Heavy minerals assemblage of sediments in Almanaqil Ridge, Gezira State, Sudan

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Abstract- Heavy mineral assemblage of sediments in Almanaqil Ridge, Gezira State, Sudan has been studied, to identify, and if possible, to know their source and transporting agent. Four sediment samples were analyzed for determinations heavy mineral assemblage. The separation of these minerals was carried out using bromoform (specific gravity 2.85). These were followed by slide examination under the petrographic microscope. Heavy minerals grains of soil samples collected from outside the study area (sample 1 and 2) were compared with those inside the study area (sample 6 and 7). The heavy minerals assemblages of Zircon, Tourmaline, Rutile, Silimatate, Andalusite , Garnet, Epidote, and Quartz indicated its derivation from mixed sources of acid igneous rock to medium and high grade metamorphic rocks. The calculated % ZTR (Zircon, Tourmaline, Rutile) values varied between 47.99% to 26.08 % in in the samples from outside the study area compared with values of those inside study area which varied between 12.92% to 17.95 % and the mean ZTR percentage indices was 37.035 % of outside the study area and 15.5% of those inside study area. The three most abundant were Quartz, Garnet and Andalusite with values 50.33 %, 34.2 % and 24.52, respectively. Heavy minerals assemblages in the sediments of study area and that outside the area indicated low Zircon Tourmaline Rutile indices. This index is used as a clue for the identification of the source and as measure of the maturity of the sediments. The low ZTR index might indicate mineralogical immaturity and mineralogical composition. Heavy sand mineralogy revealed that the origin of the sand in the area was the Nubian sandstone.

Index Terms- heavy minerals, zircon, tourmaline and rutile

I. INTRODUCTION

The study of heavy minerals in sediments was established more than 100 years ago and in spite of the general skepticism towards its value during the middle of this century, the technique has not been neglected. The large variety of often distinctive heavy minerals which are found in sediments can provide valuable information for interpreting stratigraphy and determining the provenance of sediment. They can often be traced to a source in bedrock. Furthermore, the heavy mineral fraction can provide information on the nature of geochemical anomalies that would be otherwise difficult to obtain (Suzuki, 1975).

Heavy minerals are more provenance-specific than quartz and feldspar. They are a powerful tool for assessing the provenance and dispersion of modern and ancient sediments. They have been used successfully to correlate barren sandstones and reconstruct paleogeography (Pellant, *et al.*, 1996).

There are four potential important processes that can modify a heavy mineral assemblage: source area weathering, transport abrasion, hydraulic sorting and post-depositional digenesis. The latter two processes are the most significant. The effects of hydraulic sorting can be minimised by analysing the very fine sand fraction of a sample, and by discounting platy minerals such as mica and chlorite.

Progressive chemical dissolution of minerals occurs by near-surface acid weathering and during deep burial diagenesis. The two processes have different orders of mineral stability.

Post-depositional diagenesis can be difficult to distinguish from provenance variation. Sands which have undergone significant post-depositional diagenesis have a high proportion of ultrastable minerals (zircon, tourmaline and rutile); whereas unstable minerals (olivine, pyroxene) will be present in sands which have undergone minimal mineral dissolution.

Three methods can be used to recognise provenance changes in altered mineral assemblages:

- Mapping the presence/absence of diagnostic stable mineral species such as chloritoid.
- Determining changes in the ratio of two stable mineral species (e.g. rutile and zircon) (Morton, 1985).

In this study aims at analysis of heavy minerals assemblages of sediments in Almanaqil Ridge, Gezira State, Sudan.

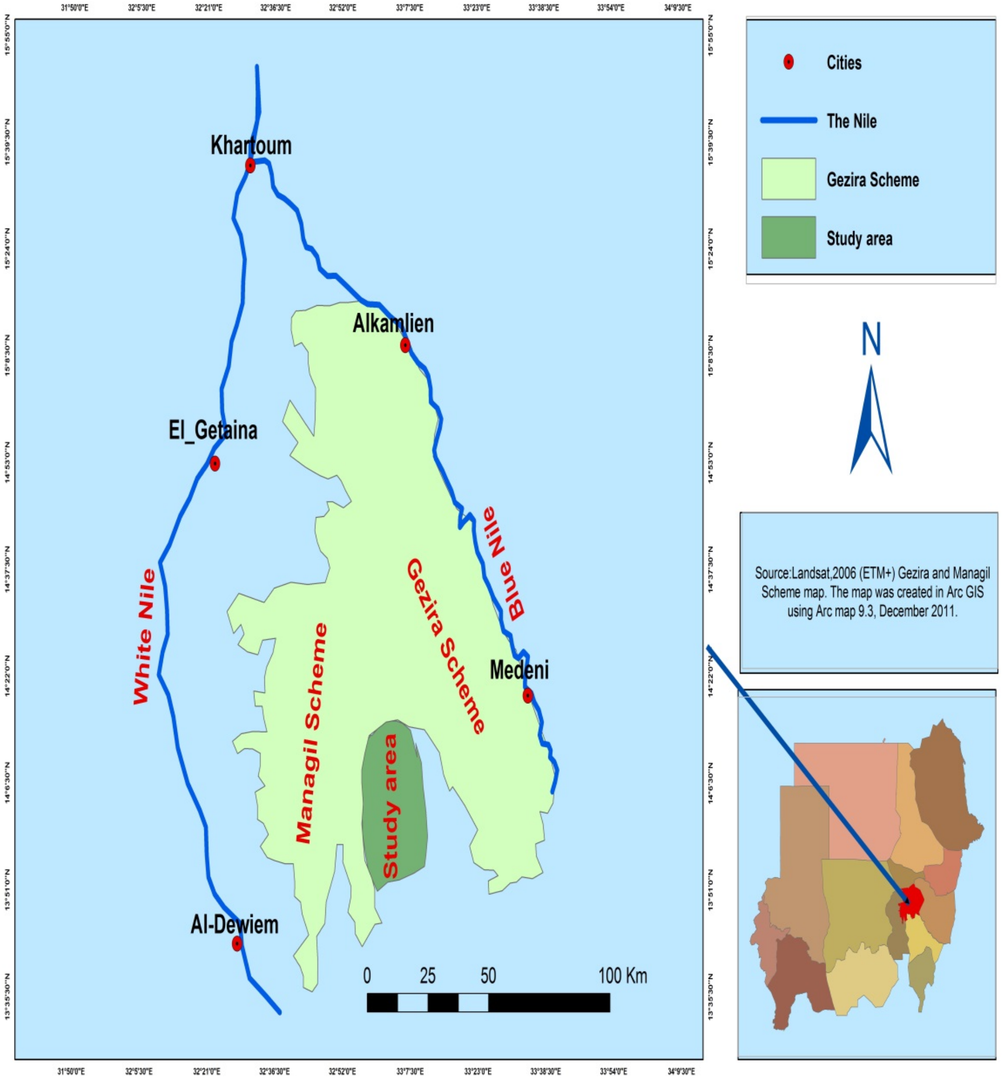
II. STUDY AREA

The study area in Almanaqil ridge is situated, south west of Gezira State, Sudan (Fig. 1). It lies approximately midway between the Blue Nile in the east and White Nile in the west, (latitude 14° 04´ to 14° 29´ N and longitude 33° 97´ to 33° 19´ E). It covers an area of about (220,000 feddan). The two distinctive climatic belts found in the study area (Meteorology Office-Gezira, 1994). The first one is semi-arid climate average rainfall of 100-250 mm/year and maximum mean annual temperature of 42°C found in the north and northeast. The second one is the dry monsoon climate average rainfall of 250 to 450 mm/ year, and maximum mean annual temperature of 47°C found in the eastern and southern parts of the state. Physically the study area, which is part of the Gezira State, is a plain surface intermitted by dispersed hills. The topography of the study area includes three major units. Namely: highlands and isolated mountains in the southeast, plain area characterized by clayey and sandy soil either along flat or gently sloping areas and valleys (*Wadis*) areas including depositional areas formed of sediment brought down by the Blue Nile from Ethiopian high land (Davies, 1964). The study area is more or less devoid of vegetation possibly due to the land clearance.

III. MATERIALS AND METHODS

Field Measurements

Representative four soil samples were collected from study area. At each representative samples, about 200g of the soil samples were collected. Each sample was packed in cellophane bags, tied, and labeled accordingly and taken to the laboratory for further investigation. Heavy mineral separation analyses were carried out at the Central petroleum Laboratory, Ministry of Energy, Sudan.



Source:Landsat,2006 (ETM+) Gezira and Managil Scheme map. The map was created in Arc GIS using Arc map 9.3, December 2011.

Fig.1: Location map of the study area

Heavy minerals grains of soil samples collected from outside the study area (sample 1 and 2) were compared with those inside the study area (sample 6 and 7). Samples were sieved with a Ro-tap machine and statistical parameters were obtained (Folk and Ward 1957).

A total of 5g of each dried samples was released into a separating funnel using the dense-liquid technique, with bromoform (specific gravity 2.8g/cm3). The above samples were processed for the estimation of total heavy mineral content using Bromoform (CHBr; specific gravity 2.89), as a medium for separation of heavier fractions from the lighter area. Methylene iodide (di-iod methane, 3.3 sp.gr.) heavy medium was used to determine very heavy minerals and light heavy minerals from the total heavy minerals obtained using bromoform heavy medium.

Samples were boiled in 10% Hydrochloric acid for two minutes in order to disintegrate the samples. Boiled samples were rinsed with water to remove the hydrochloric acid and dried in an oven in order to separate the fine sand fraction.

The mixture was vigorously stirred and left for 5 minutes. The heavy minerals present in the sample with specific gravity > 2.85g/cm3 were allowed to settle to the bottom of the separating funnel or after which the filtrate (heavy mineral) were thoroughly washed with acetone to move any trace of bromoform and also dry. The heavy minerals were mounted on slides with the aid of Canada balsam (Pellant, C. and R. Phillips, 1996) and the opaque mineral was identified based on (Mange et.al, 1992).

The non-opaque minerals were studied under a transmission light microscope (Suzuki, 1975). Table1 presents a brief description of heavy mineral grains of study area.

The “ZTR” index, which is a quantitative definition of mineral assemblage, was calculated using the percentage of combined Zircon, Tourmaline, and Rutile grains for each sample (Morton, 1985).

IV. RESULTS AND DISCUSSIONS

Polarize microscope photomicrographs of heavy minerals in the study area. Table 1 presents the quantity of the individual heavy minerals and Plate 1 gives a first insight into the heavy mineral spectrum and provides a basis for deciding on further data interpretation.

Zircon:

Zircon is one of the most extremely ultra-stable heavy resistant minerals during weathering and that may explain why it was found relatively in higher concentration in the study area (Table 2). It is higher in the northern part of study area and amounted to about (11%) where the other samples contained moderate level (≈ 1-3 %) from the total 300-350 grains mounted on each slide. The rounded shape of zircon was an indication of distance transportation from the source area, as well as strong recycling effect. The interference colors observed were generally of the forth order. This agreed with Kerr and Syme *et al.*, (USA, 1977). The source rock of zircon is mainly igneous rocks with angular, sub-angular, and complete crystalline shape, it may be as well from sedimentary rocks with rounded and sub-rounded shape. The transportation agent was wind and mixed transportation (wind and water).

Rutile:

Rutile is also an ultra-stable heavy mineral; its concentration was similar both inside and outside the area since any concentration less than 50% indicates similar content (Stapor, 1973). This agreed with Morton and Hallsworth, (1994) in USA. The color of the Rutile varied from reddish brown, dark brown to brown, generally elongated and well-rounded and may look opaque. It was characterized by strong birefringence pleochroism and parallel extension. The sources of this rutile are sedimentary rocks and sometimes the igneous rocks that are transported by wind (Stapor, 1973).

Tourmaline:

Tourmaline is as well a member of ultrastable heavy minerals. It was found in sample 1 (outside the area) contained tourmaline in higher percentage compared to others samples from inside the study area. Tourmaline occurs in sub-angular form with a color that varies from dark brown, light brown to brown. It was stained by iron oxides. The main sources of tourmaline are acid igneous rocks and to some extent metamorphic rocks, in addition to sedimentary rocks. It was transported by wind and water.

V. SUMMARY OF HEAVY SAND MINERALOGY

Heavy minerals of the study area are counted in every slide through microscopes in order to know quantity them as % (Table 2). A Frequency similarity among them was shown (Fig. 2).

The study area was grouped into two physiographic units (1and 2). The results of the study area showed that about 2.34%, 7.89% and 2.69 % of zircon, rutile and tourmaline respectively, fell within low ZTR index in unit 1 (sample 6). Similar results were also found for unit 2 (sample 7), where 1.3%, 13.88% and 2.77% of zircon, rutile and tourmaline respectively, was reported (Table 3).

The results of ZTR index indicate similar results of samples outside the area, 2.63%, 23% and 22.36% of zircon, rutile and tourmaline respectively, fell within low ZTR index (sample1), 11%, 11.31% and3.77% of zircon, rutile and tourmaline respectively, all fell within also low ZTR index (sample 2).

Table 1: brief description of heavy mineral grains of study area

Soil sample No.	**Mineral type**	**Description**
	Zircon No.	
1	Z1	Rounded with brown colors, stained by oxide of iron
1	Z2	Sub- rounded with gray colors, stained by oxide of iron
1	Z3	Sub- rounded reddish colors, stained by oxide of iron
2	Z4	Rounded with brown to reddish colors
2	Z5	Angular with gray colors, inside the Quartz
6	Z6	Sub- rounded with brown to gray colors
6	Z7	Sub- rounded with brown
7	Z8	Rounded with brown colors, stained by oxide of iron
7	Z9	Angular with gray colors
7	Z10	Sub- rounded reddish colors
	Rutile No.	
1	R1	Rounded with sub rounded shape
2	R2	Angular, reddish to brown colors
2	R3	Rounded with sub rounded shape
6	R4	Rounded with reddish colors
7	R5	Darkish colors, rounded with sub rounded shape
	Tourmaline No.	
1	T1	Sub-angular, brown with black spot
2	T2	Dark brown colors with oval shapes
6	T3	Sub-angular with oval shape, brown colors
7	T4	Semi rounded or oval shape with grayish to brown colors

Sample 1 and 2 = Outside the study area; sample 6 and 7= Inside the study area; Z= zircon; T= tourmaline; R= rutile

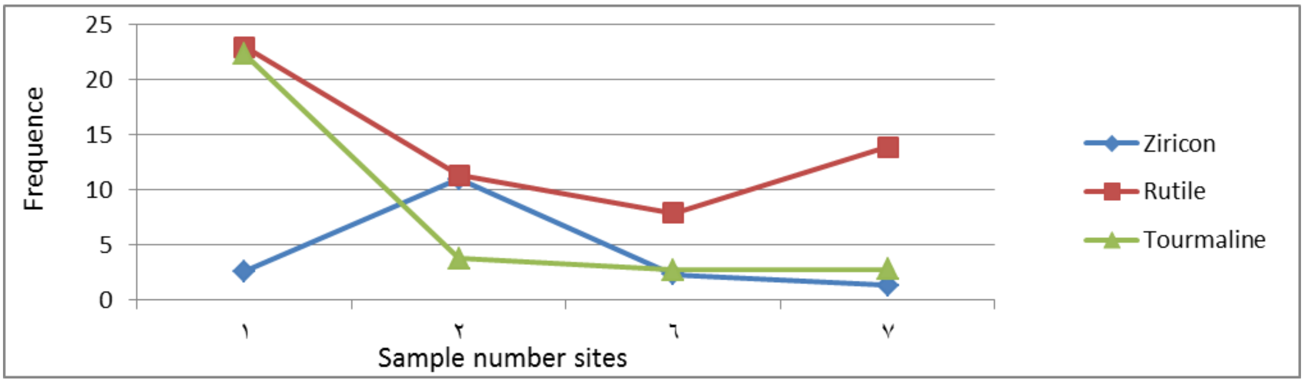


Fig. 2: Frequency symmetry in the mineralogy of outside (samples 1 and 2) and inside the study area (samples 6 and 7)

Table 2: percentage of heavy mineral in soil samples of the selected sites

Soil sample No.	**%**									**Location**
	Quartz	Zircon	Rutile	Tourmaline	Silimanite	Andalusite	Epidote	Garnet	Kynite	
1	21.28	2.63	23	22.36	3.94	10.52	6.57	7.89	1.81	White Nile
2	23	11	11.31	3.77	9.43	24.52	9.43	7.54	-	North of Amanagil city
6	44.98	2.34	7.89	2.69	2.63	5.26	-	34.21	-	North of study area
7	50.33	1.3	13.88	2.77	1.2	8.33	2.75	19.44	-	East of study area

Samles 1 and 2 = Outside the study area ; samples 6 and 7= Inside the study area

Table 3: Zircon, Tourmaline and Rutile Index

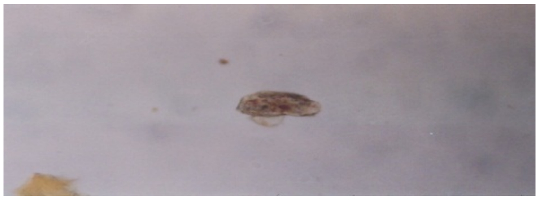
Sample No.	**Zircon**	**Rutile**	**Tourmaline**	**ZTR Index**	Location
1	2.63	23	22.36	47.99	White Nile*
2	11	11.31	3.77	26.08	North of Amanagil city*
	Average	**37.035**			
6	2.34	7.89	2.69	12.92	Northern parts of study area (unit1)
7	1.3	13.88	2.77	17.95	Eastern parts of study area (unit2)
	Average	**15.435**			

The overall ZTR index of the study area was (average 15.43 %) when compared to that outside the study area (average 37.03%), indicated similar content of heavy-mineral types of both inside and outside the area (3).

Heavy minerals assemblages in the sediments of the study area and that outside the area indicated low Zircon Tourmaline Rutile index. This index is used as a clue for the identification of the source and as measure of the maturity of the sediments.

The low ZTR index might indicate that the mineralogical immaturity mineralogical composition might have been affected by other processes during the sedimentary cycle (Morton 1985). Such processes include: (i) weathering in the source area, (ii) effects of the transport process, (iii) hydraulic conditions during the deposition period and (iv) the digenetic processes that operated after the deposition or to some of the most dynamic geomorphological responses to climate change (Morton and Johnsson 1993).

Moreover, the presence of the smaller and more dense heavy minerals grains (Zircon, Rutile and Tourmaline), are indicative of low energy environments, this agreed with Stapor (1973), who found less dense heavy minerals (Starurolite, Kyanite, etc.), in area with high energy in Northeastern Gulf of Mexico, USA. Roundness was determined by comparing the sand grains with a visual chart. Roundness was found in some samples and sphericity (equal dimensions) in other samples. The characteristics of Zircon, Rutile and Tourmaline (such as sorting, rounding and spheroiding), indicated that the origin of the sediments should therefore, have been acid igneous rocks which were subjected to intensive chemical weathering and reworking process. This agreed with Weisbroaad and Nachmias, (1986) in North Africa.

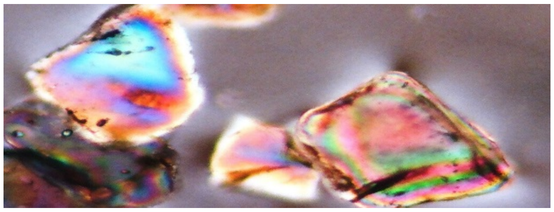


A. GARNET (SITE 2)

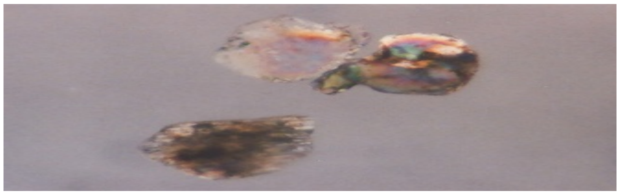
1B. ROUNDED RUTILE AND EPIDOT (SITE 7)

1 C. HORNBLEND AND EPIDOT (SITE 1)

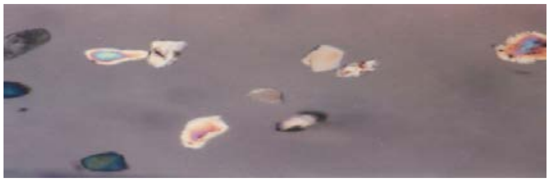
1 D. DIFFERENT TYPES OF QUARTZ IN SOIL SAMPLE FROM RECENT AEOLIAN SOIL OF THE STUDY AREA, CONTAINING ZIRCON AND TOURMALINE TOGETHER WITH QUARTZ AND ANDALUSITE MINERALS (SITE 6)



1E. DIFFERENT TYPES OF QUARTZ IN SOIL SAMPLES FROM THE NORTHERN PARTS INSIDE THE STUDY AREA, CONTAINING TWO TYPES OF ZIRCON (SITE 6)



1 F. SILLIMANITE (SITE 7)

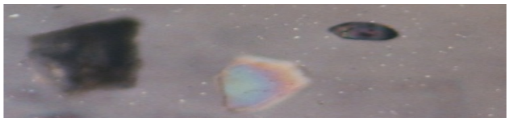


1 G. SUB-ROUNDED TOURMALINE AND QUARTZ (SITE 1)

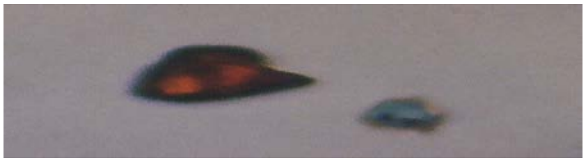
1 H. ROUNDED BROWN TOURMALINE (SITE6)

1I. SILLIMANITE (SITE 1)

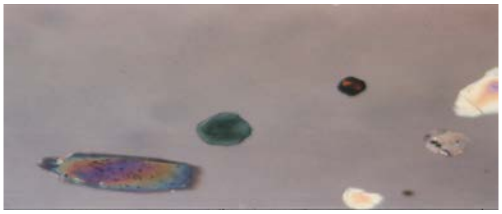
1 J. ROUNDED RUTILE (SITE 1)



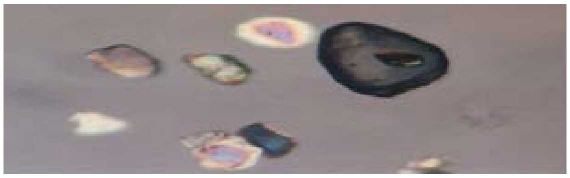
1 K. ROUNDED ZIRCON AND ANGULAR RUTILE (SITE 7)



1 L. SUBANGULAR ROUNDED RUTILE (SITE 6)

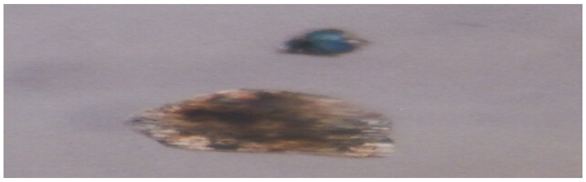


1 M. HORNBLENDE AND ROUNDED RUTILE (SITE 2)



1 O. SUBROUNDED RUTILE AND TOURMALINE (SITE 7)

1 P. SUB-ROUNDED RUTILE (SITE 1)



1 Q. SUB-ROUNDED ZIRCON (SITE 1)

1 R. SUB-ROUNDED TOURMALINE (SITE 2)

PLATE 1: POLARIZED MICROSCOPE PHOTOMICROGRAPHS OF HEAVY MINERALS GRAINS SAMPLES, INSIDE (SAMPLES 6 AND 7) AND OUTSIDE THE STUDY AREA (SAMPLES 1 AND 2).

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