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Sedimentological Study of Manchar Formation, Kari Buthi Section, Northern Laki Range, Southern Indus Basin, Pakistan

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Abstract

The lithofacies studies provide key information to interpret the depositional environments of the sedimentary rocks. Here we study the~1055 m thick Manchar Formation with the age of Miocene to Pliocene which is well exposed at Kari Buthi Division, Northern Laki Range, Southern Indus Basin Sindh, Pakistan. We applied grainsize analysis method to obtain statistical parameters, cumulative frequency curves, discriminatory and discriminatory diagrams. We found that the Manchar Formation encompasses six different fluvial depositional environments including coarse-grained flat bedding sandstone to fine, Conglomerate and agglomerate Sandstone facies, coarse grained trough the cross bedded sandstone facies to sufficient, Shale facies, Mudstone facies, and Clay facies. Principally the common sedimentary structures are trough cross bedding and planner lamination in the area. And the results based on bivariate diagrams further confirm the deposition of Manchar Formation through a braided river system.

Keywords: Sedimentological assessment; Facies analysis; Grain size analysis; Manchar Formation, Kari Buthi section; Pakistan.

Introduction

Identification of lithofacies is of great importance tounderst and the depositional environment of sedimentary rocks[1] because lithofacies units reflect actual processes of the deposition[2,28]. Hence the present study focused on the lithofacies analysis, for determination of depositional environment during the time of deposition of sedimentary unit, i.e. the Manchar Formation (MF). In the study area, sandstone beds commonly existon regular succession of a vertical change in texture and composition, which reflects the changes in debris transport load and their conditions[3]. Furthermore, the clarification of sedimentary processes may helpful for further estimations of reservoir properties through the resident amount of sandstone[4].

The MF of Miocene to Pliocene is well developed in Sindh, Pakistan in many areas, particularly in the synclinal valleys in north-west of the Laki Range, extends from latitude 26°19′ N to 26°26′N at Longitude 67°50′E[5] (Figure-1). The detailed lithofacies of MF are conducted to determine its depositional environment (Figure-2). Formations are well exposed from oldest to youngest[6] such as, Laki Formation, Kirthar Formation, Nari Formation, Manchar Formation and Dada conglomerate as shown in (Table-1). These formations are also observed for better understanding of overall stratigraphic setup of the studied area. The analysis of particle size is an essential technique in the field of sedimentology[7-9] to extract the geological information ofsandstone[10-11]. The grain size analysis and its statistical parameters are useful for the understanding of the environmental deposition of facies characterization and friable sandstones[12,13]. The transferal and depositional processes of pre-existing rock elements can be estimated by grain size technique to determine the depositional environments[3].

In this study, we analyze the sedimentological grain-size parameters, diagnostic physical parameters, texture and structure to study the depositional environments of the MF, Sindh, Pakistan region. In addition to cumulative curves and statistical parameters, various combinations of parameters were designedin the bivariate diagrams to interpret the environmental deposition of the MF.

General Geology: The MF composed of shale with subordinate conglomerate and interbedded sandstone. At the basal portion, there is dominancy of shale while sandstone increases to upper part. The shales are usually soft, yellow, brown, and brick in colored whereas the sandstone is coarse-grained to rocky, cross-bedded soft, and grey, greenish grey (Figure-2). Conglomerate encompasses sub rounded to sub-angular pebbles of sandstone, arenaceous and fossiliferous limestone fragments and the clasts were probably sourced from the Kirthar, Nari and Gaj formations[4,14,28]. The MF uncomfortably super imposes everalolden rock partslike as the Laki, Gaj, Nari, Pab, and Kirthar Formations. And transitionally influence on the Dada Conglomerate and Silicified wood fossils and mammal bones were found which further clarifying the Miocene to Pliocene age of the MF[3].

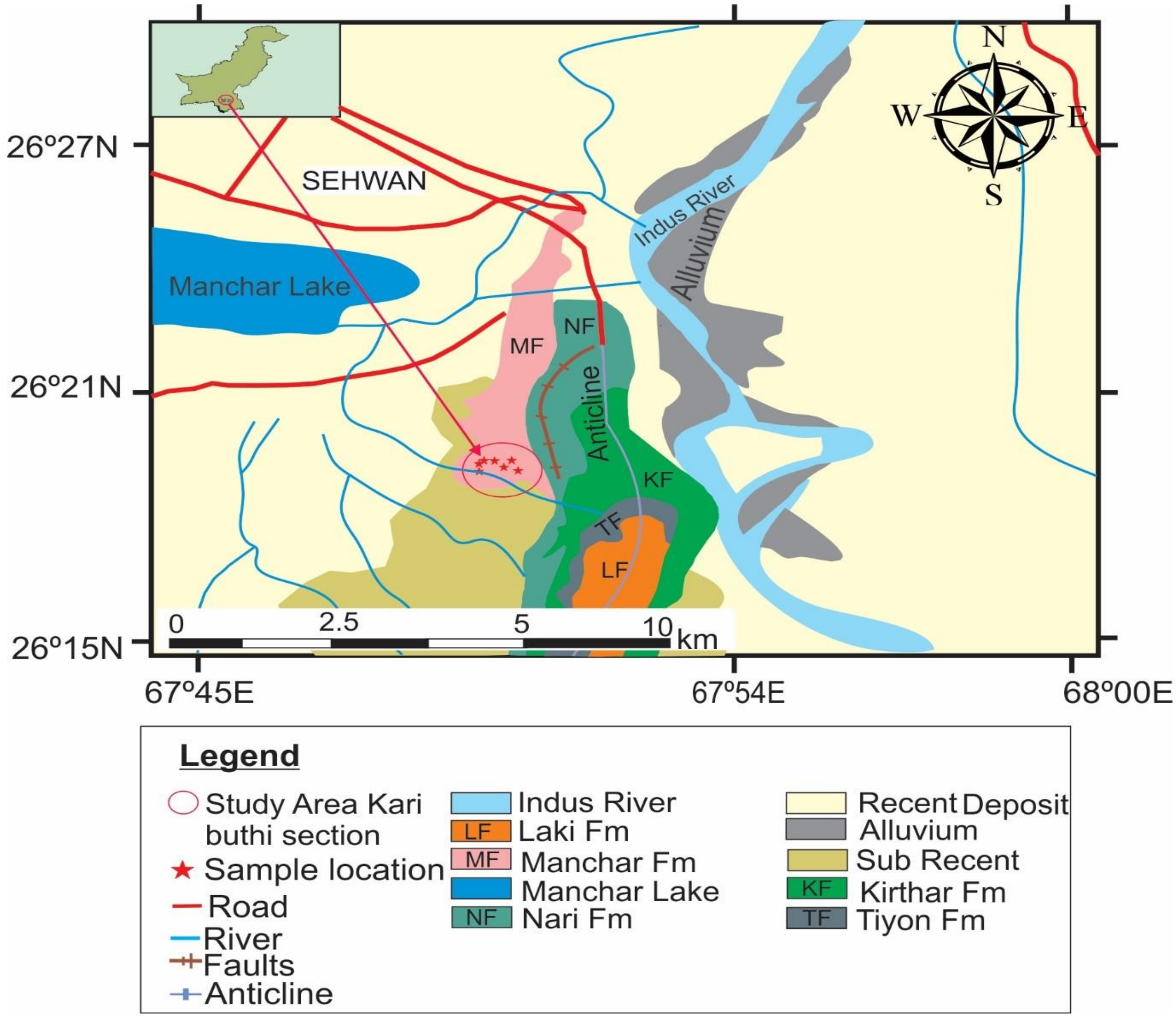

Figure-1: Geological settings of the Kari Buthi Division, Northern Laki Range, Southern Indus Basin Sindh, Pakistan[4].

Table-1: Classification of stratigraphy of the Northern Laki Range.

Age	Thickness (m)	Formation	Lithology
Pleistocene	305	Dada Conglomerate	Conglomerate, Boulders, and Pebbles
Miocene to Pliocene	152 to 2743	Manchar Formation (Present study)	Conglomerate, Sandstone, Shale, Conglomeratic Sandstone and Mudstone
Oligocene	762 to 1829	Nari Formation	Sandstone, Limestone and Shale
Eocene	152 to 305	Kirthar Formation	Limestone
Eocene	457 to 1219	Laki Formation	Limestone, Shale, and Sandstone

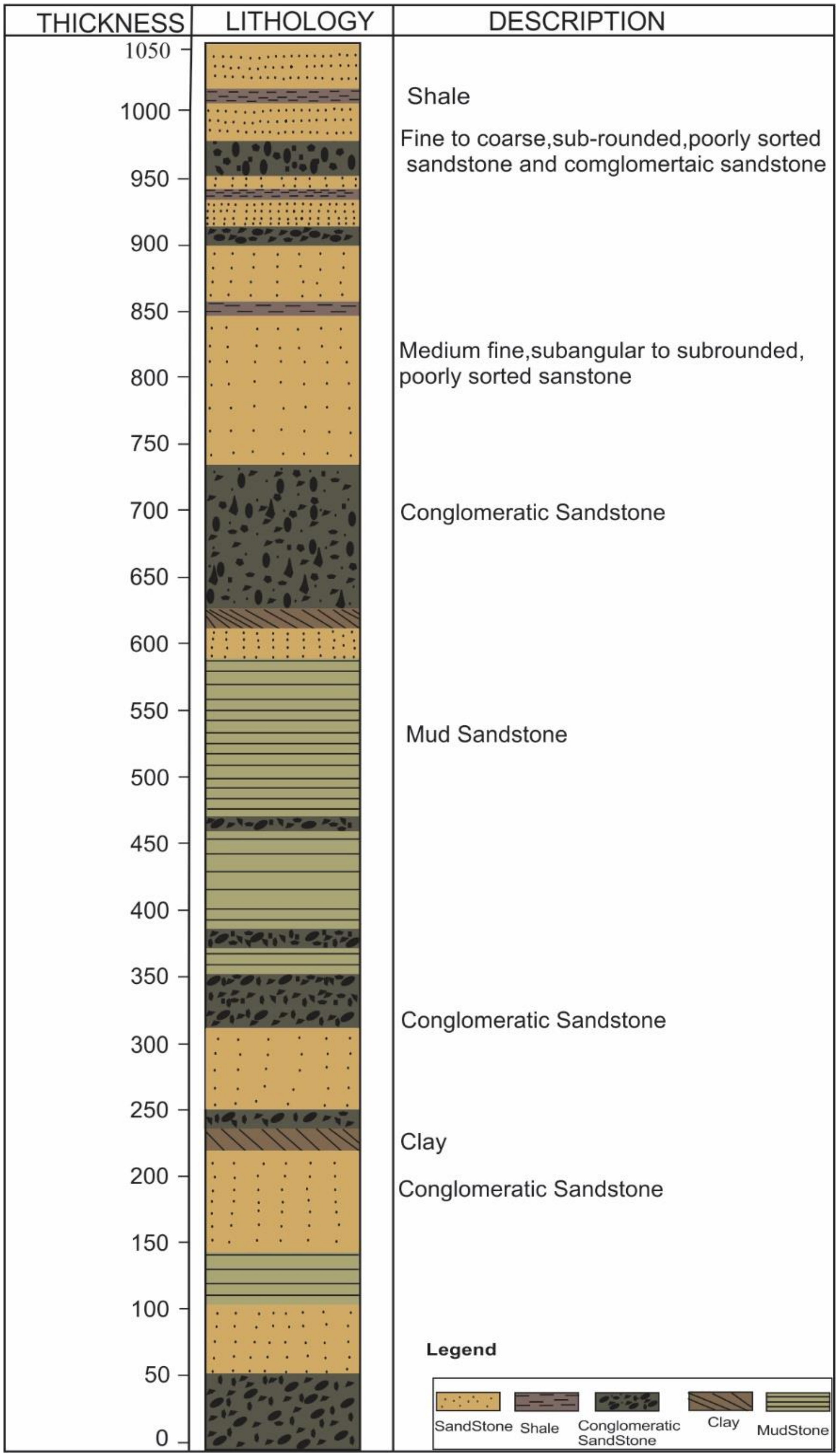

Figure-2: Columnar section of Study area.

Materials and methods

The sieve analysis method[8,9,15] was used to measure the grain size distribution of sand particles to examine the loose and friable sand and sandstone[8, 9]. Representative thirty-two loosed and friable sandstone Samples were collected and prepared with the Octagon Digital Sieve Shaker for the sieve analysis. Following the sieve of mesh size such as -1φ, 0φ, 1φ, 2φ, 3φ, 4φ, and Pan, sieved data (raw data) was calculated by following formula.

$$\text{Cumulative Weight }\% = \frac{\text{Total Weight of Sample}}{\text{Weight of sieved Sample}} \text{ X } 100 \qquad (1)$$

Results and discussion

The MF was deposited mainly in braided fluvial environment, and subsequent sediments were deposited by meandering river flow regime. On the basis of sedimentological evidences, the lithofacies classification of Manchar Formation is further classified as follows.

Lithofacies evidence: MF at Kari Buthi Section consisted four principle lithofacies with total thickness of 263m the Conglomeratic Sandstone facie (Gt) of (25%) including22layers of variable thickness. The facies specifies the abrupt deposition of sedimentary rocks underneath the high flow energy regime and depositional process in the fluvial channels[16-18]. About 168m (15.948 %) with 22 layers of variable thickness accounted as the adequate- to gritty trough crossed settled sandstone facies (St) are accounted. The total 396m width of fine to gritty flat bedding sandstone facie (Sh) is up to 37% of the total width of the studied area with 18layers of variable width the presence of fine grained sand further reveals that the process of depositional has been done at bar top sand sheets[19,20]. Shale facie (Fm) having thickness 21m in the studied area which consists 2% of the total thickness in studied area with 3 identified beds. The deposition of this facie showed very fine-grained deposition due to very low energy of fluvial settings, especially the depositional process has been done due to interruption in the over-bank sites with fine-grained sediments deposited by primary sediments[19].

Study of Grain size indications: The outcomes of grain size examination revealed that the sandstone of the selected formations vary from fine-grained to medium size. The graphic mean further classified that 12% are of very fine sand, 16% are of medium sand and 72% are of fine sand Figure-3a.The fluvial sediments are typically poor sorted, due to wide range of particles which are movable due to different processes for example suspension and saltation, and traction particularly in the flood season. Rather than its energy the persistence of the depositional processes is reflected by the sorting[21]. The result of the sorting of sediments from MF at Kari Buthi Section indicates that 3% of sand Samples were well arranged, 6% soberly well arranged, 38% poorly arranged, and 53% abstemiously arranged (Figure-3b).

Graphic mean: Graphic Mean is the statistical parameter and it is a useful tool to calculate the average of grain size. Whereas, the grain size itself is controlled by the various processes; the power of moving a medium travelled by any particle from its origin, and the composition of source rocks. The decrease in energy of transportation, results in settlement and deposition of the sediments. Provisional to the strength of environmental depositional, finer particles deposited in steady aquatic. The following equation is used to calculate graphic mean of grain size[22].

$$(\text{Mz}) = \frac{\varphi16+\varphi50+\varphi84}{3} \qquad (2)$$

Different size of grain size (phi) were selected such as 16, 50 and 84 percentiles grain size distribution for a given sedimentary rock determined by the sieving. The graphic mean of friable sandstone of MF, Western Limb of Laki Range, Kari Buthi section Southern Indus basin, Sindh, Pakistan are presented in Table-2 and Table-3.

Median: The Median is also a useful tool for analyzing statistical parameters to define the medium values of the grains[21]. Results showed that the half size (50%) of the grains by the Weight were rougher than midpoint. Another half was finer, the results of the middle showed that the dispersed sandstone of the Formation was attained by following the formulae MD=φ 50[15], showed in Table-A1.

Sorting: Sorting of the sediments is widely used statistical parameter to describe the uniform size of the particles, to determine the amount of grain size existing in any specific sediment Samples (Table-4).

$$\sigma\text{I} = \frac{\Phi84 - \Phi16}{4} + \frac{\Phi95 - \Phi5}{6.6} \qquad (3)$$

Skewness (Ski): Skewness (SKI) is very useful statistical tool to determine the symmetry of the sediments. The cumulative curve of sediments with zero skewness, normally distributed and appears symmetrically without tail. The coarser sediments are greater than the finer sediments, the results of skewness generally show the positive and vice versa values[7, 23].

$$(\text{SKI}) = \frac{\Phi16 + \Phi84 - 2\,(\Phi50)}{2\,(\Phi84 - \Phi16)} + \frac{\Phi5 + \Phi95 - 2\,(\Phi50)}{2\,(\Phi95 - \Phi5)}$$
(4)

The standard values for the Inclusive graphic skewness (SKI) are shown in Table-5, and the graphic skewness values are presented in Table-A1. The results of skewness were compared[7] and found that the skewness standards of the sediments vary from -0.01φ to 5.52φ. Such as 28% strongly coarse, 28% strongly fine, 28% fine, 10% nearly symmetrical and finally 6% are of coarse skewed (Figure-3c). After correlating the result of Graphic Kurtosis (KG) with[15] and which indicate that the KG of MF sediments varies from 0.77 to 1.59. The Graphic Kurtosis (KG) of the studied Samples represents very leptokurtic (3%), leptokurtic (34%), mesokurtic, (41%) very platykurtic (3%) and platykurtic (19%) (Figure-3d).

Table-2: Percentile of representative Samples of sandstone.

Sample No	*5	*16	*25	*50	*75	*84	*95
KBS-3	0.85	1.75	2.2	3.1	3.97	4.2	4.41
KBS-4	0.59	1.28	1.64	2.81	4.1	4.3	4.44
KBS-5B	0.21	0.55	0.79	1.59	2.71	3.62	4.4
KBS-5C	1.09	1.31	1.5	1.99	2.67	2.99	4.11
KBS-6A	1.71	2.19	2.39	2.85	3.59	3.9	4.31
KBS-6B	0.21	0.5	0.7	1.3	2.1	2.59	4.01
KBS-9	0.7	1.18	1.39	1.9	2.5	2.73	3.3
KBS-11	1.02	1.38	1.54	2.1	2.69	2.91	4.09
KBS-13	1.31	1.99	2	2.4	2.8	2.99	4.11
KBS-16	1.18	2.58	1.81	2.31	2.71	2.91	3.91
KBS-20	0.6	1.85	2.15	2.59	3.09	3.5	4.25
KBS-20A	0.8	1.99	2.21	2.89	3.69	3.95	4.38
KBS-22	1.9	2.21	2.4	2.85	3.51	3.99	4.33
KBS-24	0.86	2.01	2.35	2.99	3.78	4.01	4.4
KBS-26	0.5	1.3	1.99	3.28	4.1	4.3	4.49
KBS-27	1.39	1.94	2.2	2.61	3.17	3.58	4.2
KBS-29	1.3	2	2.2	2.59	3	3.31	4.2
KBS-33	1	1.25	1.4	1.8	2.39	2.7	3.51
KBS-35	1.11	1.39	1.54	2.01	2.69	3.09	4.2
KBS-37	0.69	1.19	1.41	2.08	2.6	2.81	3.45
KBS-40A	1.2	1.89	2.1	2.5	2.89	3.1	4
KBS-41	0.51	1.12	1.1	2.3	2.71	2.91	3.91
KBS-42	0.45	1.2	1.55	2.21	2.7	2.91	4.01
KBS-44	0.75	1.59	1.91	2.4	2.75	2.9	3.5
KBS-50	0.9	2.01	2.69	3.39	3.85	4.01	4.4
KBS-51	0.9	1.21	1.4	1.88	2.6	3.02	4.25
KBS-55	0.5	1.1	1.49	2.49	3.2	3.93	4.4
KBS-56	-1.55	0.26	0.21	1.49	2.4	2.8	4.2
KBS-57	1.08	1.6	1.9	2.49	3	3.39	4.1
KBS-59	0.8	1.8	2.1	2.55	3.09	3.57	4.31
KBS-61	0.4	0.87	1.21	2.1	2.96	3.6	4.35
KBS-63	0.36	0.81	1.19	2.1	2.88	3.4	4.36

Table-3: Standard deviation values for Graphic Mean of the Formation.

Values From	To	Grain Size
- Infinity	-1	Gravel
-1	0	Very Coarse Sand
0	1	Coarse Sand
1	2	Medium Sand
2	3	Fine Sand
3	4	Very Fine Sand
4	5	Silt
5	--------	Clay

Table-4: Standard values for sorting.

From	To	Description of Sorting
----------	<0.35	Very Well Sorted
0.35	0.50	Well Sorted
0.50	0.71	Moderately Well Sorted
0.71	1.0	Moderately Sorted
1.0	2.0	Poorly Sorted
2.0	4.0	Very Poorly Sorted
4.0	>4.0	Extremely Poorly Sorted

Table-5: Standard values for the inclusive skewness given by Folk, R. l.[15].

From	To	Skewness Description
------------	>0.30	Strongly fine skewed
+0.30	+0.10	Fine skewed
+0.10	-0.10	Near Symmetrical
-0.10	-0.30	Coarse skewed

<-0.30	------	Strongly coarse skewed

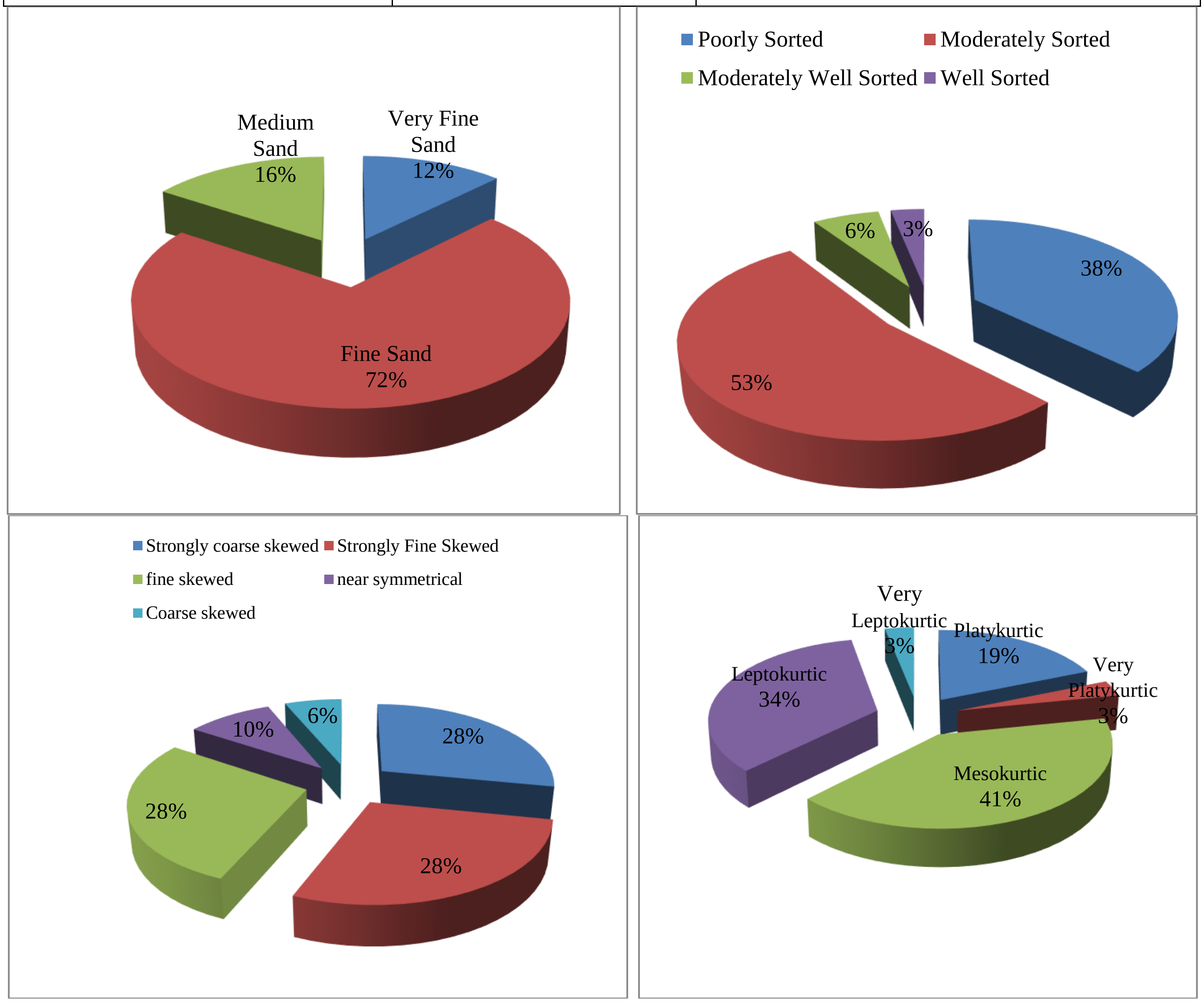

Figure-3: (a) results of Graphic Mean (b) sorting values (c) graphic skewness and (d) graphic kurtosis of the unconsolidated sandstone Samples of MF.

Fluvial sediments generally showed the positive skewed due to the time of transportation, rivers transport fine particles of clay and silt and, and during the deposition the fine particles trapped with the coarse particles[21]. The results of skewness vary from near symmetrical skewed to strongly fine. This kind of results suggest that the deposition of the sediments occurred in fluvial depositional process. Correspondingly, most of the textural evidences such as dominantly poorly sorted, coarse to medium grained and very fine- to coarse skewed sediments also support the evidence of fluvial depositional systems.

Bivariate diagrams play a pivotal role to represent the sieved data to understand the environmental analysis of the depositional sediment[6,11,24]. Which differentiated by the standard deviation (sorting) and skewness, plotted against the median[25,26]. According to Stewart Jr, H. B.[27] in steady flow regime there are three transportation deposition processes i.e. River Process, Slow depositional process and Wave Process. Furthermore, most of the sediment Samples unconfined during the braided fluvial scheme as shown in Figure-4a. The findings of this analysis confirm the deposition of sediments under the fluviatile system. Following the method of Stewart Jr, H. B.[27] the skewness graph was designed in comparison of the median, which indicated that most of the sediments were released in braided environment System, and deposited under the braided fluviatile system (Figure-4b). Median and categorization the values of friable and loose sandstones of the Formation are shown in Figures-4c and 4d. And the plot of skewness values of unconsolidated sediments are given in Table-A1.

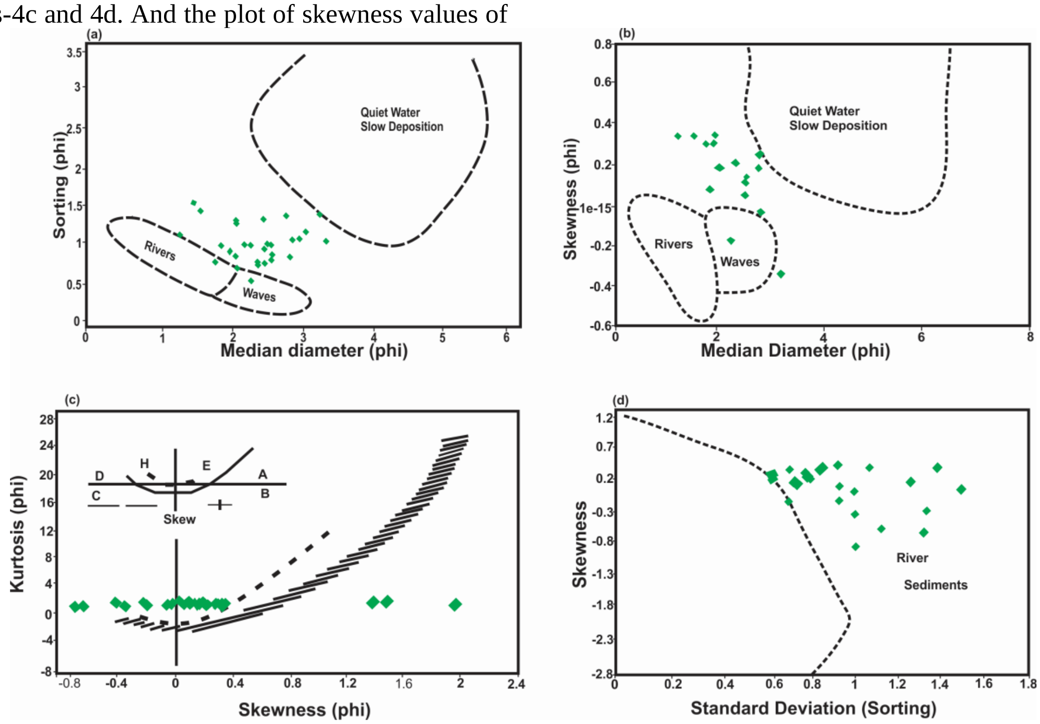

Figure-4: Various statistical plots of the study area (a) median vs sorting, (b) median vs skewness, (c) skewness vs kurtosis and (d) standard deviation vs skewness plots.

Statistical Parameters of Grains Size Data: Statistical parameters are useful for identification of the sedimentary depositional environment of sediments, especially for sandstone. Cumulative Weight percentage is widely used method to obtain the statistical parameters and the overall presentation of results obtained by grain size analysis. The geometric parameters of grain size data onto unconsolidated sandstone from MF was determined from percentile values of phi (φ) φ 5, φ16, φ25, φ50, φ75, φ84 and φ95 individually from the formulated cumulative curves.

Textural Maturity: Textural maturity is one of the most important characteristics to study about the environmental conditions of the sedimentological deposits. The deposition of immature sediments suggests either weak or very strong environment of the deposition like as flood plains, alluvial fans, neritic or lagoonal sub-environments. The values of the sorting acquired from sediment Samples of MF ranging from 0.67φ to 1.51φ, showing moderately well sorted to poorly sorted, suggesting that the depositional process was taken place in fluvial environment with the reworking of the sediments.

Cumulative graph: Generally cumulative graph is produced by the plotting the cumulative mass % of grains on y-axis against phi (φ) values (φ-1, φ0, φ1, φ2, φ3, φ4, φ4.5) on x-axis and curved typically formed in S-shape[15] (Figure-5).

The graphical representation of grain sizes data onto MF conducted by the cumulative curves. It is among the most efficient methods to interpret the sedimentological data-set. Furthermore, the sorted Samples could be signified with the central slope and poorly sorting can be shown by the gentle slope of the cumulative curve (Figure-5).

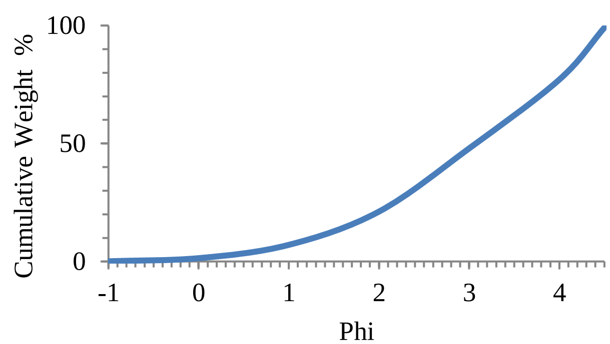

Figure-5: Cumulative curve representing the cumulative Weight and Phi values of the grain size of the study area.

Conclusion

The Manchar Formation with age of Miocene to Paleocene encompasses six different fluvial depositional environments such as Conglomerate and Fine- to coarse-grained trough cross bedded sandstone facies and, Fine- to coarse-grained flat bedding sandstone, Conglomeratic Sandstone facies, Mudstone facies, Clay facies, and Shale facies. The range of grain size was analyzed from fine to dominantly poorly sorted, coarse-grained, and the findings of sub-mature stage of maturity and skewness specified that the depositional process of the Establishment was done by the fluvial depositional environments. And the data of textural maturity also confirmed the deposition of the study area was alluvial followers, flood plains, neritic or lagoonal sub-environments classified as: (i) immature stage with more than 5% terrigenous clay matrix; the poorly sorted sand grains with regular shape. (ii) Sub-mature stage with less than <5% clay matrix; with moderately sorted sand grains (σ over 0.5φ) with sub-rounded shape. (iii) The results of mature stage of sedimentary deposits showed the little or no clay, well sorted, sub-rounded shaped sand grains (σ under 0.5φ). (iv) Mature stage reflects well sorted and well-rounded shaped sand grains with no clay. This is the detailed study about the depositional environments of the MF and the findings of this study could provide the foundations for further studies of the region.

Acknowledgments

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Appendix table A1.

Sample KBS-3					Sample KBS-4				
Weight					Weight				
Phi Value	Grain Size	Weight	Weight %	Cumulative%	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0.1	0.1	0.1	2	Granular	0	0	0
1	V.C.S	1.3	1.3	1.4	1	V.C.S	0.1	0.1	0.1
500	C.S	5.6	5.6	7	500	C.S	12.1	12.1	12.2
250	M.S	14.1	14.1	21.1	250	M.S	21.3	21.3	33.4
125	F.S	26.8	26.8	47.9	125	F.S	20.5	20.5	54
63	V.F.S	29.1	29.1	77.1	63	V.F.S	17.7	17.7	71.7
Pan	Silt & Clay	22	22	99.1	Pan	Silt & Clay	27.9	27.9	99.6
Sample KBS-5B					Sample KBS-5C				
Weight					Weight				
phi value	Grain Size	Weight	Weight%	Cumulative%	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0	0	0	1	V.C.S	0	0	0
500	C.S	34.2	34.2	34.2	500	C.S	3.9	3.9	3.9
250	M.S	28.1	28.1	62.3	250	M.S	48.2	48.2	52.2
125	F.S	17.1	17.1	79.4	125	F.S	33.2	33.3	85.2
63	V.F.S	8.6	8.6	88	63	V.F.S	9.5	9.5	95
Pan	Silt & Clay	11.3	11.3	99.3	Pan	Silt & Clay	4.9	4.9	99.9
Sample KBS-6A					Sample KBS-6B				
Weight					Weight				
phi value	Grain Size	Weight	Weight %	Cumulative%	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0	0	0	1	V.C.S	0	0	0
500	C.S	2.3	2.3	2.3	500	C.S	40.1	40.1	40.4
250	M.S	9.4	9.4	11.7	250	M.S	33.9	33.9	74.3
125	F.S	46.4	46.4	58.1	125	F.S	15.9	15.9	90.2

63	V.F.S	30.2	30.2	88.3	63	V.F.S	5.8	5.8	96
Pan	Silt & Clay	11.5	11.5	99.8	Pan	Silt & Clay	3.8	3.8	99.9
Sample KBS-9					Sample KBS-11				
Weight					Weight				
phi value	Grain Size	Weight	Weight %	Cumulative%	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0	0	0	1	V.C.S	0.5	0.5	0.5
500	C.S	12.1	12.1	12.1	500	C.S	4.5	4.5	5.1
250	M.S	43.5	43.5	55.7	250	M.S	42.2	42.2	47.2
125	F.S	36.5	36.5	92.2	125	F.S	39.7	39.7	87
63	V.F.S	5.5	5.5	97.7	63	V.F.S	8.8	8.8	95.7
Pan	Silt & Clay	2	2	99.8	Pan	Silt & Clay	4.1	4.1	99.8
Sample KBS-13					Sample KBS-16				
Weight					Weight				
phi value	Grain Size	Weight	Weight %	Cumulative%	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0	0	0	1	V.C.S	0	0	0
500	C.S	0.7	0.7	0.7	500	C.S	0.4	0.4	0.4
250	M.S	26.3	26.3	27	250	M.S	3.1	3.1	3.5
125	F.S	59.2	59.2	86.1	125	F.S	29.9	29.9	33.4
63	V.F.S	8.5	8.5	94.7	63	V.F.S	55	55	88.4
Pan	Silt & Clay	5.1	5.1	99.7	Pan	Silt & Clay	8.2	8.2	96.6
Sample KBS-20A					Sample KBS 20				
Weight					Weight				
2	Grain Size	Weight	Weight %	Cumulative%	2	Grain Size	Weight	Weight %	Cumulative%
1	Granular	0	0	0	1	Granular	0	0	0
500	V.C.S	1.9	1.9	1.9	500	V.C.S	0	0	0
250	C.S	5.4	5.4	7.3	250	C.S	11	11	11
125	M.S	12.5	12.5	19.8	125	M.S	9.8	9.8	20.8
63	F.S	35.9	35.9	55.6	63	F.S	52.3	52.3	73.2
Pan	V.F.S	30.9	30.9	86.6	Pan	V.F.S	18.7	18.7	91.9
Sample KBS-22					Sample KBS-24				
Weight					Weight				
phi value	Grain Size	Weight	Weight %	Cumulative%	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0.2	0.2	0.2	1	V.C.S	0.2	0.2	0.2
500	C.S	1.1	1.1	1.3	500	C.S	6.7	6.7	6.9
250	M.S	6.7	6.7	7.9	250	M.S	9.4	9.4	16.2
125	F.S	50.3	50.3	58.2	125	F.S	35.6	35.6	51.8
63	V.F.S	30.4	30.4	88.6	63	V.F.S	32.1	32.1	84
Pan	Silt & Clay	10.4	10.4	99	Pan	Silt & Clay	15.6	15.6	99.6
Sample KBS-26					Sample KBS-27				
Weight					Weight				

Phi Value	Grain Size	Weight	Weight %	Cumulative %	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0	0	0	1	V.C.S	0	0	0
500	C.S	14	14	14	500	C.S	2.4	2.4	2.4
250	M.S	13.6	13.6	26.5	250	M.S	15.9	15.9	18.3
125	F.S	18.4	18.4	44.9	125	F.S	52.3	52.3	70.6
63	V.F.S	27	27	72	63	V.F.S	22.3	22.3	92.8
Pan	Silt & Clay	26.4	26.4	98.3	Pan	Silt & Clay	6.9	6.9	99.7
Sample KBS-29					Sample KBS-33				
Weight					Weight				
Phi Value	Grain Size	Weight	Weight%	Cumulative %	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0	0	0	1	V.C.S	0	0	0
500	C.S	3.7	3.7	3.7	500	C.S	6.8	6.8	6.8
250	M.S	14.2	14.2	17.9	250	M.S	55	55	61.8
125	F.S	58.6	58.6	76.5	125	F.S	29.7	29.7	91.5
63	V.F.S	16.5	16.5	93	63	V.F.S	5.4	5.4	96.9
Pan	Silt & Clay	6.5	6.5	99.6	Pan	Silt & Clay	2.6	2.6	99.4
Sample KBS-35					Sample KBS-37				
Weight					Weight				
Phi Value	Grain Size	Weight	Weight %	Cumulative %	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0	0	0	1	V.C.S	0	0	0
500	C.S	2.4	2.4	2.5	500	C.S	12.3	12.3	12.3
250	M.S	48	48	50.5	250	M.S	36.7	36.7	49.1
125	F.S	34.1	34.1	84.6	125	F.S	41.7	41.7	90.8
63	V.F.S	9.3	9.3	93.9	63	V.F.S	6.3	6.3	97
Pan	Silt & Clay	5.6	5.6	99.6	Pan	Silt & Clay	2.6	2.6	99.7
Sample KBS-40A					Sample KBS-41				
Weight					Weight				
phi value	Grain Size	Weight	Weight %	Cumulative	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0	0	0	1	V.C.S	0	0	0
500	C.S	3.9	3.9	3.9	500	C.S	14.3	14.3	14.4
250	M.S	17.8	17.8	21.7	250	M.S	23	23	37.4
125	F.S	59.9	59.9	81.5	125	F.S	50.2	50.2	87.6
63	V.F.S	14.2	14.2	95.8	63	V.F.S	8.6	8.6	96.2
Pan	Silt & Clay	4	4	99.8	Pan	Silt & Clay	3.4	3.4	99.6
Sample KBS-42					Sample KBS-44				
Weight					Weight				
Phi Value	Grain Size	Weight	Weight %	Cumulative %	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0.4	0.4	0.4	2	Granular	0	0	0
1	V.C.S	3.2	3.2	3.6	1	V.C.S	0	0	0

500	C.S	8.5	8.5	12.1	500	C.S	9.5	9.5	9.5
250	M.S	29.9	29.9	42.1	250	M.S	19.6	19.6	29.1
125	F.S	45.5	45.5	87.6	125	F.S	59.8	59.8	88.9
63	V.F.S	8.3	8.3	95.9	63	V.F.S	7.8	7.8	96.7
Pan	Silt & Clay	3.9	3.9	98.8	Pan	Silt & Clay	3.2	3.2	99.9
Sample KBS-50					Sample KBS-51				
Weight					Weight				
Phi Value	Grain Size	Weight	Weight %	Cumulative %	phi value	Grain Size	Weight	Weight %	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0	0	0	1	V.C.S	0.5	0.5	0.5
500	C.S	6.9	6.9	6.9	500	C.S	7.8	7.8	8.3
250	M.S	10	10	16.8	250	M.S	49.3	49.3	57.6
125	F.S	18	18	34.9	125	F.S	26.7	26.7	84.3
63	V.F.S	49	49	83.9	63	V.F.S	8.9	8.9	93.2
Pan	Silt & Clay	15.3	15.3	99.2	Pan	Silt & Clay	6.5	6.5	99.7
Sample KBS-55					Sample KBS-56				
Weight					Weight				
Phi Value	Grain Size	Weight	Weight%	Cumulative %	phi value	Grain Size	Weight	Weight%	Cumulative%
2	Granular	0	0	0	2	Granular	1.4	1.4	1.4
1	V.C.S	0	0	0	1	V.C.S	10.3	10.3	11.7
500	C.S	14.9	14.9	15	500	C.S	25.4	25.4	37
250	M.S	25.6	25.6	40.6	250	M.S	29.3	29.6	66.4
125	F.S	31.5	31.5	72.1	125	F.S	21.6	6.6	87.9
63	V.F.S	13.9	13.9	86	63	V.F.S	6.6	6.6	94.6
Pan	Silt & Clay	13	13	99	Pan	Silt & Clay	4.9	4.9	99.4
Sample KBS-57					Sample KBS-59				
Weight					Weight				
Phi Value	Grain Size	Weight	Weight%	Cumulative %	phi value	Grain Size	Weight	Weight%	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0.4	0.4	0.4	1	V.C.S	0.1	0.1	0.1
500	C.S	4.6	4.6	5	500	C.S	8.2	8.2	8.3
250	M.S	24.4	24.4	29.4	250	M.S	14.6	14.6	22.9
125	F.S	46.4	46.4	75.7	125	F.S	51	51	73.9
63	V.F.S	19.1	19.1	94.9	63	V.F.S	16.2	16.2	90.1
Pan	Silt & Clay	5.1	5.1	99.9	Pan	Silt & Clay	9.4	9.4	99.5
Sample KBS-61					Sample KBS-63				
Weight					Weight				
Phi Value	Grain Size	Weight	Weight%	Cumulative %	phi value	Grain Size	Weight	Weight%	Cumulative%
2	Granular	0	0	0	2	Granular	0	0	0
1	V.C.S	0	0	0	1	V.C.S	0.1	0.1	0.1
500	C.S	20.9	20.9	20.9	500	C.S	21.7	21.7	21.8
250	M.S	26.6	26.6	47.5	250	M.S	26.8	26.8	48.6
125	F.S	29.7	29.7	77.3	125	F.S	30.9	30.9	79.5

63	V.F.S	12.1	12.1	89.4	63	V.F.S	11.3	11.3	90.8
pan	Silt & Clay	9.8	9.8	99.2	pan	Silt & Clay	8.2	8.2	99

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