Homrit Waggat Feldspar Sands; Sedimentological Features, Mineralogical Composition and Suitability for Ceramics Industry, Central Eastern Desert, Egypt

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Abstract

Field observations, detailed mineralogical, geochemical and sedimentological studies of stream sediments samples collected along Wadi Homrit Waggat have been carried out. The stream sediments covered an area of about 60 square km along eastern, western and southern sides of Gabal Homrit Waggat granites (HW). The stream sediments are collovial-alluvial deposits accumulated during the Recent on the flood plains and wadi El Faliq representing physical weathering products of Homrit Waggat granites. The carbonate minerals almost are rare.

The data of the grain sizes (-2 mm) show that the HW feldspar sands are chiefly granule (72.08-46.48 %) and very coarse to medium-sands (43.45-25.44 %) constituting the main bulk of the stream sediments. Sedimentological data show that the stream sediments are very fine gravelly clay, very platykurtic, very coarse to coarse - skewed and very poorly- sorted. The light minerals are chiefly feldspar (microcline and albite) and quartz. Very fine sand, silt and clay fractions are also present only ranging from 13.27-2.41%. The separated heavy minerals constituting <2 wt % of the bulk samples are rutile, zircon, biotite and chlorite, staurolite in addition to opaque minerals chiefly hematite. The recorded U and Th contents in Homrit Waggat granites, range from 14 -2 ppm and from 40 -2 ppm respectively related to zoned zircon.

The Homrit waggat feldspar sands are characterized by low quartz to feldspar ratio value 1/ 2. The separation of feldspar sands of grain size classes (-4 to 0.315 mm) eliminates the heavy minerals including zoned zircon as well as can be after treatment with cold water and 10% HCL solution to remove carbonate minerals and iron oxides consider suitable for ceramics industry.

Key words: Homrit Waggat, Feldspar sand, Mineralogy, Grain size, Ceramics.
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Introduction

The present work deals with the field observations, sedimentological and mineralogical, studies of Homrit Waggat feldspar sands to study its suitability for ceramics industry. The study area is located in the southern part of the Central Eastern Desert, Egypt, between latitudes 25°7' - 25°12'N and longitudes 34°16' - 34°22'E. The feldspar sand covers about 60 km^2 (Fig.1). The area is reached by the Mersa Alam- Idfu asphaltic road then accessible by a desert road 5 km to the north located 70 km west Marsa Alam city on the Red Sea coast.

Feldspar is important for the ceramics industry because of its content of alumina and alkalis (potash and soda) and its relatively low firing temperature. Besides, feldspar is a raw material in manufacturing of glass, white pottery and porcelin enamels. Glass grade feldspar is used in a relatively coarse (minus 20 mesh = 0.841 mm) grain size to minimize the losses in the glass furnace due to fines. Its iron oxide content should not exceed 0.15 percent. For whiteware bodies and glass in pottery, feldspar is used as a flux. It must be very finely ground (minus 200 mesh = 0.074 mm) and finer, be essentially free of quartz and iron bearing minerals and contains a high potash / soda ratio. Alkali feldspars are widely used in the ceramics industry in the ground state so called feldspar flour of below (0.09 mm or 0.075mm).

The feldspar sands in the studied area are products of physical weathering and erosion of Homrit waggat granites comprising according to **El Kady., 2014** (in press); microcline (red) granite, alkali feldspar (buff) granite, biotite granite, highly highly deformed biotite granodiorite and deformed granodiorite. These rock units are characterized by low feldspar to quartz ratio values. The present paper aims studying sedimentological features and mineralogical composition of these feldspar sands covering extensive area in detail to record its probable suitability for ceramics industry.

Therefore, the following studies will be undertaken;

1. Seven samples each weighing ~5km were collected from stream sediments at (20-30 cm) depth to avoid the aeolian sand effect (Fig.1).
2. Sieving of the seven samples was carried out using a Ro-tap electric shaker for 15 minutes per each sample using standard seven sieves of aperture size 2 mm, 1mm, 0.50 mm, 0.25 mm, 0.125 mm, 0.063 mm. Each of the obtained seven-grain size classes is weighed. The obtained grain size classes are used to determine grain size frequency distribution and sedimentological parameters; mean size, sorting, skeweness and kurtosis.
3. Mineralogical investigation of the heavy minerals separated from light minerals of the size fractions -0.25-0.125 mm (- 60 +150 mesh) and -0.125-0.063 mm (-150 +200 mesh) using bromoform (Sp.G. =2.82) to separate the heavy and the light mineral fractions and each fraction was weighted.
4. Hand picking of quartz and feldspars from weighed 5 gm was undertaken using binocular microscope. The detection of the heavy minerals was carried out using Environmental Scanning Electron Microscope (ESEM) Model Phillips XL 30 with Energy Dispersive X-ray EDX technique in the Central laboratories of the Geological Survey of Egypt. The light fractions as well as heavy minerals were also, studied using the binocular microscope.
5. Suitability for ceramics industry by considering in details accessibility, amiability for upgrading, quartz/ feldspar ratio and iron oxides content.

Geologic Field Observations

In Homrit Waggat area, the exposed rock units are metamorphic schists, serpentinites and related rocks, meta- gabbro- diorites and related rocks, granites, post-granite dikes and quartz veins. Extensive areas of feldspar sand are recorded consisting essentially of feldspar and quartz minerals accumulating in wadi El Faliq crossing Homrit Waggat granite masses and its surrounding terranes (Fig.1). Consequently, large reserves of a mixture of feldspar and quartz may be available. The most recent geological,

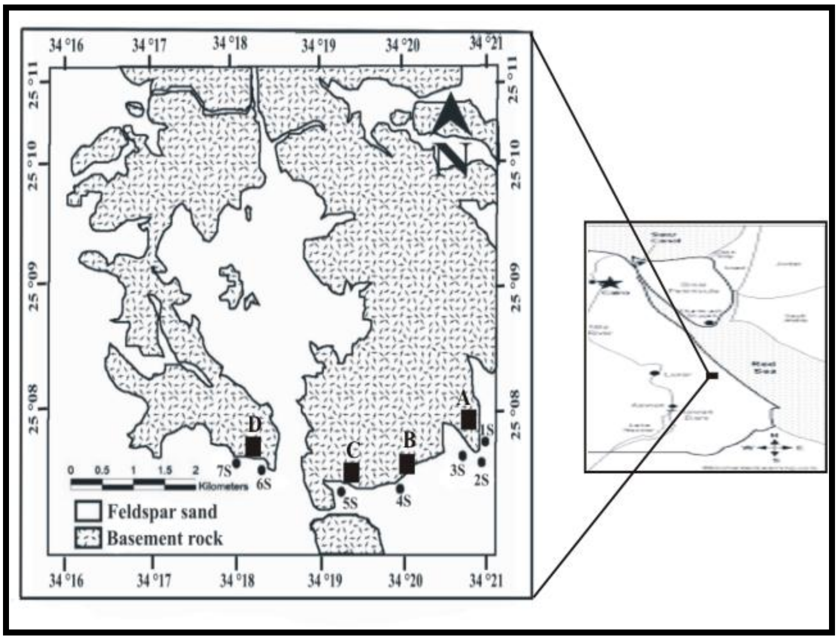


Fig.1: Location map of the feldspar sand samples.

Table.1: The frequency percent of grain size fractions for the feldspar sand samples.

	Grain size (in Wt %)								
Field. No.	S.No.	+2	-2 +1	-1 +0.5	- 0.5 +0.25	-0.25 +0.125	-0.125 +0.06	- 0.063	Total
1A	1S	46.48	19.4	15.25	8.82	2.52	5.29	1.89	99.95
2A	2S	72.08	15.49	7.4	2.52	0.76	0.76	0.89	99.93
3A	3S	58.01	20.10	11.95	4.06	1.78	1.78	2.29	99.97
B	4S	55.27	21.23	12.68	4.51	2.51	1.50	2.26	99.96
C	5S	62.42	14.37	9.83	4.78	1.76	2.64	4.16	99.96
1D	6S	55.99	16.96	13.90	5.47	0.76	2.29	4.59	99.96
2D	7S	50.99	14.74	13.28	7.69	1.59	7.70	3.98	99.97

geomorphological, mineralogical and geochemical investigations carried out on the exposed basement rocks in (HWG) are **Amin *et al*. (1954), Bentor (1985)**, **Stern and Gottfried (1986)**, **Sylvester (1989)**, **Abdel Rahman and Martin (1990)**, **Lumbers *et al.* (1991)**, **Eby (1992)**, **Mohamed (1993)**, **Hassanen (1997), Moghazi *et al.* (1999)**.

Sedimentological Features

Grain Size Analysis

The results of sieving represented by the percentage of the grain size classes are given in tables (1& 2) and the graphic presentation as histograms and cumulative curves in Figs (2, 3). The Histograms show that five of these samples (1A, 3A, C, 1D, 2D) are bimodal while sample (2A) is unimodal and sample (B) is trimodal. These histograms point to that the grain sizes +2 (> 50 % in average) is predominant class and the grain sizes -2+0.5 represent >35% in average of the studied feldspar sand. From the cumulative curves, these feldspar sand samples represent a low slope population reflecting ill- sorted sediments (**Folk, 1980**). The grain-size parameters shown in table (2) point to that these stream sediments are very fine to coarse sand as the Mz values range from 3.80 φ to 5.81 φ. They are very poorly- sorted as σ_I values range from 3.90 φ to 3.94 φ). They are very coarse to coarse- skewed as (SK_I values range from -0.09 φ to-1.33 φ) and are very platykurtic where KG values range from 0.39 φ to 0.42 φ. The graphical methods described by **Folk and Ward (1957)** as well as the estimation of the parameters using **GRADISTAT** program **(Blott and Pye, 2001)**. The plotting of these parameters table (2) of the studied samples on the ternary diagram of **Folk (1954**, Fig.4) classified these stream sediments as muddy gravel.

The relationship between the parameters mean size and inclusive graphic skewness of **Niazy *et al*. (1992)** indicates that all the samples lie in the field of river sediments were used (Fig.5). The relationships between simple skewness, mean size and sorting of **Friedman., (1967),** and **Moiola & Weiser. (1968)** were used Figs .6&7. Both figures indicate that all samples are very coarse sand and moderately sorted river sands.

Mineral Composition

The mineralogical study of stream sediments are based on examination of fine and very fine sand fractions (Table.1). The mineral constituents of the light fraction are quartz and feldspar and the heavy fractions are opaques (hematite), biotite, chlorite, zircon, rutile and staurolite.

1. The Light Minerals

The light fraction is mainly composed of quartz and alkali or potash feldspars. The quartz is colourless and feldspar is red in color. Quartz grains are monocrystalline and show uniform to slightly undulose extinction. Feldspar fresh grains are angular to subangular.

2. The Heavy Minerals

The identified heavy minerals in the -0.25+ 0.125 and -0.125+ 0.063 mm grain size fractions (Table.3, Fig.8) comprise opaques (hematite), biotite, chlorite, zircon, rutile and staurolite in a decreasing order of abundance. The opaque minerals are represented only by hematite. **Rutile** grains are of lath shape, angular, subhedral and

Table.2: The grain size parameters of the studied stream sediment samples following **Folk and Ward (1957)**.

Sample No.		1S	2S	3S	4S	5S	6S	7S
Textural Group		Muddy Gravel	Muddy Gravel	Gravelly Mud	Gravelly Mud	Muddy Gravel	Gravelly Mud	Gravelly Mud
Sediment Name		Very Fine Gravelly Clay	Clayey Very Fine Gravel	Very Fine Gravelly Clay	Very Fine Gravelly Clay	Clayey Very Fine Gravel	Very Fine Gravelly Clay	Very Fine Gravelly Clay
Folk and Ward parameters φ	Mean	3.82	5.79	3.80	5.81	5.80	3.80	3.81
	Sorting	3.90	3.94	3.92	3.92	3.93	3.92	3.91
	Skewness	- 0.09	-1.32	- 0.09	-1.33	-1.33	-0.09	- 0.09
	Kurtosis	0.42	0.39	0.39	0.39	0.39	0.39	0.39
Method of Moments Logarthmic φ	Mean	-0.063	-0.40	-0.261	- 0.235	- 0.273	- 0.242	-0.070
	Sorting	0.988	0.675	0.794	0.801	0.857	0.804	1.069
	Skewness	1.619	1.008	1.396	1.326	1.614	1.310	1.736
	Kurtosis	7.473	9.133	8.934	8.279	9.003	8.537	7.357
Folk and Ward (Description)	Mean	Very Fine Sand	Coarse Sand	Very Fine Sand	Coarse Sand	Coarse Sand	Very Fine Sand	Very Fine Sand
	Sorting	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted
	Skewness	Symmetrical	Very Coarse Skewed	Symmetrical	Very Coarse Skewed	Very Coarse Skewed	Symmetrical	Symmetrical
	Kurtosis	Very Platykurtic	Very Platykurtic	Very Platykurtic	Very Platykurtic	Very Platykurtic	Very Platykurtic	Very Platykurtic

Table.3: The weight percentage of the heavy fractions (in Wt%) of the grain sizes (< 0.315 mm).

fraction / S.No.	-0.315 +0.25	-0.25 +0.125	-0.125 +0.063
1S	3.20	4.44	6.72
2S	5.78	2.75	3.3
3S	4.41	3.14	2.95
4S	7.69	4.22	0.55
5S	0.55	0.27	0.28
6S	0.56	1.05	1.69
7S	0.29	0.23	0.53

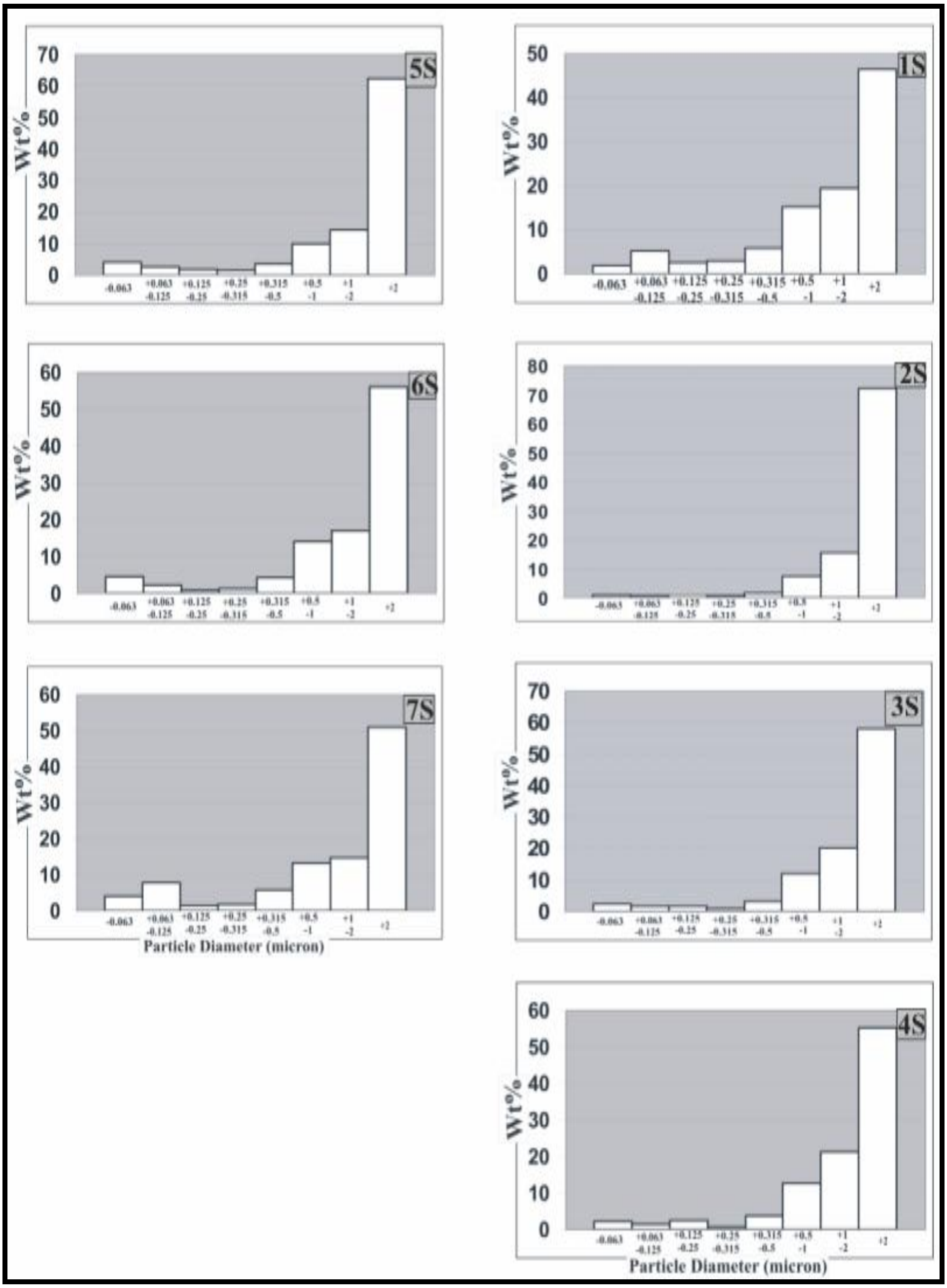


Fig.2: Histograms showing the frequency distribution of the grain size classes of the studied feldspar sand.

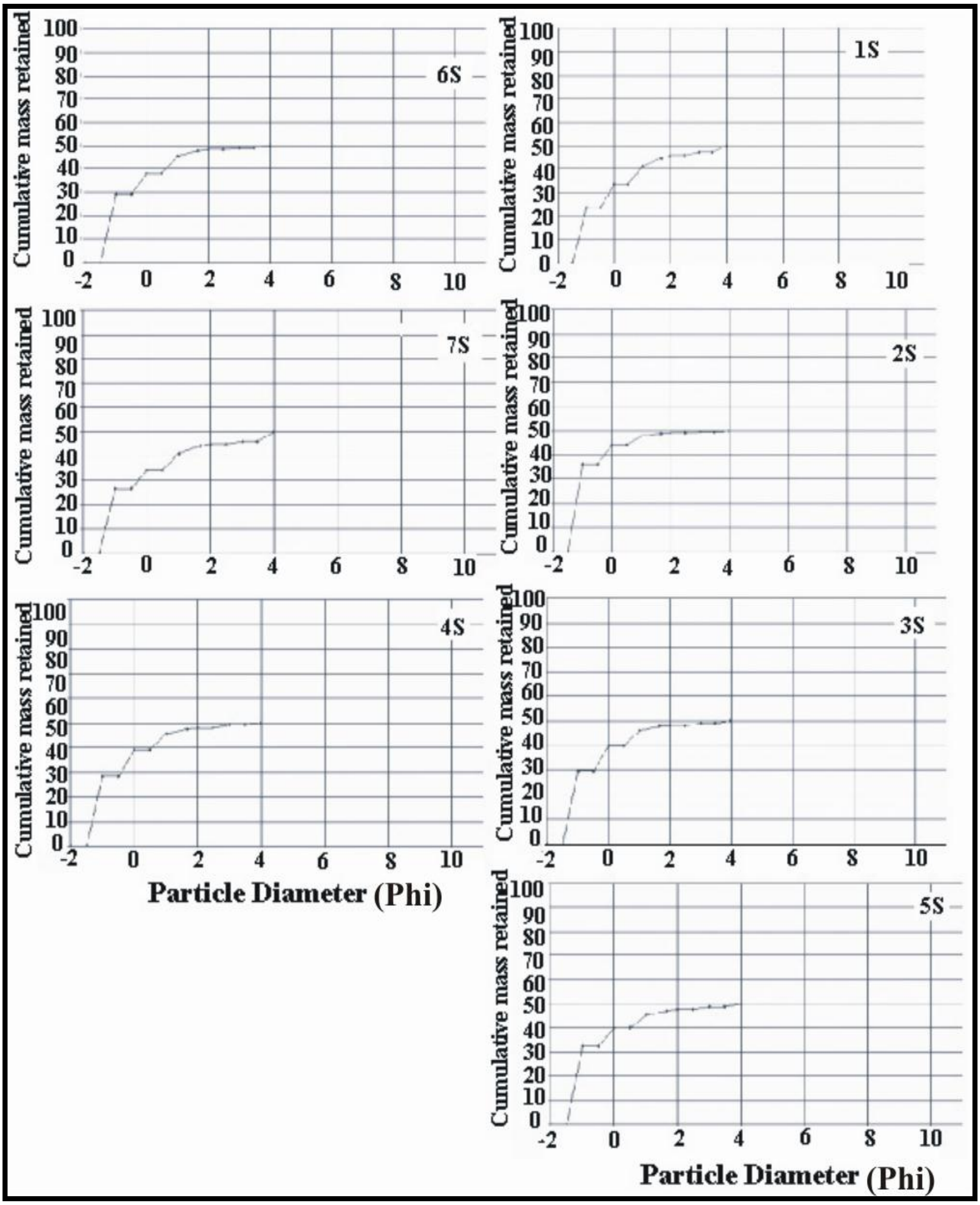


Fig.3: Cumulative curves (phi) of the sieved (<2mm) studied feldspar sand.

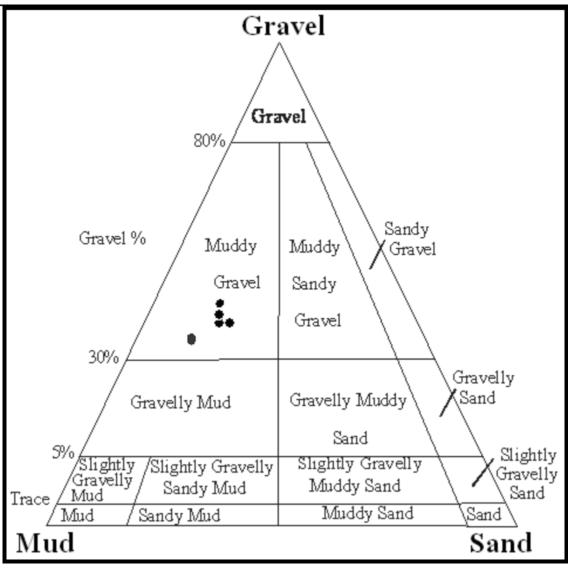


Fig.4: A plot of the study feldspar sand on the nomenclature triangle of **Folk (1954)**.

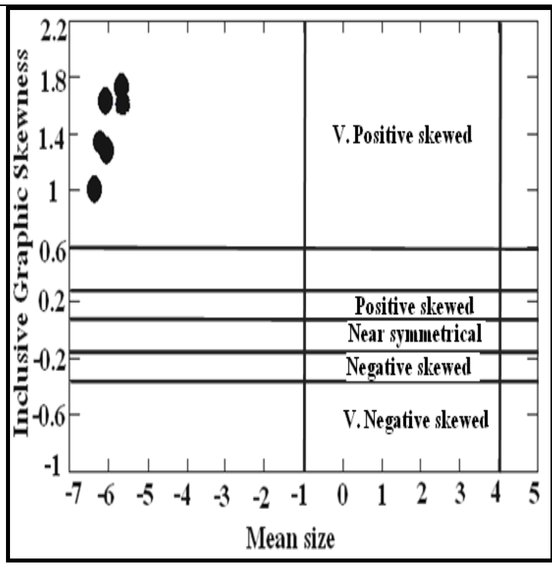


Fig.5: Relation between mean size and inclusive graphic skewness **(Niazy *et al.*, 1992)**.

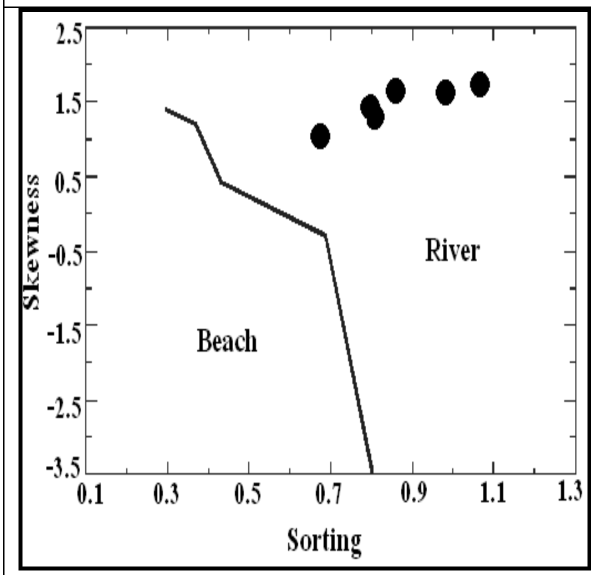


Fig.6: Relationships between simple sorting and simple skewness, **Friedman (1967)**.

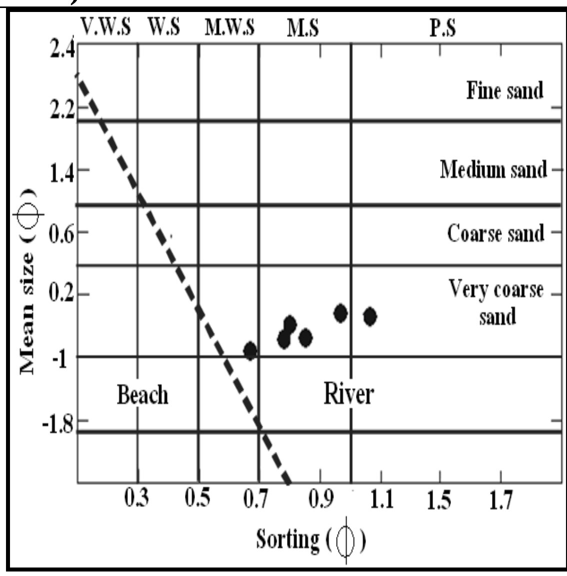


Fig.7: Bivariate plot of mean size (M_Z) versus sorting **(Moiola & Weiser, 1968)**.

rounded deep red, reddish brown and golden yellow varieties (Fig.8 a).It is characterized by its very high relief and sometimes contains solid inclusions. **Biotite** and **chlorite** are occuring in all examined samples as tabular grains. Pleochroism is marked in biotite with high absorption. **Chlorite** after biotite of yellow to pale yellow olive color (Fig.5.8 b). **Zircon** is the more common non-opaque heavy mineral in the studied samples. Zircon grains are prismatic euhedral crystals, broken eroded prismatic crystals with perfect edges, rounded, long and short crystal forms (Fig.8 c). **Staurolite** recorded in most studied samples is prismatic, angular to sub angular grains of pale brown, straw yellow and golden yellow color (Fig.8 d).

Suitability for Ceramics Industry

The feldspar sand suitability for ceramics industry must be characterized by the following: accessibility, amiability for upgrading, quartz/ feldspar ratio and low iron oxides content and radioactivity. Consequently, the studied alluvial sediments need upgrading by the following treatment methods to be suitable for ceramics industrial uses.

1-Accessibility: The area is suitably accessible as it is located near by the asphaltic road of Idfu (on the Nile river)-Marsa Allam (on the Red sea coast).

2- Amiability for upgrading:

a- Sieving

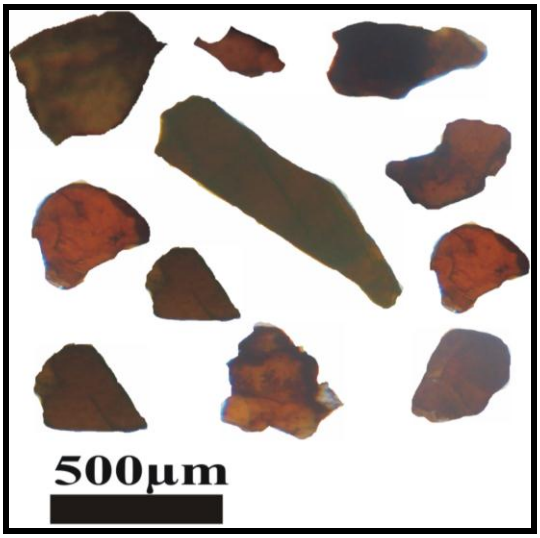
The percentages of grain size fractions given in tables 2 and 3 show that the studied feldspar sand is distinguished by highest percentage of the grain size +2mm ranging from 72.08% to 46.48%, the grain size (-2+1mm) from 21.23% - 14.37% and the grain size -1mm +0.5mm from 15.25% to 7.4% and grain size (-0.5+ 0.25mm) from 8.82 to 4.06%. The total percentage of these size classes ranges from 97.52% - 86.7% which represents the highest percentage compared to the less sizes < 0.25mm ranging from 13.27% to 2.41% (Table.4). Consequently, the grain size classes >0.25 mm represent the feldspar sand deposit.

b- Treatment by Water

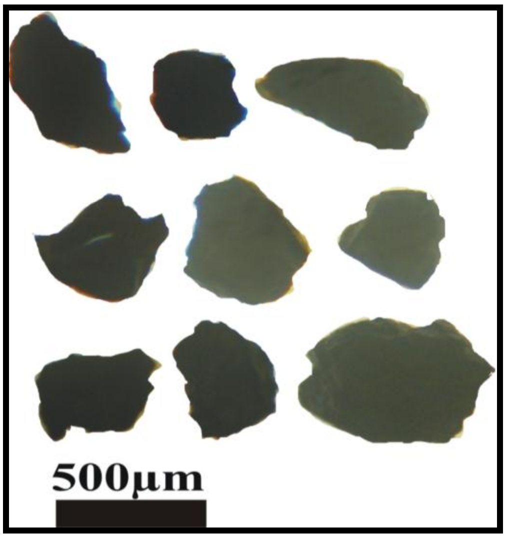
Cold water treatment is to remove silt and clay adhering on the separated by sieving the feldspar sand granules grain size > 0.25mm table (5) shows the values with H_2O. The treatment eliminated 57g/kg i.e 57 kg/Ton adherent silt and clay on the surface of the feldspar sand granules >0.25mm.

c- Treatment by HCl acid

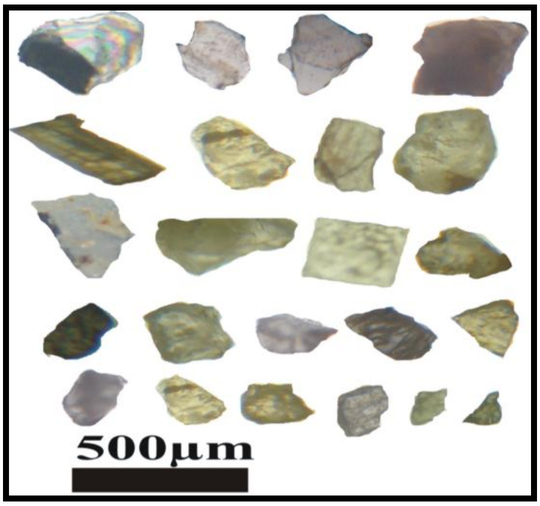
The treatment with cold 10% dilute hydrochloric acid eliminate the excess carbonates present in these stream sediments solution the values of which is given in table (6). Moreover, this treatment will remove the iron oxides staining the granules to minimize iron oxide content of the permissible value. The carbonates from the feldspar sand 24.6 g/kg i.e 24.6 kg/Ton adherent silt and clay on the surface of the feldspar sand granules >0.25mm.



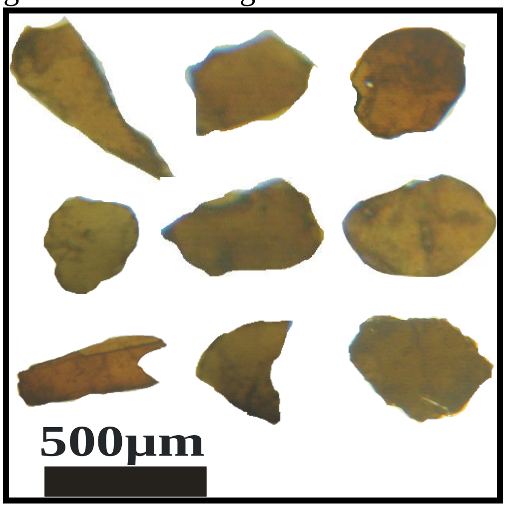
a. Rutile: reddish brown to yellow, high relief and dark borders.



b. Biotite and chlorite: yellowish green subrounded grains.



c. Zircon: anhedral grains with rounded terminations, more or less euhedral and colored with different types and forms of inclusions and bipyramidal prismatic zircon.



d. Staurolite: angular, elongated, golden brown color.

Fig.8: Photomicrograph showing the recorded grains of heavy minerals

Table.4: The frequency weight percent of grain size (0.5-0.25 mm) fractions suitable for ceramic industry.

S No.	+2	-2 + 0.25	-0.25- 0.063
1S	46.48	43.45	9.7
2S	72.08	25.44	2.41
3S	58.01	36.11	5.85
4S	55.27	38.42	6.27
5S	62.42	28.98	8.56
6S	55.99	36.33	7.64
7S	50.99	35.71	13.27

Table.5: Values of silt and clay fractions removed by water treatment.

Sample No.	Weigh before treatment (in g)	Weigh after treatment (in g)	Weight of Removed dust (in g)
1S	80	77.2	2.8
2S	80	77.21	2.79
3S	80	76.93	3.07
4S	80	75.84	4.16
5S	80	68.04	11.96
6S	80	73.81	6.19
7S	80	79.05	0.95
Total feldspar sand	**560**	**528.08**	**31.92**

Table.6: Values after treatment with 10% HCl solution.

Sample No.	Samples before treatment (in g)	Samples after treatment (in g)	Amount losses (in g)
1S	80	77.73	2.27
2S	80	78.07	1.93
3S	80	77.13	2.87
4S	80	77.76	2.24
5S	80	77.38	2.62
6S	80	79.1	0.9
7S	80	79	1
Total feldspar sand	**560**	**546.17**	**13.83**

3- Quartz / Feldspar Ratio

The weight percentage of quartz to feldspar by from weighed 5 gm of the light feldspar sand fraction recorded ratio value 1:2 contrary to that of the source rock match well with the permissible value units. Low quartz / feldspar. The feldspar minerals are chiefly albite and microcline which will provide high Na_2O and K_2O contents (Table.7).

4- Low iron oxides and radioactivity

The grain size fractions (-0.25mm) represent only (13.27-2.40 %) of the bulk samples. Of these, the two grain size fractions (-0.25+0.125) and (-0.125+0.063) contain the chief amount of the heavy minerals represented essentially by opaques and zircon.

Moreover, the petrographic study recorded zoned zircon (Fig.9) commonly considered radioactive bearing. The U and Th are recorded in the Homrit Waggat granite rock types (Table.8), the highly deformed biotite granodiorite U ranges from 2 ppm to 6 ppm and Th ranged from 2 ppm to 6 ppm. In biotite granite ranged from 4 ppm to 9 ppm and Th from 4 ppm to 9 ppm. In the alkali feldspar (buff) granite U ranges from 6 ppm to 14 ppm and Th from 19 ppm to 40 ppm.

Therefore, the separation by sieving of the grain size fractions < 0.25 mm is recommended to remove both the heavies and the silt-clay fractions bearing the iron oxides and zoned zircon harmful for ceramics industry. The iron oxides content should not excessed of 0.15% which will be available after excluding the grain sizes 0.25 mm including all opaque minerals.

Discussion and Conclusions

The studied feldspar sands represent uniform mineralogical composition comprising quartz, orthoclase, plagioclase, biotite, chlorite, rutile, zircon, staurolite and hematite reflecting the lithological composition of the exposed basement rock types chiefly Homrit Waggat granite.

The feldspar sands are classified according to the grain size data into muddy gravel. The histograms show that all samples are bimodal except (1S) which is unimodal and (4S) trimodal. These samples are very fine clayey gravel, very poorly sorted, very coarse to coarse- skewed and very platykurtic. Moreover, all the samples represent fluvial and river sand which is consistent with its accumulation during prevalence of pluvials in the Eastern Desert at internals of time every 3000 years. Minerals of the light feldspar sand fractions (grain size >0.25 mm) are mainly quartz and feldspar chiefly albite and microcline. Quartz forms monocrystalline angular to subangular and even subrounded grains. Feldspars are represented by both altered orthoclase and sodic- plagioclase. However, the less stable minerals in these feldspar sands, biotite, chlorite and hornblende are less abundant.

The Homrit waggat feldspar sands are characterized by low quartz to feldspar ratio value 1/ 2. The separation of feldspar sands of grain size classes (-4 to 0.315 mm) eliminates the heavy minerals including zoned zircon as well as can be after treatment with cold water and 10% HCL solution to remove carbonate minerals and iron oxides consider suitable for ceramics industry.

Table.7: Modal composition of the G. Homrit Waggat granites

	S.No.	Quartz	Plagioclase	K-Feldspar
Highly Deformed Biotite Granodiorite	2B	44.22	33.69	18.25
	3B	36.65	43.89	16.19
	1C	41.93	40.26	16.31
	2A	51.93	31.15	15.28
	4A	38.18	40.11	18.25
Biotite Granite	1E	42.49	44.93	9.94
	2E	35.13	45.80	13.45
Alkali-Feldspar-Granite	1A	31.14	52.53	13.85
	3A	56.86	20.46	22.43
	2C	44.76	33.42	19.57
	3C	52.31	27.56	18.67
	2D	39.28	36.04	10.49
	1B	43.46	39.29	14.16
Deformed Granodiorite	1G	23.45	61.21	0.26
	2G	٢٠	65.23	0.1
Red Granite	1F	49.66	36.99	11.34

Table.8: The recorded U and Th in the Homrit Waggat granite rock types

	U	Th
Alkali Feldspar pink granite	6-14	19-40
Biotite granite	4-9	4-9
Highly deformed biotite granodiorite	2-6	2-6

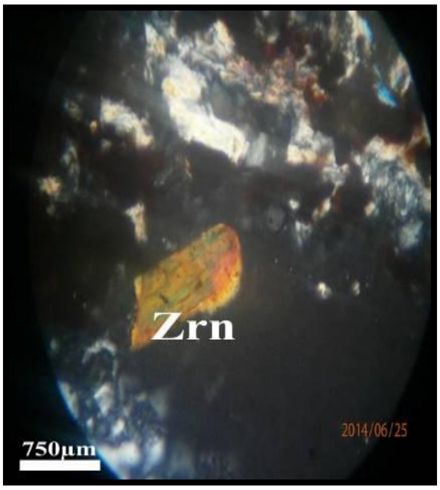


Fig.9: Photomicrograph showing short minute prismatic zircon (Zrn) crystals.

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