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Research Article

SEDIMENTOLOGICAL ATTRIBUTES AND STRATIGRAPHIC OF NANKA FORMATION, ANAMBRA BASIN,NIGERIA

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ABSTRACT

Sedimentology and stratigraphic architecture of the outcropping Tertiary Facies of the Anambra basin were carried out. The lithostratigraphicunits in the study area isNsugbe Sands-(Oligocene). These outcrops were exposed along the Onitsha-Otocha-Omor-Nsukka road and the Onitsha-Enugu Expressway. The univariate, bivariate, multivariate, pebble morphometry and sedimentary structures indicate that the sandstones were deposited in a variety of depositional settings such as fluvial, lagoonal, tidal and shallow marine environments. Petrographic and palaeocurrent results show that the sediments are derived from two sources namely the basement area and from pre-existing sedimentary terrain which exist east and northeast of the study area. The stratigraphic architecture shows various facies associations such as the tidally influenced channels, braided fluvial channels, flood plains and fluvial channels. The sands are medium-coarse grained mainly moderately sorted, subrounded, negatively to positively skewed and leptokurtic in distribution. The sands are mainly quartz arenites with a good to excellent reservoir quality hence have the potential to accumulate hydrocarbons. Tide dominated depositional system is proposed in this study based on integrated ichnological and sedimentological data.

INTRODUCTION

Several workers have studied the Anambra Basin and Niger Delta in terms of sedimentology, stratigraphy and sequence stratigraphic concepts (Nwajide and Reijers 1996; Obi, 2000). This author studied the depositional model of the outcrops along IseleAzagba-Onitsha-Akwa areas of the northern Niger Delta and Anambra Basins. The analysis and interpretation of the data sets allow the reconstruction of sedimentary facies parameters, diagenetic histories, dominant controls on sequence development, and allow an added interpretation of the sediments of the northern Niger Delta and Anambra Basin reservoir qualities.

AIM/OBJECTIVES OF THE STUDY

The aim of this research was to carry out a detailed study of the sedimentological and stratigraphic architecture of outcropping Tertiary facies of the Anambra and northern Niger Delta Basins, with a view to delineate the depositional model and to evaluate the outcropping units hydrocarbon potential.

(i) Location of Study: The study area lies within latitudes 6^0 0' N and 6^0 30′ N and longitudes 5^0 30' E and 7^0 30' E. The area delineated for the present study stretches through Onitsha, Umunya, Akwa, Nanka, Ekwulobia all in Anambra State.

(ii) Previous WorkPREVIOUS WORK: Several workers have studied the Anambra and Niger Delta Basins. They include, Short and Stauble (1967); Adegoke (1969), Agagu*et al.,* (1980, 1986); Amajor (1986, 1987, 1991); Arua (1980, 1986); Avbovbo (1978); Benerjee (1981); Coleman and Ladipo (1988); Burke (1971); Ekewozor*et al.,* (1994); Hoque (1977); Ladipo (1988); Ladipo *et al.,* (1992); Knox *et al,* (1989); Koledeye*et al*., (2003); Nwajide (1980, 1996, 2004); Obi (2001, 2003); Reijers and Nwajide (1997).

Ladipo (1986) and Amajor (1991) reported on the sedimentary facies and depositional mode of the Cretaceous Ajali Sandstone of the Anambra Basin. Ladipo concluded that the sandstones were deposited in a tidal shelf environment based on process interpretation while Amajor concluded that they were deposited in a fluvio-marine setting.

The depositional model for the Campamain-Maastrichtian Anambra Basin were studied by Ladipo 1988, Mode (2000) and Obi (2000). In their various studies, they suggested various depositional setting such as fluvial channels, estuarine, proximal/distal lagoon, shoreface foreshore and tidally influenced channels.

Houck, K. J, (1997), studied the effects of sedimentation, tectonics and Glacio-eustasy on depositional sequences, Pennsylvanian Minturn Formation, North central Colorado. He utilized Lithofacies, sedimentary deposits, geometric surfaces and cycles. He concluded that each of the agents are responsible for the various facies architecture and distribution of petroleum reservoirs.

Nwajide and Reijers (1996), investigated the sequence architecture of the CampanianNkporo Group and the Eocene Nanka Formation and interpreted the development in the basins. They concluded that development of sequences in both locations was dependent on sediment supply, local tectonics and relative sea level changes.

METHODOLOGY

(1)FIELD WORK: The aspects of the sedimentary rocks usually recorded include bed thickness, texture, composition, diagenetic features, sedimentary structures.

In this study, the spot sampling method was employed whereby the outcrops were sampled as they were encountered, ensuring that all the lithologies were duly represented. One hundred samples were collected from the various locations studied.

(2) LABORATORY WORK:

(a) Sieve analysis is a widely accepted form of mechanical analysis to determine grain size parameters of sand size sediments. (Krumbein and Pettijohn, 1961; Folk, 1974; Buller and McManus, 1979) Sedimentary petrography involves the studies of depositional and diagenetic fabrics from thin sections of samples collected from an outcrop or exposure. The analysis results in mineralogical composition, grain shape, grain orientation, compaction, cementation, mineral replacement, matrix and porosity changes. In this study, seventy (70) thin sections of representative samples were studied

(b)Light Minerals: The modal compositions of the sediments are obtained by knowing the nature of the contained grains which is obtained by grain mineralogy and the proportions of these grains present in the sediment. Two main techniques are used in determining the proportion of different grains, viz: point counting and visual estimation.

Point counting is the most accurate method of determining the modal composition of a sediment. The method employed in this work is the spot identification of each gain, cement and clayey matrix to identify pore spaces. (Van der Plas and Tobi, 1965; Soloman and Green, 1966). 250 points were counted on each thin section to give a sufficient representation of the components present in a given thin section to show composition and textures.

Visual estimation involves the visual comparison of the thin section with visual comparators. The visual comparators include grains of different shapes and sizes (Terry and Chilingar, 1955) and computer - generated random percentages (Folk et al., 1970).

(c) Heavy Mineral Analysis: Heavy minerals are seldom seen in thin section and in order to investigate them, they must be concentrated and isolated. In this study, the separation employed the gravity separation method which allows the heavy minerals to be separated from the lighter fraction using tetrabromoethane $CHBr_3$ of specific gravity greater than 2.9. The samples already sieved at $\frac{1}{2}$ ϕ interval were used in the range of -1/16mm or 2 - 4ϕ. This is so because some heavy minerals occur as fine grains hence are more in fine grained sediments.

PRESENTATION OF RESULTS

(A) FACIES ARCHITECTURE OF THE NANKA FORMATION:

The Umunya type section is subdivided into sets of units based on stratigraphic succession, lithology, texture and sedimentary structures. It is divided into five litho units shown in fig 1.

(a) Tidal Bar Facies: This unit consists of about 29m of white-yellowish moderately sorted, friable, medium coarse grained sandstones. The sandstones are texturally immature but are compositionally mature with the framework grains consisting almost exclusive of quartz. The entire unit has sigmodal clay drape forests with a concave-upward geometry (Mutti et al, 1985) which are asymmetric. They are tangential to the horizontal giving rise to a tidal bundle sequences. The cross bed are of the trough type which dip to the northeast at approximately 50^0 and grade into lenticular beds at the upper part. Reactivation surfaces are numerous. In some other places, herringbone structures are found. Trace fossil burrow of *ophimorpha*&*Skolithos* are common. This unit is thought have been deposited in a high energy sub environment.

(b) Tidal Bar Facies: This subunit consists of fine, white, clean, well sorted sands with conspicuous planar bedsets at the upper part, while lenticular and flaser bedding dominate the lower part where the beds are sometimes wavy. Below sandstones are clayey sands with burrows of Ophiomorpha and Skolithos. The unit is 5m with burrows of Ophiomorpha and Skolithos. The unit is 5m thick with beds dipping at 28^0 and shows a moderate energy of deposition.

(c) Flood-Plain Facies: This is a grey-greenish siltstone - claystone shale intercalation. The unit is 3m thick, fissile and easily splits along planes. The greenish colour of the unit may be due to the mineral glauconite which indicates a shallow marine environment.

(d) Delta Front: This unit 8m thick and shows on alternation of sands and mudrocks i.e. it is heterolithic. The mudrocks are sandwiched between two sharp based ferruginized sandstone beds which are planar cross bedded and pebbly upwards. The cross beds dip southwest. There are also bands of ironstone which tend to influence the colour of the underlying sand. The sandstone have hematite cement showing mineralogical maturity while they are texturally immature. The depositional energy of this unit is believed to have been low and fluctuating. There are channels formed as a result of continuous flow.

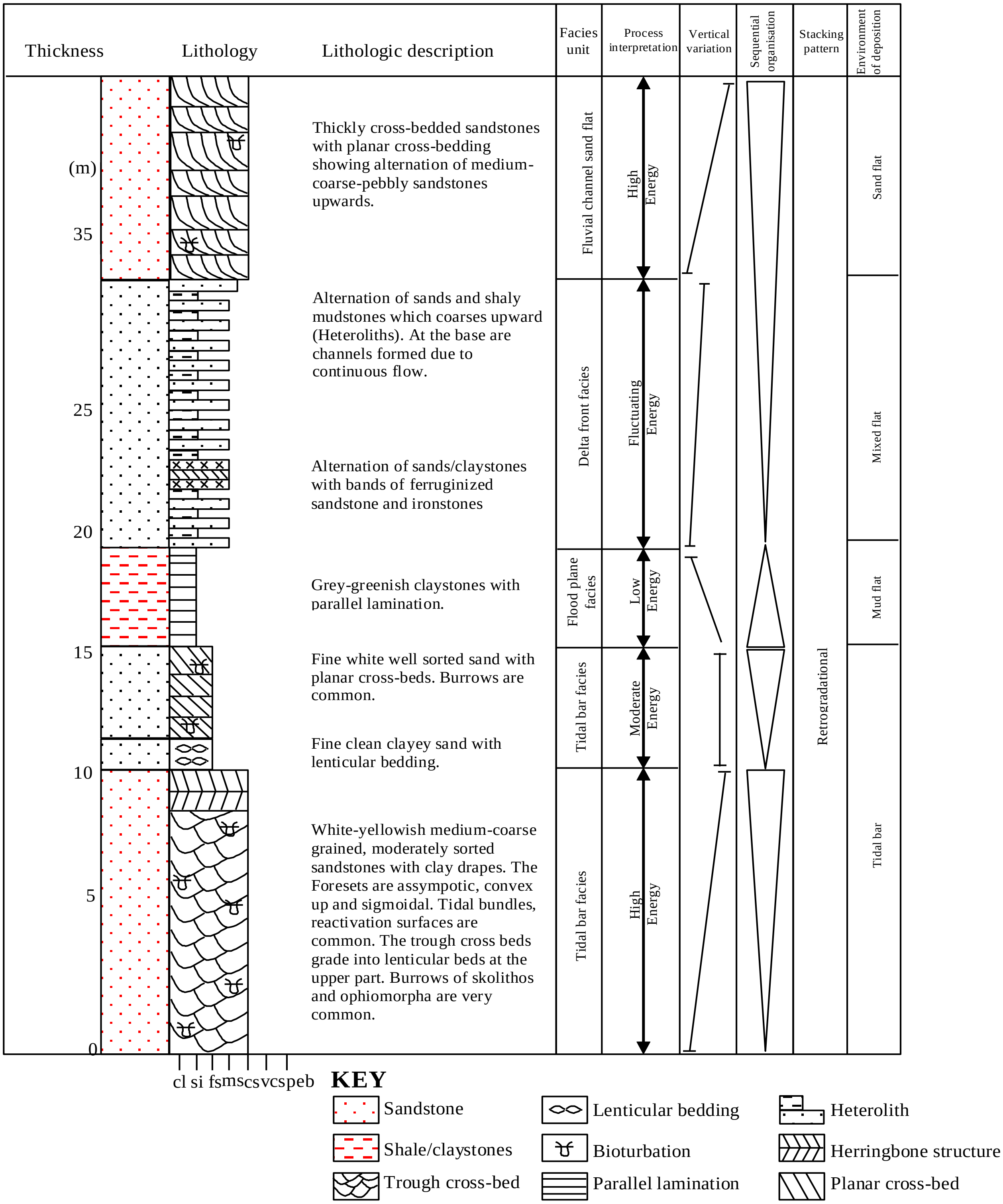

Figure 1: Facies Architecture of the Nanka Formation

(B) PETROGRAPHIC ANALYSIS:

Petrographic Analysis for Nanka Formation:

This is an analysis for both depositional and diagenetic fabric from thin sections and it includes mineralogic composition, grain textures, sediments provenance and determination of the sequence of diagenetic events. Eighteen thin sections were prepared for the loose and ferruginized sandstones of the Nanka Formation.

(i) Size: The mean grain size of the Nanka Sands as measured by the micrometer eye piece shows a range of 0.25 – 0.50mm (1 - 2ϕ range) with a total average of 0.39mm medium-coarse sand grains. These data indicate that the sand is predominantly medium – coarse grained, and occasionally pebbly. This result is complemented with the plan view chart of grain size comparator of Blatt (1982) where medium grained sands are in the range of 0.25 – 0.50mm (1 - 2ϕ). Figs 15 a & b show histograms of mean and sorting values of the samples.

(ii) Roundness: Grain roundness as defined by Waddell 1932 in Tucker (1988) is the average radius of curvature of all corners of a grain, divided by the radius of the largest inscribed circle hence is it a property of grain corners (angularity). The roundness of the grain is estimated by the use of charts for visual estimation of roundness and sphericity of sand grains, Lewis and McCoconchie, (1994). A total of 120 grains were counted using the counting method. Pettijohn (1957) redefined the class limits of Wadell's scale such that the mid points of the classes from an arithmetic progression. The roundness of the grains measured in this work based on Wadell and Pettijohn (1987) scale, ranges from 0.25 – 0.50mm (sub angular – subrounded) with the mean roundness of 0.38mm (subrounded class). This results shows that finer grains are less rounded than medium and coarse grains. According to Blatt *et al.,* (1972), the differences between the finer, medium and coarse grain sediments lie in their mode of transport. Traction and/or saltation are more effective for rounding of coarse or medium grained sediments, compared to the less effective action in suspension for finer grain sediments.

(iii) Sphericity: Sphericity defines the form of a sediment as a measure of approach of a particle to a sphere, Tucker, (1988). Measurement of the sphericity of the grains in this study was made possible by the use of a visual comparism chart, Power's (1982); Scale &Pettijohn*et al*., (1978). The grains are generally sub equant to equant (Zingg's 1938 classification in Tucker 1988) in the range of 0.54 – 0.69, Folk, (1974); Pettijohn*et al.,* (1987). On account of these moderate values, the sediments are believed to have undergone some sort of reworking from pre-existing sediments. These tend to lay credence to the multiple origins of quartz arenites of Suttner *et al.,* (1981).

(iv) Surface Features: In the thin sections of the ferruginized sandstones, some of the grains show sharp protrusions which are formed as a result of the corrosion of the grains by iron oxide cement or coating by clay. The other thin sections show that the surfaces of the grains are rather smooth, indicating no breakage. For the medium, to coarse grains, the absence of breakage, demonstrates the absence of exceptionally high velocity currents as these could have caused reasonable breakage during transportation..

DISCUSION OF RESULT

(a) Light Minerals: The Nanka sands consists essentially of quartz as the dominant light mineral and framework element while iron oxide is the main void filling cement in the ferruginized sandstones. Due to the type of extinction exhibited by the quartz grains, four varieties of quartz are recoganized. These are the monocrystalline quartz with undulose extinction, monocrystalline quartz with sharp extinction polycrystalline quartz with sharp extinction and polystalline with undulose extinction. Of the four varieties of quartz recognized, the monocrystalline variety with nonundulose extinction is dominant. Monundulose quartz according to Basu*et al.,* (1975), is one in which the extinction angle is less than $5^{0.}$ The polycrystalline variety constitutes about 9-11% of the framework quartz grains and are generally larger than the monocrystalline species. Polycstalline species show bimodal arrangement whereby small grains exist side by side the larger ones and also have preferred orientation of grain elongation. Some of the grains have sutured or crenulated contacts and some others have straight to slightly undulating crystal boundaries.. The dusty appearance is to the presence of very small particles referred to as microlites and are usually arranged in bands or line

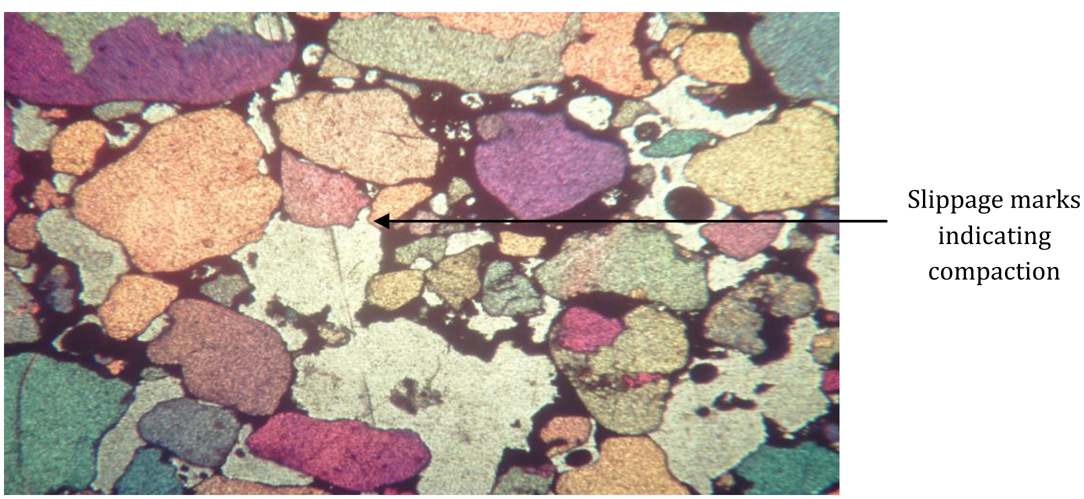

Plate 1 : Photomicrograph showing compaction of the sedimentFrom Nanka Formation

(b) Heavy Minerals: The heavy minerals found in the study area includes the opaques – limonite and ilmenite and the non-opaques – zircon, tourmaline, rutile, kyanite, staurolite and probably sillimanite. The opaque minerals are not useful for provenance studies. Zircon encountered in this study are rounded hence they may be from paragneises, paraschists and reworked sediments, Blatt *et al.,* (1972. In elucidating further the provenance of the sediments in the study area, the best indicator is the occurrence of the metamorphic mineral suite of kyanite – staurolite and probably sillimanite. This suite or assemblage is highly diagnostic of a metamorphic terrain, Folk, (1974); This observation gives credence to the multiple origin deduction given in the present work.

The distribution of the cross beds suggest that there are two sample population where one is represent a destructional and the other constructional phases, Klein (1970). These phases represent a complete tidal cycle, depending on which of ebb or flood tide is dominant at the time of time (See figure 2). Then it seems that flood tide was dominant at the Ebenebe and Nsugbe sandstones due to unimodal distribution and ebb tide is dominant at the Ogwashi-Asaba Formation and the Nanka sandstones

Nanka Formation:

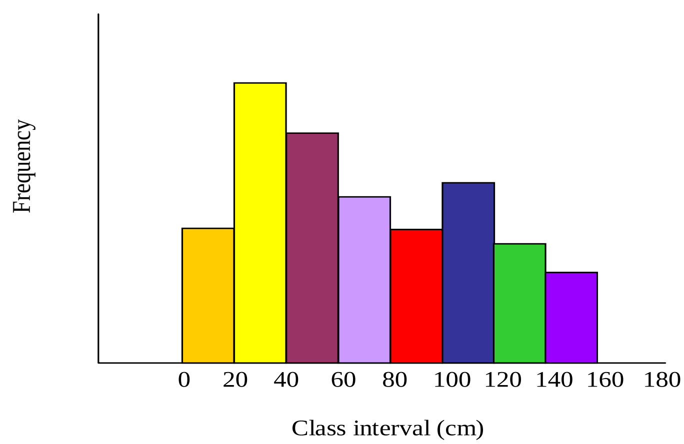

Figure 2: Histograms of crossbeds for four outcropping units

(c) Depositional Model for the Nanka Formation: The paleoenvironmental reconstruction of the Nanka Sand is based on its physical, biological and chemical characteristics which give rise to the sedimentary facies. A sedimentary facies is a mass of sedimentary rock which can be distinguished from others by its geometry, lithology, sedimentary structures, paleocurrent pattern and presence or absence of body fossils or trace fossils. A sedimentary facies is therefore a product of a depositional environment.

The geometry of the Nanka Sand belongs to the sheet sand bodies type with great horizontal extent in relation to its thickness (See figure 3). This is possible because of lateral sedimentation of the formation which means that their boundaries transect laterally at a low angle and time plane. Sheet sands are typical of quartz arenites as in the Nanka Sand which occurs as a series of coalesced bodies of linear deposits.

The statistical parameters of size such as mean (1.48ϕ) indicates a moderate to high energy depositional medium, while combination plots of skewness and kurtosis indicate a fluctuating environment. The Nanka Sand is compositionally matured with very close heavy mineral suite which have been interpreted as abrasion due to prolonged tidal circulation.

The stratisgraphic analysis of the type section shows a pattern of repetition of the various lithofacies which are representative of a tidal environment in terms of regressive – transgressive, fluctuating conditions in which a coarsening upward sequence is followed by a fining – upward sequence. However theNanka Sand tends to deviate from this sequence due to greater wave action along the exposed coast hence they are coarser grained than tidal flat sediments in protected areas. A combination of sedimentary structures are strong indicators of a particular sedimentary regime or environment. In the study area, sharp and lower cross stratification boundaries, flaser and lenticular beddings, herringbone structures, tidal bundles, clay drapes, and reactivation surfaces are common, which all indicate a tidal environment.

The pattern of paleocurrent dip – azimuths of the study section shows a bimodal – bipolar orientation, which is common in environments characterized by flow reversals – ebb and flood currents. This type of reversals is characteristic of a tidal environment.

Based on the composition (textural and mineralogical), sedimentary structures, paleocurrent orientation, trace fossils and the internal arrangement of the various lithologic units observed in the study area, a tide dominated shallow marine depositional environment is proposed for the Nanka Sand. The depositional environment consists of several sub-environments based on process interpretation as mud flats mixed flats, and sand flats. All these belong to a tidal flat and an offshore bar or subtidal bar or a tidal marine environment

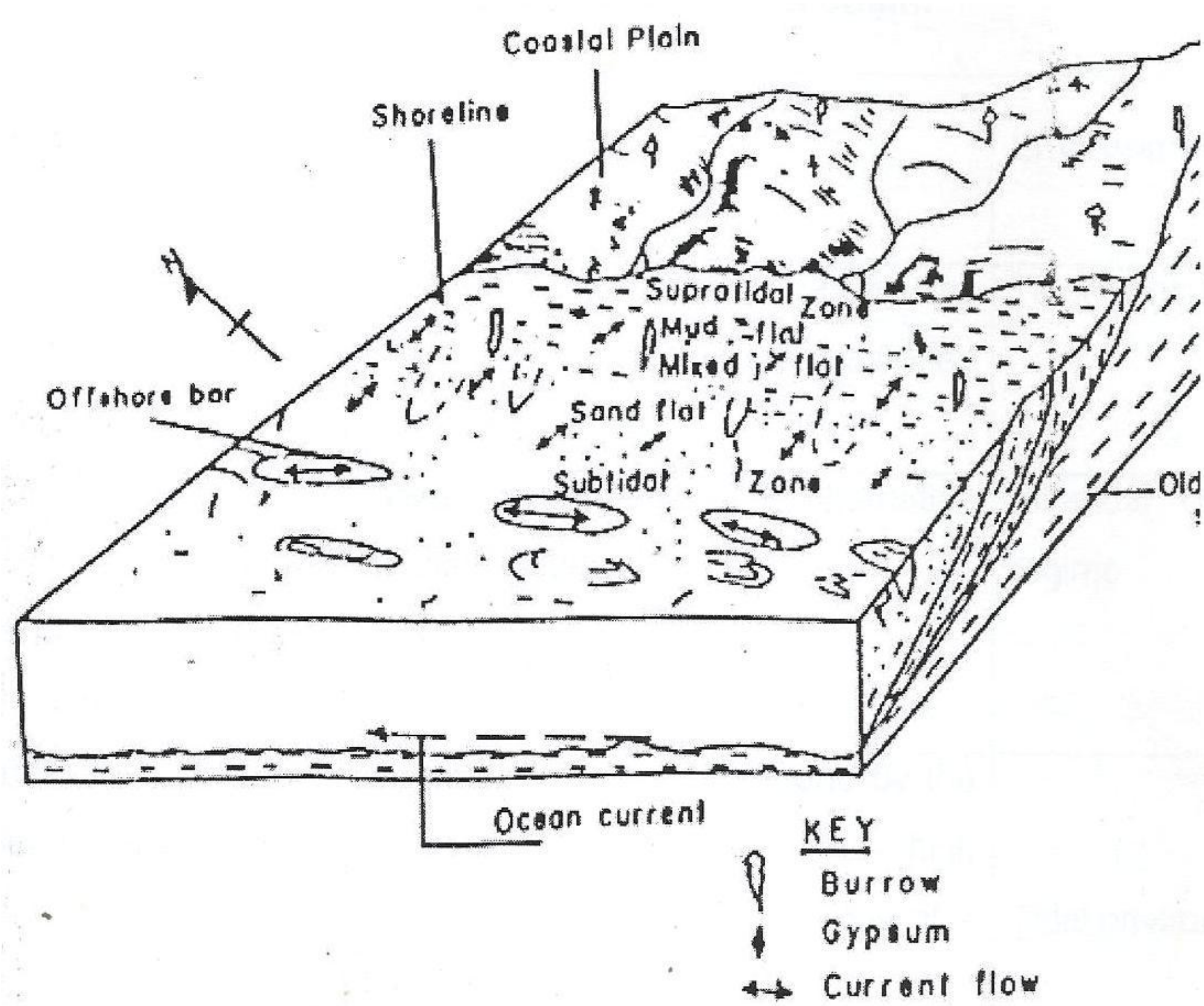

Figure 3: Depositional Model for the Nanka sandstone(modified from Nwajide, 1980)

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