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# Tectonic Environments and Distribution of Gold Deposits in the Pan African Nubian Shield, Egypt.

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**Abstract:** More than 120 gold deposits and occurrences are distributed in the pan-African Nubian Shield in the Eastern Desert of Egypt. The exposed rock units are tectonically grouped into ophiolite, island arc and cordilleran-extensional. This work is a trial to reveal more evidence to recognize impact of these tectonic environments on the structures and tectonics controlling distribution of these gold deposits using the remote sensing techniques. The present work concerns application of google Earth and in the present position ETM+ images which provide new and exciting windows for geological mapping to discriminate probable presence of tectonic environments similar to the Allaqi-Heiani, Onib-Sol Hamed suture and Himasana shear zones. The obtained layers overlain by geologic maps indicated that the 16 gold deposits occurring in both Allaqi-Heiani, and Onib-Sol Hamed suture zones are geographically and geologically distributed within the ophiolite nappes and island arc rock units as well as the related rocks (metagabbros) in its surroundings. In these tectonic zones developed D1-D4 Neoproterozoic deformation phases. Both D1 and D2 phases associated early collision stage between the Gerf terrane, the Haya and Gabgaba Terranes while D3 and D4 phases associated the later collision stage. The D2 produced regional E-W thrust zones overprinted by several shear zones formed during the emplacement of the ophiolitic over the island arc assemblagesat several districts if the Eastern Desert.. Foliations and shearing overprinted by regional deformational thrust zones produced by D2 and D3 control distribution of these 16 gold-bearing quartz-veins and the associated alteration zones. The obtained layers recorded occurrence of another similar five suture and shear zones. These zones occur in Wadi Kharit also Wadi Hodein, Barramiya, Atud-Sukkari, Umm Khariga-Wadi Abu-Dabbab and Talat Gadalla-Umm Samara districts. These tectonic environments control distribution of not only the gold deposits but also the chromite occurrences in both the central and southern tectonic segments of the Eastern Desert. The localization of gold mineralization in its present position in certain mode of occurrence is related to action of hydrothermal fluids produced due to thrusting, regional deformations (faulting and folding), shearing and/or emplacement of younger intrusive rocks. These fluids leached gold in its pathways from the source rock units of each of the three tectonic environments. This is indicated by that each process and rock type left its own impact on the geochemical association and ore minerals assemblage of each group at each locality.

**Key words:** Gold Deposits, Distribution, Tectonic Environments, Nubian Shield.

## INTRODUCTION

Gold mineralization was recorded in more than 120 localities in the Eastern Desert of Egypt (Fig. 1). According to the mode of occurrence and the nature of mineralization, all the gold deposits and occurrences hosted by the Pan-African Late Proterozoic basement rocks are of the vein and dyke types. The vein type comprises the majority of the gold deposits. Most of the gold in these veins occurs as disseminations of native gold. Relative amounts, however, are found in the gold-bearing pyrites and generally in the sulphide minerals. The ore bodies of the vein type are usually of a more complicated form. They represent fissure fillings (arsenopyrite, pyrrhotite, chalcopyrite and sphalerite) associated with some wall-rock alterations in the contact zone of the host rock units. The distribution of the primary gold deposits and occurrences is structurally controlled (fault planes or highly fractured zones (Moharram *et al*., 1970).

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In Egypt the late Proterozoic basement rocks cover an area of about 100.000 square kilometers, the greater part of which covers the Eastern Desert. The basement rocks of Sinai, the Eastern and Western Deserts, Sudan, Ethiopia and Somalia constitute the Nubia Shield that was formed as a contiguous part of the Arabian Shield of the Arabian Peninsula, perior to the opening of the Red Sea, since less than 30 Ma Age. Two essential models for the evolution of the Arabian-Nubian Shield have been proposed viz; geosynclinal and plate tectonic. The recent model is based on the plate tectonic concepts (Greenwood 1976, Camp 1984, and Stoeser and Camp 1985, El Gaby *et al*., 1988, and Ragab and El-AIfy, 1996). According to these models the basement rocks were interpreted and grouped into the following litho-tectonic units that developed mainly during the Pan-African orogeny: pre-Pan-African gneisses and migmatites, Pan-African ophiolites (serpentinites, and associated talc quartz carbonates and metagabbros), island arcs (calc-alkaline- and volcanic plutonism, metavolcano-sediments, metagabbros, diorites), and cordilleran-extensional (Dokhan volcanics, Hammamat; sediments, old granites, felsite porphyry, younger granitoids that include mica granite and alkali feldspar granite and rift related alkaline to per-alkaline rocks, dikes and quartz veins (Hassaan, 2001).

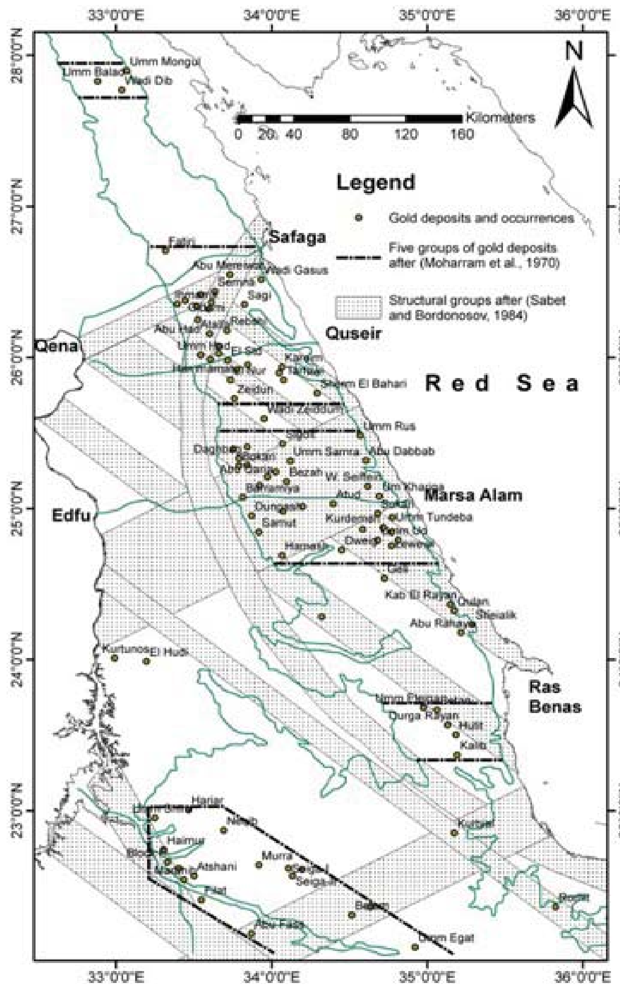


**Fig. 1:** Map showing the distribution of gold deposits and occurrences in the Eastern Desert.

### *1. Previous Work:*

#### *a. Age of the Gold Mineralization:*

Regarding the age of the gold mineralization in the Eastern Desert there are two points of view. Hume (1937), El Alfy (1946), El Shazly (1957 and 1959) and Moharram *et al*. (1970) considered that these gold mineralizations are of probably one epoch. Hume (1937) and El Alfy (1946) considered the gold mineralization of hydrothermal origin accompanied the diorites. El Shazly (1957 and 1959) considered the so-called by Hume

(1935) Gattarian granites definitely responsible for the formation of the gold deposits. Moharram *et al.* (1970) mentioned that the gold deposits and occurrences are to be younger than the granodiorites and some dykes. According to Moharram *et al.* (op.cit) the gold mineralization is known to be present in the following subdivisions of the basement rocks 1. Schist-mudstone-greywacke series; 2. Altered ultrabasic rocks; 3. The epidiorite-diorite complex; 4. Gabbro-diorites; 5. Grey granites and granodiorites; 6. Pink and red granites; and 7. Felsite porphyry and other dyke rocks. Only 20 gold deposits are hosted in the granitoids. According to them it was difficult to assign a precise age. On the other hand Sabet *et al.* (1976) subdivided the formation of the gold mineralization into 4 major epochs namely; 1- The pre-orogenic epoch, 2- The syn to late orogenic epoch. 3- The Rephean – Lower Paleozoic epoch and 4- The Mesozoic – Cenozoic epoch.

According to the plate tectonic concept, El Gaby, *et al*., (1988) mentioned that the gold mineralizations in the Eastern Desert are connected to the sudduction related calc-alkaline magmatic activity formed during the cordilleran stage. In this respect El-Mezayen *et al*., (1995) mentioned the presence of more than one phase of gold mineralization depending on the ore microscopic studies and microprobe analysis which recorded three phases of pyrite crystals. Hassaan and El-Mezayen (1995) genetically classified the gold deposits and occurrences into three tectonic groups: ophiolite (schist-mudstone-greywacke series; serpentinites and talc carbonates, altered ultramafic rocks and the metagabbro, sheeted basalts etc.), island arc (metvolcanic, metavolcanosedimentary rocks, metagabbro-diorites, Dokhan volcanics, granites and granodiorites) and cordilleran-extensional (pink and red granites as well as, felsite porphyry and other dyke rocks). They mentioned that each of the three tectonic groups possesses its specific ore minerals assemblage and geochemical association that is related to its rock types.

***b. Distribution:***

The distribution of the gold deposits and occurrences is considered by Moharram *et al.* (1970), Sabet and Bordonosov (1984), Hassaan and El-Mezayen (1995) and Hassaan (2006) in the light of the suggested ages. Moharram *et al*. (1970) recorded a certain pattern in the areal distribution of gold deposits and occurrences in the Eastern Desert when three main belts of deposits and occurrences were identified; the eastern belt, the central belt and the western belt (Fig. 1). Another two small belts occur. The fourth one runs through the deposits of Umm Tuyur and Umm Egat. The fifth includes wadi Allaqi gold deposits. The auriferous veins in these three belts are of submeridional, north-eastern, and occasionally sub-latitudinal trends. According to them, such a linear distribution is probable due to the fact that they are confined to certain zones of tectonic activity. In this respect in the fourth and fifth belts these veins are elongated north-northwestwards.

Sabet and Bordonosov (1984) mentioned that the deep-seated faults, the faults trending NW and ENE and the zones of the intersection of these faults control this distribution (Fig. 1). The trend of the suggested belts corresponds to the direction of the main structural trends of the Eastern Desert, which run parallel to both the Red Sea Graben and the Gulf of Aqaba.

Hassaan and El-Mezayen (1995) mentioned that the distribution of the tectonic rock assemblages and stages controls the distribution of gold deposits and occurrences. The deposits and occurrences of ophiolitic and island arc gold groups and their interferences occur in the southern and central tectonic segments of the Eastern Desert forming a belt trending NW-SE. The gold group of the cordilleran-extensional stage occurs in the central-northern segments of the Eastern Desert distributed following the same trend. Hassaan (2006) considered the first belt to be two belts. One belt is bordered by Um Egat-Um Tuyur at its SE end and Hariari-Um Ashira at its SW end including wadi El Allaqi gold deposits and occurrences (Fig. 2). The second belt is bordered by wadi Hodein-Sukkari deposits at its SE end and Hamash-Erediya deposits at its NW end (Fig. 2).

***2. Aim of the Work:***

The development of remote sensing techniques provides new and exciting windows to reality and serves to stimulate thought in a broader context on the formulation of hypotheses and methodologies in geologic mapping. The present work is a trial to apply of remote sensing techniques in revealing the tectonic environments and its propable role in controlling the distribution of the gold deposits and occurrences in the Pan African Nubian Shield of the Eastern Desert in relation to the plate tectonic concept regarding source rock, mode of formation and genesis. Since the Google Earth image discriminates the zones of Allaqi-Heiani, Onib-Sol Hamed sutures and Himazana shear zone, this study is a trial to use the Google earth and ETM+ images to search for probable revealing presence of other similar tectonic zones to assure its role in controlling distribution of gold deposits and occurrences. This is to be a guide in exploration for new sites of gold mineralization.

### 3. Methodologies:

Rationing is an effective method for distinguishing the rock types because the main spectral differences in the visible and near-infrared spectral regions are found in the slopes of the reflectivity curves. Principle Component analysis is a technique for reducing correlation between ariables and commonly produces images with separate geologic features. Because geologically important information might occupy only a small portion of the spectral range of band that is otherwise highly correlated with other bands, it is possible that such information will be lost through one of these other bands being chosen instead.

Principle Components of false color composite bands 7 and 2 and ratioing bands (5/7, 5/1 and band 4) processed through RGB and the Landsat Enhancement Thematic Mapper (ETM) images, were used by Hassaan (2001 and 2006) in discriminating the outcropping rocks units of the ophliolitic and island-arc assemblage and the cordilleran-extensional stages hosting the gold deposits and occurrences in such tectonic environments as follows: 1- The color ratio (5/7, 5/1 and 4/3) composite image discriminated the serpentinites–(bright red color); gabbroic rocks-(green color) and granitic rocks – (blue color). That of the color ratio 5/7, 5/1 and 3/1 discriminated the metavolcanic rocks (whitish blue color), ophiolitic mélange (dark blue), gabbroic rocks (purple color), fresh biotite granites (greenish color), muscovite microcline quartz albite granites (whitish blue color), and sulphide and/or fluorite bearing altered granites (yellowish color). The image of ratio 5/7, 5/1 and band 4 registered the metagabbro in dark reddish color, the dioritic rocks in dark brown color, the tonalite-granitoids in dark blue color, biotite granites in blue color and muscovite granites in whitish blue tint. The image of 2, 4 and 7 bands exhibits the alkali feldspar granites (Gattar granites) in pinkish color. The regional alteration zones bearing gold mineralizations of the ophiolitic (listweanites) and island arc (shear zones) groups exhibit yellowish color in the false composite bands 2, 4 and 7.

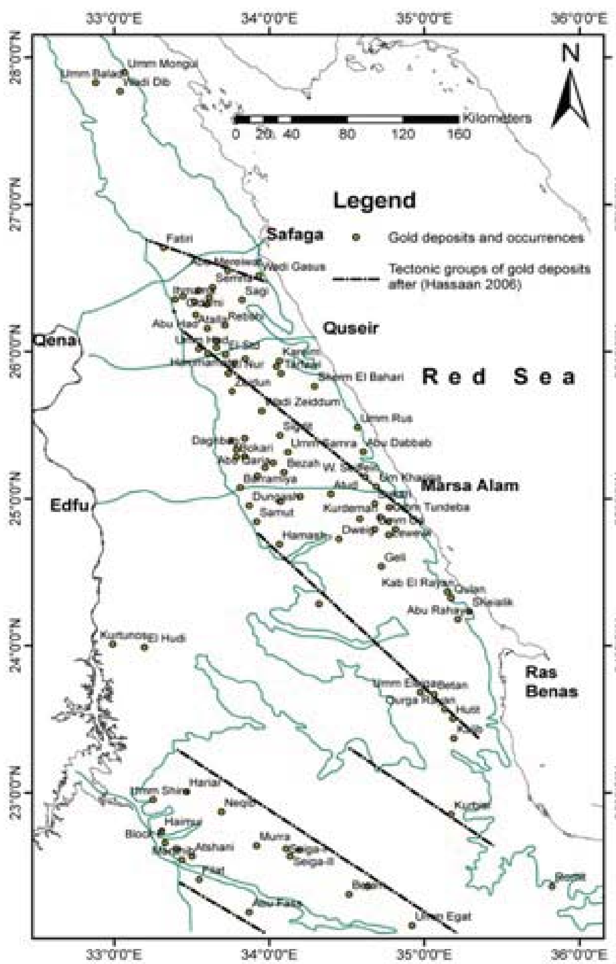


**Fig. 2:** Map showing the distribution of gold deposits and occurrences in the tectonic groups, Eastern Desert.

Only the simplest ETM false color combination of bands 7, 4, 2 in RGB (Red, Green, Blue) will be used as a first approach to express and to reach to the target of the present work. Moreover these images will be verified by overlaying a geologic map layer on the ETM+ image and will be supported by reviewing the mineralogical and geochemical data on several gold deposits from the published literature and field observation of the authors. These obtained layers will be used to achieve the goal of the present study.

***Discussion:***

The Arabian–Nubian Shield represents a complex amalgam of arcs and microcontinents assembled during Neoproterozoic closure of the Mozambique Ocean. The two ensimatic island arc (Gerf and Gabgaba terranes, Fig. 3) evolved from 830-720 Ma in the Mozambique Ocean, and collided between 750 and 720 Ma forming the Allaqi suture where ophiolite belts were formed (Kroner *et al*., 1987; Greiling *et al*., 1994; Shackleton, 1994 and Abdelsalam and Stern, 1996). The Onib-Sol Hamed, the Wadi Allaqi-Jabal Heiani and the Nakasib-Amur ophiolite belts are bent and dragged into a broad N-S trending major transcurrent shear zone named by Kroner *et al*. (1987) Hamisana shear zone. They considered The Onib-Sol Hamed, the Wadi Allaqi-Jabal Heiani belts two sutures.

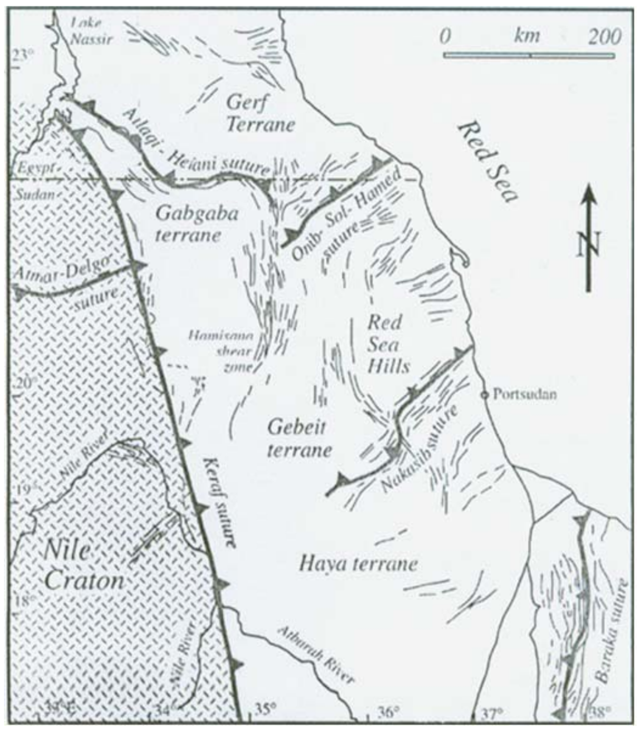


**Fig. 3:** Map showing the two ensimatic island arcs; Gerf and Gabgaba terranes (after Abdelsalam and Stern, 1996).

Sixteen gold deposits and occurrences of Wadi Allaqi and Sol Hamed districts were plotted on Google Earth and ETM+ Images. The obtained layer of Google Earth Image overlain by geologic map indicates that these 16 gold deposits and occurrences are occurring in Allaqi -Heiani and Onib-Sol Hamed suture zones (Fig. 4a, b), and are geographically and geologically distributed within the ophiolite nappes and island arc metavolcanic, metavolcanosedimentary rock units as well as the metagabbros outcropping there in the surroundings.

In these tectonic zones developed D1-D4 Neoproterozoic deformation phases (Kusky and Ramadan, 2002). According to them the D1 and D2 associated the early collision stages (between the Gerf terrane, and the Haya and Gabgaba Terranes) while D3 and D4 associated the later stage (Abdelsalam and Stern, 1996, Fig. 3). The D2 produced regional E-W thrust zones overprinted by several shear zones formed during the emplacement of the ophiolitic over the island arc assemblages. Foliations and shearing overprinted by regional deformational thrust zones produced by D2 and D3 within both suture zones control distribution of these 16 auriferous quartz-veins in the present position.

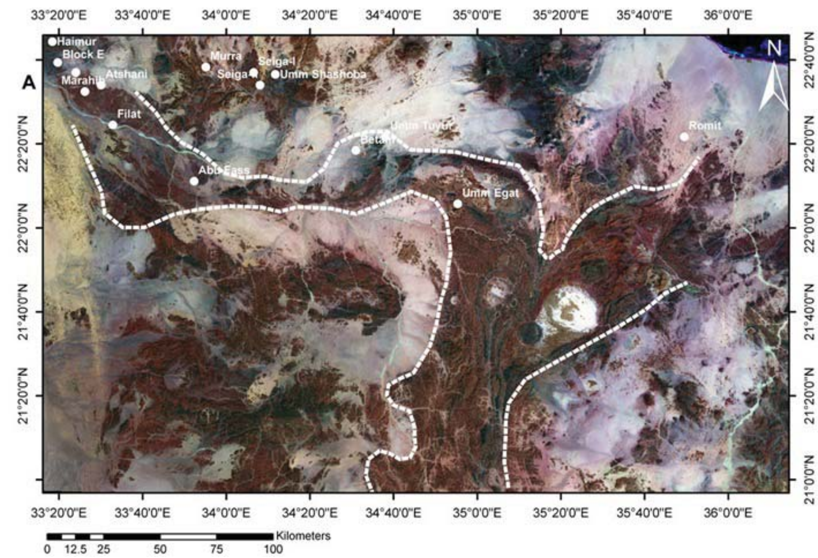


**Fig. 4a:** ETM+ false color image combination of bands 7, 4, 2 in (RGB) showing the distribution of gold deposits in the (Allaqi-Heiani,) – (Onib-Sol-Hamed) suture zones.

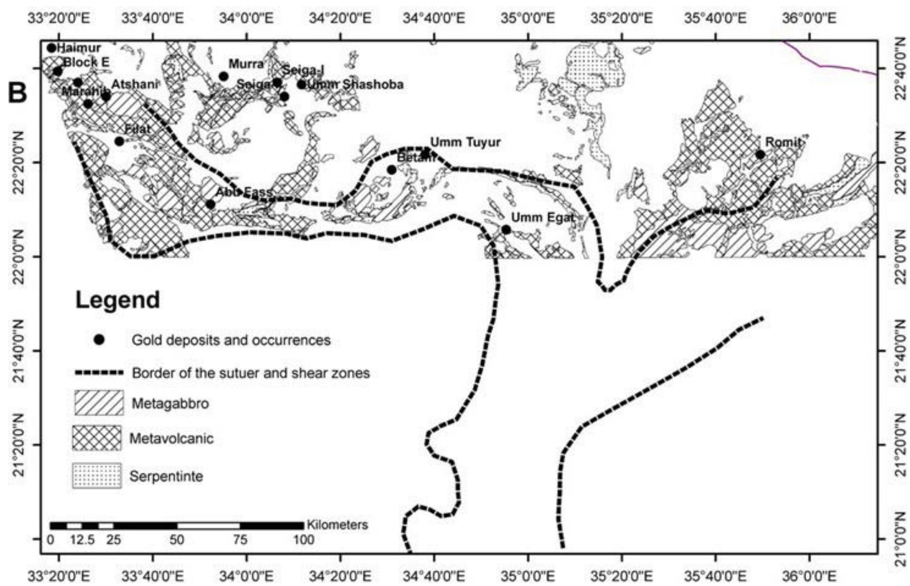


**Fig. 4:** Map showing the geology (after Conoco, 1987) and distribution of gold deposits and occurrences in the (Allaqi-Heiani,) – (Onib-Sol-Hamed) district.

From the ETM+ and Google Earth Image the authors recorded another new five sutures and/or shear zones namely Wadi Kharit- Wadi Hodein; Barramiya, Atud-Sukari; Um Khariga-Wadi Abu Dabbab and Talaat Gadallah-Um Samara (Fig. 5). The ophiolite belts in these five sutures are bent and dragged into N-S to NNW-SSE trending shear zones.

Greiling *et al*. (1994) suggested that the regional structures in the part of the Nubian Shield in the Eastern Desert originated mainly during post-collision events, started with extensional collapse, which was followed by NNW-SSE shortening and related large-scale thrusting and folding. Consequently thrusts are overprinted by transpressional regime; early transpression produced Allaqi shear zone and final transpression is documented

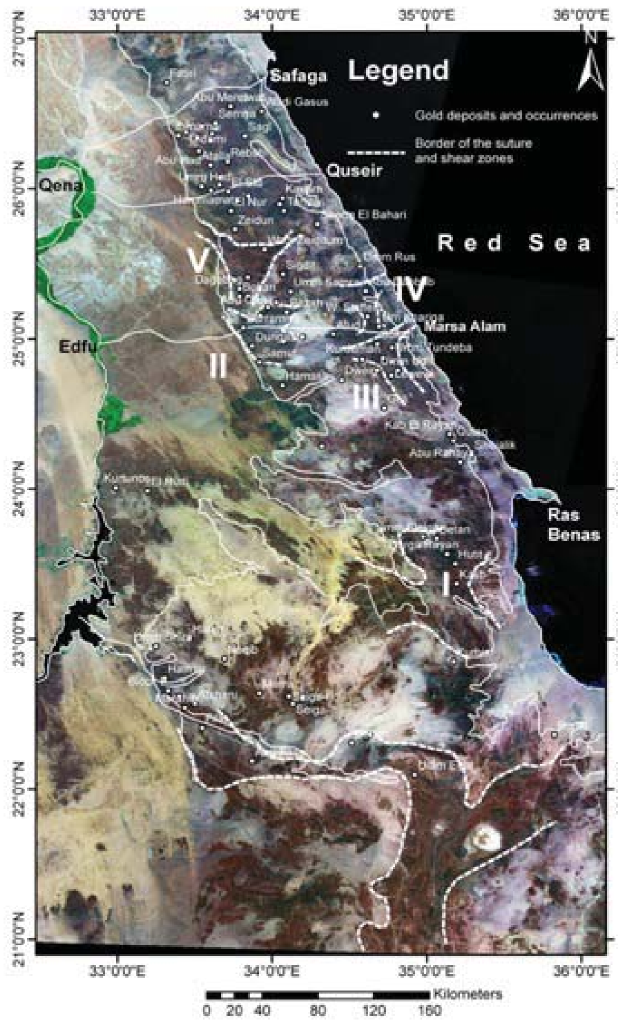


**Fig. 5:** Google Earth false color image showing the distribution of gold deposits and occurrences and borders of Allaqi-Heiani and Onib-Sol Hamed and the 5 recorded suture and shear zones in the Nubian Shield, Eastern Desert.

in Wadi Kharit-Wadi Hodein shear zones. The originated thrusts are overprinted by a final transpression document in Wadi Kharit-Wadi Hodein suture and shear zone (Fig. 6a, b) in the ophiolite and island arc rocks in which occur a total of five gold deposits and occurrences.

Both Barramiya, and Atud-Sukari sutures are located on the eastern and western sides of the Idfu-Mersa Alam road which is considered by Hamimi (1999) a major shear zone. In this respect Greiling *et al.* (1994) considered Idfu-Mersa Alam road a shear zone trending E-W most probably originated as extension collapse during a post collision event. However, Salloum *et al.* (1989) considered Idfu-Mersa Alam shear zone as a major E-W deep seated fault, overprinted by a number of thrusts and strike-slip faults having N-S, NE-SW and NW-SE directions. The eastern zone represents the Atud-Umm Ud-Sukkari district, in which distribute 15 gold deposits and occurrences (Fig. 7a, b). The western zone is located within Barramiya district which includes six gold deposits and occurrences.

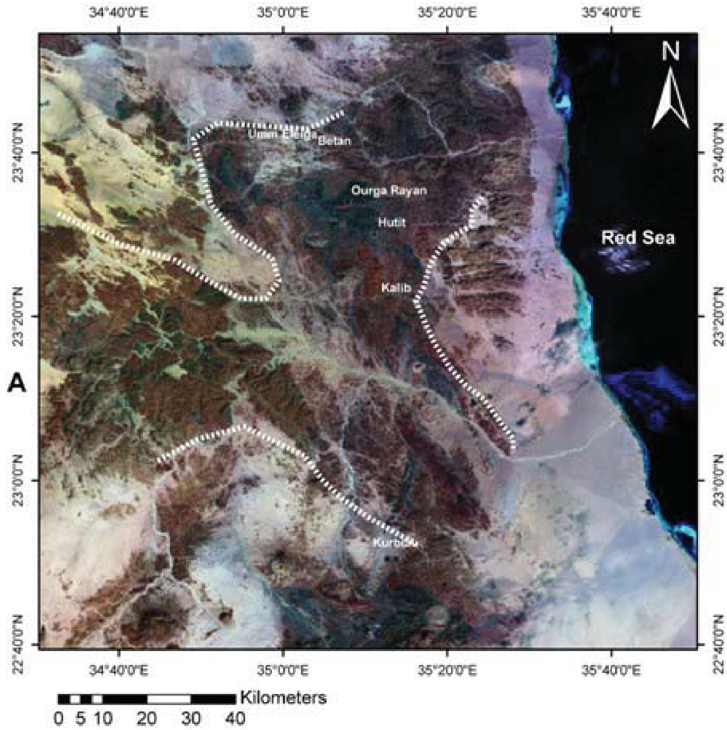


**Fig. 6a:** ETM+ false color image combination of bands 7, 4, 2 in (RGB) showing the distribution of gold deposits and occurrences in the Wadi Kharit- Wadi Hodein, suture (I).

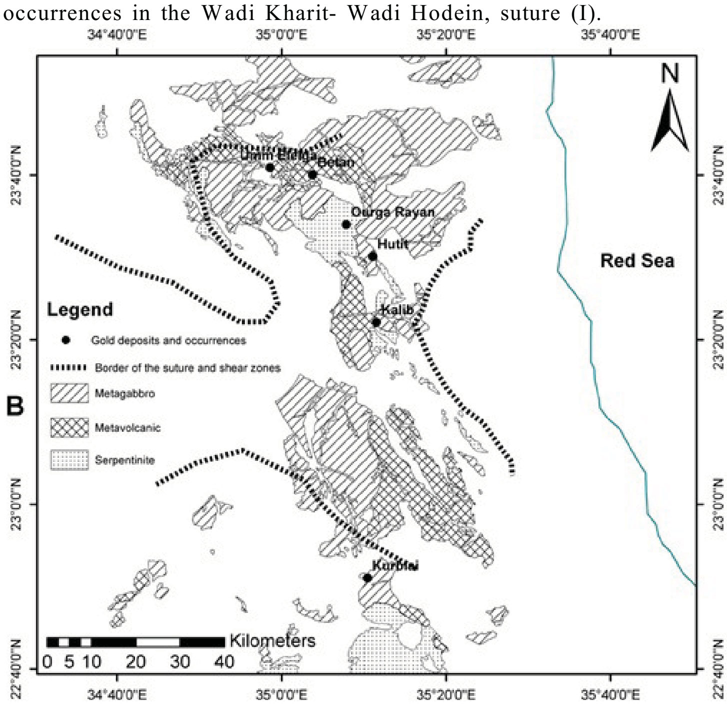


**Fig. 6b:** Map showing the geology (after Conoco, 1987) and distribution of gold deposits and occurrences in the Wadi Kharit- Wadi Hodein, (I) suture.

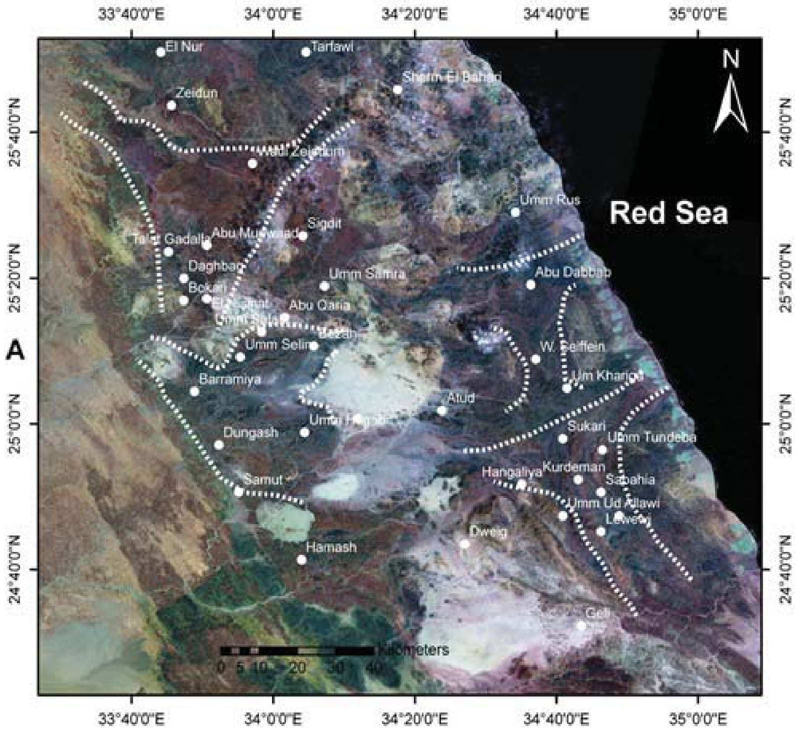


**Fig. 7a:** ETM+ false color image combination of bands 7, 4, 2 in (RGB) showing the distribution of gold deposits and occurrences in the Barramiya (II), Atud-Sukari (III), Um Khariga-Wadi Abu Dabbab (IV) and Talaat Gadallah-Um Samara (V) suture and shear zones (for location No. see Fig. 5).

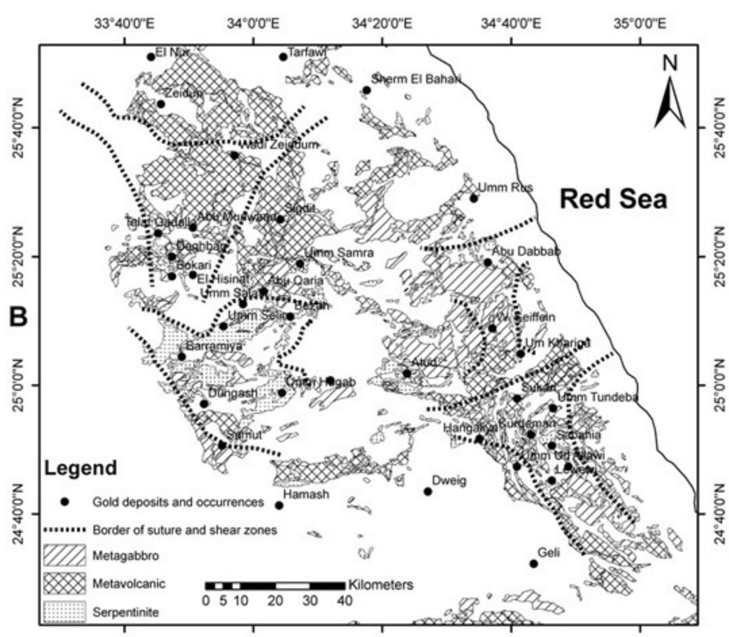


**Fig. 7b:** Map showing the geology (after Conoco, 1987) and distribution of gold deposits and occurrences in the II, III, IV, and V suture and shear zones.

The present authors believe that both districts are two sutures formed due to collision of the two island arcs (Gerf and Gabgaba terranes) where ophiolite belts are exposed in both Barramiya and Atud – Sukkari districts. Both sutures were connected by the NNW-SSE trending shear zones followed by the post collision extensional collapse caused NNE-SSW shortening of thrusts and folding recorded in both districts.

The authors are convinced that effect of the two collided island arcs, extensional collapse and the followed shortening associated with thrusts and folding affected the province north of the E-W Idfu-Mersa Alam road formed the two sutures and\or shear zones; viz Talat Gadalla – Umm Samara to the west and Um-Khariga-Wadi Abu Dabbab to the east. These findings can be supported by the ideas of Kusky and Ramadan, (2002). Both D3 and D4, are characterized by development of reactivation of some of the thrust faults in the E–W imbricate thrust zones. The D2 produced regional thrusts formed during the emplacement of mafic–ultramafic rocks of the ophiolitic assemblages over the metasedimentary and metavolcanic rocks of the island arc assemblage. Major WNW–ESE and NW–SE shear zones formed during D3 (Kusky and Ramadan, op.cit). The foliations and faults overprinted by both events control distribution of the gold-bearing quartz-veins.

In Talaat Gadallah-Um Samara district, five gold deposits and occurrences are distributed in the ophiolite and the metavolcanic island arc assemblages (Fig. 7a, b). Only three gold deposits are recorded in Um Khariga – Wadi Abu Dabbab microsuture where Um Khariga serpentinite and the island arc rock, metavolcanic units are outcropping (Fig. 7a, b).

Comparing the distribution of gold deposits and occurrences in these tectonic environment with that of chromite deposits, the authors noticed that both match well with each other (Fig. 8).

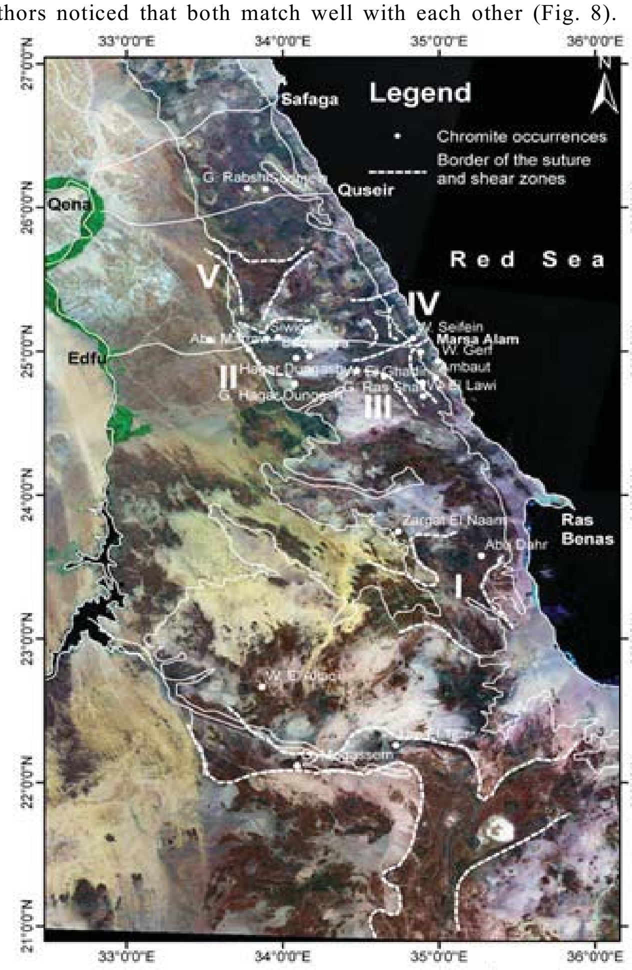


**Fig. 8:** ETM+ false color image combination of bands 7, 4, 2 in (RGB) showing the distribution of chromite occurrences and borders of the 5 recorded suture and shear zones in the Nubian Shield, Eastern Desert.

The following table summarizes the geochemical association and ore minerals assemblage of some deposits to show the variation of the associated metals and ore minerals from a tectonic environment to another.

| Tectonic setting | Site | Geochemical association | Ore minerals Assemblage |
|---|---|---|---|
| Cordelleran-extensional | Hariari (Hassaan, 2006) | Ag, As, Co, Cu, Ni, Pb, Zn | Pyrite, Arsenopyrite, Chalcopyrite, Galena |
| | Gattar(El Bakri *et al.,* 1995) | Sb, Ag, Sn, W, Co, Ni, Pb, Mo | Pyrite, Chalcopyrite, Chalcocite, Bornit, Malachite |
| Island Arc | Abu Marawat (Hassaan *et al.,* 1996) | Ag, Mo, As, Cu, Pb, Sn, Zn, Ni, ba | Pyrite, Pyrrhotite, Chalcopyrite, Sphalerite, Galena, Covellite |
| | Samut (Hassaan *et al.,* 1986-1990) | Cr, Ni, Mo | Pyrite, Arsenopyrite, Chalcopyrite, |
| | Umm Rus (Hassaan, 2006) | As, Cr, Ni, Cu, Ag | Pyrite, Arsenopyrite, Sphalerite, Chalcopyrite, Galena, Etrahedite, |
| | Um Ud (Hassaan *et al.,* 1986-1990) | Ag, As, Pb, Ni, Cu, Zn, Co, Cr | Pyrite, Arsenopyrite, Chalcopyrite, Magnetite |
| | Um El Touyur El Fuqani (Hassaan, 2006) | Ni, Ag, Cu, Pb, Mo | Pyrite, Arsenopyrite, Pyritization, Chalcopyrite |
| Ophiolite | Barramiya(Hassaan, 2006) | Cr, Zn, Ag, Cu, Ni | Pyrite, Chalcopyrite |
| | Um El Touyur El Fuqani (Hassaan, 2006) | Ni, Co, Ag, Cr | Cromite, Cobaltite, Pentalendite, Pyrite, Arsenopyrite, Pyritization |
| | Fawakhir(Hassaan, 2006) | Ni, Co, Pb, Zn, Sn, Ag, As | Pyrite, Arsenopyrite, Sphalerite, Galena, |
| | Sukkari(Hassaan, 2006) | As, Mo, Ni, Sn, pb, Co | Pyrite, Arsenopyrite, Sphalerite, Chalcopyrite, Galena, |
| | Um Ud (Hassaan *et al.,* 1986-1990) | Cr, Ni, Mo, Ba | Pyrite, Arsenopyrite, Chalcopyrite |

The rocks units of each group are the source of the gold and sulphide-gold mineralization that are supported by the geochemical associations of the metals given in the table, which reflect the lithological nature of each tectonic environment from ultramafic to acidic rock units. The localization of each gold mineralization in its present position in certain mode of occurrence is influenced by the action of hydrothermal fluids produced due to thrusting, regional deformations, shearing and/or emplacement of younger intrusive rocks. These fluids leached gold in its pathways from the source rock units of each of the three tectonic environments. Each process left its own impact on the geochemical association and ore minerals assemblage of each tectonic group at each locality as indicated from the table.

From the field observations and reviewing the previous works, the authors recorded the following supporting criteria:

In both Um Khariga and Wadi Seifein the auriferous quartz veins are trending N 25° E and N 20° E respectively. Wadi Abu Dabbab galena rich auriferous two veins are cutting metagabbro-diorites and trending N 25° W. Both may represent one trend of the Abu Dabbab cassiterite-colmbite bearing quartz stock veins of from NE-SW to submeridioneal trends. This stock of veins is cutting listweanized serpentinite, metavolcanics, metagabbros and muscovite-microcline-albite granite. The serpentinites in this suture zone especially at Wadi Seifein are extensively listweanized. Moreover plagogranites usually associating the ophiolite sequences like that hosting Sukari lodes trending NE-SW are present in Abu Dabbab area (Sabet *et al*., 1976). In this respect Sukari area as a part of Wadi Alam district is considered by Fawzy (1986) metaophiolite ancient ocean floor succession.

In Atud-Sukari suture and shear zone extensive number of auriferous quartz veins (Soliman *et al*., 1988; Hassaan *et al*., 1986-1989) are present in Um Ud area cutting ophiolites, listweanized serpentinites, metavolcanics, and metagabbros. In Wadi Garf and Um Khasila extensive carbonitized and listweanized serpentinites, due to doplex thrusting bearing pyrite-gold mineralization and cinnabar are recorded by Ramadan, 2004 and Sabet *et al*., 1976 respectively. For this reasons this area is considered by Hassaan, (2006) a promising exploration target for gold as Hg represent the upper zone of these hydrothermal gold deposits.

At alweys Barramiya the aurifeous lodes are hosted in the metavolcanosediments and graphitic schists as well as the serpentinites.

In Wadi Kharit-Wadi Hodein suture and shear zone gold bearing listweanized serpentinite at Wadi Hodein and altered metavolcanics at Wadi El Khashab and Um El Touyur El Fuqani are recorded by Hassaan *et al*. (1996) and Ramadan (2004).

***Conclusion:***

The ophiolites, island arcs and cordilleran-extensional tectonic environments control the distribution of the known gold deposits and occurrences in the Eastern Desert. The rocks units of each group are the source of the gold and sulphide-gold mineralization supported by the geochemical association of the metals, which reflect the lithological nature of each environment from ultramafic to acidic rock units. The districts of these tectonic zones are recommended for detailed exploration using the corresponding ETM imagies recommended in the methodologies following the given above criteria as a guide.

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