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Depositional Environment of Nari Formation from Lal Bagh Section of Sehwan Area, Sindh Pakistan.

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Abstract: The main purpose of this study is to investigate the depositional setting of the Nari Formation (Oligocene) Kirthar Province, along with NS trending Laki Range, Southern Indus Basin, Pakistan where tertiary rocks are well exposed. Grain size analysis of twelve representative samples of sandstone of Nari Formation(Oligocene) has been carried out. These results specify very fine to fine grain sedimentsand unimodal nature of grain size distribution. The results are also indicated that sediments are fine skewed and generally nearly symmetrical in nature and leptokurtic, mesokurtic and platykurtic in nature. Linear discriminant function mostly confirms low energy (shallow marine) settings. The most of the interpretation diagramindicates that the samples are clustered, that may beowing to the combination of two modes either in identicalamount in bimodal or good sorting in unimodal sediments. Coarse one percentile to Median interpretation diagram for Oligocene Nari Formation sandstone implies that sediments were deposited in beach depositional settings as bed load and suspended load mode of transportation.

Keywords: Nari Formation, Sieve analysis, Depositional setting, linear discriminate function (LDF)

1. INTRODUCTION

Source rock, disintegration and erosion, transportation and digenesis are important parameters that give important information about Sedimentary rocks. Grain size characteristics are the fundamental and significant descriptive property in silici-clastic (Sedimentary rocks) sediments. Depositional process, hydrodynamic condition and depositional environment an be understand through the grain-size properties and these are extensively used by various geoscientists (Boggs, 2009). According to (Selley, 1969) Sedimentary environment is a part of earth surface which physically chemically and biologically is distinct from the adjacent area, which can be identify through grain size analysis technique which differentiate sedimentary depositional setting of sedimentary rocks (Edwards, 2001).The valuable evidence to the sediment source, mechanism of transportation and the depositional setting is also revealed by grain size parameters (Blott and Pye, 2001).It is valuable communicative characteristic feature of sedimentary rock (Baiyegunhi *et al.*, 2017; Hakro, and Baig, 2014; Hakro, and Baig, 2013; Khokhar *et al.*, 2016; Khokhar *et al*, 2014)

An attempt has been made in the present work for the detailed fieldwork and sieves analysis data to provide new controls for depositional setting of Nari Formation (Oligocene) in Kirthar Provence, northern Laki range, Southern Indus Basin, Pakistan (**Fig 1a,b,c**). The grain size parameters i.e mean, sorting, skewness, and kurtosis calculated from sieved data. The Several bivariate interpretation diagrams developed to understand the pattern sedimentation processes and depositional setting.

2. GEOLOGY OF AREA

The study is present in the southwest direction of Sehwan city of Jamshoro district, Sindh Province of Pakistan **(Fig.1b)** and it is 225 km Northeast of Karachi. Geologically it is part of the Laki Range of Southern Indus Basin (Kazmi & Jan, 1997; Bender and Raza, 1995; Kadri, 1995; Shah, 2009).The studied section of Nari Formation is bounded by Hyderabad anticlinorium in southwest direction (HSC, 1961), Karachi embayment in southeast direction, Kirther foldbelt in the western direction and Indus river in the east direction (See Figure 1a,b). The structure of southern Indus Basin of Pakistan is composed of Sukkur Rift zone which contains Kandhkot-Mari Horst, Pano-Aqil Graben, Jacobabad-Khairpur Horst, Sindh Monocline, Karachi Depression/embayment and Mazarani Folded zone (Farshori, 1972).

Nari Formation of the Momani group is recognized in the Kirthar Province, parts of Sulaiman Province and the Axial Belt(Shah, 2009).It has a thickness of 660m at its type section; i.e., the Gaj River in Kirthar Range, Dadu, Sindh (latitude 26º 56'12" N, longitude 67º 10'10" E). Whereas the type section of Nari Formation is proposed by (Williams, 1959).Fine to coarse grained gritty Sandstone is dominant lithology of Nari Formation (Oligocene) with shale as subordinate lithology (Shah, 2009).

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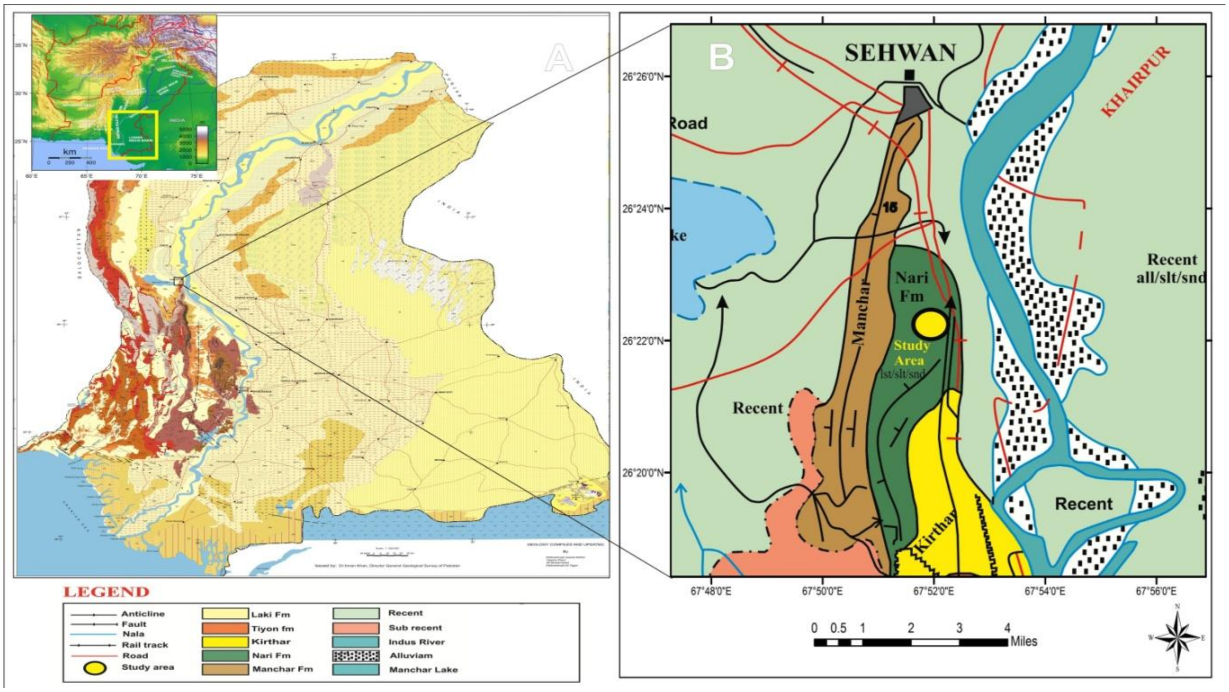

Fig. 1A Show the Geological map Sindh 1B)

Shows the location and Geology of the study area lower part of the Southwest of Lal Bagh section is predominantly composed of crystalline and granular limestone which is Yellowish Grey, Pale Yellowish Orange.Sandstone of Nari Formation vary in Orange color family Yellowish Orange,Pale Yellowish Orange, Dusky Yellowish Brown, Pale Yellowish Orange, Greyish Orange, Moderate Reddish Orange) Cross bedding is reported from three to four beds, Gypsiferrous laminations from three beds are reported, interbeds of laterite bed were also reported. Shale of Nari Formation vary in color as Moderate Orange, Moderate Reddish Orange, Moderate Yellow, Dark Yellowish Orange, Very Dark Red, Light Brown).A few laminations of Gypsum were also noticed during the fieldwork of study area.

The central part of this section is composed of sandstone and variegated shale (figure 4c and 4e). The upper part of the formation is predominantly composed of sandstone which is yellow-grey, grey-brown, pinkish, reddish and white-colored, interblended with fine to very fine grain often gritty and calcareous subordinate shale and conglomerate. Beds of conglomerate are present at the basal and upper part while the ironstone is exposed in the form of thin bed in the central and upperparts, The lithology column section of study area is shown in Figure 2. The main objective of this study is to know the depositional environment of Nari Formation from Lal Bagh section by using grain size technique.

3. MATERIALS AND METHODS

The stratigraphic section is measured at southwest of Lal Bagh with a true thickness method. The coordinates of section are(Latitude 26° 22' 09.3" N and Longitude 67° 52' 20.0" E). Twenty four (24) representative samples are collected from identified lithofacies of Nari Formation (Oligocene) from study area. Twelve (12) loose and friable sandstone samples were selected out of twenty-four (24) for particle analysis. A standard sieving method (Folk and Ward, 1957) has been introduced for the classification of different groups of grain sizes. The individual unconsolidated sandstone samples were disaggregated. One hundred gram (100gm) of each sample was used for the sieve analysis. Samples were crumbled with hands steadily and cautiously. moreover, the samples were blended for the mixing of all sediments (Samtio *et. al.,* 2020). The standard sieves (-2, -1 phi, 0 phi, 1 phi, 2 phi, 3 phi, and 4 phi) were used for sieving of samples (Samtio *et. al.,* 2020).

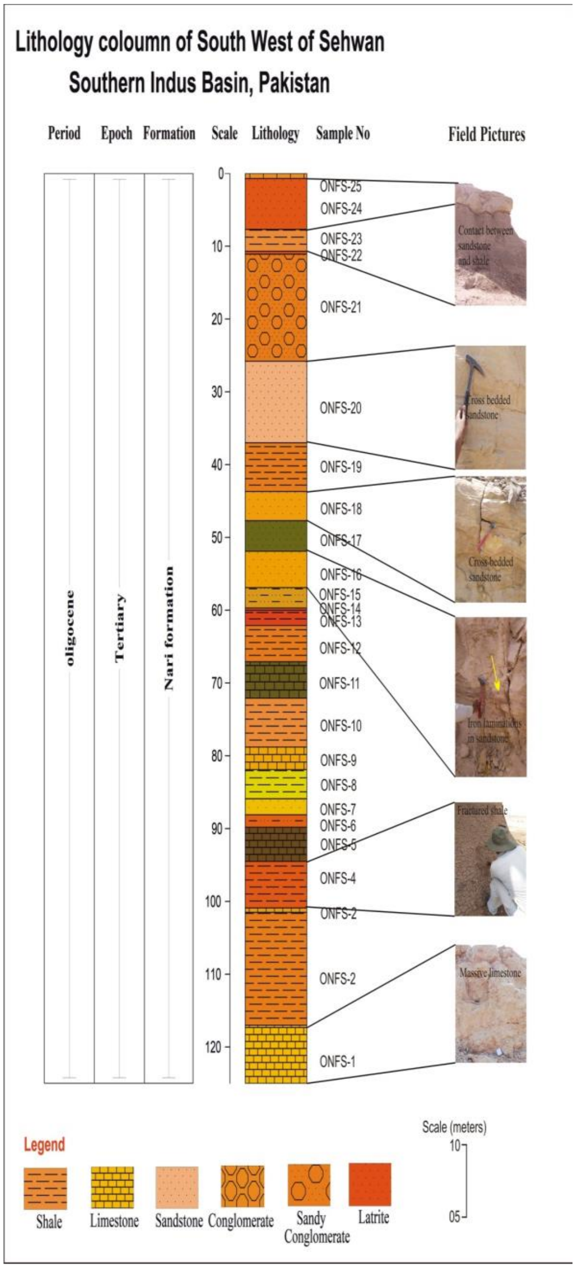

Fig. 2 shows the stratigraphic section that represents the Lithological column of the study area.

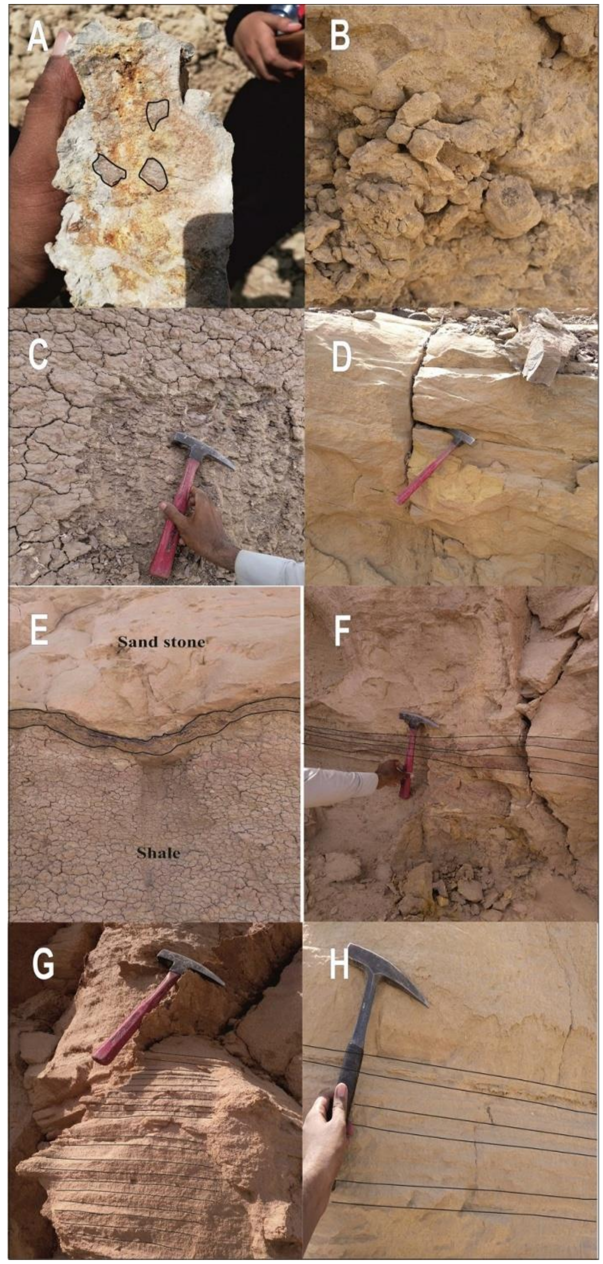

Fig. 3 shows the lithology and sedimentary structures of study area.

The whole stack of sieves was shaken by an electrically powered strainer for at least fifteen to twenty minutes to separate each class properly. Cumulative weight percent was computed from the weight of grains retained by each sieve. Particle size analysis was carry out with electric digital octagon machine at Center for Pure and Applied Geology, University of Sindh, Jamshoro, grain size classes frequency curves of particle size variation were computed (Udden, 1914; Wentworth, 1929) millimeter scale of particle sizes were transformed to phi or Krumbein scale specified by (Krumbein, 1934). It is logarithmic scale to base 2. (Phi= -log2D) here phi is scale and D represents diameter of particle in millimeter scale. Cumulative frequency curves **(Fig. 4b)** were reproduced based on weight percentage information, which functions as an essential method in the computation of statistical parameters. These cumulative curves were used to calculate different grain variables as suggested by (Sahu, 1983)

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Table 1 Stratigraphy of study area after(Shah, 2009)

Age	Formation	Lithology
Pleistocene	Dada Conglomerate	Conglomerate, Boulders and Pebbles
Miocene to Pliocene	Nari Formation	Conglomerate, Sandstone and Shale
Unconformity		
Oligocene	Nari Formation	Sandstone, Limestone and Shale
	Kirthar Formation	Limestone
Eocene	Tiyon formation	Shale, Limestone, Marl
	Laki Formation	Limestone, Sandstone and Shale

Table 2 Standard Statistical formulae given after(Folk, 1968)

STATISTICAL PARAMETER	FORMULA
Graphic Mean	MZ= (16φ+ 50φ+ 84φ)/3
Median	(MD = 50φ
Standard Deviation	SD = (84φ-16φ)/4+ (95φ-5φ)/6.6
Graphic Skewness	SKI= 84φ+ 16φ -2(50φ)/2(84φ-16φ) + 95φ + 5φ -2 (50φ)/ 2(95φ-5φ)
Graphic Kurtosis	KG = (95φ - 5φ) (75φ - 25φ)/2.44

4. RESULTS AND DISCUSSION

Grain Size Parameters

Frequency curves are indicated that most of the sandstone samples from Nari Formation are unimodal in nature. The unimodality nature of studied sediments indicates the uniform depositional setting when they were deposited. The Narisediments are indicated the excess of finer sediments and it is reflected in +ve SKI. Most of the cumulative curves point toa inconsistent trend that, reveals moderately to moderate well sorting. The outcome of the data plotting is the typical S-shaped curves. The inclination cumulative frequency curve at middle portion indicates sorting of sediments the steepness recommends to well-sorting whereas, gentleness reflects poor sorting in sediments **(Fig 3**a**)**. Statistical parameters are described in **(Table 03).** The percentile values of the unconsolidated sediments of the Nari Formation (Oligocene) from south of Lal Bagh section were read from the cumulative curves **(Fig 3b)**. (Folk and Ward, 1957) suggested equations as **(Table 02)** (Graphic mean, Sorting, Skewness, and Kurtosis) were calculated and mentioned in **(Table 03).** The values of the percentile read are 5% (1.02-2.03phi), 16% (1.30-2.28phi), 25% (1.52-2.8phi), 50% (3.16-3.10phi), 75% (2.82-3.59phi), 84% (3.18-3.79phi), and 95% (3.78-4.48phi).

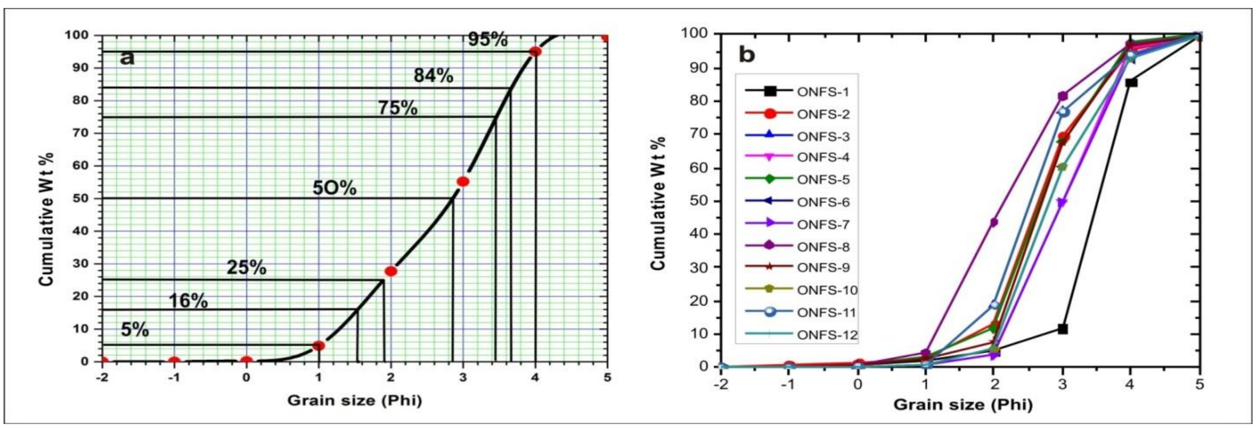

Fig. 3a shows the procedure of measuring selected percentile values, 3b) shows cumulative frequency curves of selected samples.

Table 3 shows the calculated statistical parameters, Mz=Median, M_D=Median, SD=Standard Deviation, SK=Skewness, KG=Kurtosis, C=Coarse one Percentile, M=Median

Sample No	Mz	M_D	SD	SK	KG	C	M
ONFS-01	3.02	3.01	0.706	0.058	0.801	510	1505
ONFS-02	2.756	2.64	0.83	0.107	1.108	900	1320
ONFS-03	2.593	2.54	0.867	0.112	1.439	505	1270
ONFS-04	3.01	3	0.664	0.01	0.73	540	1500
ONFS-05	2.783	2.7	0.774	0.034	1.137	200	1350
ONFS-06	2.92	2.81	0.778	0.254	0.961	530	1405
ONFS-07	3.053	3.1	0.713	-0.037	0.791	550	1550
ONFS-08	2.213	2.16	0.896	0.137	0.886	1000	1080
ONFS-09	2.86	2.72	0.826	0.214	1.169	300	1360
ONFS-10	2.50	2.19	0.721	0.172	1.11	450	1095
ONFS-11	2.781	2.41	0.795	0.11	1.05	515	1205
ONFS-12	2.63	2.39	0.779	0.15	0.99	525	1195

Graphic Mean Size (Mz) value offers primarily an indication of the relative size of clastic grains. The analyzed samples ' low and high amount was measured and listed **(Table 03)** and varies between 3.01-2.21phi.Themean grain size is (2.76phi) of Nari Formation sediments reveals that excess fine sand sediments. The predominance of fine-grain sediments is evidenced bythe low energy condition of deposition (Baiyegunhi et al., 2017; Boggs Jr & Boggs, 2009).

Sorting or Standard Deviation (σ1) Sorting or coherence is determined by the inclusive standard deviation which help to understand the hydrodynamic sedimentary basin mechanism. The sorting results of the Nari Formation sandstones vary from 0.66-0.90phi which suggests that the sediments are moderate to moderately well-sorted.

Skewness analyses proportion of particle size variation. The –ve skewness is reflection of coarse grain dominancy in the tail.whereas, +ve skewness in the frequency curve tail suggests excess of fine grain content. The skewness of the investigated samples varies between -0.04-0.25phiwhich reveals nearly symmetrical to fine skewed nature of the Nari Formation sandstone. Out of twelve, eight sandstone are finely skewed. Four samples exhibit a nearly symmetrical distribution of grains. The Fine skewness Nari Formation sandstone samples specify the low level of energy settings.

Graphic Kurtosis (KG) calculates the proportion of sorting in the scattering extremes relative to sorting in the middle of frequency curves and represents peakedness. Kurtosis of Nari Formation sediments varies between 0.73-1.44phi (Table 03). Most of the represented sandstone shows platykurtic, mesokurtic, and leptokurtic nature **(Fig 4c, d.)** The change in kurtosis can be attributed to periodic variability in the depositional medium's current characteristic.

BIVARIATE PLOTS OF STATISTICAL PARAMETERS

The cross plot of among various grain size variables of classic rocks supports in understanding the environment of deposition setting, and energy level of transporting agent (Folk and Ward 1957; Passega, 1964; Friedman, 1967; Sahu, 1964; Stewart Jr, 1958).To discriminate between fluvial, coastal and aeolian depositional setting interpretation diagrams are widely used by cross plotting of various grain-size statistical parameters. In view of the importance of these interpretation diagrams in sediment logical research, interconnection between these diagrams has been used in the current study. Various bivariate scatter diagrams are developed by cross plotting of grain-size parameters as proposed by (Folk and Ward, 1957).

Linear discriminate function (LDF)

The Statistical treatment is applied to understand the variation in energy conditions and fluidity factors through or precedent to sediment deposition appears to have good relationship to a variety of depositional settings (Sahu 1964).

The equation Y2 is used to discriminate between sediments of shallow marine and beach depositional environments. The equation Y3 is used to discriminate between sediments of shallow marine and deltaic or lacustrine. The equation Y4 is used to distinguish between deposits of deltaic and turbidity current.

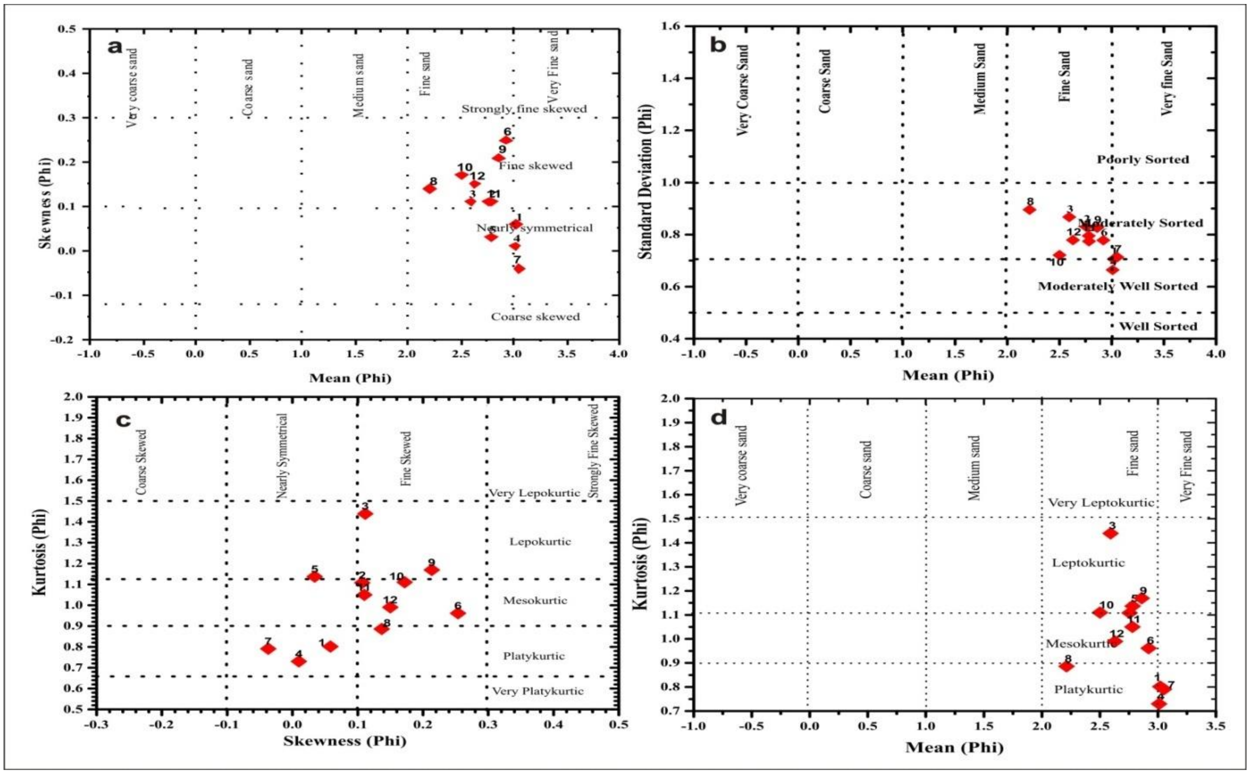

Fig. 4a shows mean versus skewness plot, b)show mean versus standard deviation plot, c) show kurtosis versus skewness plot, d) show mean versus kurtosis plot, by Folk, and Ward (1957).

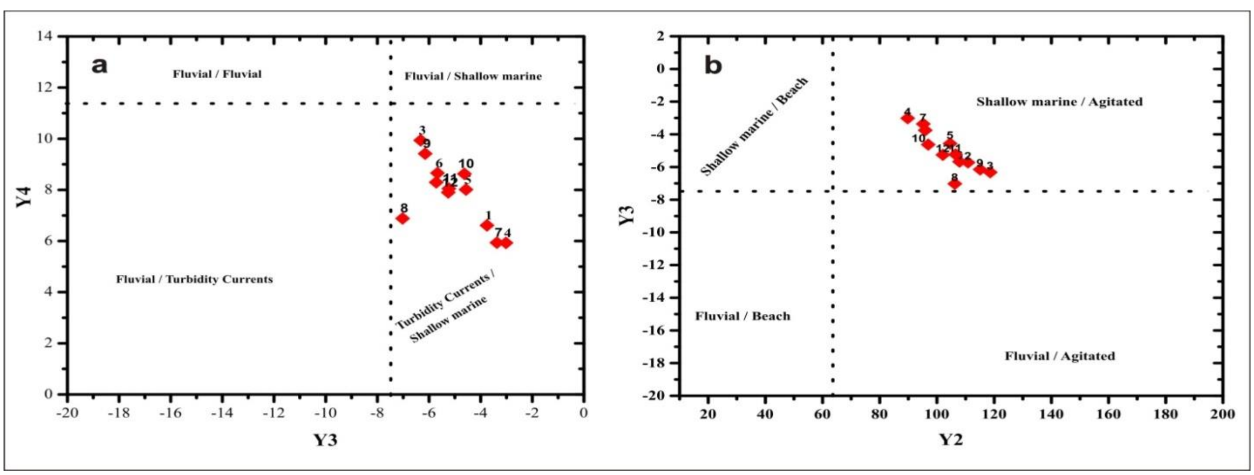

Fig. 5a Discrimination of environments based on Linear Discrimination functions (LDF) plot of Y3 against Y4(Basanta K Sahu, 1964), **5b)** Discrimination of environments based on Linear Discrimination functions (LDF) plot of Y2 against Y3 (Basanta K Sahu, 1964), here **Y2** = 15.6534M + 65.7091r^2 + 18.1071SK+18. 5043KG, **Y3** = 0.2852M − 8.7604r^2 − 4.8932SK + 0.0482KG and **Y4** = 0.7215M − 0.4030r^2 + 6.7322SK + 5.2927KG, here **M**, **R**, **SK**, and **KG** represent mean, standard deviation, kurtosis, and skewness respectively. If **Y2** is less than −63.3650, the environment is "beach" and if it is greater than −63.3650, the environment is "shallow marine". If **Y3** is greater than −7.4190, the environment is "shallow marine" and if Y3 is less than −7.4190, the environment is "deltaic or lacustrine". If **Y4** is less than 9.8433, it indicates turbidity current deposition and if Y4 is greater than 9.8433, it indicates deltaic deposition.

Sahu (1964) produced a binary plot of Y3 against Y2 to discriminate between shallow marine, beach, fluvial depositional settings. When the data of the present study area is plotted in diagram shown in figure 5b which specifies that Nari Formation samples cluster in the field of shallow marine or agitated water, in general this diagram specifies the shallow marine depositional setting. Another diagram of Sahu (1964) produced a binary plot of Y4 against Y3 to discriminate between fluvial, fluvial or shallow marine, fluvial or turbidity currents and turbidity currents or shallow marine depositional settings. When the data of the present study area is plotted in diagram shown in figure 5a which specifies that Nari Formation samples cluster within field of shallow marine, in general this diagram specifies the deltaic to shallow marine depositional setting.

Table 4 Calculated statistical parameters of Linear Discriminate function after (Sohu, 1964).

Sample Name	(Y1)	(Y2)	(Y3)	(Y4)
ONFS-01	-6.56	95.91	-3.75	6.61
ONFS-02	-4.06	110.85	-5.72	8.30
ONFS-03	-2.22	118.63	-6.32	9.94
ONFS-04	-6.86	89.78	-3.02	5.93
ONFS-05	-4.24	104.58	-4.57	8.01
ONFS-06	-5.71	107.90	-5.67	8.66
ONFS-07	-6.47	95.19	-3.37	5.94
ONFS-08	-2.46	106.23	-7.02	6.88
ONFS-09	-4.49	115.09	-6.15	9.41
ONFS-10	-3.90	96.95	-4.63	8.63
ONFS-11	-4.54	106.48	-5.23	8.05
ONFS-12	-4.37	102.08	-5.25	7.90

Passega Diagram (CM Pattern)

To interpret the mechanism of sedimentation processes active in the course of deposition of sediment an important interpretation diagram (C-M plot) was proposed by (Passega, (1964).The bivariate diagram represents the correlation between C-M here (C) and (M) is median in micron (Table 03). To interpret type of sediment and level of energy of transporting media the C and M diagram serves the function efficiently (Passega, (1964). In the current research work from C and M results in micron **(Table 3)** Passega bivariate plot was developed. The result indicates that most of the samples of Oligocene Nari Formation sandstone clustered in 1 and 2 fields between N-P regions Figure 6a which illustrate that the mode of transportation of sediments were rolling and suspension. C-M diagram reveals that sediments of Nari Formation were dump in beach depositional setting.

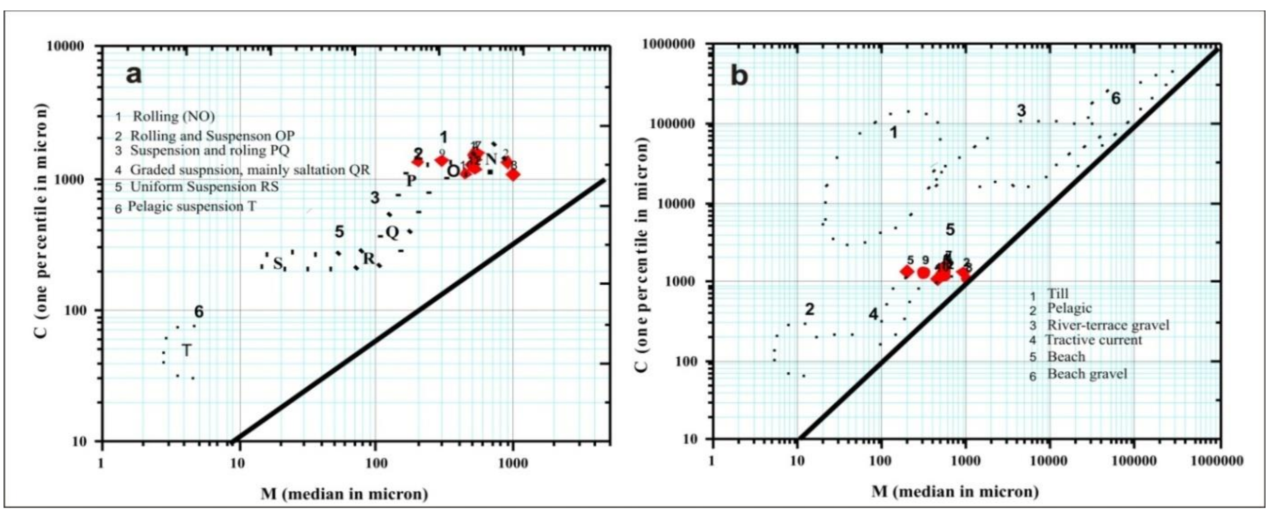

Fig. 6a C-M plot showing the transporting mechanism of the Nari Formation sandstones. Rolling (NO); Rolling & suspension (OP); Suspension & rolling (PQ); Graded suspension, mainly saltation (QR); Uniform suspension (RS); Pelagic suspension (T).Figure 6b.C-M plot showing the depositional environment of the Nari Formation sandstone.

5. CONCLUSION

Nari Formation sandstones indicate the majority of fine-grained with sub-ordinate very fine particles, moderately to moderately well sorted and fine skewed to nearly symmetrical implies the supremacy of fine deposits. Platykurtic, mesokurtic, and leptokurtic nature reveals transitional maturity of sediments. The Linear discriminant function mostly confirms low energy (shallow marine) settings. C-M interpretation diagram for Oligocene Nari Formation sandstone implies that sediments were deposited in beach depositional settings as bed load and suspended load mode of transportation.

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