Gold and Copper Mineralization bearing ferruginous siltstone in Lower Carboniferous, Um Bogma Formation, Sinai, Egypt: Geologic Setting and Recovery

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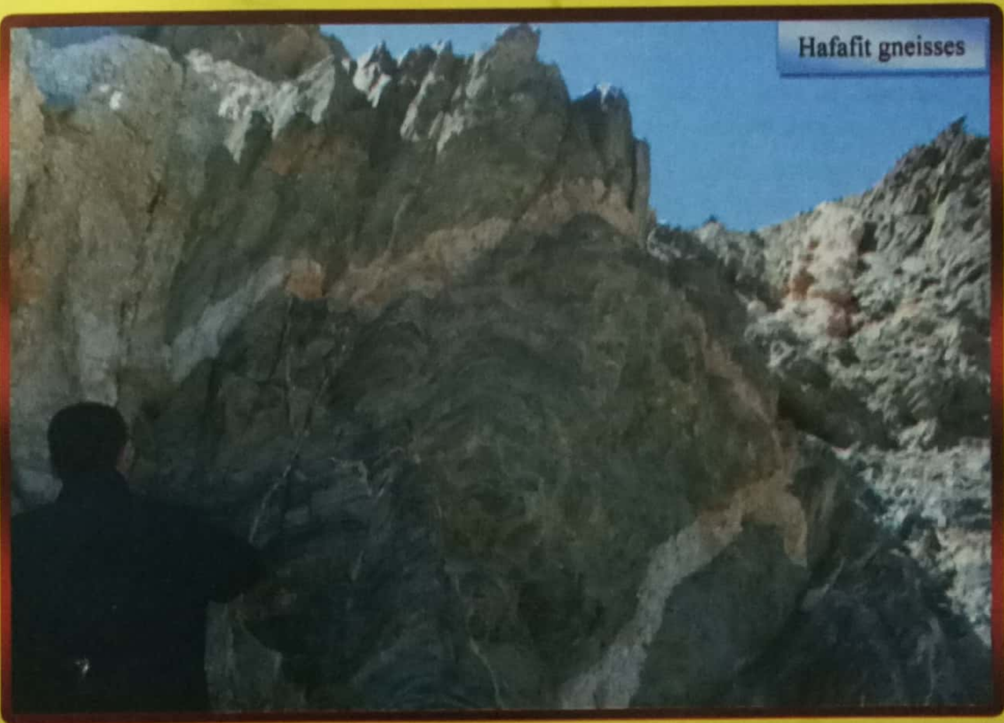

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GOLD AND COPPER MINERALIZATION BEARING FERRUGINOUS SILTSTONE IN LOWER CARBONIFEROUS, UM BOGMA FORMATION, SINAI, EGYPT: GEOLOGIC SETTING AND RECOVERY

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ABSTRACT

Au-Cu mineralization-bearing ferruginous siltstone bed (1.5 m thick) is identified at the lower Carboniferous Middle Um Bogma Formation (20 m thick), Sinai, Egypt. It is unconformably overlying Sarabit El Khadem (Cambrian) and overlain by the base of Abu Thora sandstone. The latter is covered by Triassic basaltic sill (30 m thick).Two samples are collected from the siltstone bed (each sample is 20 kg) and are analyzed for major oxides and trace elements by ICP- MS. The heavy mineral separation and mineralogical identification by XRD and Scanning Electron Microscope (SEM) techniques are carried out. The Au content is determinate by fire assay for the two samples which gives 50- 60 g/t thus reports new data in Sinai.

The copper minerals (Av.6.6 % Cu), e.g. [atacamite {$Cu_2Cl(OH)_3$} and azurite ($Cu_3(CO_3)_2(OH)_2$] and brass alloy are usually associated with As (Av.58 ppm), Pb (Av.79 ppm), Ba(Av.170 ppm) and Zn(Av.480 ppm). The extrusion of the basaltic sheet supplied the heat, fluid and CO_2 favorable to the transportation and precipitation of Cu- Au deposits from its solutions. The origin of Au - Cu deposits in siltstone seem to be related to hydrothermal activity and derived from the igneous rocks as external source. The potential of gold and copper recoveries from the mineralized siltstone is achieved.

A sulfuric acid agitation leaching is used to upgrade gold and to recover the associated copper. The studied optimum conditions involve ore ground to -100 mesh size treatment with140 g /l H_2SO_4 concentration, 1/3 ore/ $CaCO_3$, 15min. agitation time and at 100 °C in a solid / liquid ratio of 1/10.

Keywords: Gold, Copper, siltstone, Um Bogma Formation, recovery

INTRODUCTION

Sinai Peninsula is a famous poly-metallogenetic province in Egypt, such as ferromanganese, copper, REEs and uranium with other rare metals. Although old Egyptian exploited copper in Sinai, there is no evidence for gold mining up till now either in geological or archaeological maps in Sinai.

Little studies have addressed the likely concentration and mode of occurrence of gold in sedimentary rocks in Egypt. A minor content of gold was recorded in some Egyptian black beach sands (El Gemmizi, 1985) that represent beach placers on the Mediterranean Sea. The stream sediments of Dahab area in Sinai contain considerable amounts of placer gold (15.34 g/t), (Surour *et al.*, 2003). Sallam et al., (2014) studied the Paleozoic lower member of Um Bogma Formation at El Sheikh Soliman area, south Sinai and recorded minerals bearing Ag and Au such as uytenbogaardtite ($AgAuS_2$) and furutobeite [$(Cu,Ag)_6PbS_4$].Conglomerate bed at the base of Upper Cretaceous Nubian Formation overlying the Precambrian basement rocks at El Ghurfa ring structure, Southeastern Desert, contains gold (1-8 g/t, (Ibrahim et al., 2012). El-Aassy et al., (2015) reports the presences of gold (1-5 g/t) in Carboniferous sandstone in Abu Thora Formation at Wadi El Sahu, southwestern Sinai. On contrast, more than 95 occurrences of gold were recorded in quartz veins and igneous rocks at the Eastern Desert of Egypt since Pharonic times.

Acid leaching of copper is the most common method suitable to leach oxidized copper minerals such as azurite, malachite, tenorite and chrysocolla as these minerals readily dissolve at room temperature (Warhurst, 2005). Typical acidic leaching solutions include hydrochloric acid, sulphuric acid and ferric sulphate (Biswas and Davenport 1994). Ibrahim and El-Sheikh, (2014) applied an innovative procedure for gold recovery as an alternative method for cyanidation.

The study sheds the light on new data showing the presence of gold and copper mineralization in ferruginous siltstone bed (1.5 m), middle Um Bogma Formation, Sinai to investigate the potential of gold and copper recoveries from their mineralized siltstone.

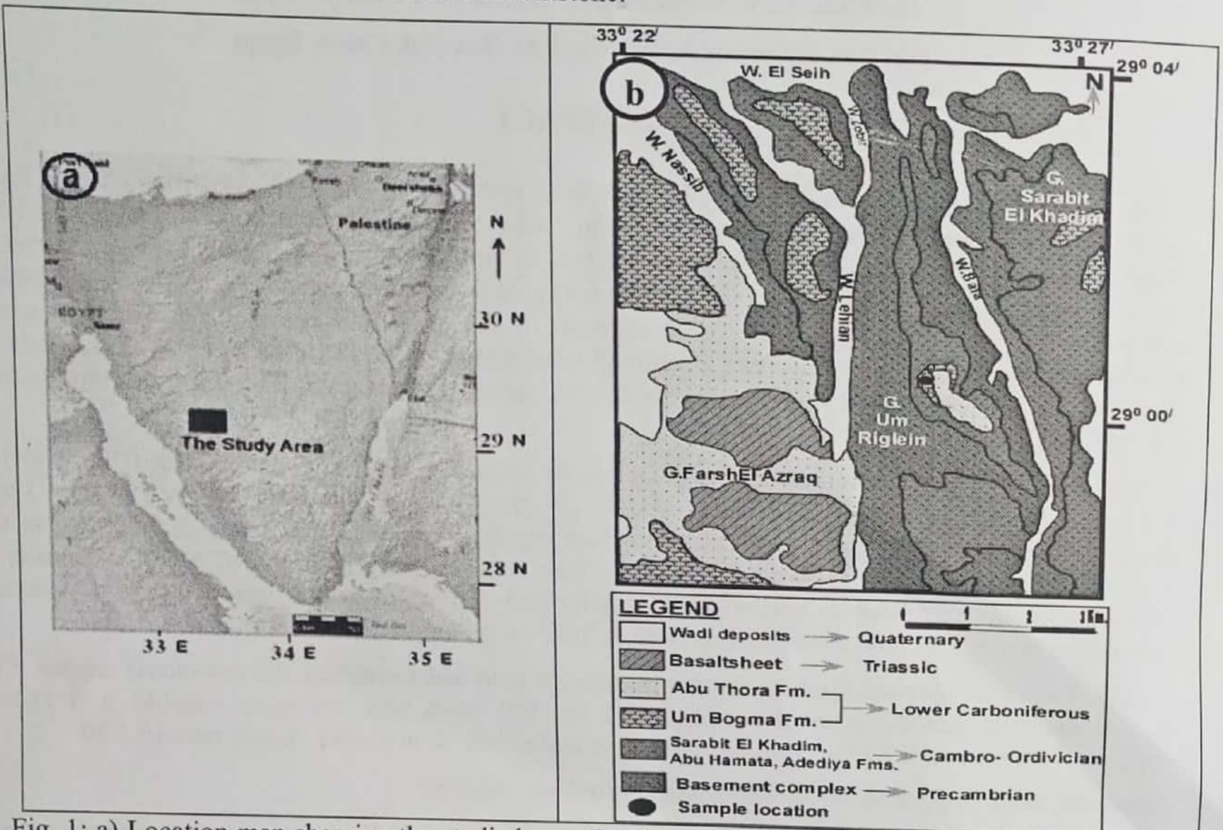

Fig. 1: a) Location map showing the studied area, Southwestern Sinai, Egypt. b) Geological map of Gabel Um Riglein area East Abu Zenima, Sinai, Egypt after (Morsy et al., 1995).

GEOLOGICAL SETTING

In the study area, the granitic rocks are nonconformably overlain by the Paleozoic succession that capped by Triassic basalt sheet. The Paleozoic rocks are mainly composed of Cambrian and Carboniferous rocks. The Carboniferous rocks consist of marl, sandstone, sandy dolostone, shale and siltstone Soliman and El Fetouh, (1969).

The Paleozoic sedimentary rock units in Sinai comprise three stratigraphic units arranged from base to top: Lower sandstone series, Um Bogma Formation and Upper sandstone series. The Lower sandstone series of Barron, (1907) classified into Sarabit El Khadim, Abu Hamata and Adedia Formation by Soliman and El Fetouh, (1969), the Middle Carbonate series of Barron (1907), renamed as Um Bogma Formation by Weissbrod (1969). He (Op.Cit) also collected El Hashash, Magharet El Maih and Abu Zarab Formations (from base to top) of Soliman and El Fetouh, (1969) into one independent rock unit under the term Abu Thora Formation (Upper sandstone series).

The Um Bogma Formation overlies unconformably the Adedia Formation and has been subdivided by El- Agami et al., (1999) into three members. The lower member is represented by shaly ore - sandy dolostone followed by marly dolostone- siltstone (middle member) and ended by upper member (dolostone – sandstone).Um Bogma Formation has a maximum thickness of 41 m at the upper part of Wadi Khaboba and Gabal Nukhul. It decreases to about 20 m at Um Bogma mines and to about 10 m at Gabal Sarabit El Khadim and becomes almost absent further southeast.

Abu Thora Formation overlies conformably the Um Bogma Formation and is topped by a basaltic sill or flow sheet of probable Triassic age. It varies in thickness from 60-170 m and could be subdivided informally into two members: Glass-sand member on top and kaolinitic claystone member at the base (Kora et al., 1994).

Au-Cu mineralization-bearing ferruginous siltstone bed (1.5 m thick) in between dolostone beds and close to Gabel Um Riglein, Sinai is identified (Fig. 3).

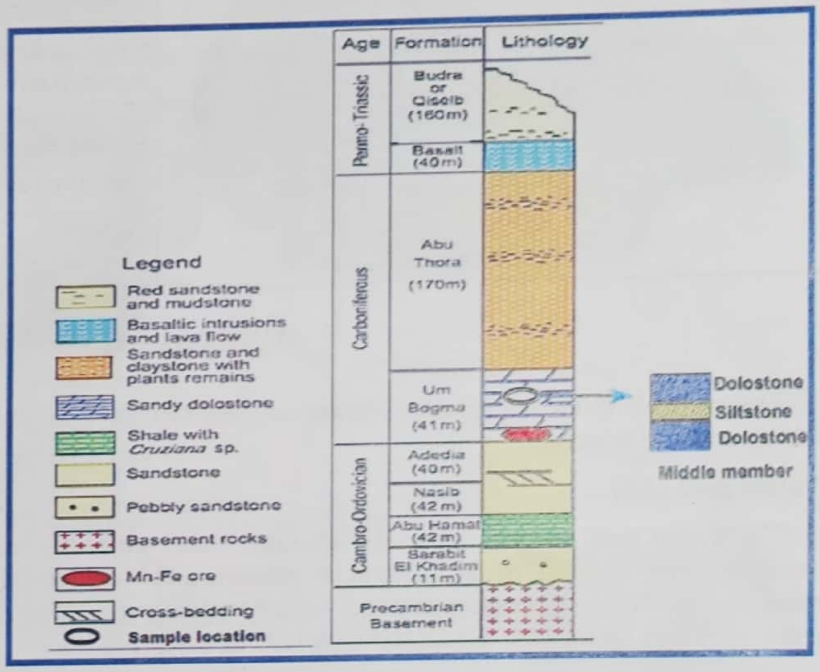

Fig. 2: Lithostratigraphic section of the Paleozoic rocks in the Um Bogma area, west central Sinai (Kora, 1984).

METHODOLOGY

Two samples (each one 20Kg) represent ferruginous siltstone are collected at about 200 m distance interval then selected for detailed mineralogical and the work interest shifted to investigate the potential of gold and copper recoveries from their host rocks. This involves disaggregation, crushing and removing the slimes by washing and decantation. The slimed dry samples are then sieved using a mechanical shaker. The size fractions (0.4, 0.3, 0.2 mm) are then subjected to heavy liquid separation using bromoform (sp. gr. 2.8) into light and heavy fractions.

The obtained heavy fractions are handpicked using the binocular microscope to obtain the mineral grains. These include heavy mineral separation and mineralogical identification by means of X-Ray Diffraction analysis (XRD) and Scanning Electron Microscope (SEM). The used equipment is housed in the laboratories of the Nuclear Materials Authority of Egypt. The two samples are quartered for chemical analyses by ICP-MS technique in Faculty of Engineering, Kyushu University, Japan for major oxides and trace elements (Table1). Au is measured in the two samples by fire assay in the Egyptian Mineral Resources Authority. A laboratory grade of sulphuric acid (specific gravity and concentration of 1.84 g/ml and 98%, respectively) is prepared and used as leaching agent in different stages of the experimental work.

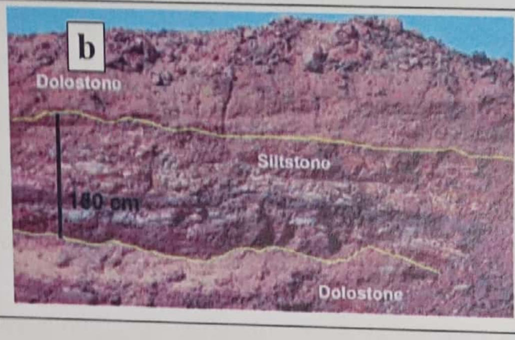

Fig. 3: a &b)Field Photographs showing Au-Cu mineralization-bearing ferruginous siltstone (1.5 m thick) in between dolostone beds, Middle Um Bogma Formation, Sinai. C) Hand spacemen showing copper mineralization.

MINERALOGY

The minerals in the ferruginous siltstone are represented by a) gold, b) copper minerals, c) brass alloy and d) uranium mineral.

Native gold (Au)

The native gold (Fig. 4) occurs as separated flakes picked by naked eye with copper mineralization from the heavy fractions of the ferruginous siltstone and is associated with quartz grains. Two samples are measured by fire assay contain (50- 60 Au g/t respectively). Also Au is confirmed by XRD and ESEM techniques and found to be associated with very rare Ag (Fig. 5).

Atacamite [$Cu_2Cl(OH)_3$]

Atacamite is a copper halide mineral, formed from the alteration of primary copper minerals in the oxidation or weathering zone of arid climates. Atacamite is characterized by massive, green color. Atacamite is found on graphite flakes (good adsorbent) as green layers. X-ray (Fig. 6) and SEM analysis revealed that the chemical composition of atacamite is relatively rich in Cu and Cl about over 90% (Fig. 7).

Azurite $Cu_3(CO_3)_2(OH)_2$

A secondary copper mineral frequently found in the oxidized zones of Cu-bearing ore deposits. It is a secondary mineral formed by the action of carbonated water acting on copper surface. Azurite is typically found as tabular to prismatic crystals of a deep "azure blue" color. The ESEM analysis revealed that, the chemical composition is relatively rich in Cu about over 88% (Fig. 8).

Brass alloy

Brass is a metal alloy made of copper or zinc. It is a substitutional alloy; atoms of the two constituents may replace each other within the same crystal structure. Its color is yellow to brassy yellow, with metallic luster and is associated with pyrite (Fig. 9).

Kasolite [$Pb(UO_2)SiO_4.H_2O$]

Kasolite is found on the surface of atacamite mineral as small veinlet's. The EDX analysis gives Pb: U: Si ratio equal 1:1.2- 1.1 with traces of Cu and Fe (Fig. 10).

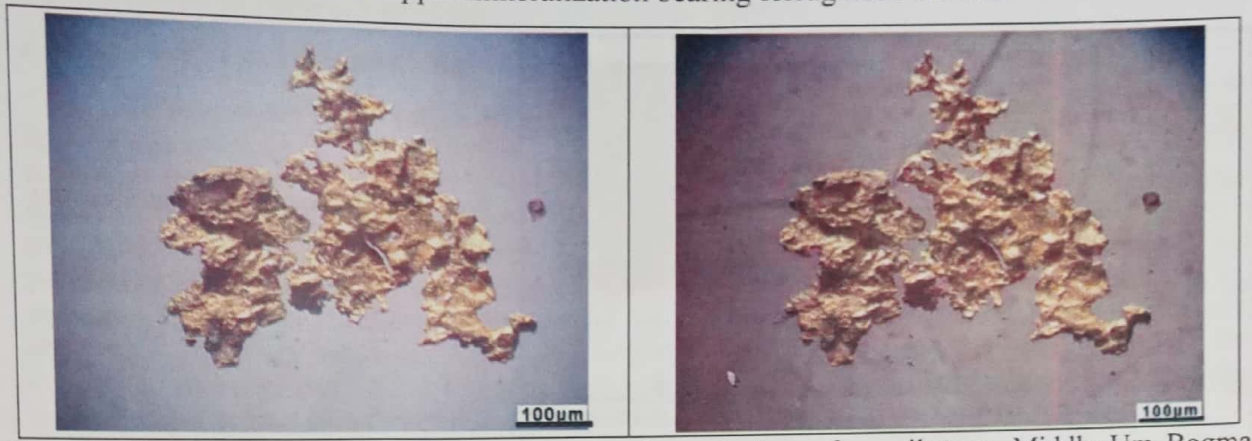

Fig. 4: Flakes of gold picked from heavy fraction by naked eye from siltstone, Middle Um Bogma Formation.

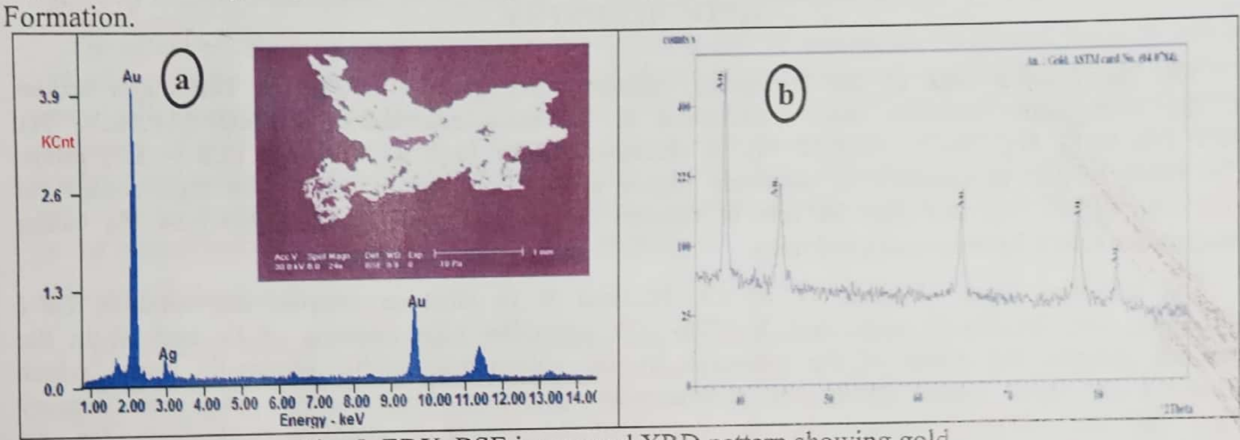

Fig. 5: EDX, BSE image and XRD pattern showing gold.

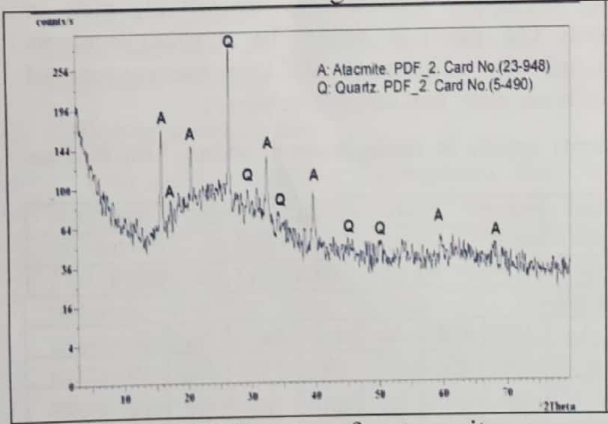

Fig. 6: XRD pattern for atacamite.

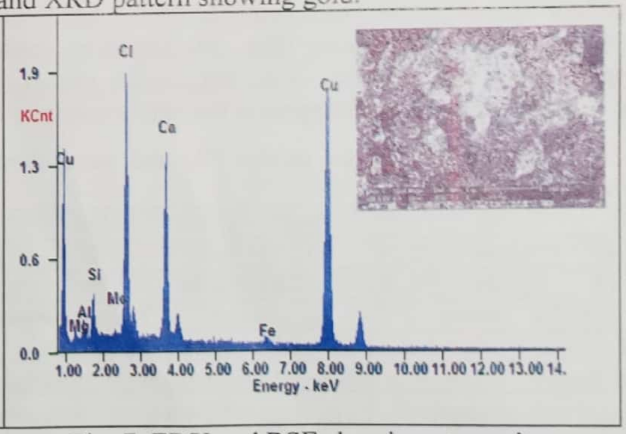

Fig. 7: EDX and BSE showing atacamite.

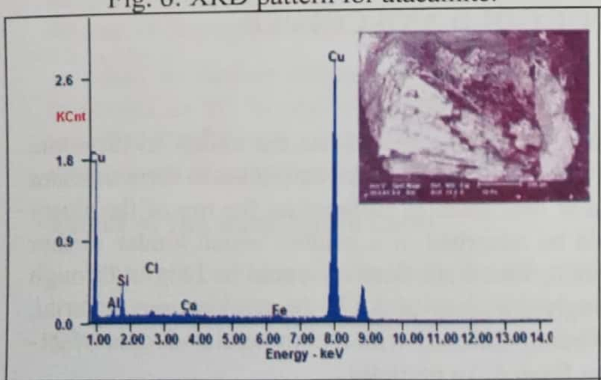

Fig. (8): EDX and BSE image showing azurite.

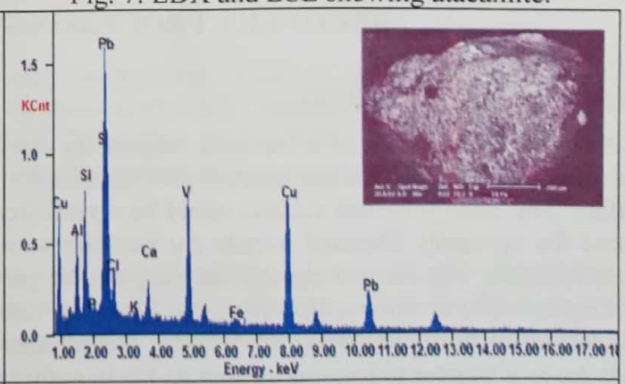

Fig. 9: EDX and BSE image showing brass alloy.

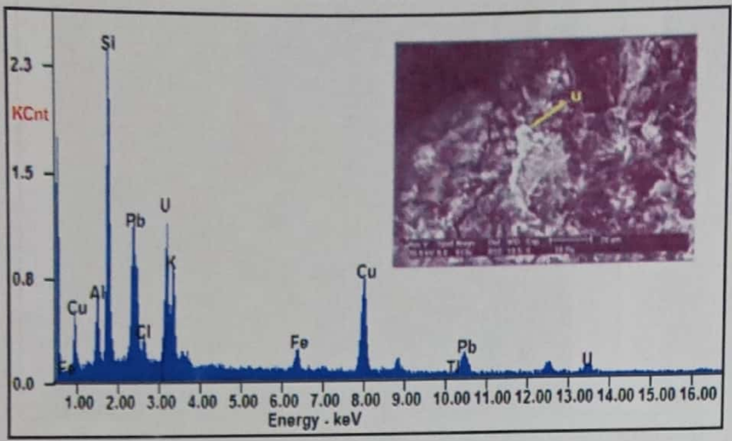

Fig. 10: EDX and BSE image showing kasolite (U: uranium).

GEOCHEMISTRY

The geochemical data of the ferruginous siltstones are given in Table 1. The major oxides of the ferruginous siltstones show enrichment in the main constituents of SiO_2 (Av.58.30 %), FeO^t (Av.18.11 %), Al_2O_3 (Av.8.12 %). It characterized by high K_20 / Na_2O (2.5 – 3.0) ratios. The latter is due to presence of relatively higher amount of clay minerals. The high content of total iron (18.11 %) may play its role in fixation of Au and Cu. The TiO_2 (Av.0.34 %) values suggest derivation from opaque's and mica.

The transition trace elements (TTE) Cr, Ni, and V in siltstone samples are variable, Cr (190-204 ppm), Ni (64-67 ppm) and V (278- 279 ppm).The high contents of Cr and Ni in the samples indicate the effect of the siltstones by the surrounding mafic/ ultramafic rocks, which provided additional inputs during the sedimentation processes. High Arsenic (As) and mercury (Hg) (59 and 21ppm respectively) is considered as the main pathfinder elements for Au deposits. Copper and gold contents (6.5– 6.8% and 50-60 g/t respectively) are usually rich in ferruginous siltstone layers (Fig. 3). Uranium contents (16 ppm) is twice the thorium contents (8ppm), both are relatively low, but U /Th ratio (2) indicates enrichment of U on the expense of Th. The Pb content (58-100 ppm) is the main constitute of brass alloy and kasolite minerals.

Table 1: Average of major oxides (%) and trace elements (ppm) in ferruginous siltstone, Um Bogma Formation, Sinai

SiO_2	$Ti0_2$	Al_20_3	$Fe0^t$	Mn0	Mg0	Ca0	Na_20	K_20	P_20_5	L.O.I	Total
58.85	0.44	8.24	17.58	0.01	0.86	0.51	0.28	0.71	0.05	5.22	٩٢,٧٥
57.75	0.24	8.10	18.65	0.01	0.89	0.50	0.23	0.70	0.04	5.10	92.8

Trace elements (ppm)

Cl	V	Cr	Pb	Ni	Cu %	Zn	Ag	Hg	Cd	As	Au	Ba	Th	U
2752	279	204	100	64	6.81	200	2	21	15	57	50	179	8	16
2746	278	190	58	67	6.50	761	1	17	6	59	60	161	10	15

RECOVERY PROCESSING OF GOLD AND COPPER

Experimental procedures

Sulfuric acid is used as a leaching reagent for Au and Cu. Sulfuric acid has the ability to dissolute several metal values in the ore material and would react with the added calcium carbonate to form calcium sulfate. The latter (calcium sulfate) could be crystallized at heat transfer surfaces on the top of the slurry where the upwardly liberated minute Au particles would be adsorbed in a manner which hinder further crystallization. The formed crystals carrying the Au particle, which are floating would be helpful through boiling and CO_2 evolution. However, due to the exceedingly the assay of Au in the working ore material, it is found convenient to study the relevant factors after being enriched with a commercial sample of 21-kirat Au in a manner to become as high as 1% to optimize floated Au particles.

Optimization of recovery process

Effect of ore / $CaCO_3$ ratio (S/R):

To investigate the effect of ore / $CaCO_3$ ratio upon Au recovery through its adsorption upon upwardly in situ formed, calcium sulfate is studied using ratios ranging from 1:1 to 1:4 while the other conditions are fixed at 120 g/l Sulfuric acid, -100 mesh ore size, 20min. agitation time, 100°C temperature and using a S/L ratio of 1/10. The obtained results are given in table (2). From the obtained results, it can be concluded that the adsorption efficiency of Au increases accordingly with increasing the ore /$CaCO_3$ ratio indicating its role in $CaSO_4$ formation. Thus, by decreasing the ore / $CaCO_3$ ratio from 1/1 to 1/3 the corresponding adsorption efficiencies increase for Au. It is almost complete adsorption of Au and reaches about 99 %. On other words, the added $CaCO_3$ content of the ore sample (about 75%) has almost been completely converted into $CaSO_4$. It is important to mention herein that, under these mentioned conditions the leaching efficiency of copper realized is only about 80%.

Effect of H_2SO_4 concentration upon Cu leaching and Au adsorption

The effect of H_2SO_4 concentration upon Cu leaching and Au adsorption is studied between 120 and 150 g/l, while the other leaching conditions are fixed at -100 mesh size,1/3 ore/ $CaCO_3$, 20 min. agitation time, 100°C temperature and using a S/L ratio of 1/10. The leaching efficiency of copper and adsorption efficiency of gold which are given in table (3) indicate that the best concentration is 140 g/l for copper leaching and gold adsorption. Under these conditions, the leaching efficiency of copper has attained about 99% with gold adsorption efficiency of 99%. Higher concentrations of the acid don't have marked effect on the copper leaching or the gold adsorption efficiency.

Effect of agitation time

The effect of agitation time upon Cu leaching and Au adsorption efficiencies is studied in the range from 5 to 20 minutes while the other leaching conditions are fixed at 140 g /l H_2SO_4 concentration 1/3 ore/ $CaCO_3$, -100 mesh size ore fineness, a leaching temperature of 100 ^{0}C and using a solid / liquid ratio of 1/10. The obtained data shown in table (4) revealed that a high copper leaching efficiency of 98% occurs within the experiment of 15 min. associated with about 99 % Au adsorption efficiency. Also, it can be concluded that 20 minutes are required to almost complete copper leaching and gold adsorption although15 minutes can indeed be considered adequate and optimum value.

Effect of temperature

Four acidic leaching experiments have been carried out to investigate the effect of leaching temperature upon copper leaching and gold adsorption efficiencies in the range from room (about 25°C) up to 100°C. In these experiments, the other leaching conditions were fixed at -100 mesh size ore material, 140 g /l H_2SO_4 concentration, 1/3 ore/ $CaCO_3$, 15min. agitation time and using a S/L ratio of 1/10. The obtained data are given in table (5), in comparison to that obtained at 100°C ensure actually the importance of temperature to obtain a high leaching efficiency of copper and adsorption of gold upon surface of calcium sulfate. Working at room temperature under the mentioned conditions doesn't leach more than 13 % of copper while that of gold adsorbed amounted to only10 %. Increasing the leaching temperature to 50°C has increased the leaching efficiency of copper and adsorption efficiency of gold to 40 and 18 % respectively.

Also, its further increase to 80°C increased the Cu leaching efficiency to 85% while that of gold increased to 90 % and after which there has showed completely leaching efficiency of copper and adsorption efficiency of gold to about 99% of both .It can thus be concluded that an optimum leaching temperature of copper and gold adsorption under the above mentioned conditions would be 100°C.

Effect of the solid/liquid ratio

It has not been possible to study the effect of the solid/liquid ratio of 1/1 and 1/2 upon copper and gold leaching or adsorption efficiencies from the working Cu/Au mineralization. This has been due to the nature of the clay component in the latter which resulted in almost total absorption of the solution at the

S/L ratios of 1/1 and 1/2. Thus, a S/L ratio of 1/3 to 1/10 has been studied , with fixed condition of 100 mesh size ore material, 140g /l H_2SO_4 concentration, 1/3 ore/ $CaCO_3$, 15 min. agitation time and at 100 °C as leaching and or adsorption temperature. From Table (6), it is found that at s/l 1:10 the leaching or adsorption efficiency of both metal values have attained about 98.9 % for Cu and complete adsorption of about 99 % for gold.

RESULTS OF GOLD AND COPPER RECOVERY

For the recovery of gold and copper from the sulfate leach liquor of the working sample, proper 4 liter leach liquor is prepared from 400 g of the working ore sample using the above mentioned determined optimum leaching or adsorption conditions. The ascending gold particles are found to be surface adsorbed along with the in-situ formed $CaSO_4$ (Fig.11a, b). In the latter, native Au particles about (20mg) from the working sample have been collected. To recover the adsorbed Au from the calcium sulfate scales, washing the calcium sulfate with a large amount of water up to 2 liters is applied through the filter paper to leave behind the Au particles. The latter then subjected to ESEM-EDX analysis of Au recovery, Au of 90% purity is revealed in figure (11).With respect to copper, its chemical analysis in this liquor was found to attain 6.43Cu g/l. Blue copper sulfate crystals have been obtained by adjusting its pH to 5.5 using dilute ammonium hydroxide solutions. The obtained crystals have been subjected to XRD analysis to confirm the degree of its purity and which was found to attain up to about 99% Cu (Fig. 12).

Table 2: Effect of ore / $CaCO_3$ ratio upon Au adsorption and Cu leaching efficiencies

Ore/$CaCO_3$ ratio	Au adsorption	Cu leaching efficiencies.
1/1	86.00	80.14
½	90.00	80.13
1/3	99.00	80.19

Table 3: Effect of H_2SO_4 concentration upon Au adsorption and Cu leaching efficiencies

H_2SO_4 concentration	Au adsorption	Cu leaching efficiencies.
120	99.00	80.19
130	99.00	89.59
140	99.00	98.99
150	99.00	99.01

Table 4: Effect of agitation time upon Au adsorption and Cu leaching efficiencies

Agitation time	Au adsorption	Cu leaching efficiencies.
5	99.00	81.35
10	99.00	93.78
15	99.00	98.00
20	99.00	98.99

Table 5: Effect of S/l ratio upon Au adsorption and Cu leaching efficiencies

Temp	Au adsorption	Cu leaching efficiencies.
25	10.00	13.76
50	18.00	40.52
80	90.00	85.00
100	99.00	98.99

Table 6: Effect of temperature upon Au adsorption and Cu leaching efficiencies

S/l	Au adsorption	Cu leaching efficiencies.
1/3	11.45	87.13
1/4	53.11	93.17
1/6	64.13	96.68
1/8	86.54	97.80
1/10	99.00	98.99

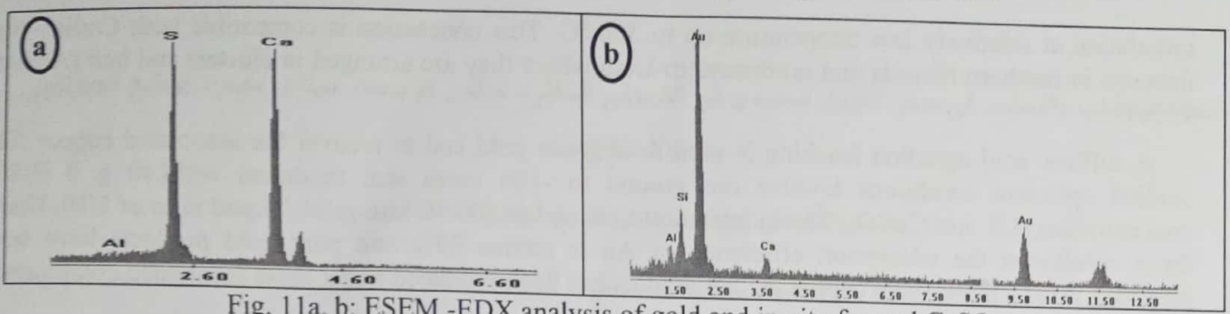

Fig. 11a, b: ESEM -EDX analysis of gold and in-situ formed $CaSO_4$

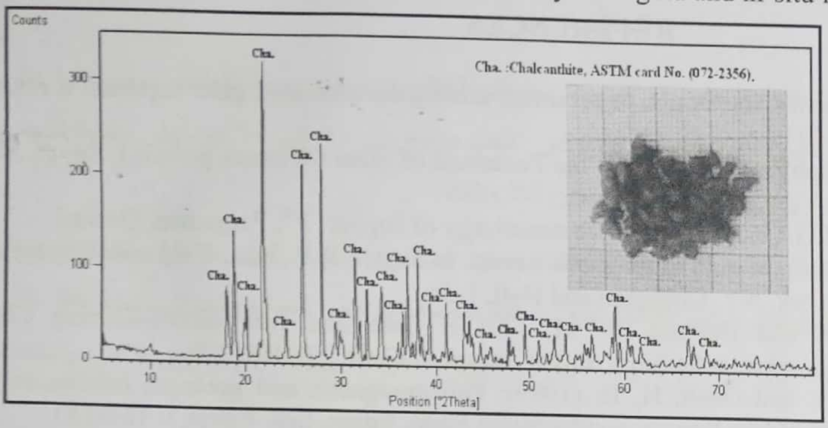

Fig. 12: XRD pattern for synthetic copper (chalcanthite).

DISCUSSION AND CONCLUSIONS

Au-Cu mineralization-bearing ferruginous siltstone bed (1.5 m thick) is identified at the lower Carboniferous Middle Um Bogma Formation (20 m thick) and located close to Gabel Um Riglein, southwestern Sinai, Egypt. It is unconformably overlying Sarabit El Khadem (Cambrian) and overlain by the base of Abu Thora sandstone. The latter is covered by Triassic basaltic sill (30 m thickness). The mineralogical results show native gold, copper minerals (e.g. atacamite [$Cu_2Cl\ (OH)_3$], azurite $Cu_3(CO_3)_2(OH)_2$ and brass alloy. Rare uranium mineral (kasolite [$Pb\ (UO_2)\ SiO_4.H_2O$]) as minute veinlet's cut the copper minerals. The Au content by fire assay for two samples (20kg) for each gives 50-60 g/t with an average 55 g/t and repots new data in Sinai.

The extrusion of the basaltic sheet of Gabal Farsh El-Azrag 2.5 km east of the present study, supplies the heat, fluid and CO_2 favorable to the transportation and precipitation of Cu- Au deposits from its solutions. The presence of atacamite and kasolite minerals on graphite surface reflect reduced environment.

Shale, siltstone, sandstone and conglomerate are commonly reported to contain gold concentrations that range from 0.1 to 30 ppb (Crocket, 1991). The epigenetic Carlin-type deposits are arranged in clusters and belts (*Arehart, 1996).* These deposits show enrichment in the elements of gold, antimony, mercury, thallium and barium. This enrichment is created by hydrothermal circulation with a temperature of up to 300°C. Two main theories have been developed regarding the origin of the gold;

1. Placer theory, gold has been derived by erosion of adjacent areas, transported and deposited by streams along with the conglomerates (Hutchinson & Viljoen, 1986).
2. Hydrothermal theory, the gold, uranium, and some of the other metals have been introduced in hot aqueous solutions derived from an external source, such as an igneous intrusion (Phillips, 1989).

The origin of Au - Cu mineralization in siltstone seem to be related to hydrothermal theory and derived from igneous rocks as external source.

The ferruginous siltstone shows enrichment in Cu (Av.6.65%), Au (Av.55 ppm), As (Av.58 ppm), Pb (Av.79 ppm), Ba (Av.170ppm) and Zn (Av.480ppm), (Table 2) which are created by hydrothermal circulation at relatively low temperature up to 300 °C. This conclusion is compatible with Carlin –type deposits in northern Nevada and northwestern Utah where they are arranged in clusters and belt (Archart, 1996).

A sulfuric acid agitation leaching is used to upgrade gold and to recover the associated copper .The studied optimum conditions involve ore ground to -100 mesh size treatment with140 g /l H_2SO_4 concentration, 1/3 ore/ $CaCO_3$, 15min. agitation time and at 100 °C in a solid / liquid ratio of 1/10. Under these conditions the adsorption efficiency of Au is attains 99% and pure gold products have been prepared. Also a marketable copper sulfate product has been produced under these mentioned conditions.

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تمعدنات الذهب والنحاس فى حجر الغرين الحديدى فى الكربونى السفلى، متكون ام بجما، سيناء، مصر، الوضع الجيولوجى والاستخلاص

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هيئة المواد النووية ص.ب. ٥٣٠ القاهرة مصر.

الخلاصة

توجد طبقة الغرين الحديدى الحامل للذهب والنحاس فى الكربونى السفلى لمتكون ام بجما وسمك الطبقة حوالى ١,٥ متر. وهذه الطبقة تعلو سرابيط الخادم ويعلوها متكون أبو ثورا. وجد ان تركيز الذهب يتراوح بين ٥٠ إلى ٦٠ جرام/طن ونسبة النحاس حوالى ٦,٦% وممثل فى معادن الاتكاميت والازورايت كما وجد معدن الكازولايت.

يعتقد أن نشأة الذهب والنحاس مرتبط بالمحاليل الحرمائية الناتجة من الصخور النارية الموجودة فى منطقة الدراسة. الصفائح البازلتية لجبل الفرش الازرق والذى يبعد حوالى ٢,٥كم شرق منطقة الدراسة زادت من الحرارة والسوائل وايضا غاز ثانى أكسيد الكربون الازم لعملية النقل والترسيب لرواسب الذهب والنحاس. ويستخدم حمض الكبريتيك لرفع مستوى الذهب واستعادة النحاس المرتبط به.

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