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Textural Maturity and Depositional Environment of Bara Formation at Ranikot, Sindh.

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Abstract: Bara Formation (Middle Paleocene) at Ranikot area is investigated for the purpose to interpret its environments of deposition, grain texture and textural maturity. Out of sieving data statistical parameters are calculated which are used to determine textural maturity and are plotted on interpretation diagrams. With multiple approaches such as the study of grains texture, plotting the statistical data on the diagrams of Passega (1964) and Stewart (1958) and by evaluating the textural maturity, it is interpreted that the Bara Formation sediments at Ranikot area were deposited under fluviatile/continental environments. The sandstone of Bara Formation at Ranikot has been classified as sub-mature and sub-mature to mature sandstones, respectively.

Keywords: Sieving, Statistical parameters, Textural maturity, Interpretation diagrams, Depositional Environment

1. INTRODUCTION

This paper deals with the evaluation of results obtained by statistical treatment of grain size data of loose sands collected from Bara Formation at Ranikot area for the interpretation of the environments of deposition and the textural maturity of sandstones. The studied area is located about 33 KM to the west of Sann Railway Station, District Jamshoro **(Fig. 1).** Previously the Bara Formation has been investigated by many workers, including Gingerich *et. al.,* (1979), Wnuk, *et. al.,* (1993), Abbas, *et. al.*, (2005), Siddique (2008), Shah (2009), Hakro (2012 & 2013) for its stratigraphy, coal resources, paleontological, sedimentological, geochemical and mineralogical aspects.

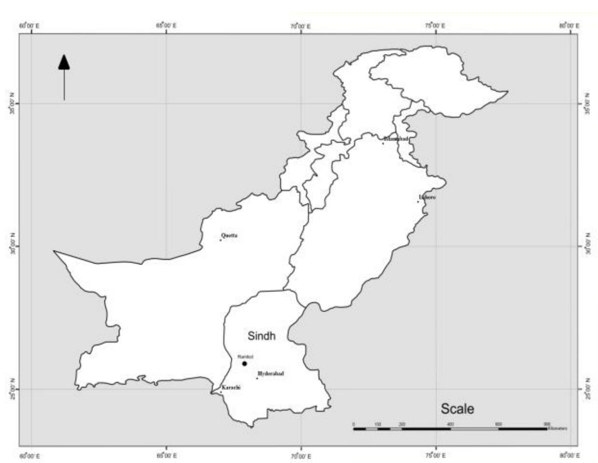

Fig. 1: Map showing the location of study area

The present study is using the sieving data of 22 samples collected from loose sands of Bara Formation at Ranikot area Tables -1. After statistical treatment data is plotted on the interpretation diagrams in order to infer the depositional environment and textural maturity. These diagrams reflect the energy gradients responsible for transportation and deposition of sand bodies and are, therefore, important in reconstructing the geological environment (Friedman, 1962).The exposed section of the Bara Formation on the eastern flank of Ranikot anticline is 250 meter thick; it is located in Ranikot Dhoro, and is composed of sandstone, shale and minor siltstone. The sandstones are about two third of the formation and display variegated colors. It is fine to coarse grained, soft, crumbly, and poorly sorted. Massive beds are calcareous, ferruginous, having ripples marks and cross-beddings (Hakro, 2013). Quadri and Shuaib (1986) described that the outcrops of Bara Formation are rare and it is present in subsurface throughout sindh province. Main outcrops of the Bara Formation are in Lakhi Range (HSC, 1961). The Khadro Formation, Bara Formation, Laki Formation and Manchhar Formation are the main stratigraphic units of the Ranikot (Hakro, 2013). Cheema, et al (1977) and Wnuk, *et al .,* (1993) marked the contact between Bara & Khadro rock units on the top of the basalt unit in Ranikot area. The lower contact of the Bara Formation is conformable with Khadro Formation (Hakro, 2013). The range of thickness of studied Formation is 1000 m in Karachi trough (Quadri and Shuaib, 1986) and less than 60 m in Sulaiman range, Baluchistan (Williams, 1959). Bara Formation is 600 m thick (Cheema, *et al*, 1977) and 486 m (Wnuk, *et al*, 1993) in the Ranikot. Coal bearing Formation (Bara) is composed of sandstone, shale, siltstone, petrified wood, plant traces,

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and volcanic debris (Shah, 2009). Sandstone is in gray, purple, white, red and maroon colors, poorly sorted, noncalcareous, and fine – coarse grained; forty percent (40%) of Bara comprises beds of siltstone and claystone (Wnuk, *et al*, 1993).

2. MATERIALS AND METHODS

Fieldwork was carried out to collect rock samples of the studied formation. Ranikot anticline is an asymmetrical anticline with steep eastern flank and gentle western flank **(Fig. 2).** The eastern flank of Ranikot anticline **(Fig. 3A & 3B)** was measured by Jacob staff's method with total thickness of 250 meters. Fifty one samples were collected from the outcrop of the Bara Formation. In the studied area, Bara Formation has lower conformable contact with Khadro Formation (Fig. 3C), while it's upper contact with Laki Formation is unconformable **(Fig. 3D).**

Twenty two samples of loose sand were selected for sieving by utilizing the method proposed by Folk (1968). One hundred grams from each sample was taken; it was carefully disintegrated, mixed thoroughly and sieved with stack of sieves of -2φ, -1 φ, 0 φ, 1 φ, 2 φ, 3 φ, 4 φ mesh sizes and pan **(Table - 1).** The sieving data was used for making of histograms and cumulative curves, out of which various statistical parameters i.e. mean, median, sorting, skewness and kurtosis were calculated **(Table 2 & 3)** for plotting on various interpretation diagrams.

Leica MS5 zoom stereo microscope was used for binocular study of samples to analyze the shape, sphericity and roundness of the loose sandstone grains of Bara formation **(Table -4).**

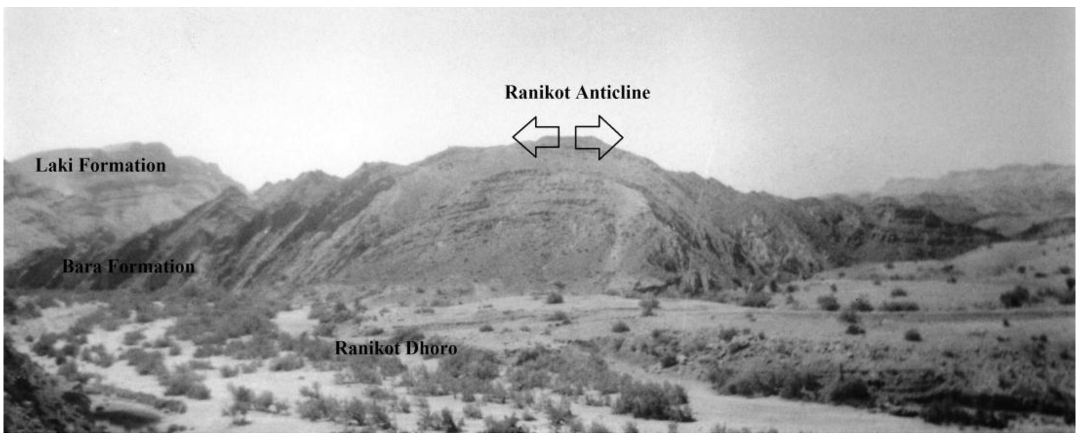


Fig. 2: Ranikot Anticline (Asymmetrical fold), at Ranikot Dhoro, Fort Ranikot Area, Looking toward South.

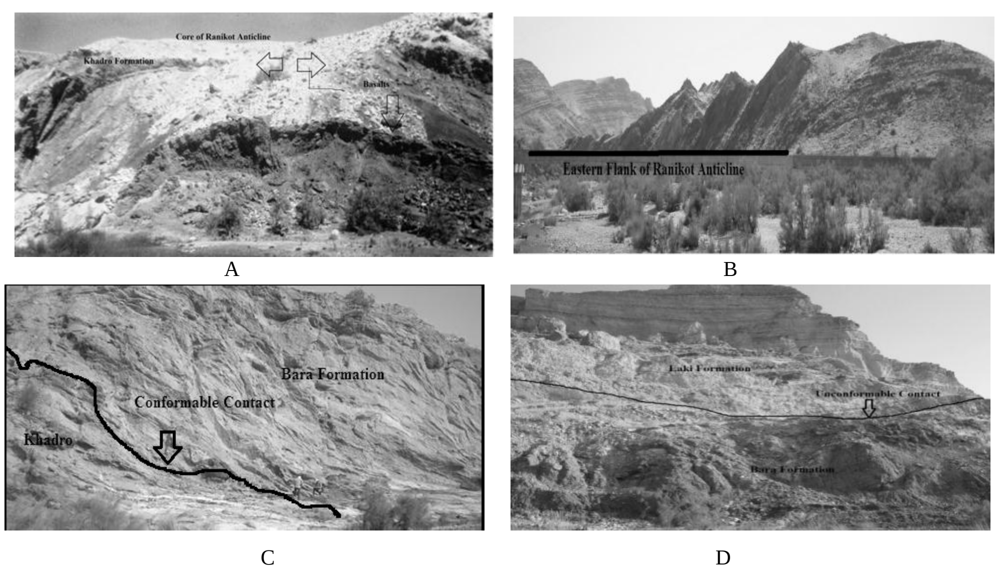


Fig. 3: Field photographs of the studied areas.

A= Core of Ranikot Anticline, at Ranikot Dhoro, Looking towards North,
B= Studied section of Bara Formation Fort Ranikot Area;
C= Lower conformable contact of Bara Formation with Khadro Formation, (25^0 53' 26" 67^0 55' 00")
D= Upper unconformable contact of Bara Formation with Laki Formation (25^0 53' 48" Latitudes 67^0 55' 32" longitude

Table - 1: Seieve analysis of samples of Bara Formation

Parameters	RN - 1								RN – 2							
	Weight of sample: 100 grams								Weight of sample: 100 grams							
Phi Value	-2	-1	0	1	2	3	4	Silt/Clay	-2	-1	0	1	2	3	4	Silt/Clay
Weight	0	0.2	2.2	10.5	12.5	47	26.5	1	0	0.3	4	27.5	27	21.2	14.5	5.5
Weight Percentage	0	0.2	2.2	10.5	12.5	47	26.5	1	0	0.3	4	27.5	27	21.2	14.5	5.5
Cummulative Weight Percentage	0	0.2	2.4	12.9	25.4	72.5	99	100	0	0.3	4.3	31.8	58.8	80	94.5	100
Parameters	RN - 3								RN – 4							
	Weight of sample: 100 grams								Weight of sample: 100 grams							
Phi Value	-2	-1	0	1	2	3	4	Silt/Clay	-2	-1	0	1	2	3	4	Silt/Clay
Weight	0	0.3	3	23	28.7	27.5	11.5	6	0	1	4.5	40.2	23.5	28.5	2.3	0
Weight Percentage	0	0.3	3	23	28.7	27.5	11.5	6	0	1	4.5	40.2	23.5	28.5	2.3	0
Cummulative Weight Percentage	0	0.3	3.3	26.3	55	82.5	94	100	0	1	5.5	45.7	69.2	97.7	100	100
Parameters	RN - 5								RN – 7							
	Weight of sample: 100 grams								Weight of sample: 100 grams							
Phi Value	-2	-1	0	1	2	3	4	Silt/Clay	-2	-1	0	1	2	3	4	Silt/Clay
Weight	0	3	3	17	35	33	8	1	0	2.1	7	45	24.7	15.8	4	0.9
Weight Percentage	0	3	3	17	35	33	8	1	0	2.1	7	45	24.7	15.8	4.5	0.9
Cummulative Weight Percentage	0	3	6	23	58	91	99	100	0	2.1	9.1	54.1	78.8	94.6	99.1	100
Parameters	RN - 10								RN – 11							
	Weight of sample: 100 grams								Weight of sample: 100 grams							
Phi Value	-2	-1	0	1	2	3	4	Silt/Clay	-2	-1	0	1	2	3	4	Silt/Clay
Weight	0	2	5	26	30	29.5	6.5	1	7	26	27	22	11	4	3	0
Weight Percentage	0	2	5	26	30	29.5	6.5	1	7	26	27	22	11	4	3	0
Cummulative Weight Percentage	0	2	7	33	63	92.5	99	100	7	33	60	82	93	97	100	100
Parameters	RN - 12								RN – 13							
	Weight of sample: 100 grams								Weight of sample: 100 grams							
Phi Value	-2	-1	0	1	2	3	4	Silt/Clay	-2	-1	0	1	2	3	4	Silt/Clay
Weight	0	2	6.5	21	38.5	21.5	6.5	4	0	2	3	7.5	22.5	53.5	11	1
Weight Percentage	0	2	6.5	21	38.5	21.5	6.5	4	0	2	3	7.5	22.5	53.5	11	0.5
Cummulative Weight Percentage	0	2	8.5	29.5	68	89.5	96	100	0	2	5	12.5	35	88.5	99.5	100
Parameters	RN - 16								RN – 17							
	Weight of sample: 100 grams								Weight of sample: 100 grams							
Phi Value	-2	-1	0	1	2	3	4	Silt/Clay	-2	-1	0	1	2	3	4	Silt/Clay
Weight	0	4	8.5	17	15.5	43	11.5	0.5	0	3.7	12	66	16	1.3	1	0
Weight Percentage	0	4	8.5	17	15.5	43	11.5	0.5	0	3.7	12	66	16	1.3	1	0
Cummulative Weight Percentage	0	4	12.5	29.5	45	88	99.5	100	0	3.7	15.7	81.7	97.7	99	100	100
Parameters	RN - 24								RN – 28							
	Weight of sample: 100 grams								Weight of sample: 100 grams							
Phi Value	-2	-1	0	1	2	3	4	Silt/Clay	-2	-1	0	1	2	3	4	Silt/Clay
Weight	0	0	0.5	15.5	51	26	6.5	0.5	0	7	6	14	25	37	9	2
Weight Percentage	0	0	0.5	15.5	51	26	6.5	0.5	0	7	6	14	25	37	9	2
Cummulative Weight Percentage	0	0	0.5	16	67	93	99.5	100	0	7	13	27	52	89	98	100
Parameters	RN - 31								RN – 37							
	Weight of sample: 100 grams								Weight of sample: 100 grams							
Phi Value	-2	-1	0	1	2	3	4	Silt/Clay	-2	-1	0	1	2	3	4	Silt/Clay
Weight	0	0.6	2.5	32	39	21	4.6	0.3	0	1	5	19	20	34	17	4
Weight Percentage	0	0.6	2.5	32	39	21	4.6	0.3	0	1	5	19	20	34	17	4
Cummulative Weight Percentage	0	0.6	3.1	35.1	74.1	95.1	99.7	100	0	1	6	25	45	79	96	100
Parameters	RN - 41								RN – 47							
	Weight of sample: 100 grams								Weight of sample: 100 grams							
Phi Value	-2	-1	0	1	2	3	4	Silt/Clay	-2	-1	0	1	2	3	4	Silt/Clay
Weight	1	9	13.5	26.5	13	21.5	13.5	2	0	2	1	12	35	31.5	16.5	2
Weight Percentage	1	9	13.5	26.5	13	21.5	13.5	2	0	2	1	12	35	31.5	16.5	2
Cummulative Weight Percentage	1	10	23.5	50	63	84.5	98	100	0	2	3	15	50	81.5	98	100
Parameters	RN - 48								RN – 49							
	Weight of sample: 100 grams								Weight of sample: 100 grams							
Phi Value	-2	-1	0	1	2	3	4	Silt/Clay	-2	-1	0	1	2	3	4	Silt/Clay
Weight	0	0.8	1.5	45.5	32	13	3.5	3.7	0	4	9.5	22	19	21.5	20	4
Weight Percentage	0	0.8	1.5	45.5	32	13	3.5	3.7	0	4	9.5	22	19	21.5	20	4
Cummulative Weight Percentage	0	0.8	2.3	47.8	79.8	92.8	96.3	100	0	4	13.5	35.5	54.5	76	96	100
Parameters	RN - 50								RN – 51							
	Weight of sample: 100 grams								Weight of sample: 100 grams							
Phi Value	-2	-1	0	1	2	3	4	Silt/Clay	-2	-1	0	1	2	3	4	Silt/Clay
Weight	0	4	12	17	7	11	45	4	0	3	6	17	14.5	39	18.5	2
Weight Percentage	0	4	12	17	7	11	45	4	0	3	6	17	14.5	39	18.5	2
Cummulative Weight Percentage	0	4	16	33	40	51	96	100	0	3	9	26	40.5	79.5	98	100

Table -3: One percentile and Median of Bara Formation at Ranikot area.

Sample No.	One %	Conv. in Micron	Median	Conv. in Micron
RN – 1	-1	2000	2.8	182
RN – 2	-2	4000	1.8	283.2
RN – 3	-1.2	2380	1.9	266.6
RN – 4	-1	2000	1	500
RN – 5	-2	4000	1.8	283.2
RN – 7	-2	4000	0.9	590
RN - 10	-2	4000	1.8	283.2
RN - 11	-2	4000	-1.5	2830
RN - 12	-2	4000	1.6	325
RN - 13	-2	4000	2.6	160
RN - 16	-2	4000	2.3	200
RN - 17	-2	4000	0.7	590
RN - 24	0	1000	1.8	283.2
RN - 28	-2	4000	2	250
RN - 31	-1.3	2450	1.3	396.6
RN - 37	-1	2000	2.4	188
RN - 41	-2	4000	1	500
RN - 47	-2	4000	2	250
RN - 48	-1.2	2380	1	500
RN - 49	-2	4000	1.8	283.2
RN - 50	-2	4000	3	125
RN - 51	-2	4000	2.2	210

Table No.4 Grain texture of Bara Formation Ranikot.

Sample Number	Grain Shape	Grain Roundness	Grain Sphericity	Sphericity Class
RN – 1	Oblate	Subrounded	Low Sphericity	Subrounded
RN – 2	Oblate	Subangular	Low Sphericity	Subangular
RN – 3	Equant	Subangular	Low Sphericity	Subangular
RN – 4	Equant	Angular	Low Sphericity	Angular
RN – 5	Equant	Subangular	Low Sphericity	Angular
RN – 7	Equant	Subrounded	Low Sphericity	Subrounded
RN - 10	Equant	Subangular	Low Sphericity	Subangular
RN - 11	Bladed	Angular	Low Sphericity	Angular
RN - 12	Equant	Subangular	Low Sphericity	Subangular
RN - 13	Equant	Subrounded	Low Sphericity	Subrounded
RN - 16	Bladed	Subangular	Low Sphericity	Subangular
RN - 17	Equant	Subrounded	Low Sphericity	Subrounded
RN - 24	Equant	Subrounded	Low Sphericity	Subangular
RN - 28	Equant	Subangular	Low Sphericity	Subrounded
RN - 31	Equant	Subrounded	Low Sphericity	Subrounded
RN - 37	Equant	Subangular	Low Sphericity	Subangular
RN - 41	Bladed	Angular	Low Sphericity	Subrounded
RN - 47	Equant	Subrounded	Low Sphericity	Subangular
RN - 48	Equant	Subrounded	Low Sphericity	Angular
RN - 49	Equant	Subangular	Low Sphericity	Subrounded
RN - 50	Equant	Subrounded	Low Sphericity	Subrounded
RN - 51	Equant	Subangular	Low Sphericity	Subangular

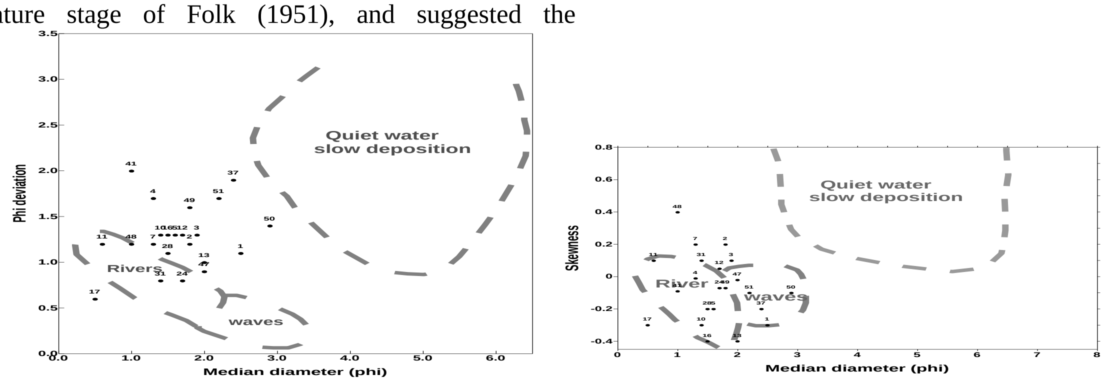
3. RESULTS AND DISCUSSION

Grain textural parameters i.e. grain shape; grain roundness and sphericity were observed. Shapes of particles have been divided into four classes; spherical (equant), oblate (disc or tabular), blade and roller (rod shape) or prolate; all shapes are illustrated in the Figure given by Zingg (1935). Majority of the samples of friable sandstones of the Bara Formation from Ranikot, are equant, while few of them are oblate and bladed. Folk (1974) adopted the classification of *Powers (op.cit)* and same classification is used here for roundness analysis. Powers (op.cit) roundness images for sand grains are facilitated by a logarithmic (rho,*P*) scale, in which the limits of the very angular class are taken as 0.01-1.0, angular 1.0-2.0, subangular 2.0-3.0, subrounded 2.0-4.0, round 4.0-5.0, and that of very round 5.0 – 6.0 *P* (Folk, 1974). The grain roundness of Ranikot samples ranges from angular, sub-angular, sub-rounded, subangular to subrounded. The Sphericity of grains is directly measured and noted with the help of chart, proposed by Wadell (1932). All samples of Bara Formation from Ranikot section belong to the class of low sphericity, and different subclasses of low sphericity. Ranikot samples are sub-angular, sub-angular to subrounded, sub-rounded, sub-rounded to rounded. These results are indicating that the grains of Bara Formation had not transported to a greater distance from their source rock.

Folk (1957) proposed the classification of textural maturity for the sandstone. According to Folk (1957) the immature sediments accumulate in locations, such as flood plains, alluvial fans, or neritic or lagoonal environments, where the current action is either weak or very rapid, and the deposition of the sediments do not get chance, to be subjected to input of any mechanical energy after the deposition. He further mentioned that the supermature sediments, on the other hand, indicate deposition in loci of intense abrasion and sorting, such as beaches or desert dunes, where energy is constantly being expended on the grains (Folk, 1957).

The textural maturities pass sequentially through the four stages.(1): Immature stage, in which sediment contains over 5 percent terrigenous clay matrix; sand grains usually are poorly sorted and angular.(2): Sub mature stage, in which sediments contain fewer than 5 percent clay, but sand grains are still poorly sorted (σ over 0.5φ) and are not well rounded.(3): Mature stage, in which sediments contain little or no clay, and sand grains are well sorted (σ under 0.5φ), but still not rounded.(4): Supermature stage: in which sediments contain no clay, sand grains are well sorted and well rounded (Waddel roundness over 0.35; ρ over 3.0). The sorting of the sediments from the Fort Ranikot area is ranging from (0.8 φ) to (1.9φ) indicating that they are poor to moderately sorted. On the basis of the comparison of textural maturity stages of Folk (op.cit.), the results of the present study, correspond with the sub-mature stage of Folk (1951), and suggested the existence of low energy condition under which studied sediments were deposited. Therefore the results of sorting of sediments obtained from Ranikot section support the fluvial depositional system.

Grain size data is plotted on discriminatory diagrams proposed by Stewart (1958) & Passega (1964) for the interpretation of the environment of deposition. According to diagram of Stewart (1958), median is plotted against the standard deviation, from the statistical data of Bara Formation from Ranikot section. The majority of the samples of Bara Formation at Ranikot fall in the river processes system with the exception of few samples (1, 37, 50 and 51) **(Fig 4a).** These results indicated that the depositional environments of the Bara Formation were mostly fluvial and represent ancient river systems. In other diagram **(Fig.4b)** the median is plotted against skewness, where most of the samples again fall in the river processes system with the exception of a few odd samples. The diagram of median against the skewness suggests that the depositional environments of the Bara Formation were mostly fluvial and represents the ancient river channels.



(a) (b)

Fig. 4: Bivariate plots of Bara Formation from Ranikot (After Stewart, 1958).

Passega (1964) presented the diagram which interprets the depositional environments of the sediments. He suggested that the ratio of the one percentile, *C*, to the Median diameter, *M*, could be used as an indicator of the dynamics of the depositional environment. According to him the strongest currents should define the largest stable particle size. Counter-plotting has the *C-M* diagram within which he defined the envelopes typifying deposits from traction currents, from beaches or from various forms of suspension. Two parameters of the grain size distribution of individual samples are particularly significant, C, the one percentile, and M, the median diameter. The CM patterns on a logarithmic diagram are the characteristic of the depositional agent. Bottom currents capable of transporting sediments, are of two types. (1) Tractive currents which are capable of transporting their load, either by rolling or in suspension. (2) Turbidity currents generally flow during a limited time and are so rapid that they cannot be followed by the rolling grains; their load is entirely a suspension load. Exceptionally, the turbidity currents which can roll particles relatively short distances from their origin, if the currents are formed continuously during a certain time, or longer distances, if, in an area of non-deposition, the particles are rolled by successive currents. Rivers, marine currents and waves touching the bottom of the depositional basin are Tractive currents (Passega, 1957). The majority of the samples of the Ranikot fall in the normal fluvial environments, with the exception of a few samples **(Fig.5).** According to the plotting of samples in the reproduced diagram of Passega the studied samples pointed out that the depositional environments were fluviatile. Some samples indicated high energy environments which may be related with the flooding of the river channels.

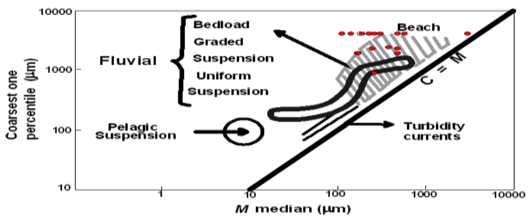


Fig. 05: Showing the approximate position of the samples of loosely cemented sediments from the Bara Formation, Fort Ranikot (After Passega-1964).

4. CONCLUSION

1. The dominant shape of grain in loose sandstone samples from Bara Formation at Ranikot is equant, with few samples containing oblate and bladed grains.
2. All samples of Bara Formation from Ranikot section fall in the class of Low Sphericity, and different sub classes of low sphericity as per chart given by Wadell (1932).
3. Ranikot samples are sub-angular, sub-rounded, sub-rounded to rounded and sub-angular to subrounded. These results indicate that the grains of Bara Formation had not transported to a greater distance from their source rock.
4. The results of the present study correspond with the sub-mature stage of Folk, which suggests the existence of low energy condition under which studied sediments were deposited. The results of sorting of the Ranikot have supported the fluvial depositional system.
5. According to bivariate diagram of Stewart (1958), by plotting median against standard deviation and skewness, the majority of the Bara Formation samples are plotted in the river processes system with the exception of few samples. These results indicated that the depositional environments of the Bara Formation, was mostly fluvial and represents ancient river systems.
6. According to the plotting of samples in the reproduced diagram of Passega (1964) the studied samples pointed out that the depositional environments were fluviatile. Some samples indicated high energy environments which may be related with the flooding of the river channels.

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