PORPHYRY-EPITHERMAL CU ± AU MINERALIZATION IN EL SAMRA AREA, SOUTHEASTERN SINAI, EGYPT.

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ABSTRACT

El Samra area in southeastern Sinai is occupied by Dokhan volcanic and Hammamat sediments. The Dokhan volcanic separated into (a) older Dokhan volcanic of intermediate compositions, and (b) younger Dokhan volcanic of rhyolitic composition. The two subunits are separated by a time interval of considerable magnitude during which deposition of the Hammamat sediments. The volcanic-sedimentary succession intruded by high level younger granites (Syenogranites and monzogranite) and albitite.

The copper-gold-sulphide mineralizations are widely distributed in Dokhan volcanic and the dominance of the calc-alkaline granitic rocks. The mineralization represented by sulphide disseminated in rhyolite sheet, copper and sulphide mineralization in Stockwork in Wadi El Samra, alteration zone of copper mineralization in Wadi Ghorabi-El Hatemeia, alteration zones mainly along shear zones in Wadi Khashm El Fakh and copper-sulphide gossans in Wadi Tarr. The copper-gold ores exhibit Cu/Au atomic ratios of the mineralization in Wadi El Samra area about 0.38, which signifies them as gold-rich porphyry copper deposits. The gold-rich signature of Wadi El Samra deposits complies with features such as higher contents of chalcopyrite and bornite in the hypogene ores, reflect rather high temperature (more than 600°C) of the primary ore-forming fluids involved in the formation of the porphyry copper-gold deposits, and it formed at relatively shallow depth (approximately <3 km). Wades Ghorabi-El Hatemeia and Khashm El Fahk_areas mineralization has an average Cu/Au ratio of 1.3 and Ag/Au ratio less than 10/1 ratio these values characterized to the epithermal type mineralization and temperatures of homogenization are greater than 250°C.

Keywords: Dokhan volcanic and Hammamat sediments, porphyry copper-gold deposits, epithermal type mineralization, El Samra area and Sinai.

1. INTRODUCTION

The past decade of research in magma-hydrothermal systems in volcano-plutonic arcs has focused on active geothermal systems as analogs for ore-forming systems and on the potential genetic links between relatively deep-seated porphyry Cu-(Au) deposits and volcanic-hosted epithermal precious metal deposits. These and other deposit-types, such as base- and precious-metal skarns, replacement bodies, and veins form part of large magma-hydrothermal systems that occur in the upper 5 km of the Earth's crust. Minor quantity of copper-gold porphyry-epithermal mineralization in Egypt, south Um Manqul, prospect (Botros and Watait 1997, Botros 1999), Hamash area (Ivanov and Hussein 1972) and Umm Garayat area (Hussein 1990) are of the porphyritic type mineralization in Eastern Desert of Egypt. Recently, Botros (2004, 2002) stated that the porphyritic calc-alkaline granites and their surface expression (Dokhan volcanic) formed along active continental margins represent one of

the lithological environments for copper-gold mineralization in Egypt. This is in agreement with Ivanov and Hussein (1972) who is stated that at least one generation of gold deposits in chronologically and genetically related to Dokhan volcanic or their co-magmatic batholiths. The link between the known epizonal Au, Cu (Ag, Sb) mineralization and the calc alkaline magmatic activity, comprising the calc-alkaline G1-G2granites and Dokhan volcanic was also stated by El Gaby (1993).

In Egypt debate is still active about the possibility of finding porphyry-epithermal copper-gold in the pan-African belt, although Ivanov and Hussein (1972) and Hussein (1990) suggested the possible occurrence of two porphyry copper prospects at Hamash and Um Garayat. Recently, Botros and Watait (1997), based on geological, petrographical and geochemical studies, also suggested that south Um Manqul gold prospect has many features in common with other porphyry systems in the world and the presence of acid-sulphide alterations (Botors 1999) which is a common feature in the porphyry deposits (Ashley 1982, Sillitoe and Gappe 1984, Sillitoe and Angeles 1985, Sillitoe et al 1990), also validated the suggestion of Botros and Watait 1997.

In El Samra area the copper-gold-sulphide mineralization are widely distributed in Dokhan volcanic and the dominance of the calc-alkaline granitic rocks, make it ideal environments for the genesis porphyry-epithermal copper-gold mineralization (Elkhan A. et al. 2012).

The present paper describes the geotectonic setting, ore mineralogy, petrography and geochemistry of copper-gold-sulphide mineralization in El Samra area in southern Sinai. The genetic interpretation of the examination results, used to clarify genetic questions.

2. REGIONAL GEOLOGY

The (Meta) sediments and (Meta) volcanics of the Wadi Kid area have been assembled into four broadly accepted stratigraphic units: the Malhaq Formation, the Um Zariq Formation, the Heib Formation and the Tarr Complex Fig (1).

2.1. The Malhaq Formation. comprises a series of volcanic of silicic, intermediate and minor basic composition. These include vesicular lavas, breccias, coarse pyroclastics and finely bedded tuffs, and sediments derived from them, mainly conglomerates, pebbly greywackes and pelites. Less common are graphitic metapelites and impure carbonates and limy mudstones.

2.2. Um Zariq Formation. The Um Zariq metasediments composed of graphitic phyllites and mica schists with porphyroblasts of biotite, garnet, cordierite, staurolite and andalusite. These originally quartz-rich aluminous metapelites and metapsammites are interbedded with plagioclase-rich lithic metagreywackes, related metatuffs and minor lavas of silicic and intermediate composition that are similar to units in the Malhaq Formation.

2.3. Heib Formation. This is a thick sequence of subaerial silicic to intermediate porphyritic volcanics. Silicic volcanics (typically rhyolites) dominate and include lavas, ignimbrites and lapilli tuffs.

2.4. Beda Turbidites and Kid Conglomerate. Beda Turbidites is a conspicuous member within the Heib Formation constitutes a thick sequence of turbiditic slate with graded tuff or greywacke interbeds. They form a NE trending belt that divides the Heib Formation into two parts. Kid Conglomerate form a continuous NE-trending thick belt (800 m) crossing the mapped area, and are polymictic is thick lenses of cobble and boulder conglomerate with coarse volcanogenic sandstone intervals. The gravels of the conglomerates are derived particularly from the silicic volcanites of the Heib Formation, though there are some granitoid clasts with well rounded to flattened metavolcanic and metasedimentary clasts (up to 1 m length) embedded in a finer grained tuffeceous matrix.

2.5. Younger granites occur as a minor exposure in south and west. The mapped Younger Granites intrude the (Meta) volcanics and (Meta) sediments, and are identified in the field as syenogranites and monzogranite

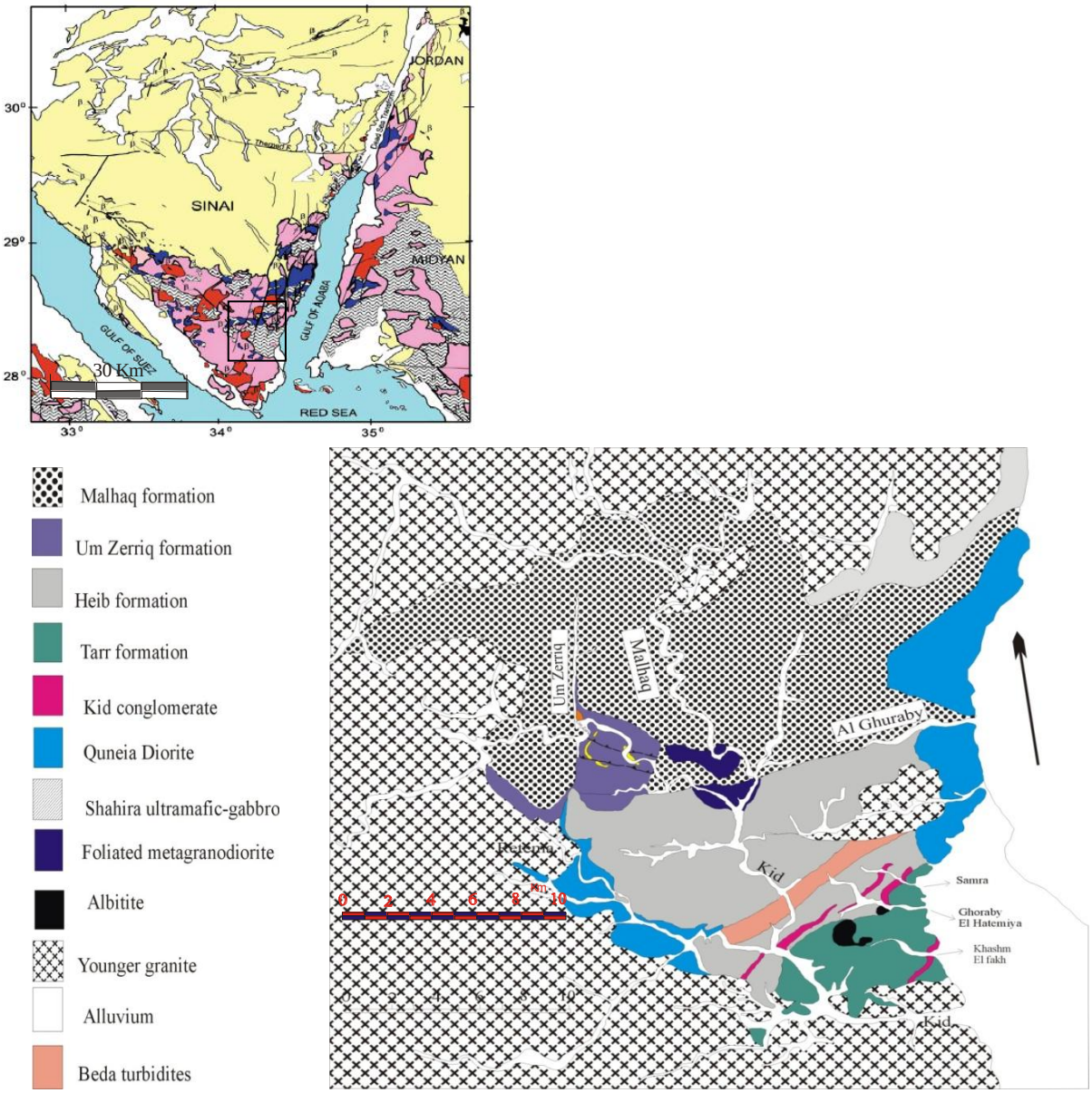

Fig. 1.*Geological map of the Kid Island arc area in Southern Sinai (after A. Fowler 2010).*

3. GEOLOGY OF EL SAMRA AREA

According to El Gaby et a1 (1991), the area of El Samra is occupied by Dokhan volcanic and Hammamat sediments intruded by younger granites and albitite.

The Dokhan volcanic in the area under consideration are separated into (a) older Dokhan volcanic of intermediate compositions, and (b) younger Dokhan volcanic of rhyolitic composition.

The two subunits are separated by a time interval of considerable magnitude during which deposition of the Hammamat sediments.

3.1. The older Dokhan volcanic:- The older Dokhan volcanics constitute a thick and well bedded succession of pyroclastics interbedded with volcanic sheets attaining about 2000 m in thickness. The pyroclastics include crystal-tuffs, crystal-lithic tuffs, and lapilli tuffs. The volcanic sheets are less abundant than the pyroclastics and are represented by prophyritic andesite and less abundant porphyritic dacite.

Pyroclastics. This part is showing dark grey, gray, light grey, bluish grey and grayish green color. The hand specimens are hrad and massive, sometimes foliated.

Crystal tuffs comprise the- *dacitic crystal tuffs*: they are composed of hypidiomorphic plagioclase and quartz crystals and crystal fragments and glass shards, rock fragments are rarely observed. b- rhyolitic crystal tuffs: they are composed of crystal and crystal fragments of plagioclase, quartz and less abundant potash-feldspars.

Crystal lithic tuffs comprises the a- *andesite crystal-lithic tuffs:* They are composed of angular to sub-angular andesite, basalt and dacite fragments together with variable amounts of plagioclase and quartz crystal fragments. b- *basaltic crystal-lithic tuffs:* They are composed of angular to sub-angular basalt and andesite fragments together with variable amount of plagioclase crystal and crystal fragments.

lapilli tuffs Under the microscope, they are formed of angular to sub-angular chips (2-64 mm long) of accessory volcanic rocks of fine tuffs, andesite, dacite and volcanics glass , siltstone and chert. The rock fragments are scattered in a fine-grained groundmass formed of volcanics dust, iron oxide granules, sericite and chlorite.

The volcanic rocks. They are differentiated petrographically into the following rock types. *Basalitic andesite:-* They are fine to medium-grained and of greenish grey and grey colour. In thin section, the interserttal variesties are built of plagioclase laths, while plagioclase phenocrysts are rarely present. Actinolite, dark glass and iron oxides occupied the interstices between the plagioclase laths, as interstitial irregular pools. *Andesite:-* are fine to medium-grained, and of grey, greenish grey colours. Composed of euhedral to subhedral plagioclase phenocrysts set in a hyalopilitic and pilotaxitic groundmass. Quartz may occur as microporphyritic crystals in the varieties transitional to dacite. *Dacite:-* They are fine to medium-grained and of light green, yellowish green, and grey colour. In thin section, dacite are mainly constructed of plagioclase and quartz, phenocrysts disposed in a felsitic groundmass of quartz and feldspar.

3.2. The Hammamat sediments:- The greywackes comprise lithic greywackes, subgreywackes, and fledspathic greywackes. They occur as beds 2-5m thick, lacking internal stratification, and interlayered with siltstone and silty mudstone beds. They are ill-sorted grey or grayish green in color and commonly contain lithic fragments. The siltstones and the less abundant silty mudstones are composed mainly of subangular fine Sand and silt-size clastic grains embedded in chlorite and sericite-rich paste. They occur as variably, thick beds 5-10 m thick, interbedded with the predominating greywacke. The conglomerate is quite abundant in the lower part of the succession closed to the contact with the underlying older Dokhan volcanic. They composed of pebbles and cobbles up to 15 cm long, of dacite, andesite, quartz and tuffs, embedded in a greywacke matrix.

3.3. Younger Dokhan volcanics:- Petrographical studies reveals that the younger Dokhan volcanics are unmetamorphosed, and comprise a- *the rhyolite:-* are fine-grained with well developed porphyritic texture. They are pink, buff, cream, reddish brown, grey, and light grey in colour. Microscopically, they are composed of potash-feldspar, quartz and very limited amount of albite phenocrysts, in a microcrystalline groundmass. b- *the rhyodacite*:- are fine-grained, porphyritic, and of buff, cream and

grey colour. Microcopically, they are composed of oligolcase –feldspar and quartz phenocrysts, embedded in a cryptocrystalline to felsitic groundmass. c- the *alkali-rhyolite:-* is fine-grained with well developed porphyritic texture, and of pink, buff, and reddish brown colour. Microscopically, they are composed of potash-feldspar, quartz and rarely albite. The phenocrysts are embedded in a felsitic groundmass.

4. MATERIAL AND METHODS

Samples from the different mineralized sites collected from the alteration outcrops, shear zones and quartz veins, polished and thin sections were prepared for petrographical and mineralogical studies using transmitted light microscope and reflected light microscope. The mineralogical data were analyzed to different mineral assemblages and used to identify the different types of mineralization in the study area. Samples collected from the alteration outcrops, shear zones and quartz veins were analyzed for Au, Ag, Cu, Zn and Pb elements using atomic absorption analysis.

5. PETROGRAPHY AND ORE MINERALOGY

1- Wadi Samra Sulphide area:- the main largest area for the mineralization, in this locality is pyrite-bearing rhyolite- ignimbrite sheets, which carry appreciable amount of pyrite, the pyrite bearing rhyloite-ignimbrite sheet vary in length from 2 to 3 km and up to 1m in thickness. Pyrite occurs as irregular patches in a random distribution account from 20% to 40 % by volume Fig. (2A).

2- Stockwork area: - the most important occurrences of the sulphide mineralization in Wadi Samra area. It occur as a system of intersecting randomly oriented quartz veins (few centimeters thick) forming Stockwork Fig (2B), copying area of about 0.15 km^2. The trend of the quartz veins within the Stockwork are diverse and include NNW-SSW, E-W and NW-SE directions. Generally the quartz veins and veinlets are stained by iron oxides and malachite and accompanied by extensive brecciation. The mineralized Stockwork at Wadi El Samra containing low dissemination of chalcopyrite and pyrite, as well as small pockets of (1-5 centimeters) of galena, chalcopyrite sometimes occurs as coarse grained subhedral crystals forming massive pockets. The quartz Stockwork in wadi El Samra cutting cross the crystal lithic tuff that belong to Dokhan volcanics, on the other hand, they rarely cutting cross the Hammamat sediments.

3- Wadi Ghorabi-El Hatemeia old copper mine: - Wadi Ghorabi-El Hatemeia copper mine is located in the upper stream of Wadi Ghorabi-El Hatemeia, in which the mineralization occurs in two large mineralized gossans outcrops Fig (2C). The mineralized zone extend in an N45^{o}E direction in which the mineralized bodies controlled mainly by NNW-SSE fractures trend. The gossans bodies characterized by blue and green malachite and. The largest one is thick oxidized zone containing green and blue azurite staining. The gossans body rang in thickness from 2.5 m to 18.5 m (Noor et al 2008) and extends along strike for about 195 m. The mineralization at Wadi Ghorabi-El Hatemeia represented by sphalerite , galena and chalcopyrite in which sphalerite occur usually as aggregates of coarse grained subhedral crystals associated with small chalcopyrite crystals. Ghanite occur as massive aggregates which fill the microfracture in the Dokhan volcanics (Hegazi A. et al 1998). Galena is common sulphide mineral in the wadi Ghorabi-El Hatemeia area form massive bodies in the Dokhan volcanic rocks. Chalcopyrite minerals Fig. (2E) occur associated with sphalerite in which partially altered at the grain boundaries to chalcocite and covellite. The gossans alteration zone at Wadi Ghorabi-El Hatemeia represented by fracture filling deposits cutting in the Dokhan volcanics.

4- Wadi Khashm El Fahk mineralization area:- the mineralization at Wadi Khashm El Fakh represent by three alteration zone mainly along shear zones Fig. (2D), trending NW-SE and dipping 80° to the NE. The mineralization characterized by bright green and red color due to the oxidation of the sulphide minerals

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forming malachite and iron oxide. The alteration process is representing by kaolinitization, carbonitiztion, chloritization and sericitization. The sulphide mineralizations of Wadi Khashm El Fakh contain sphalerite, galena and littlie chalcopyrite. Sphalerite is the most widespread mineral and represent by massive bodies in the shallow shafts at Wadi Khashm El Fakh, galena is usually occur as fracture- filling and isolated fine to medium grained anhedral, which occasionally contain inclusion of chalcopyrite. Chalcopyrite is the least widespread mineral occur as coarse anhedral grains and partially altered at the

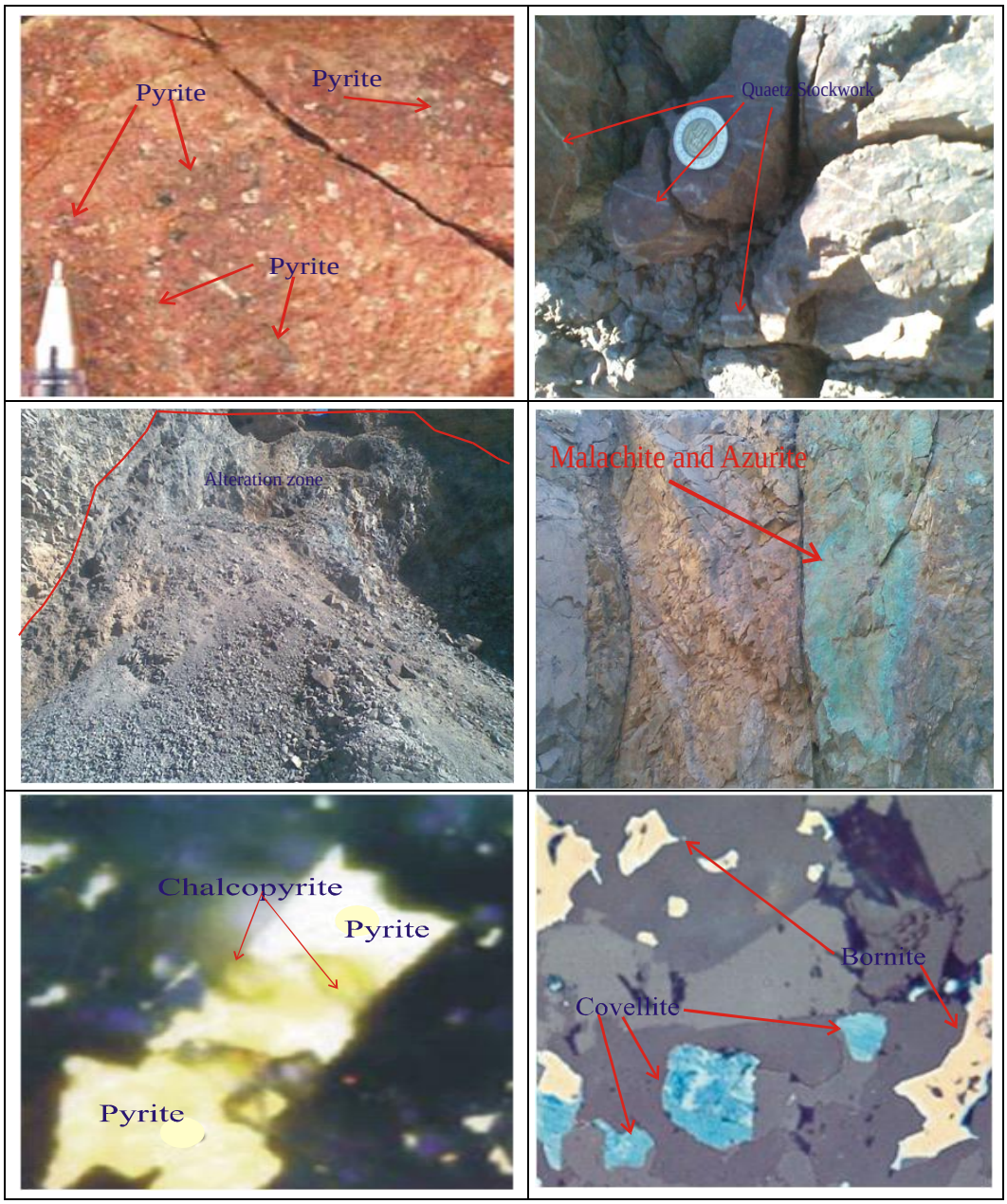

Fig. (2) *A. disseminated pyrite in rhyolite sheets B- Stockwork quartz wadi Samra, C. alteration zone Wadi Ghorabi-El Hatemeia, D. Copper mineralization along shear zones Wadi Khashm El Fahh, E. Chalcopyrite grain corroded the pyrite in alteration zone Wadi Ghorabi-El Hatemeia old copper mine, F. Bornite and covellite wadi Tarr mineralization zone.*

grain boundaries to chalcocite and covellite. The alteration zones at Wadi Khashm El Fakh occur mainly in the Beda turbidities which composed of slat and greywacke (Fowler A. et al. 2010).

5- Wadi Tarr mineralization The mineralizations are more or less linear in shape gossans extends in NE-SW direction for several hundreds of meters length and width. The gossans bodies vary in character from strongly massive hematite to merely iron-stained rocks associated with copper carbonate staining. silicification of the volcanic rocks especially the dacitic verities is frequently observed. The linear shape of the mineralized body and its strike parallel to the foliation suggest the influence of structural elements on controlling its localization. The sulphide minerals identified in the volcanic rocks of the Wadi Tarr mineralized zone are chalcopyrite, chalcocite, covellite, bornite Fig. (2F), galena and sphalerite.

6. GEOCHEMISTRY

The correlation of gold with copper, zinc and silver show positive correlation but it show negative correlation with lead Fig. (3).

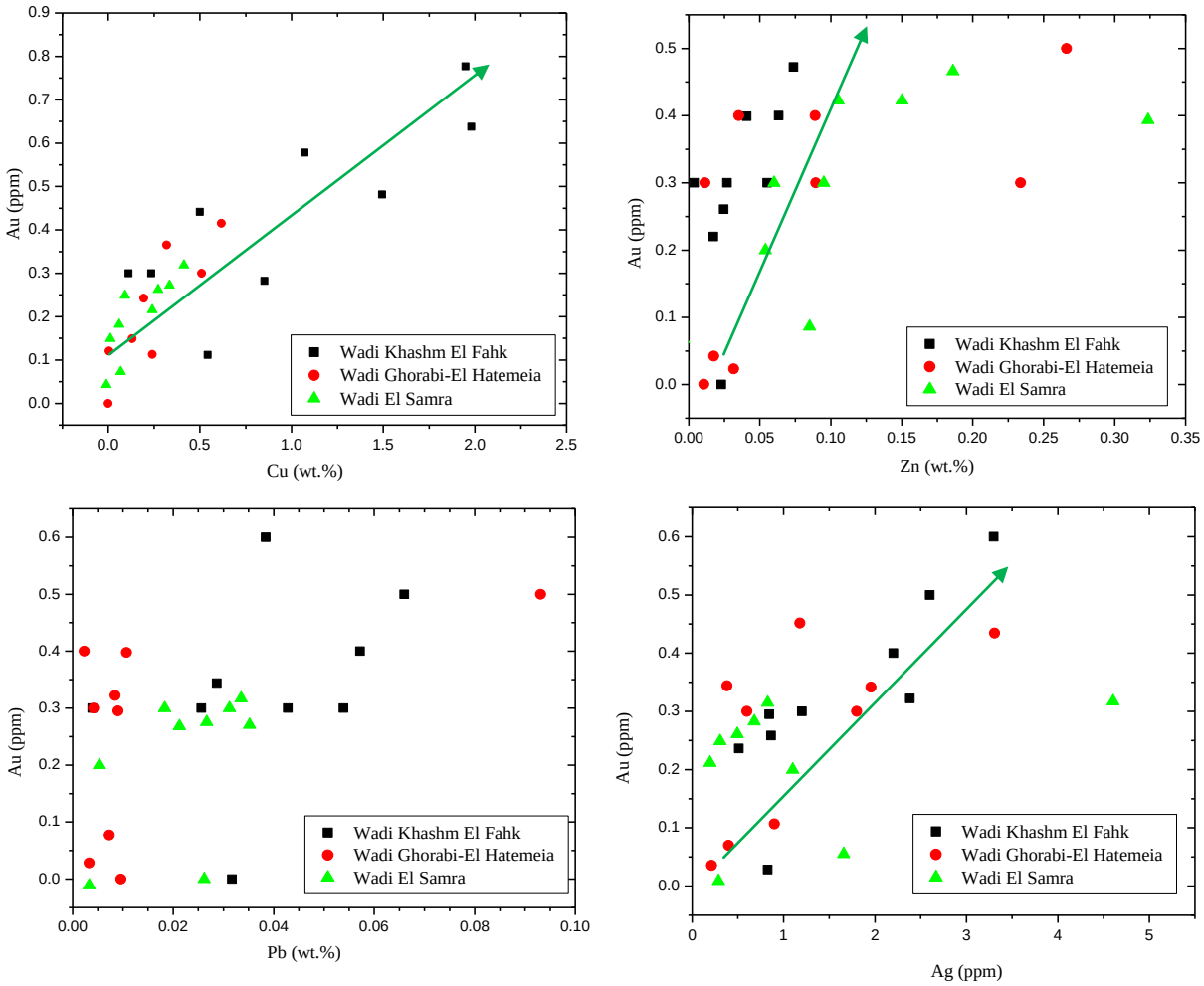

Fig. (3). *Correlation of Au with Cu, Zn, Pb and Ag*

The average Cu (wt. %) /Au (ppm) of the mineralization in Wadi El Samra area about 0.38 (table 1) and fill in the porphyry type mineralization (Sillitoe 1997). The copper (wt.%) / gold (ppm) of the

mineralization from Wades Ghorabi-El Hatemeia and Khashm El Fahk_areas has an average Cu/Au ratio of 1.3 this value characterized to the epithermal type mineralization Kalin Kouzmanov et al. (2009).
Hedenquist et al. (2000) and Sillitoe and Hedenquist (2003) classified gold vein deposits into two types, Au-rich and Ag-rich. The former is characterized by low Ag/Au ratio (about 1/10 to 10/1) and trace amount of base metals, whereas the latter is characterized by high Ag/Au ratio (>40/1), commonly with appreciable quantities of Zn and Pb. The Wadi Ghorabi-El Hatemeia and Wadi Khashm El Fahk belongs to Au-rich style of epithermal gold deposit in which the Ag/Au ratio less than 10/1.
The triangular plot of the base metal (Cu+Zn+Pb)-gold-silver diagram modified after (Poulsen et al. 2000) of the ore mineralization from El Samra area located in the field of porphyry and epithermal deposits Fig. (4).

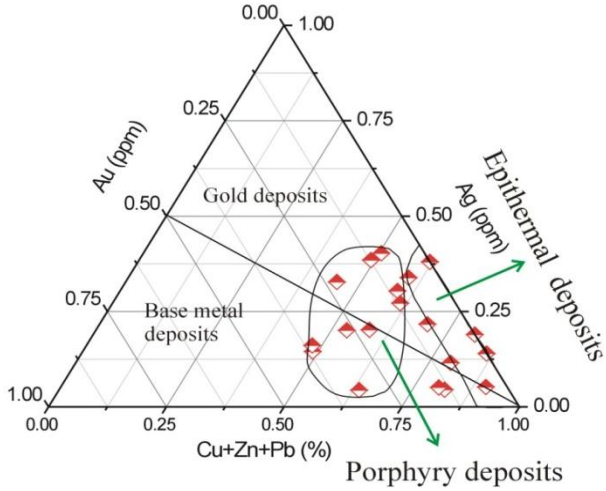

Fig. (4). *Base metal (Cu+Zn+Pb)-gold-silver diagram modified after (Poulsen et al. 2000)*

Furthermore, most of the porphyry copper -gold deposits of Wadi El Samra region mostly plot within the field of Au-rich porphyry copper deposits (porphyry PCD-Au) and very little amount in the PCD-Mo (the gold-poor porphyry) Fig. (3) as defined by Cox and Singer's diagram (1988).

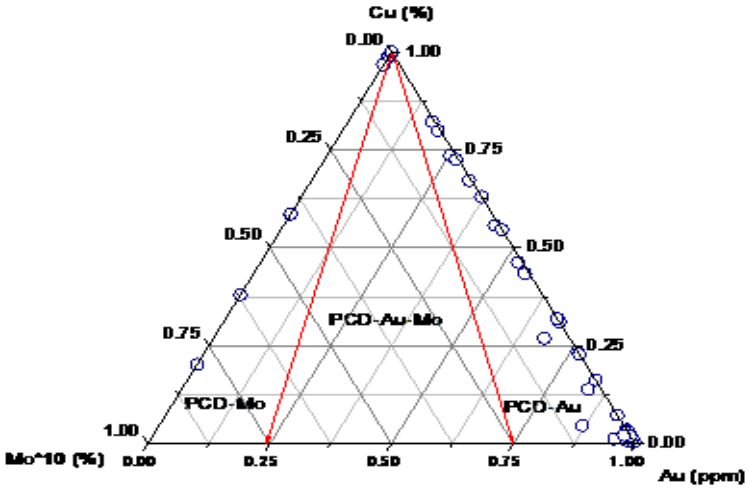

Fig. (5). *Cu (%)-Mo*10 (%)-Au (ppm) diagram of Cox and Singer's diagram (1988).*

Table1. Atomic Absorption analysis of sample from El Samra area southeastern Sinai

Location	samples	Cu	Au	Ag	Mo	Zn	Pb	Ag/Au	Cu/Au
Wadi El Fakh Khasham	1A	1110	0.3	0.4	0	36.7	39.1	1.333333	3700
	2A	8720	0.3	1.2	13.9	234	428	4	29066.67
	3A	3860	0.3	0.6	6.7	270	256	2	12866.67
	4A	2340	0.3	0.8	5.4	182	266	2.666667	7800
	5A	4973	0	0.9	8.7	229	317	0	-
	6A	16140	0.6	3.3	9	498	384	5.5	26900
	7A	10400	0.5	2.6	7.2	526	660	5.2	20800
	8A	16300	0.4	2.2	10.4	634	572	5.5	40750
	9A	14280	0.3	2.7	8.9	553	539	9	47600
Wadi El Hatemeia Ghorabi	21A	4820	0.4	3.6	0	352	45.5	9	12050
	22A	1582	0.4	0.2	30.8	890	22.9	0.5	3955
	23A	2240	0	1	7.7	0	96.2	0	-
	24A	5094	0.3	2.4	0	2338	41.7	8	16980
	25A	37.1	0.3	1.8	11.6	895	52	6	123.6667
	26A	68	0.3	0.6	0	113.4	33.6	2	226.6667
	27A	97	0.5	0	0	2661	931	0	194
Wadi El Samra	28A	67	0.3	0.4	3.8	951	327	1.333333	2966.667
	29A	106	0.2	1.1	19.7	540	53.4	5.5	1660
	30A	890	0.3	0	0	2616	312	0	4500
	31A	498	0.3	0.6	10	1578	183	2	4700
	32A	1350	0.3	0	0	1941	201	0	8753.333
	33A	1410	0.3	0	0	1023	326	0	-
	34A	2626	0.3	6	5.4	600	257.6	20	-
	35A	1795	0	2	1.8	1188	262	0	2966.667

The Au–Cu correlation is very strong, probably resulted from superposition of gold on copper mineralization and the occurrence of gold in pyrite–chalcopyrite intergrowths. Kesler et al., (2002) indicated that gold in porphyry copper deposits commonly is carried by bornite and chalcopyrite where they are sufficiently abundant. In deposits that contain abundant bornite, it is the preferred host for gold. Where bornite is rare or absent in the early alteration and mineralization stage, gold is associated with chalcopyrite Perrello J.A.,et al., (1996), Rebagliati C.M., et. al., (1995)- Ulrich T., et. al., (2002). In porphyry copper deposits, gold is found mainly as native grains in the form of inclusions in Cu-Fe-S sulfides, but more commonly it is found along their grain margins.

The experimental data have indicated that bornite and chalcopyrite in many porphyry copper deposits are saturated with gold between about 700 and 400°C Kesler et al (2002) and Sillitoe R.H. (1997). Since this temperature range is considerably higher than those at which porphyry copper deposits commonly form, many of the above mentioned researchers believed that gold originally have been deposited as solid solution in Cu-Fe-S sulfides when the porphyry copper deposits formed at high-temperature (700-600°C), and then exsolved to concentrate along sulfide grain boundaries at the temperatures typical of ore deposition (400-250°C). The extent of such solid solution can be evaluated with recent experimental data on the solubility of gold in high-temperature phases in the Cu-Fe-S systems, especially in bornite rather than chalcopyrite Sillitoe R.H. (1997). Kesler et al (2002) noted that if ore-forming fluids starts

deposition at 700°C, the gold saturated Cu-Fe-S sulfides will contain 800 ppm gold. This will decrease to 200 ppm at 600°C.They believed that this decrease in temperature of about 100°C could release almost 75% of the gold in the Cu-Fe-S sulfides. Also, they indicated that if ore deposition started at 600°C with bornite-chalcopyrite assemblage to form chalcopyrite-bornite-pyrite at lower temperature alteration-mineralization stage (400-200°C), this drop in temperature could release only 200 ppm gold from Cu-Fe-S sulfide solid solution. These relations not only indicate that the Au-content in high-temperature ore-forming fluids will be more due to higher solubility of gold but also suggest that Au is exsolved from Cu-Fe-S sulfides during the cooling of deposits.

Therefore, it seems the high content of gold in the El Samra porphyry copper deposits can be the result of the originally Au-rich hydrothermal fluids due to their high temperature which let high gold to enter the structure of the early formed Cu-Fe-S sulfides (chalcopyrite). The high temperature of the early ore-forming fluids for the El Samra porphyry copper deposits can be confirmed by the high content of higher and moderate temperature Cu-Fe-S sulfides such as bornite and chalcopyrite.

The ratios of Ag/Au are important in determining the type of dominant metal complexing and the expected metallogenic nature of the epithermal system (Cole & Drummond 1986). The Au (HS)–2 bisulfide complexes are very important for gold transportation in the epithermal environment (Benning and Seward 1996; Seward & Barnes 1997). Thus, systems with Ag/Au ratios less or equal to 1 tend to be dominated by native gold and electrum, sulfide complexing of Au and show homogenization temperatures are less than 250°C is dominant (Pirajno 1995). Systems showing Ag/Au ratios greater than 1 (as is the case for Wadi Ghorabi-El Hatemeia and Wadi Khashm El Fahk), are characterized by base-metal sulfides and sulfosalts and electrum, with minor Au. In such cases chloride complexing is dominant and temperatures of homogenization are greater than 250°C (Pirajno 1995).

The relation between Cu/Au ratio and formation depth of El Samra porphyry-style Cu– Au deposits.

Defining an primarily subdivision at a molar Cu/Au ratio of 4 ×104, copper-gold deposits have a shallower average depth of formation (2.1 km) compared with the average depth of copper-molybdenum deposits (3.7 km), based on assumed lithostatic fluid pressure from microthermometry (Hiroyasu Murakami et al. 2010). By comparison with published experimental data of Hiroyasu Murakami et al. (2010), the observed correlation of the Cu/Au ratio of the porphyry copper-gold mineralization in Wadi El Samra formed at relatively shallow depth (approximately <3 km), in which the Cu/Au ratio average 0.39. Under these conations the solubility of both metals decreases rapidly with decreasing density of the ascending vapor plume, forcing both Cu and Au to be coprecipitated. In contrast, magmatic vapor cooling at deeper levels (approximately >3 km) and greater confining pressure is likely to precipitate copper ±molybdenum only, while sulfur-complexed gold remains dissolved in the relatively dense vapor. Upon cooling, this vapor may ultimately contract to a low-salinity epithermal liquid, which can contribute to the formation of epithermal gold deposits above the Au-poor porphyry Cu-(Mo) deposit. Low-pressure brine + vapor systems are favorable for coprecipitation of both metals, leading to Au-rich porphyry-copper-gold deposits. Epithermal gold deposits may be associated with such shallow systems, but are likely to derive their ore-forming components from a deeper source, which may include a deeply hidden porphyry-copper ±molybdenum deposit (Hiroyasu Murakami et al.2010).

7. Conclusion

The copper-gold-sulphide mineralizations are widely distributed in Dokhan volcanic and Hammamat sediments (Elkhan A. Mamedov and Faissal A. Ali 2010). The dominance of the porphyritic calc-

alkaline granitic rocks and their surface expression (Dokhan volcanic-Hammamat sediments Botros (2004, 2002) formed along active continental margins represent one of the lithological environments for copper-gold mineralization.

Based on their common geological setting, the ore-mineralogy and paragenesis, as well as their geochemical character, where their close association of this mineralization with porphyritic rocks, the explosive brecciation, quartz Stockwork, the disseminated nature of much of the mineralization, some of the hydrothermal type alteration, all suggest that this mineralization show many similarities with both porphyry copper-gold and epithermal vein type deposits.

At Wadi El Samra the mineralization represented by sulphide disseminated in rhyolite sheet, copper and sulphide mineralization in quartz Stockwork, The copper-gold ores exhibit Cu/Au atomic ratios of the mineralization in Wadi El Samra area about 0.38, which signifies them as gold-rich porphyry copper deposits. The gold-rich signature of Wadi El Samra deposits complies with features such as higher contents of chalcopyrite and bornite in the hypogene ores, reflect rather high temperature (more than 600°C) of the primary ore-forming fluids involved in the formation of the porphyry copper-gold deposits, and it formed at relatively shallow depth (approximately <3 km).

At Wadis Ghorabi-El Hatemeia, Khashm El Fakh and Tarr, the mineralization represented by large alteration zones of copper mineralization, alteration zones mainly along shear zones and copper-sulphide gossans. The mineralization has an average Cu/Au ratio of 1.3 and Ag/Au ratio less than 10/1 ratio these values characterized to the epithermal type mineralization and temperatures of homogenization are greater than 250°C.

It is clear that copper-gold-sulphide deposits in area are Non-stratabound deposits were formed during the Pan-African orogeny and post cratonization period. They are housed in different lithologies in the study area. During the orogenic stage (Pan-African orogeny) a pronounced phase of cal-alkaline magmatic activity, represented by the emplacement of G-2 and G-3 granites (Hussein et al., 1982) and the eruption of their volcanic equivalents (Dokhan volcanics) took place (El Gaby et al., 1988, 1990). The eruption of Dokhan volcanic leads to the formation of early massive pyrite ores towards the end of the dacite volcanism. It was suggested that magma forming the granite porphyry at El Samar area provided both heat and chemical constituents including copper, potassium, and gold (Botros and Wetait, 1997, Botros 1991) form the copper-gold porphyry. When the magmatic hydrothermal solutions mixed with the convection meteoric solutions, the manifestation of the epithermal stage in the evolution of the porphyry copper system began. This model is similar to that commonly put forward for the development of porphyry copper deposits.

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