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Geochemical Zonal Distribution Of Gold And Associating Elements At Site (S.Ii), Marahiq Gold Mineralization, Wadi Allaqi District, Southern Eastern Desert, Egypt

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ABSTRACT

Marahiq gold mineralization comprising three sites , S I,S II,S III, existing within Wadi Allaqi district Southern Eastern Desert of Egypt is hosted by Pan-African island-arc meta-volcanic, meta-andesite and meta-basalt. Systematic sampling for quartz veins, surrounding alteration zones and host rocks was carried out at surface level, along four successive profiles perpendicular to the strike of site (S.II) quartz veins. The samples were chemically analyzed for Au, Ag, As, Co, Cu, Pb and Zn..Egypt curves, statistical parameters, Clark of Concentration, linear productivity zonation index and zoning coefficient were used to investigate lateral zonal distribution of the gold and associated metals. The recorded ore minerals are magnetite, specular hematite, gold, cobaltite; chalcopyrite and pyrite follow two phases of mineralization. Covellite, goethite and hematite are secondary minerals. The recorded geochemical association is Ag, As, Co, Cu, Pb, Zn. The recorded lateral zoning sequence of deposition along the NW- SE extension of the quartz veins is[Ag--Pb--Zn--Au--As--Cu--Co],while that along the SW to NE trend crossing the quartz veins is As ,Co ,Cu ,Au ,Zn ,Pb, Ag. The difference in position of the elements in both sequences reflects two elevation levels of sampling of the gold mineralization area related to the erosional section. The obtained averaging regression lines of (υ) values favor the following: 1- Presence of high gold content in association with abnormal Co, Cu, As contents in the higher elevation surface level at the northwestern part of P I and P II. 2- Presence of Au, Ag, Pb, Zn low contents in the lower elevation surface level at the southeastern part of P III and P IV. Consequently, the SE part of the S II mineralization, where Au accumulationat deeper level from the surface is expected could be recommended for detailed drilling.

General Terms
Geologic setting, Ore Minerls, Geochemical zonation

Keywords
Gold Marahiq, Egypt, zoning sequence and accumulationlevel

1. INTRODUCTION

WadiAllaqi region lies at about 200 Km southeast of Aswan city, between latitudes 22° and 23° N, and longitudes 33° and 34° 30\ E in the Southern Eastern Desert of Egypt. The region is characterized by discrete occurrence of more than 16 gold deposits genetically related with the ophiolitic and island arc tectonic events (Hassaan and El Mezayen, 1995 and Hassaan and El Sawy 2009). The NE-trending WadiMarahiq which is hosting three sites ,SI,SII, SIII of gold bearing quartz veins is located at the central part of WadiAllaqi district between latitudes 22º 27\ & 22º 32\ N and longitudes 33º 25\ & 33º 31\ E (Fig. 1). Two of the Marahiq gold mineralization sites(SI,SΠ) lie at intersection of latitude 22° 30\ 52\\ N and longitude 33° 28\ 14\\ E. The Marahiq area is occupied by Pan-African belong to ophiolite, island and cordilleran-extension stagesHassaan and El Mezayen(1995) and Hassaan (2007, 2011) considered the gold mineralization in the Eastern Desert of Egypt genetically related to three tectonic groups viz; ophiolitic, island arc and cordilleran- extensional. During the ophiolitic tectonic event the oceanic ultramafics anomalous with Au were formed in back-arc basin environment followed by serpentinitization in low grade metamorphism and metasomatism. These processes led to remobilization of Au and other metals, formation of lisweanites and concentration of gold, Cr, Co,As, Ni, Cu in the metasomatic hydrothermal liquidforming the quartz veins. In the island arc tectonic event the differentiated magma produced calc-alkaline plutonic and volcanic rock units enriched with sulphide minerals.These rocks affected by regional metamorphism that caused deformation, metasomatism remobilization, concentration and redeposition of As,Co,Cu, Pb and Fe sulphides within Au and Ag bearing quartz veins and associated alteration zones

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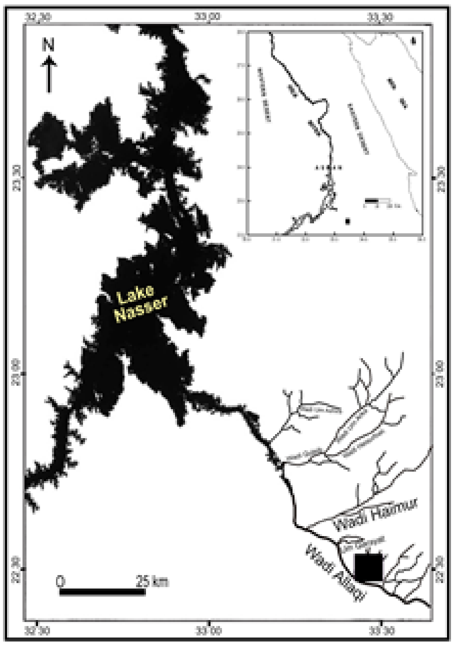

Fig. 1: Location Map

hosted in these rock units. Hassaan and El-Sawy (2009) and Hassaan (2011) discussing role of tectonic environments controlling distribution of gold mineralizations mapped 16 localities of gold bearing quartz-veins and associated alteration zones within the ophiolitenappes, island arc volcanic rocks and related rocks in the Allaqi-Heiani, Onib-Sol Hamed belts. The gold-bearing veins are controlled by foliation and shear planes that are overprinted by regional D2 and D3 thrust structures. Several of these gold-bearing quartz veins along the Allaqi–Heiani belt are confined to discrete brittle–ductile shear zones formed related to a late transpressive shearing events (e.g., El-Shimi, 1996; El Kazzaz, 1996a; Kusky and Ramadan, 2002; Zoheir, 2008a, b).El Shimi et al. (1996) stated that, WadiAllaqi gold mineralization occurs commonly in planner brittle-ductile shear zones extending NW-SE and steeply dipping to NE direction. The gold mineralization was derived from metamorphic fluids created by dehydration and decarbonatization of ophioliticmelange assemblage located between the two accreted island-arc belts in the area during regional metamorphism. These fluids were able to leach and form complexes with the accessible gold from its source rocks of the ophioliticmelange assemblage. These auriferous fluids tend to migrate from its high pressure source zones to low pressure host zones in the island arc belts depositing their lodes in structural traps of dilational sites along brittle-ductile shear zones in the hinge zones of first generation (F1) antiformal structures. However, El Shimi et al (op.cite) mentioned following Hassaan and El Mezayen (1995) the spatial and genetic relationship between the granitoids intruding the metamorphosed ophiolitic-island arc rocks and WadiAllaqi gold mineralization.El-Kazzaz (1996a) suggested metasomatic rather than epithermal fluids favored for the origin of gold deposits of central WadiAllaqi during the earliest tectonic deformation phase (D1) of the Pan-African orogeny. The mineralized veins and associated alteration zones were formed from the mineralizing fluids released during deformation and metamorphism along fractures in brittle-ductile shear zones.Kusky and Ramadan (2002) assumed that gold–bearing quartz veins of WadiAllaqi region are generally structurally controlled and are genetically related to the alteration of the ultramafic rocks associated with imbricate thrust faults, or to shear zones truncating the thrusted slices. The SII gold mineralization is hosted by meta-andesites and metabasalts.(Hassaan et al,1997).Abdel Rahman et al (1999) and Fawzi et al (1999) studied the geologic setting, magma type and tectonic settings of the rock units exposed in WadiMarahiq as well as the geochemical zonal distribution of ore metals in SI of Marahiq mineralization. The obtained results favored studying the gold distribution in the area of site (S.II) quartz veins in detail by investigating the lateral geochemical zonal distribution of the ore metals in site (S.II) area of the Marahiq gold mineralization. In this respect, the extent and variation in distribution of various elements along the (NW-SE) extension of the quartz veins and (NE-SW) perpendicular direction to the extension of the quartz veins will be undertaken in detail to reveal probable accumulations of gold at deeper levels by calculating the ratios between linear productivity of gold and its associated elements.

1.1 Methodology

A total of 48 samples were collected from 4 profile perpendicular to extension of the quartz veins at site (S.II). Forty representative samples were chemically analyzed to determine Au, Ag, As, Cu, Co, Cr, Ni, Pb, Zn concentrations (11 quartz vein samples, 21 alteration zone samples and 8 host rock samples). These samples were collected from the surface level (Fig.2). Chemical analyses were carried out using the atomic absorption spectrophotometer, modal (GBC-932 AAS) at the laboratories of Nuclear Materials Authority, Cairo, Egypt.The SII gold geochemical distribution curves of the ore metals along profiles will be drawn to show probable existence of geochemical zonation. Moreover, linear productivity, contrast coefficient, geochemical zonality index and zoning coefficient will be calculated to reveal such geochemical association of gold and their lateral zonal distribution to define the level of gold accumulation within site (S.II).The geochemical zoning controlling distribution of ore metals is used to solve different geological problems related to genesis, level of the erosional section and paragenetic sequence of minerals of the ore-body (Kviatkoviscky, 1977 after Hassaan, 1977; Hassaan et al. 1991; Hassaan, 2007, 2011). In geochemical exploration, the most reliable criteria of the supra-ore halos, the linear productivity (M) is calculated as the amount of chemical element in excess of the background value, along particular cross section to represent the geochemical anomaly using the following equation:

M = $\Delta X(\sum C_{i,n} - C_b)$ …………………………….... (1)

where ΔX is the sampling interval along the profile, n is number of samples on the profile, Ci is the element content in the analyzed samples and Cb is the geochemical background of element.

The contrast coefficient is laterally determined by using formula (2).

Contrast Coefficient = Content of the element in the northern start point / Content of the element in the southern end point …………………………………(2)

The elements are to be arranged in decreasing order of their contrast coefficient values. The resulting sequence will illustrate the geochemical zonation of the elements. Zonality index of an indicator (pathfinder) element is defined as the ratio of linear productivity of a given element in the studied mineralization to the sum of linear productivities of all pathfinder elements in each lateral profile expressed by formula (3).

Zonality index = $M/(\sum M_{i,2\,n})$ …………………… (3)

The geochemical zoning coefficient (□) as given in Hassaan (1977) and Hassaan et al (1991) manifests the difference in the concentration (Ci) or productivity (Mi1,2) of each of the trace pathfinder elements to those of the main ore element or the most inert element (C1 or M1) at different distances from the center or periphery of the ore body calculated by using the following equation:

$\nu = Ci_{1,2}/nC_1$ or $Mi_{1,2}\ldots n/M_1$…………………… (4)

Where $Mi_{1,2}\ldots n$ is the linear productivity for each of the associated elements and M_1 is the productivity for the main element. If the zoning coefficient values drop with depth, this means that the element in the numerator has been deposited in upper level or later than that in the denominator. On contrast, if the values increase with depth, the element in the numerator has been deposited in deeper level than that in the denominator.In the present study, zoning coefficient values were obtained along lateral profiles, by calculating the ratio values between linear productivity of gold and each of associated elements. The erosional level of accumulation of chief ore metal of a deposit and expected depth of the deposit can be provided according to Hassaan (1977) by geochemical zoning indices of any ore occurrence.

2. GEOLOGIC SETTING

The Neoproterozoic rocks covering theWadiAllaqi region include a mafic-ultramafic ophiolitic assemblage, at least two volcanosedimentary-plutonic island-arc assemblages and late- to post-tectonic granitic intrusions (Kroner et al., 1987; Berhe, 1990; Taylor et al., 1993; Greiling et al., 1994, Abdel Salam and Stern, 1996 and Abdel Rahman et al., 1999 and Hassaan, 2011). These rock units were deformed and

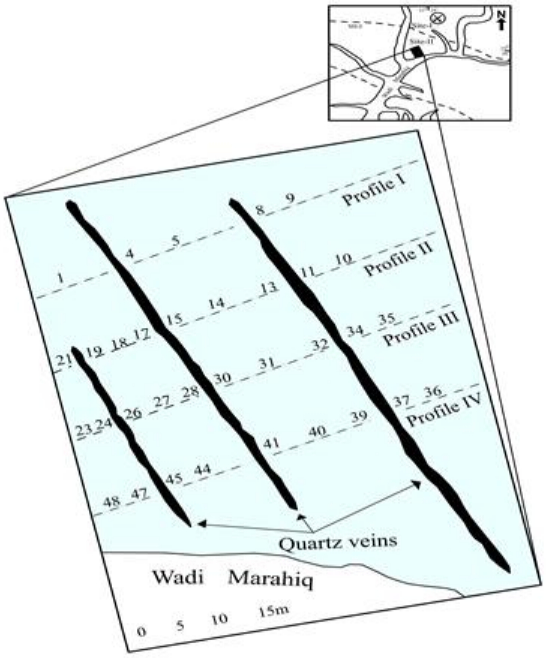

Fig. 2: Sampled Profiles

metamorphosed to the green-schist facies during the Pan-African orogeny, probably dating from 750 Ma to 650 Ma (El Kazzaz, 1996b).Several authors have studied the tectonic setting of WadiAllaqi region. The most recent is that given by Greiling et al. (1994) refering to WadiAllqi as a suture-zone between Aswan and Gabgabaterranes. The geologic setting of WadiMarahiq area was studied by Hassaan et al. (1997); Abdel Rahman et al. (1999) and Emam et al. (2014). In Marahiq area, the exposed rock units are ophiolitic and island arc rocks, intruded by cordilleran quartz-diorites and invaded by basic to acidic dykes as well as quartz veins (Fig. 2). The ophiolite assemblage comprises serpentinites and their related talc-carbonate rocks that represent the oldest rock units. They form small, curved and stretched lensoidal bodies highly sheared altered to talc and talc carbonate rocks as huge elongated masses along NW-trending shear zone in the eastern part of the mapped area. They tectonically interlacing the sheared metavolcanics and the metavolcano-sedimentary rocks, exhibiting sharp structural contact. The Island arc assemblage comprises metavolcanosedimentary and varieties of metavolcanics chiefly metabasalt and meta-andesite highly sheared and exhibit NW foliations. The basic to intermediate dykes and quartz veins are cutting these talc-carbonates in the eastern side of the Marahiq area. The quartz diorite is intruding the metavolcanicrocks in the north eastern part of the maped area. Two NW-SE and NE-SW fault systems traverse these rock units exposed in Marahiq area. The rock units exhibit well foliation with foliation planes mainly trending in the NW-SE. Two main shear zones (SH-I & SH-II) traversing the area were recodedtrending NW-SE, parallel to one another and parallel to the WadiAllaqi trend (See Hassaan et al. 1997, Emam,2014). The two shear zones are expressed by high shearings exhibiting NW foliation planes (Fig.3).

quartz veins, allotriomorphic fine-grained crystalline aggregates within needle-like specularite

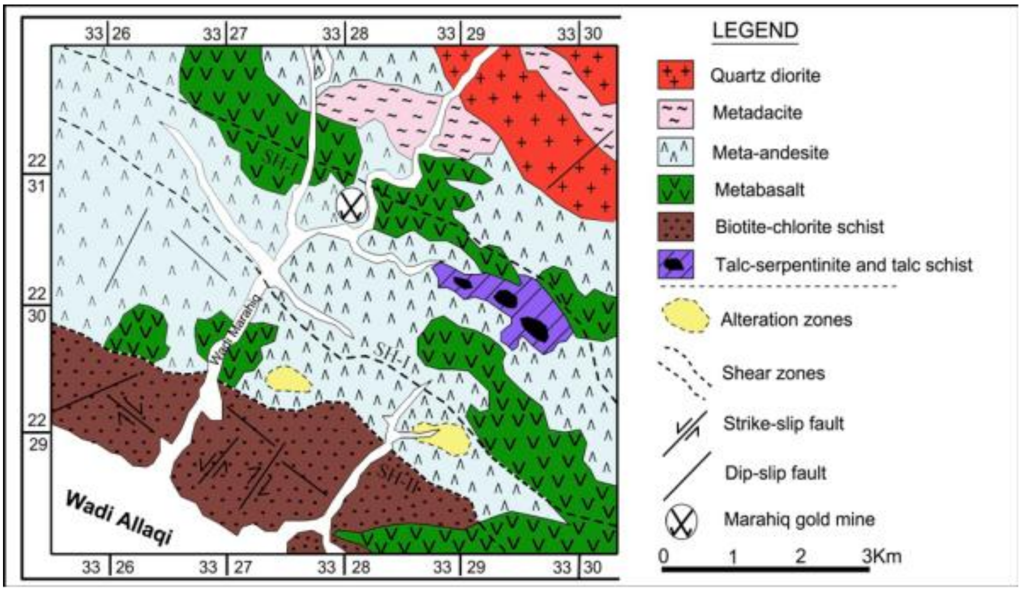

Fig. 3. Geological Map of Marahiq Area

crystals and occurring as botryoids within the secondary hematite distributed and oriented in a certain mostly shearing trend(Figs 4 A,B). Gold is also recorded within the pyrite cubes in the host metavolcanic rocks as well as fine disseminated grains and specks filling the microfractures and fissures. Pyrite occurs as fine crystals in the quartz veins and commonly as a very large number of perfect euhedral cubic crystals and phenocrysts, with axes nearly up to 1 cm in the alteration zones(Figs 4 D,F). These cubes preserve the original zoning of pyrite. In the alteration zones, gold occurs principally as fine disseminations and as fillings of the micro-fractures and fissures within the goethite cubes isomorphous after pyrite. Two cobaltite varieties coarse- and fine grained crystals are recorded in the quartz veins alteration zones and host rocks. The euhedral coarse grain cobaltite is abundant. Fine grained cobaltite forms numerous fine euhedral to subhedral prismatic crystal filling the micro- fracture in the host meta-volcanic rock. Chalcopyrite occurs mainly as fine euhedral, subhedral to anhedral crystals and fine specks filling cavites and fissures(Fig 4E). Presence of fine and coarse grained pyrite and cobaltite crystals indicates two phases of mineralization. The fine grained corroded and the highly deformed crystals represent following El- Mezayen et al (1995) the earlier (older phase) while the coarse crystals represent the younger phase. The older (earlier) phase was formed during early oxidizing metamorphic hydrothermal stage, at relatively high temperature (>200ºC) from polymetal-rich liquids forming the magnetite and specular hematite followed by progressive addition of

Three mineralized quartz veins trending NW-SE at site (S.II) exists in the central part of the area SW of site (S.I) within shear zone SHI. The three mineralized quartz veins are mainly milky. They are structurally controlled extending parallel to each other and parallel to the general (NW-SE) direction of the two fault systems and SHI. The first quartz vein (Q1) of thickness averaging about 2 m extends for about 200 m. It is striking N20□ W and dipping to the SW direction with dip angle about (45□). The second gold-bearing quartz vein (Q2) extends for 170 m with 1.5 m average thickness. It is striking N15□ W and dipping to the SW with dip angle of about (42□). The third quartz vein (Q3) is the smallest one where it extends 95 m with 1 m average thickness. It is striking N15□ W anddipping to the SW with dip angle of about (44□). These quartz veins show a vermiform and in some parts they form swarms. The wall rock alteration zones extend parallel to the quartz veins and have thickness, varying from 1 m to 3 malong each side of each vein.

3. ORE MINERALOGY

Magnetite, specularite, pyrite, cobaltite, chalcopyrite and covellite, primary ore minerals and malachite, goethite, hematite secondary minerals are recorded by using the ore microscope as well as SEM and EDEX (Figs. 4A-F) these minerals form the mineral assemblage of site II Marahiq gold mineralization. Gold occurs as native electrum, fine disseminations withinthe

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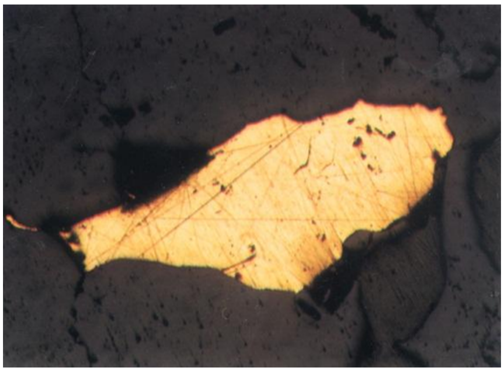
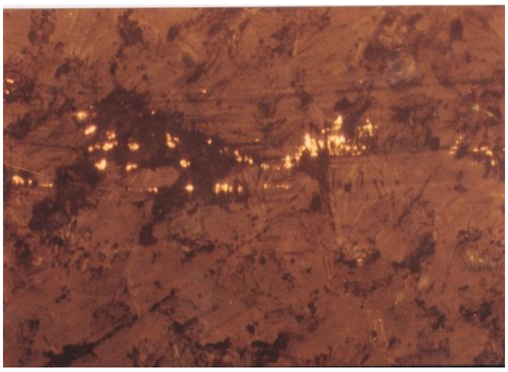
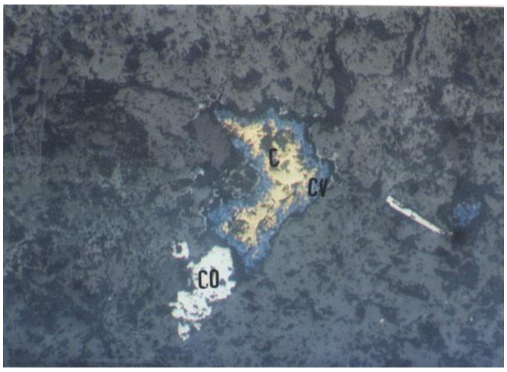


A

D



B



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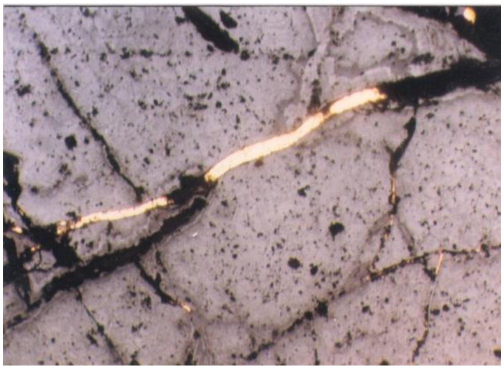
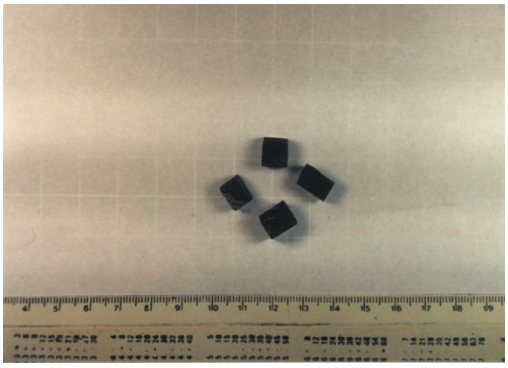


C



F

Fig.4 . Photomicrographs of quartz vein(A,B) and alteration zone(C) polished surfaces .

A. Coarse elongated gold grain.
B. Fine gold specks, disseminated and filling micro-fractures
C. Gold grains, disseminated and filling micro-fractures in goethite after pyrite.
E. Chalcopyrite (C) with covellite(CV) rim and fine cobaltite (CO) crystals filling cavities and micro- fractures.
D,F. Photographs of hand specimen showing cubes of goethite pseudomorph after pyrite.

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sulfur depositing fine pyrite and cobalite crystals. With decrease in temperature the other sulphide minerals.

4. GEOCHEMICAL RESULTS AND DISCUSSION

The results of analysis of 40 samples shown in table (1) will be used to achieve the aim of the study. The lithochemical distribution of the ore metals using the values of calculated statistical parameters (X, S.D, V.C., r) factor of Clark of concentration (CC) given in tables (2,3,4) for the host rocks in contact with the site II mineralization will discuss the mutual effect of the invaded gold- bearing quartz veins and the metabasalt -metandesite host rocks.

4.1.Distribution Characteristics of Metals in the Host Rocks

The metabasalt and meta-andesite hosting the three quartz veins show abnormal concentration of Co and Cu in the meta-andesite samples while As, Ag and Pb are concentrated in the metabasalt samples. This is indicated from the range, S.D and V.C values of each of these metals in both rock units (Tabl 2). The elements Au, Co, Cu, Pb and Zn show moderate ranges that reflected on the moderate values of S.D. and low values of V.C. The silver content shows narrow range and low values of S.D. and V.C., while arsenic content widely fluctuates and shows high S.D. value and very low V.C. values.The atomic absorption semi-quantitative analyses recorded extraordinary Au contents in these samples. However, the ore microscopic study recorded gold grains filling the microfractures and disseminated in both rock units. Therefore, gold is chemically inert elements will be considered the chief ore metal. Consequently the arrangement of the ore metals in decreasing order of CC values(Table 3) show the following geochemical spectra:

Metabasalt: Au-As, Ag, Pb.

Metandesite: Au-As, Ag, Co, Cu.

Moreover the expression of these CC values for both rock units in the formula [(A/B) C (D)] indicated the following geochemical spectra:

Metabasalt: **Au/As Ag, Co, Pb, {Cu, Co, Zn}**

Metandesite: **Au/As Ag, Co, Cu, Pb,{ Zn}**

These geochemical spectra point to arsenic as chief Au associating element in both rock units, while the associated elements are Ag and Pb in metabasalt and Ag, Co, Cu and Pb in meta-andesite. Copper Co, and Zn, show normal abundance in metabasalt and Zn in meta-andesite. The correlation coefficient values of gold and associated elements for the host rocks shown in table (4) record significant positive correlation ($r \geq 0.66$) for Ag with As and negative for As with Co.Meanwhile, Au shows r=0.6 pointing to significant correlation with Co.dueto the abnormal content of Co in only meta-andesite. This points to that gold within the host rock units exists as native gold disseminations & filling cavities and microfractures .Distribution Characteristics of Metals in the Concentration Patterns.

4.2.Statistical Parameters

The calculated statistical parameters (Tables 5& 6) for gold and other ore elements in the quartz veins and alteration zones illustrate several characteristics. The contents of As and Pb show wide range and vice versa for Ag. Moderate fluctuation of both Au and Co contents in quartz veins and alteration zones is noticed .Cu and Zn show moderate range in the quartz veins but wide range in the alteration zones. This is related to the variable degree of geochemical mobility of each The elements Au, Ag, Co, Cu and Zn show highest average contents in the alteration zones while Pb and As average contents are the highest in the quartz veins. Consequently, these elements form the gold geochemical association of Marahiq S.II mineralization. The recorded sulphide minerals are pyrite, cobaltite, chalcopyrite, covellite and gold, forming the ore mineral assemblage each member of which represents the proper mineral of each element and/or the existence of these elements in corporated with in the crystal lattices of these sulphide minerals.

4.3. The Clark of Concentration

The calculated CC values for gold and these associated elements in the quartz veins and alteration zones (Tables 7&8) show extraordinary high CC values of gold in both quartz veins and alteration zones. The elements Ag, As, Co and occasionally Cu, show high abnormal CC values for the alteration zones reveling to presence of anomalous concentration. Gold and other ore elements arranged in decreasing order of their CC values form the following geochemical spectra:

Quartz veins (Au-As, Ag, Co, Pb, Cu)

Alteration zones (Au-As, Ag, Co, Cu, Pb)

The expression of these geochemical spectra in the form of [(A/B) C (D)] formula is as follows:

Quartz veins Au/As Ag, Co, Pb, Cu, [Zn]

Alteration zones Au/As) Ag, Co, Cu, Pb, Zn

Consequently, the chief ore element associating Au in Marahiq S. II mineralization is As and Au Ag, Co, Cu, Pb are the associated elements while Zn shows normal concentration.

4.4. The correlation coefficient

The correlation coefficient values (r) for the elements (Table 9) show significant correlation of Ag with Au at p 0.01 and with pb at p 0.001 while Co shows significant correlation with Zn at p 0.05. This points to that metals forming the mineralization are Au, Ag, Pb, Co, Zn. Copper did not record correlation with either of these metals because of its mobility in the oxidation zone from which quartz vein samples were collected. The correlation coefficient (r) values for the elements in the alteration zones show significant and confident positive correlation of Co, Pb and Zn and negative correlation of Cu with Au. Zinc is correlated with Co at p 0.001 (r = 0.77) enhancing its existence incorporated at p 0.01 with Cobaltite. Meanwhile Ag is correlated at p 0.01 with Co pointing to its incorporation in cobaltite during alteration.

Consequently, gold in the chief ore element As the chief associated element and Ag, Co, Cu, Pb are the gold associated elements. It is obvious that the obtained geochemical spectra for the basic-intermediate host rocks, the quartz veins and the alteration zones are. However, copper due to its geochemical mobility is more abundant in the alteration zones than lead.

4.5.DistributionCurves Along profiles

The plotted distribution curves of the metals along the sampled profiles (PI- Plv) given in Figs $5_{a,b}$ and $6_{a,b}$ show the following characters :**a)** The plotted variation curves using both normal and lognormal scales for the element concentration show consistent distribution of Au, Ag , Co along the profiles PΠ, PШ and PIV only. These distribution curves ales point to the increased contents of these elements in the alteration zones compared to quartz veins due to over lapping of the hales of the mineralization bearing quartz veins **b)** The plotted curves using the lognormal scale clarify the moderate contrast increase of Cu and Zn contents compared to Au and Ag in the alteration zones within PΠ area and occasionally PШ area . The distribution of these elements expresses by both normal and longnormal scales reflect the mutual effect of elements concentration in each of the host rock types and the mineralization.

4.6. Geochemical Zonation

An approach to estimate probable existence of lateral zonation controlling distribution of ore metals in SII mineralization is undertaken by using the calculated linear / productivity of elements contrast coefficient and zonality index for each of the 4 profiles (Tables 11-14) .Arrangement of in decreasing order of the values of each of these parameters along NW-SE extension of the quartz veins is as follows:

NW-SE
Linear productivity (Ag, Pb, Zn)--(Au, As, Co, Cu)
Contrast coefficient Ag--Zn--Au--Cu--Co--As--Pb
Zonality index (Au, Co, Cu, Zn)--(Ag, Pb)--As

NE-SW
Linear productivity(Ag, Pb)--Zn--Cu--(Au, Co)-As)
Contrast coefficient Zn--Cu--Ag--Co--As--Au—PbZonality index (Ag, Pb)--(Co, Cu, Zn—Au-As

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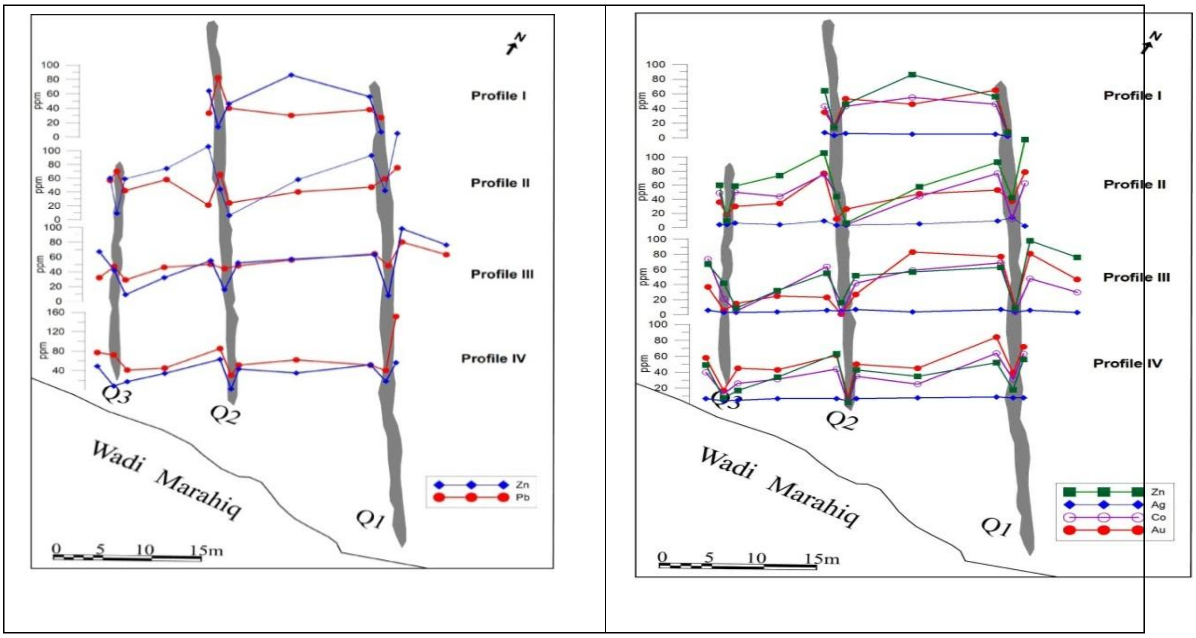

Fig. 5. Normal distribution curves of gold andassociated elements

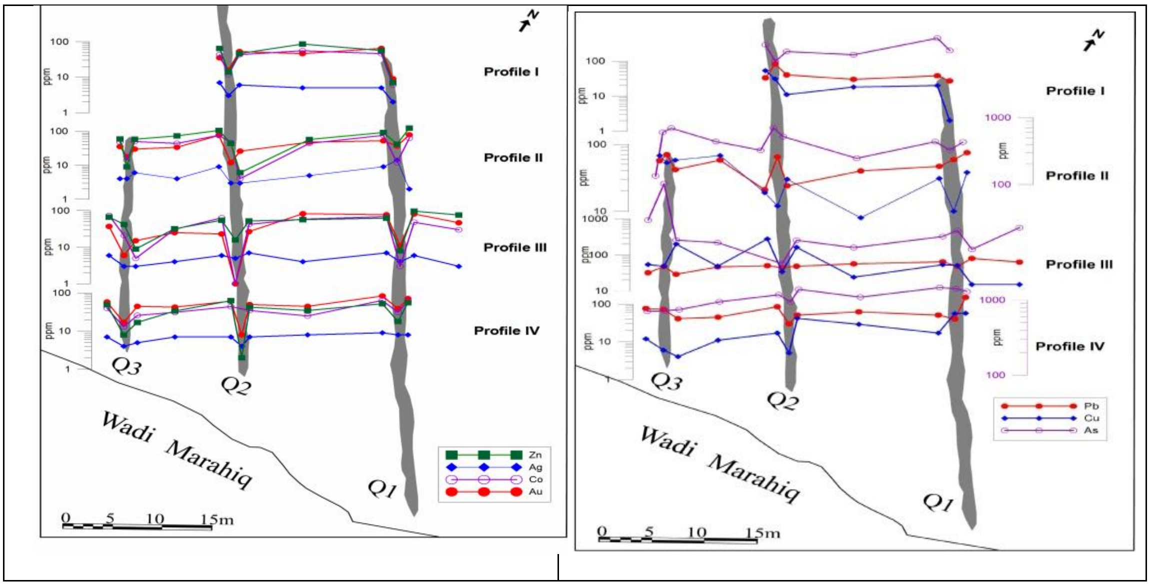

Fig. 6. Log - normal distribution curves of gold and associated elements

4.7. Lateral Geochemical Zoning

The calculated zoning coefficient values along the NW- SE (Table 15) and NE-SW (Table 16) profiles were plotted versus the lateral distance (Figs. 7,8). The arrangement of regression lines for these plotted values gives the following lateral zoning sequences:

NW Ag---Pb---Zn---Au---As---Cu---Co SE
SW AS---Au---Zn--Co---Cu--Pb—Ag NE

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The obtained, averaging regression lines of (υ) values favor presence of high gold content in association with abnormal Co, Cu, As contents in the higher elevation surface level at the northwestern part of P I and P II and low Au, Ag, Pb, Zn contents in the lower elevation surface level at the southeastern part of P III and P IV. Consequently, the SE part of the S II mineralization, where Au accumulation at deeper level from the surface is expected could be recommended for detailed drilling.

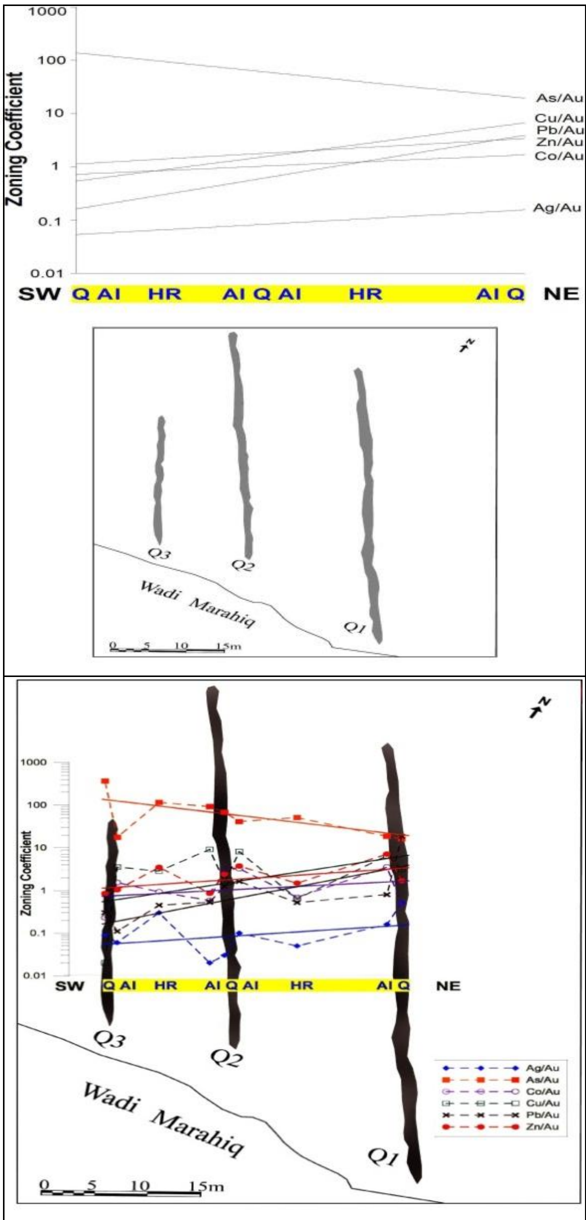

Fig. 7. Zoning coefficient values plotted VS. lateral distance from SW to NE.

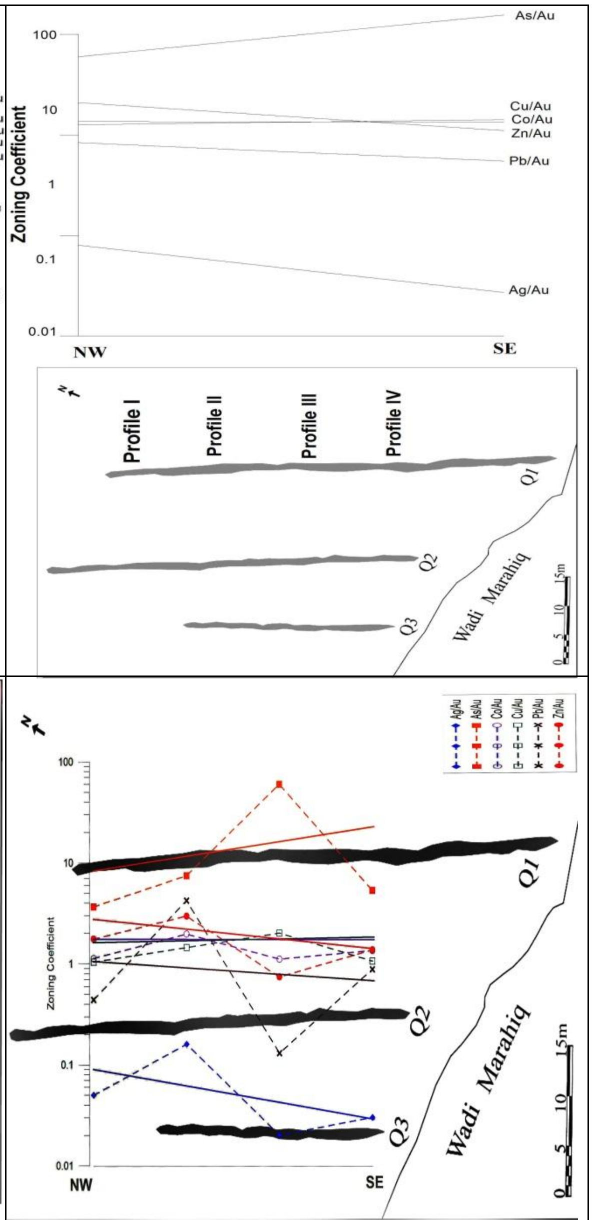

Fig.8. Zoning coefficient values plotted VS. lateral distance from NW to SE.

5. CONCLUSIONS

1- The S II of Marahiq gold mineralization is hosted in island arc meta-andesite and meta-basalt.

2- The primary ore minerals forming the mineralization are magnetite , specularite , gold ,fine and coarse pyrite , fine and coarse cobaltite , chalcopyrite. Covellite, goethite and hematite are oxidation products . Native gold occurs in the quartz veins and alteration zones and also occasionally incorporation mainly pyrite and other sulphide minerals while in the host rocks it is mainly native.

3- The ore elements Au, As, Ag, Co, Pb, Cu and Zn form the geochemical association of Marahiq site (S.II) gold mineralization.

4- The performed geochemical parameters for gold and associated elements illustrate two levels of Au accumulation.

5- The lateral zoning sequences along the extension of quartz veins (NW-SE) and across these veins (SW -NE) are:

NW Ag---Pb---Zn---Au---As---Cu---Co SE

SW As---Co---Cu---Au---Zn---Pb---Ag NE

6- The obtained, averaging regression lines of (υ) values favor the following: 1- Presence of high gold content in association with abnormal Co, Cu, As contents in the higher elevation surface level at the northwestern part of P I and P II. 2- Presence of Au, Ag, Pb, Zn low contents in the lower elevation surface level at the southeastern part of P III and P IV. Consequently, the SE part of the S II mineralization, where Au accumulation at deeper level from the surface is expected could be recommended for detailed drilling.

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Table (1): Contents in ppm of gold and associated elements in quartzveins, alteration zone and host rocks samples

Profile No.	Type	S. No.	Au	Ag	As	Co	Cu	Pb	Zn
SW	Al	2	35	7	289	43	53	33	64
	Q	3	16	3	97	12	31	82	14
PI	Al	4	53	6	188	43	11	40	46
	Mb	5	46	5	152	55	18	30	86
	Al	6	65	5	449	46	20	38	56
NE	Q	7	9	2	201	6	2	27	7
SW	Al	21	36	4	135	49	68	57	60
	Q	20	18	4	602	14	53	70	9
	Al	19	30	6	692	50	58	42	59
	Ma	18	34	4	440	44	68	58	74
	Al	17	77	9	326	76	19	21	106
PII	Q	16	12	3	701	47	12	65	44
	Al	15	26	3	521	4	30	24	6
	Mb	14	48	5	247	44	8	40	58
	Al	13	53	9	435	77	31	47	93
	Q	12	37	14	328	12	10	359	42
NE	Al	11	79	2	430	63	38	75	125
	Al	24	37	6	917	74	54	32	67
SW	Q	25	6	3	9302	21	48	47	42
	Al	26	15	3	255	5	199	29	9
	Ma	27	25	4	218	31	48	46	32
	Al	28	23	6	-	64	277	50	55
PIII	Q	29	1	5	57	1	34	44	16
	Al	30	27	7	253	42	161	48	52
	Mb	31	83	4	159	59	24	56	57
	Al	32	77	7	321	69	53	64	63
	Q	33	11	4	478	3	51	48	8
NE	Al	34	81	6	141	48	15	80	98
	Mb	35	47	3	564	30	15	63	76
SW	Al	47	72	8	1296	63	57	151	56
	Q	46	39	8	1415	31	56	40	18
	Al	45	84	9	1465	64	17	51	52
	Ma	44	45	8	1095	25	29	62	35
	Al	43	50	7	1392	35	42	51	43
PIV	Q	42	8	4	945	-	5	30	2
	Al	41	61	7	1175	44	17	85	63
	Mb	40	43	7	950	31	11	45	34
	Al	39	45	5	745	26	4	41	17
	Q	38	17	4	718	13	6	72	8
NE	Al	37	58	7	709	40	12	77	49

Q = quartz vein, Al = alteration zone, Mb = metabasalt, Ma = meta-andesite

Table (2): Statistical parameters for gold and associated elements in (8) host rock samples

Statistical Parameters	Au	Ag	As	Co	Cu	Pb	Zn
Max.	83	8	1095	59	68	63	86
Min.	25	3	152	25	8	30	32
Average	46	5	478	40	28	50	57
S. D.	16.8	1.7	366.7	12.6	20.6	11.7	21.1
V.C	0.36	0.34	0.77	0.32	0.75	0.23	0.37

Table (3): Clark of Concentration values for gold and associated elements in the host rock samples,

Rock type	S. No	Au	Ag	As	Co	Cu	Pb	Zn
Mb	5	11500	45	76	1.1	0.2	5	0.8
	14	12000	45	124	0.9	0.1	6.7	0.6
	31	20750	36	80	1.2	0.3	9.3	0.5
	35	11750	27	282	0.6	0.2	10.5	0.7
	40	10750	64	475	0.6	0.1	7.5	0.3
Ma	18	11250	73	782	25	5.8	5.2	0.3
	27	8500	36	314	44	13.6	4.8	0.6
	44	6250	36	156	31	9.6	3.8	0.2

Table (4): Correlation Coefficient Values between Goldand AssociatedElements in the Host Rocks

	Au	Ag	As	Co	Cu	Pb
Ag	-0.08					
As	-0.19	0.75				
Co	0.60	-0.38	-0.75			
Cu	-0.43	-0.25	-0.12	-0.03		
Pb	0.15	-0.07	0.46	-0.41	0.32	
Zn	0.18	-0.57	-0.49	0.58	-0.01	-0.15

No. of samples = 8, r =0.66 at P =0.05, r = 0.79 at P=0.01, = 0.89 at P = 0.001

Table (5): Statistical parameters for gold and associated elements in (11) quartz veinsamples

Statistical Para.	Au	Ag	As	Co	Cu	Pb	Zn
Max.	39	14	9302	47	56	359	44
Min.	1	2	57	1	2	27	2
Average	16	5	1349	16	28	80	19
S.D	12.1	3.4	2667.4	13.9	21.6	94.1	15.8
V.C	0.76	0.69	0.20	0.87	0.77	0.12	0.83

Table (6): Statistical parameters for gold and associated elements in (21) alteration zonesamples

Statistical Para.	Au	Ag	As	Co	Cu	Pb	Zn
Max.	84	9	1465	77	277	151	125
Min.	15	2	135	4	4	21	6
Average	52	6	607	49	59	54	59
S.D	21.6	2.0	429.3	20.4	69.4	28.8	29.2
V.C	0.42	0.32	0.71	0.42	0.12	0.53	0.50

Table (7): Clark of Concentration values of gold and associated elements in the quartz veins.

S. No.	Au	Ag	As	Co	Cu	Pb	Zn
3	4000	60	65	12	3.1	4.3	0.4
7	2250	40	134	6	0.2	1.4	0.2
12	9250	280	219	12	1	18.9	1.1
16	3000	60	467	47	1.2	3.4	1.1
20	4500	80	401	14	5.3	3.7	0.2
25	1500	60	6201	21	4.8	2.5	1.1
29	250	100	38	1	3.4	2.3	0.4
33	2750	80	319	3	5.1	2.5	0.2
38	4250	80	479	13	0.6	3.8	0.2
42	2000	80	630	-	0.5	1.6	0.1
46	9750	160	943	31	5.6	2.1	0.5

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Table (8): Clark of Concentration values of gold and associated elements in the alteration zone.

S. No.	Au	Ag	As	Co	Cu	Pb	Zn
2	8750	140	193	43	5.3	1.7	1.6
4	13250	120	125	43	1.1	2.1	1.2
6	16250	100	299	46	2	2.0	1.4
11	19750	40	287	63	3.8	3.9	3.2
13	13250	180	290	77	3.1	2.5	2.4
15	6500	60	347	4	3	1.3	0.2
17	19250	180	217	76	1.9	1.1	2.7
19	7500	120	461	50	5.8	2.2	1.5
21	9000	80	90	49	6.8	3.0	1.5
24	9250	120	611	74	5.4	1.7	1.7
26	3750	60	170	5	19.9	1.5	0.2
28	5750	120	-	64	27.7	2.6	1.4
30	6750	140	169	42	16.1	2.5	1.3
32	19250	140	214	69	5.3	3.4	1.6
34	20250	120	94	48	1.5	4.2	2.5
37	14250	140	473	40	1.2	4.1	1.3
39	11250	100	497	26	0.4	2.2	0.4
41	15250	140	783	44	1.7	4.5	1.6
43	12500	140	928	35	4.2	2.7	1.1
45	21000	180	977	64	1.7	2.7	1.3
47	18000	160	864	63	5.7	7.9	1.4

Table (9): Correlation coefficient values between gold and associated elements in the quartz vein samples.

	Au	Ag	As	Co	Cu	Pb
Ag	0.78					
As	-0.20	-0.17				
Co	0.33	0.02	0.22			
Cu	0.12	-0.02	0.34	0.11		
Pb	0.60	0.86	-0.15	0.00	-0.25	
Zn	0.22	0.38	0.47	0.65	0.01	0.50

No. of samples = 11, r =0.57 at P=0.05, r

0.0.7 at P=0.01, r = 0.82 at P=0.001

Table (10): Correlation coefficient values between gold and associatedelements in the alteration zone samples.

	Au	**Ag**	**As**	**Co**	**Cu**	**Pb**
Ag	0.38					
As	0.30	0.36				
Co	0.52	0.57	0.06			
Cu	-0.62	-0.19	-0.39	-0.10		
Pb	0.46	0.18	0.37	0.24	-0.11	
Zn	0.59	0.25	-0.16	0.77	-0.23	0.22

No. of samples = 21, r =0.43 at P=0.05, =0.0.54 at P=0.01, r =0.65 at P=0.001

Table (11): Linear productivity and contrast coefficient of gold and associated elements along the (NW-SE) direction.

	NW Linear Productivity (M) SE				Contrast coefficient
	P1	**P2**	**P3**	**P4**	
Au	206.20	289.45	836.88	376.98	0.55
Ag	11.07	45.44	13.57	12.13	0.91
As	756.87	2159.70	50095.27	2000.73	0.38
Co	233.68	570.30	928.27	510.75	0.46
Cu	214.90	420.99	1685.92	399.07	0.54
Pb	90.61	1224.64	105.27	330.17	0.27
Zn	362.86	859.98	620.17	517.11	0.70
	1876.19	5570.50	54285.37	4146.94	

Table (12): Zonality indices of gold and associated elements along the (NW-SE) direction.

	NW ZonalityIndex SE			
	P1	**P2**	**P3**	**P4**
Au	0.11	0.05	0.02	0.09

Ag	0.006	0.008	0.0003	0.0029
As	0.40	0.39	0.92	0.48
Co	0.12	0.10	0.02	0.12
Cu	0.11	0.08	0.03	0.10
Pb	0.05	0.22	0.002	0.08
Zn	0.19	0.15	0.01	0.12

Table (13): Linear productivity and contrast coefficient of gold and associated elements along the (NE-SW) direction.

	NELinear Productivity (M)SW									**Con. Coeff.**
	Q	**Al**	**Mb**	**Al**	**Q**	**Al**	**Ma**	**Al**	**Q**	
Au	216.2	97.67	161.4	234.9	239.2	343.4	58.40	566.4	291	0.74
Ag	111.9	16.02	8.51	24.03	6.97	6.23	17.62	32.9	25.27	4.43
As	3473	1809	8206	9693	16319	31599	6751	10018	106763	0.03
Co	97.6	343.4	110.6	760.5	830.14	198.76	54.33	868	66.70	1.46
Cu	672.4	636.8	102.9	1914	371.36	3139.5	165.5	1993.5	6.33	106.19
Pb	4034	77.8	83.9	381	299.8	183.19	26.35	63.8	88.10	45.78
Zn	363.1	692.2	239.2	873.1	572.08	296.87	204	586.5	243.06	1.49
	8968	3673	8913	13881	18639	35767	7277	14129	107483	

Table (14): Zonality indices of gold and associated elements along the (NE-SW) direction.

	NEZonality IndexSW								
	Q	**Al**	**Mb**	**Al**	**Q**	**Al**	**Ma**	**Al**	**Q**
Au	0.024	0.027	0.018	0.017	0.013	0.010	0.008	0.040	0.003
Ag	0.012	0.004	0.001	0.002	0.001	0.0002	0.002	0.002	0.0002
As	0.387	0.493	0.921	0.698	0.876	0.883	0.928	0.709	0.993
Co	0.011	0.094	0.012	0.055	0.045	0.006	0.007	0.061	0.001
Cu	0.075	0.173	0.012	0.138	0.020	0.088	0.023	0.141	0.0001
Pb	0.450	0.021	0.009	0.027	0.016	0.005	0.004	0.005	0.001
Zn	0.040	0.188	0.027	0.063	0.031	0.008	0.028	0.042	0.002

Table (15): Zoning coefficient values for gold associated elements throughout the (NW-SE) direction

	NWZoning Coefficient SE			
	P1	**P2**	**P3**	**P4**
Ag/Au	0.05	0.16	0.02	0.03
As/Au	3.67	7.46	59.86	5.31

Co/Au	1.13	1.97	1.11	1.35
Cu/Au	1.04	1.45	2.01	1.06
Pb/Au	0.44	4.23	0.13	0.88
Zn/Au	1.76	2.97	0.74	1.37

Table (16): Zoning coefficient values of gold associated elements throughout the (NE-SW) direction

	NEZoning CoefficientSW								
	Q	**Al**	**Mb**	**Al**	**Q**	**Al**	**Ma**	**Al**	**Q**
Ag/Au	0.52	0.16	0.05	0.10	0.03	0.02	0.30	0.06	0.09
As/Au	16.06	18.52	50.86	41.27	68.23	92.1	115.6	17.69	366.85
Co/Au	0.45	3.52	0.69	3.24	3.47	0.58	0.93	1.53	0.23
Cu/Au	3.11	6.52	0.64	8.15	1.55	9.14	2.84	3.52	0.02
Pb/Au	18.65	0.80	0.52	1.62	1.25	0.53	0.45	0.11	0.30
Zn/Au	1.68	7.09	1.48	3.72	2.39	0.86	3.49	1.04	0.84