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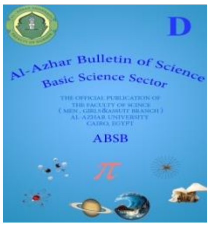

MINERALOGICAL STUDIES AND RADIOACTIVITY OF WADI STEIH STREAM SEDIMENTS, SOUTH SINAI, EGYPT.

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ABSTRACT

Wadi Steih stream sediments are generally produced from long term successive physical and/or chemical weathering and consequence erosion processes of the surrounding rock units such as younger granites, Iqna volcanics and gabbro. The representative diagrams of the plotting of the average trace element contents versus those of the surrounding rock units along with the Co/Th ratio indicate that the trace elements recorded in the Wadi Steih stream sediments are derived from the surrounding rock units. The radiometric surveying indicates the over dominance of thorium rather than uranium. The thorium content ranges from 4.4 ppm to 335 ppm with an average of 62.5 ppm. Uranium content ranges from 2 ppm to 15 ppm with an average 6.2 ppm. The high thorium contents of these stream sediments are generally ascribed to the presence of monazite, zircon and huttonite. These minerals are trapped by widespread basic dykes that act as physical barriers. The source of uranium present in the stream sediments is ascribed, in part, to its mobility from the surrounding uraniferous younger granites and its adsorption along the grain boundaries of the clay minerals which are originated from the weathering processes acting on the basic dykes where uranium is ultimately adsorbed along their boundaries. The other probable source of uranium is the presence of secondary lead uranyl hydroxide mineral spriggite. The distribution of the radioelements of Wadi Steih stream sediments is mainly controlled by the presence of both basic dykes which are acting as physical barrier and the prevailed NW-SE drainage patterns.

Keywords: Stream sediments; Mineralogy; Radioactivity; Wadi Steih; South Sinai.

1. INTRODUCTION

Wadi (W.) Steih is a major tributary of W. El Ager, which is one of the main Wadis of the southwestern Sinai of Egypt. It located between latitudes 33°40′-33°48′N and longitudes 28°45′-28°53′E (Fig.1). Wadi Steih is considered as a semi closed basin as it has only one outlet at its western tip, while the other parts of this Wadi collect floods from the internal tributaries along granites and other rock types. The Precambrian rocks of Sinai are generally dissected by dry valleys that are filled with a wide variety of stream sediments.

Stream sediments are generally produced from long term successive physical and/or chemical weathering and consequence erosion processes. The loosed materials are then transported by wind and/or water to deposit later within tributaries and drainages which draining finally in the wadis to form stream sediments. These stream sediments may transport for short and/or long distances away from their sources. However, stream sediments are generally containing valuable and precious metals such as gold, silver, uranium, etc. Wadi Steih area is completely surrounded by Precambrian basement rocks that mainly represented by younger granites (syenogranite) along with minor volcanic and gabbroic intrusions [1,10].

The present work is aimed to study the mineralogy and radioactivity of Wadi Steih stream sediments.

2. Regional Geology:

The southern part of Sinai Peninsula constitutes the northern-most segment of the Precambrian Arabo-Nubian Shield which extends over an area of about two million square kilometers of both sides of the Red Sea. This Shield consists of several lithostratigraphic units affected by metamorphic events and plutonic intrusions in several cycles which took place from Ca. 1100 to 540 Ma. The late Precambrian rocks of Sinai cover about 20.000 km^2 out of about 61.000 km^2, of the total area of the Sinai Peninsula [1]. These rocks comprise a suite of metamorphic, plutonic and volcanic types.

Wadi Steih environ is covered with a suite of intrusive and extrusive rock units include older granite, gabbro, porphyritic rhyolite and rarely rhyodacite, monzogranite, quartz syenite and syenogranite (Fig. 1).

The gabbroic rocks are exposed at the NW corner of the studied area as two limited intrusions within the older granites. They classified as hornblende pyroxene younger gabbro [1,2].

The granitic rocks in Wadi Steih environ are classified into older and younger granites [1]. The older granites are exposed along the outer peripheries of the area (Fig.1) and contain gabbroic xenoliths of variable sizes and shapes (Fig.2). These older granites are distinguished as orogenic I-type, subduction related granites originated from calc-alkaline magma that emplaced within volcanic-arc tectonic environment [3,4].

The authors (op.cit) concluded that the younger granites in the studied area are anorogenic A-type granites originated from peraluminous magma that emplaced in within – plate tectonic environment. The younger granites of Sinai, in general, and Wadi Steih environ, in particular, are classified as syeno-, and monzogranites [1, 3, 5- 8, 9, 10- 12, 13-16] which are corresponding to phase II and phase III of the Egyptian younger granites recognized by [17].

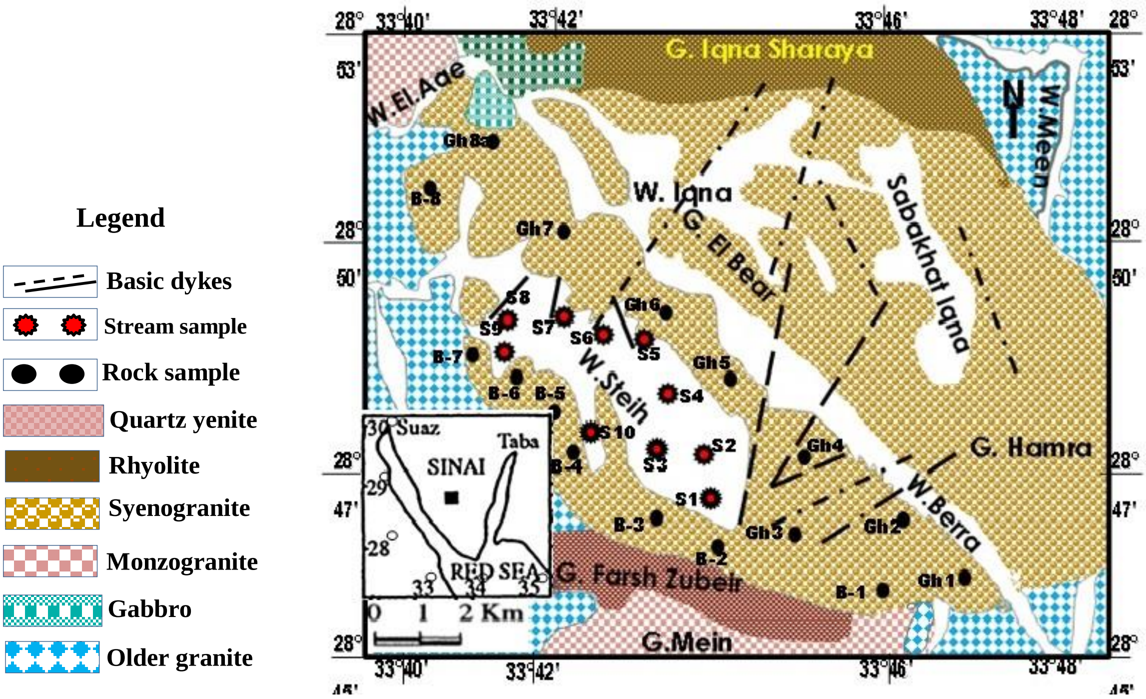


Fig. (1). Location and geologic maps of Wadi Steih area south Sinai, Egypt. Note:Gh= Rock samples collected from southern side of W. Steih. B= Rock samples collected from eastern and northern sides of W. Steih.

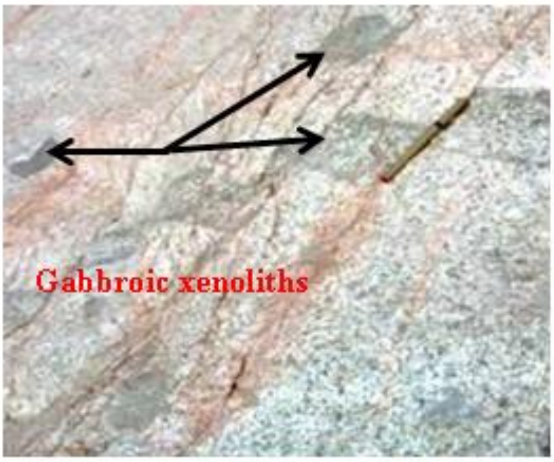


Fig. (2). Gabbroic xenoliths are enclaved by the older granites of Wadi Steih environ.

The volcanic rocks are well exposed at Gabal Iqna Sharayi,a. These volcanics are distinguished as anorogenic, within-plate originated from alkaline magma and seems to be belonging to the alkaline volcanic complex that similar to the Katharina province [1, 2, 18, 19, 20, 21, 22]. These volcanics are classified into rhyolite and rhyodacite varieties. They intruding the monzogranites and sharply intruded by the syenogranites (Fig. 3A & B).

The quartz syenite is only outcropped as elongated strip on Farsh Zubeir that located on the southern side of the area (Fig.1).

The morphology of the drainage pattern of Wadi Steih (Fig.4) indicates that these drainages are crossing and cross-cutting the surrounding rock units and extending to the far east at Wadi Barrah and Wadi Iqna. Although most of these drainages are running in NW-SE direction, the NE-SW and NNE-SSW drainages are also represented. So, the stream sediments filling Wadi Steih are suggested to be formed as a result of successive weathering and erosion processes acting on the surrounding rocks such as gabbro, volcanics and younger granites.

3. Methodology:

In order to study the distribution of the radioelements in Wadi Steih stream sediments, a grid pattern was constructed on the plain of the wadi along six profiles with some selected random measurements. The intensity of radioactivity of 54 stations is measured using the multichannel spectrometer model Gs-512 manufactured by Geofyzika Brno-Czech Republic. It measures the gamma rays as total radiation counts (Tc), equivalent uranium (eU ppm), equivalent thorium (eTh ppm) and 40K%. Twenty-six bulk samples (16 granites and 10 stream sediments) are selected for trace elements analyses. Ten representative stream sediment samples were collected to identify their U&Th-bearing minerals as well as other minerals. The stream sediment samples are crushed using the jaw crushers and sieved using (60-30 mesh) sieves. Separation was conducted using bromoform (specific gravity = 2.82gm/cm3) and methylene iodide (specific gravity = 3.325gm/cm3) and magnetic fractionation using a Frantz Isodynamic Magnetic Separator (Model L-1). The obtained fractions were carefully handpicked using the Binocular Stereomicroscope. The picked grains are examined at the laboratory of the Nuclear

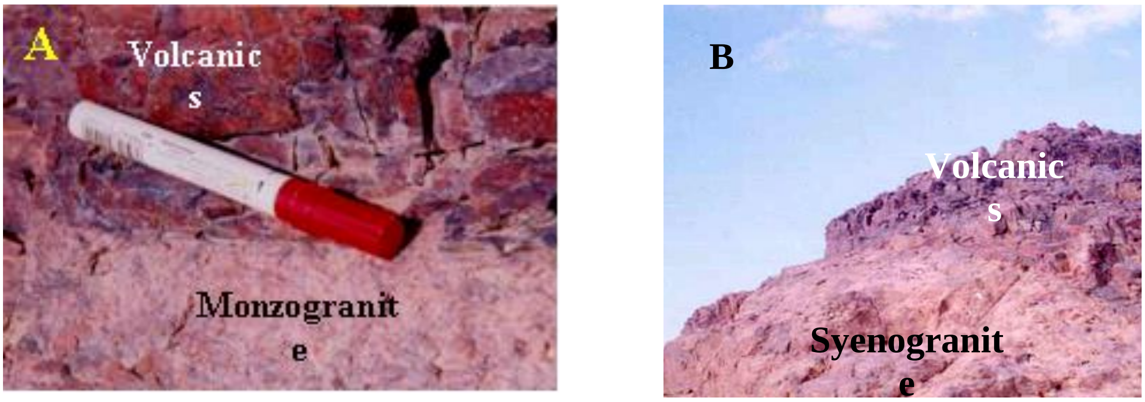


Fig. (3). A: Sharp contact between monzogranite and volcanic. B: sharp contact between syenogranite and volcanic, Wadi Steih environ.

Materials Authority (NMA) using X-ray diffraction technique and Environmental Scanning Electron Microscope (ESEM). A Phillips X-ray diffractometer (Model PW-1010) with a scintillation counter (Model PW-25623/00) and Ni filter. ESEM supported by energy dispersive spectrometer (EDS) unit (model Philips XL 30 ESEM). The trace elements were determined by XRF techniques on pressed powder pellets. All these studies were carried out in the Laboratories of the Egyptian Nuclear Materials Authority (NMA), Qattamiya city, Cairo.

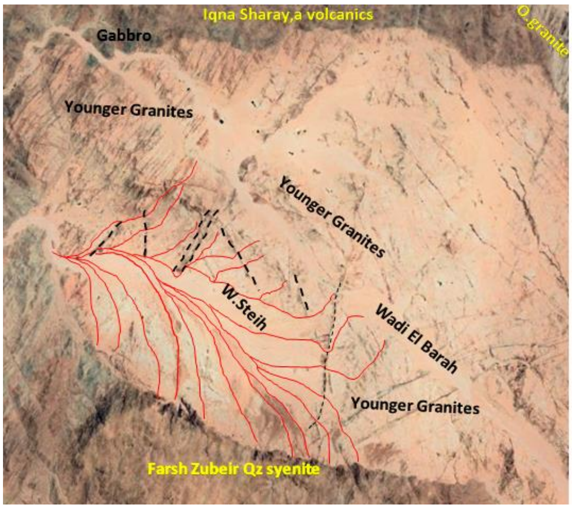


Fig. (4). Shows the drainage pattern of the studied Wadi Steih.

4. RESULTS AND DISCUSSION:

4.1. Trace elements studies of Wadi Steih stream sediments and the surrounding rocks:

The trace elements analyses of Wadi Steih stream sediments and the surrounding rocks units such as younger granites are presented in tables (1and 2) and studied to unravel the distribution issue and the source of these trace elements. The average of the analyzed trace elements of other surrounding rock units [23,24] is presented in table (3).

4.2. Source of the trace elements of Wadi Steih stream sediments:

Generally, trace elements can be found in stream sediments as major elements in trace minerals, as trace constituents of primary rock-forming minerals or minerals formed during weathering, as ions adsorbed on colloidal particles or in the lattices of clays, and in combination with organic matter [25]. However, the trace elements contained within the lattice of rock-forming minerals and within minerals formed during weathering probably make up the greatest proportion of the background variation in most stream sediments.

The intensity and distance of transportation from the source and the topographical suitability of the sites for deposition are among the main

Table 1: Trace elements (ppm) analyses of the stream sediments, Wadi Steih.

Elem/S.No.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Average
Ba	316	270	280	220	240	180	260	225	240	310	254.1
Rb	332	280	165	183	195	201	361	121	240	268	234.6
Sr	190	180	200	135	155	175	165	170	145	135	165
Ga	12	16	18	13	11	14	15	17	10	9	13.5
Nb	33	31	26	24	16	19	30	25	28	24	25.6
Zr	146	200	741	90	213	577	145	40	679	118	294.9
Y	54	45	120	38	59	130	75	67	40	30	65.8
Cr	26	24	43	29	37	28	24	25	33	40	30.9
Ni	12	17	21	13	17	23	12	13	20	14	16.2
Co	12	16	31	13	16	27	12	11	25	13	17.6
V	29	52	230	40	53	166	29	25	148	37	80.9
Cu	65	66	61	69	70	62	61	77	60	67	65.8
Zn	61	77	125	90	78	122	65	54	105	61	83.8
Pb	28	24	41	22	49	26	49	20	23	37	31.9
Total	1316	1298	1822	759	969	1570	1043	665	1556	853	1380.6

factors control the depositional regime of these sediments [26]. Accordingly, the trace element contents of the stream sediments of Wadi Steih are also expecting to be driven from the successive weathering and erosion processes acting on the surrounding rock units.

The average trace elements contents of these studied surrounding rocks are plotting separately versus those contained in the stream sediments (Figs. 5, 6, 7, 8, and 9). The distribution of some trace elements in the stream sediments is strongly controlled by some specific rock units. For example, Zn is strongly controlled by the occurrence of gabbro while Co and Ni are relatively controlled by its presence (Fig.5). Also, the distribution of Nb, Pb, Sr and Ga is controlled by the younger granites e.g. Iqna syenogranite and south Steih granite (Iq.Sgr and S.Gr respectively) (Fig. 6 and 7). The Ga content in both Iqna rhyolite and stream sediments shows very little difference, so, its distribution may be controlled to a lesser extent by the Iqna rhyolite (Fig. 8).

Table 2: Trace elements (ppm) analyses of the granitic rocks along the eastern and northern sides (B-1 to B-8) and the southern side (Gh-1 to Gh-8) of W. Steih.

	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	Av.	Gh1	Gh2	Gh3	Gh4	Gh5	Gh6	Gh7	Gh8	Av.
Zr	110	112	99	111	115	105	114	113	110	55	60	80	90	75	90	106	92	81
Y	34	19	35	32	20	25	30	34	28.6	22	26	20	18	24	21	16	8	19.4
Sm	80	90	40	50	70	60	65	55	63.7	20	19	28	21	23	190	42	26	46.1
Rb	220	170	200	180	190	210	215	175	195	150	200	210	180	220	155	170	150	17.9
Nb	16	15	13	14	12	17	16	13	14.5	42	18	20	15	21	19	24	18	22.1
Cu	30	28	25	40	50	45	35	32	35.6	12	14	15	11	20	24	65	80	30.1
Pb	50	45	48	30	44	35	47	38	42.1	160	65	220	140	135	275	270	225	186
Ba	80	250	90	95	200	230	240	220	176	35	30	68	45	35	110	115	100	176
Sr	255	87	17	15	209	99	150	60	112	200	80	20	22	190	100	155	65	104
Ga	22	17	13	19	17	20	16	14	17.3	20	18	14	17	16	21	15	16	17.1
Cr	9	7	10	8	11	10	9	7	8.88	10	8	9	7	8	11	6	8	8.88
Ni	5	6	4	5	4	7	6	4	5.13	6	5	7	6	6	5	7	6	5.13
Co	7	6	4	3	4	5	6	7	5.25	6	7	5	4	3	6	5	3	5.25
V	37	6	4	2	14	22	20	7	14	30	7	6	5	12	20	24	9	14
Zn	74	47	37	21	63	50	40	33	45.6	70	40	30	20	60	55	44	34	44.1
U	18	15	19	20	22	17	16	21	18.5	15	12	14	13	12	15	16	14	13.9
Th	34	36	33	29	30	32	28	31	31.6	30	26	24	32	29	33	31	28	29.1

Table 3: Averages of trace elements (ppm) contents of the studied stream sediments and all surrounding rock units of Wadi Steih environ.

	Stream	E&N.Gr.	S. Gr.	IQSG*	IQ.Rhyo**	Gabbro***	A. All rocks in the studied area
Ba	254.1	176	67.25	597.5	896.17	88.5	434.14
Rb	234.6	195	179	160.7	107.8	71	160.7
Sr	165	112	104	167.3	206.17	549	147.25
Ga	13.5	17.3	17.1	19.5	17.17		17.76
Nb	25.6	14.5	22.1	27.2	46.5	15	27.6
Zr	294.9	110	81	232.7	162.8	182.9	45.1
Y	65.8	28.6	19.4	232.7	52.3	37	83.25
Cr	30.9	8.88	8.38	9.5	12.67	158	9.85
Ni	16.2	5.13	6	4.8	5.8	39	5.44
Co	17.6	5.25	4.875	4.3	6.	43.7	5.2
V	80.9	14	14.13	13.3	40.83	161	20.57
Cu	65.8	35.6	30.1	11.8	22		24.89
Zn	83.8	45.6	44.1	59.3	68.137	86.7	54.31
Pb	31.9	42.1	186	32	46.5		76.72

E&N.Gr.=Eastern and northern side granite; S. Gr.= Southern side granite; *IQSG=Iqna Sharay·a syenogranite;* IQ.Rhy= *Iqna Sharay·a rhyolite;* A. All rocks= *average of all surrounding rocks*
*(Ghonim et.al.2009); **(Ghonim et.al.2009); *** Azer and El-Gharbawy (2011)

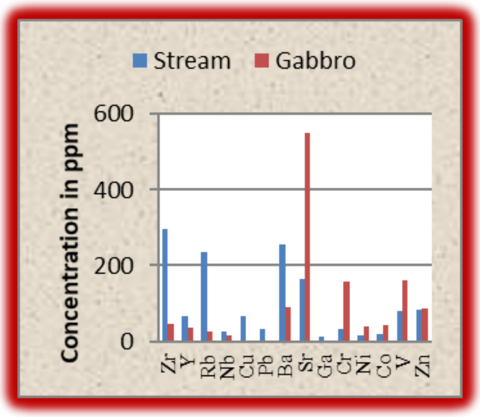


Fig. (5). Distribution of Zn, Ni and Co in the studied gabbro at Wadi Steih, Sinai.

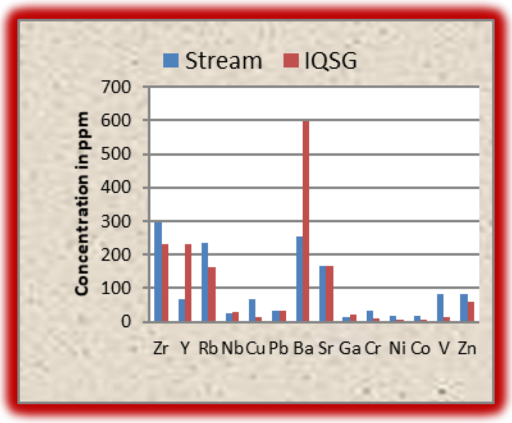


Fig. (6). Iqna syenogranite controls the distribution of Nb,Pb, Sr and Ga in Wadi Steih, Sinai.

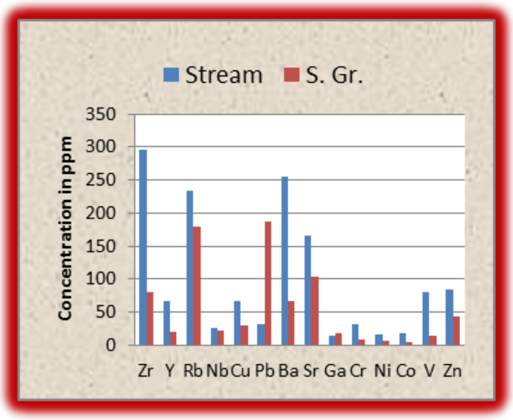


Fig. (7). South Steih younger granite controls the distribution of Ga in Wadi Steih, Sinai.

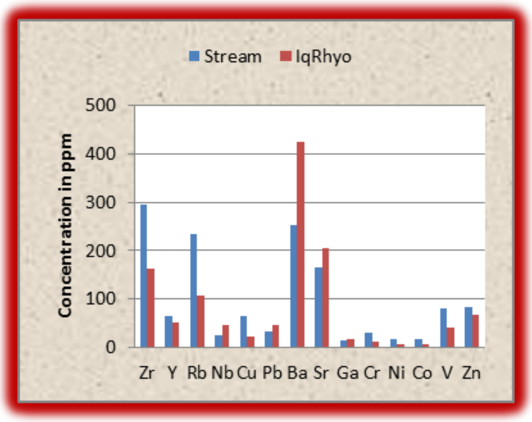


Fig. (8). Iqna rhyolite relatively controls the distribution of Ga in Wadi Steih, Sinai.

It seems to be that the distribution of the trace elements in Wadi Steih stream sediments is controlling by the weathering processes acting on all its surrounding rock units (Fig.9). The stream sediments are significantly enriched in each of Zr and Rb and slightly enriched in Cu, V and Zn. Some of these elements have higher values compared with Clarke values [27,28] but lower than those reported by [29] for Wadi Reddah in the Eastern Desert of Egypt (Table 4). The high content of Zr in mainly attributed to the presence of zircon which is widely distributed in stream sediments. The rules of trace element distribution in igneous processes predict that Rb should replace K. Rubidium forms no mineral of its own, being always incorporated in potassic minerals; in granitic rocks it is in muscovite, biotite, and K-feldspar [30]. Since the studied stream sediments are enriched in the previously mentioned potassic minerals, the studied stream sediments were expected to be enriched in Rb.

Some elements and particularly their ratios are useful indicators of the provenance as they are least affected by different processes such as weathering, transporting and sorting. In particular, the immobile elements, such as Th, Sc, Co, Cr and REEs and their ratios have been found to be useful for provenance studies. These elements have short residence in water and therefore, are almost quantitatively transferred to the sediments [31].

The Co/Th ratio is used to discriminate between the provenance of the trace elements in the stream sediments wither they are derived from felsic and/or mafic source rocks [32] since thorium is generally concentrated in felsic rocks such as granite while cobalt is enriched in mafic rocks. The lower Co/Th values suggest that the source rock is felsic [op.cit].

Table 4: Average values for some elements in the studied stream sediments compared with those of Clarke values for the indicator elements in stream sediments, Gromet, et. al.(1984), El Mezayen, et. al.(2017) and Mira et al. (2020)

Element	Clarke values	The studied stream sediments	Stream sediment of W.Reddah (Mira et al. (2020)	El Mezayen, et. al.(2017)	Gromet, et. al.(1984)
Zr	200	294.9	471	225	125
Rb	80	234.6	262	114	35
Nb	10	25.6	167	10.3	13
Zn	25	83.8	133	85	200
Y	18	65.8	514	17.5	

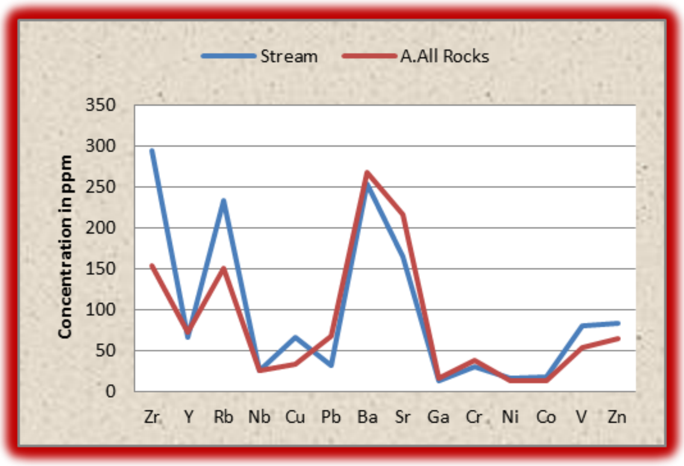


Fig. (9). Trace element distribution is controlled by the weathering processes affecting all rock units, Wadi Steih, Sinai

The studied stream sediments have an average of cobalt content 17.6 ppm (Table 5) while the average of thorium content is 63 ppm. Co/Th ratio (0.28) revealed that the probable source of the trace elements present in the studied stream sediments is the felsic rock such as the younger granite and the rhyolite. However, the potentiality of the mafic source is not negligible and also expected since these stream sediments are also containing considerable proportion of elements such as Ni, Co, Zn and V. These elements are essential trace elements in mafic rocks.

4.3. Radioelements distribution in Wadi Steih stream sediments:

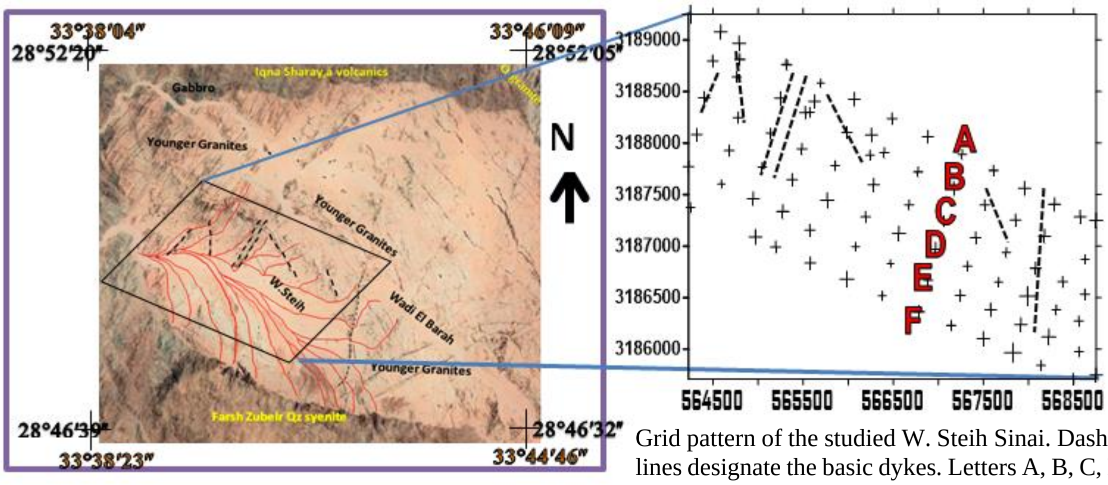
Stream sediments, in general, especially those having granitic constituents are found to be radioactive [1,33-36]. Wadi Steih stream sediments are chosen in particular to study the radioelement distribution because they are surrounding by fertile uraniferous granite [1]. The surrounding granites contain more than twice the Clarke value for uranium (> 8 ppm U) as mention by [1] (Tables (2 and 5).

For studying the radioelements distribution of Wadi Steih stream sediments, a grid pattern is constructed along six profiles, designated by letters from A to F, in addition to some random measurements (Fig.10). The obtained data (Table 5) showed that eU ranges from 2 to 15 ppm with an average 6.2 ppm whereas eTh ranges from 4.4 to 335 ppm with an average 62.53 ppm.

The radiometric contour maps that representing the distribution of the radioelements in the studied stream sediments (Figs.11, 12, 13 and 14) revealed the presence of three main concentrations. Two of them localized along the NNE-SSW and NE-SW directions while the third concomitant with the NW-SE direction.

Table 5: Radiometric measurements of Wadi Steih stream sediments

S.N	Total	K%	eU	eTh	S.N	Total	K%	eU	eTh
1	62.2	3.1	7	86.2	28	49.9	3.4	8.1	56.8
2	201.4	2.4	4.8	355.8	29	42.1	3.7	5.8	48.9
3	44.5	3.9	3.4	44.7	30	28.8	1	1.7	50.6
4	42.4	2.8	15.00	49.8	31	105.9	2	5.8	169.2
5	38.4	4.6	3.2	41	32	121.2	5.4	9.4	178.4
6	39.7	3.9	9	30.4	33	184.8	5	8.3	288.4
7	47.9	3.8	10.9	54.5	34	113.1	4.6	9.5	150.6
8	34.1	3.7	3.8	33.7	35	33.3	4.2	5.3	26.3
9	47.3	3.2	8.4	47.3	36	49.2	3.2	9.3	53.8
10	37.6	4.3	3.8	29	37	43.7	4	3.4	46.9
11	36.9	5.3	6.6	24	38	39.1	4	4.1	39.5
12	45	4.9	7.4	37	39	34.8	4.1	6.1	25.5
13	20	3.7	3.1	4.4	40	27.1	3.1	4.7	21.1
14	39.2	3.5	14	23.5	41	49	3.1	7.6	67.1
15	28.9	3.8	2.4	18.4	42	38.6	4.1	8.2	31.9
16	34.7	4.4	5.4	21.9	43	74.3	3.9	13.7	89.5
17	32.1	4.5	3.5	22	45	109.9	4.6	4.2	157.5
18	37.4	5	2.2	30.9	46	96.7	5.7	3.8	128.9
19	38	3.5	4.6	30	47	148.6	4.2	7.4	234.2
20	39	4.2	3.8	38.8	48	68.8	4.2	10	83.1
21	40.2	5	10.8	23	49	48.5	4.7	8.1	47.3
22	28.6	3.8	6.2	16.7	50	42.4	4.6	7.9	24.6
23	26.2	4.1	3	18.3	51	46.8	3.5	8.1	42.2
24	33.1	4.7	0.3	25.9	52	34.2	3.9	7.1	27.6
25	31.9	3	6.2	25.5	53	39	3.4	1.2	42.6
26	31.8	4.4	2	22.8	54	37.1	4	5.9	30.6
27	49	4.3	3.1	52					
Average				Total	K%	eU	eTh		
				54.10	3.97	6.2	62.53		



Grid pattern of the studied W. Steih Sinai. Dashed lines designate the basic dykes. Letters A, B, C, D, E and F mark the profile numbers.

Figure (10): Shows the area selected for spectrometric surveying

The total counts intensity (Fig.11) follow three main maxima, two of them trend in NNE-SSW while the third trends NW-SE. The distribution of Potassium[40] (Fig.12) has three main trends NNE-SSW, NE-SW and NW-SE. Uranium distribution is shown in figure (13) where it coincides with four main directions. Two of them follow the NNE-SSW direction while the other two coincide with the NE-SW trend. The behavior of thorium (Fig.14) follows three main directions locating mainly in NNE-SSW, NE-SW and ENE-WSW trends.

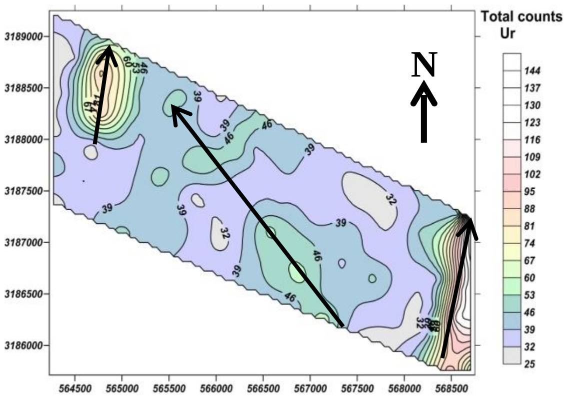


Figure (11): Shows the spectrometric contour map for total counts

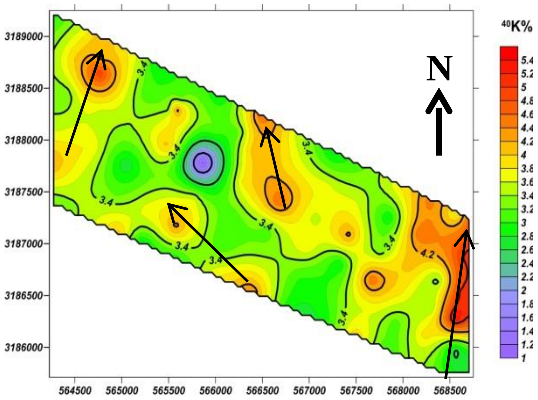


Figure (12): Shows the spectrometric contour map for Potassium

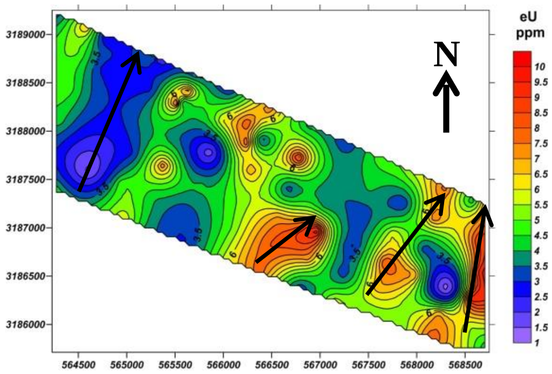


Figure (13): Shows the radiometric contour map for eU

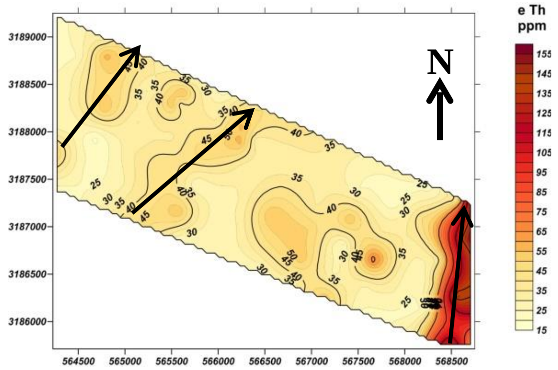


Figure (14): Shows the radiometric contour map for eTh.

Several basic dykes are trending in NNE-SSW, NE-SW and NW-SE directions (Fig.1&10) along the studied Wadi Steih and the stream filled-tributaries has mostly NW-SE direction (Fig. 10). The studied radioelements in Wadi Steih stream sediments may be controlled by the occurrence of basic dykes and some stream filled-tributaries. Basic dykes are generally acting as physical traps for radioelements. These dykes may be altered due to the effect of CO2-bearing meteoric water which is considered as an effective alteration source acted on the basic dykes leading to the development of carbonates, iron oxides, especially hematite, and clay minerals. The uranium that leached from the surrounding granitic rocks is generally transported and concentrated along the basic dykes since it can be adsorbed along the grain boundaries of the resulted clay minerals. Thorium is generally incorporated in U& Th- bearing accessory minerals such as monazite, zircon and the thorium oxide-bearing-mineral huttonite [37,38]. These minerals are transported with the weathering products resulted from the weathering processes acting on the surrounding rock units. These minerals are ultimately deposited along the upstream side of the basic dykes. The highly anomalous thorium spots are suggested to be due to the Th-bearing aforementioned minerals. The role of basic dykes as physical traps for radioelements is also mentioned by [3] when he studied the uranium potentiality to the west of the studied area, at Wadi Seih area, south Sinai.

4.4. Mineralogical studies of Wadi Steih stream sediments:

The anomalous radioactive stream sediment samples are chosen for XRD and SEM studies. The obtained results show the presence of U&Th- bearing minerals such as huttonite, zircon and monazite. Also, secondary lead uranyl hydroxide uranium mineral (spriggite) as well as the REEs-bearing mineral gadolinite are recorded. The following is a brief description of each mineral.

4.4. a: Huttonite : (ThSiO4)

Huttonite is a thorium nesosilicate mineral with the chemical formula $ThSiO_4$. [37,38] mentioned that the mineral was first identified in 1950 in samples of beach sands from the West Coast region of New Zealand by the mineralogist Colin Osborne Hutton (1910–1971). The mineral is dimorphous with tetragonal thorite, and isostructual with monazite.

In the studied stream sediments, the examined hand-picked grains of heavy minerals are investigated using the XRD and Environmental Scanning Electron Microscope (ESEM) techniques where the data obtained proved the presence of thorium silicate mineral huttonite (Fig. 15).

The probable source of the recorded huttonite mineral in the studied stream sediment is suggested to be the surrounding Iqna volcanics, the younger granites and the pegmatite. Iqna volcanics were studied by [1] where he mentioned that these volcanics contain several miarolitic cavities filled with pale yellow aggregates. Huttonite is recorded worldwide in several rock types as for example in the miarolitic cavity [39] and associated with monazite and xenotime in the fractionated A-type granites [41], and in the granitic pegmatite dykes [42].

4.4. b:Monazite-(La): [(Ce, La, Nd, Th) PO4

Monazite- (La) is one of the most important nuclear minerals, being a major host for REEs and actinides Th and U [43-45]. It is widely disseminated in granitic rocks and schistose metamorphic rocks as well as the detrital sediments and typically associated with zircon and sphene.

In the present study, the recorded monazite-(La) occurs as rounded to oval form ranging in color from colorless to pale yellow with vitreous luster. The monazite grain is examined using XRD technique (Fig.16).

4.4. c: Zircon ($ZrSiO_4$):

Zircon is a common accessory mineral present in the igneous rocks, particularly in the plutonic rocks and especially those rich in sodium. It is generally present as small early formed crystals often enclosed in later minerals, but may form large well developed crystals in granite pegmatites and particularly in those of

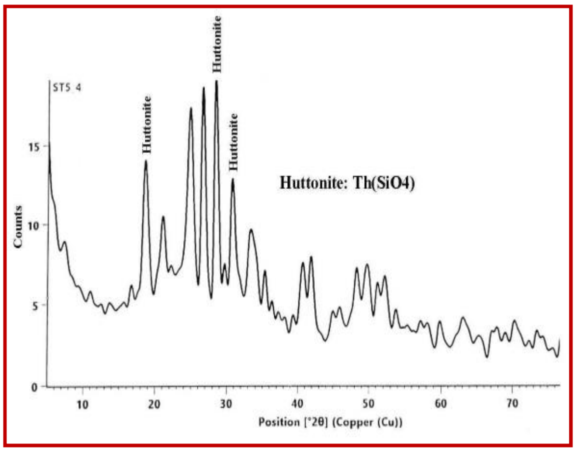


Figure (15): Shows X-ray pattern of the Huttonite mineral.

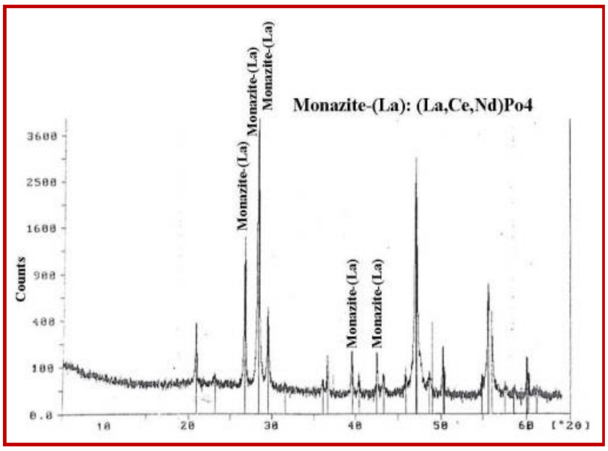


Figure (16): Shows X-ray pattern of the monazite-(La) mineral nepheline-syenite [46]. In metamorphic rocks, zircon is found in mica schists and granite gneisses, either as rounded relict grains from detrital sediments or as original euhedral crystals of high-grade metamorphism [47].

In the present study, zircon grains have subhedral to anhedral form (Fig. 17). They are mostly long prismatic grains, while some crystals are short and have adamantine luster. The recorded zircon has yellow, yellowish red to reddish brown colors and sometimes is colorless.

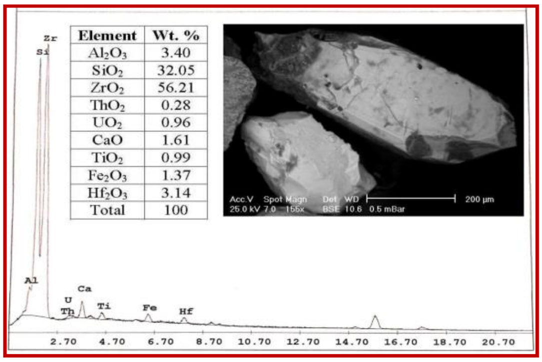
Zircon and monazite are also recorded at eastern part of the study area in the stream sediments of Wadi Iqna [48].

4.4. d: Spriggite: ($Pb_3(UO_2)_6O_8(OH)_2 \cdot 3H_2O$).

In the present study, the handpicked orange grains are examined by XRD technique where the pattern obtained shows the presence of spriggite mineral (Fig.18). Spriggite has the highest Pb: U ratio among the known hydrated Pb uranyl oxyhydroxide minerals. Although the main constituents of spriggite are uranium and lead, some other elements such as barium and calcium are also recorded by [49] (Table 6).

4.4. e: Gadolinite: ($(Ce,La,Nd,Y)_2Fe^{2+}Be_2Si_2O_{10}$)

Gadolinite sometimes known as ytterbite, is a silicate mineral consisting principally of the silicates of cerium, lanthanum, neodymium, yttrium, beryllium, and iron. It is called gadolinite-(Ce) or gadolinite-(Y), depending on the prominent composing element (Y if yttrium predominates, and Ce if cerium is over dominates). It may contain 35.5% yttria sub-group rare earths, 2.2% ceria earths, as much as to 11.6% BeO, and traces of thorium. It occurs generally in syenite pegmatite veins along a contact between basalt and monzonite. Often slightly radioactive due to minor U and/or Th



Element	Wt. %
Al_2O_3	3.40
SiO_2	32.05
ZrO_2	56.21
ThO_2	0.28
UO_2	0.96
CaO	1.61
TiO_2	0.99
Fe_2O_3	1.37
Hf_2O_3	3.14
Total	100

Figure (17): BSE image for zircon obtaining thorium and uranium inclusions

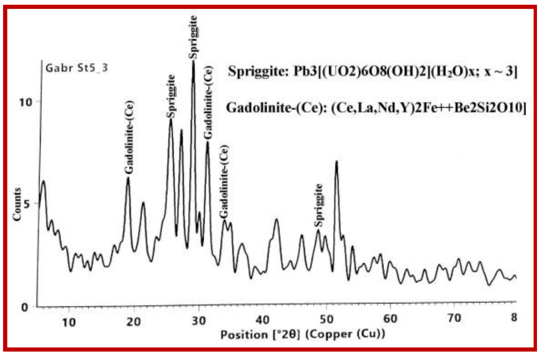


Figure (18): Shows X-ray pattern of spriggite and gadolinite minerals

Table 6: Shows the constituents of spreggite and gadolinite

Spriggite (Brugger et. al. (2004)		Gadolinite (Segalstad and Larsen 1978)	
Oxides	Wt%	Oxides	Wt%
BaO	0.25 %	SiO_2	23.17
CaO	0.14 %	TiO_2	0.14
UO_2	67.04 %	B_2O_3	0.55
PbO	25.59 %	Al_2O_3	0.05
H_2O	2.99 %	Y_2O_3	6.78
Oxygen	16.48 %	La_2O_3	14.00
		Ce_2O_3	21.25
		RE_2O_3	12.05

contents therefore often metamict. Although SiO_2, Ce_2O_3 and La_2O_3 are the main constituents of gadolinite, it also contains other constituents such as TiO_2, B_2O_3, Al_2O_3 and Y_2O_3 (Table 6) [50].

The XRD examination of the studied hand-picked grains shows the presence of the REEs-bearing Ce-gadolinite (Fig 18) .

5. Origin of the uranium and thorium in Wadi Steih stream sediments:

The origin of uranium and thorium in Wadi Steih stream sediments can be discussed through two proposed concepts; the leachability and accessory minerals. In natural magmatic conditions thorium is about three times as abundant as uranium in granitic rocks i.e. U/Th is equal to 0.33 [51]. In this case the uranium and thorium are generally incorporated in the accessory minerals such as zircon, monazite, xenotime and allanite. If this ratio is disturbed, post magmatic and/or secondary hydrothermal processes are expected and a process of depletion or enrichment of uranium is occurred. Uranium and thorium may also accumulate along the inter-granular boundaries and fractures or they may be entrapped in lattice imperfections or adsorbed on the surface of crystal faces. It is estimated that about 40% of uranium content in granite is not fixed in crystal lattices of minerals. Therefore, uranium is readily leachable with dilute acids [51] and easily transported with circulating solutions to ultimately deposit in favorable environment.

In the study area, the measured uranium of the surrounding rocks (Iqna granite, South W.Steih granite and E& N W.Steih granite) have uranium averages that are; 8.5ppm, 13.9 ppm and 18.5 ppm respectively (Tables 7and 8). So, these granites are considered as uraniferous since they contain more than twice the Clarke value for uranium (8 ppm). Also, thorium contents of these granites are relatively high, averaging 27.5, 29.13 and 31.4 ppm respectively; taking in consideration that thorium is an immobile element under oxidizing conditions, whereas uranium is a mobile one under the same conditions [52]. This suggests that uranium is affected by post-magmatic redistribution processes.

Table 7: U, Th (ppm) and U/Th of the studied granites and volcanics that surrounding the Wadi Steih stream sediments

	Iqna granite *			Iqna volcanics *			E& N W.Steih granite			South W.Steih granite		
	U	Th	U/Th	U	Th	U/Th	U	Th	U/Th	U	Th	U/Th
	9.5	29.8	0.003	5	19.4	0.26	18	34	0.53	15	30	0.50
	10	36.5	0.27	6.2	14.3	0.43	15	36	0.42	12	26	0.46
	11	27.6	0.39	6	10	0.60	19	33	0.58	14	24	0.58
	6.8	20.7	0.33	4.6	11.7	0.39	20	29	0.69	13	32	0.41
	7	31	0.23	5.5	15	0.37	22	30	0.73	12	29	0.41
	8	24	0.33	7	21	0.33	17	32	0.53	15	33	0.45
	7.6	23	0.32	4.2	12	0.35	16	26	0.62	16	31	0.52
	9	27	0.33	6.5	21.5	0.30	21	31	0.68	14	28	0.50
Av.	8.5	27.5	0.31	5.6	15.6	0.38	18.5	31.4	0.60	13.9	29.13	0.48
* Iqna granite and volcanics are after Sherif (1993) and Nagib (2008)												

Table 8: Average U, Th (ppm) and their ratio of stream sediments and the surrounding rocks

	U	Th	U/Th
Iqna granite *	8.5	27.5	0.31
Iqna volcanics *	5.6	15.6	0.38
East and north Wadi Steih granite	18.5	31.4	0.60
South Wadi Steih granite	13.9	29.13	0.48
W. Steih stream sediments	6.2	62.53	0.099
Iqna granite * Iqna volcanics * are after Nagib (2008) and Sherif (1993)			

Values of uranium and thorium in the surrounding rocks are plotted versus each other and versus their ratios. Figure (19) shows the plotting of uranium versus thorium of the surrounding rocks and revealed strong positive correlation. The positive correlation between U and Th may suggest their incorporation within the U&Th-bearing accessory minerals present in these rocks such as zircon, monazite, allanite and apatite (Fig. 20). If the crystal lattices of these minerals are distorted or destructed due to radiation damage, processes of metamictization is occurred leaving these minerals amorphous and became highly fractures (Fig. 20). The weathering and erosion processes acting on the host rocks can liberate these U &Th-bearing minerals and ultimately deposited in the meanders and streams of Wadi Steih. During the course of their transportation, partial dissolution of these minerals will occur and uranium can easy have leached to ultimately deposit in favorable environment in Wadi Steih stream sediments. This may explain the presence of relatively high uranium contents in the stream sediments of Wadi Steih (Table 8) compared with other stream sediments. The recorded high thorium contents in the stream sediments are ascribed to the accumulation and deposition of the Th-bearing minerals along the upstream side of the presented basic dykes. The relation between U and U/ Th ratio (Fig.21) of the surrounding rock units shows a positive correlation. [53] argued that if the U/Th ratio increases strongly with uranium but not with thorium, post-magmatic redistribution of uranium is suggested, and this could be a favorable economic criterion because uranium might have concentrated into deposits within or near the granite.

The U/Th ratio is an important parameter for determining the oxidation state in which uranium can be transported. Tetravalent U and Th can be accommodated within the same minerals, and both will be transported in solution under reducing condition. U is transported alone in the hexavalent state, and unusually high U/Th ratios can be expected at the site of deposition [54]. The plotting of Th versus U/Th ratios of the surrounding rocks (Fig. 22) shows a negative correlation.

The negative correlation between Th and U/Th ratio suggests that the distribution of uranium and thorium is controlled by magmatic differentiation, while, the positive correlation between U and U/Th ratios indicates enrichment of uranium through post magmatic processes. [55].

The studied granite samples have U/Th ratios more than 0.33 (Tables 7 and 8) which suggest an enrichment in uranium relative to thorium. This uranium content may present along the grain boundaries of the granites and

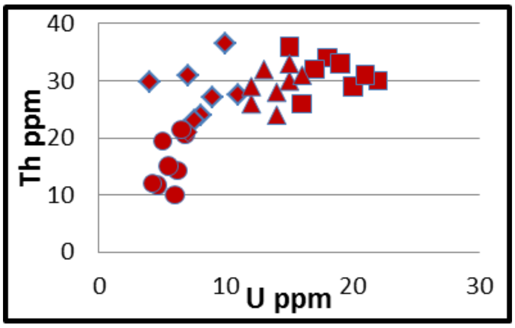


Fig. (19). Shows the plotting of U versus Th of the surrounding rock units.

■ = N and E Wadi Steih granite
▲ = South Wadi Steih granite
● = Iqna granite
◆ = Iqna volcanics

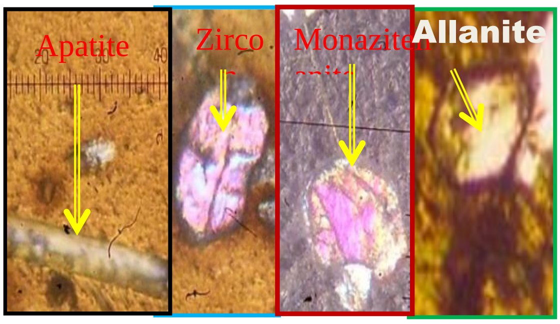


Fig. (20). Shows highly fractured metamictized accessory minerals included within the granitic and volcanic rocks surrounding Wadi Steih.

can easy leached by meteoric water and/or hydrothermal solutions and transported to the meanders and streams of Wadi Steih. The uranium content presents in the Wadi Steih stream sediments may be attributed to the leached uranium and the presence of the secondary uranium mineral spreggite.

The contents of radioelements in the stream sediments, in general, depend largely on their contents in the source rocks. Accordingly, if the source is rich in these radioelements, the resultant stream sediments are consequently rich in them and vice versa. Anyhow, the measured eU and eTh of the studied Wadi Steih stream sediments together with their ratios (Table 5) are graphically represented to elucidate their relationship. Plotting of the radioelements eU versus eU/eTh ratio shows a positive correlation (Fig. 23A&B) with few scatters samples which suggest a process of uranium enrichment. The plotting of eTh against eU/eTh ratio shows a negative correlation (Fig. 23C). The excess of uranium in the studied stream sediments, relative to other stream sediments, is suggested to be driven from the surrounding uraniferous granites through leaching processes.

6. CONCLUSION

The representative diagrams of the plotting of the average trace element contents versus those of the surrounding rock units along with the Co/Th ratio indicate that the trace elements recorded in the Wadi Steih stream sediments is derived from the surrounding rock units. Wadi Steih stream sediments are generally produced from long term successive physical and/or chemical weathering and consequence erosion processes of the surrounding rock units such as younger granites, Iqna volcanics and gabbro. The radiometric surveying of Wadi Steih stream sediments indicate that these stream sediments are dominated by thorium rather than uranium. The thorium content of the stream sediments ranges from 4.4 to 335 ppm with an average of 62.5 ppm while uranium is relatively low if

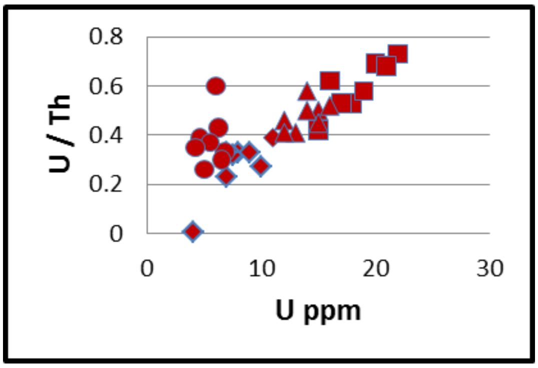


Fig. (21). Shows the plotting of U versus U/Th of the surrounding rock units.
Symbols as in figure 19

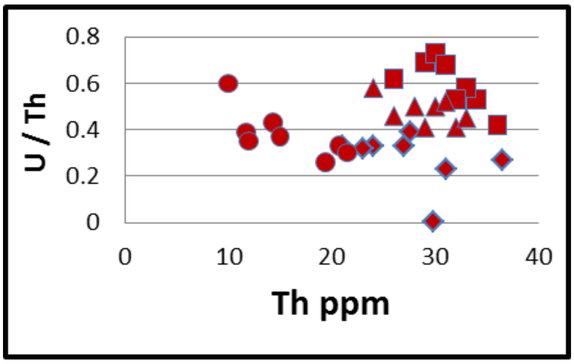


Fig. (22). Shows the plotting of Th versus U/Th of the surrounding rock units.
Symbols as in figure 19

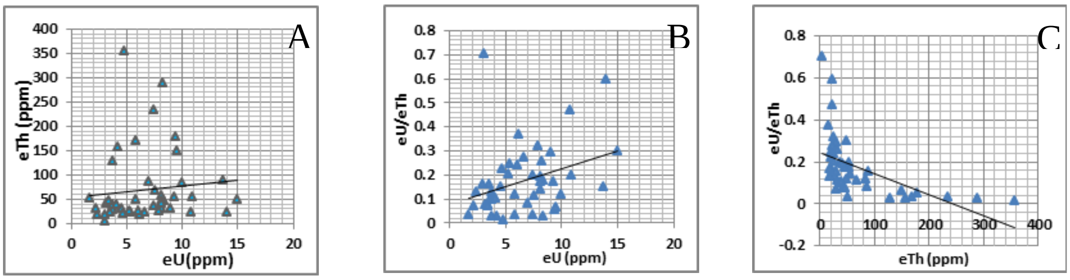


Figure (23 A, B and C): Shows the plotting of eU versus eTh (A), eU versus eU/eTh (B) and eTh versus eU/ eTh (C) of the studied W. Steih stream sediments.

compared with thorium. The high thorium contents of these stream sediments are generally ascribed to the presence of Th- bearing minerals such as monazite, zircon and huttonite.

The relatively high uranium content, relative to other stream sediments, is suggested to be due to its leachability from the surrounding uraniferous younger granites and its adsorption along the grain boundaries of the clay minerals. These clay minerals are originated from the weathering processes acting on the basic dykes where uranium is ultimately adsorbed along their boundaries. Also the presence of the secondary uranium mineral spreggite may contribute to the total uranium contents of the studied stream sediments. The distribution of the radioelements of Wadi Steih stream sediments is mainly controlled by the presence of both basic dykes which are acting as physical barrier and the its prevailed drainage patterns.

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دراسات معدنية وإشعاعية لرواسب وادى سطيح جنوب سيناء , مصر.

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الملخص

يهدف هذا البحث إلى إجراء دراسات معدنية وإشعاعية لرواسب وادى سطيح الذى يقع بجنوب سيناء والمحاط كليا بصخور الجرانيت الحديث المتمثل بالسيانوجرانيت وبعضا من الصخور البركانية والجابرو. وقد اثبتت الدراسات التى تم إجرائها على العناصر الِشحيحة لكل من رواسب وادى سطيح والصخور المحيطة به وكذلك من دراسة نسبة الكوبلت الى الثوريوم ان هذه الرواسب قد نتجت من عوامل التجوية طويلة الامد سواء أكانت طبيعية أو كيميائية أو كليهما والمتبوعة بالتعرية ونقل نواتج التعرية هذه وترسيبها فى الروافد المائية وترسيبها لتكوين رواسب وادى سطيح. لقد تم عمل الدراسات الاِشعاعية والمسح الاِشعاعى على رواسب وادى سطيح وتبين وجود شذات اِشعاعية متمركزة على طول أسطح القواطع البازلتية من ناحية منبع روافد الوديان. ومن خلال المسح الاِشعاعي للمنطقة تبين انها غنية بعناصر الثوريوم مع قليل من اليورانيوم حيث تتراوح تركيزات الثوريوم من 5 الى 335جزء فى المليون بمتوسط قدره 62 جزء فى المليون بينما يتراوح تركيز اليورانيوم من 2 الى 16 جزء فى المليون. وقد وجد ان نسبة اليورانيوم فى وادى سطيح عالية إذا ما قورنت برواسب الوديان فى مناطق أخرى بسيناء والصحراء الِشرقية. لقد تبين من خلال الدراسات المعدنية وجود عديد من المعادن الحاملة للثوريوم مثل الزيركون والمونازيت والهوتونايت حيث ان هذه المعادن هى المسؤولة عن تركيزات الثوريوم العالية بالمنطقة. أما بالنسبة لليورانيوم فإنه ناتج عن إذابته من صخور الجرانيت الحديثة الغنية باليورانيوم والمحيطة بمنطقة الدراسة وحمله بالمحاليل وإعادة تركيزه وإمتصاصه على أسطح المعادن الطينية الناتجة عن تجوية صخور القواطع البازلتية. وقد تبين من خلال دراسة تركيزات العناصر المشعة أنها محكومة بوجود القواطع البازلتية والتى تمثل حواجز طبيعية متحكمة فى حجز هذه العناصر على طول أسطحها المواجهة لمنبع روافد المياه والتى يوجد بها تركيزات معقولة من الثوريوم.