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Research Article

Mineralogical and Geochemical Characteristics of stream sediments at Gulf of Al Aqaba, Sinai, Egypt

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Abstract

The study area is part of south eastern Sinai, Egypt, western coastal zone of Gulf of Al -Aqaba. The area of study is drained by Wadi (w) Lethel, W. Zewarai (trending NW-SE), W.Tarter and W. Um Adawi (trending E-W). The ESEM-EDAX analyses revealed the presence of five groups. The first group includes secondary uranium mineral; kasolite. The second group contains; Th-bearing mineral as uranothorite. The third one include base metal as galena. The fourth group include accessory minerals; columbite, xenotime and zircon. The last group contains supergene sulfide minerals; barite and atacamite, beside hematite and goethite may reflect that the sediments have been subjected to the extensive alteration. The concentrations of trace elements in stream sediment have been determined by X-ray fluorescence spectrometry. The stream sediment samples at the downstream of W. Um Adawi, shows high U and Th (from 687 to 1 ppm and from 589 to 3 ppm respectively), Zr and Y contents (more than 1% and 2400- 3490 ppm respectively), manifesting the common presence of both zircon - xenotime minerals .The later usually carrier for heavy rare earth elements (HREEs) . Also, Pb contents in W. Um Adawi stream samples is also high ranging between about 1000 and 5000ppm ,suggesting the presence of galena mineral. Nb, varies between (1496-2165 ppm). Some samples in W. Um Adawi contain high Ba (1759- 2500 ppm) and Sr (more than 1%) clarify the presence of barite mineral .Cu element in some samples up to (297 ppm) may be indicator to the occurrence of atacamite mineral. Barium, nickel, zircon, strontium and chromium contents were found to be high in most stream sediment samples. The origin of uranium appears to be closely associated with Zn, Nb and Y mineralization and may be reflects their intimate coherence.

Keywords: Stream sediments, Gulf of Al Aqaba, uranium mineral, base metals.

INTRODUCTION

Uranium, thorium and potassium are the most abundance of three naturally radio elements occurring in the upper earth crust. ^{238}U, ^{235}U and ^{234}U are the most abundant isotopes of uranium.

Most of the gamma emission that is useful for uranium exploration originates from the decay of lead (^{214}Pb) and bismuth (^{214}Bi) .In respect to thorium, the most useful gamma ray emitter is thallium (^{208}Tl). Uranium is the most mobile element compared to potassium and thorium. It can remobilize and redistribute in rocks according to tectonic activities and alteration processes. While thorium does not oxidized and remains stable. This permits the formation of secondary uranium minerals.

The study area is part of south eastern Sinai, Egypt, western coastal zone of Gulf of Al Aqaba. The area of study is drained by Wadi (w) Lethel, W. Zewarai (trending NW-SE), W.Tarter and W. Um Adawi (trending E-W).They are bounded by Gabal (G.) El Gofa , G.Um Adawi and G. Zewarai representing the basement rocks in the study area (Figure 1). At the southeastern part of the mapped area (Sharm El-Sheik City), Miocene sedimentary rocks (carbonate rocks) cover the downstream of the main Wadis in close contact with coast of the Gulf of Al Aqaba, are common. Although numerous geological and geochemical studies have been carried out on the basement rocks by (Ahmed, 1985; El Shishtawy,1989; Higazy et al., 1992; Abass, 2008; Saleh, 2006). The Quaternary stream sediments survey here still was not undertaken from the mineralogy, geochemistry and radioactivity point of view (the main objective of the present work).

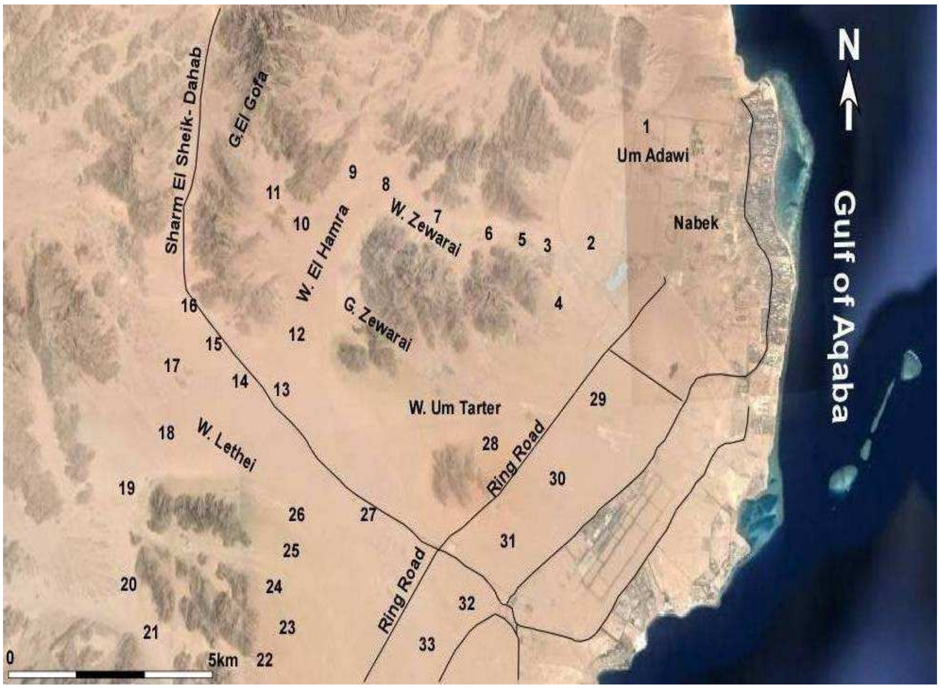

Figure 1. Photogeologic map showing the Location of the stream samples

Sampling and Analytical methods

Four technological samples (10Kg for every sample) collected from the stream sediments at the western part of Gulf of Al- Aqaba, Sinai, were separated by heavy liquid (Bromoform Sp. Gr. =2.8) to separate the light fraction from heavy minerals. Magnetite was separated from the heavy fraction by a hand magnet. The heavy mineral fractions were separated to magnetic and non-magnetic fractions using Frantz isodynamic separator. Then, the heavy minerals were easily picked as individual minerals under the binocular microscope. The picked minerals were identified by X-ray diffraction (XRD) techniques and were analyzed using the Environmental Scanning Electron Microscope (ESEM) supported by energy dispersive model XL-30 ESEM) at the laboratories of the Nuclear Materials Authority (NMA). The analytical conditions were 25-30 Kv accelerating voltages, 1-2 mm beam diameter and 60-120 second counting time. Minimum detectable weight concentration is from 0.1 to 1 wt%. Precision is well below 1% while the relative accuracy of concentration measurements range from 2% to 10% for elements with Z>9 (F) and from 10% to 20% for the lighter elements B, C, N, O and F.ESEM-EDAX analyses were also made to investigate morphological characteristics of these minerals as well as to give a semi- quantitative evaluation of their elemental composition.

The Trace elements were analyzed using the X-ray fluorescence technique (XRF) at the laboratories of the Nuclear Materials Authority, Cairo, Egypt. Analytical precision as calculated from replicate analyses, varies from 2-5% for trace elements of >80 ppm, 2-10% for trace elements of 10 to 80 ppm and 5-20% for trace elements of <10 ppm. The analytical accuracy depends on the elemental concentration and is monitored by international rock standards. At concentrations >10 times the detection limit, is 10-15% for the trace. The analyses of selected representative 33 stream sediment samples representing the main Wadis (from upstream and downstream) west Gulf of Al-Aqaba, Sinai, were carried out to clarify their geochemical characteristics and identified the mineralization bearing sediments (Table1).

RESULTS AND DISCUSSIONS

Mineralogy

The microscopic examination of the separated heavy fraction and the identified minerals by both XRD and ESEM-EDAX techniques can be classified into 5 groups. The first group includes secondary uranium mineral; kasolite. The second group contains; Th-bearing mineral as uranothorite. The third one include base metal as galena. The fourth group includes accessory minerals; columbite, xenotime and zircon. The last group contains supergene sulfide minerals; barite and atacamite, beside hematite and goethite may reflect that the stream sediments have been subjected to the extensive alteration.

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

Kasolite is a common secondary supergene mineral that is found in oxidation condition. Its color is green, gray green, yellow brown, reddish orange, with radial, prismatic or fibrous habit crystal. The kasolite is composed of 25 %U, 15% Pb and 40% Si (Figure 2a).

Uranothorite [(Th, U) SiO_4]

Uranothorite occurs as fine opaque grains. The ESEM analysis shows that it consists essentially of ThO_2, which exceeds significantly UO_2. According to Heinrich, (1958), uranium content is usually present in amounts up to about 10% in uranothorite. It is color black, to brown, with resinous to pitchy luster. Uranothorite has Th: U: Si ratio equal 2.6:1:4.2 with considerable amounts of Y (Figure 2b).

Galena (PbS)

Galena is a primary mineral. Most of the lead minerals, such as cerrusite and anglesite are secondary mineral formed from galena. Its color is lead to silver grey with metallic luster. It was confirmed by ESEM technique. Pb: S ratio equal 3:1 with traces of Ni, Mg, Al, Ca, and Ti (Figure 2c).

Columbite [(Fe, Mn, Mg) (Nb, Ta) $_2O_6$]

Columbite is the most widespread niobium mineral and makes for an important ore of the industrially useful metal. Columbite also called niobite; it is black to dark brown tabular or prismatic crystals. Columbite was confirmed by ESEM technique and contains (30%) Nb_2O_5, (21%) TaO, (2%) Y_2O_3, (1%) UO_2, (6%) ThO_2, (3%) Fe_2O_3 and (3%) ∑REEs. Nb_2O_5/TaO ratio equal to 1.4mol indicates enrichment in Ta (Figure 2d).

Xenotime (YPO_4)

Xenotime crystals are similar to zircon (carrier for heavy rare earth elements, HRREs) and can easily be confused with the duller luster.. It's color brown but also gray, with vitreous to resinous luster. The crystals are translucent to opaque. The EDX analyses give Y: P ratio equal 2.5:1 with amounts of HREEs (Figure 2e).The identified xenotime carrier for uranium mineral and depleted in thorium manifesting autogenetic origin.

Zircon ($ZrSiO_4$)

Zircon occurs in igneous rocks as primary crystallization product, in metamorphic rocks and sedimentary rocks as detrital grains. Zircon occurs as euhedral six-sided or eight-sided prismatic crystals. It is mainly colorless, pale yellow and violet. Also, some of the studied zircon grains show lengthening where a high fluid content causes the period of zircon crystallization to lengthen (Pupin et al., 1979). Zircon contains (41%) ZrO_2, (0.6%) Hf_2O_3, (57%) SiO_2 and (0.15%) UO_2 (Figure 2f).

Barite ($BaSO_4$)

Barite is the main ore of barium. Barite is isomorphous with celestite and may partially replace it. Barite color is variable but is commonly found as blue, green, yellow and red shades of tabular crystals. The high Ba contents (ranges from 2504 to 30 ppm) in the stream sediments reflect the occurrence of barite veins cross cut granitic rocks. The EDX analysis show, Ba: S ratio equal 1.1:1 (Figure 2g).

Atacamite [$Cu_2Cl(OH)_3$]

Atacamite is an unusual and attractive halide mineral. It is a secondary copper mineral formed through the oxidation of other copper minerals, especially in arid, saline conditions. Its color is dark green with vitreous luster. The crystals are transparent to translucent. The EDX analysis gives Cu: Cl ratio equal 3.1:1, with traces of P, Sn, S, V, Al, Si and Fe (Figure 2h).

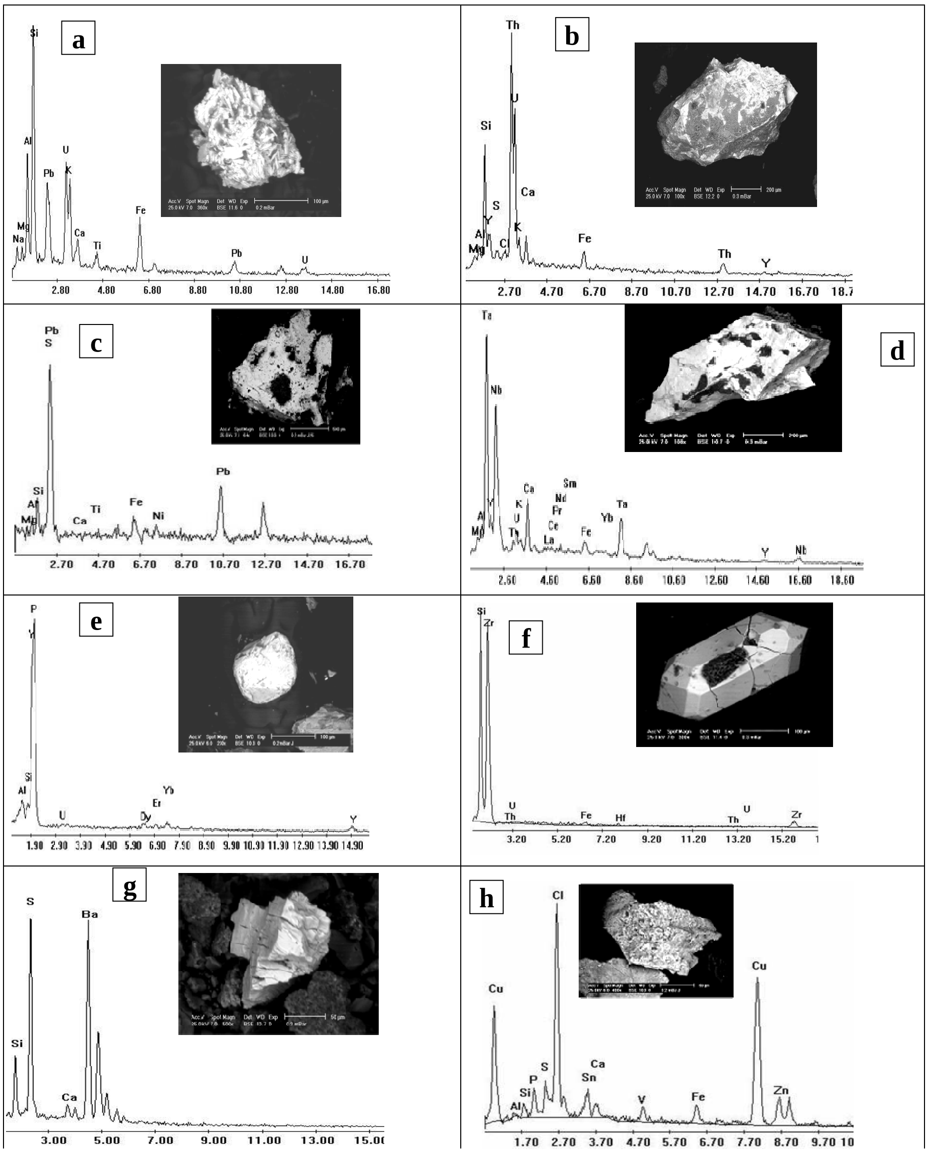

Figure 2. EDX and BSE image showing: a) kasolite b) uranothorite c)galena d) columbite e)xenotime f)zircon g)barite h)atacamite

Trace Elements

Samples No.1, 2 and 3 have abnormal contents of Zr and Sr (more than 1%)as well as Pb ,Nb, Y, , Zn, and Cr relative to the other samples. The downstream of the studied Wadis close to the Gulf of Al -Aqaba shows extraordinary anomalous contents in particular Zr, Pb, Sr, Nb, Y, Cr and Zn. The recorded values of Ni and Cr relatively in samples No.4, 5 and 6 are abnormal for the downstream sediments; such geochemical association favors the epithermal origin of the Pb –Zn mineralization. In addition, the variety of the members of Cr and Cu on one side and Nb and Y on the other side suggests that this epithermal solution originated from the granitic sources.
Regarding abnormal contents of Sr, celestite may be disseminated in the carbonate rocks or filling fractures favor the role of accumulation of Sr as veins after mobilization by hydrothermal solutions from the disseminated celestite.
The stream sediment samples at the downstream of W. Um Adawi (Figure 3) shows high U and Th (from 687 to 1 ppm and from 589 to 3 ppm respectively), Zr and Y contents (more than 1% and 2400- 3490 ppm respectively), manifesting the common presence of both zircon - xenotime minerals .The later usually carrier for heavy rare earth elements (HREEs) . Also, Pb contents in W. Um Adawi stream samples is also high ranging between about 1000 and 5000ppm ,suggesting the presence of galena mineral. Nb, varies between (1496-2165 ppm). Some samples in W. Um Adawi contain high Ba (1759- 2500 ppm) and Sr (more than 1%) clarify the presence of barite mineral .Cu element in some samples up to (297 ppm) may be indicator to the occurrence of atacamite mineral .
The high concentration of trace elements in the alluvial sediments, particularly the chalcophile ones; Zr, Sr, Ba, Y, Nb ,Pb, Zn, Cr and Cui are mainly due to the abundance of their host minerals- bearing of the country rocks in close vicinity with the studied sediments. Thus, this is indicating that the Quaternary sediments to be related to contribution either from the neighboring Miocene carbonate rocks (southeastern the mapped area) or from the basement rocks (hot granites).

Table 1. Trace elements result analyses of stream sediments, west of Gulf of Al -Aqaba, Sinai, Egypt

Sample No	Cr	Ni	Cu	Zn	Zr	Rb	Y	Ba	Pb	Sr	V	Nb
1	230	u.d	u.d	227	>10000	u.d	2424	553	3744	8643	63	1496
2	115	u.d	u.d	307	>10000	u.d	3491	824	5461	>10000	85	2165
3	244	u.d	u.d	262	>10000	u.d	3457	578	3959	>10000	65	2145
4	637	438	36	91	5093	11	392	227	1322	1444	47	236
5	650	470	44	71	82	25	7	255	2134	15	63	4
6	695	475	45	64	56	23	5	185	625	9	45	3
7	295	32	156	42	1040	26	81	266	1998	261	60	48
8	214	29	160	33	1162	11	90	224	2062	285	54	53
9	299	47	139	36	953	16	74	189	1423	235	47	44
10	637	178	297	100	1486	103	115	946	1459	377	164	68
11	288	50	166	47	1372	25	107	289	2299	360	61	63
12	387	97	200	72	1378	61	107	494	1897	362	84	63
13	249	31	85	41	430	44	34	95	417	121	20	20
14	100	13	60	32	63	28	5	30	2120	7	6	3
15	125	16	56	35	100	36	8	54	877	19	7	4
16	777	187	240	237	105	187	9	2504	941	4	354	4
17	671	176	226	188	425	153	34	1759	1875	95	273	20
18	702	161	198	207	176	150	14	2046	1782	38	287	8
19	171	13	64	111	312	127	24	154	1531	82	13	15
20	97	8	55	101	356	132	27	35	273	87	4	16
21	188	20	66	94	242	133	20	115	151	59	15	20
22	240	25	73	92	336	119	25	145	1049	85	21	15
23	114	10	55	87	634	155	49	41	1135	174	7	29
24	138	10	49	78	588	156	46	44	1624	156	5	27
25	195	62	73	295	156	153	13	765	u.d	34	96	7
26	129	48	48	269	205	123	17	539	u.d	45	64	9
27	163	40	46	253	1274	154	99	483	1236	355	57	59
28	114	11	56	21	244	24	20	200	381	61	11	11
29	80	25	45	21	253	14	21	201	u.d	62	11	11
30	63	8	41	22	224	27	18	379	1387	46	17	9
31	193	21	68	62	150	118	13	194	826	29	17	7
32	83	7	52	40	245	89	20	143	259	59	9	11
33	141	13	53	51	168	150	14	178	977	33	10	7

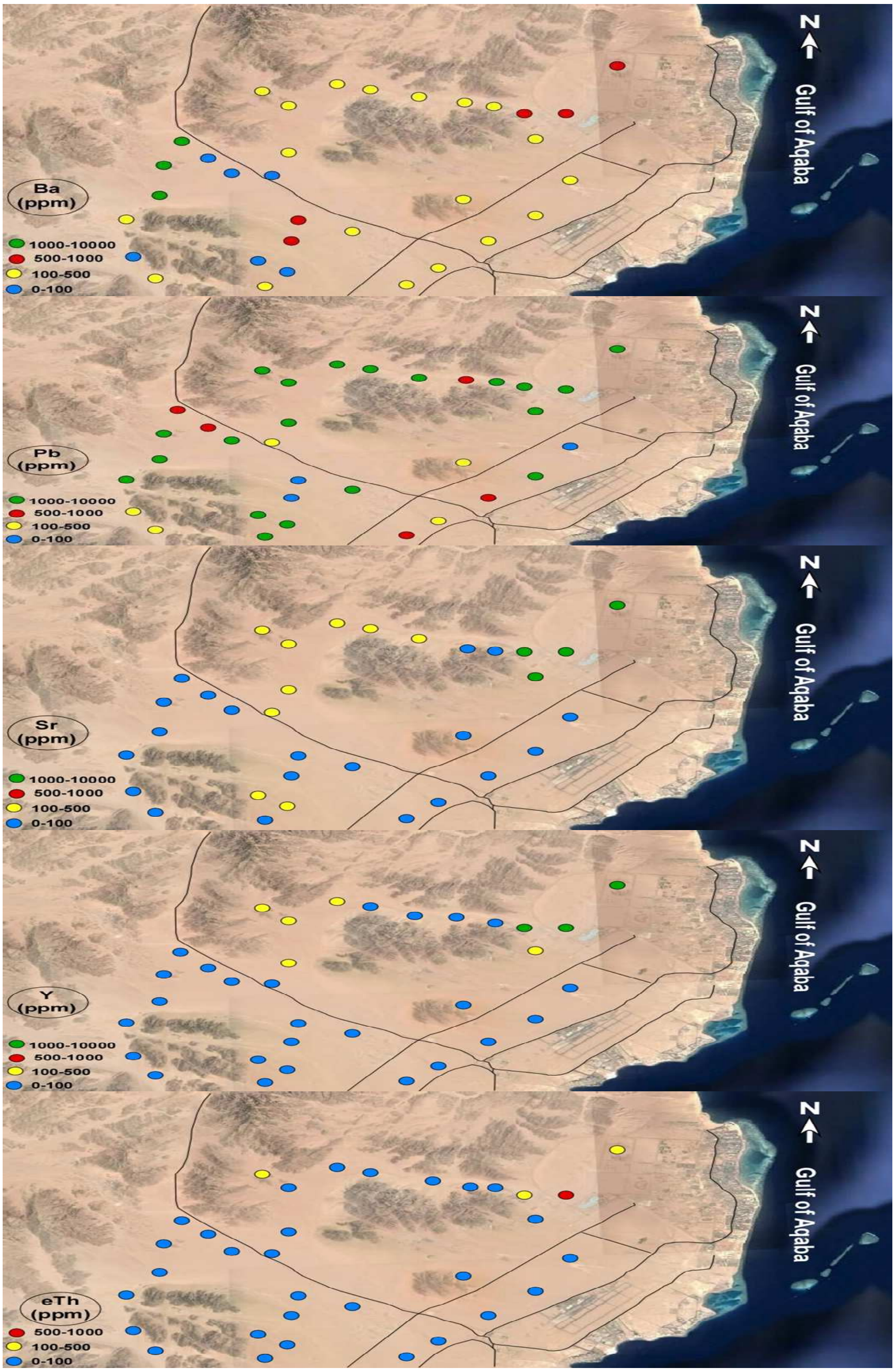

Figure 3. Showing the distribution of some trace elements; Ba, Pb, Sr, Y, eTh, eU, Zr and Nb in western part of Gulf Al-Aqaba

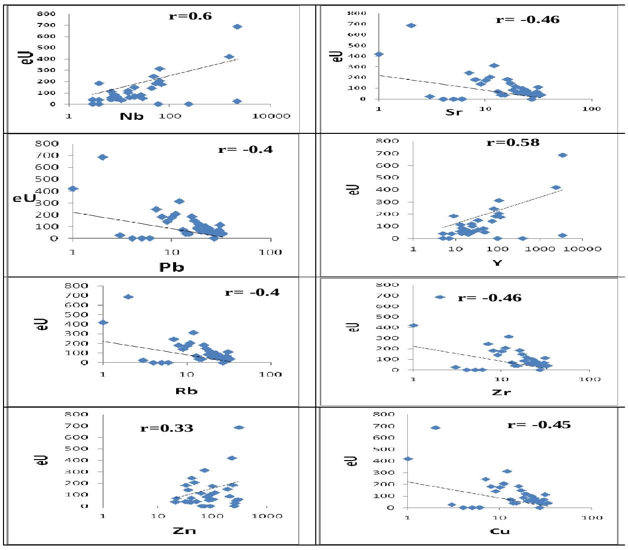

Figure 4. Showing the relation between eU versus Pb, Y, Rb, Zr, Zn and Cu

RADIOMETRIC RESULTS

Table 2. Showing results of radiometric analyses of 33 streams sediment samples at west of Gulf Al-Aqaba, Sinai, Egypt

Sample No.	eU(ppm)	eTh(ppm)	Ra(ppm)	K%	eU/eTh	eTh/eU
1	420	456	839	ULD	0.92	1.09
2	687	589	913	0.37	1.17	0.86
3	25	390	599	ULD	0.06	15.6
4	ULD	ULD	5	3.17	ULD	ULD
5	ULD	4	3	0.75	ULD	ULD
6	1	3	1	0.32	0.33	3
7	245	38	175	2.03	6.45	0.16
8	182	82	159	ULD	2.22	0.45
9	141	53	130	ULD	2.66	0.38
10	175	64	309	4.48	2.73	0.37
11	206	126	189	ULD	1.64	0.61
12	313	83	280	ULD	3.77	0.27
13	70	9	34	4.07	7.78	0.13
14	39	18	23	0.92	2.17	0.46
15	38	15	23	1.62	2.53	0.40
16	184	ULD	166	3.4	ULD	ULD
17	148	42	159	1.52	3.52	0.28
18	85	20	85	2.85	4.25	0.24
19	118	ULD	55	1.89	ULD	ULD
20	58	24	42	3.08	2.42	0.41
21	62	21	46	2.82	2.95	0.34
22	100	32	106	6.86	3.13	0.32
23	51	76	80	3.8	0.67	1.49
24	81	34	88	2.63	2.38	0.42
25	58	ULD	55	1.84	ULD	ULD
26	46	27	42	2.45	1.70	0.59
27	ULD	30	39	0.98	ULD	ULD
28	36	77	31	1.94	0.47	2.14
29	38	74	23	0.11	0.51	1.95
30	68	110	52	ULD	0.62	1.62
31	112	40	29	1.63	2.8	0.36
32	34	46	27	1.87	0.74	1.35
33	40	43	27	3.64	0.93	1.08

The eU contents in the stream sediments samples range from 34 -245ppm ,whereas the eTh content ranges from 3-589 ppm, eU/ eTh ratios are mainly more than 0.4 revealing the enrichments of eU over eTh . Figure (5 and 6) shows eU has strong positive with eTh and Ra. The eU shows positive moderately correlation with Nb and Y, and weakly with Zn. On the other hand, the eU shows weakly negative correlation with Sr, Pb, Rb, Zr and Cu(Figure 4) .

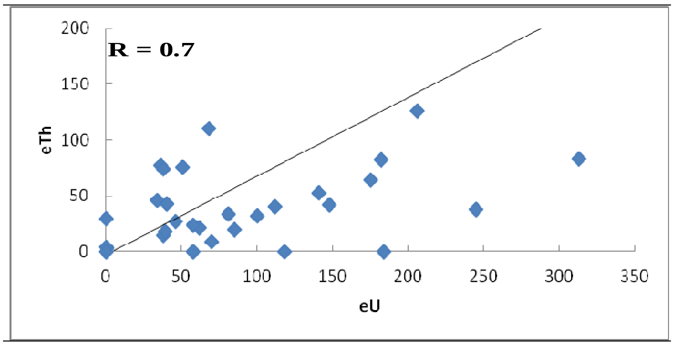

Figure 5. Binary relation between eTh and eU

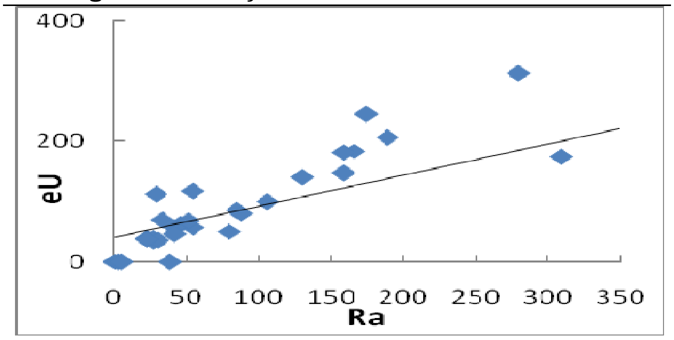

Figure 6. Binary relation between eU and Ra

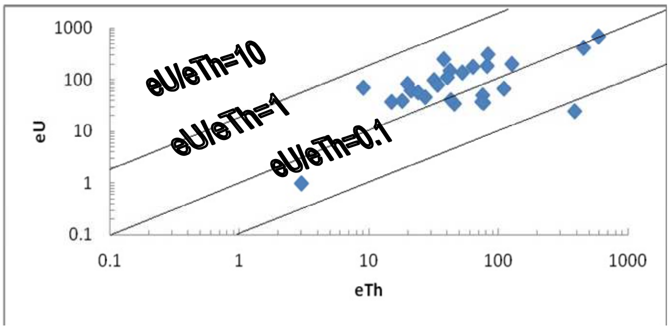

Figure 7. Binary relation between eU and eTh

While eTh over eU ratios are mainly less than the Clarks value (3-4) which predict the enrichment of U

CONCLUSIONS

The study area is located westward of Gulf of Al-Aqaba coast, Sinai, Egypt. The Quaternary deposits along the Wadis courses considered as a favorable accumulators for certain base-metals mineralization that widely used in the commercial and industrial applications. This means that the studied areas are significantly enriched in a suite of trace elements, notably the chalcophile elements; Zr, Y, Nb, Sr, Ba, Th, U, Pb, Zn and Cr. These metals exhibiting a wide variations and can be occurred mainly as native aggregates.

The mineralogical study reveals five groups. The first group includes secondary uranium mineral; kasolite. The second group contains; Th-bearing mineral as uranothorite. The third one include base metal as galena. The fourth group includes accessory minerals; columbite, xenotime and zircon. The last group contains supergene sulfide minerals; barite and atacamite, beside hematite and goethite may reflect that the sediments have been subjected to the extensive alteration.

Thus, the identified base metals suggesting that the Quaternary sediments seem to be related to contribution from the surrounding country rocks; uraniferous younger granites and the mafic basement rocks. Actually, the numerous trace elements in the study area may be due to the nature of the drained area from which they leached through the supergene processes, particularly the chemical weathering and the acidic meteoric water. The origin of uranium appears to be closely associated with Zn, Nb and Y mineralization and may be reflects their intimate coherence.

This result is consistent with the conclusion reported by Hassan (1990 and 2002), Ramadan et al., (1999), Ibrahim and Afifi, (2007) and Hassan and Zaki ,(2010), during their studies on the stream sediments, south El Quseir City , Red Sea coast.

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