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RESEARCH ARTICLE

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TEXTURAL ANALYSIS AND ENVIRONMENTAL DEPOSITION OF LATE CRETACEOUS SEDIMENTS, KHARTOUM BASIN, OMDURMAN, SUDAN

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ABSTRACT: Merkhiyat Member of Omdurman Formation occurs in Omdurman area is situated in the north western part of Khartoum basin of central Sudan. Merkhiyat Member in the study area is composed of coarse to medium grained sandstone, conglomerate and minor mudstone. They represent, fining upward cycle and each sequence (cycle) based on conglomerate facies represent fill of minor channel or sand body of channel fill (CH) facies to over bank deposits facies (OF) deposit in fluvial environment. Sandstone of Merkhiyat Member can be classified as quartz arenite of fluvial deposit derived from warmed humid metamorphic, igneous rocks as external source and reworked sedimentary rock of sandstone and mudstone as local intra-basin source which are governed predominantly by interior basin of continental Cratonic tectonic setting. They represent fluvial deposits run toward NW as indicated by sedimentary primary structures. The source area is probably located to SE of study area.

Key words: Omdurman Formation, Merkhiyat Member, Khartoum basin, central Sudan

INTRODUCTION

Sandstone of Merkhiyat Member, Omdurman Formation is most part of Khartoum basin which is study with special emphasis by many sedimentologists. Merkhiyat Member is subdivided of Omdurman Formation (Brier, 1993; Awad, 1994). The term of Omdurman Formation is firstly proposed by Whiteman (1970) after renamed term Merkhiyat Sandstone of (Nubian Sandstone Formation) Kheiralla (1966) to describe the outcropping west of the White Nile and river Nile in Omdurman area. Merkhiyat Member consists of predominantly of moderately to poorly sorted, medium to coarse grained, pebbly sandstone, claystone, Siltstone and conglomerate (Awad, 1994). Wycisk et al. (1990) used the term Omdurman Formation to include fluvial, cross-bedded sandstone with intercalations of kaolinite fine-grained sediments occurring in and near the Omdurman (Schrank & Awad, 1990). The grain size analysis gives an idea about the statistical measurement (central tendency, sorting, skewness and kurtosis) and helps in the classification of sedimentary rocks and also used to give information on its depositional environment and depositional mechanism. Sandstone compositions are influenced by the character of the sedimentary provenance, the nature of the sedimentary processes within the depositional basin, and the kind of dispersal paths that link provenance to basin. The key relations between provenance and basin are governed by plate tectonics, which thus ultimately controls the distribution of different types of sandstones (Dickinson and Suczek, 1979). Provenance analysis serves to reconstruct the predepositional history of a sediment or sedimentary rock. This includes the distance and direction, size and setting of region, climate and relief in the source area, and specific type of sedimentary rocks (Al-Juboury, 2007). Compositions of detrital sediments are controlled by four factors: Provenance, transportation, depositional environment, and diagenesis. The area of intensive tectonic/magmatic activity, source-rock type determines sediment composition more than do climate and relief. Where tectonism/magmatism is absent, climate and relief are more important in determining composition. An additional complicating factor is that recycling of sediment may have a profound effect on compositions but commonly may be difficult to recognize or quantify (Ingersoll et al., 1983).

GEOLOGICAL AND TECTONIC SETTING

The study area is northern part of Khartoum basin (KB) west the River Nile. The KB is a one of Sudanese rift basins, which are mainly intra-continental basins, they characterized by thick non-marine clastic sequence of Jurassic? Cretaceous and Tertiary age (Schull, 1988). KB is a NW-SE trending rift basin lies on the eastern side of CARS. KB is half-graben geometry with major bounding fault on the south side, characterized by thick non-marine clastic sequences which include thick lacustrine shales and claystones, fluvial and alluvial sandstones and conglomerates (Opcit, 1988). KB is a large elongated basin aligned NW-SE, boarded to North the Sabaloka basement complex and to the south by faulted basement blocks North of Sinnar and Elduaim (Omer, 1983). The general geology in Omdurman area is Pre-Cambrian basement rocks (gneisses, marbles, foliated batholitic granite and sheared acidic dyke), Cretaceous Omdurman Formation (Merkhiyat Member), Tertiary volcanic rock (basic and acidic) and Quaternary deposits (Fig.1). The Merkhiyat Member consists predominantly of moderately to poorly sorted, medium- to coarse –grained pebbly sandstone, claystone, siltstone and conglomerate. Trough and tabular cross stratified represented the major lithofacies (Awad, 1994).

MATERIALS AND METHOD

The materials used in this study include lithostratigraphic sections from outcrops around Omdurman City, which belong to Merkhiyat Member, Omdurman Formation. To obtain depositional environment and textural analysis of Cretaceous sediments of Merkhiyat Member, we examined vertically seven sections or profiles. These profiles classified into lithofacies according to Miall (2006), sixteen representative samples selected for grain size analysis. In the grain size analysis samples were immersed in distilled water, then were disaggregated using porcelain mortar and pestle, dried in room temperature and quartered and 40 grams were weighted from one quarter. Samples were sieved using a set of 7 sieves with mesh sizes ranging from 4mm to 0.032mm with 0.5 intervals. Fractions less than 0.032mm analyzed using the Atterberg method; each sample transferred to Atterberg cylinder (30cm^3), added distilled water to 30cm^3, then the cylinder was shaken carefully for few minutes. After 24 and 2 hours and 15 minutes liquid in the cylinder content was poured into a beaker consequently to separate fractions as less than 0.002mm , (0.002- 0.006) mm, (0.006- 0.02) mm, then the remaining fraction in cylinder represents grain size between (0.02- 0.032) mm. All samples were dried, weighted. After computing, calculating and recording the weight percentage, cumulative weight percentage of each fraction retained by wet sieving and Atterberg, the cumulative curves were drawn. According to Tucker (1991) the statistical parameters have been calculated. Thin sections were prepared from the collected samples from outcrops of sandstone of Merkhiyat Member, Omdurman Formation. Nine thin sections were examined with a petrographic microscope for modal composition and a variety of other petrographical features. For each thin section minimum 300 points were counted using Gazzi-Dickinson method (Ingersoll et al, .1983).

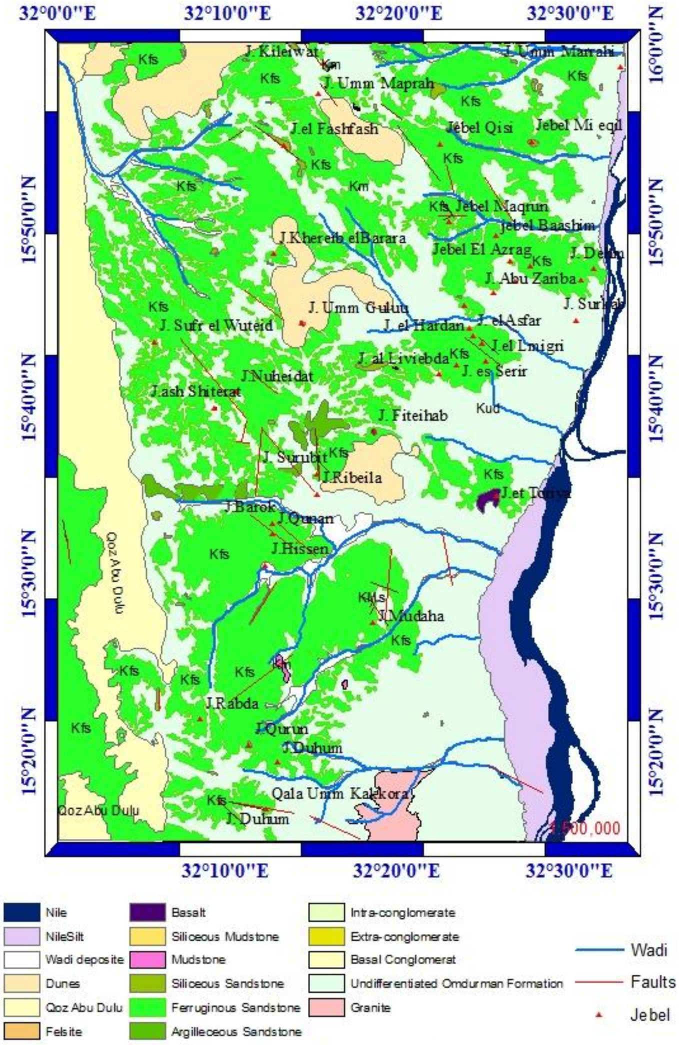

Fig.(1):Geological map of the study area.

RESULTS

Lithofacies analysis: Facies analysis of the unit was carried out and resulted in sedimentary logs, field sketches and photos. Applying Mialls' lithofacies classification scheme, 12 lithofacies types were identified (Table1).

Facies Description

Twelve lithofacies are recoded, recognized in studied area, which are classified in three groups; gravel lithofacies (Gmm, Gcm, Gcg, Gp and Gt), sand lithofacies (Sp, St, Sh and Sm) and fine-grained clastic lithofacies (Fl, Fsm and Fm).

Gravel lithofacies: The gravel lithofacies classified on the basis of texture and internal structure into five lithofacies Gmm, Gcm, Gcg, Gp and Gt as the following:

Lithofacies Gmm: Matrix-supported massive conglomerate. This facies composed mainly of gravel and a little of mudclast. The gravel diameter is less than 3cm. The clasts, gravel or mudclast are poorly sorted and supported by poorly sorted sand, mud matrix. It is massive, sharp contact with lower bed. The total thickness is 3.8m, represents 2.9% of studied area (Fig.2C). This facies recorded at J. Qisi (channel fills 1*0.7m) (Fig.3) and J. Baashim (S4).

Lithofacies Gcm: Clast-supported massive conglomerate. This facies composed of gravel and mudclast. The gravel is dominant where the conglomerate is extra-formational which is reported at J. Qisi and mudclast (intra-clast of siltstone and mudstone) is intra-formational conglomerate at J. Merkhiyat (channel5*0.3m) and J. Barok. This facies is massive, poorly moderate sorting and sharp contact. The total thickness is 1.4m, represents 1.1% of the studied area.

Lithofacies Gcg: Clast- supported graded conglomerate. This facies composed of mudclast and gravel. The mudclast are dominant and it is mainly intra-formational conglomerate. This facies is graded bedded fining upward, moderately sorting. The total thickness is 0.4m, represents 0.3% of studied area. This lithofacies recorded at J.Qisi (channel fills).

Lithofacies Gp: Planar- cross bedded conglomerate. This facies composed mainly of mudclast with few gravel in semi matrix of medium to fine sand and it is intra-formational conglomerate with planar cross bedded. It is intercalated with sandstone. The total thickness is 2m, represents 1.5% of studied area. This facies recorded only at J. Sufr el wuteid (Fig.2A).

Lithofacies Gt: Trough-cross bedded conglomerate. This facies composed mainly of gravel, in semi matrix of coarse to medium grained sand, poorly to moderately sorting with trough cross bedded, brownish in color. It is extra-formational conglomerate. The total thickness is 1.1m, represents 0.8%. This facies recorded at J. Umm Marahi and J. Mudaha (Fig.2H).

Table 1: lithofacies classification (modified after Miall, 2006).

Facies code	Facies	Sedimentary structure	interpretation
Gmm	Matrix-supported, massive gravel	Weak grading	Plastic debris flow
Gcm	Clast-supported, massive gravel		Pseudoplastic debris flow
Gcg	Clast-supported	grading	Pseudoplastic debris flow
Gp	Gravel stratified	Planar cross-beds	Traverse bed forms, deltaic growths form older bar remnants
Gt	Gravel stratified	Trough cross-beds	Minor channel fills
St	Sand, fine to very coarse, may be pebbly	Trough cross-beds	Sinuous-crested and linguoid (3D) dunes
Sp	Sand, fine to very coarse, may be pebbly	Planar cross-beds	Transverse and linguoid bed forms (3D) dunes
Sh	Sand, fine to very coarse, may be pebbly	Horizontal lamination	Plane-bed flow (critical flow)
Sm	Sand, fine to coarse	Massive or faint lamination	Sediment-gravity flow deposits.
Fl	Sand, silt, mud	Fine lamination	Overbank, abandoned channel, or waning flood deposits
Fsm	Silt, mud	Massive	Back swamp or abandoned channel deposits
Fm	Mud, silt	Massive, desiccation cracks	Overbank, abandoned channel, or drope deposits

Sand Lithofacies: Sand lithofacies are classified on the basis of dominant primary structure, modal of grain size and the presence of intra- clasts (siltstone and mudstone) and extra-clasts (gravel or pebble) into four sandstone facies Sp, St, Sh and Sm as the following:

Lithofacies Sp: Planar-cross bedded sandstone. This facies composed mainly of medium to coarse grained, with gravel on the basal or scattered pebble in the whole facies (J. Merkhiyat) and sometime mudclast with varied size as normal distribution or channel fill (scoured base) at J. Mudaha, moderate sorting and yellowish, brownish color. The total thickness is 55.9m, represents 42.7% of total area (Fig.2G).

Lithofacies St: Trough-cross bedded sandstone. This facies composed of medium to coarse grained, rarely fine grained, pebbles and mudclast, poorly to moderate sorting, hard to moderate indurations and usually sharp contact with lower bed, yellowish to, whitish and brownish in color. The thickness is 32.8m, represents 25.1% of total studied area (Fig.2F).

Lithofacies Sh: Horizontally bedded sandstone. This facies composed of fine to medium grained, moderately to well sorting, sharp contact and brownish color. The total thickness is 1.0m, represents 0.8% of studied area.

Lithofacies Sm: massive sandstone facies. This facies composed of fine to coarse grained, with few gravel seem as pebble or mudclast, moderately sorting, moderate to hard and yellowish to brownish color. The total thickness is 15.9m, represents 12.2% of total studied area. This facies recorded at J. Mudaha, J. Umm Marahi and J. Merkhiyat, J. Barok.

Fine grained clastic lithofacies: These facies classified on the basis of grain size (very fine sand, mud fraction) and laminated or massive structure into three Lithofacies Fl, Fsm and Fm.

Lithofacies Fl: Laminated mudstone facies. This facies composed of mud, silt and very sand grained. Sand, silt and mud made interlamination. It is grey, yellowish and violet color and moderate indurations. The total thickness is 11.9m, represents 9.1% of studied area. This facies recorded at J.Qisi, J. Al Bahashem, J. Mudaha, J. Barok and J. Sufr el wuteid (Fig.2D).

Lithofacies Fsm: Laminated mudstone facies. This facies composed mainly of mud (silt and clay), laminated, grayish in color. Fsm differentiated from Fl by the absence of sand laminar. The total thickness 0.3m represents 0.23% of total studied area. It is recorded at J. Sufr el wuteid.

Lithofacies Fm: Massive mudstone facies. This facies composed mainly of massive mudstone. It is grayish to violet color, hard induration. The total thickness 4.5m represents 3.4% of total studied area. It recorded at J. Al Bahashem, J. Barok (Fig.2E).

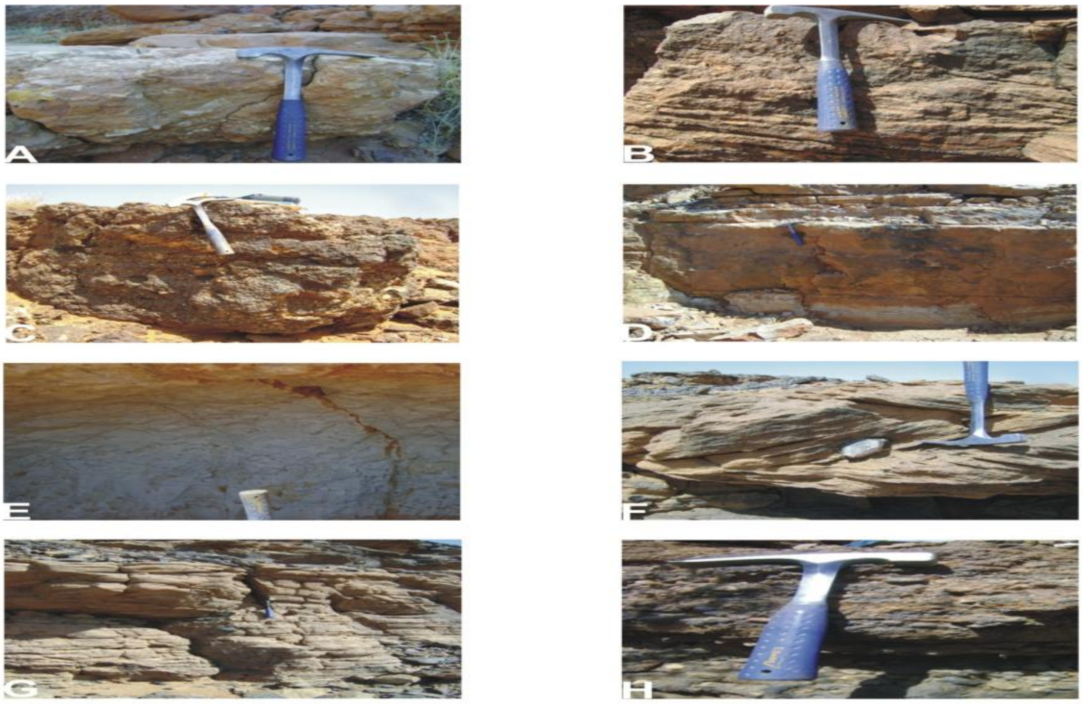

Fig.(2): Photographs of lithofacies showing:(A) clast-supported massive conglomerate(Gcm), J. Merkhiyat (B) planar-cross bedded conglomerate (Gp), J. Sufr elwuteid.(C) matrix-supported massive conglomerate(Gmm). (D) laminated mudstone(Fl),J.Mudaha.(E) massive mudstone (Fm),J. Barok. (F) trough-cross bedded sandstone (St), J. Sufr elwuteid.(G) planar-cross bedded sandstone (Sp) ,J. Qisi. (H) trough-cross bedde conglomerate (Gt), J.Umm Marahi.

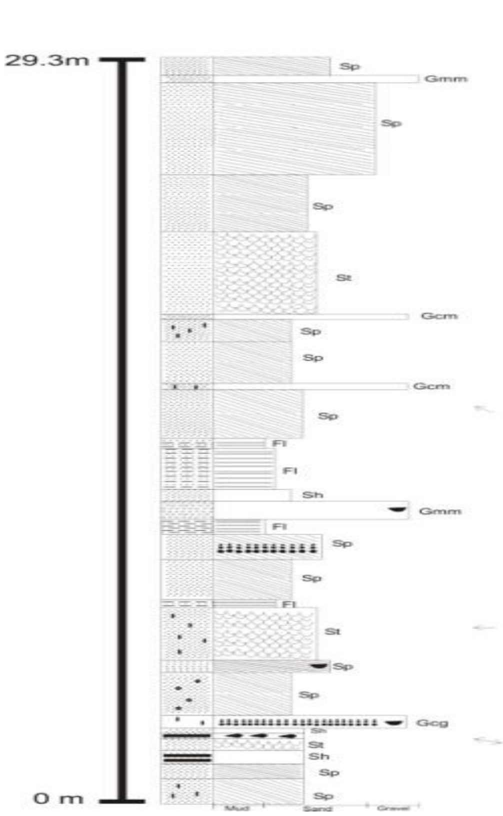

Fig. (3): Lithostratigraphic section of J. Qisi.

Grain sizes analysis

Basic statistics or textural parameter for grain size analysis such as median (Md), mean (Mz), standard deviation or sorting (Ω), skewness (Sk) and kurtosis (KG) have been calculated according to Folk (1974); (Tucker, 1991). After sieving each fraction weight of sample calculated to obtain the percentage of sample components; gravels, sands, silts and clays Table (2). The textural parameter of study area reveals median values range from 0.4 to 2.3 Ø. The mean gives a fair picture of grain size distribution, which varies from (1.42 to 3. 07) at J. Qesi, (0.23 to 1.87) at J. Mudaha, (1.32 to 1.33) at J. Merkhiyat, and generally, the mean values of the analyzed sediments range from 0.23 to3.07 or coarse to very fine grain size for the whole area. Generally, sorting range from 1.06 to 2.25, they reveal poorly sorted to very poorly sort. The sorting at j. Qesi is poorly sorted to very poorly sorted, J. Mudaha, Markhyat, j. Barok, J. Sufr elweteid and j. Umm Marahi are poorly sorted. According to Folk (1974), the sorting values is about (1.06- 2.25) mm in a river sediments. Skewness (Sk) values range from 0.02 to 0.36, the values are positive. The samples reveal near- symmetrical to strong fine skewed. The skewness also is a reflection of the depositional process. The sand usually positive skewed, since much silt and clay is not removed by currents, but trapped between large grains. At J. Qesi samples are fine skewed to strongly fine skewed, J. Mudaha are near- symmetrical to strongly fine skewed. The Kurtosis (KG) values range from 0.06 to 9.9.38 for the studied samples. This indicates very platy kurtic to extremely leptokurtic distribution.

Table (2): Statistical (texture) parameter of representative samples

SN	Md	Mz	Ω	Sk	KG	Gravel	Sand	Mud	Silt	Clay
S1210	1.05	1.32	1.55-PS	0.40-SFS	2.25-VL	0.67	79.07	20.25	20.13	0.12
S113	1.1	1.33	1.12-PS	0.39-SFS	9.38-EL	3	84.29	13.24	13.21	0.03
S112	1.05	1.19	1.43-PS	0.32-SFS	2.44-VL	0.75	86.37	12.89	12.86	0.03
S81	1.7	1.87	1.81-PS	0.02-NS	2.25-VL	2.88	82.23	14.85	14.82	0.03
S83	1.3	1.33	1.33-PS	0.18-FS	2.58-VL	1.48	90.23	8.31	8.28	0.03
S84	0.4	0.23	1.85-PS	0.03-NS	1.08-L	12.19	82.15	5.66	4.5	1.16
S86	1.7	1.8	1.06-PS	0.37-SFS	2.59-VL	0.16	91.95	7.9	7.85	0.05
S31	0.84	1.42	1.69-PS	0.54-SFS	2.82-VL	0.26	85.8	13.94	13.89	0.05
S32	2	2.7	1.73-PS	0.48-SFS	1.20-L	0	78.79	21.2	21.2	0
S34	1.25	1.46	1.37-PS	0.42-SFS	2.16-VL	0.52	86.69	12.8	12.74	0.06
S36	1.1	2.21	2.25-VPS	0.57-SFS	1.47-L	0.36	80.66	18.98	18.9	0.08
S38	1.85	2.75	1.79-PS	0.63-SFS	1.51-VL	0.16	79.85	19.98	19.95	0.03
S313	2.3	3.07	1.69-PS	0.23-FS	0.60-VP	0.39	72.41	27.2	27.2	0
S91	1.8	2.33	1.4-PS	0.60-SFS	1.81-VL	0.03	84.33	15.59	15.49	0.1
S133						29.41	65.87	4.71	4.61	0.1
S37						11.69	57.58	33.24	30.6	2.64

Petrographic analysis

The analyzed sandstones are sub angular to rounded, medium to coarse grained, poorly to moderate sorted. The framework grains of sandstones are composed of mono (Qm)-, poly (QP)-crystalline quartz, feldspar (F) and rock or lithic fragments (L) with average of quartz (97-99) %, feldspar (1-2) % and rock fragments (1-3) %. (Table3).

Table3. Detrital modes of selected samples of Merkhiyat sandstone Member

Sample	Q	QP	Qm	F	Lt	Ls	Lm
S135	99	51	48	1			
S131	99	52	47	2			
S1213	99	32	67	1			
S1211	99	41	58		1	0.9	0.1
S119	97	81	16		3		
S46	97	51	46	1	2	2	
S33	99	42	57		1	1	
S88	96	40	56	2	2	2	
S95	97	53	44	1	2	2	
Average	98.3333	49.2222	48.8889	1.33333	1.83333	1.58	
St. dev	1	13.8724	14.4087	0.5164	0.75277	0.57619	
Minimum	97	32	16	1	1	0.9	
Maximum	99	81	67	2	3	2	

The Mono-poly-crystalline quartz occurs throughout the sandstone of Merkhiyat Member. They are sub-rounded to sub-angular, medium to coarse grained, low to moderate sphericity and moderate to well sorted. Both of quartz types show andulose or composite extinction. The Qm is range in amount (16-67) % and 48.9 as average. They sub-angular to sub-rounded and sometimes rounded (may be recycled quartz (Fig.4B). The Qp is range in a mount (32-81) % and 49.2 as a verge. They sub-angular to sub-rounded. The contacts between sub- grains are sutured, straight, concavo-convex contact and sometimes in elongate form (Figs.4B&E). The polycrystalline quartz has undulated extinction. The grain is variable in size. Inclusions are present within both Qm and Qp grains. They in include zircon, kyanite, pressure solution and fluid inclusion. Quartz overgrowth is common. Rims of iron oxide (hematite) occur (Fig.4F). Feldspar is very less amount, highly weathered and commonly altered sericite and kaolinite and other clay mineral. Feldspars are amount average from (1-2) %. Lithic fragments were found in range of (1-3) % in studied sandstone. They include sedimentary and metamorphic. Lithic sedimentary (Ls) ranges from (0.9-2) %, the lithic sedimentary fragments are dominantly composed of mudstone and rarely sandstone. The Lithic metamorphic fragments are mainly quartzitic composition and other low grade metamorphic rock (Figs.4A&B). Sandstone classification was made using Folk scheme, it classified by their matrix content and mineralogical content (Folk, 1974; Osae et al., 2006). On the basis of their mineralogical contents, the Merkhiyat sandstones are classified as quartz-arenite (Fig.5).

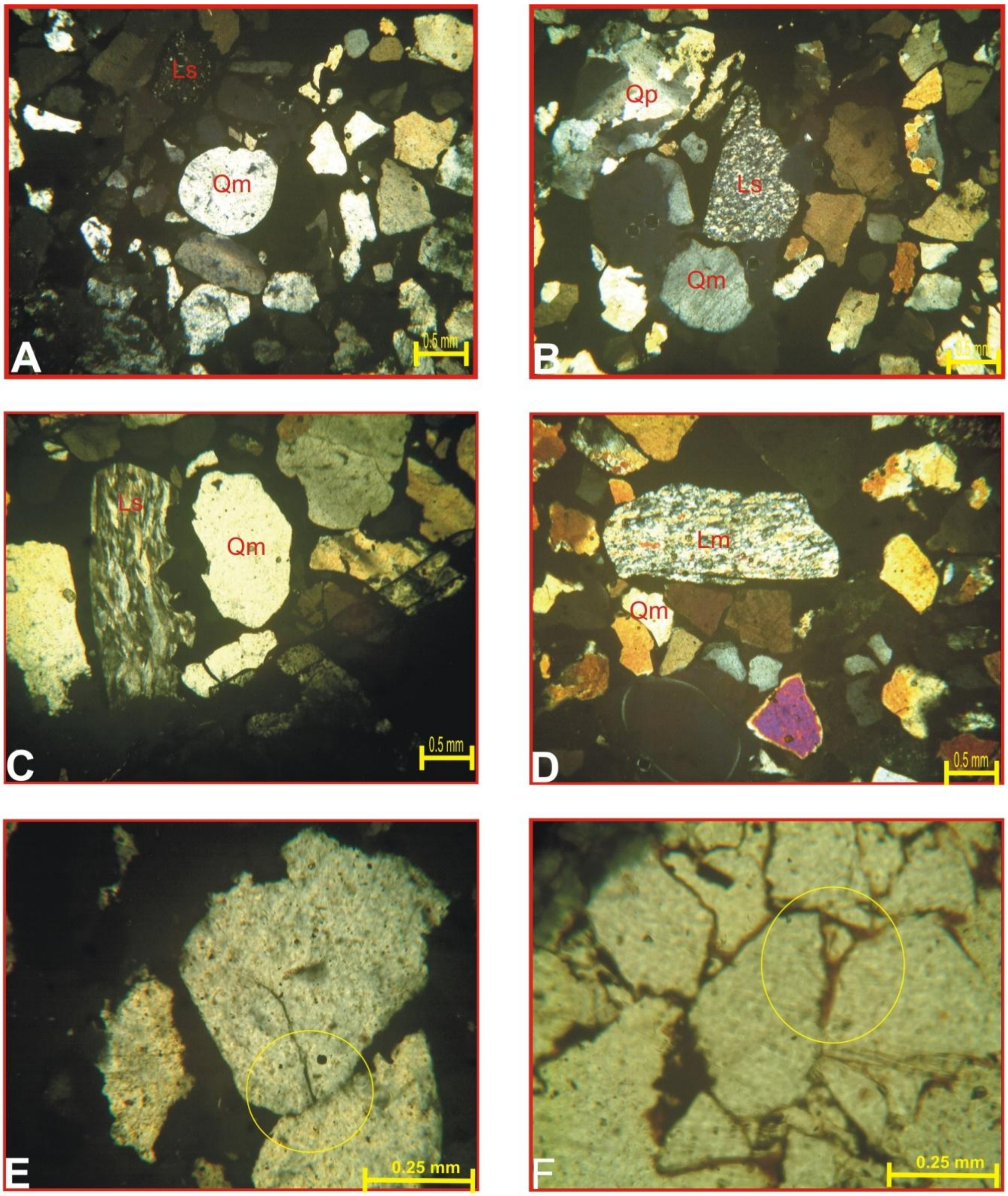

Fig.(4): Photomicrographs of Merkhiyat member sandstones showing:Quartz arenite,(A) monocrystalline quartz(Qm) and sedimentary rock fragment (Ls; mudstone), (B);polycrystalline quartz(Qp) , (C) and(D). (D):metamorphic rock fragment (Lm; quartzitic). (E):concavo-convex quartz contact (circle) . (F) iron oxide(haematite) rims (circle):

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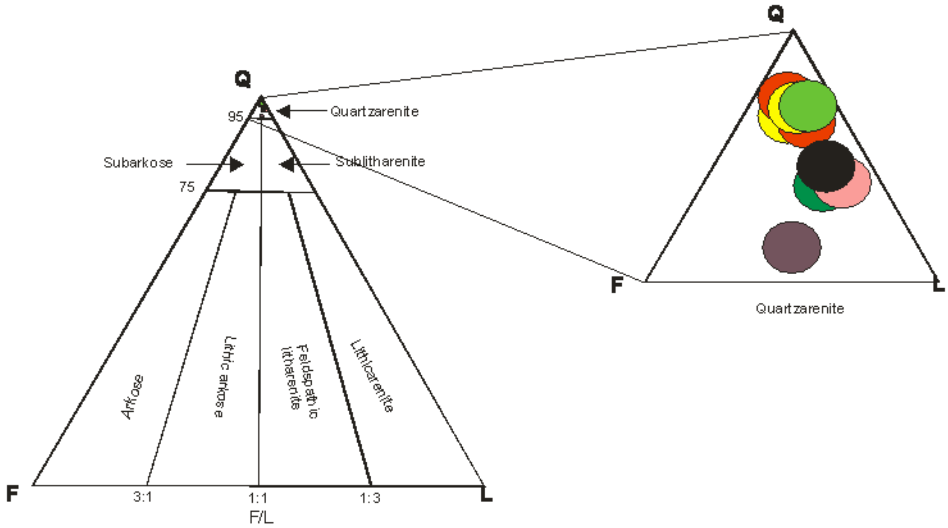

Fig.(5): QFL tringular classification plot after Folk,(1974)of sanstone from Merkhiyat Member, Omdurman Formation.

DISCUSSIONS AND INTERPRETATION

Lithofacies: Twelve lithofacies were defined from the field data. Gravel sheets building into deeper water or areas of flow expansion, or these covered by gradually waning floods may develop lee-side separation eddies. This is accompanied by and encourages the growth of forests, leading to the development of transverse bed forms (Gp); also (Gt) represented migration of transverse bed forms with curved crests, while other represent the fill of minor channels. If channel debouch into pools they developed cross-bedded chute bars (Gp) Miall (2006). Sandstone lithofacies in fluvial system result from the transported of sand by traction current as (bed-load and saltation). The morphology of sand bed forms depends primarily on sand grain size, flow depth, and flow velocity (Miall, Op.cit). Sand bodies (SB) represent most of channel fill (CH) of study area. Tabular or planar cross-bedded lithofacies (Sp) represent 2-D dune as transverse bars and sand wave. Lithofacies (St) represent 3-D dune as (linguoid and lobate bars), with high flow speeds. Massive sandstone lithofacies (Sm) are deposits of sediment gravity flows, it characteristic in small channels resulting from bank collapse. Fine grained clastic facies are represent deposits from suspension load of rivers. They deposit in floodplain. Lithofacies (Fl and Fm) are subdominant facies of study area represent a gradation in grain size from proximal floodplain to distal deposit. These lithofacies represent over bank deposits (OF) (Fig.6). Elamein (2001) interpret the Merkhiyat Member as broad low sinuosity braided rivers. Facies model constructed to understand the fluvial style and their related which controlled the depositional environment including tectonic setting, climate and geology of source area …etc. Merkhiyat Member is very complex interstratified sequence of fluvial deposits composed of three lithofacies association; sand facies which is a dominant (Sp, St, Sh & Sm), represented as sand body element (SB) and subdominant conglomerate (Gmm, Gcm &Gcg) represented as SG and GB elements and fine grained facies (Fl& Fm) represented as overbank facies element (OF). These association can be subdivided into two assemblages ;1) (SG(GB)), SB & OF which is a bed load system represent channel fill sediments consist of sand or pebbly sand with lag deposit of gravel and over bank sediment(braid system) and 2) SB & OF which is dominantly sand with some intra-formational deposits and overbank sediments (meandering system). They are interpreted to present fluvial depositional environments. Thus the Merkhiyat Member in study area can be interpreted as transitional zone between braided and meandering systems. Palaeocurrent data give NW direction of palaeo-flow. Due to that and the regional geology, the source area may located at south east and south directions of study area, in addition to Palaeocurrent data the composition material of various rock especially the conglomerate (intra-clast) reveal that the drained rivers are tectonically active in discontinuous periods.

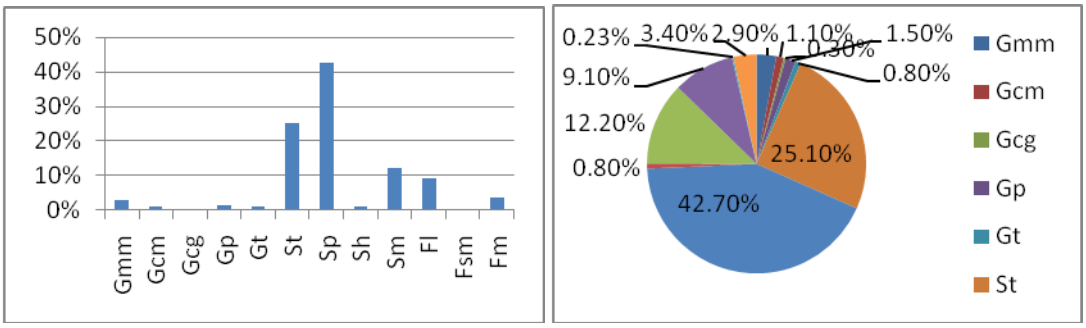

Fig. (6): show lithofacies distribution of total study area.

Grain size: Friedman (1962) suggested that the extreme high or low values of kurtosis imply that part of sediment achieved its sorting elsewhere in high-energy environment. Variation in the kurtosis values is a reflection of the flow characteristic of the depositing medium and the dominance of finer size of platykurtic nature of sediments reflects the maturity of the sand. This may be due to the aggregation of sediment particle size by compaction, and the variation in the sorting values are likely due to continuous addition of finer/coarser materials in varying proportions (Rajganapathi et al. 2012).

Many studies are done to interpret the depositional environment of sediments using grain size distribution. In this field (Friedman, 1967), (Moiola and Weiser, 1968) were developed bivariate plot diagram using various statistical parameters. Scattered plot diagrams used to acheif this study were sorting against skewness and sorting against mean (Figs.7&8) to distinguish between river sediments and beach sediments (Fig.9). Also scattered plots sorting against mean used to differentiate river sediments from dune sediments. The scattered plot diagrams used above have been shown the representative samples of area under study are within the field of river sediments. Thus, the sediments (sandstones) of study area were deposited in fluvial environment. Histograms and Smooth frequency curves are a valuable because they readily show the relative proportions of each size class and modal class of the distribution. The histograms mode range from coarse to medium sand with 37.5% to 62.5% (Fig.10). The smooth frequency curves have been shown they are bimodal and polymodal (Fig.11). The bimodality results from a combination of bed and suspension load transport, infiltration of fines, post-depositional diagenesis, or lack of certain size grades in some source materials. Grain size analysis is very useful to classify and nomenclature the sedimentary rocks. Grain size distribution of sedimentary rocks is often plotted on triangular diagrams (Figs.12, 13&14), which were constructed after Shepard (1954), Folk (1974).

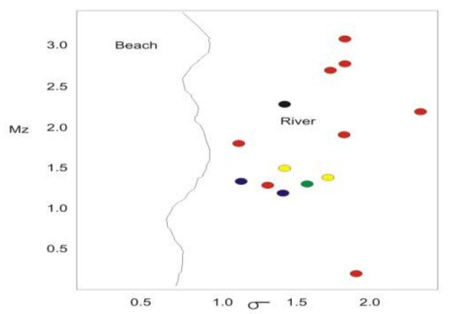

Fig.(9):Scattered plot diagram Mz Vσ after Friedman, 1967

J. Umm Marrahi Section
J.Qesi Section
J.Merkhiyate Section
J.Barok Section
J.Sufr elwuteid Section
J.Mudaha Section

σ =Standard Deviation (sorting)
Mz= Mean
Sk=Skewns

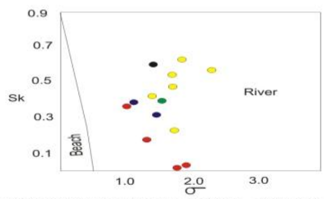

Fig.(7):Scattered plot diagram Sk V σ, after Friedman, 1967

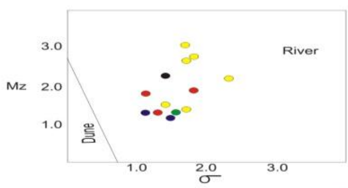

Fig.(8): Scattered plot diagram Mz V σ,a fter Moiola and Weiser,1968

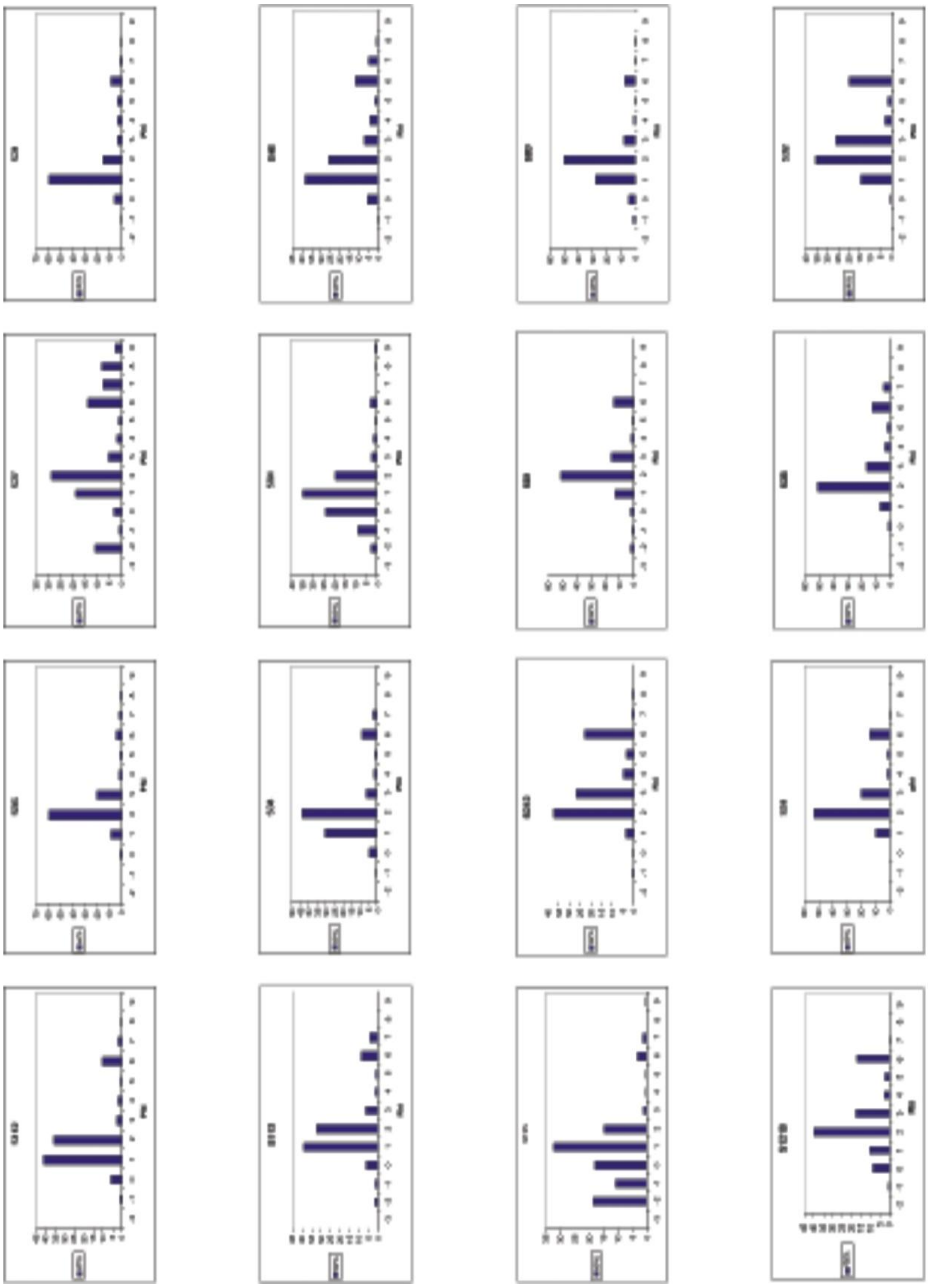

Fig.(10): Histograms show mode of grain size distrbution

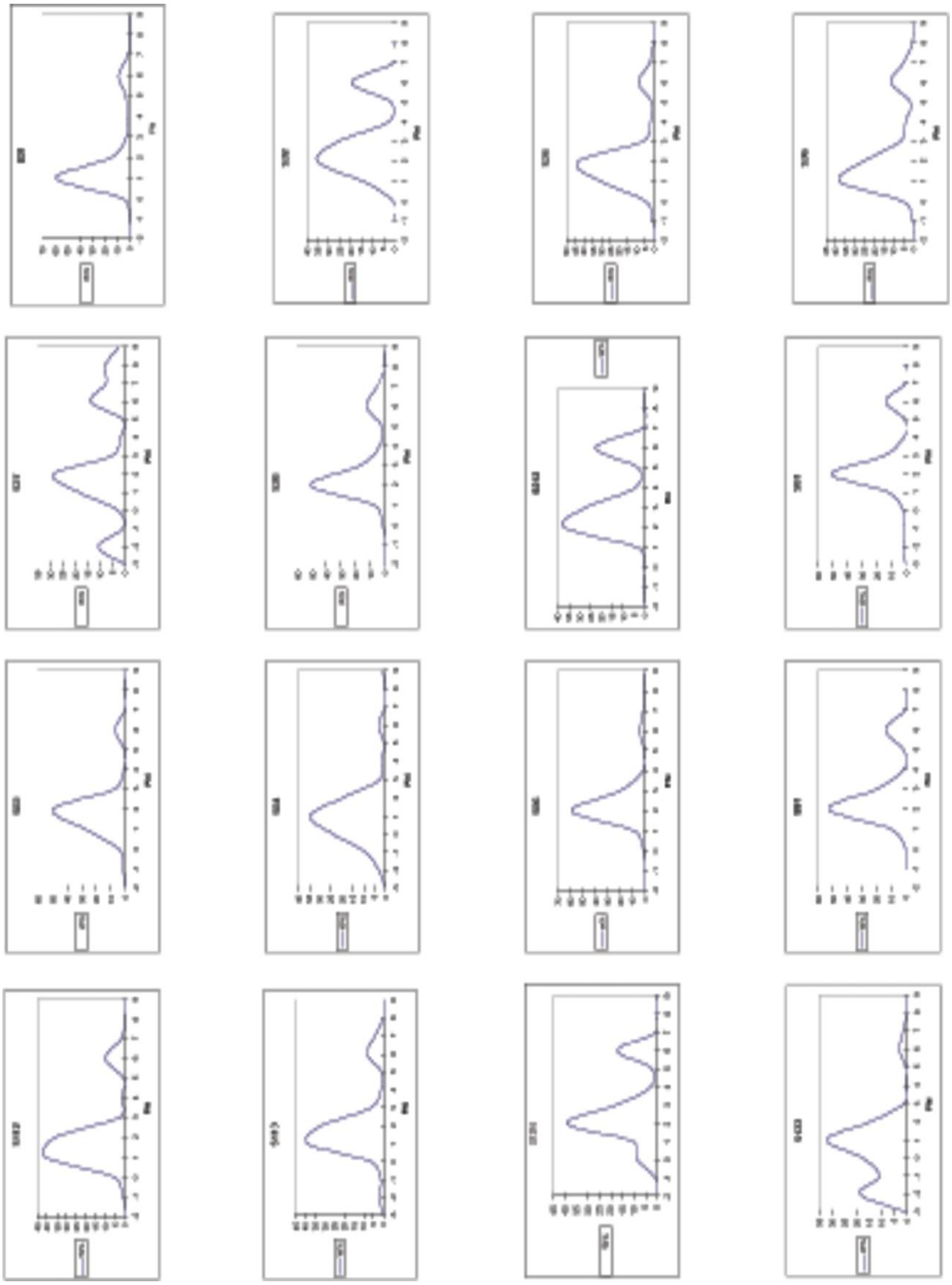

Fig.(11): smooth frequency curves show mode of grain size distribution

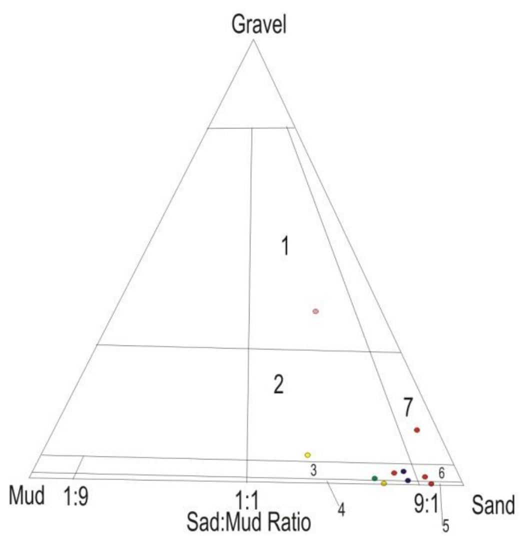

Fig.(14):Triangular diagram showing the Nomenclature classification of sandstone (after Folk,1974)

1=muddy sandy conglomerate
2=conglomeratic muddy sandstone
3=slightly conglomeratic muddy sandstone
4=muddy sandstone
5=sandstone
6=slightly conglomerate sandstone
7=conglomeratic sandstone

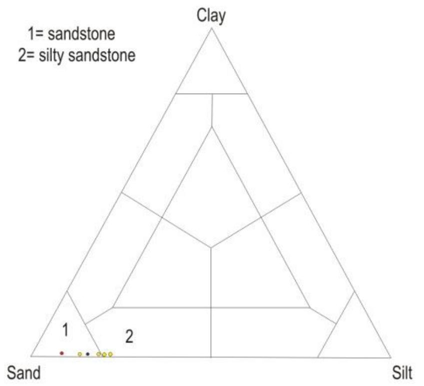

Fig.(12):Triangular diagram showing the Nomenclature classification of sandstone (after Shapard,1954)

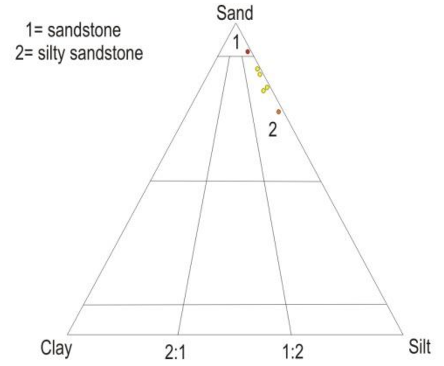

Fig.(13):Triangular diagram showing the Nomenclature classification (after Folk,1974)

SANDSTONE PETROGRAPHIC

Based on petrographic analysis study the Merkhiyat Member sandstones are classified as quartz arenite have been composed mineralogically of mature quartz arenite sandstone, characterized by the lack of feldspar and rock fragments content. The quartz arenite is very common and defined simply as sands of which the detrital fraction in 95 or more percent quartz. It's difficult to make distinction between quartz arenite derived directly from plutonic source rock and this derived from preexisting sandstones. The quartz arenite were mostly produced due to warmed humid climate revealed at the source area and facilitate removal and destruction of unstable grain .The climate evidence is supported by the occurrences of kaolinitic mudstones and ironstone formation (Mohamed, 2004). The composition and texture of Merkhiyat Member sandstone are interpreted as fluvial deposits derived from metamorphic, igneous and reworked sedimentary rocks. Dominating of quartz; mineralogical mature, lack of feldspar and rock fragment indicate long –distance transport. In spite of lack of rock fragment, but the presence of sedimentary rock fragment as mudstone that represent locally source within interior basin. Monocrystalline quartz grains are derived from igneous plutonic and quartz vein, but rounded or recycled quartz derived from older sandstone. Dickinson and Suczek (1979) and Dickinson et al. (1983), have related detrital sandstone compositions to major provenance types such as stable cratons, basement uplifts, magmatic arcs and recycled orogens (Zaid,2012).

To interpret the tectonic discrimination source fields, the Merkhiyat Member sandstones were plotted on ternary diagrams (Dickinson et al., 1983) indicate all of these sandstones were derived from interior Cratonic which is the most part, transitional continental and basement and recycle origin (Fig.15). Also by plotted in (Suttner, et al., 1981) diagram, the source area of the sandstone of studied area affected humid climate (Fig.16). Poly crystalline quartz derived from metamorphic rocks. Basement complex around study area are granitic and granitic gneiss at jebel Aulia area and Ad Douiem south of Khartoum, Butana massif and granulite in J. Moya in southeast. Palaeocurrent direction in study area generally, directed towards the Northwest and rarely to North. From above can obtain that the source area is located somewhere, towards the southeast that means could be in southeast Sudan and/or Ethiopia. The concept that sandstone composition reflects not only the source area but also the tectonic setting of sandstone accumulation has been expressed quite early (Schieber, 1990.). The source of interior Cratonic sediments are uplifted terrains of folded and faulted strata from which recycled detritus of sedimentary and meta-sedimentary origin were in put in the basin (Dickinson and Suczek, 1979).

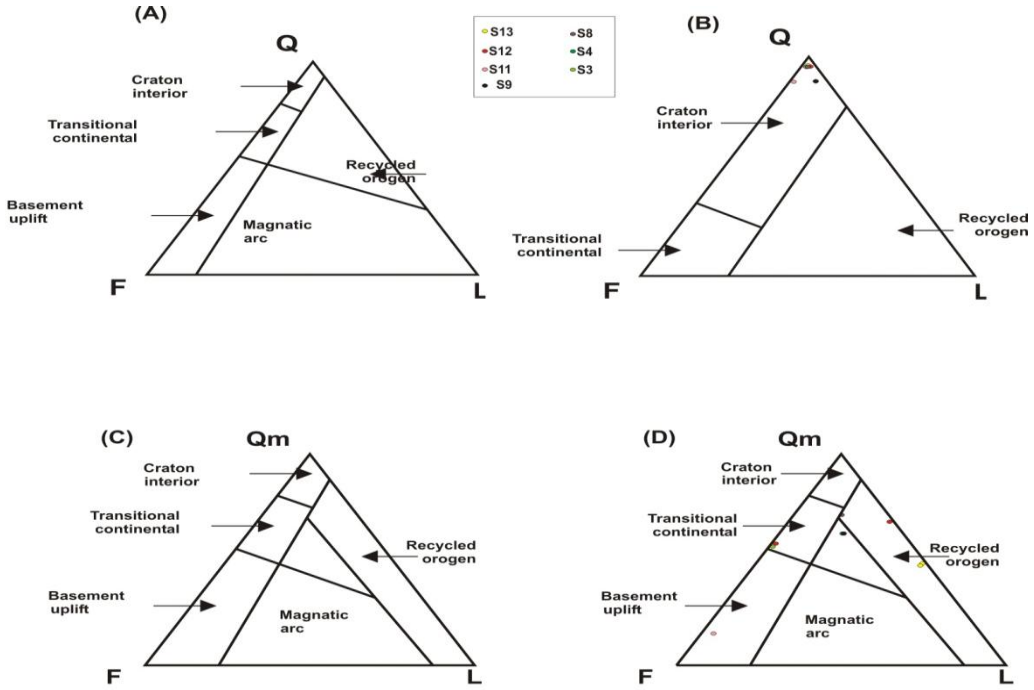

Fig.(15): QFL and QmL plots.(A) and(C) provenance field after Dickinson et al.(1983). (B) and (D) sandstones from the Merkhiyat member, Omdurman Formation.

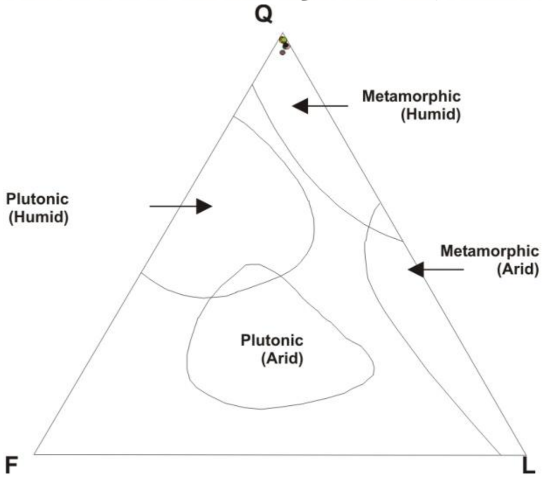

Fig.(16): The effect of source rock on composition of sandstone from Merkhiyat Member, Omdurman Formation using Suttner et al. (1981) diagram

CONCLUSIONS

Sandstone, silty sandstone, conglomeratic sandstone, and muddy sandy conglomerate are represent, fining upward cycle and each sequence (cycle) based on conglomerate facies represent fill of minor channel or sand body of channel fill (CH) facies to over bank deposits facies(OF) of fluvial environment. They are coarse to very fine grained, poorly to very poorly sorting and texturally immature to sub mature sediments. Positive skewness indicates the fine grains have a larger proportion of these sediments. Medium grained size represents the mode of grain size distribution of these sediments. According to grain size analysis, these sediments deposit in fluvial (river) environment. Sandstone of Merkhiyat Member can be classified as quartz arenite of fluvial deposit derived from warmed humid metamorphic, igneous rocks as external source and reworked sedimentary rock such as sandstone and mudstone as local intra basin source, which are governed predominantly by interior basin of continental Cratonic tectonic setting.

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