Sedimentary Facies and Depositional Environments of AL Musauwarat-Umm Ali Area, Shendi Formation, River Nile State, Sudan

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***Abstract*—This paper presents the results of Sedimentary Facies and Depositional Environments of AL Musauwarat-Umm Ali Area, Shendi Formation, River Nile State, Sudan. Study area is dominated by Mesozoic sediments of continental origin from fluvial and lacustrine depositional environments which are widely spread in central Sudan. This study aims to the interpretation of depositional environment using lithofacies analysis, grain size analysis and petrographic description. During the field work trip, fourteen vertical and three lateral sedimentary profiles have been examined and discussed. The studied profiles exhibit eleven lithofacies identified at the outcrop section which are matrix supported massive conglomerate (Gmm) facies, stratified conglomerate (Gt), trough cross-bedded sandstone facies (St), Shallow scour pebbly sandstone (Ss), planar cross-bedded sandstone facies (Sp), horizontally–bedded sandstone facies (Sh), ripple cross-bedded sandstone facies (Sr), massive sandstone facies (Sm), massive mudstone (Fm), fine-laminated mudstone (Fl) and rootbed mudstone (Fr). On the basis of their sedimentological character theses facies are interpreted to be deposited in fluvial depositional environment, by multi braided river channels. 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. Thin section investigations of the outcrops samples that the sedimentary rocks in Shandi basins consist mainly of polycrystalline quartz occurs in higher percentages than monocrystalline quartz indicate a metamorphic source region, feldspar which found are usually altered, lithic fragments, detrital micas are present and also some fine-grained matrix. The cementing materials are quartz, carbonates, iron oxides and some matrix (kaolinite and chlorite), The most abundant kind of the sedimentary rocks is arenite which support the hypothesis that area is fluviatile.**

***Index Terms*—Facies, depositional environments, Shendi Formation, representative, fluvial.**

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I. Introduction

The study area is bounded by the longtitude 16°23'52.30" and 17°15'30.30" & latitude 33018'51.9"and 33°45'31.50", in eastern and western parts of River Nile State. The Shendi-Atbara Basin covers a strip that extends along the eastern side of the Nile between Shendi and Umm Ali village. It is bounded from south by the Sabaloka basement complex, Butana plain which extends to the east, Bayuda desert to the north and west and the Red Sea hills to the north east. The distance from Khartoum to Al Musawarat is about 180 km, and can be reached by paved road of Altahady or by the Sudan railway line at the right bank of the Nile joining Khartoum- Atbara- Barber (Fig. 1). Al Musawarat area can be reached via land road to the east about 35 km from main paved road. The study area is characterized by physiographic features varying from isolated hilly terrains (the sediments attain a maximum thickness of about 30m in outcrops) in the south and southwest arts of the basin in Al Musawarat, Umm Ali, and Bagraweia lying in generally flat plains basins, and in between there are negative relief (valleys) caused bydifferential erosion, which are seasonal streams and flow westward to the Nile, and take straight paths, which are probably controlled by faults. Wadis and Khors are seasonal streams drainage system in the study area and their tributaries are dense. Wadi Awatib and Wadi Mukarab are among the prominent seasonal streams in the area. The main direction of these streams is to the West and Northwest towards the River Nile, which is the main drainage in the study area (Fig. 2). Semi-desert condition dominates and the rainfall ranges from 150 mm south to 25 mm north in the year and temperature range from 47° in the summer maximum to 8° degrees in the winter. Winter The area is poor in vegetation, with only acacia trees and short grasses along the seasonal valleys [5].

II. Geology of the Study Area

The main geological units are composed of Basement Complex (Pre-Cambrian), upper Cretaceous Sedimentary Formation (Nubian sandstone), Hudi Chert (Oligocene)

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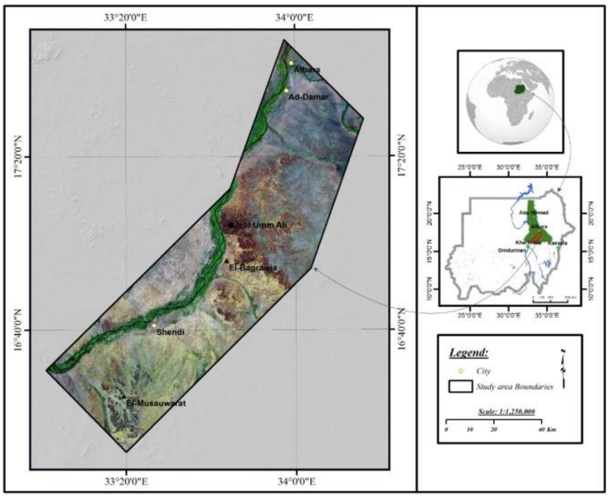
and Quaternary superficial deposit (Fig. 3) in ascending chronological order [35]. The stratigraphic sequence has been established as follows:



Fi 1. Location map of the study area.

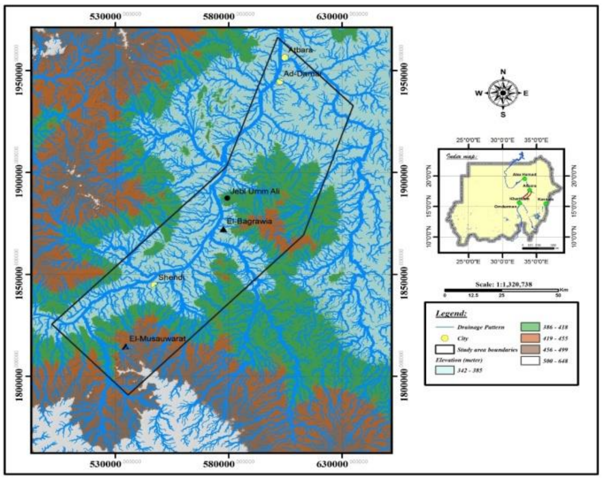


Figure 2. Drainage System map of the study area.

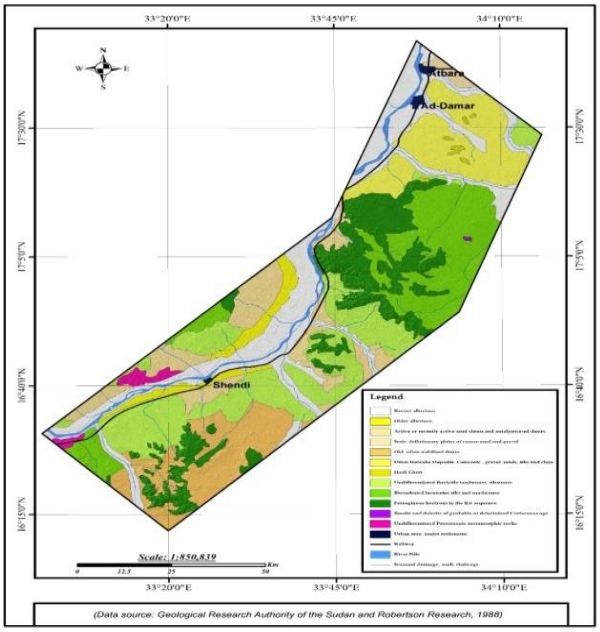


Figure 3. Geological map of the study area.

A. Basement Complex

Basement complex includes Igneous, Metamorphic & Metasedimentary rocks that overlain by Palaeozoic or Mesozoic sedimentary or igneous rock and they are mainly of Pre-Cambrian age [35], [34]. A good example is the Sabaloka Ring Complex that appeared to be of Cambrian age. The oldest rocks exposed in the central Sudan include an ancient group of crystalline gneiss and schist, metamorphic rocks and granites [32]. Representatives of this unit crop out in four places namely, in the sabaloka inlier north of the capital, west of the White Nile between Omdurman and Ed Dueim, east of the blue Nile in the parts of the Butana plains and south of the Gezira between Sennar and Kosti, elsewhere younger deposits cover them (Fig. 3).

B. Shendi Formation (Upper Cretaceous Sandstone)

Kheiralla [21] introduce the name quartoze sandstone to describe silisiclastic sedimentary rocks cropping out in Shendi area. These are well bedded, non-pebbly, clean, well sorted sandstone which contain ripple marks, rib and furrow structures. The sandstone contain mainly of quartz coated with iron oxide with interstices filled with ferruginous matter. A formal lithostratigraphic nomenclature of the units was given by Whiteman [35] 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. Consequently, the Shendi formation has been formally subdivided into two member: 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. The type section previously selected to describe Shendi Formation Whiteman [35] has been retained for the Kabushiya member. Lacustrine to fluvial-lacustrine condition could have prevailed during deposition of the Umm Ali member, while fluvial-dominated setting characterizes the Kabushiya member. Terrestrial palynomorph of Campanian - maastrichian age were reported with the subsurface part of unit represented by Kabushiya member and the upper most part of the Umm Ali Member (Fig. 3).

C. Hudi Chert (Tertiary Sediments)

The represents in Hudi chert which composed of sub-rounded boulders, yellowish brown in color, which range in size from 5 to 20 cm. The rocks are very hard and fossiliferous with Gastropods fossils. The Hudi chert was first identified by Cox [12] from Hudi Railway Station about 40 km NE of Atbara and later studied by [11], [12], [35]. The Hudi chert rocks were regarded as lacustrine chalky posits that have been silicified into chert [11], [12]. The source of silica was probably from silica flow from the young volcanic activity of Jebel Umm-Marafieb of NW Berber. Cox [12] reported that the Hudi chert is an upper Eocene/lower Oligocene Formation, which contains some types of fossils such as Gastropods and plant fossils. The sediments of Jebel Nakhara Formation represent part of the Nubian Sandstone Formation Hills from Shendi-Atbara region [21]. These rocks of Jebel Nakhara Formation are exposed west of the River Nile between the Cenozoic volcanic and the Nile. The Jebel Nakhara Formation mainly comprises sandstones with varying grain size, siltstones, mudstones and conglomerates. They overlie the basement discordantly and in turn covered uncomfortably by Cenozoic volcanic. They are poorly sorted, coarse to medium-grained in texture and mainly consist of quartz and some clay minerals as the main components. Trough cross bedding, tabular cross bedding and graded bedding structures are common sedimentary structures. There is a general agreement that these sediments have been deposited mainly in Tertiary times [21] while Whiteman [35] suggested a Cretaceous age to the same sediments (Fig. 3).

D. Cenozoic Volcanic

First descriptions of these volcanic were given by [10], [30] described them in more detail and related them to Tertiary-Quaternary volcanic activity. Almond et. al., [35], [31] 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 [31]. They are assumed to be NW extensions of the great East African Rift System (Fig. 3).

E. Superficial Deposits(Resent)

The superficial deposits include wadies and galley deposits which course the Jebels. Recent fan deposits that emerged from the out crops and consist of poorly sorted sediments redeposit from pre-existing sedimentary boulders, fragments and leached coarse and fine sediments. North to Shendi area numerous mobile sediments consist of well sorted medium to fine sand, are covering the underlying Shendi formation and extend to the east and north east to the river Atbara boundary. The superficial deposits in Buttana include the clayey soil covering the flat plains, in addition to the valley fill and the deltaic deposits which are seasonally transported by the ephemeral streams during the rainy season. The valley deposits cover the drainage beds and are mainly composed of sands and pebbles. The superficial deposits in Bayuda include gravels, sands, clays, sandy clays and silt. 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 fined 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. Superficial deposits in Sabaloka include Nile silts, alluvial fans, Aeolian sands and lag gravels, sandy residual soils [2] (Fig. 3).

III. Objectives of This Study

The present study focuses on the Sedimentary Facies and Depositional Environments of AL Musauwarat-Umm Ali Area, Shendi Formation. 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.

IV. Methodology

The Present study is based on describing the different facies to predict the depositional environment, reconstruction of the paleoenvironment paleogeography and paleocurrent direction that lead to deposition of the sediments. These objectives will be reached through the following:

Lithofacies analysis which include: Facies analysis, Grain size analysis and sandstone petrography and palynological studies which include: identification of marker species to estimate the age and depositional envinronment of the study area. 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.

V. Results and Discussion

A. Lithofacies Analysis

The study and interpretation of the textures, sedimentary structures, fossils, and lithological associations of sedimentary rocks on the scale of an outcrop, well section, or small segment of a basin comprise the subject of facies analysis [24] Facies is generally an interpretive term and refers to the sum of the characteristics of a sedimentary unit resulting from some particular set of physical, chemical and biological parameters that work to produce a unit with Specific textural, structural, and compositional properties [24]. A Facies is produced by one or several processes operating in a depositional environment, some may be repeated several or many times in succession, a facies also may change laterally or vertically into another facies by change in one or several of it is characteristic features.
The facies concept refers to the sum of characteristics of a sedimentary unit, commonly at a fairly small scale (cm-m), Lithology, grain size, sedimentary structures, color, composition, biogenic content, Lithofacies (physical and chemical characteristics), biofacies (macrofossil content) and ichnofacies (trace fossils). Fourteen vertical and three

lateral sedimentary profiles have been examined and discussed. The studied profiles exhibit several lithofacies identified at the outcrop section. The collected information was used in the final drawing; the symbols used are based on [28]. The terminology of Miall [24] facies codes were adopted for description and classification of facies types in the study area. Based on Maill facies codes ten Lithofacies have been recognized in the study area. The depositional processes which control the development of clastic fluvial lithofacies, such as traction-current transportation, with its accompanying fluid turbulence and its effects on beds of clastic grains, are common to all rivers and obey the same physical laws everywhere, with the production of similar suites of lithofacies. For example, hydrodynamic structures, such as ripples and cross-bedding, are formed by migration of ripples and dunes. Miall [24] reviewed braided-river deposits and demonstrated a consistency in the lithofacies assemblages occurring in a wide range of modern and ancient sandy and gravelly sediments. To prevent confusion of common depositional themes, Miall proposed a simple classification, making use of a two-letter code to facilitate quick field and laboratory identification and documentation. Subsequently, the classification has been used by dozens of researchers and has become a standard field methodology for the examination of fluvial deposits (Miall, 2006). The capital letter in the facies code indicates dominant grain-size (G=gravel, S=sand, F= fine-grained facies,including very-fine sand, silt and mud). The lower case letter serves as a mnemonic for the characteristic texture of structure of the lithofacies (e.g., p=planar cross-bedding, t=trough cross-bedding) [24]. The following table represents only the investigated lithofacies in the study area.

Trough cross-bedded sandstone facies (St): This facies is represents 36% (Fig 4). The distribution of this facies is different mainly composed of quartz, feldspar and minor amounts of mudclast and it commonly ranges in grain size from medium to very coarse and some where it is pebbly sandstones, where the trough cross lamination occurs in fine grained sandstone , the grains are sub rounded to angular and they are poorly to moderately sorted. Geometrically, this facies occurs as lenticular or wedge-Shaped bodies that are pebbly in places and that are commonly arranged into stacked trough crossbedded cossets that extend laterally for several tens of meters, this facies usually exhibits continuous flat bedding. The gently inclined dip of the larger fore-sets and the coarse grain size suggests 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 [12]. The lower boundary is either gradational with facies Gm or is erosional with facies Fm of the underlying cycle. The upper contact is sharp with overlying facies Sp or sometime Sm.

Massive sandstone facies (Sm): The percentage of this facies in the total succession is 13%, (Fig. 4). Distinguished by the presence of thin layer of iron oxides intercalations, dominated by medium to coarse with some pebbles and fine grained, moderately to well sorted sandstone; also mudclast are noted in this Lithofacies in addition to quartz and iron oxides grains containing root fossils. This facies is interpreted as rapid deposition from heavily sediment-laden flows during waning floods; rapid scour filling [26]. This facies has a wide spread in the study area, and is usually, underlain by Fm, but in some cases by St and Sp, and it is overlain by Sr, St, Sl, Fl and Fm. The lower and upper boundary are mostly sharp, the lateral extension of this facies is discontinuous, tabular shaped.

Rippled cross laminated sandstone facies (Sr): This facies is represents 1% (Fig. 4). This Lithofacies is composed of quartz, iron oxides with fine to medium - grained, moderately to well sorted and moderately to well cemented, bioturbated
rippled sandstone.

Horizontal bedded sandstone facies (Sh): This facies is represents 1% (Fig. 4). Mainly composed from quartz sand ranging from very fine to medium, but mainly fine grained with minor amount of pebbles, and mudclast. This facies is distinguished by flat, parallel lamination, with parting lineation occurring on bedding planes, with continuous lateral extension. Interpretation of this facies accumulated as plane beds under conditions of either upper or lower flow regime [23]. The thin, discontinuous, sheet-like geometry and fine-grained nature of the lithology suggests deposition as bar-top sand sheets or as in channel deposits during the waning stage of (possibly seasonal) flood events [24]. The Sh is usually overlain by Sp, Fm and Sm, while it 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 boundary.

Plannar cross-bedded sandstone facies (Sp): This facies represents 20 % of the total succession (Fig. 4). It consists of medium to coarse planer cross bedded sandstone, and planer cross laminated sandstone mainly fine to medium grained, found assets and cosets, 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 no 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. The characteristic planar geometry and the associated grain size indicates formation by processes operating in the lower to middle part of the lower flow regime, whereby deposition took place during periods of low water level or waning flow in channels. The deposition of low-angle cross-bedding within largescale examples of sets of facies Sp indicates that these larger sets are a product of bar migration.

Shallow scours pebbly sandstone facies (Ss): This facies is represents 2% (Fig. 4). This facies was found in Al Musawarat and Umm Ali. Characterizing poorly sorted coarse sandstone, the lower boundary of this facies is a scour surface of polymict (consist of conglomerate and finer sand which form the facies below) this facies lack sedimentary structure appears as a scour surface of conglomeratic or pebbly sandstone. As an interpretation this facies occur when a new channel intercepted sedimentary strata of finer grain size (scour fill).

Weak grading matrix supported, massive gravel facies (Gmm): This lithofacies is represents 8% (Fig. 4). The distribution of this facies is different in thickness From Al-Musawarat to Umm Ali area. Geometrically; this facies consists of lens and ribbon shaped bodies, mainly composed from quartz pebbles with minor amount of the mudclasts and some lithic fragments of igneous origin, varies in color, poorly to moderately sorted and subrounded to sub-angular. The quartz pebbles is angular to sub rounded, poorly sorted, supported by poorly sorted matrix of sand, silt, mud and sometimes it is cemented by ferruginous material, this facies has a sharp boundary erosional relationship with underlying beds a transiently boundary in some beds. They commonly have a sharp lateral termination. Commonly has geometry of channel. The interpretation of this facies is gravel bar Bed load deposition as gravel sheets or splays by high magnitude flood flows.

Stratified Conglomerate facies (Gt): This facies represents less than 4% of the total succession, (Fig. 4). It consists of trough cross bedded gravels that infill channelized erosive basal surfaces, commonly composed of Quartz pebbles with minor mud clasts, Geometrically, this facies has a lenticular shape, an approximate thickness about 60cm, and about 3m of width , commonly interbedded with sandy bodies, 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 is interpreted as Channelized lag and bed form deposits, lower flow regime. Paleocurrent orientations discordant to Channel axis support the interpretation of facies Gt as Channel-base deposits. The characteristics of this facies are consistent with deposition in fluvial channels from high velocity flows in the deepest part of the stream.

Massive mudstone facies (Fm): This facies represents 4 % of the total succession (Fig. 4). This facies mainly consists of silt and clay size grains, the color changes from grey to violet, in some areas the Fm is inter- bedded with thin layers of massive sandstone and intercalated with thin iron crusts. This facies occurs as wedge, lens and flat bed shaped bodies, the lower boundary usually sharp and non-erosional, the upper boundary is erosional. This facies has been noted almost found in all the studied profiles. This facies is interpreted to represent deposition from suspension in overbank settings where the fine-grained sediments drape underlying deposits.

Massive rote bioturbated mud facies (Fr): This facies represents 1% of the total succession (Fig. 4) and it usually interperated as top bed that is exposed or floodplain.

Laminated Sand, Silt and Mud facies (Fl): This facies represents 9% of the total succession (Fig. 4), consists of parallel laminated Sandstone,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, the lateral extension is approximately more than 90m. 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 claystone laminae, together with their sheet-like geometry, and indicates widespread deposition from suspension over the upper parts of sandy barforms and/or across low relief, abandoned flood plains.

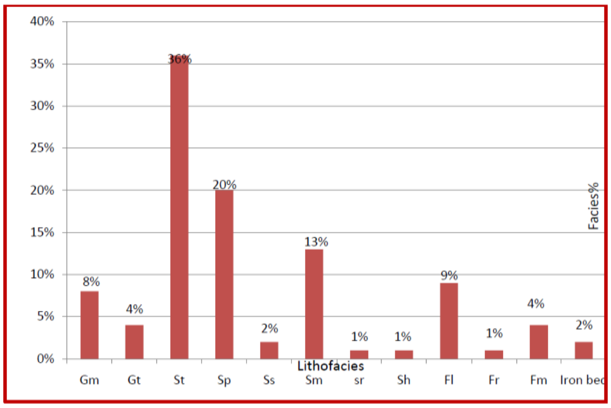


Figure 4. Relative lithofacies abundance for the studied area.

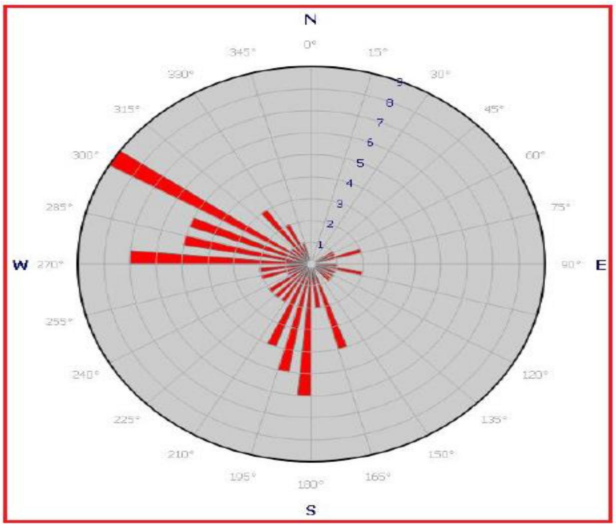


Figure 5. Rose diagram show the paleo-current direction.

B. Grain Size Analysis

For many years sedimentary scientists have attempted to use the grain size analysis. Tucker [27] provided a careful study about the relations of sediment textures for known depositional environments. He classified the distribution curves according to seven different depositional environments: relict, strand, tidal flat, shelf, tidal inlet, minor tidal channel and fluvial. Friedman [18] gave a useful correlation between sorting measured by standard deviation and the depositional environment. In this way, the grain size analysis is used in the present work in order to classify sedimentary strata in the study area, with an attempt to infer the depositional environments as well as recognizing the depositional processes responsible for the sediment formation. This analysis is carried out to determine the weight percentage of different grains sizes in that sediment, and to identify the statistical parameters to plot them in special charts to infer the depositional environment. It also used in sandstone classification after calculating the percentage of mud, sand and gravel in each sample. Grain size analysis is used widely for the interpretation of depositional environments. From the plotting of one statistic parameters (e.g. Skewness, sorting, mean or sorting) ageist to another; can be suggest the paleodepositional environment in the study area. In the present study the following scattered diagram (Fig. 6, Fig. 7) for assessed paleodepositional environment. All of most representative samples plotted on river field, and river sand, excepted four sample abortion in the beach zone in & transitional zone. Based on combination plotting of the representative samples and description of the samples depend on statistic parameters; the paleodepositional environment represented fluvial sediments, deposited by multi braided river channels, gravel, sand and silt. This is supported by the fact that the sediments are varies in degree of sorting: very well sorted, moderately to well sorted, moderately to poorly sorted and very poorly sorted, poorly in organic matter dominated by medium to coarse grain fraction shows fining upward. However, the paleoenvironmental implication of grain size analysis supported interprets the result of lithofacies analysis. The palaeodepositional environment can be assessed using the grain-size analysis by plotting the textural parameters in special discrimination diagrams. Such diagrams are constructed on the basis of textural parameters which are calculated from the recent sediments. In the present work the following scattered diagrams have been selected: A plot of skewness (Sk) against standard deviation (So). This plot shows two fields, one for the river sands and others for beach sands. A plot of Mean (Mz) against the slandered deviation (So), this plot shows two fields, one for river sands and the other is for beach sands. More ever the scattered plots showed the upper Shendi Formation representative samples From Umm Ali, Bagraweya and Al Musawarat area are fluvitile sediments deposited by multi braided river channels. This result is supported by the following: The sediments are varies in degree of sorting: very well sorted, moderately to well sorted and, moderately to poorly sorted and very poorly sorted, poorly in organic matter dominated by medium to coarse grain fraction shows fining upward and coarsing upward sequences. The presence of both coarse and fine Fractions throughout the studied profiles (Table I). The variation of sedimentary facies. Umm Ali area profiles showed that it is dominated by fine material unlikely to the Bagrawiya area and Al Musawarat area where sediments are coarser (Fig. 6, Fig. 7).

TABLE I. STATISTICAL PARAMETERS OF GRAIN SIZE ANALYSIS

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

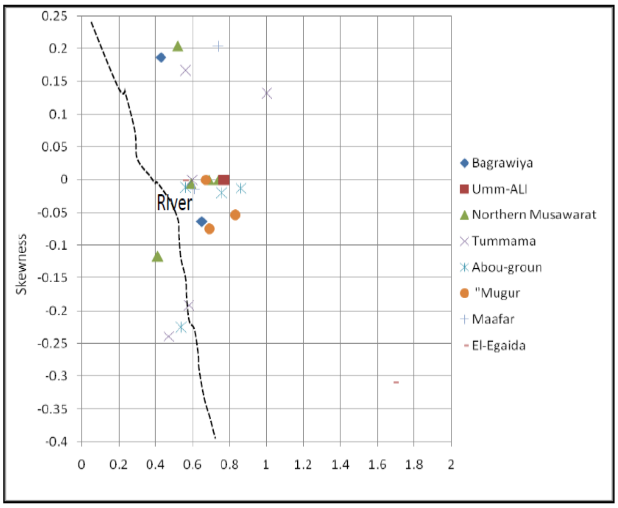


Figure 6. Scattered plot diagram shows Skewness vs. the sorting coefficient based on the samples of the study area to determine the depositional environment (after Friedman 1967).

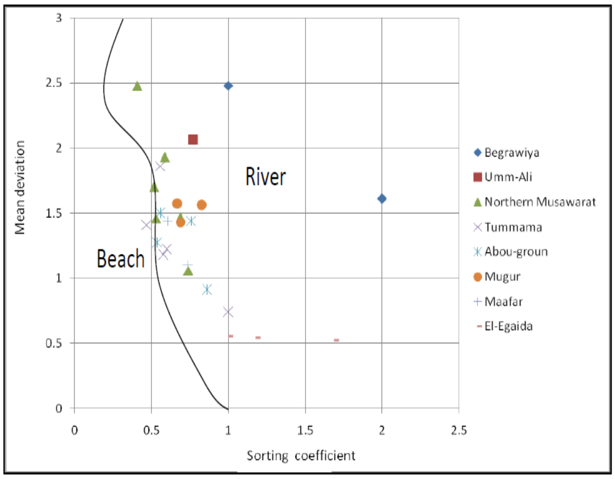


Figure 7. Scattered plot diagram shows mean deviation vs. the sorting coefficient based on the samples of the study area to determine the depositional environment (after Friedman 1967).

C. Sandstone Petrography

This part of study area associated dealing with petrography of the representative sandstone samples at the study area. It determines the mineralogical composition and classifies the sandstone types to have knowledge about their source areas, depositional environments, paleoclimate, diagenetic process and to infer the tectonic history of the study area. To study the thin-section polarized-light microscope at used with different magnifications. The optical property (color, relief, extension angle, twining and bifringence) was the base to identification of minerals. Twenty one rock samples were prepared and studied under the polarized-light microscope. Bagrawiya area samples are fine grained, sub angular to sub rounded grains, well sorted sandstone. The sample Composes mainly of considerable quantities of monocrystalline with some amount of polycrystalline quartz, some amount of K-feldspar (can be identified by its cloudy appearance resulted from the alteration), minor amount of plagioclase, some amount of mica in which the perfect cleavage can be seen in some grains while the others were altered, some quantities of clay and heavy minerals (such as pyroxene) found as accessories and others are enclosed inside the quartz grains. Considerable quantities of iron oxides, and obvious carbonates mainly siderite cement the sample is classified as ferruginous sandstone (Fig. 8). Umm-Ali area samples are Fine grained, sub angular, moderately to well sorted grains. The sample Composes mainly of considerable quantities of monocrystalline, minor amount of polycrystalline quartz, few amount of K-feldspar, minor quantities of plagioclase, as well as minor amount of mica (mainly muscovite), some quantities of clay and few heavy minerals (such as amphibole; the sample is immature texturally and mature compositionally. Considerable quantities of iron oxides occur as pore filling and grain lining. The sample is classified as ferruginous, quartz arenite sandstone (Fig. 9). El-Musawarat area samples are Fine to medium grained, sub angular – sub angular grains, moderately to well sorted grains. The sample Composes mainly of considerable quantities of monocrystalline, minor amount of polycrystalline quartz, few amount of K-feldspar, as well as minor amount of mica (mainly muscovite), some quantities of clay, rock fragments. Considerable quantities of iron oxides occur as pore filling and grain lining. The sample is classified as litharenite ferrigenous sandstone (Fig. 10).

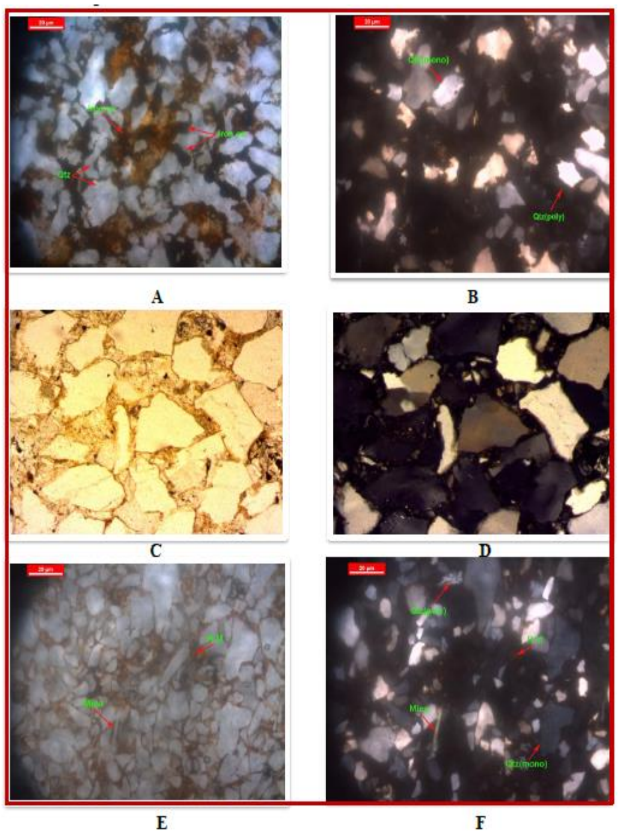


Figure 8. Samples petrography description (A, B sample 1 profile 1; C,D sample 3 profile 1; E,F sample 2 profile 2). A: showing Qtz and Iron oxide, B: showing mono and poly Qtz Grains, C: showing poly and mono Qtz grains , D: showing poly and mono Qtz grains , E: showing Mica and Haematite, F: showing Mica and mono and poly Qtz grains. The samples on the left hand studied under plane polarized light, while samples on the right hand were studied under cross polarized light.

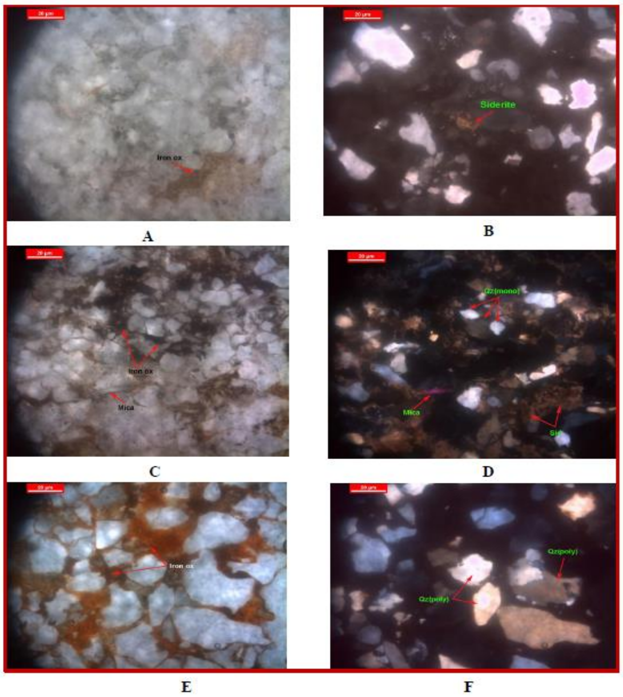


Figure 9. Samples petrography description: (A,B sample 1 profile 3; C,D sample 2 profile 3; E,F sample 4 profile 3) A: showing Iron oxide, B: showing Siderite ,C: showing Mica and Ironoxide , D: showing Mica, Siderite and monocrystaline Qtz , E: showing Iron oxide, F: showing polycrystalline Qtz. The samples on the left hand studied under plane polarized light, while samples on the right hand were studied under cross polarized light.

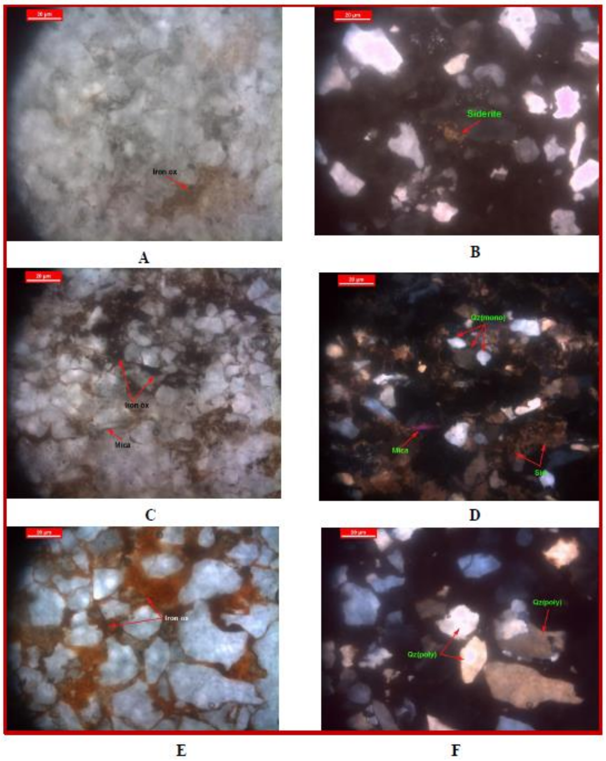


Figure 10. Samples petrography description:(A,B sample 5 profile 3; C,D sample 1 profile 4; E,F sample 3 profile 4) A showing Iron oxide , B showing polycrystaline Qtz, C: showing Iron oxide, D: showing Siderite and poly crystalibe Qtz , E: showing Mica and Iron Oxide, F: showing Mica and Siderite. The samples on the left hand studied under plane polarized light, while samples on the right hand were studied under cross polarized light.

VI. Conclusion

The identified lithofacies using scattered plots indicate that the upper Shendi Formation representative samples From Umm Ali, Bagraweya and Al Musawarat area are fluvitile sediments have been laid down under fluvial settings namely meandering river and multi breaded channels. 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 represented by Massive mudstone (Fm), Fine-laminated mudstone (Fl) and Rootbed mudstone (Fr). From the sandstone petrographic results, we found that; the coarse materials are more abundant in Al Musawarat area samples and less in Bagrawiya and Umm Ali areas samples, which are dominated by finer materials. Musawarat area samples are commonly sub angular to sub rounded and contain high matrix, but the Umm Ali area samples are sub-rounded to and contain few matrix and this support the interpretation of the grain size results that Al Musawarat area is the proximal areas (the material transported short distance), while Bagrawiya and Umm Ali areas. Based on combination plotting of the representative samples and description of the samples depend on statistic parameters; the paleodepositional environment represented fluvial sediments, deposited by multi braided river channels, gravel, sand and silt. This is supported by the fact that the sediments are varies in degree of sorting: very well sorted, moderately to well sorted, moderately to poorly sorted and very poorly sorted, poorly in organic matter dominated by medium to coarse grain fraction shows fining upward. However, the paleoenvironmental implication of grain size analysis supported interprets the result of lithofacies analysis. Thin section investigations of the outcrops samples that the sedimentary rocks in Shandi basins consist mainly of polycrystalline quartz occurs in higher percentages than monocrystalline quartz indicate a metamorphic source region, feldspar which found are usually altered, lithic fragments, detrital micas are present and also some fine-grained matrix. The cementing materials are quartz, carbonates, iron oxides and some matrix (kaolinite and chlorite), The most abundant kind of the sedimentary rocks is arenite which support the hypothesis that area is fulvitile.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

The authors were collaborating to produce this manuscript in terms of each background competency and experts. This study is a part of the research in order to further developing of the oil and gas field in AL Musauwarat- Umm Ali Area, Shendi Formation, River Nile State, Sudan. Hence, the application of Sedimentary

Facies analysis of the reservoir and to know of the reservoir potentials is very important as once of the Depositional Environments. The studied profiles exhibit eleven lithofacies identified at the outcrop section. Then, based on grain-size analysis, the upper cretaceous strata can be classified as fluvial-dominated units. Thin section investigations of the outcrops samples the sedimentary rocks in Shandi basin consist mainly of polycrystalline quartz occurs in higher percentages than monocrystalline quartz indicate a metamorphic source region.

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