Sedimentary Environments and Lithofacies Distribution of Upper Shendi Formation, Central Sudan

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Abstract: ***Shendi formation is dominated by Mesozoic sediments and is considered as one of the major sedimentary formations of the Nubian group of formations. It basically consists of upper cretaceous sediments that are mostly fluvially dominated. The Nubian formation overlies basement complex rocks of assumed pre-Cambrian age. In a few places in the Sudan it is overlain by the Hudi Chert formation of lower tertiary age. The vertical sedimentary profiles recorded from Musawwat area including Qurun, Muqur, Maafar and Tumama, in addition to Bajrawiyyah and Umm-Ali area generally indicated a fining upward depositional sequence. The facies description and analysis of rock samples from these areas revealed the presence of eleven major lithofacies types. These included massive conglomerate (Gm), trough cross-bedded conglomerate (Gt), massive sandstone (Sm), trough cross-bedded sandstone (St), planar cross-bedded sandstone (Sp), low-angle horizontally bedded sandstone with pebbles (Sl), Massive sandstone with pebbles (Ss), Ripple Cross-Laminated Sand (Sr), Massive mudstone (Fm), Rootbed mudstone (Fr) and Fine-laminated mudstone (Fl). Trough cross-bedded sandstone (St) represented the highest total succession (56.45%), while Ripple Cross-Laminated Sand (Sr) represented the lowest total succession (0.24%). Based on grain-size analysis, the upper cretaceous strata can be classified as fluvial-dominated units. According to the plot of skewness against sorting, all samples proved to show a river, fluvial-dominated environment origin. The formations may have been formed in meandering rivers or multi-braided channels. In relation to the revealed lithofacies, there is no doubt that these formations were formed mostly in channel environments, and also overbank environments due to channel-breaking or flooding.***

Keywords: Formation, Fining upward, Depositional, Fluvial, Channel**.**

1. Introduction

The study area is located in the eastern part of the River Nile State of northern Sudan between Latitudes 17º 20` and 16º 40`N and longitudes 33º 30` and 34º 10`E (Fig. 1). The distance from Khartoum to the study area is about 180 Km, and can be reached from Khartoum by a paved road, passing through Shendi, to Atbara, following the River Nile on the eastern bank. The Sudan railway line at the right bank of the Nile joining Khartoum-Atbara can also be used to reach the area. Topographically, the area is characterized by high relief, mountains and some of low relief features valleys, dusty plains and seasonal streams such as Elawataib valley which flows to the NW and represents the southern boundary of the study area and wadi El Mukabrab which represents the northern boundary. The area is poor in vegetation, which includes Acacia trees and short grasses along the seasonal valleys. There are date palm trees along the River Nile in addition to some other crops in the terraces of the River Nile. The area is dominated by parallel to dendritic seasonal streams flow in sedimentary rocks and seems to be structurally controlled. The main direction of these streams is to the W and NW, towards the river Nile.

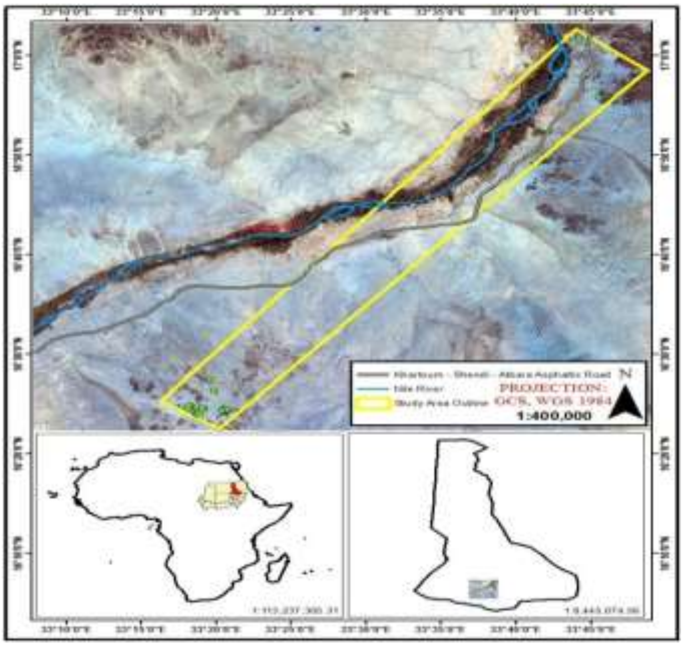

Figure 1: Location map of study area.

2. Regional geology

The geology of study area appears in outlier, in which cretaceous sediments are surrounded by Precambrian basement rocks .These basement rocks are exposed in Sabaloka at southward, Butana at east, Red sea hills in north east in addition to Buda desert at north west of the study area The area has high variation in lithology and ages, which extend from Precambrian to Quaternary. Based on previous geological studies the stratigraphic sequence has been established as follows [18] [19]:

2.1. Basement Complex

Basement complex rocks surrounded the study area and they are characterized by acidic and basic rocks, they associated Volcaniclastic sediments and Pyroclastic [18]. This Basement complex includes Igneous; Metamorphic and Metasedimentary rocks that are overlain by Palaeozoic or Mesozoic sedimentary or igneous rock and they are mainly of Pre-Cambrian age [19]. The oldest rocks exposed in the central Sudan include an ancient group of crystalline gneiss and schist, metamorphic rocks and granites [10].

2.2. Shendi Formation (Upper cretaceous sandstone)

[13] Introduced the name quartoze sandstone to describe silisiclastic sedimentary rocks cropping out in Shendi area. These are well bedded, non-pebbly, clean, well sorted sandstones which contain ripple marks, rib and furrow structures. The sandstone contains mainly quartz coated with iron oxide with interstices filled with ferruginous matter. A formal lithostratigraphic nomenclature of the units was given by [19] who proposed the name Shendi formation whose type locality is represented by outcrops north east of Kabushiya village, River Nile state. The lithological evidence, from shallow borehole and the Kandaka-1 well permits a downward extension of Shendi formation to include the mud-dominated lithofacies mainly identified sequences, the Shendi formation has been formally subdivided into two members: the umm Ali member and the Kabushiya member. The former, was mainly identified from boreholes with its type section located approximately 100m south of Umm Ali village.

2.3. Hudi Chert (Tertiary sediments)

Hudi Chert is represented in Hudi area and it is composed of sub-rounded boulders, yellowish brown in color which ranges in size from 5 to 20 cm. The rocks are very hard and fossiliferous with Gastropods fossils. The Hudi Chert was first identified by [9] from Hudi Railway Station about 40 km NE of Atbara and later studied by [4] [19]. The Hudi chert rocks were regarded as lacustrine chalky deposits that have been silicified into chert [5]. The source of silica was probably from silica flow from the young volcanic activity of Jebel Umm-Marafieb of NW Berber. [9] Reported that the Hudi Chert is an upper Eocene/lower Oligocene Formation which contains some types of fossils such as Gastropods and plant fossils.

2.4. Cenozoic Volcanic

First descriptions of these volcanic were given by [4] [18] who described them in more details and associated them to Tertiary-Quaternary volcanic activity. [2] Suggested a late Pliocene to Recent ages for the younger Bayuda volcanic rocks based on the slight degree of erosion. In Bayuda the lava flows cover both the Precambrian basement and the Tertiary Sandstone Formation. The outcrop is faulted in the eastern side of Jebel Nakhara, thus showing the unconformity relationship with the underlying sandstone. Their extrusion is connected with post-Nubian N-S and E-W striking faults [18]. They are assumed to be NW extensions of the great East African Rift System.

2.5. Superficial Deposits

These deposits represent a group of unconsolidated sands and gravel that spread to a larger scale in the study area including Musawarat, umm-Ali and Bijrawiya and consist of mud and sand dunes and ripple marks. These are usually recent fan deposits that emerged from outcrops and consisted of poorly sorted sediments re-deposited from preexisting sedimentary boulders, fragments and leached coarse and fine sediments. North to Shendi area numerous mobile sediments consisting of well sorted medium to fine sand, covering the underlying Shendi formation and extending to the east and north east to the river Atbara boundary. The alluvial deposits are very thick around the River banks consisting mainly of dark clays and clayey silt with fined-grained sands used for cultivation. The Wadi alluvial consists of fine to medium-grained sands which form the middle and lower courses of the Wadis while the upper parts are covered with unconsolidated coarse sand and fine gravels.

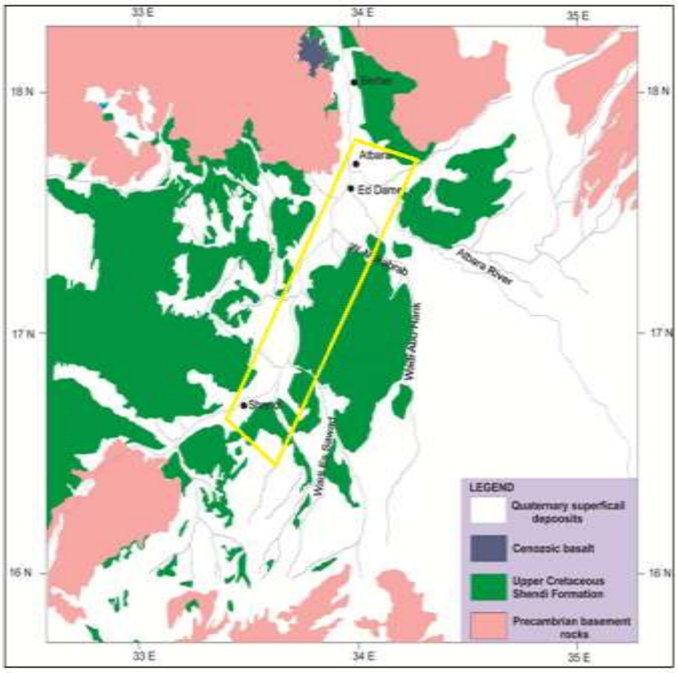

Figure 2: Regional geological map of the study area.

3. Objectives of the Study

The present study focuses on the sedimentology and stratigraphy of the Atbara-Shendi Basin. The main objectives of this study are to construct a conceptual model describing the depositional environments and determining the source area and paleogeography of the sediments accumulated in the study area.

4. Material and Methods of the Study

The field work is the most important phase of this study during the field work which extended for 14 days in which adequate measurements of vertical profiles have been carried out, described and classified into several lithological units on the basis of composition, grain size and sedimentary structures (lithofacies classification) and collection of the representative samples for grain size analysis and description of vertical sedimentary profiles (observation, measuring and recording different lithofacies parameters). It also identified sedimentary facie, observed their vertical relations and finally, Photographic imaging of characteristic features of different facies type in the study area was conducted.

5. Results

5. 1. Litholithofacies Analysis

Vertical sedimentary profiles have been examined and discussed. The collected information has been used in classifying the strata into several lithofacies associations. For lithofacies classification the terminology of [14] is adopted. Each profile was measured and sampled and photographed. The collected information has been used in the final drawing of the profiles. Consequently, each profile was subdivided into several lithofacies on the basis of texture and sedimentary structures and the symbols used in final drawing are in [16].

5.2 Lithiofacies Description

Lithofacies is a useful first step in description and classification. Most beds may be classified into one or other of these groups reflecting a natural separation of processes and sorting of the sediment load. Some mixed lithofacies, such as pebbly sandstones, do occur but can normally be classified according to their dominant grain-size class .Table (1) shows lithofacies classification and their codes to facilitate quick field and laboratory identification and documentation. The capital letter in the facies code indicates dominant grain size while the lowercase letter indicates the characteristic of texture or structure of the lithofacies [15].

5.2.1. Massive Conglomerate Facies (Gmm)

Gravel lithofacies is matrix-supported massive conglomerate (Gmm). This facies is composed mainly of gravel and little of mudclast .The gravel diameter is 2cm- 4cm, and they are poorly sorted and supported by poorly sorted sand, mud matrix and cemented by iron oxide. This facies has been identified in Fig. (3, 4, 5, 6, 7) in the study area. It represents 5% of the total thickness of the study area. This facies is interpreted as channel fills deposit with minimum thickness of 0.49m and maximum thickness of 3.15m.

5.2.2. Stratified Conglomerate (Gt)

This facies consists of trough cross bedded gravels that infill channelized erosive basal surfaces that are commonly composed of Quartz pebbles with minor mud clasts, geometrically, this facies has a lenticular shape, commonly interbedded with sandy bodies, and the lower contact is usually erosive where the upper is non-erosive. Commonly, this facies is overlain by massive gravel (Gm) or pebbly coarse massive sandstone (Sm), and underlain by massive mudstone (Fm) which represents the end of the lower cycle, sometimes massive sandstone would be found instead of the (Fm) because of the massive erosion. The main difference between this facies and (St) facies is the grain size. This facies has been identified in the Fig. (3, 4, 5, 6, 7) in the study area. This facies represents about 3% of the total succession thickness of the study area with minimum thickness of 0.18m and maximum thickness of 3.24m. This facies is interpreted as channelized lag, bed form deposits and lower flow regime.

5.2.3. Trough Cross Stratified Sandstone (St)

This facies consists of trough cross bedded sandstone which commonly ranges in grain size from medium to very coarse and pebbly where the trough cross lamination occurs in fine grained sandstone. Several sets or co-sets, geometrically, this facies usually exhibits continuous flat bedding. The lower and upper boundary is usually sharp but in some cases the latter is erosive. Commonly, this facies is overlain by massive sandstone (Sm) and occasionally massive mudstone (Fm). It extends to tens of meters laterally. This facies is dominant in all the study area representing 62% of the total succession with minimum thickness of 5m and maximum thickness of 8.2m. The gently inclined dip of the larger fore-sets and the coarse grain size suggest that larger sets of this facies probably formed low-angle-inclined fronts of bars whereas the smaller troughs were probably generated by dunes or mega-ripples that migrated over or across the lee faces of these bars [8].

5.2.4. Planer Cross Stratified Sandstone (Sp)

This facies represents 6% of the total succession with minimum thickness of 0.2m and maximum thickness of 3.2m. It consists of medium to coarse planer cross bedded sandstone and planer cross laminated sandstone mainly fine to medium grained, found assets and co-sets. In some cases the scale of the set was large (more than1m); it exhibits flat bedding with continuous but in some cases discontinuous lateral extension approximately 70m. The upper and lower contacts are usually sharp and not erosive but the lower is mostly erosive. Commonly, this facies is overlain by (St), (Sr), (Sl) and (Fm) but mostly (Sr) while it is usually underlain by (Fm).This facies is found in Fig. (3, 4, 5, 6, 7) in the study area with minim thickness of 0.5m and maximum thickness of 2.2m. This facies (Sp) is interpreted to be formed by the migration of straight crested dunes or bars [8]. This facies is deposited under conditions of lower flow regime.

5.2.5. Horizontally bedded Sandstone (Sh)

This facies is composed of fine horizontally bedded sandstone and distinguished by flat bedding with continuous lateral extension. It is usually overlain by (Sp), (Fm) and (Sm) while it is underlain by (Sm) and (Sp). The lower and upper boundaries are usually sharp but in some cases the lower boundary of this facies is erosive. This facies is rare in the study area we found Fig. (3, 4).This facies was accumulated as plane beds under conditions of either upper or lower flow regime.

5.2.6. Massive Sandstone (Sm)

The representation of this facies in the total succession is 6 %, with minimum thickness of 0.2m and maximum thickness of 5m. It is composed of fine to coarse grained sand with some pebbles. In this facies, there is no occurrence of sedimentary structures and it is usually underlain by (Fm) but in some cases by (St) and (Sp) and it is overlain by (Sr), (St), (Sl) and (Fm). The lower and upper boundaries are mostly sharp and the lateral extension of this facies is discontinuous and tabular shaped. This facies is interpreted as rapid deposition from heavily sediment-laden flows during waning floods and rapid scour filling.

5.2.7. Ripple Laminated Sandstone (Sr)

This facies is composed of fine to very fine sandstone intercalated with iron crusts, continuous flat beds and discontinuous (pinching out) beds are the main geometry. The upper boundary is usually sharp and the lower is commonly erosive. This facies is usually overlain by massive mudstone facies (Fm) while it is, in most instances, underlain by (Sm) or (Fm). The presence of asymmetrical current ripples and cross lamination draped by clay lamination indicates deposition via alternating subaqueous traction and suspension processes [14]. Facies (Sr) may be attributed to the down current migration of sinuous trains of asymmetrical ripples under controlled conditions of sediment supply in a lower flow regime of low intensity [1]. This facies, therefore, records slow sedimentation within largely inactive channels as fill deposits.

5.2.8. Massive Mudstone (Fm)

This facies represents 3 % of the total succession with minimum thickness of 0.2m and maximum thickness of 1.74m. This facies is composed of silt and clay size, the color varies from grey to violet. In some areas it is found inter-bedded with thin layers of massive sandstone and intercalated with thin iron crusts, geometrically, it can be found in wedge, lens and flat bed shaped bodies. The lower boundary is usually sharp and non-erosive while the upper boundary is commonly erosive. It is overlain by coarse massive sandstone (Sm) and underlain by (Sr). The lateral extension ranges from (20-80m). Facies (Fm) is interpreted to represent deposition from suspension in overbank settings where the fine-grained sediments are draped underlying deposit.

5.2.9. Laminated Mudstone (Fl)

This facies represents 12% of the total succession with minimum thickness of 0.1m and maximum thickness of 4.25m. It is composed of parallel laminated claystone and siltstone, grey and dark grey in color. Geometrically, it is continuous and flat bedded. The lower and upper boundaries are sharp. This facies is usually overlain by massive mudstone (Fm) and underlain by (Sp) and (Sm). It is found in Fig. (3, 4, 5, 6, 7). Facies (Fl) is interpreted to represent the deposits of waning stage flood deposition, chiefly in overbank areas. The thin, parallel lamination of alternating siltstone and clay stone lamina, together with their sheet-like geometry, indicate widespread deposition from suspension over the upper parts of sandy bar forms and/or across low relief abandoned flood plains [1].

5.2.10. Paleosol iron Crusts (Ferricretes) (Fc)

This facies is composed of iron crusts that show nodular form structures, commonly, the shape of this facies is thin crusts a few centimeters thick and beds which can reach more than 50 cm. It usually overlays facies (Fm) with a sharp non-flat contact. Paleosol iron crusts (i.e., ferricretes) are commonly regarded as part of deep lateritic weathering profiles which typically consist of unweathered parent rocks at the base, grading upward into saprolite ferricrete and a soft surficial zone. The formation of these ferricretes may be attributed to the in situ alteration of ferromagnesian silicates.

Table 1: shows lithofacies classification and their codes

Facies code	*Lithofacies*	*Sedimentary structure*	*Interpretation*
Gmm	Massive, matrix Supported gravel	Weak Grading	Plastic debris flow(high strength)
Gt	Gravel ,Stratified	Trough cross beds	Transverse bedforms, deltaic growths from older bar remnants
St	Sand fine to very coarse may be pebbly	Solitary or grouped trough cross Beds	Sinuously crested and linguoid (3D) Dunes
Sp	Sand, fine to very coarse may be pebbly	Solitary or grouped planar cross beds	Transverse linguiod bed forms (2D)
Sh	Sand, very fine to coarse , may be pebbly	Horizontal lamination parting or streaming lineation	Plane bed flow (critical flow)
Sm	Sand , fine to coarse	Massive or faint lamination	Sediment gravity flow Deposits
Sr	Sand ,very fine to coarse	Ripple cross lamination	Ripple (lower flow regime)
Fm	Mud, Silt	Massive desiccation cracks	Over bank abandoned channel or drape deposits
Fl	Sand ,Silt ,mud	Fine lamination v small ripples	Over bank , abandoned channel or waning flood deposits
P	paleosol carbonate calcite , siderite)	Pedogenic features	Soil with chemical precipitation

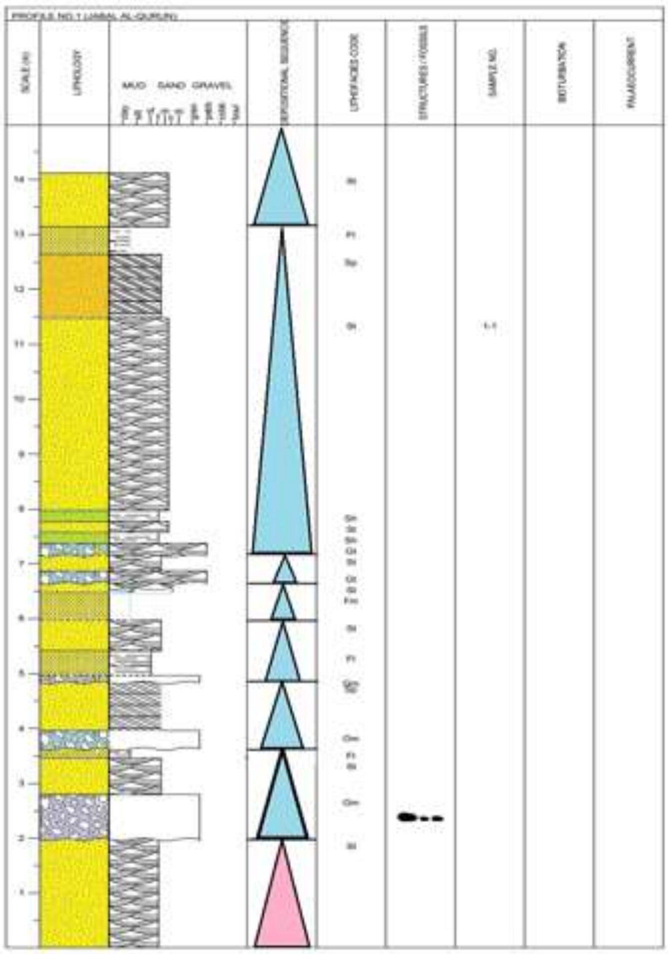

Figure 3: Vertical Sedimentary profile - Musawarat area – Jebel Groun

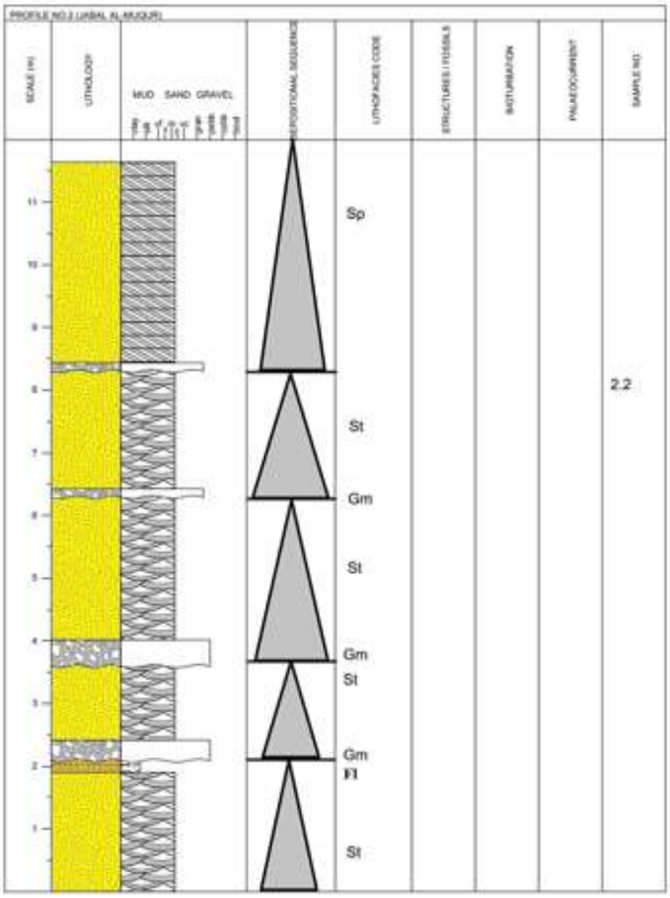

Figure 4: Vertical Sedimentary profile – musawarat area - Jebel Maqarah.

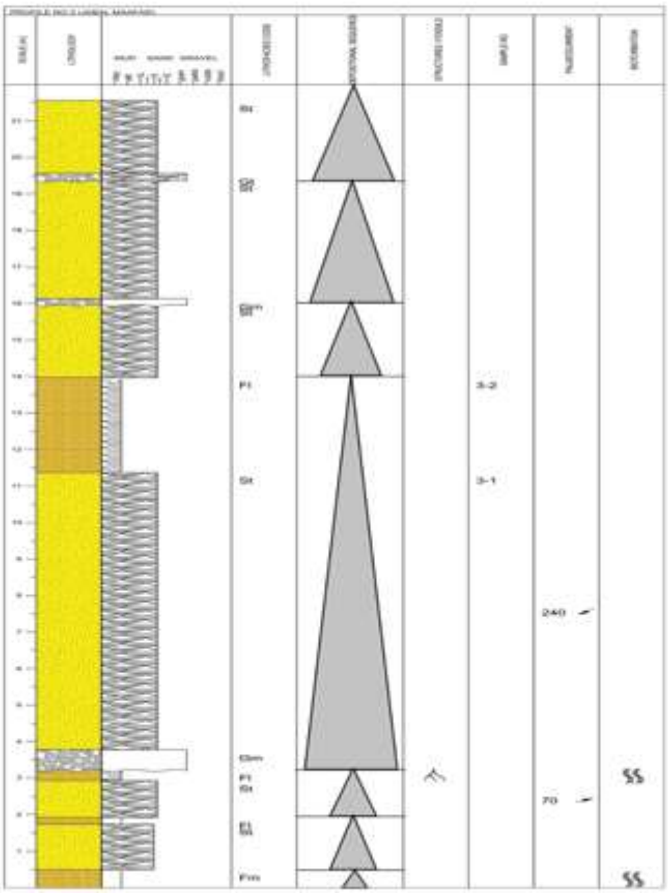

Figure 5: Vertical Sedimentary profile - musawarat area – Jebel Mafar.

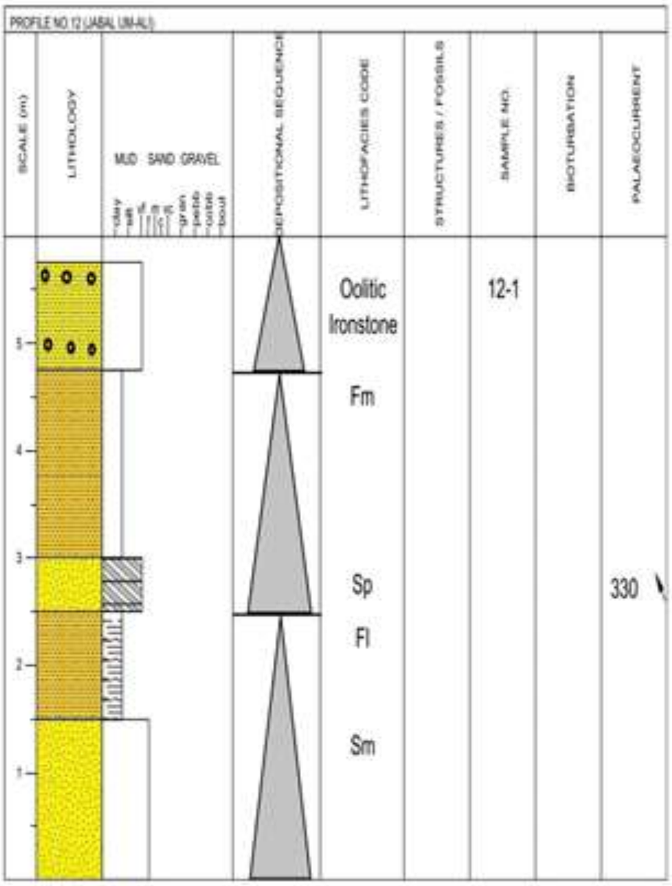

Figure 6: Vertical Sedimentary profile - Jebel Ummu Ali .

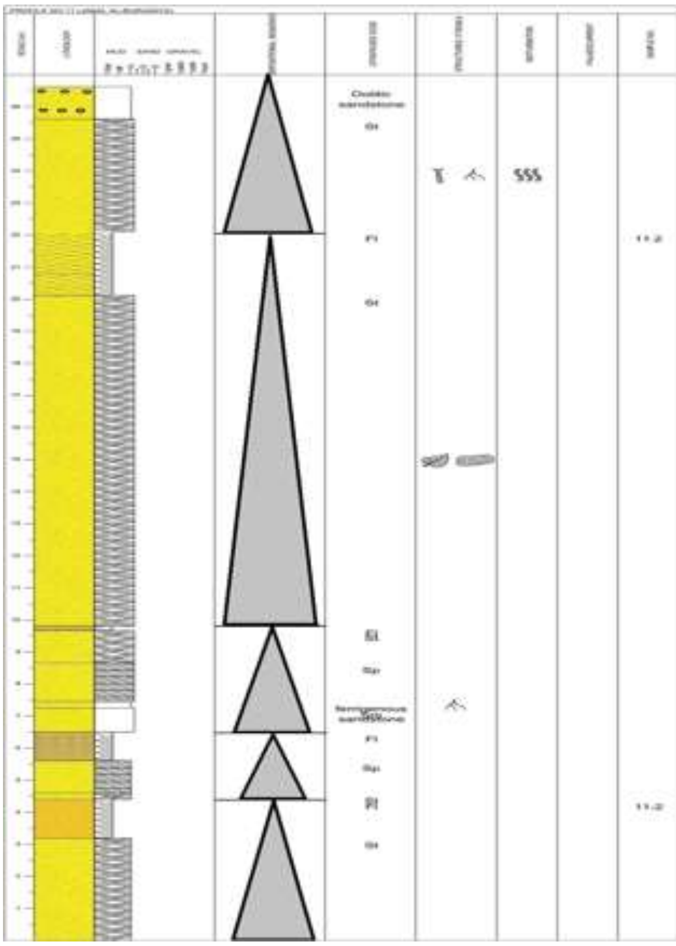

Figure 7: Vertical Sedimentary profile - Jebel Bajrawiya.

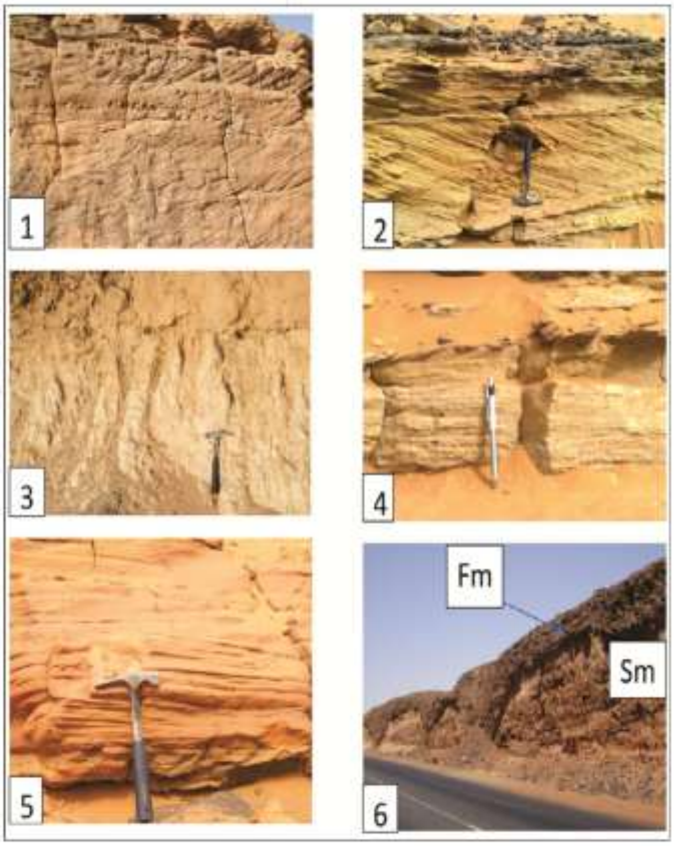

Plate 1: General facies of the study area 1, 2 and 5 planer Cross bedded sandstone facies (sp). 3 Massive mudstone facies (Fm). 4 Laminated sandstone facies (Sl). 6 Massive sandstone facies overlain by (Fm) massive mudstone facies with load structure in Umm Ali area (road cut).

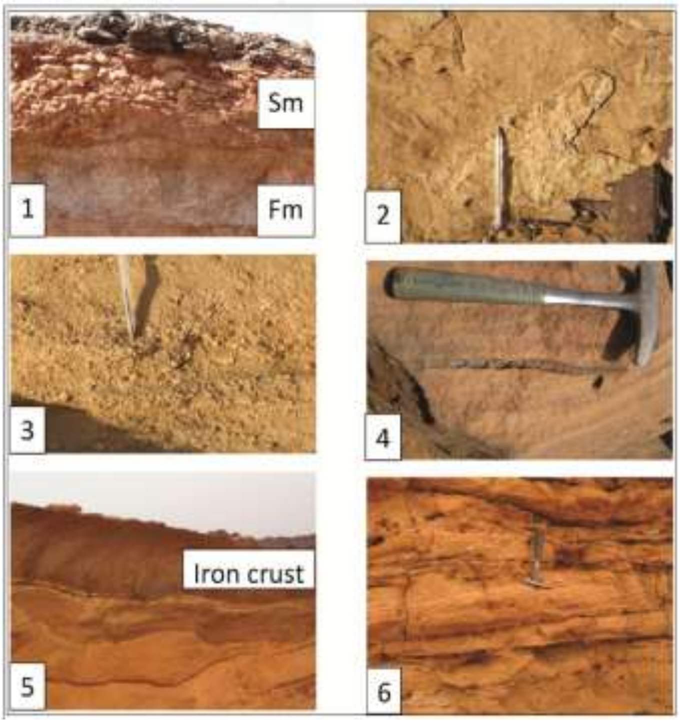

Plate 2: General lithofacies of the study area. 1 Horizontally bedded that shows massive mudstone facies (Fm) overlain by massive sandstone facies (Sm). 2 Massive sandstone facies (Sm) showing fault criteria (slicing slide). 3 Massive sandstone facies (Sm) with pebble or pebbly base sandstone. 4 Trough Cross bedded sandstone (St), with root fossils. 5 Thick layer of iron oxide. 6 Rippled sandstone facies (Sr).

5.3. Depositional Environments

Based on the lithofacies association and its rations, the paleodepositional environments in the study area can be assessed where any lithofacies association characterized for specific depositional environments is because the lithofacies association constitutes several litho-facieses that occur in combination and typically represent one depositional environment. In the study area, litho-facies association represents braided and meandering fluvial system. The fundamental components of any fluvial system are channel fills, channel bars, natural levees, crevasse splays and flood plains. Generally, in the study area the succession is fining upward; where reflecting progressive weak flows during filling, then the appearance of both coarse and fine fractions and variation of sedimentary lithofacieses (St), (Sp), (Sh), (Sm), (Sh), (Sr), (Fl), (Fm), (Gt), and (Gm) follows and all that is typical as multi-braided and meandering fluvial system.

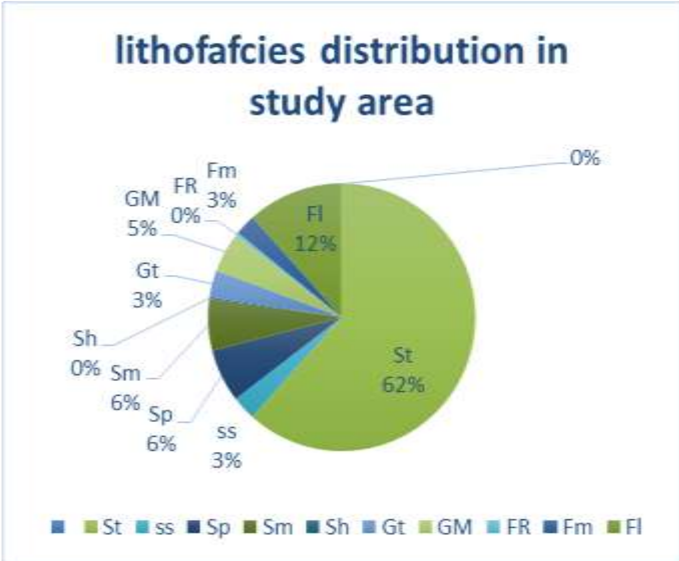

Figure 8: Percentage of lithofacies distribution in the study area.

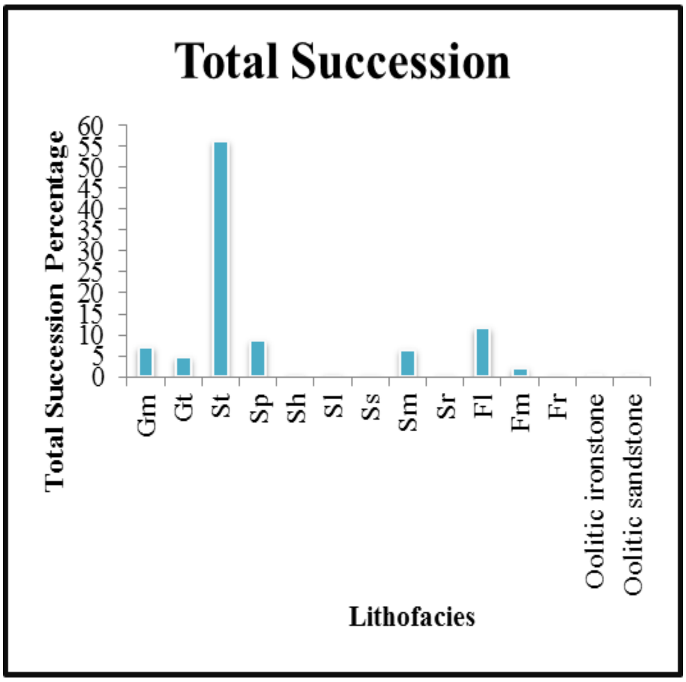

Figure 9: A histogram representing the total succession of the lithofacies.

5.4. Grain size analysis

Grain size refers to the diameter of individual grains of sediment or lithified particles in clastic rocks. The grain size analysis is used to determine the percentage and distribution of different grain sizes contained within the rock. Grain size sieving is a method that is widely used to directly measure the different sizes of sediments. This analysis gives us information on depositional mechanism and depositional environments of the sediments. The analysis is also performed to determine the distribution of the coarser larger sized particles and distribution of finer particles and calculating statistical parameters to obtain sedimentary environments. Combined with studies of sedimentary structures, these data can be useful in facies description and analysis [17]. In this study the grain size analysis is used in the present work in order to classify the sedimentary strata in the study area with an attempt to infer the depositional environments as well as to recognize the depositional processes responsible for the sediment formation [6]. The obtained data tables from sieving were then used to construct graphical presentations (Histograms, Smooth curves, and Cumulative frequency curves) and calculate arithmetical presentations involved computing statistical parameters suggested by [11].

Table 2: Phi values measured from cumulative frequency curves.

Sample No.	*φ5*	*φ16*	*Φ25*	*φ50*	*Φ75*	*φ84*	*Φ95*
1-1	0.3	1	1.2	1.5	1.8	2.0	2.7
1-2	0.2	0.5	0.9	1.4	1.9	2.3	2.8
1-3	0.4	1.2	1.4	2.0	2.5	2.7	2.9
1-4	-0.8	0.1	0.3	0.9	1.6	1.8	2.4
2-2	0.2	0.9	1.2	1.6	1.9	2.3	2.8
3-1	0.1	0.3	0.5	1.1	1.7	1.9	2.7
4-1	0.1	0.6	1	1.6	2.2	2.5	2.9
4-2	0.1	0.7	1.1	1.4	1.9	2.2	2.8
6-1	0.3	0.9	1.1	1.4	1.8	2	2.7
8-3	0.2	0.5	0.9	1.3	1.7	1.8	2
10-1	0.2	0.6	1	1.4	1.7	1.9	2.3
11-1	1.1	1.8	2.1	2.5	2.9	3.1	3.7
11-3	1.1	1.2	1.3	1.6	1.9	2	2.7
12-1	0.5	1.2	1.4	2.2	2.7	2.9	3.4
13-1	1	1.2	1.8	1.7	2	2.4	2.8
13-2	1.5	2.1	2.2	2.5	2.8	2.9	3.3
13-4	0.3	1	1.1	1.5	1.8	1.9	2.6
13-5	0.9	1.2	1.4	1.9	2.4	2.7	2.9
14-1	0.2	0.7	1.1	1.5	1.9	2.2	2.8
14-3	-0.6	0.2	0.5	1.2	1.7	1.8	2
15-1	0.1	0.5	0.8	1.3	1.7	1.9	2.4
15-3	1.1	1.2	1.4	1.8	2.3	2.6	2.9
15-5	-1.0	-0.3	0.1	0.7	1.4	1.8	2.6
16-2	0.2	1	1.1	1.4	1.8	1.9	2
16-4	0.1	0.4	0.7	1.3	1.7	1.8	2

5.4.1. Scattered Plot Diagrams

Scattered Plot Diagrams is a graph in which the values of two variables are plotted along two axes. Many researchers do it to interpret the depositional environments of sedimentary units using grain size distribution. Scattered plot diagrams are used to achieve this study were sorting against skewness and sorting against mean and skewness against median (Fig. 10,11) to distinguish between river sediments and beach sediments. Also scattered plots sorting against mean used to differentiate between river sediments and dune sediments. The scattered plot diagrams used above have shown that 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.

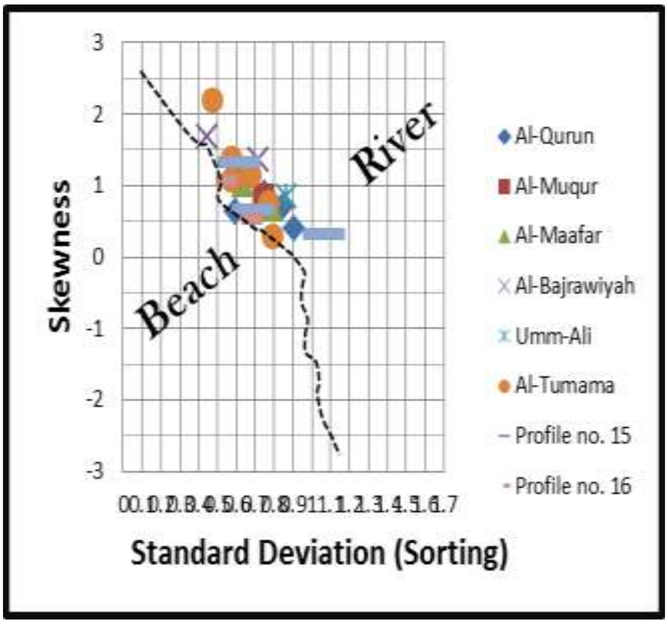

Figure 10: Graphical Plot of Skewness against standard deviation (Sorting) to show the depositional environments modified after [12]. Samples retrieved from the same area or same geological sections are given a similar symbol.

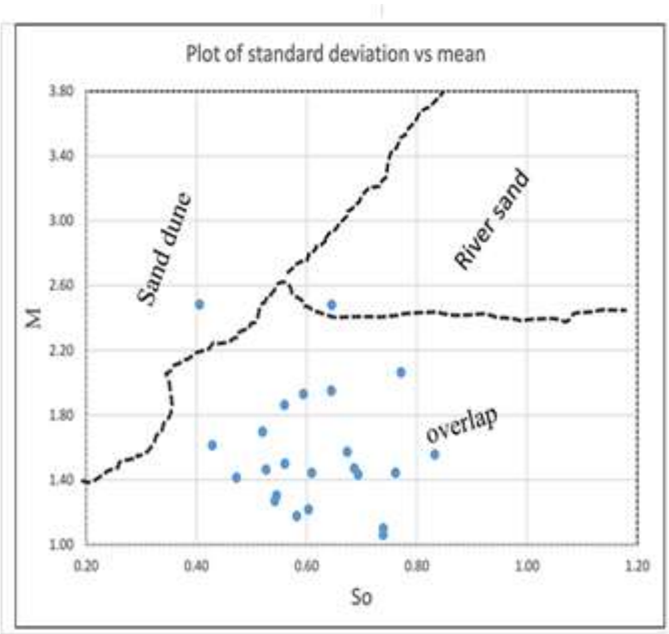

Figure11: Scattered plot diagram Mean (M) Vs. Sorting So

Table 3: Statistical parameters.

Sample No.	Mean (Mn)	Median (Md)	Sorting (So)	Skewness (SK)	Kurtosis (KG)	Interpretation
1-1	1.5	1.5	0.61	1.1	1.64	Moderately well sorted , very positively skewed, very leptokurtic
1-2	1.4	1.4	0.84	0.7	1.1	Moderately sorted, very positively skewed, mesokurtic
1-3	2	2	0.8	0.9	0.93	Moderately sorted, very positively skewed, mesokurtic
1-4	0.93	0.9	0.9	0.4	1.01	Moderately sorted, very positively skewed, mesokurtic
2-2	1.6	1.6	0.74	0.84	1.52	Moderately sorted, very positively skewed, very leptokurtic
3-1	1.1	1.1	0.8	0.7	0.9	Moderately sorted, very positively skewed, platykurtic
4-1	1.6	1.6	0.9	0.64	0.96	Moderately sorted, very positively skewed, mesokurtic
4-2	1.43	1.4	0.8	0.8	1.4	Moderately sorted, very positively skewed, leptokurtic
6-1	1.43	1.4	0.64	1.02	1.41	Moderately well sorted, very positively skewed, leptokurtic
8-3	1.2	1.3	0.6	0.63	0.92	Moderately well sorted, very positively skewed, mesokurtic
10-1	1.3	1.4	0.64	0.7	1.23	Moderately well sorted, very positively skewed, leptokurtic
11-1	2.5	2.5	0.72	1.4	1.3	Moderately sorted, very positively skewed, leptokurtic
11-3	1.6	1.6	0.44	1.7	1.1	Well sorted, very positively skewed, mesokurtic
12-1	2.1	2.2	0.9	0.9	0.9	Moderately sorted, very positively skewed, mesokurtic
13-1	1.8	1.7	0.6	1.4	3.7	Moderately well sorted, very positively skewed, extremely leptokurtic
13-2	2.5	2.5	0.5	2.2	1.23	Well sorted, very positively skewed, leptokurtic
13-4	1.5	1.5	0.6	1.1	1.35	Moderately well sorted, very positively skewed, leptokurtic
13-5	1.93	1.9	0.7	1.14	0.82	Moderately well sorted, very positively skewed, platykurtic
14-1	1.5	1.5	0.8	0.8	1.3	Moderately sorted, very positively skewed, leptokurtic
14-3	1.1	1.2	0.8	0.3	0.9	Moderately sorted , positively skewed, platykurtic
15-1	1.23	1.3	0.7	0.7	1.05	Moderately well sorted, very positively skewed, mesokurtic
15-3	1.9	1.8	0.62	1.33	0.82	Moderately well sorted, very positively skewed, platykurtic
15-5	0.73	0.7	1.1	0.32	1.13	Poorly sorted, very positively skewed, leptokurtic
16-2	1.43	1.4	0.5	1.1	1.1	Well sorted, very positively skewed, mesokurtic
16-4	1.2	1.3	0.64	0.53	0.8	Moderately well sorted, very positively skewed, platykurtic

6. Discussion

Representative samples were selected for grain size analysis. The majority of the study samples occur moderately sorted ranging from(0.41-1.0) and very platykurtic to platy kurtic in terms of kurtosis ranging from(0.31-1.43), and the skewness value very negatively skewed to negatively skewed ranging from(-0.01-0.2),. Also the results of scattered plot diagram and all samples of study area were found in the field of river sediments. Thus, they may indicate the sediments of the study area were deposited in fluvial environment and showing fining upward sequences starting with a basal conglomerate followed by sub-dominated course to medium sandstone.

7. Conclusions

The surface fluvial part of Shendi formation is characterized by erosional channel surface and matrix supported massive conglomerate (Gmm) facies, trough cross-bedded sandstone facies (St), planar cross-bedded sandstone facies (Sp), horizontally –bedded sandstone facies (Sh), ripple cross-bedded sandstone facies (Sr) and massive sandstone facies (Sm) with some overbank and floodplain sediments. This fluvitile surface part may represent different channel types such as low sinuosity braided channels. The iron sediments are strongly leached within intensive warm humid climate from the source areas transported and deposited within oxic and shallow environments such as overbank and floodplain. These environments provided suitable physico-chemical conditions for the precipitation. The iron sedimentation is controlled by alloucyclic and autocyclic processes.

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