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Spectrometric Prospecting, Geochemical Distribution and Mineralogical Investigation for Wadi Abu Rusheid Stream Sediments, South Eastern Desert, Egypt

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Abstract: *The loose stream sediments covering wadies of Abu Rusheid area are derived from the weathering of the different surrounding rocks. Thes are ophiolitic melange, consisting of ultramafic rocks and layered metagabbros set in a metasediment matrix; cataclastic rocks, including protomylonites, mylonites, ultramylonites, silicified ultramylonites; granitic rocks; and post-granite dykes (lamprophyre), pegmatite and quartz veins. The thickness of the stream sediments was determined by different geophysical techniques, which revealed that the depth to the surface of the basement rocks has an average value of about 21 m. Geochemical maps were constructed to delineate anomalous areas with abnormally high rare metal contents. The latter nearly the same as in the mineralized cataclastic rocks and lamprophyre dykes. The weak correlations between almost of these elements indicate that the element constituents are governed by many geochemical factors and are from different sources. According to the radiometric maps of the different radioactive elements, the high concentrations are close to the mineralized cataclastic rocks along the studied part of Wadi Abu Rusheid, especially in the upstream part. The investigated heavy minerals in the studied parts of the stream sediments can be classified according to their anion groups into the following: silicate minerals group (kasolite, uranothorite, zircon, garnet and titanite), phosphate minerals group (monazite and apatite), oxide minerals group (columbite, cassiterite, rutile, leucoxene, magnetite, hematite and ilmenite), carbonate mineral group (cerussite), sulfides minerals group (galena and pyrite). The preliminary assessment of some economic elements in stream sediments revealed that the ore metals in ton are: Zr (4936.93), Nb (978.98), Rb (1561.56), Zn (1297.3), Pb (1039.04), Y (1033.03) and Ga (240.24). Finally, this assessment need deeper investigations and requires more samples along grid patterns and at different depths.*

Keywords: *Wadi Abu Rusheid, Stream sediments, Geochemical, Radiometric maps, Egypt.*

1. Introduction

Wadi (W.) Abu Rusheid area is located at the southern part of the Eastern Desert of Egypt, along and about 95 km of Marsa Alam city. The area could be reached from the Red Sea coast through W. El Gemal and then W. Nugrus along a desert track of about 45 km long. The area is characterized by low topographic features, where as the highest topographic features are about 509m above sea level, whereas the average wadi level is about 315 m above sea level. The area is dissected by Khour Abaleia, several gullies, NNW-SSE and ENE-WSW shear zones.

The stream sediments are composite products of erosion and weathering and thus represent the source catchment area of the stream drainage network (Darnley, 1990 and Cocker, 1999). Stream sediments may be the natural sink of large amounts of chemical elements that derived from the drainage basin, where sediments possess a great capacity to accumulate and integrate those elements and their accumulate is dependent on the properties of the adsorbed chemical and the prevailing physicochemical conditions (El Nemr et al., 2007). The composition of clastic sedimentary rocks is controlled by several factors, which include source rock, weathering, erosion, deposition, transport, burial and diagenesis (Johnsson, 1993).

The background levels of the rare metals; Sn, Nb, Y, Be and Li are higher than their corresponding world average abundance (Levinson, 1980) in normal soil. The high standard deviation values of Zr, Nb, Pb, Ga and Y reflect that these metals have wide concentration ranges. The abnormal concentrations of such elements are mainly related to the cataclastic rocks of W. Abu Rusheid area (Sabet et al., 1976; Ibrahim et al., 2002, 2004; Khaleal, 2005; Raslan, 2008; El Afandy et al., 2003, 2016; El Kameesy et al., 2015; Kamar et al., 2016-2018, Saleh, 2019 and Yousef, 2019) and their metasomatized parts.

The present study aims to discuss the distribution and concentration of the different radioactive and valuable elements in the stream sediments of W. Abu Rusheid, South Eastern Desert, Egypt.

2. GEOLOGICAL SETTING

W. Abu Rusheid is situated between latitude 24°36`29``- 24°39`22``N and longitude 34°44`40``- 34°47`23``E (Fig. 1). The tectono-stratigraphic sequence of rock types starting from the oldest are: (1) An ophiolitic melange, consisting of ultramafic rocks and layered metagabbros set in a metasediment matrix; (2) Cataclastic rocks, including protomylonites, mylonites, ultramylonites, silicified ultramylonites; (3) Granitic rocks; and (4) Post-granite dykes (lamprophyre), pegmatite and quartz veins; (5) Wadi deposits. The cataclastic rocks are cross cut by NNW-SSE and E-W trending shear zones.

The ophiolitic dismembers are mainly metagabbros and serpentinites. In many parts, serpentinites are transformed, partly or totally into talc-carbonate rock. They are thrusted over both ophiolitic mélange and ophiolitic matrix with WNW-ESE and dips 33°/NNE (Saleh, 1997, Assaf et al., 2000). The ophiolitic mélange is mainly composed of mélange matrix encloses abundant fragments of meta- peridotites, amphibolites, metagabbros, serpentinites and talc-carbonates. Those fragments occur in various sizes, reaching big slabs or mountainous size. The matrixes are represented by biotite schist, garnetiferous biotite schist and tourmaline-hornblende schist. They are characterized by high foliation and featured by the frequent presence of macro- and meso-folds. The remnant ophiolitic schists are observed over mylonites and may be covering the all Abu Rusheid mylonite rocks but were later eroded away.

The protomylonites are coarse to very coarse grained rocks, green to dark greenish grey in colour. They crop out at the eastward flank of of W. Abu Rusheid, covering about 12.0 in vol. % of the cataclastics (Ibrahim et al., 2004). The rocks are banded (NNW – SSE), dipping 30°/SW, with frequent occurrence of greenish-microcline veinlets running parallel to the banding planes (amazonite, 1-2 cm in length and 0.5 in width). They are invaded by two generations of quartz veins. The oldest quartz vein (3×0.2 m) , mineralized (U, Sn and W) and parallel to the banding planes (WNW-ESE) and dipping 12˚/ NNE, whereas the youngest vein is barren and normal to the banding planes (5×0.4 m across).

The mylonite covers a large area representing 65.0 in vol. % of the cataclastic rocks with low to medium relief (Ibrahim et al., 2004). They are fine to medium grained and well banded (NNW- SSE and dips 10˚/SW). These rocks are intercalated with protomylonite and affected by weathering in a variable degrees producing red to yellow colours due to the alteration of sulfides producing iron oxides (hematite-limonite).The ultramylonite is light grey to grey in colour, fine to medium grained and exhibits both banding and augen structures. The ultramylonite covers about 17.0 % of the cataclastic rocks. Some pyrite crystals were removed leaving vugs filled with quartz, carbonates and yellow U– minerals. Columbite-tantalite occurs abundantly as disseminated minute grains either as single crystal or aggregates, visible by naked eyes (Ibrahim et al., 2004).

The silicified ultramylonite (quartzite) covers about 6.0 % of the cataclastics rocks with irregular and oval shape, it overlies all the previous cataclastic rocks (Ibrahim et al., 2004). Sulfides are dominantly pyrite, arsenopyrite, with rare galena impregnations along fractures and cleavage planes of other minerals. Smoky quartz is the dominant mineral in the silicified ultramylonite.

Abu Rusheid granitic rocks are elongated in the NW –SE and are represented from the NW direction by porphyritic biotite granites followed due to SE by deformed biotite granites and two mica peraluminous granites whereas the muscovite granites occupy the extreme SE part of the pluton (Ibrahim et al., 2004).The biotite granites can be classified into two phases; high deformed biotite granites and low deformed biotite granites. 1- Highly deformed biotite granites are exposed at the extreme NE side of W. Abu Rusheid and occupy a moderate relief lands. 2-Weakly deformed biotite granites forming high lands in the central NE of the Abu Rusheid pluton.

The cataclastic rocks of the Abu Rusheid area are cut by two approximately perpendicular two shear zones (NNW-SSE and E-W trends). The two shear zones are intruded by discontinuous and brecciate lamprophyre dykes. The NNW-SSE lamprophyre dykes are located at the central part of the cataclastic rocks, whereas the E-W ones are distributed at the margins of the area. Abu Rusheid lamprophyre dykes act as physical-chemical traps for REEs, Zn, Y, U, Cu, W, and Ag (Ibrahim et al., 2015).

The studied wadi deposits are covered by the sediments, which derived from the weathering of the different surrounding rocks. They are composed of clastic fragments ranging from pebble size to fine silt and clay with pink to dark grey colour according to composition of the source rocks. A total of forty- five (45) stream sediment samples were systematically collected covering the drainage patterns of W. Abu Rusheid. Sampling distance was 1100m apart and was taken at a depth varying from 25 to 100 cm (Fig. 2). The samples were properly sieved to obtain a fraction ranging from –1 to +0.25 mm and ground in an agate mill to pass 200 mesh for chemical analyses. This fraction is recommended (Bugrov et al., 1973) as the most suitable size for geochemical survey of stream sediments in arid conditions like those prevailing in the Eastern Desert.

The different geophysical techniques used for the determination of the thickness of stream sediments and revealed that; in the southern part of the wadi, the depth to the basement is more deeper than the rest of the wadi that reach about 27 m, while at the middle part of the wadi the depth to the basement rocks is shallower and reaches about 16 m. Finally, the depth to the surface of the basement rocks has an average value of about 21 m (Khalil et al., 2011).

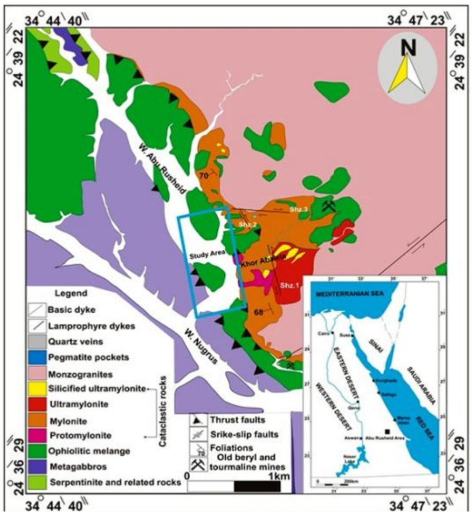


Fig1. *Geological map of Wadi Abu Rusheid area, south Eastern Desert, Egypt (Ibrahim et al., 2004)*

Fig2. *Sampling of stream sediment at W. Abu Rusheid area, SED, Egypt*

3. METHODOLOGY

The trace elements for forty-five samples were analyzed in the Laboratories of Nuclear Materials Authority (NMA), Cairo, Egypt. In situ gamma–ray spectrometry measurements was carried out using RS-230 instrument on grid pattern of 10 x 10 m along profiles trending perpendicular to the wadi direction. Ground γ-ray spectrometric survey can detect dose rate (D.R.) in unit (nanosieverts per hour ($nSvh^{-1}$)), potassium (K%), equivalent uranium content (eUppm), and equivalent thorium content (eTh ppm).Eight (8) representative samples were taken from the different sites for mineral separation. Separation was conducted using bromoform (Sp. Gr. 2.86g/cm^3) and magnetic fractionation using a Frantz Isodynamic Magnetic Separator (Model L-1). Mineralogical investigation of the mineral constituents of the stream sediments was carried out by a Phillips XL-30 Scanning Electron Microscope (SEM), semi-quantitative EDX chemical analyses at Laboratories of NMA, Cairo, Egypt.

4. Geochemical Mapping

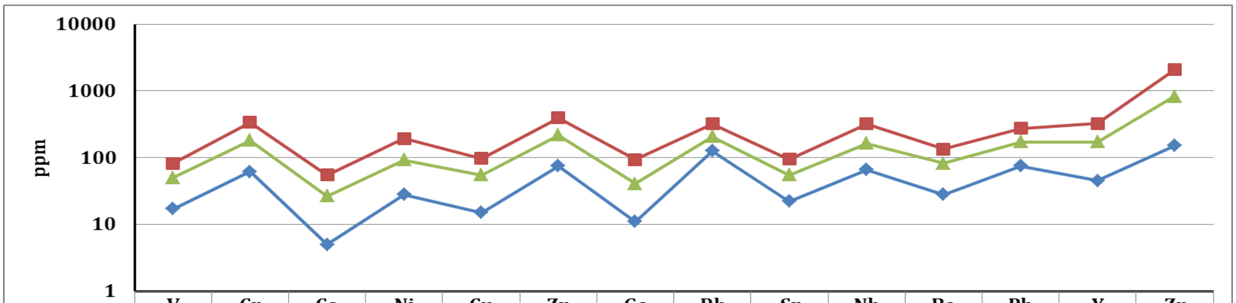
The trace elements data of 45 samples from stream sediments are listed in table (1). The following paragraphs will discuss some of them with short notes.

Table1. *Trace elements concentration (ppm) of W. Abu Rusheid stream sediments, SED, Egypt*

S.No.	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Nb	Ba	Pb	Y	Zr
1	30	140	5	40	35	190	12	130	75	90	55	120	97	290
2	42	195	12	99	40	120	30	125	60	110	62	136	45	370
3	25	210	15	129	70	230	15	210	46	66	77	145	165	575
4	55	260	20	155	29	275	20	255	39	75	86	220	125	437
5	60	292	29	175	55	292	25	230	53	145	42	210	175	610
6	72	305	32	192	58	310	29	266	59	135	52	235	187	725
7	18	160	10	78	72	236	15	179	86	210	69	275	236	635
8	20	192	25	86	69	249	12	188	94	129	74	149	240	245
9	32	215	12	59	65	255	29	235	30	86	89	152	296	336
10	46	320	47	62	74	261	27	242	39	205	71	139	284	790
11	59	309	19	77	49	265	36	255	27	230	63	115	262	624
12	48	225	22	123	37	272	42	261	22	175	57	99	245	520
13	62	245	28	125	42	279	22	275	26	180	92	86	227	425
14	73	262	32	130	55	325	14	195	29	162	89	75	90	317
15	79	185	27	145	57	319	17	172	56	155	96	142	85	285
16	66	175	36	152	45	185	29	166	57	236	77	156	75	150
17	52	199	42	149	36	239	37	155	46	244	88	220	62	1010
18	48	182	46	105	29	252	43	125	41	265	105	215	55	1090
19	69	335	55	117	15	165	57	138	62	275	110	245	210	2080
20	34	175	26	90	38	155	76	169	64	124	132	229	256	855
21	44	261	18	86	64	140	11	185	69	136	120	247	243	915
22	28	245	15	75	69	272	18	205	76	147	74	199	323	984
23	37	135	14	74	72	265	23	274	87	132	87	187	159	392
24	54	146	9	132	78	305	28	285	92	123	76	163	160	410
25	74	125	8	118	88	296	36	297	73	185	67	169	142	457
26	82	120	17	79	83	288	32	320	64	148	56	155	124	549
27	31	115	34	62	92	270	45	281	56	95	43	125	82	1246
28	42	219	38	54	97	219	57	198	42	76	135	143	75	1049
29	56	235	43	49	46	210	63	210	47	135	128	135	112	842
30	76	259	46	36	49	394	42	237	59	207	112	142	129	567
31	25	83	10	46	30	106	19	206	82	92	37	115	97	1575
32	29	70	17	36	39	135	43	186	64	86	52	214	130	1235
33	36	62	12	112	46	149	56	174	37	147	69	236	176	1124
34	44	78	27	105	57	115	72	152	44	158	74	245	188	978
35	52	86	36	78	42	96	61	217	38	193	28	232	236	923
36	47	92	15	86	27	85	58	236	27	206	102	219	245	845
37	72	104	9	54	68	109	47	231	72	320	132	226	277	736
38	62	125	29	32	15	136	92	201	68	232	116	97	236	822
39	69	132	34	28	21	204	88	192	72	274	98	124	233	910
40	59	210	46	47	75	96	26	177	57	263	84	146	225	1326
41	66	172	52	65	79	75	14	159	73	178	76	137	212	1439
42	82	143	28	72	82	274	67	149	82	143	57	112	174	1565
43	17	122	16	84	65	186	84	127	32	129	64	264	189	1752
44	26	112	45	103	53	179	93	201	29	107	108	179	92	1095
45	45	97	37	126	49	235	59	199	22	145	117	192	82	865

- **Zirconium (Zr)**

Zirconium content ranges from 150 to 2080 ppm with an average of 821.56 ppm (Fig.3) and represent 35% (Fig. 4) from all the analyzed elements. The geochemical map for zirconium (Fig. 5) revealed that, the concentrations are fluctuated downs and ups from the upstream to the downstream of the studied part of W. Abu Rusheid.



	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Nb	Ba	Pb	Y	Zr
Min.	17	62	5	28	15	75	11	125	22	66	28	75	45	150
Max.	82	335	55	192	97	394	93	320	94	320	135	275	323	2080
Aver.	49.89	180.64	26.56	91.71	54.58	215.84	40.47	206.00	55.00	163.42	82.18	172.58	172.40	821.56

Fig3. *Profile line diagram showing minimum, maximum and average concentration of some trace elements in stream sediments, W. Abu Rusheid, SED, Egypt.*

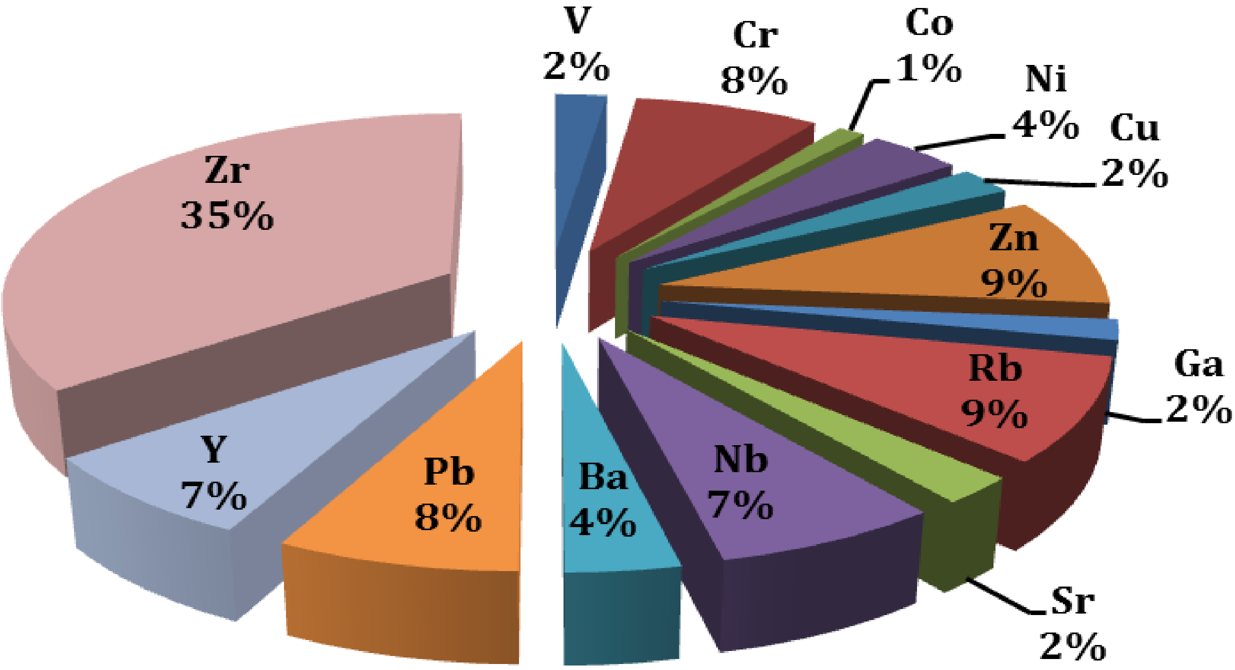


Fig4. *Pie-graph showing the (%) distribution of some trace elements in stream sediments, Abu Rusheid area, SED, Egypt*

- **Zinc (Zn)**

Zinc content ranges from 75 to 394 ppm with an average of 215.84 ppm (Fig. 3) and represent 9% (Fig. 4) from all the analyzed elements and considered the highest. The geochemical map for zinc (Fig.6) revealed that, the high concentrations were close to the ophiloitic mélange especially the northern part of the studied W. Abu Rusheid.

- **Rubidium (Rb)**

Rubidium content ranges from 125 to 320 ppm with an average of 206ppm (Fig. 3) and represent 9% (Fig. 4) from all the analyzed elements. The geochemical map for rubidium (Fig. 7) revealed that, the high concentrations are in the northern part of the studied W. Abu Rusheid.

Fig5. *Stream sediments geochemical map for (Zr), W. Abu Rusheid, SED, Egypt, (O.M.= ophiolitic mélange, Ca= Cataclastic rocks)*

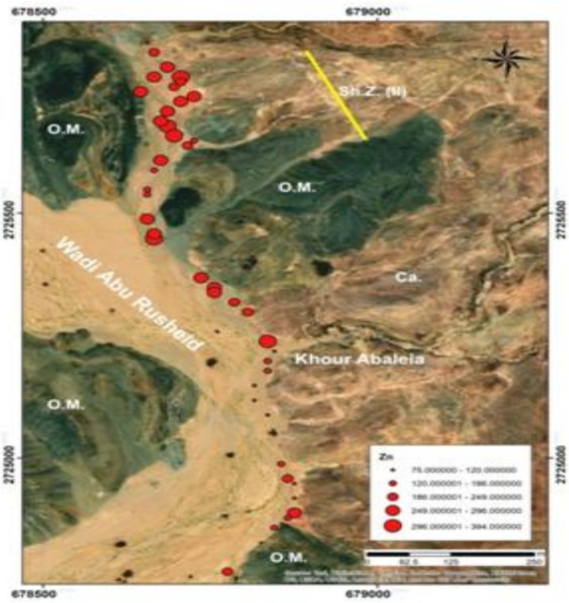


Fig6. *Stream sediments geochemical map for (Zn), W. Abu Rusheid, SED, Egypt*

- **Lead (Pb)**

Lead content ranges from 75 to 275 ppm with an average of 172.58 ppm (Fig. 3) and represent 8% (Fig. 4) from all the analyzed elements. The geochemical map for lead (Fig. 8) revealed that, the concentrations fluctuated ups and downs from the north to the south of the studied part of W. Abu Rusheid.

- **Chromium (Cr)**

Chromium content ranges from 62 to 335ppm with an average of 180.64ppm (Fig. 3) and represent 8% (Fig. 4) from all the analyzed elements. The geochemical map for chromium (Fig. 9) revealed that, most of the high concentrations are in the upstream part of W. Abu Rusheid closed to the ophiolitic mélange.

- **Yttrium (Y)**

Yttrium content ranges from 45 - 323 ppm with an average of 172.40 ppm (Fig. 3) and represent 7% (Fig. 4) from all the analyzed elements. The geochemical map for yttrium (Fig. 10) revealed that, the high concentrations are in the northern and southern parts of the studied W. Abu Rusheid.

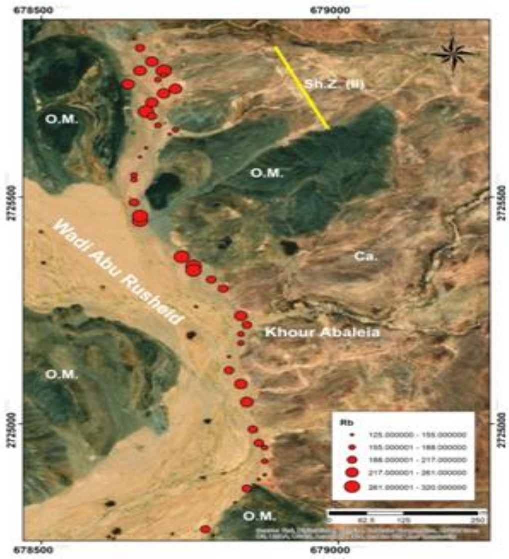


Fig7. *Stream sediments geochemical map for (Rb), W. Abu Rusheid, SED, Egypt*

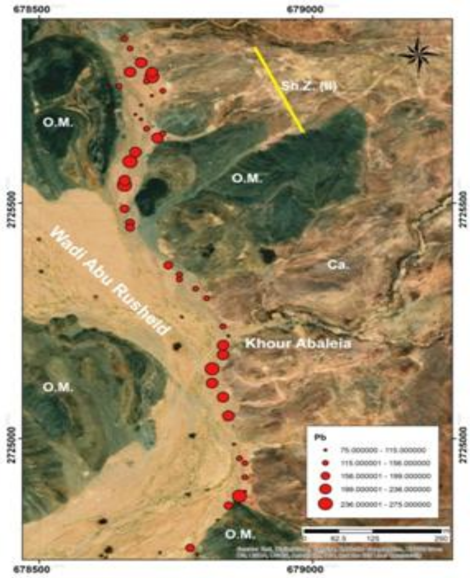


Fig8. *Stream sediments geochemical map for (Pb), W. Abu Rusheid, SED, Egypt*

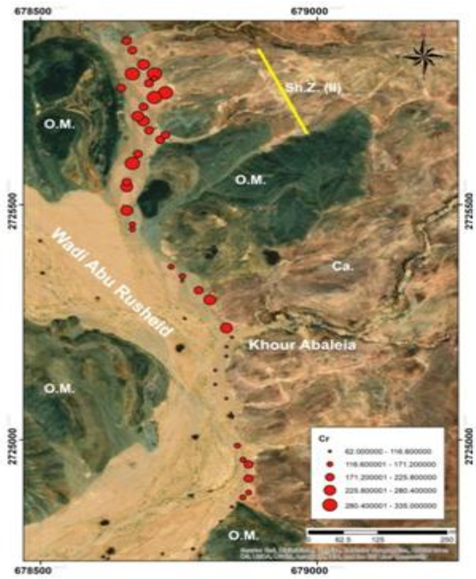


Fig9. *Stream sediments geochemical map for (Cr), W. Abu Rusheid, SED, Egypt*

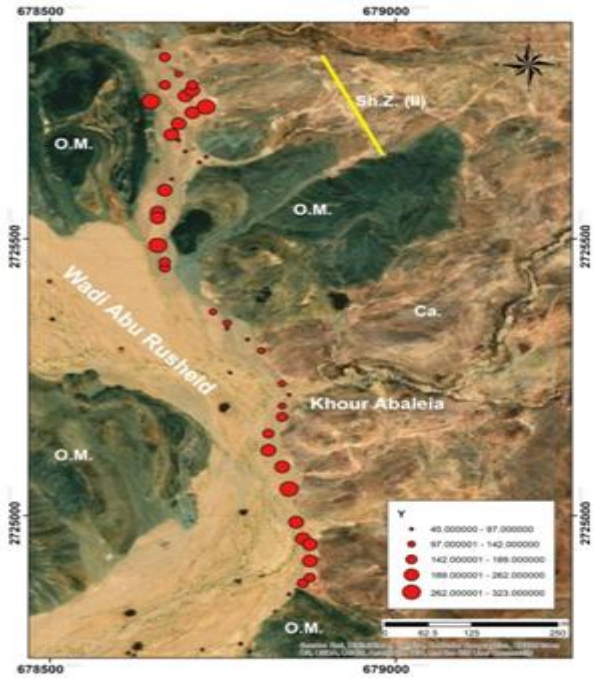


Fig10. *Stream sediments geochemical map for (Y), W. Abu Rusheid, SED, Egypt*

- **Niobium (Nb)**

Niobium content ranges from 66 – 320 ppm with an average of 163.42ppm (Fig. 3) and represent 7% (Fig. 4) from all the analyzed elements. The geochemical map for niobium (Fig. 11) revealed that, the high concentrations are in the stream closed to the shear zone (II) in the northern part and also in the southern part of W. Abu Rusheid, where the visible columbite minerals occur in the cataclastic rocks.

- **Nickel (Ni)**

Nickel content ranges from 28 to 192ppm with an average of 91.71ppm (Fig. 3) and represent 4% (Fig. 4) from all the analyzed elements. The geochemical map for nickel (Fig. 12) revealed that, most of the high concentrations are in the upstream part of W.Abu Rusheid closed to the ophiolitic melange.

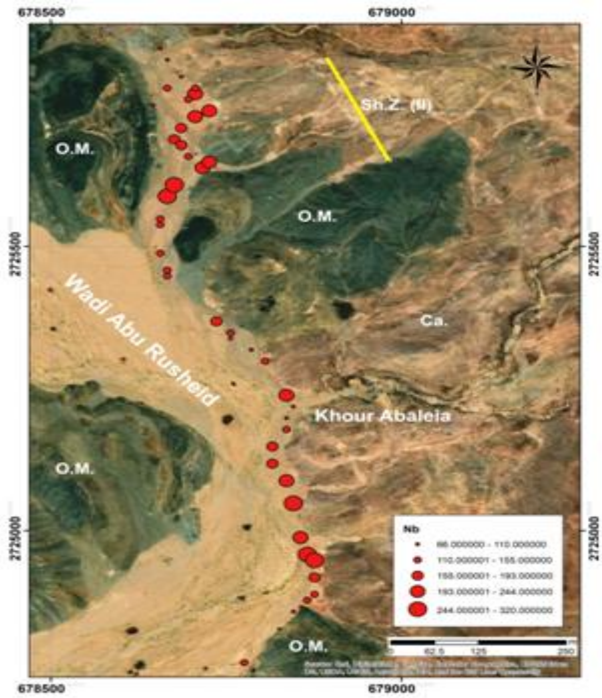


Fig11. *Stream sediments geochemical map for (Nb), W. Abu Rusheid, SED, Egypt*

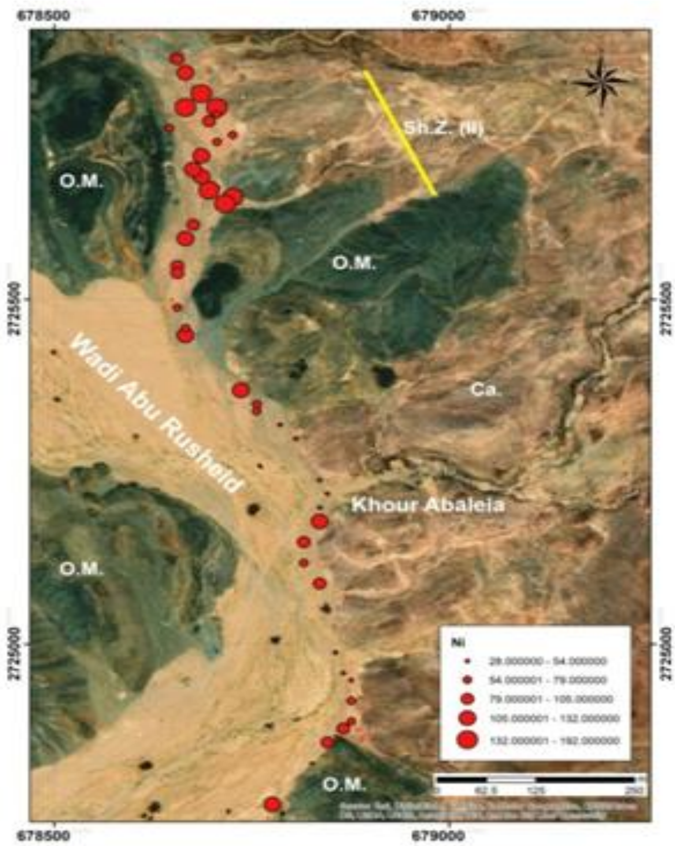


Fig12. *Stream sediments geochemical map for (Ni), W. Abu Rusheid, SED, Egypt*

- **Barium (Ba)**

Barium content ranges from 28 to 135ppm with an average of 82.18ppm (Fig. 3) and represent 4% (Fig. 4) from all the analyzed elements. The geochemical map for barium (Fig. 13) revealed that, most of the high concentrations are closed to the ophiolitic mélange.

- **Gallium (Ga)**

Gallium content ranges from 11 to 93ppm with an average of 40.47ppm (Fig. 3) and represent 2% (Fig. 4) from all the analyzed elements. The geochemical map for gallium (Fig. 14) revealed that, most of the high concentrations are closed to the southern part of W. Abu Rusheid.

- **Vandium (V)**

Vandium content ranges from 17 to 82ppm with an average of 49.89ppm (Fig. 3) and represent 2% (Fig. 4) from all the analyzed elements. The geochemical map for vandium (Fig. 15) revealed that, the concentrations have random pattern distribution in the studied part of W. Abu Rusheid.

- **Strontium (Sr)**

Strontium content ranges from 22 to 94ppm with an average of 55ppm (Fig. 3) and represent 2% (Fig. 4) from all the analyzed elements. The geochemical map for strontium (Fig. 16) revealed that, the concentrations fluctuates between downs and ups along the studied part of W. Abu Rusheid.

- **Copper (Cu)**

Copper content ranges from 15 to 97 ppm with an average of 54.58 ppm (Fig. 3) and represent 2% (Fig. 4) from all the analyzed elements. The geochemical maps for copper (Fig. 17) revealed that, the high concentrations were closed to the contact of the ophiloitic mélange with the mineralized cataclastic rocks at the northern parts of W. Abu Rusheid.

- **Cobalt (Co)**

Cobalt content ranges from 5 to 55ppm with an average of 26.56ppm (Fig. 3) and represent 1% (Fig. 4) from all the analyzed elements. The geochemical map for cobalt (Fig. 18) revealed that, the concentrations fluctuates between downs and ups along the studied part of W. Abu Rusheid.

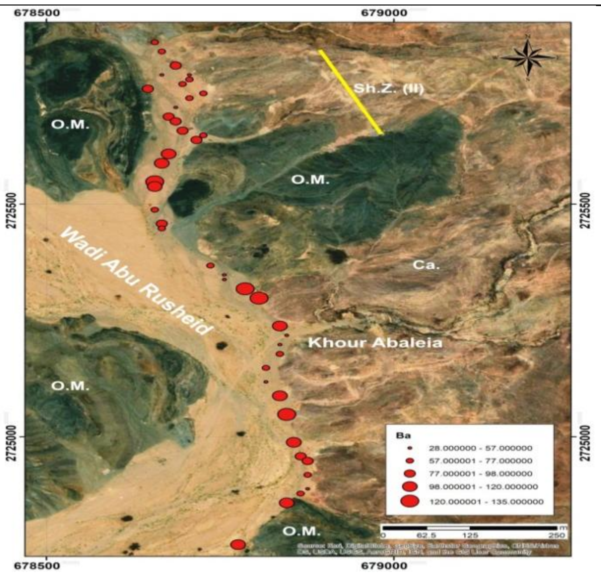


Fig13. *Stream sediments geochemical map for (Ba), W. Abu Rusheid, SED, Egypt.*

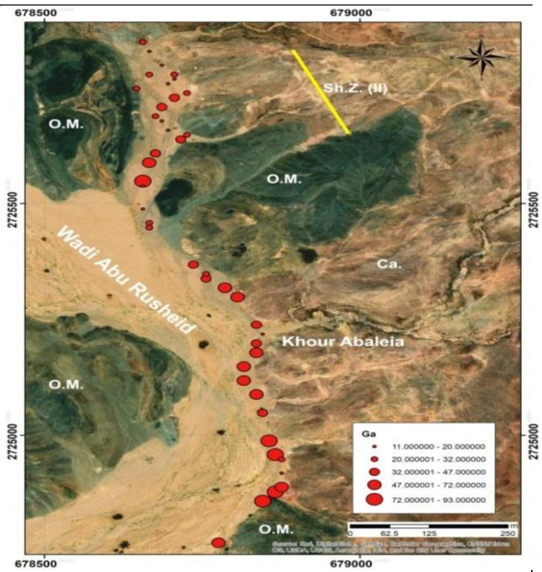


Fig14. *Stream sediments geochemical map for (Ga), W. Abu Rusheid, SED, Egypt.*

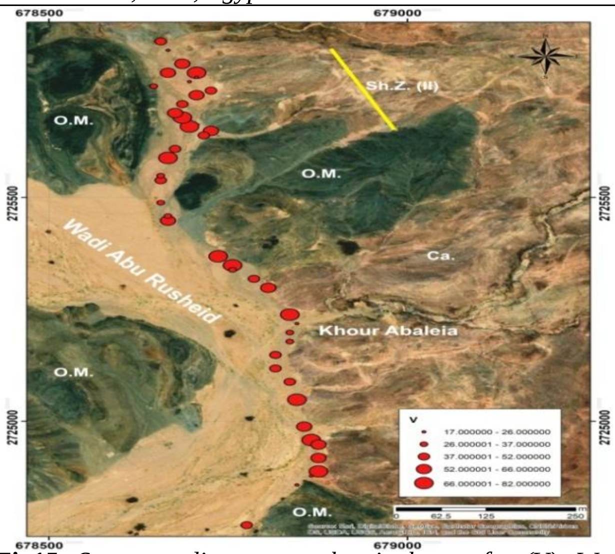


Fig15. *Stream sediments geochemical map for (V), W. Abu Rusheid, SED, Egypt.*

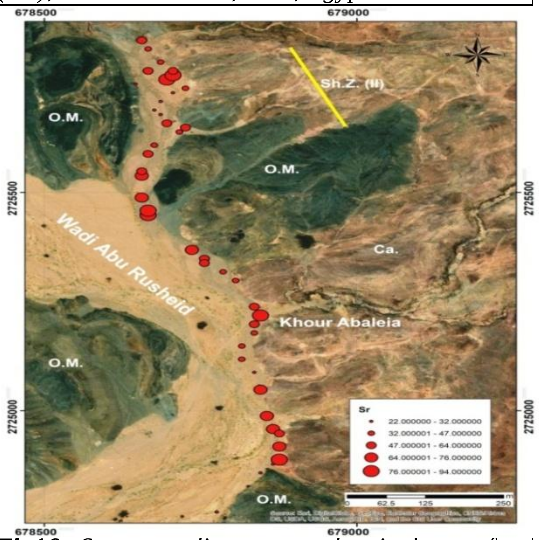


Fig16. *Stream sediments geochemical map for (Sr), W. Abu Rusheid, SED, Egypt.*

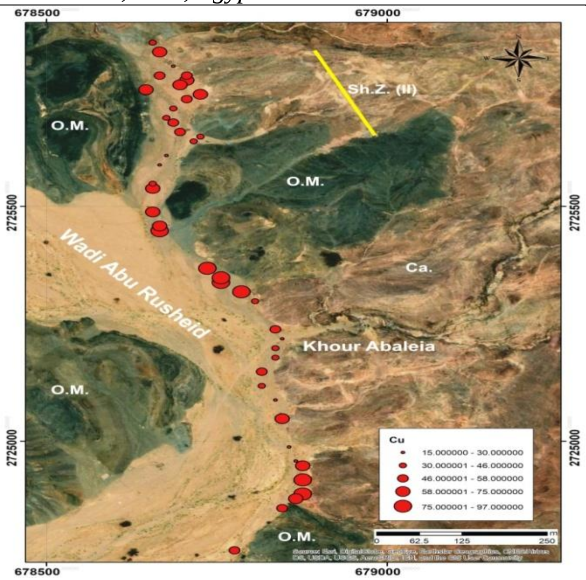


Fig17. *Stream sediments geochemical map for (Cu), W. Abu Rusheid, SED, Egypt.*

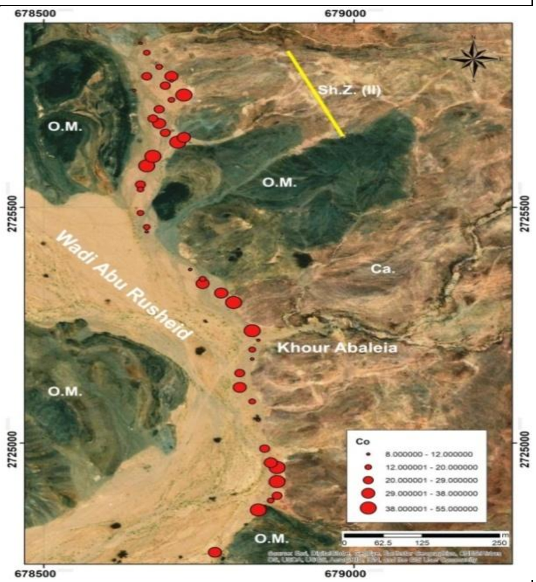


Fig18. *Stream sediments geochemical map for (Co), W. Abu Rusheid, SED, Egypt.*

From the previous geochemical maps, the most economic elements are Zr, Nb, Rb, Y, Zn, Pb and Ga, where, the source of these elements is the mineralized cataclastic rocks and lamprophyre dykes. The concentration of these elements in both bed rock (cataclastic) and the stream sediments are listed in table (2). The values of the elements concentration in the bed rock are higher than that in stream sediments except in zirconium.

Table2. *Comparison between average of the most economic elements concentration (ppm) in both cataclastic rocks and stream sediment of W. Abu Rusheid, SED, Egypt.*

Element	Cataclastic rocks, (after Kamar et al., 2016-2018)	Stream sediments (The present study)
Zr	528	822
Nb	905	163
Rb	804	260
Y	693	172
Zn	2777	216
Pb	3924	173
Ga	73	40

The correlation matrix between almost trace elements of the studied stream sediments are weak either positive or negative (Table 3). These weak correlations indicates that the trace element constituents are governed by many geochemical factors and are from different source.

Table3. *Correlation coefficient of the trace elements in the studied stream sediments, W. Abu Rusheid, SED, Egypt*

	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Nb	Ba	Pb	Y	Zr
V	1													
Cr	0.26	1												
Co	0.33	0.35	1											
Ni	0.20	0.31	0.03	1										
Cu	-0.03	-0.01	-0.11	-0.06	1									
Zn	0.27	0.45	0.01	0.35	0.27	1								
Ga	0.02	-0.39	0.26	-0.24	-0.29	-0.29	1							
Rb	0.23	0.10	-0.22	0.10	0.31	0.46	-0.19	1						
Sr	0.01	-0.16	-0.26	-0.27	0.24	-0.03	-0.26	-0.05	1					
Nb	0.49	0.10	0.36	-0.08	-0.27	-0.14	0.18	-0.11	0.006	1				
Ba	0.14	0.14	0.30	-0.14	-0.14	-0.07	0.31	-0.15	-0.119	0.26	1			
Pb	-0.27	-0.14	-0.09	0.25	-0.06	-0.27	0.15	-0.22	0.025	0.09	0.065	1		
Y	-0.07	0.19	-0.16	-0.24	0.04	-0.17	0.03	0.18	0.070	0.28	0.027	0.15	1	
Zr	-0.11	-0.15	0.37	-0.28	-0.06	-0.45	0.44	-0.39	0.004	0.13	-0.005	0.29	0.06	1

5. RADIOMETRIC MAPPING

The minimum, maximum and average of the radiometric measurements are listed in table (4). These radiometric measurements are used in constructing radiometric maps for the different radioactive elements (Fig. 19a-d). These maps revealed that; all the radioactive elements are compatible with each other’s. The highest concentrations of all radioactive elements are in the upstream part. The high concentration of radioactive elements close to the mineralized cataclastic rocks along the studied part of W. Abu Rusheid.

Table4. *Minimum, maximum and average of different radioactive elements in stream sediments, W. Abu Rusheid, SED, Egypt.*

N=1351	D.R.($nSvh^{-1}$)	K%	eU(ppm)	eTh(ppm)	eTh/eU
Min.	**57.30**	**0.80**	**1.00**	**4.20**	**0.23**
Max.	**2500.00**	**6.60**	**104.00**	**507.00**	**15.13**
Aver.	**272.92**	**3.92**	**12.65**	**39.69**	**3.04**

N= number of measurements

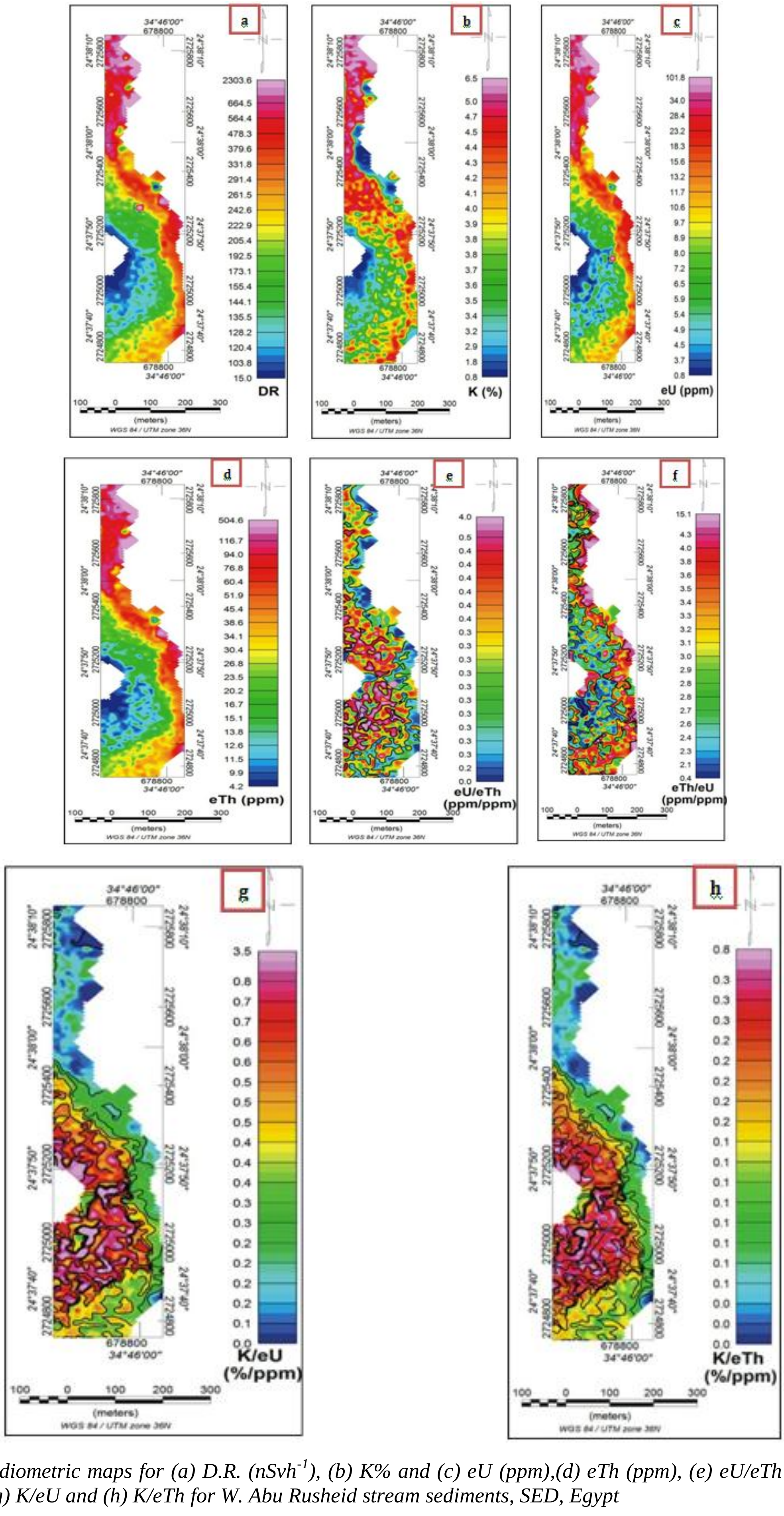


Fig19. *Radiometric maps for (a) D.R. (nSvh^{-1}), (b) K% and (c) eU (ppm),(d) eTh (ppm), (e) eU/eTh (ppm), (f) eTh/eU, (g) K/eU and (h) K/eTh for W. Abu Rusheid stream sediments, SED, Egypt*

The correlation between D.R. (Dose Rate) – K%, D.R - eU and D.R - eTh, eU-eTh, eU-eTh/eU, eTh-eTh/eU within all measurements are illustrated in (Fig. 20). The relationship between D.R. with eU (r= 0.89) and eTh (r=0.92)are very strong positive relation and is moderately positive relation with K (r=0.57). The relation between eU with eTh (r= 0.92) is also very strong positive relation. The relation between eU and eTh/eU (r=0.11) is slight weak positive relation, while the relation of eTh with eTh/eU(r= 0.34) shows slight moderate positive relation. The relation between eU, eTh with K/eU and K/eTh respectively shows strong negative relation.

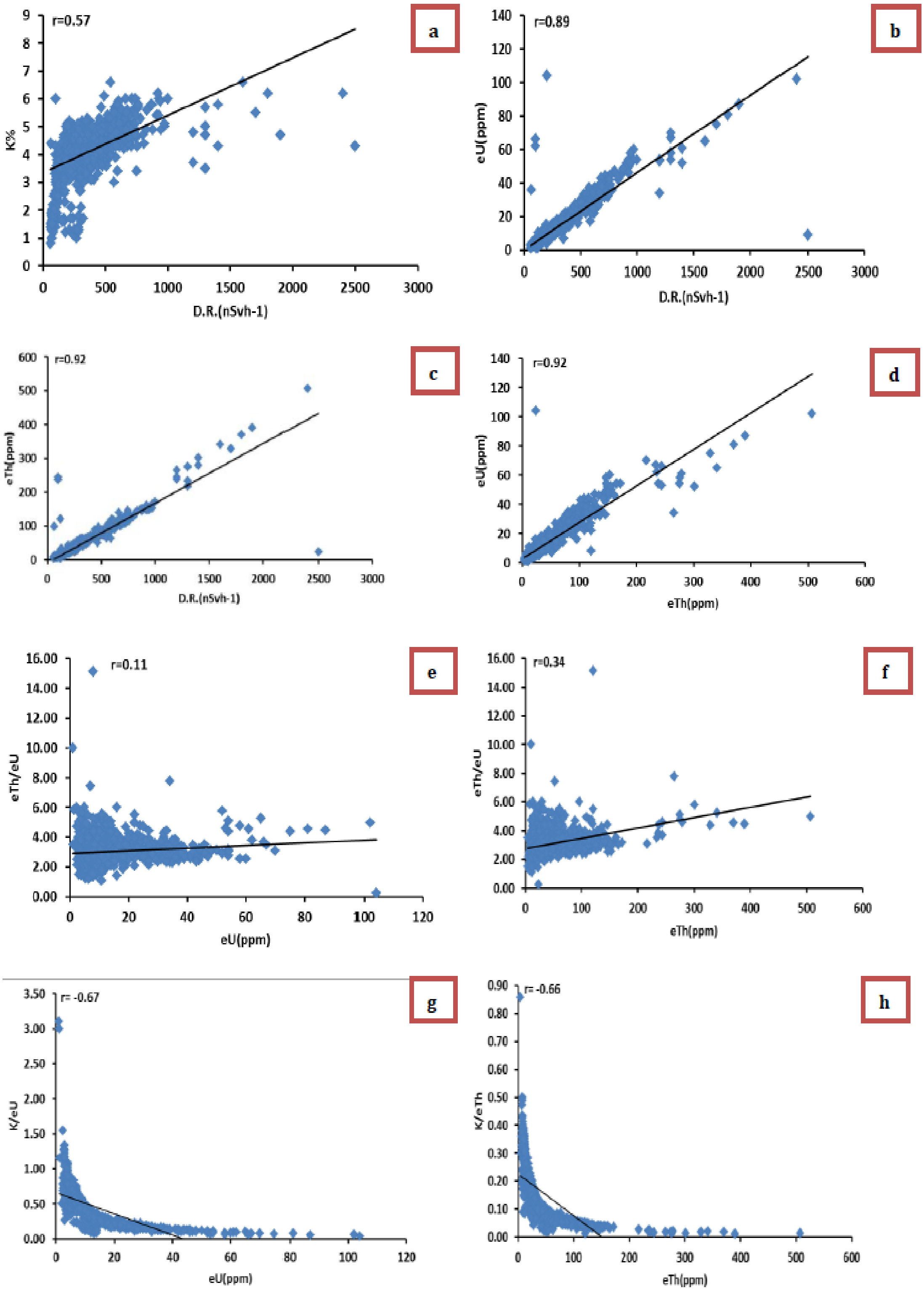


Fig20. *Binary relation between (a) D.R. –K%, (b) D.R.-eU, (c) D.R.-eTh, (d) eTh-eU, (e) eU-eTh/eU, (f) eTh-eTh/eU, (g) eU- K/eU and eTh –K/eTh for W. Abu Rusheid stream sediments, SED, Egypt*

6. MINERALOGICAL INVESTIGATIONS

The investigated minerals in the studied part of the stream sediments of W. Abu Rusheid can be classified according to its anion groups into the following:

6.1. Silicate Minerals Group

- **Kasolite [$Pb(UO_2)SiO_4(H_2O)$]** is a hydrated silicate of lead and hexavalent uranium and is characterized by its bright colour from yellow to yellowish orange with resinous luster (Fig.21). It is confirmed by SEM techniques (Fig. 21), and contains46.59% U, 45.25% Pb, 7.42% Si and 0.74% Cu.
- **Uranothorite [$(Th, U)SiO_4$]** occurs as anhedral opaque mineral grains varying in colour from dark brown to black and exhibiting submetallic to greasy luster (Fig. 22). It is confirmed by SEM techniques (Fig. 22), and contains 41.44% Th, 9.10% U, 8.74% Ce, 20.79% Si and 7.27% P.
- **Zircon [$ZrSiO_4$]** occurs as short and long euhedral prismatic and/ or bipyramidal crystals, of various colours (pale yellow, reddish brown, reddish orange and colourless) (Fig. 23). It is confirmed by SEM techniques (Fig. 23), and contains 43.12% Zr, 12% Hf and 44.88% Si.
- **Garnet [$(Ca, Mg, Fe, Mn)_3Al_2(SiO_4)_3$]**group can be divided in two subgroups based on different ionic radii of Mg, Fe, Mn on one hand and Ca on the other, the first type pyrol-spite consists of pyrope (Mg, Al)- almandine (Fe, Al) and spessartine (Mn, Al) , the second type grondites include Ca in the structure. In the studied area, the garnet has reddish orange colour and is confirmed by SEM techniques (Fig. 24), and contains 15.24% Fe, 7.91% Ca, 4.54% Mn, 3.54% Mg, 22.31% Al and 45.06% Si.
- **Titanite [$CaTiSiO_5$]** occurs as equal grains, yellowish to brown in colour (Fig. 25). It is confirmed by SEM techniques (Fig. 25), and contains 16.3% Ca, 34.57% Ti and 34.17% Si.

6.2. Phosphate Minerals Group

- **Monazite [$(Ce, La) PO_4$]** is wide spread in different igneous and metamorphic rocks (Ziemann et al., 2005). It occurs as transparent and vitreous luster, pale yellow, honey yellow, greenish yellow and reddish yellow grain. It is confirmed by SEM techniques (Fig. 26), and contains 26.57% Ce, 13.16% La, 13.36% Nd, 4.78% Th, 2.67% Sm, 2.22% Gd, 1.28% U and 19.24% P.
- **Apatite [$Ca_5 (PO_4)_3F$]** is the most common phosphate mineral, and is the main source of the phosphorus required by plants. The bones and teeth of most animals, including humans, are of the same material. Its colour ranges from green, brown to dark brown. It is confirmed by SEM techniques (Fig. 27), and contains 57.8% Ca, 25.20% P, 10.16% Si, 4.25% Al and 1.6% Ni.

6.3. Oxide Minerals Group

- **Columbite [$(Fe,Mn)(Nb,Ta)_2O_6$]** is iron-black, grayish and brownish black, opaque, rarely reddish brown and translucent.It is confirmed by SEM techniques (Fig. 28), and contains 49.39% Nb, 12.49% Fe, 7.88% Mn, 6.98% Ta and 10.16% Si.
- **Cassiterite [SnO_2]** is the main constituent of greisens, granitic pegmatites and hydrothermal veins. It is a brown to black tetragonal mineral, massive or compact with concentric structure. It is confirmed by SEM techniques (Fig. 29), and contains 69.73% Sn, 3.59% Fe, 4.57% Si and 17.50% O.
- **Rutile [TiO_2]** is an important economic heavy mineral. It occurs as elongated, needle like and prismatic grains with a foxy red, reddish brown to opaque colour. It is confirmed by SEM techniques (Fig. 30), and contains 91.73% Ti, 3.48% Al and 4.87% Si.
- **Ilmenite [$FeTiO_3$]** occurs as iron black or asphaltic in colour with metallic and dull luster (Fig. 31a).
- **Leucoxene [TiO_2]** is an alteration product of ilmenite and is the transition stage between ilmenite and the secondary rutile. The leucoxene commonly occurs as elongated, needle like grains with yellow to brown colour (Fig. 31b).
- **Hematite [Fe_2O_3]** existed as granular grains with reddish brown to black in colour (Fig. 31c). It is often formed by the decomposition of iron-bearing minerals, particularly silicate.

- **Magnetite [Fe_3O_4]** is black in colour and has metallic to submetallic luster. Sometimes converted into secondary hematite (martite), through martitization particularly along grain boundaries, cracks and cleavage. Some grain surfaces showing pitting and caving of black or dull black color. It is confirmed by SEM techniques (Fig. 32), and contains 86.58% Fe and 10.29% Si.

6.4. Carbonate Mineral Group

- **Cerussite [$PbCO_3$]** is an ore for lead and is a common alteration product of galena and occurs as yellowish colour with subrounded form. It is confirmed by SEM techniques (Fig. 33), and contains 88.43% Pb, 3.99% Mg and 2.38% Si.

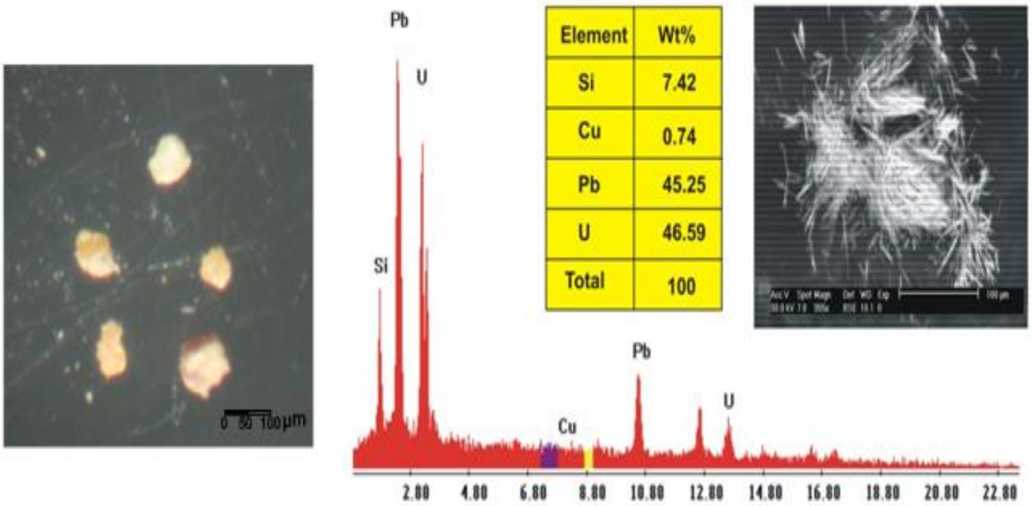


Fig21. *Stereophotograph and SEM back-scattered data and image of kasolite, W. Abu Rusheid stream sediments, SED, Egypt*

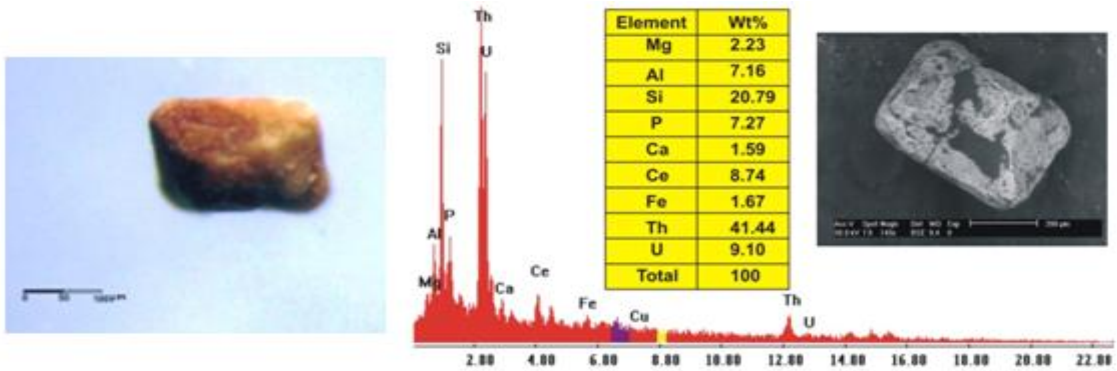


Fig22. *Stereophotograph and SEM back-scattered data and image of uranothorite, W. Abu Rusheid stream sediments, SED, Egypt*

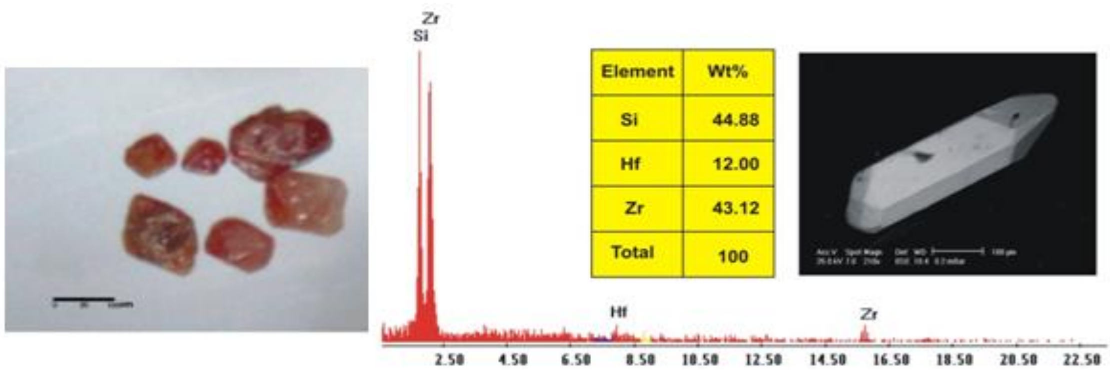
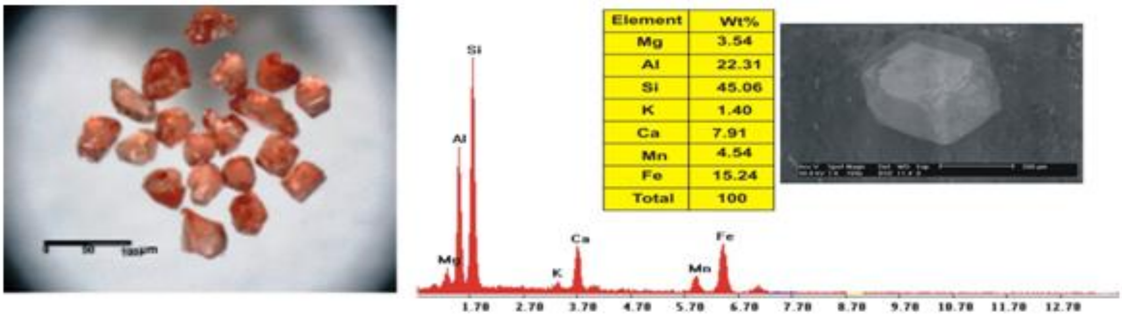
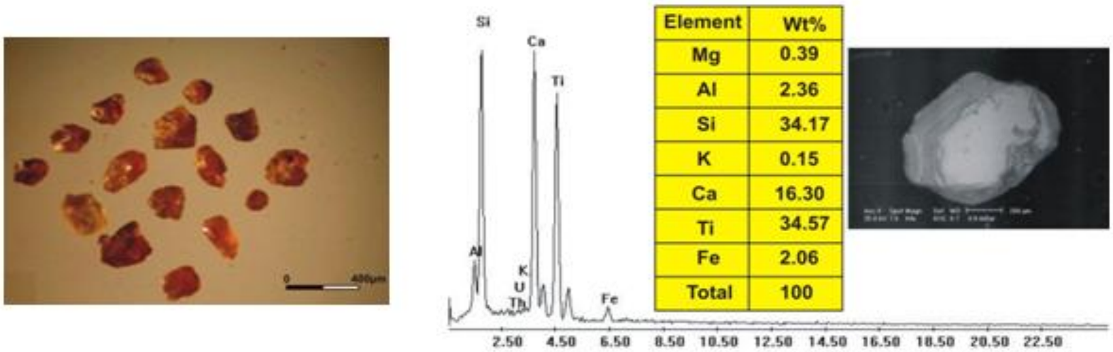


Fig23. *Stereophotograph and SEM back-scattered data and image of zircon, W. Abu Rusheid stream sediments, SED, Egypt*



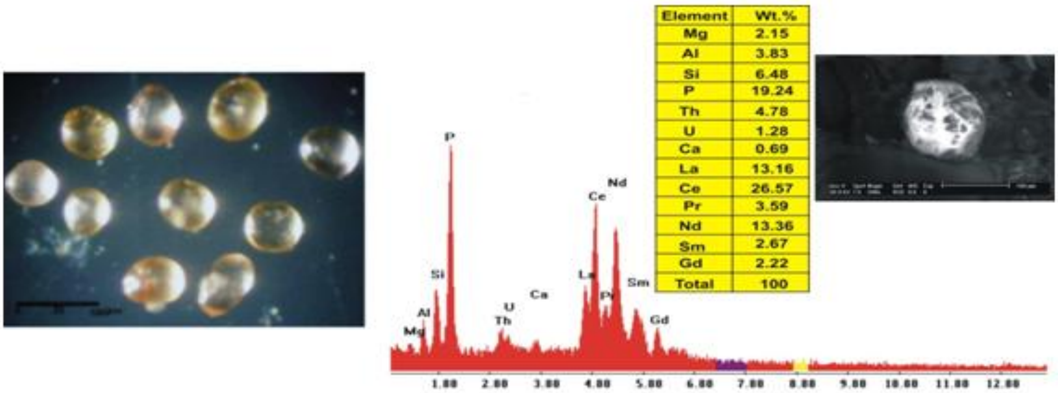
Element	Wt%
Mg	3.54
Al	22.31
Si	45.06
K	1.40
Ca	7.91
Mn	4.54
Fe	15.24
Total	100

Fig24. *Stereophotograph and SEM back-scattered data and image of garnet, W. Abu Rusheid stream sediments, SED, Egypt*



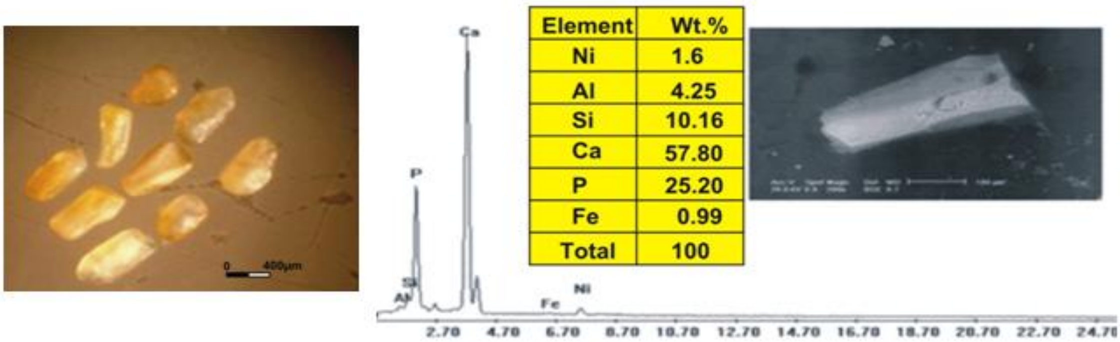
Element	Wt%
Mg	0.39
Al	2.36
Si	34.17
K	0.15
Ca	16.30
Ti	34.57
Fe	2.06
Total	100

Fig25. *Stereophotograph and SEM back-scattered data and image of titanite, W. Abu Rusheid stream sediments, SED, Egypt*



Element	Wt.%
Mg	2.15
Al	3.83
Si	6.48
P	19.24
Th	4.78
U	1.28
Ca	0.69
La	13.16
Ce	26.57
Pr	3.59
Nd	13.36
Sm	2.67
Gd	2.22
Total	100

Fig26. *Stereophotograph and SEM back-scattered data and image of monazite, W. Abu Rusheid stream sediments, SED, Egypt*



Element	Wt.%
Ni	1.6
Al	4.25
Si	10.16
Ca	57.80
P	25.20
Fe	0.99
Total	100

Fig27. *Stereophotograph and SEM back-scattered data and image of apatite, W. Abu Rusheid stream sediments, SED, Egypt*

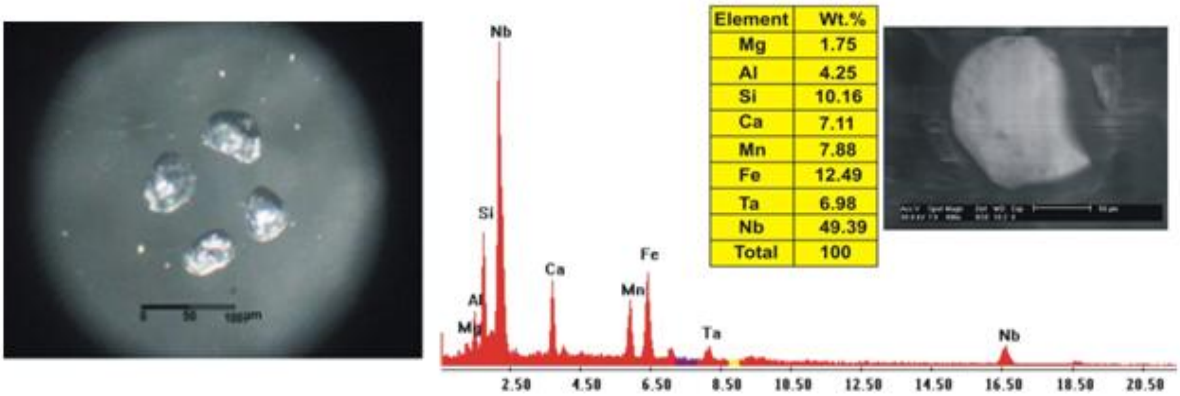


Fig28. *Stereophotograph and SEM back-scattered data and image of columbite, W. Abu Rusheid stream sediments, SED, Egypt*

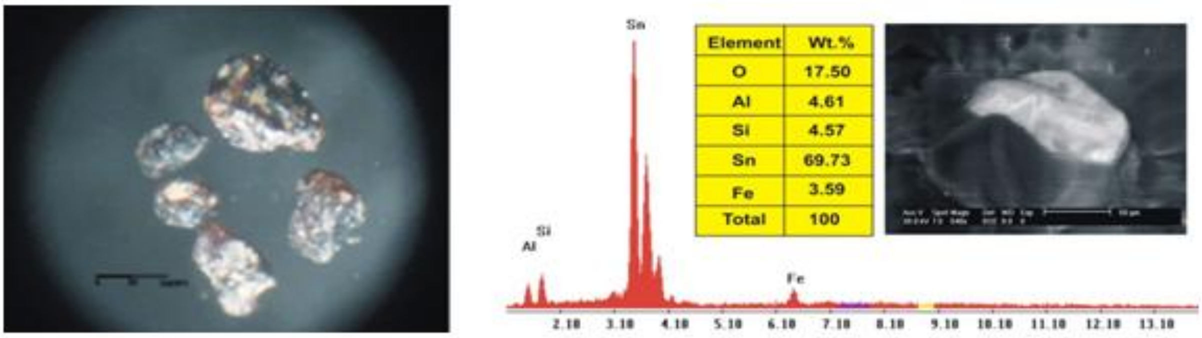


Fig29. *Stereophotograph and SEM back-scattered data and image of cassiterite, W. Abu Rusheid stream sediments, SED, Egypt*

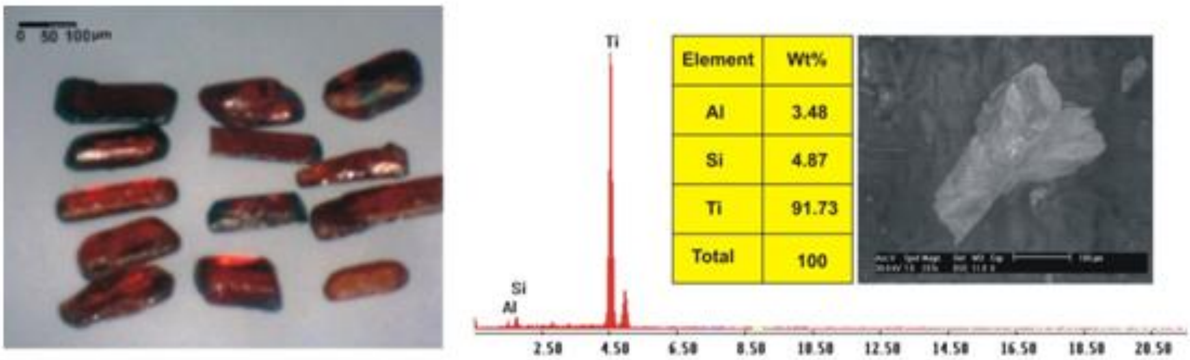


Fig30. *Stereophotograph and SEM back-scattered data and image of rutile, W. Abu Rusheid stream sediments, SED, Egypt*

Fig31. *Stereophotograph of (a) ilmenite, (b) leucoxene and (c) hematite, W. Abu Rusheid stream sediments, SED, Egypt*

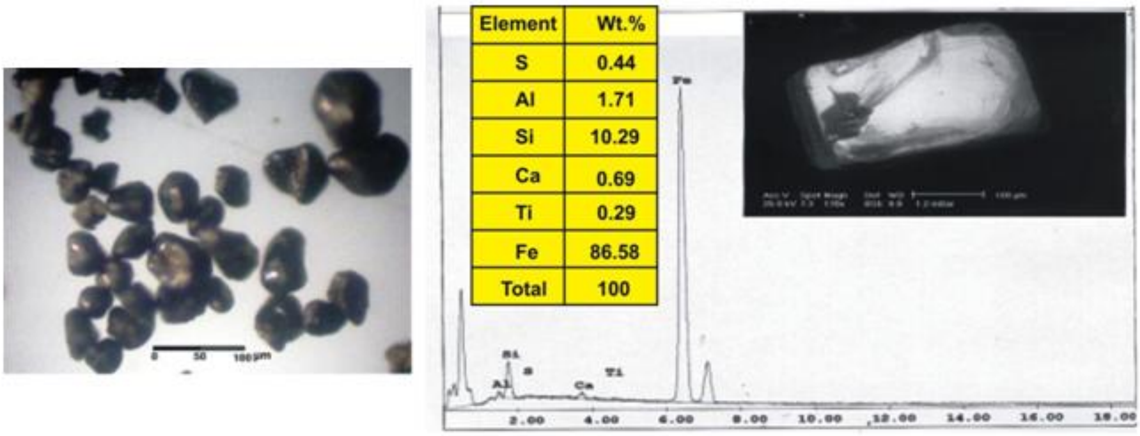


Fig32. *Stereophotograph and SEM back-scattered data and image of magnetite, W. Abu Rusheid stream sediments, SED, Egypt*

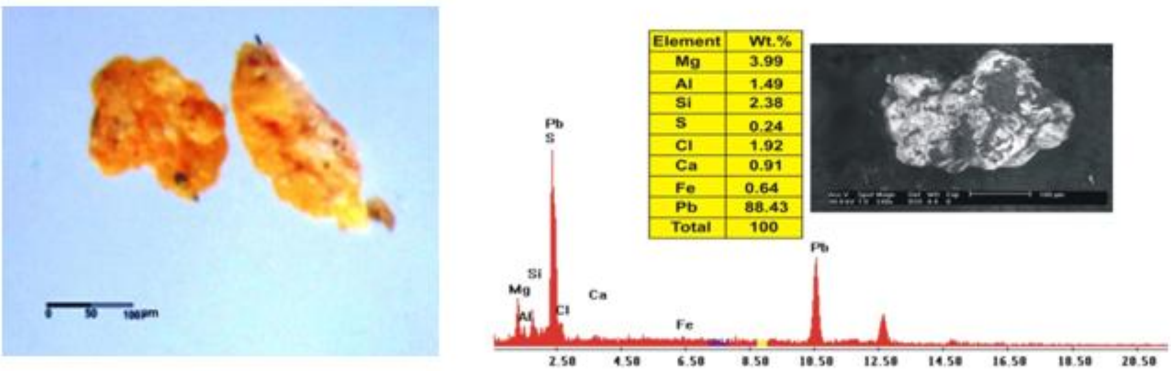


Fig33. *Stereophotograph and SEM back-scattered data and image of cerussite, W. Abu Rusheid stream sediments, SED, Egypt*

6.5. Sulfide Minerals Group

- **Galen [PbS]** has a cubic structure and occurs as lead-grey colour. It is confirmed by SEM techniques (Fig. 34), and contains 45.23% Pb, 14.47% Cl, 8.36% S and 9.38% Si.
- **Pyrite [FeS_2]** is one of the most widespread and abundant sulfide minerals. It exhibits golden yellow or shiny brassy yellow colour with metallic luster. It is confirmed by SEM techniques (Fig. 35), and contains 56.14% S and 43.86% Fe.

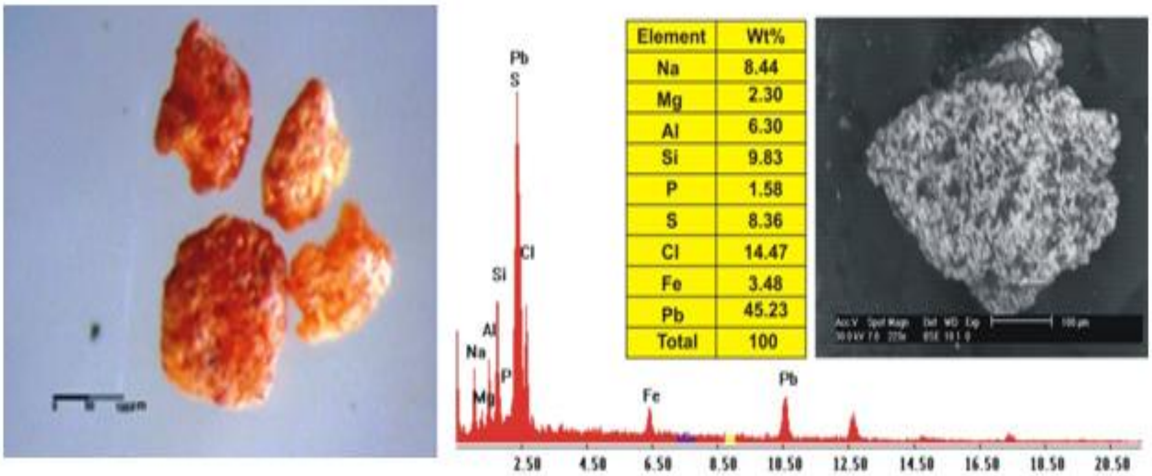


Fig34. *Stereophotograph and SEM back-scattered data and image of galena, W. Abu Rusheid stream sediments, SED, Egypt*

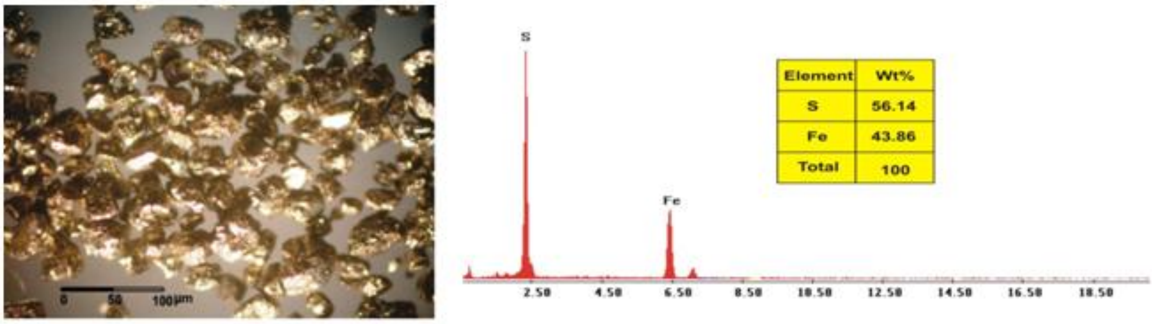


Fig35. *Stereophotograph and SEM back-scattered data and image of pyrite, W. Abu Rusheid stream sediments, SED, Egypt*

7. Preliminary Estimation of Some Economic Elements

The assessment of some economic elements in the studied area of W. Abu Rusheid stream sediments requires data about the three dimensions of the deposits and the concentration of these elements. According to the ground geophysical report after Khalil et al. (2011), the average thickness of the deposits is 21m.The average concentration of 45 stream sediments samples and the assessment values are listed in table (5).The dimension of studied part is 1100m length, 100m width and21m depth with density 2.6 g/cm^{3}and the average elements concentration as in table (2).

The surface area =110,000m^2, the volume =2,310,000m^3, the tonnage =6,006,000 ton

Table5: *The assessment values of some economic elements, W. Abu Rusheid stream sediments, SED, Egypt.*

Element	Ore metal (ton)
Zr	4936.93
Nb	978.98
Rb	1561.56
Zn	1297.30
Pb	1039.04
Y	1033.03
Ga	240.24

8. Conclusion

W. Abu Rusheid is situated between latitude 24^{o}36`29``- 24$^o$39`22``N and longitude 34^{o}44`40``-34$^o$47`23``E. The tectono-stratigraphic sequence of Abu Rusheid rock types starting from the oldest are: (1) An ophiolitic melange, consisting of ultramafic rocks and layered metagabbros set in a metasediment matrix; (2) Cataclastic rocks, including protomylonites, mylonites, ultramylonites, silicified ultramylonites; (3) Granitic rocks; and (4) Post-granite dykes (lamprophyre), pegmatite and quartz veins; (5) Wadi deposits. The cataclastic rocks are cross cut by NNW-SSE and E-W trending shear zones.

The studied wadi deposits are covered by the loose sediments, which are derived from the weathering of the different surrounding rocks. The different geophysical techniques are used for determining the thickness of stream sediments and revealed that; in the southern part of W. Abu Rusheid, the depth to the basement is deeper than the rest of W. Abu Rusheid that reach about 27 m, while at the middle part of W. Abu Rusheidthe depth to the basement rocks are shallower and reaches about 16 m. Finally, the depth to the surface of the basement rocks has an average value of about 21 m under the sediments.

The geochemical maps show that, zirconium, lead, niobium, yttrium, barium, cobalt and strontium concentrations fluctuated downs and ups from the upstream to the downstream of the studied part of W. Abu Rusheid. Zinc, rubidium, chromium and nickel concentrations were close to the ophiloitic mélange especially at the northern part of the studied W. Abu Rusheid. The high gallium concentrations are close to the downstream of W. Abu Rusheid. The high concentrations of copper are closed to the contact of ophiloitic mélange with the mineralized cataclastic rocks, whereas vandium have random pattern distribution in the studied part of W. Abu Rusheid.

The correlation matrix between almost trace elements of the studied stream sediments are weak either positive or negative. These weak correlations indicating that the trace element constituents are governed by many geochemical factors and are from different source.

The eU and eTh concentration in the stream sediment ranges from 1 to 104ppm and 4.2 to 507ppm with an average 12.65ppm and 39.69ppm respectively. These radiometric measurements were used in constructing the radiometric maps of the different radioactive elements. These maps revealed that; all the radioactive elements are compatible with each other's. The highest concentrations of all radioactive elements are in the upstream part. The high concentration of radioactive elements are close to the mineralized cataclastic rocks along the studied part of W. Abu Rusheid.

The investigated minerals in the studied parts of the stream sediments of W. Abu Rusheid can be classified according to its anion groups into the following: silicate minerals group (kasolite, uranothorite, zircon, garnet and titanite), phosphate minerals group (monazite and apatite), oxide minerals group (columbite, cassiterite, rutile, leucoxene, magnetite, hematite and ilmenite), carbonate mineral group (cerussite), sulfides minerals group (galena and pyrite).

The preliminary assessment of some economic elements in the studied area of W. Abu Rusheid stream sediments revealed that the ore metals in ton are: Zr (4936.93), Nb (978.98), Rb (1561.56), Zn (1297.3), Pb (1039.04), Y (1033.03) and Ga (240.24). This assessment need more accuracy and requires more sampling along grid patterns and at different depths.

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