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Textural Characteristics and Depositional Environment of a Late Quaternary Alluvial Plain of Haryana

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Abstract

The present study deals with the textural characteristics of the sediments from the exposed palaeochannel situated at Dhyangla village near Ladwa, district of Kurukshetra in north-western Haryana. It is a part of vast alluvial plains of India. Samples were taken from a 3 m thick exposed section. Grain size distribution and Palynofacies analyses of these sediments were carried out to study their textural parameters and the organic matter content respectively. Sediments are mostly fine to medium grained sand with silt percentage increasing upwards in the section. These sediments are mostly unimodal showing the grain size population controlled by a single type of grain size, mostly sand. Further the sand samples are moderately well sorted and mesokurtic in nature. Samples with silt are poorly sorted and leptokurtic with positive skewness, denoting those sediments have already sorted elsewhere in the high energy environment and are now transported and modified by the low energy environment. Palynofacies analysis also shows the presence of amorphous particles in the silt samples which indicate low energy environment of the sequence while presence of black debris in the sand samples indicates high energy depositions environment.

Keywords

Alluvial Plains, Palaeoenvironment, Palynofacies, Textural Analysis

1. Introduction

Long-standing research suggests that sediments produced under similar geological and environmental circumstances should have similar grain-size distribution characteristics [1]-[10]. Grain size distribution is helpful in determining the nature of parent rock and palaeoenvironmental conditions. As a result, examination of palaeochannel sediments can provide insight into the general hydrodynamic environment at the deposition site.

Great alluvial plains, also known as the Indo-Gangetic plains of India are formed from the Himalayan Rivers. These rivers have carried ample amounts of sediments from the Himalaya and deposited in the Indian foreland basin. Northwest-Southeast running Aravalli-Delhi Ridge divides the alluvial plains into two drainage basins. Sindhu, Beas, Sutlej, Ravi, Chenab, and Jhelum feed the western half of the plains, whereas the Ganga-Brahmaputra drainage system feeds the eastern part of the interfluves, for approximately 20 million years.

The Himalayan Mountains have been regularly supplying sediment to this foreland river basin similar to the present-day river systems as testified by the existence of a network of buried palaeochannels [11] [12] [13] [14] [15]. The current study focuses on characterization of the sediments of a palaeochannel of Quaternary alluvial plains of Haryana, which serves as good archives for understanding the role of earth surface processes. In the above research, the depositional environment is inferred from the grain-size variation of the sediments from a palaeochannel. To get a sense of the depositional environment, the quantitative variables of each litho-unit in the section, coupled with the sedimentary texture and structure, have been worked out from the part of the vast alluvial plain of north western India. The area under study is a site of deposition of several Himalayan rivers and the spatiotemporal changes of the palaeochannel that endured can address palaeoenvironment of the region. One of the proxy indices that can be used to reveal depositional events and, consequently historical climatic fluctuations, is the analysis of grain-size distribution. The characteristics of the sediment, depositional environment and energy conditions are discussed in this work.

2. Geomorphology and Geology of the Area

Haryana has a typical morphometric position in the Indo-Gangetic alluvial plains. It is bounded by the Himalayan foothills in the north, and is bounded with the Yamuna River in the east, the vast Thar Desert in west and the degraded Aravalli hills in the south. Its natural drainage system is not much developed. Streams flowing in Haryana are Markanda, Ghaggar, Sahibi, Krishnavati (Dohan), Yamuna, etc. (**Figure 1**). The Quaternary deposit comprises older fans and piedmont, central alluvial plains and younger alluvium overlying the basement rocks, ranging from Delhi Supergroup to the Siwalik Group [16]. The lithology of the study area comprises grey and micaceous sand and silty facies with ripple marks and planar laminations. Further, silty sand layers are intercalated with sand layers showing fluvial cycle influence in the palaeoriver channel [17].

3. Climate of the Area

The climatic condition is extremely hot during the summer season (May and June) and temperature remains at around 42˚C to 45˚C, whereas in winters the

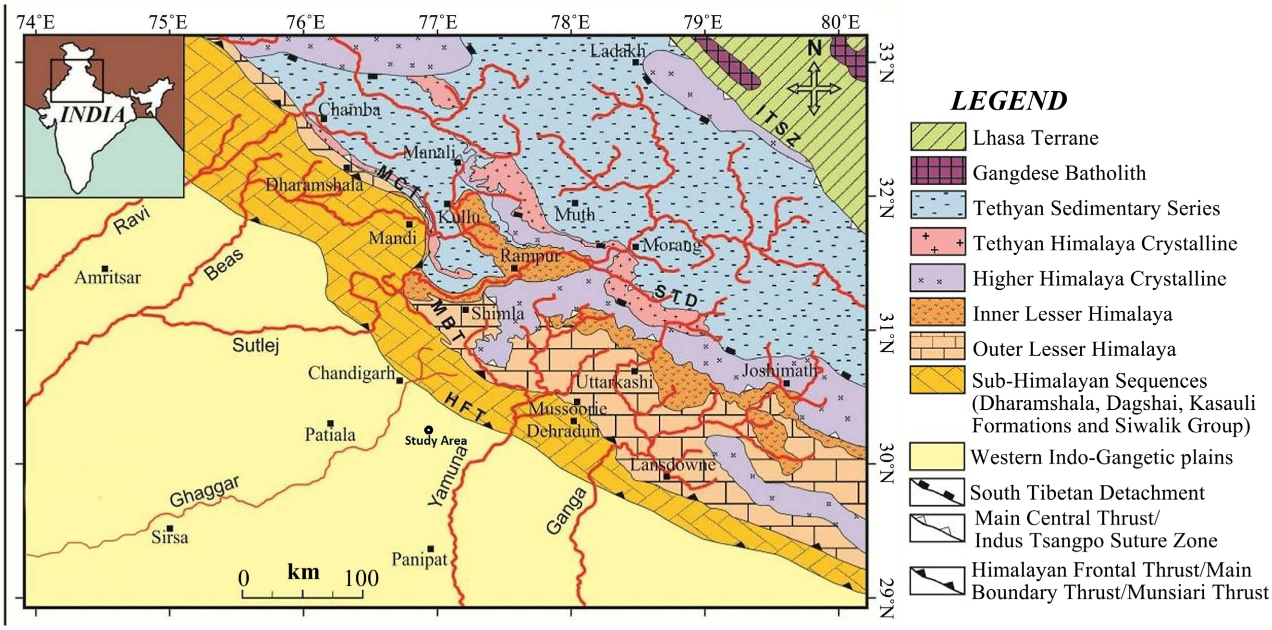

Figure 1. Simplified geological map of NW Himalaya along with major drainage and site Location DH. The map is taken from A. Singh *et al.* 2016 (based on the compilations taken from Webb *et al.*, (2011), Yin (2006), Vannay *et al.*, (2004), and Myrow *et al.*, (2015).

mercury drops to around 4˚C - 5˚C (December and January). Haryana gets maximum rainfall in the month of August followed by July (33% and 32% respectively). Overall, 82% of annual rainfall is received by the Indian Summer Monsoon (ISM) during June to September months and the remaining rainfall is received during the winter season extending from December to February months. The weather remains pleasant during spring and autumn.

4. Lithology of the Area

The palaeochannel section consists of the bands of sands from medium to very fine sand from bottom to top albeit the base was not exposed. On the basis of texture (grain size) and colour of the lithology, the sedimentary sequence of 3 m has been divided into 7 lithological zones from bottom to top (**Figure 2**). Top most part of the investigated section marks the presence of ancient pottery (approximately 30 cm from the top), mixed with black to light brown scree which indicates human inhabitation and considered as the cultural layer. The Dhyangla palaeochannel sediments are showing a fining upward sequence. Zone 7 and 5 of the section is medium sand with only 1% - 2% of silt. Zone-7 also has prominent ripple marks confirming that it is a palaeochannel of a flowing river. Zone 2, 4 and 6 has dominance of fine-grained sand (80% - 84%), silt (15% - 18%) and 1% - 2% of clay. Zone 1 and 3 has 70% - 75% of very fine-grained sand, silt (20% - 25%) and 3% - 5% of clay.

5. Materials and Methods

The study area lies about 23 kilometres east of Kurukshetra city towards Ladwa

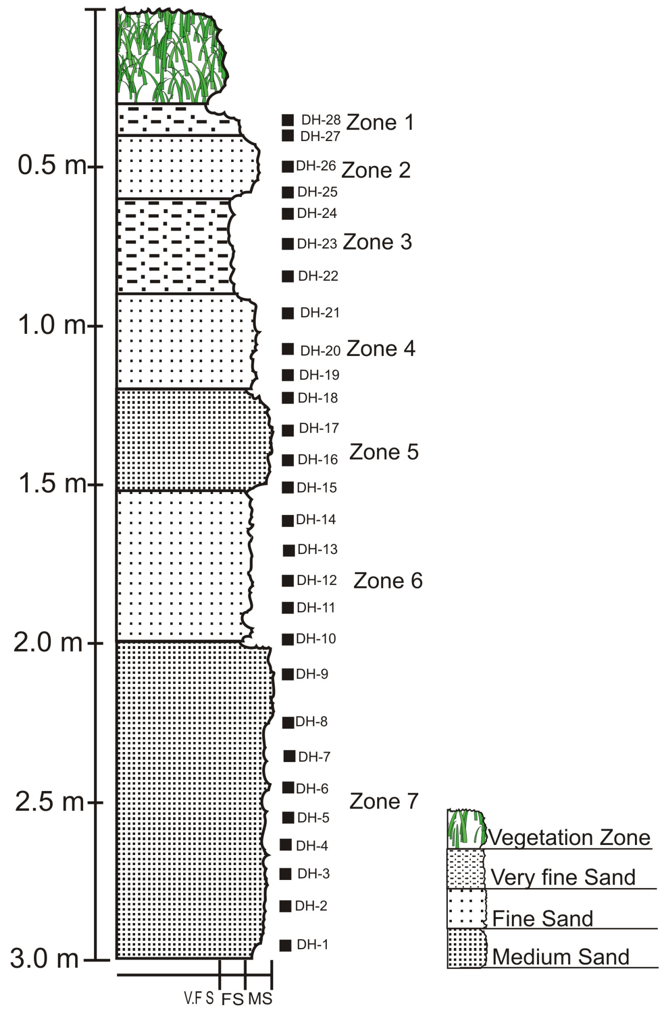

Figure 2. Lithology of the studied section.

in the Dhyangla village (**Figure 3**). The Kurukshetra is one of the religious cities of the country. The mythologically famous Mahabharata battle was also fought here. Besides, many historical and religious places are present in this city. The Dhyangla, in particular, is famous for its Shiv temple. The 3 meters thick exposed sedimentary section of a palaeochannel was systematically sampled. Scrapping of the exposed section was done to collect samples, leaving the uppermost 0.3 meters to minimize the anthropogenic and surface contamination. Sampling was done depending on the physical heterogeneity like grain size, compactness, colour and biological activity observed in the exposed section. Total 28 samples were taken out of which 12 representative samples were selected for textural analysis.

5.1. Textural Analyses

Regarding grain size assessment, 10 g of each sample was taken. In order to separate the grains from one another, coatings made of carbonate, organic carbon, and iron-manganese were removed using sodium acetate (1N), hydrogen peroxide

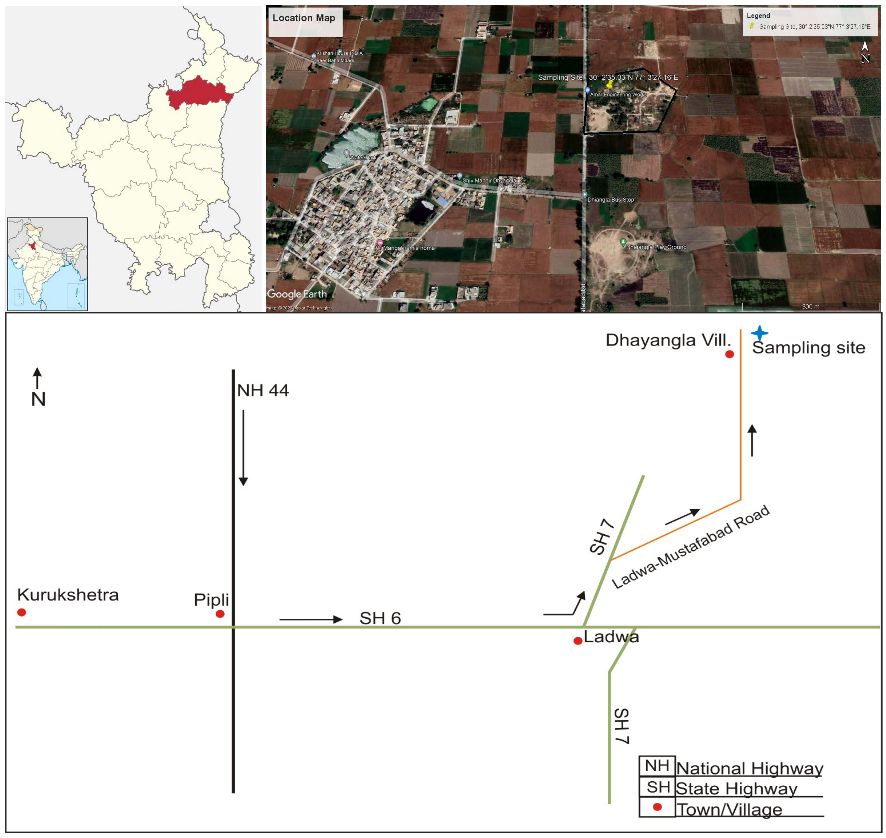

Figure 3. Location map of the sampling site (Map not to scale).

(30%), sodium citrate (0.3M), and a solution of sodium dithionite, respectively. By adding about 1 - 2 drops of the well-homogenized disaggregated sample, a laser particle size analyser (Beckman-Coulter LS 13 320) was employed to collect the grain-size data spanning from 0.04 to 2000 m.

5.2. Palynofacies

10 - 15 gm of each sample was taken in a plastic bottle and a few drops of water is added to moist the samples. The moist material is then treated with conc. HCL to remove the carbonate present. After treatment with HCL the sample is washed thoroughly and then treated with 40% HF to remove the silica content of the sample. Samples were again washed and sieved. The residue is then transferred to a watch glass and separated from the extra water. The suspended residues are then used to make permanent slides by using Poly Vinyl Alcohol and Canada Balsam.

6. Results and Discussion

Palaeochannel samples of alluvial plains show little variability in distribution of grain size in the studied section. Majority of samples lie in the sand fraction on the Gravel-Sand-Mud ratio diagram (**Figure 4**), while some samples are in muddy sand fraction, which clearly depicts river deposits. Another plot of Sand-Silt-Clay ratio (**Figure 5**) diagram showed equal distribution of the sand and silty-sand

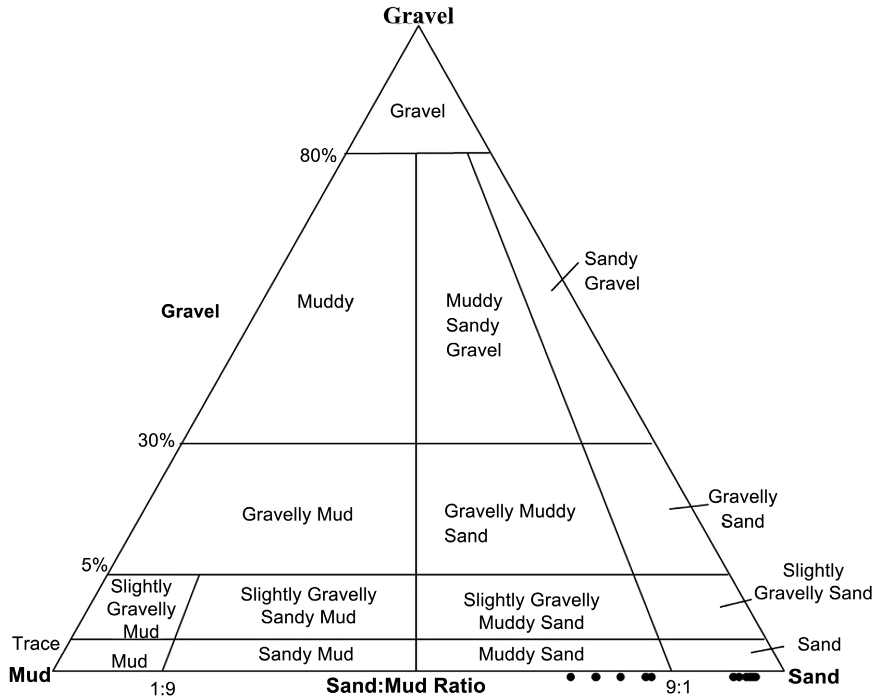

Figure 4. Gravel-Sand-Mud ratio diagrams, showing samples are in muddy sand fraction, depicting river deposits.

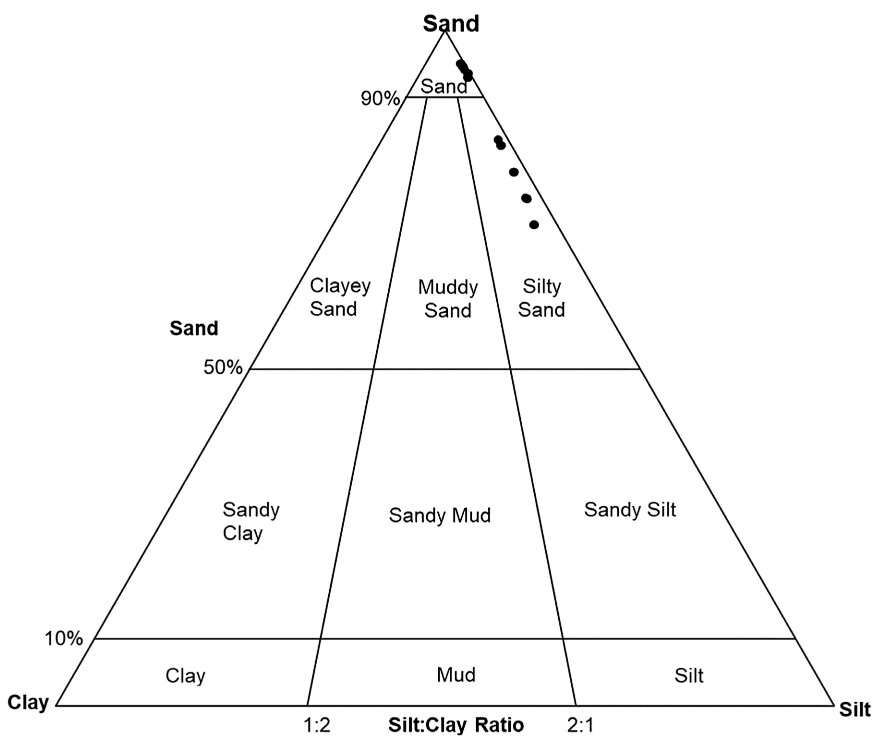

Figure 5. Sand-Silt-Clay ratio diagram showed equal distribution of the sand and silty-sand fraction.

fraction, which can be due to variation in energy at the time of deposition [18]. Sampled section is divided into 7 zones based on the values of weight percentage of sand, silt, and clay in the section. Samples from zones 7 and 5 show a higher percentage of sand fraction (95% - 97%) in which medium grained sand is present. Zone 6, 4 and 2 is typified by the presence of the fine-grained sand particles with 80% - 85% of sand and 13% - 17% of silt. Zone 1 and 3 marked the presence of clay size particles (2% - 3%) along with silt (20% - 25%) and very fine sand (73% - 77%). Dominance of sand throughout the section clearly showed the deposition by the river processes.

Variation in mean size of the particles could be seen from top to bottom in the zones (**Table 1**) Mean size varied from 1.6 Φ to 3.3 Φ in whole of the section marking the presence of medium size grain in zones 7 and 5 (1.6 Φ - 1.9 Φ), fine grain size particles in zone 6, 4 and 2 (2.1 Φ - 2.7 Φ) and very fine grain size particles in zone 1 and 3 (3.1 Φ - 3.3 Φ). Increasing the mean size of the particles from bottom to top exemplified the deposition energy of the river which decreased through the time.

Mode is the most frequently occurring particle diameter. It is useful to determine the genesis of sediment and mechanism of their transport. Present section shows the unimodal nature of sediments showing the deposition of the sediments by river.

The sorting/standard deviation values of sediment samples ranged between 0.8 Φ - 2.1 Φ, hence showing the moderately well sorted to very poorly sorted grains. Sorting evaluates how consistently the distribution of particle sizes and serves as a tool for depicting the depositional environment energy. Overall section has different sorting values; zones 7, 5 and 3 show moderately well to moderately sorted grains, attributing to the result of strong energy conditions of the deposition agent. Zones 6, 4, 2 and 1 have poorly sorted sediments and can be attributed to the hardly any grain sorting during transportation or deposition due to high variable energy or lack of constant energy input. Variation in the sorting values can be due to the difference in the velocity of the depositing current.

Table 1. Showing the different textural characteristics of the sediments.

Sample No.	Sorting	Skewness	Kurtosis	Mean	% Sand	% Silt	% Clay
DH-1	0.8	−0.002	1.0	1.978	96.5	3.0	0.5
DH-3	0.9	0.076	1.2	1.847	95.7	3.8	0.5
DH-6	0.9	−0.073	1.0	1.978	96.1	3.5	0.4
DH-8	1.0	0.187	1.1	1.611	95.3	4.4	0.3
DH-11	0.7	0.016	1.3	2.137	96.3	3.2	0.5
DH-15	1.3	0.285	1.5	2.727	84.3	14.4	1.3
DH-18	0.9	0.072	1.3	1.944	95.0	4.4	0.6
DH-20	1.8	0.642	1.9	2.764	79.3	19.0	1.7
DH-22	2.1	0.527	1.3	3.367	70.0	27.0	3.0
DH-24	1.8	0.390	1.5	3.115	74.8	23.2	2.0
DH-27	1.5	0.331	1.7	2.584	83.4	15.2	1.4
DH-28	1.8	0.541	1.7	3.251	74.7	23.1	2.2

Asymmetry of the grain distribution can be measured by the skewness. Skewness helps in distinguishing different sedimentary environments [19] [20]. It acts as an indicator of mixing of sub-populations of grains [6]. Moreover, it can also talk about environmental energy [21]. Lower part of the section *i.e.*, zones 7, 6 and 5 have skewness values in order of −0.07 Φ to 0.1 Φ. Negative value of skewness indicates the presence of medium grained particles with high energy of the deposition agent. However, the value of skewness got positive along the upper part of the section *i.e.*, in zones 4, 3, 2 and 1, ranging from 0.2 Φ to 0.5 Φ indicating fine grained sediments and lower energy conditions.

In a high energy environment, a qualitative estimate of the portion of sediments that have previously been sorted elsewhere, after that transported and altered by a different environment is the graphic kurtosis value of the sediments [19]. Value of kurtosis for the present study varies from 1.0 Φ to 1.7 Φ showing the nature of sediments from mesokurtic to very leptokurtic. Zone 7 had sediments of mesokurtic nature depicting that good sorting of sediments was achieved in a high energy environment. While the rest of the zones showed leptokurtic to very leptokurtic nature of the sediments. The very leptokurtic nature of the sediments specified that sediments of the principal population of grains with lesser amounts of finer and coarser materials [6]. Leptokurtosis is also a sign of variable energy conditions prevailing in the environmental arrangement for deposition of the sediments. Further, positive leptokurtic character of the sediments typified the concentration of finer grained sediments showing the fluctuated energy conditions during deposition of the sediments [7]. High concentration of the fine-grained particles in the section indicated the low to moderate energy of the deposition environment [22].

Palynofacies results are plotted on the graph (**Figure 6**), which reveals that the plant derived Dispersed Organic Matter in the present samples are classifiable into Amorphous Organic Matter, Phytoclasts, Opaque Phytoclasts, Fungal Remains and Palynomorphs (**Figure 7**). [23] Amorphous Organic Matter is in abundance in samples with sand percentage < 80% and opaque particles are more

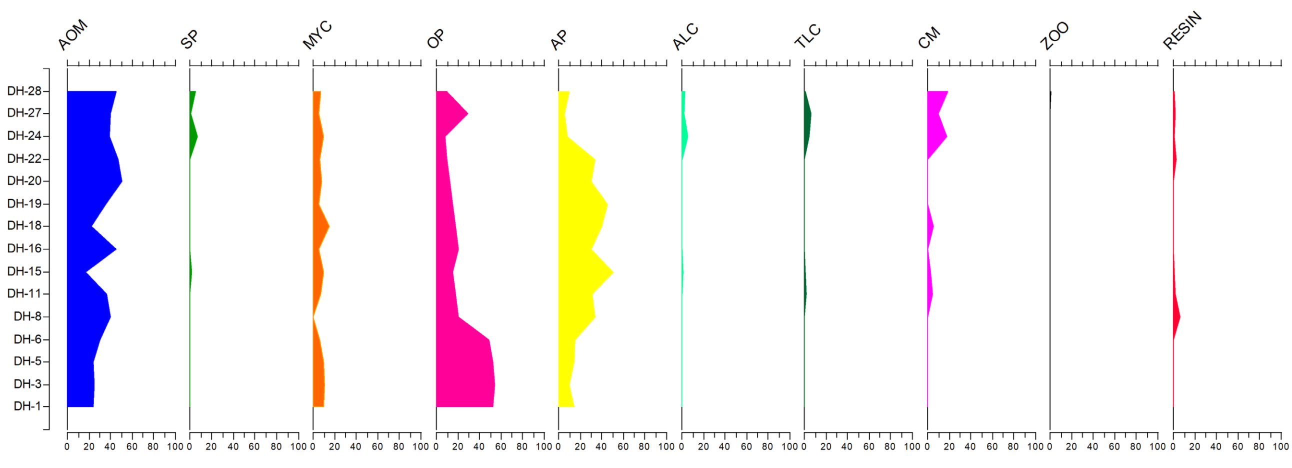

Figure 6. Palynofacies diagram showing the different variations of various organic matter particles present in the sediments.

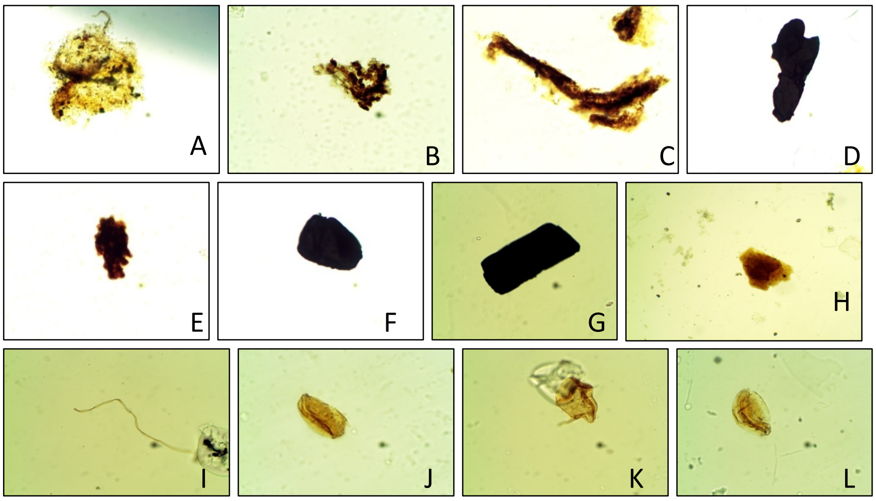

Figure 7. Amorphous organic matter (A & H); biodegradable (B, C, E); Black Debris (D, F, G); Algal remain (I); Spore-pollen (J, K, L).

in the samples with sand percentage > 80%. 5% - 15% of Fungal remains are also present in the sequence.

7. Depositional Environment

Scatter graphs or bivariate plots of grain size data is widely used to differentiate depositional settings. Figure 8 presenting mean grain size and sorting relationship depicts that very fine grained to fine grained sediments are mostly poorly sorted. Many studies have concluded that fine sands are better sorted [19]. It is also explained in many studies that the best sorted sediments are those of the fine sand size range in practically all sedimentary environments, and both mean size and sorting are controlled hydraulically [24] [25]. Analyses of present study showed opposite nature of sediments as poorly sorted sediments are those of fine grained to very-fine grained type. The contradictory results can be the result of numerous manners of transport (creep, saltation, and suspension) which can be due to fluctuating environmental energy conditions of the sediments leading to poorly sorted sediments [26].

Figure 9 is the bivariate plot between skewness and mean. Poorly sorted sediments were symmetrical, fine skewed or very fine skewed. River sediments are positively skewed [27] [28] and positive skewness is a result of the unidirectional sediment transport [29]. Negative to positive shift in the skewness is due to the dominance of fine-grained sediments in the upper part of the section, which are poorly sorted.

Figure 10 is the bivariate plot of kurtosis and mean, laying out evidence about origin of the sediments, by evaluating the gradation of normality of its size dispersal [2]. Kurtosis and mean scatter plot for this study showed that positively skewed sediments attain leptokurtic to very leptokurtic nature while symmetrical and less negative sediments are mesokurtic. Mesokurtic nature denotes those sediments have gained good sorting in the high energy environment. Leptokurtic

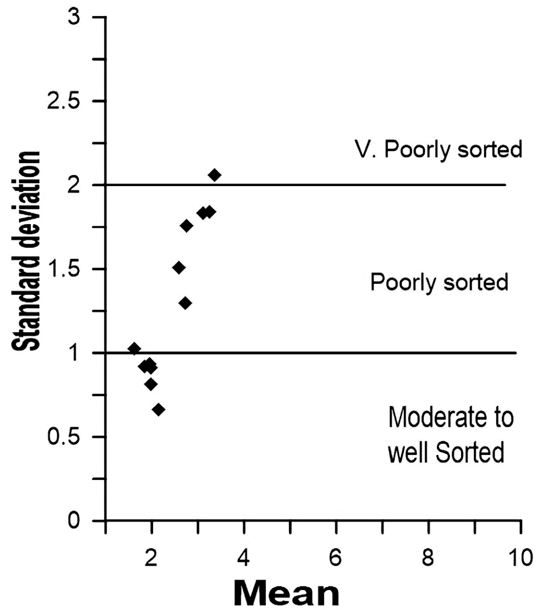

Figure 8. Presenting mean grain size and sorting relationship depicting that very fine grained to fine grained sediments are mostly poorly sorted.

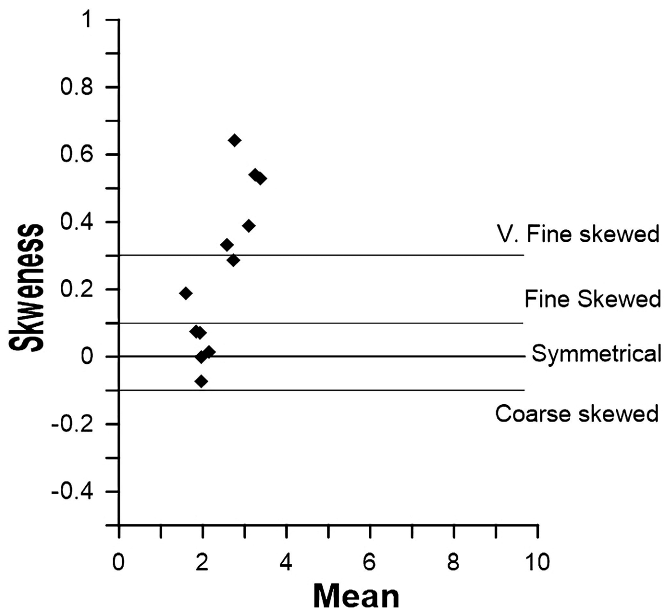

Figure 9. Bivariate plot between mean and skewness.

nature of the sediments results from fluctuated energy conditions in the deposition of the sediments [7].

Palynofacies results also coincide with the results of textural analysis of the samples. It is observed that Sandy layers in the channel fill show dominance of the Opaque Phytoclasts and indicates high energy fluvial environment and oxidising conditions during its deposition whereas silty strata documented the dominance of Amorphous Organic Matter, deposited in quiet and low energy environments and indicate reducing conditions [30] [31].

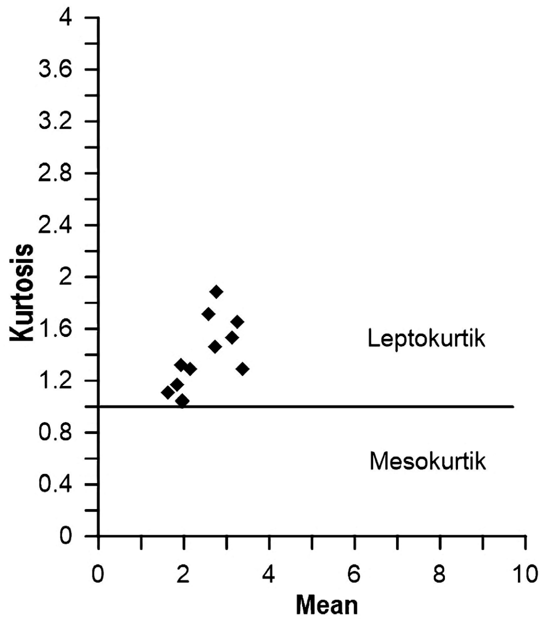

Figure 10. Bivariate plot between kurtosis and mean.

Considerable amount of algal remains in the channel shows aquatic fresh water conditions during the deposition of the above river channel.

8. Conclusion

Textural characteristics of sediments from exposed palaeochannel from Dhyangla village show a fining upward sequence in the section typifying the energy conditions which are decreasing upward in the section. Most of the fine-grained sediments are positively skewed and coarse-grained sediments are negatively skewed, indicating relatively calm and decreasing energy conditions. Value of sorting is increasing upward in the sequence depicting various modes of transport with fluctuating energy conditions which are gradually decreasing. Kurtosis value for the sedimentary sequence changes from mesokurtic to leptokurtic, again pointing towards the decreasing energy conditions of the river. Same results are also depicted by the Palynofacies as the amount of Amorphous organic Matter is increasing upwards in the sequence. Depositional environment shows that the channel has gradually changed from a high energy environment to a low energy environment with the passage of time.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Bagnold, R.A. and Barndorff-Nielsen, O. (1980) The Pattern of Natural Size Distributions. *Sedimentology*, **27**, 199-207.
https://doi.org/10.1111/j.1365-3091.1980.tb01170.x

[2] Folk, R.L. (1966) A Review of Grain-Size Parameters. *Sedimentology*, **6**, 73-93. https://doi.org/10.1111/j.1365-3091.1966.tb01572.x

[3] Glaister, R.P. and Nelson, H.W. (1974) Grain-Size Distributions, an Aid in Facies Identification. *Bulletin of Canadian Petroleum Geology*, **22**, 203-240.

[4] Hakanson, L. and Jansson, M. (1983) Principles of Lake Sedimentology. Vol. 316, Springer-Verlag, Berlin. https://doi.org/10.1007/978-3-642-69274-1

[5] Inman, D.L. and Chamberlain, T.K. (1955) Particle-Size Distribution in Nearshore Sediments. In: Hough, J.L. and Menard, H.W., Eds., *Finding Ancient Shorelines*, SEPM Society for Sedimentary Geology, Tulsa.

[6] Mason, C.C. and Folk, R.L. (1958) Differentiation of Beach, Dune, and Aeolian Flat Environments by Size Analysis, Mustang Island, Texas. *Journal of Sedimentary Research*, **28**, 211-226. https://doi.org/10.1306/74D707B3-2B21-11D7-8648000102C1865D

[7] Prabhakara Rao, A. (2001) Grain Size Parameters in the Interpretation of Depositional Environments of Coastal Sediments between Bendi Creek and Vamsadhara River, East Coast, India. *Journal of the Indian Association of Sedimentologists*, **20**, 106-116.

[8] Reineck, H.E. and Singh, I.B. (2012) Depositional Sedimentary Environments: With Reference to Terrigenous Clastics. Springer Science & Business Media, Berlin.

[9] Udden, J.A. (1914) Mechanical Composition of Clastic Sediments. *Bulletin of the Geological Society of America*, **25**, 655-744. https://doi.org/10.1130/GSAB-25-655

[10] Visher, G.S. (1969) Grain Size Distributions and Depositional Processes. *Journal of Sedimentary Research*, **39**, 1074-1106. https://doi.org/10.1306/74D71D9D-2B21-11D7-8648000102C1865D

[11] Chaudhri, A.R. (2021) Saraswati River in Northern India (Haryana) and Its Role in Populating the Harappan Civilization Sites—A Study Based on Remote Sensing, Sedimentology, and Strata Chronology. *Archeological Prospection*, **28**, 565-582. https://doi.org/10.1002/arp.1829

[12] Sinha, R., Tandon, S.K., Gibling, M.R., Bhattacharjee, P.S. and Dasgupta, A.S. (2005) Late Quaternary Geology and Alluvial Stratigraphy of the Ganga Basin. *Himalayan Geology*, **26**, 223-240.

[13] Valdiya, K.S. (2016) Prehistoric River Saraswati: Geological Appraisal and Social Aspects. Springer, Berlin, 136. https://doi.org/10.1007/978-3-319-44224-2

[14] Valdiya, K.S. (2002) Saraswati: The River That Disappeared. Universities Press, Hyderabad.

[15] Yashpal, S.B., Sood, R.K. and Agrawal, D.P. (1980) Remote Sensing of the Lost Saraswati River. *Earth*, *Planets and Space*, **89**, 317-331.

[16] Thussu, J.L. (1995) Quaternary Stratigraphy and Sedimentation of the Indo-Gangetic Plains, Haryana. *Journal of the Geological Society of India*, **46**, 533-543.

[17] Thussu, J.L. and Chopra, S.C. (1991) Compilation of Quadrangle Maps of Haryana. *Records of the Geological Survey of India*, **128**, 1-3.

[18] Lindhlom, R.C. (1987) A Practical Approach to Sedimentology. Springer, Berlin, 276. https://doi.org/10.1007/978-94-011-7683-5

[19] Folk, R.L. and Ward, W.C. (1957) Brazos River Bar: A Study in the Significance of the Grain Size Parameters. *Journal of Sedimentary Research*, **27**, 3-26. https://doi.org/10.1306/74D70646-2B21-11D7-8648000102C1865D

[20] Mahender, K. and Banerji, R.K. (1989) Textural Study and Depositional Environ-

ment of Sand Grains from Rocks of Jaisalmer Formation, Jaisalmer District, Rajasthan, India. *Journal of the Geological Society of India*, **33**, 228-242.

[21] Duane, D.B. (1964) Significance of Skewness in Recent Sediments, Western Pamlico Sound, North Carolina. *Journal of Sedimentary Research*, **34**, 864-874. https://doi.org/10.1306/74D711B8-2B21-11D7-8648000102C1865D

[22] Leeder, M.R. (1982) Sedimentology. George Allen & Unwin Pub. Ltd., London.

[23] Tyson, R.V. (1987) The Genesis and Palynofacies Characteristics of Marine Petroleum Source Rocks. In: Brooks, J. and Fleet, A.J., Eds., *Marine Petroleum Source Cocks*, Special Publications, No. 26, Geological Society, London, 47-67. https://doi.org/10.1144/GSL.SP.1987.026.01.03

[24] Griffiths, J.C. (1967) Scientific Methods in the Analysis of Sediments. 508.

[25] Rajganapathi, V.C., Jitheshkumar, N., Sundararajan, M., Bhat, K.H. and Velusamy, S. (2012) Grain Size Analysis and Characterization of Sedimentary Environment along Thiruchendur Coast, Tamilnadu, India. *Arabian Journal of Geosciences*, **6**, 4717-4728.

[26] Angusamy, N.G. and Rajamanickam, V. (2007) Coastal Processes of Central Tamil Nadu, India: Clues from Grain Size Studies. *Oceanologia*, **49**, 41-57.

[27] Friedman, G.M. (1961) Distinction between Dune, Beach, and River Sands from Their Textural Characteristics. *Journal of Sedimentary Research*, **31**, 514-529. https://doi.org/10.1306/74D70BCD-2B21-11D7-8648000102C1865D

[28] McLaren, P. (1981) An Interpretation of Trends in Grain Size Measures. *Journal of Sedimentary Research*, **51**, 611-624. https://doi.org/10.1306/212F7CF2-2B24-11D7-8648000102C1865D

[29] Martin, P.L.C. (1965) The Contribution of Sedimentology to Hydrography in the Study of Coast and Estuary Changes. *The International Hydrographic Review*, **42**, 160-171

[30] Traverse, A. (1994) Sedimentation of Organic Particles. Cambridge University Press, Cambridge, 1-544. https://doi.org/10.1017/CBO9780511524875

[31] Tyson, R.V. (1993) Palynofacies Analysis. In: Jenkins, D.J., Ed., *Applied Micropalaeontology*, Kluwer Academic Publishers, Dordrecht, 153-191. https://doi.org/10.1007/978-94-017-0763-3_5