, Carb—carbonate, Ch—chlorite, Ep—epidote, Ser—seircite, apy—arsenopyrite, cpy—chalcopyrite, gn—galena, py—pyrite, sl—sphalerite, tet—tetrahedite, g—gold.

donor. The heat of the granite drives the convective cells to circulate through the fractured zone at the gabbro-granite contact (Takla et al., 1990), leaching gold and other elements and depositing it in structurally favorable sites. The activity of the circulated water within the fractured zone is attested by the abundance of chlorite, actinolite, tremolite, kaoline, and injected quartz in the gabbroic rocks, and white mica in the altered granite. The mobilization of gold took place during the oxidation of sulphides and the fracturing of gabbro attendant upon the granite. The latter was emplaced at shallow depth as indicated by the geothermometry of arsenopyrite in the quartz-injected gabbro (Takla et al., 1998) and the presence of porphyritic texture (Takla et al., 1990). The role of granite as a source for metals is indicated by the high concentration of Sn and W (300 and 4000 ppm, respectively) in the heavy mineral concentrates of the quartz vein from Umm Tenedba gold mine (Takla et al., 1995).

To sum up, it seems that the intrusion of a specific phase of the post-tectonic granite in a sulphide-bearing younger gabbro in the Eastern Desert of Egypt results in the formation of quartz vein containing Au and Ag at the contact of both rocks. Quartz veins far from the granite-gabbro contact are unmineralized (Kamel et al., 1998). This setting (i.e. gabbro-granite contact) is found in a great number of ancient gold

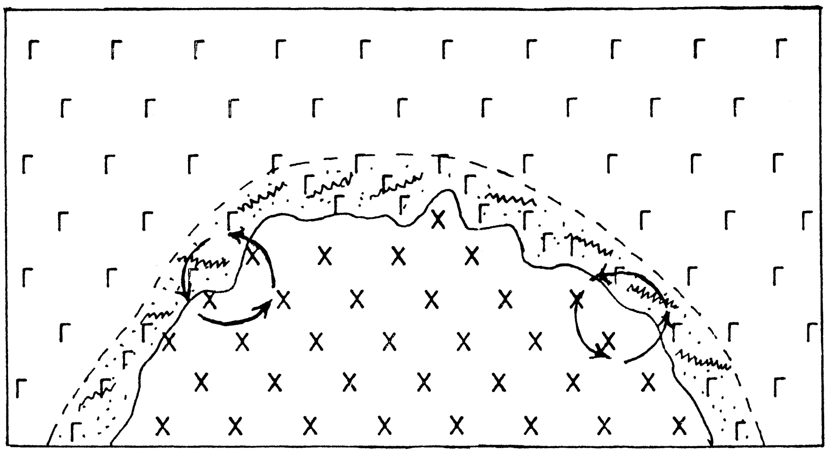

Fig. 23. Sketch diagram showing circulation of fluids in the contact zone between granite and gabbro, leaching available gold from the auriferous gabbro. [x x] Granite. [Γ Γ] Auriferous gabbro. [Γ Γ] Contact zone (development of chlorite, actinolite, tremolite, kaoline and injected quartz in the gabbro and white mica in the granite). [—] Quartz veins. [ ] Direction of fluid circulation.

mines (Table 9). The amount of leached gold from the gabbros depends on the sulphide parentage and the volume of granite intrusion. Therefore, some of the mines are large and others are of smaller scale (Takla et al., 1998).

Fig. 23 represents a sketch diagram showing circulation of fluids in the contact zone between granite and younger gabbro.

3.2.1.5. Vein-type mineralization connected with and hosted in anorogenic granites. Anorogenic sub-alkaline to per-alkaline granites lumped together as G-3 granites (Hussein et al., 1982) occur in the Eastern Desert of Egypt. By definition, G-3 granites are intraplate granites formed within the plates subsequent to cratonization. They are related to hot spots and incipient rifting. Rare metal mineralization of

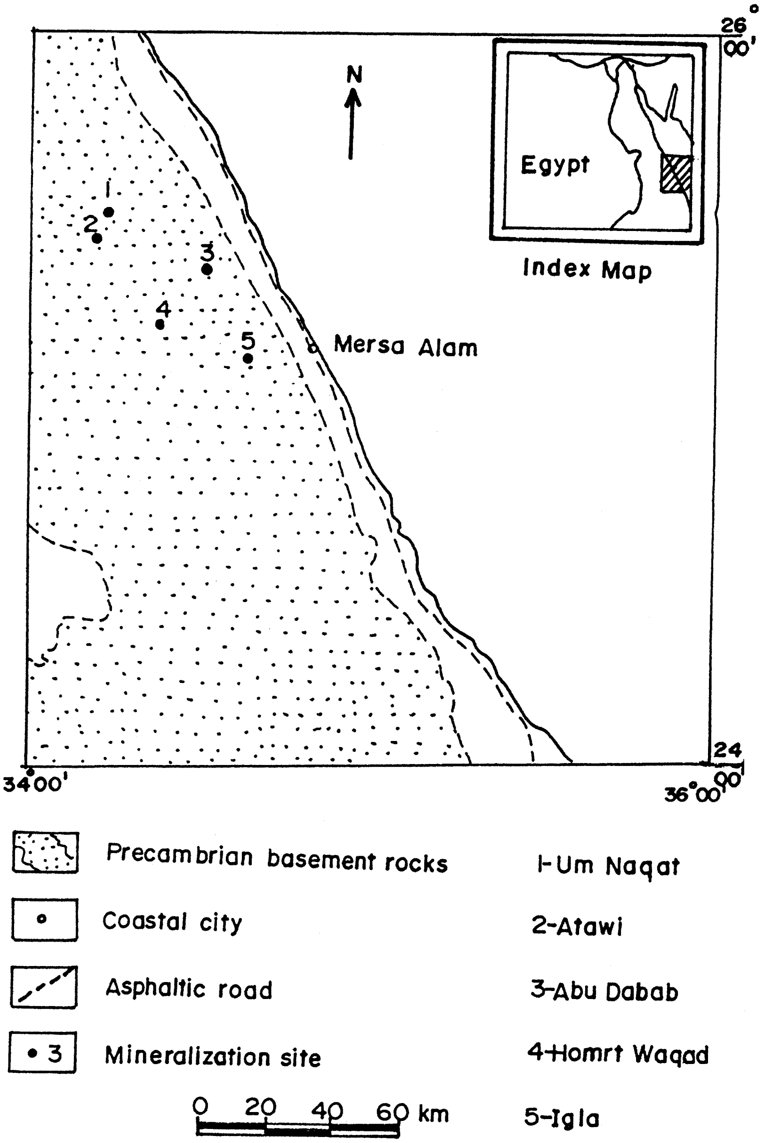

Fig. 24. Distribution of the principle localities for Sn–W–Ta–Nb mineralizations in the Eastern Desert.

one or more of the elements: Mo, Sn, W, Nb–Ta and U are linked to some phases of these granites in some localities such as Um Naqat, Atawi, Abu Dabab, Homrt Waqad and Igla (Fig. 24). Mineralization is represented by disseminations, stockworks or quartz veins within the plutons or in their close vicinity. On the other hand, traces of gold were recorded as disseminations in quartz veins hosting the (Mo, Sn, and U, etc., mineralization). Examples are typified by the occurrence of gold up to 0.5 g/t in jasperoid silica veins hosting uranium mineralization (Hussein, 1990), presence of races of gold in tantalum–niobium mineralization at Abu Dabab locality and the occurrence of 0.5–24 ppm of gold in rare-metals-bearing quartz veins at Igla (Sabet et al., 1976a,b).

Not much is known about gold mineralization of this style. However, fluid inclusion studies, conducted on some Sn–W-bearing quartz veins (Mohamed and Bishara, 1998), may be useful in defining the P–T conditions that prevailed during rare-metal-gold mineralization (Botros, 2002a).

Results of fluid inclusion studies showed that the Sn–W mineralizing fluid at Igla area was originally H_2O–CO_2 homogenous fluid, composed of miscible carbon dioxide and aqueous salt solution. Sn and W might have been transported as chloride complexes (Mohamed and Bishara, 1998). Deposition took place ate temperatures between 320 and 230 °C and at minimum pressure between 2.2 and 1.6 kbars for Sn-mineralization, and at temperature between 300 and 250 °C and pressure between 2 and 1.4 kbars for W mineralization (Mohamed and Bishara, 1998).

It is clear that, Sn and W were transported as soluble Sn–W chloride complexes and deposition took place at temperature range 320–230 °C. Botros (2002a) believed that these conditions were suitable for transportation and deposition of gold. This is supported by the following criteria: (1) gold can be transported as chloride complex (Henley, 1973), (2) deposition of gold is currently uncertain. However, the possibility that available gold could be mobilized from gold mineralization

Fig. 25. Alteration zone (AZ) surrounding auriferous quartz vein. Um Balad gold prospect.

Fig. 26. Wall-rock alteration (Alt.) along shears in granite. Um Monqul gold prospect.

styles mentioned before by the hydrothermal fluids related to the G-3 granitic bodies, is not precluded (Botros, 2002a). The hypothesis that gold mineralization connected with anorogenic granites may represent some mobilization of earlier gold is currently under review.

Gold mineralization associated with intra-plate G-3 granites corresponds on the Riphean–Lower Paleozoic epoch of gold mineralization adopted by Sabet et al. (1976a,b).

3.2.2. Disseminated-type mineralization hosted in hydrothermally altered rocks (alteration zones)

Extensive rock alterations are a clearly visible characteristic feature of most Egyptian gold deposits and occurrences. The alterations occur either surrounding the auriferous quartz veins (Fig. 25) and/or structurally controlled by specific structural features, such as fractures shear surfaces (Fig. 26).

The most important types of wall rock alteration are sericitization, beresitization, silicification, sulphidation, carbonatization, listwaenitization, chloritization and kaolinitization (Botros, 1993b).

Two main styles of alterations could be recognized in the Egyptian gold deposits (Botros, 2002b). The first results during the liberation of gold from the source rocks, and is characterized by a widespread distribution and being spatially related to major structures. The second style, however, is related to the deposition of gold and is recognizable only within 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 retaining some of 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 of which that are dissected by minor quartz veins, veinlets and Stockworks (silicification) where gold is believed to be migrated to such sites with silica liberated during the different types of alterations. The alteration zones around the mineralized veins are of economic interest as they contain reasonably high gold values (Osman and Dardir, 1989; Botros, 1993b) and could be considered as new target for disseminated gold in the Eastern Desert of Egypt (Botros, 1993b).

Table 10
Some of the Egyptian gold deposits and occurrences that show wall-rock alterations and their gold values

Deposit	Type of alteration	Au (g/t)	Parameters of the alteration zone
Um Ud	Listwaenitization	1–15	Width: up to 700 m; Length: up to 300 m
Hangalia	Chloritization	0.02–0.82, average: 0.63	Width: no data; Length: no data
Sukkari	Beresitization	1.24–5.89	Thickness determined by drilling is variable (37–174 m); Length: 700 m
Um Qareiyat	Silicification, Carbonatization	2–5, average: 2.3	Length: 30–160 m; Width: 4–10 m
Abu Marawat	Silicification, Ferrugination, Listwaenitization	1.37–11.96, average: 6.9	Width: 0.05–5 m; Length: 200 m (discontinuous)
Um Balad	Ferrugination, Silicification, Sericitization, Propylitization	0.6–13, average: 3.7	Width: 0.05–3 m; Length: 2000 m (discontinuous)
Um Monqul	Ferrugination, Carbonatization, Silicification	0.6–2.39, average: 1.1	Width: 0.01–5 m; Length: 2000 m (discontinuous)
Tallet Gadalla	Listwaenitization	Traces—8.2	Width: up to 20 m; Length: no data
Um Tenedba	Silicification, Sericitization, Pyritization	Up to 8	Width: 0.5 m; Length: no data
Hutite	Silicification, Ferrugination, Carbonatization	1–33, average: 8	Width: 0.5 m; Length: no data
Kulyeit	Ferrugination, Kaolinitization, Sericitization, Carbonatization	0.3–1.9	Width: 200–1000 m; Length: up to 2000 m (discontinuous)

References: Botros (1991), Khalaf and Oweiss (1993), Khalid et al. (2000), Khalil and Helba (2000), Oweiss (1992), Oweiss (1995), Oweiss and Khalid (1991), and Takla et al. (1995).

Table 10 gives some examples of Egyptian gold deposits and occurrences where wall-rock alteration is recorded.

3.3. Placer deposits

Most placer gold deposits accessible to ancient Egyptians were close to the auriferous quartz veins. The arid and hot climate that characterizes the Egyptian deserts results in dominantly physical weathering. This is the most important factor responsible for the disintegration of potential source rocks by a combination of thermal and mechanical weathering, working together over long periods of time.

Two main categories of placer gold have formed in Egypt. These are modern placers and lithified placers (Botros, 1993a). Modern placers are subdivided into alluvial placers and beach placers. The predominant accumulation of ore materials in a mechanically dispersed form in the wadis (dry water courses) of the Eastern Desert favours the collection of panned samples from the alluvial placers even where the alluvium contains considerable amounts of wind-blown sand (Bugrov, 1974). This method was successfully applied in Egypt while prospecting for gold in alluvial placers (Bugrov, 1974; Sabet et al., 1976a,b; Botros, 1998; Abdel Rahman et al., 2001). Minor amounts of gold recorded in some Egyptian black beach sands (El Gemmizi, 1985) represent beach placers on the Mediterranean Sea.

Conglomerate represents lithified placers. It occurs at the base of the Upper Proterozoic molasse sediments of the Hammamat unit and/or the base of Upper Cretaceous Nubian Formation that overlies the more or less peneplained surface of the Precambrian basement rocks (Botros, 1993a).

4. Summary and conclusions

In addition to the auriferous quartz veins that constituted the main target for gold since ancient times, gold is associated with other ore deposit types in Egypt. As a consequence, a new classification of gold deposits of Egypt utilizing the geological and tectonic environments that were prevailing during mineralization is offered to serve as a framework for the detailed study of these deposits and to facilitate their correlation with worldwide deposits. Table 11 shows the classification of the different types of gold deposits in Egypt and their tectonic environments. From the table, it is clear that gold deposits in Egypt are classified into three categories. These are stratabound deposits, non-stratabound deposits and placer deposits. Both stratabound deposits and non-stratabound deposits are hosted in igneous and metamorphic rocks and each has its own geological and tectonic environments, time of formation and type of the mineralizing fluids. The stratabound deposits were formed in a sub-marine environment dominated by island-arc volcanic and vocaniclastic rocks of comparable composition. Gold-bearing Algoma-type BIF accompanying gold-bearing tuffaceous sediments were formed in the early stages of island arc formation (immature arc), whereas the mature island-arc stage was accompanied by the formation of gold-bearing volcanogenic massive deposits. In the present classification, these stratabound deposits are considered as syngenetic exhalative deposits analogous to present-day hot springs or fumarolic discharges.

Non-stratabound deposits are divided into two main types: vein-type mineralization and disseminated-type mineralization hosted in hydrothermally altered rocks (alteration zones). These deposits were formed during the Pan-African orogeny and post cratonization period. They are housed in different lithologies and are formed by mineralizing fluids of different sources. Two main categories of placer gold are recognized in Egypt. These are modern placers and paleoplacers. Concentration of gold in wadis, gullies, guts and gulches draining from the nearby gold mineralization, as well as, beach placers recorded in some Egyptian black beach sands belong to modern placers.

Paleoplacers (lithified equivalents to modern placers) are represented by auriferous conglomerates occurring on or near ancient eroded surfaces. Gold and heavy minerals found in depressions and chan-

Table 11
The classification of the different types of gold deposits in Egypt and their tectonic environment

Class	Types of mineralization	Tectonic environment	Remarks
Strata-bound deposits	(A) Gold hosted in Algoma-type BIF (B) Gold hosted in tuffaceous sediments (C) Gold hosted in volcanogenic massive sulphide deposits	Immature island-arc environment Mature island arc environment	Syngenetic mineralization
Non-stratabound deposits	(A) Vein-type mineralization (1) Auriferous quartz veins hosted in metamorphic rocks and/or the granitic rocks surrounding them (2) Auriferous quartz veins in sheared ophiolitic ultramafic rocks (3) Auriferous quartz veins associated with porphyry copper mineralization	Continental margin environment	Epigenetic mineralization
	(4) Auriferous quartz veins at the contact between younger gabbros and granites (5) Small amounts of the element in quartz veins of Sn–W–Ta–Nb mineralization	Intra-plate environment	
	(B) Disseminated-type mineralization hosted in hydrothermally altered rocks (alteration zones)	Continental margin environment and intra-plate environment	Epigenetic mineralization
Placer deposits	(A) Modern placers (1) Alluvial gold in wadis and gullies (2) Beach placers (B) Lithified placers	Intra-plate sedimentation	Uncertain?

nels (paleochannels) scoured into the underlying Precambrian basement rocks also belong to paleoplacers.

The link between the tectonic environment and gold mineralization can be used as a criterion at any exploration strategy for new targets of gold mineralization in Egypt.

5. Uncited references

Ghoneim et al., 1986
Viljoen, 1979
Winkler, 1976

References

Abdel Monem, A.A., Hurley, P.M., 1979. U–Pb dating of zircons from psammitic gneisses, Wadi Abu Rusheid–Wadi Sikait area, Egypt. Inst. Appl. Geol., Geddah, Bull. 3, 165–170.

Abdel Khalek, M.L., Takla, M.A., Sehim, A., Hamimi, Z., El Manawi, A.W., 1992. Geology and tectonic evolution of WadiBeitan area, South Eastern Desert, Egypt. Proceedings of the 1st International Conference on Geology of the Arab World, vol. 1. Cairo University, pp. 369–394.

Abdel Rahman, E., Fawzy, K.M., Mohammady, S., 2001. Chemical studies on placer gold deposits at Um Grayat gold mine, South Eastern Desert, Egypt. Proceedings of the Fifth Conference On Geochemistry. Alexandria University. 113 pp.

Ahmed, A.M., Said, M.M., El Baghdady, M.M., Abdel Wahab, G., 2001. Mineral potential of the eastern part of Wadi Allaqi, south Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 22, 451–462.

Akaad, M.K., Noweir, A.M., Abu Elela, A.M., 1996. Geology of the Pan-African basement rocks of the Jabal al Hadid, E.D., Egypt. Geol. Surv. Egypt, Pap. 73, 1–78.

Al Filali, I.Y., Hassan, M.A., Hashad, A.H., 1993. Significance of some mantled gneiss domes in the Arabian Nubian shield. Ann. Geol. Surv. Egypt 19, 33–46.

Aly, S.M., Salem, I.A., Sharkawy, M.F., 1992. Mineralogical studies on Gebel El-Hadid iron ore, Eastern Desert, Egypt. Egypt. Mineral. 4, 1–21.

Anhaeusser, C.R., Fritz, K., Fyfe, W.S., Gill, R.C.O., 1975. Gold in primitive Archaean volcanics. Chem. Geol. 16, 129–135.

Antweiler, J.C., Campbell, W.L., 1982. Gold in exploration geochemistry. Levinson, A.A. (Ed.), Precious Metals in the Northern Cordillera Association of Exploration Geochemists, pp. 33–44.

Arslan, A.L., Khalil, S.O., El Sayed, M.M., Mohamed, F.H., El deeb, M.M., 2000. Contribution to the geochemistry of bedrocks and wall-rock alterations, El-Eradia gold mine area, Central Eastern Desert, Egypt. 13th Ann. Meeting, Min. Soc., Egypt. Abstract.

Basta, E.Z., Takla, M.A., 1974. Distribution of opaque minerals and the origin of gabbroic rocks of Egypt. Bull. Fac. Sci., Cairo Univ. Egypt 47, 346–364.

Basta, F., Takla, M.A., Bakhit, B.R., 1996. Gold mineralization of Atalla and Semna areas, Central Eastern Desert, Egypt. Abstracts of Geology of the Arab World, Third Inter. Conf., Cairo.

Bernau, R., Derbyshire, D.P.F., Franz, G., Herms, U., Huth, A., Mansour, N., Pasteels, P., Schandelmeier, H., 1987. Petrology, geochemistry and structural development of the Bir Safsaf-Aswan uplift, southern Egypt. J. Afr. Earth Sci. 6, 79–90.

Botros, N.S., 1991. Geological and geochemical studies on some gold occurrences in the north Eastern Desert, Egypt. PhD thesis, Zagazig Univ., Zagazig, Egypt. 146 pp.

Botros, N.S., 1993a. The possible occurrence of placer gold in areas lacking quartz veins in Egypt. J. Geochem. Explor. 49, 287–290.

Botros, N.S., 1993b. New prospects for gold mineralization in Egypt. Ann. Geol. Surv. Egypt 19, 47–56.

Botros, N.S., 1995a. Stratiform gold deposits in a Proterozoic BIF, Abu Marawat area, Eastern Desert, Egypt. Eleventh Symp. on Precambrian and Development, Cairo. Abstract.

Botros, N.S., 1995b. Genesis of gold mineralization in the North Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 20, 381–409.

Botros, N.S., 1998. Alluvial gold: a pathfinder for a porphyry copper mineralization in South Um Monqul prospect, Eastern Desert, Egypt. Arab Gulf J. Sci. 16 (3), 497–517.

Botros, N.S., 1999. Acid sulphate alteration type at south Um Monqul, North Eastern Desert, Egypt. Arab Gulf J. Sci. 17 (1), 15–34.

Botros, N.S., 2002a. Metallogeny of gold in relation to the evolution of the Nubian Shield in Egypt. Ore Geol. Rev. 19, 137–164.

Botros, N.S., 2002b. Alteration zones: are they good target for gold deposits in Egypt. Egypt. Arab Gulf J. Sci. 20 (4), 209–218.

Botros, N.S., 2003. On the relationship between auriferous talc deposits hosted in volcanic rocks and massive sulphide deposits in Egypt. Ore Geology Rev. 23, 223–257.

Botros, N.S., Wetait, M.A., 1997. Possible porphyry copper mineralization in South Um Monqul, Eastern Desert, Egypt. Egypt. J. Geol. 41 (1), 175–196.

Boyle, R.W., 1961. The geology, geochemistry and origin of the gold deposits of the Yellowknife district. Geol. Surv. Can. Mem. 310, 193 p.

Bugrov, V., 1974. Geochemical sampling techniques in the Eastern Desert of Egypt. J. Geochem. Explor. 3, 67–75.

Dardir, A.A., Elshimi, K.A.M., 1992. Geology and geochemical exploration for gold in the banded iron formation of Um Nar area, Central Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 18, 381–409.

Dardir, A.A., Greiling, R.O., 1987. Tectonic and structural control of some Pan-African ore deposits in the Eastern Desert of Egypt. Publ. Occas. - Cent. Int. Form. Echanges Geol. 12, 161–162.

Dardir, A.A., Greiling, R.O., Rashwan, A.A., 1990. Structural control of Pan-African sulphide deposits in SE Egypt. Publ. Occas. - Cent. Int. Form. Echanges Geol. 20, 344.

Deyab, T.M., 1986. A Study on the geology and genesis of some Zn–Pb deposits in the Eastern Desert of Egypt, (Um Samuki and Um Gheig areas). MSc thesis, Ain Shams Univ., Egypt. 85 pp.

Egyptian Geological Survey (EGS), 1977. Results of prospecting and revisory work for gold at Barramiya, Sukary and Um Nar prospects. Internal report No. 19/77. Documentation center of the Geology Survey of Egypt.

Egyptian Geological Survey (EGS), 1978. Results of prospecting-evaluation carried out at the Eastern flank of the Barramiya gold ore deposit in 1976–1977. Internal report No. 16/78. Documentation center of the Geology Survey of Egypt.

El Gaby, S., 1983. Architecture of the Egyptian basement complex. In: Riad, S., Baars, D.L. (Eds.), Proceedings of the 5th International Conference on Basement Tectonics Cairo Univ., Cairo, Egypt, pp. 1–8.

El Gaby, S., List, F.K., Tehrani, R., 1988. Geology, evolution and metallogenesis of the Pan-African Belt in Egypt. In: El Gaby, S., Greiling, R.O. (Eds.), The Pan-African belt of Northeast Africa and Adjacent Area Friedr Viewegsohn, Braunschweig/Wiesbaden, pp. 17–68.

El Gaby, S., List, F.K., Tehrani, R., 1990. The basement complex of the Eastern Desert and Sinai. In: Said, R. (Ed.), The Geology of Egypt. Balkema, Rotterdam, pp. 175–184.

El Gaby, S., El Aref, M., Khudeir, A., El Habbak, G., 1994. Geology and genesis of banded iron formation at Wadi Kareim, Eastern Desert, Egypt. 7th Ann. Meeting, Min. Soc., Egypt. Abstract.

El Gemmizi, M.A., 1985. Note on the occurrence of gold and cassiterite in the Egyptian beach placer deposits. Econ. Geol. 80, 769–772.

El Kazzaz, Y., 1996. Shear zone-hosted gold mineralization in South Eastern Desert, Egypt. Proc. Geol. Surv. Egypt Cent. Conf.., pp. 185–204.

El Ramly, M.F., 1972. A new Geological map for the basement rocks in the Eastern and South western Deserts of Egypt, scale1, 1,000,000. Ann. Geol. Surv. Egypt, 2, 1–18.

El Ramly, M.F., Ivaanov, S.S., Kochin, G.C., 1970. The occurrence of gold in the Eastern Desert of Egypt. Studies on Some Mineral Deposits of Egypt. Part I, Sec. A, Metallic Minerals. Geological Survey of Egypt 21, 1–22.

El Ramly, M.F., Soliman, F.A., Rasmay, A.H., Abu Elfarh, M.H., 1998. Petrographic and geochemical characteristics of the island arc volcanic rocks in the area between Wadi Garf and Wadi Um Khariga, Central Eastern Desert of Egypt. Ann. Geol. Surv. Egypt 21, 1–22.

Elshimi, K.A.M., 1996. Geology, structure and exploration of gold mineralization in Wadi Allaqi area, SW Eastern Desert, Egypt. PhD thesis, Ain Shams Uni. Cairo, Egypt.

Foster, R.P., 1989. Archaean gold mineralization in Zimbabwe: implications for metallogenesis and exploration. Econ. Geol. Monogr. 6, 54–70.

Fyon, J.A., Schwarcz, H.P., Crocket, J.H., 1982. Oxygen, carbon and hydrogen isotopes: traces for gold mineralization. Abstract. Ontario Geol. Surv. Geoscience Research Seminar, Toronto, December 1981.

Gass, I.G., 1977. The evolution of the Pan-African crystalline basement in NE Africa and Arabia. J. Geol. Soc. (Lond.) 134, 129–138.

Gass, I.G., 1982. Upper Proterozoic (Pan-African) calc-alkaline magmatism in northeastern Africa and Arabia. In: Thorpe, R.S. (Ed.), Orogenic Andesites and Related Rocks. Wiley, New York, pp. 591–609.

Ghoneim, M.F., Abu Ela, A.M., Salem, H.A., 1986. Geochemistry, mineralogy and evolution of some ultramafic rocks from the Eastern Desert, Egypt. Delta J. Sci. 10 (3), 912–943.

Goldfarb, R.J., Leach, D.L., Rose, S.C., Landis, G.P., 1989. Fluid inclusion geochemistry of gold bearing quartz veins of the Juneaugold belt, South eastern Alaska: implications for ore genesis. Econ. Geol. Monogr. 6, 363–375.

Greiling, R.O., Rashwan, A.A., 1994. Large-scale shear zones and related mineral deposits: examples from the Nubian Shield (Proterozoic), Egypt. Africa Geosci. Rev. 1 (4), 503–514.

Greiling, R.J., Abdeen, M.M., Dardir, A.A., El Akhal, H., El Ramly, M.F., Kamel El Din, G., Osman, A.F., Rashwan, A.A., Rice, A.H.N., Sadek, M.F., 1994. A structural synthesis of the Proterozoic Arabian Nubian Shield in Egypt. Geol. Rundsch. 83, 484–501.

Grothaus, B., Eppler, D., Ehrlich, R., 1979. Depositional environment and structural implications of the Hammamat Formation. Ann. Geol. Surv. Egypt 9, 564–590.

Groves, D.I., Barley, M.E., Ho, S.E., 1989. Nature, genesis and tectonic setting of mesothermal gold mineralization in the Yilgarn Block, Western Australia. Econ. Geol. Monogr. 6, 71–85.

Habib, M.E., Ahmed, A.A., El Nady, O.M., 1985. Two orogenies in the Meatiq area of the Central Eastern Desert, Egypt. Precambrian Res. 30, 83–111.

Hamimi, Z., El Amawy, M.A., Wetait, M., 1994. Geology and structural evolution of El Shalul Dome and environs, Central Eastern Desert, Egypt. Egypt. J. Geol. 38 (2), 575–595.

Hannington, M.D., Scott, S.D., 1989. Gold mineralization in volcanogenic massive sulphides: implication from active hydrothermal vents on the modern sea floor. Econ. Geol. Monogr. 6, 491–507.

Harraz, H.Z., Hassanen, M.A., Eldahhar, M.A., 1992. Fluid inclusions and stable isotopic studies at EL-Sid gold mine, Eastern Desert, Egypt. Egypt. J. Geol. 36 (1–2), 243–332.

Harris, N.B., Hawkesworth, C.J., Rice, A., 1984. Crustal evolution in north and east Africa from model Nd ages. Nature 309, 773–775.

Helmy, H.M., 2000. Pyrite zoning in the Sukkari gold mine, Eastern Desert, Egypt: a possible mechanism of gold deposition. 13th Ann. Meeting, Min. Soc., Egypt. Abstract.

Henley, R.W., 1973. Solubility of gold in hydrothermal chloride solutions. Chem. Geol. 11, 73–87.

Hussein, A.A., 1990. Mineral deposits. In: Said, R. (Ed.), The Geology of Egypt. Balkema, Rotterdam, pp. 511–566.

Hussein, A.A., Shalaby, I.M., Gad, M.A., Rasmy, A.H., 1977. On the origin of Zn–Cu–Pb deposits at Umm Samiuki, Eastern Desert, Egypt. 15th Annual Meeting, Geol. Soci., Egypt. Abstract.

Hussein, A.A., Ali, M.M., El Ramly, M.F., 1982. A proposed new classification of the granites of Egypt. J. Volcanol. Geotherm. Res. 14, 187–198.

Kamel, O., El Mahalallawi, M., Niazy, E., Helmy, H., 1998. Geochemistry of Umm Rus gold-quartz veins central Eastern Desert of Egypt. Egypt. Mineral. 10, 31–50.

Keays, R.R., 1984. Archaean gold deposits and their source rocks: the upper mantle connection. In: Foster, R.P. (Ed.), Gold 82, The

Geology, Geochemistry and Genesis of Gold Deposits. Balkema, Rotterdam, pp. 17–52.
Keays, R.R., Scott, R., 1976. Precious metals in ocean ridge basalts as source for gold mineralization. Econ. Geol. 71, 705–720.
Kennedy, W.Q., 1964. The structural differentiation of Africa in the Pan-African (±500 Ma) tectonic episode. 8th Ann. Rep. Res. Inst. Afr. Geol. University of Leeds, pp. 48–49.
Khalaf, I.M., Oweiss, Kh.Kh., 1993. Gold prospection in the environs of Sukkari gold mine, Central Eastern Desert. Ann. Geol. Surv. Egypt 21, 97–108.
Khalid, A.M., Said, M.M., El Naggar, A.A., Moselhy, N., 2000. Geological and geochemical exploration at Gabal Kulyeit and its environs, South Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 23, 223–233.
Khalil, I.K., 2001. Banded Iron Formation (BIF) at Wadi El Dabbah area, Central Eastern Desert Egypt: a genetic concept. The Fifth Conference On Geochemistry, Alexandria Univ. 113 pp.
Khalil, K.I., Helba, H.A., 2000. Gold mineralization and its alteration zones at the Hangalia gold mine area, Eastern Desert, Egypt.
Khalil, K.I., Helba, H.A., Mucks, A., 2000. Paragenesis of gold mineralization at Dungash gold mine area, Eastern Desert, Egypt: a mineralogical study. 13th Ann. Meeting, Min. Soc., Egypt. Abstract.
Kochine, G.G., Bassuni, F.A., 1968. Mineral resources of the U.A.R.: Part I. Metallic minerals. Interact. Rep. Geol. Surv. Egypt, pp. 305–436.
Kroner, A., 1979. Pan-African plate tectonics and its repercussions on the crust of northeast Africa. Geol. Rundsch. 68, 565–583.
Kroner, A., Greiling, R.O., Reischmann, T.I.M., Stern, R.J., Durr, S., Druger, J., Zimmer, M., 1987. Pan-African crustal evolution in the Nubian segment of the northeast Africa. In: Kroner, A. (Ed.), Proterozoic Lithospheric Evolution. Amer. Geophysical Union, Washington, DC, pp. 69–94.
Loizenbauer, J., Neumayr, P., 1996. Structural controls on the formation of the Fawakhir gold mine, EL Sid-Eastern Desert, Egypt: tectonic and fluid inclusion evidence. Proc. Geol. Surv. Egypt Cent. Conf.., pp. 447–488.
Mansour, S., Hamimi, Z., El Amawy, M.A., 1999. Geology and structural evolution of Bir Haimur area, South Eastern Desert Egypt. Ann. Geol. Surv. Egypt 21, 395–405.
Mohamed, M.A., Bishara, W.W., 1998. Fluid inclusions study of Sn–W mineralization at Igla area, central Eastern Desert, Egypt. Egypt. J. Geol. 42, 207–220.
Nasr, B.B., Masoud, M.S., El Sherbeni, H., Makhlouf, A.A., 1998. Some new occurrences of gold mineralization, Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 21, 331–344.
Neumayr, P., Mogessie, A., Hoinkes, G., Puhl, J., 1996. Geological setting of the Meatiq metamorphic core complex in the Eastern Desert of Egypt based on amphibolite geochemistry. J. Afr. Earth Sci. 23 (3), 331–345.
Osman, A.M., Dardir, A.A., 1989. On the mineralogy and geochemistry of some gold-bearing quartz veins in the central Eastern Desert of Egypt and their altered wall rocks. Ann. Geol. Surv. Egypt 21, 17–25.
Oweiss, Kh.A., 1992. Geochemical exploration for gold at Tallet Gadalla, Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 18, 147–155.
Oweiss, Kh.A., 1995. Geochemical exploration for gold at Um Ud, Central Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 20, 327–332.
Oweiss, Kh.A., Khalid, A.M., 1991. Geochemical prospecting at Um Qareiyat gold deposit, south Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 17, 145–151.
Oweiss, Kh.A., El Naggar, A.A., Abdel Razik, K.A., Moselhy, N., Ali, A.B., 2001. Gold exploration at the Heianai area, South Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 24, 435–450.
Peters, S.G., Golding, S.D., 1989. Geologic, fluid inclusion and stable isotope studies of granitoid-hosted gold-bearing quartz veins, Charters Towers, Northeastern Australia. Econ. Geol., Monogr. 6, 260–273.
Rasmy, A.H., Takla, M.A., Gad, M.A., 1983. Alteration associated with ore formation at Umm Samiuki, south Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 13, 1–21.
Ries, A.C., Shackleton, R.M., Graham, R.H., Fitches, W.R., 1983. Pan-African structures, ophiolites and melange in the Eastern Desert of Egypt: a traverse at 26°N. J. Geol. Soc. (Lond.) 140, 75–95.
Rocci, G., 1965. Essai d'interpre' tation des me'sures ge'ochronologiques. La structure de l'q'uest African. Sci. Terre 10, 461–479.
Sabet, A.H., Bordonosov, V.P., 1984. The gold ore formations in the eastern Desert of Egypt. Ann. Geol. Surv. Egypt 16, 35–42.
Sabet, A.H., Bykov, B.A., Butenko, B.P., 1976a. A short account on the results of geochemical prospecting and panning sampling in the central Eastern Desert of Egypt. Ann. Geol. Surv. Egypt 6, 237–243.
Sabet, A.H., Tscgoev, V.B., Bordonosov, V.P., Babourin, L.M., Zalata, A.A., Francis, M.H., 1976b. On gold mineralization in the Eastern Desert of Egypt. Ann. Geol. Surv. Egypt 6, 201–212.
Schandelmeier, H., Darbyshire, D.P.F., Harms, U., Richter, A., 1988. The east Sahara Craton; evidence for Pre-Pan-African crust in NE Africa west of the Nile. In: El Gaby, S. (Ed.), The Pan-African belt of Northeast Africa and Adjacent Area, pp. 69–94. Friedr Viewegsohn, Braunschweig/Wiesbaden.
Searle, D.L., Carter, G.S., Shalaby, I.M., 1976. Mineral exploration at Umm Samiuki, U.N. Technical Report, Egypt. pp. 36–76. Internal Report.
Seward, T.M., 1984. The transport and deposition of gold in hydrothermal systems. In: Foster, R.P. (Ed.), Gold 82. Balkema, Rotterdam, pp. 511–566.
Shackleton, R.M., Ries, A.C., Graham, R.H., Fitches, W.R., 1980. Late Precambrian ophiolitic melange in the Eastern Desert of Egypt. Nature 285, 472–474.
Sillitoe, R.H., Angeles, C.A., 1985. Geological characteristics and evolution of a gold-rich porphyry copper deposit at Guinoang Luzon, Philippines. Asian Mining, vol. 85. Inst. Min. Metall., London, pp. 15–26.
Silliitoe, R.H., Angeles, C.A., Comia, G.M., Antioguia, E.C., Abeya, R.B., 1990. An acid sulphate type lode gold deposit at Nalesbitan, Luzon, Philippines. In: Hedenquist, J.W., White, N.C., Siddeley, G. (Eds.), Epithermal Gold Mineralization of the

Circum-Pacific: Geology, Geochemistry, Origin and Exploration. Jour. Geochem. Explor., vol. 35, pp. 387–412.

Sims, P.K., James, H.L., 1984. Banded iron formation of Late Proterozoic age in the Central Eastern Desert, Egypt: geology and tectonic setting. Econ. Geol. 79, 1777–1784.

Stern, R.J., 1981. Petrogenesis and tectonic setting of the late Precambrian ensimatic volcanic rocks, Central Eastern Desert of Egypt. Precambrian Res. 16, 196–230.

Suror, A.A., Attawiya, M.Y., Hussein, H.A., El Feky, M.G., 1999. Shear zone microfabrics and multiple source of gold at the Hangaliya mine, Eastern Desert, Egypt. Egypt. J. Geol. 43/1, 39–52.

Takla, M.A., 2002. Economic potentialities of the shield and Phanerozoic rocks of Egypt. 6th International Conference on the Geology of the Arab World. Cairo Univ., Feb. 2002.

Takla, M.A., Suror, A.A., 1996. On the occurrence of Ni-sulphides and arsenides in some Egyptian serpentinites. Egypt. Mineral. 8, 1–18.

Takla, M.A., El Dougdoug, A.A., Rasmay, A.H., Gad, A.A., El Tabbal, H.K., 1990. Origin of Um Eleiga gold mineralization, south Eastern Desert, Egypt. Egypt. Mineral. 2, 3–20.

Takla, M.A., El Dougdoug, A.A., Gad, M.A., Rasmay, A.H., El Tabbal, H.K., 1995. Gold-bearing quartz veins in mafic and ultramafic rocks, Hutite and Um Tenedba, south Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 20, 411–432.

Takla, M.A., Surour, A.A., Elmansi, M.M., 1998. Microfabrics and mineral chemistry of sulphides from "Shadli" metavolcanics and younger gabbros, Eastern Desert, Egypt. Ann. Geol. Surv. Egypt 21, 191–215.

Taylor, H.P., 1974. The application of oxygen and hydrogen isotope studies to problems of hydrothermal alteration and ore deposition. Econ. Geol. 69, 843–883.

Viljoen, M.J., 1979. The geology and geochemistry of the "Antimony Line" in the United Jack Complex, Murchison Range. Geol. Soc. S. Afr., Spec. Publ. 5, 133–158.

Viljoen, M.J., 1984. Archaean gold mineralization and komatiites in Southern Africa. In: Foster, R.P. (Ed.), Gold 82, The Geology, Geochemistry and Genesis of Gold Deposits. Balkema, Rotterdam, pp. 595–627.

Wetait, M.A., Botros, N.S., in press. Genesis and mechanism of gold deposition of EL-Sid gold deposit, Eastern Desert, Egypt Arab. Gulf Jour. Sci.

Windley, B.F., 1984. The Evolving Continents. John Wiley and Sons, New York. 399 pp.

Winkler, H.G.F., 1976. Petrogenesis of Metamorphic Rocks. Springer, New York. 334 pp.

Wyllie, P.J., 1983. Experimental studies on biotite- and muscovite-granites and some crustal magmatic sources. In: Atherton, M.P., Gribble, C.D. (Eds.), Migmatites, Melting and Metamorphism. Shiva Pub., Cheshire, UK, pp. 12–26.