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SIGNIFICANCE OF GRAIN - SIZE (MOMENT) STATISTICS IN THE INTERPRETATION OF DEPOSITIONAL ENVIRONMENT OF JAISALMER SANDS, WESTERN INDIA

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Abstract : A detailed study of Jaisalmer (Middle Jurassic) Formation in Western India was undertaken to describe their sedimentologic texture and using some of the available techniques of environments and transportation mechanisms. This study suggests that these sands are mostly fluvial transported mainly by saltation and suspension processes and deposited in a nearshore beach to shallow marine environment.

INTRODUCTION

Interpretation of sedimentary environments using univariate, bivariate and multivariant plots of statistical grain-size parameters has been employed on recent and ancient sediments. (Mason and Folk, 1958; Friedman, 1961, 67; stewart, 1958; Passega, 1964; and Moiola and Weiser, 1968). The purpose of this contribution, is to describe the Jaisalmer grain-size textures based on univariate, bivariate and multivariate parameter combinations and to determine their depositional environments. The signifcance of moment statistics over graphic parameters and their utilization in interpreting depositional environment is also considered. The area has been investigated in the past by various researchers. (Dasgupta, 1975; Kalia et al 1983). The sedimentologic nature of the coarse clastics of the Jaisalmer Formation has been carried out by Mahender et al (1989). In their study, the interpretation of depositional environment of these sands has been made based exclusively on graphic grain-size parameters calculated using Folk and Ward (1957) formulae. The present paper provides an additional data on grain-size parameters of Jaisalmer Formation, calculated by moment measures and their use in the interpretation of environment. The graphic parameters of the earlier work have also been used in the present study for comparison purposes. The general lithology and stratigraphy of the area has been presented in Table 1.

PROCEDURE

In all a total of 43 samples have been analyzed for the grain-size, which are collected from various outcrops in the study area (Fig 1). About 600 grains from each samples (acid digested) are used for the present study. The largest and smallest diameters of each grain have been measured to determine the grain size using the following formulae

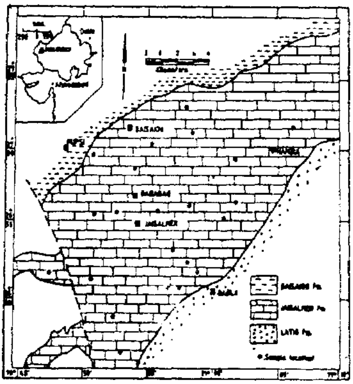

Fig. 1 Geological map of Jaisalmer showing sample locations.

$$\text{Size} = \sqrt{\frac{d_1 \times d_s}{m}}$$

where d_1 is the largest diameter, d_s is the smallest diameter and m is the magnification The various size parameters for the 43 samples analyzed by grain projections have been computed using moment statistics following the procedure of Griffith's (1981) The data is presented in Table 2

DISCUSSION

Log Probability Grain - Size Plots : Many workers have contributed towards the interpretation of grain size distributions. When plotted on log–probability paper, grain-size frequency data of most sand-size populations deviate from normality. The result is multi-segmented curves which have been interpreted by some researchers as resulting from a mixture of two or more overlapping log-normal populations (Spencer, 1963; Tanner, 1958). Visher (1969) in his work on the size distributions of modern sands and their relationship with ancient sands and their depositional processes has shown that most distributions comprise one or more sub-populations, each of which displays a log-normal distributions. These straight line segments of the log normal plots representing truncated log–normal populations corresponding to the grain sub-populations which are transported by traction, saltation and suspension. The number, amount, size range and mixing of the populations vary in relation to provenance, sedimentary processes and sedimentary dynamics. A number of processes may be uniquely defined in log-normal probability curves, and on this basis Visher (1969) has assigned specific curve shapes to the sands formed in various recent environments, i e., channel, deltaic, dune, eolian fluvial, wave and turbidity current. This approach provides a genetic and fundamental basis for interpreting grain size distributions, and therefore, the grain size curves of the Jaisalmer sands have been interpreted in the light of Visher s (1969) results. A few selected log probability plots have been presented in Fig. 2.

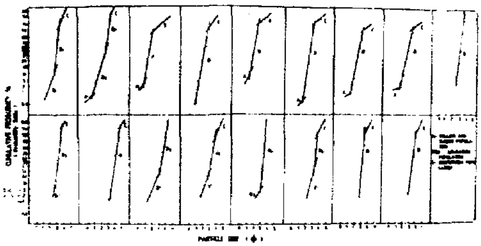

FIG. 2 LOG-PROBABILITY CUMULATIVE-FREQUENCY CURVES OF JAISALMER SAND CONSISTING OF STRAIGHT LINE SEGMENTS (AFTER G.S. VISHER 1969)

These plots show that saltation and suspension sub populations dominate the size populations of distribution, although a few of them also reflect the presence of population belonging to the third mode of sub-population, traction mode.

The saltation sub-population comprises between 85-90 percent of the total grain size distribution. The suspension population comprises 4-10% of the total distribution The truncation points between i) traction and saltation and ii) saltation and suspension are variable but generally occur in the range of 1 to 2 and 2 5 to 4.0 respectively. A few samples contain a very small percentage of the third mode, the traction subpopulation, which rarely exceeds 5 percent of the total distribution. The size range in the saltation population strongly suggests a slope for sorting intermediate between deposits formed by suspension and those produced by waves or oscillatory currents. The presence of this suspension sub-populations and the truncation of the coarse population (saltation) can be interpreted as indicative of a positive skewness (also shown in Table 2 are the calculated skewness values). The presence of varying amounts of suspension sub population in the present samples probably indicates the influence of diverse fluvial transports. The size distributions of the present Jaisalmer samples, represented in Fig. 2, show some fundamental similarities with those presented by Visher (1969). Nearly all localities yield typical fluvial type size distributions, showing only two main size sub populations i.e. saltation and suspension. Similar fluvial transportation of these samples has been interpreted, based on shape and roundness studies (Mahender et al, 1989).

Univariate Parameters : The statistical parameters of grain size frequency distribution have been employed as parameters for delineating the influences of transportation processes and depositional mechanisms (Friedman, 1961; 1967; Folk, 1966). In particular standard deviation and skewness are considered to be environmentally sensitive indicators while the mean grain-size is a reflection of the overall compentency of the transportational dynamic system. Fig. 3 shows the variation of these parameters in vertical section of the Jaisalmer Formations. The following is a summary of the behaviour of these textural parameters within the area

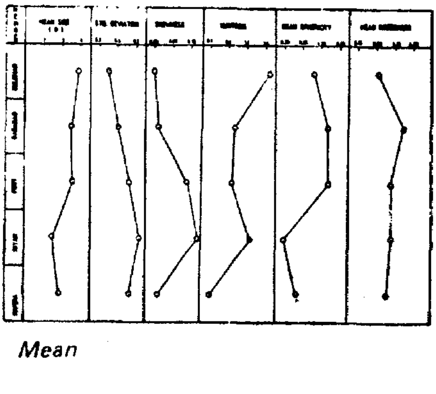

Fig. 3 Vertical textural variation within the Jaisalmer Formation.

Mean

A marked bimodality in mean grain - size exists between members. Although there is an apparent homogenity of Mz in each member, the uppermost samples of each unit show a coarsening upward trend. This could be attributed to the winnowing of the finer grain - size populations by wave and current actions in near shore environments as proposed by Mason and Folk (1958), Friedman (1961, 1962, 1967) and Duane (1964). The changes in mean grain - size between various members is artributed to changes within the depositional environment whereby truncation is due to channelized eroding currents probably tidal in nature. A bimodality of grain - size in the area is readily observed from of the frequency distribution curves as shown in Fig. 3. This feature has been commonly recognized in beach foreshore sediments where differentiation in sorting is produced by swash and backwash currents.

Standard Deviation : Standard deviation values fall in the range (0. 2435 - 0.7818) which according to the nomenclature of Friedman (1962) fit into the category of very well sorted to moderately sorted sands. The upper three members have the low standard deviation value as compared to the lower two members. As a whole there is a gradual decrease in the standard deviation value from base to top of the formation (Fig. 3) indicating a gradual change in the energy conditions of the depositional area.

Skewness : The skewness variation can be readily explained by the presence of sand in the coarse and fine tails of the distribution. The skewness value fluctuates between negative to positive value indicating the presence of both finer and coarser fractions. The marked negative skewness as observed in some samples relates to the presence of small amounts of coarser sands, whereas, the skewness values close to zero reflect the broader spectrum of populations present in these members. The general upward trend of skewness values could be a result of increasing fine - grained sand populations.

Kurtosis : Kurtosis values shown in Table 2 fluctuate erratically around a central value of 1 with Leptokurtic sands dominating the upper unit. Friedman (1962) points out that most sands are leptokurtic, a fact interpreted by Mason and Folk (1958) as resulting from mixing of predominant population with very minor amount of finer gravel material. In general the present samples collected from Jaisalmer area vary from platykurtic to leptokurtic nature.

Bivariant Grain - Size Parameters : Various researchers have used scatter plots of grain size parameters to differentiate depositional environments. Friedman (1961, 1967) has used scatter plots of moment measures to differentiate between river and beach sands. On the basis of his studies, Friedman established that among all statistical parameters either mean cubed deviation or standard deviation about the mean is most effective parameter for separating sands of various origins. Moiola and Weiser (1968) showed many scatter plots to distinguish between modern beach, dune (inland and coastal), and river sands. Their figures reflect a combination of mean diameter versus standard deviation and are considered to be the most effective in differentiating between river and beach sands, and coastal and dune and rivers sands. Since differences between the graphic parameters are relatively small (Folk and Ward, 1957), the environmental boundaries of Friedman (1961, 1967) and those of Moiola and Weiser (1968) are perhaps the best tools to use for differentiating the depositional environments represented by Jaisalmer sands.

Folk and Ward (1957) indicated that the graphic parameters provide good approximations of the moment parameters. This was tested on a few Jaisalmer samples and the difference between these parameters appeared negligible. However, Friedman's (1961, 1967) discriminating boundaries, which are based on moment summation calculations, can be applied to the present graphic bivariant figures. The plotting of mean size versus standard deviation provides an effective means to differentiate among river, dune and beach sands. In the present study, the various bivariate plots have been used which include i) Standard deviation vs. Mean size (Fig. 4), ii) Standard deviation vs. Skewness (Fig. 5) and iii) Mean size vs. Skewness (Fig. 6). and iv) Standard deviation vs. Third moment (Fig. 7).

Fig. 5 Bivariate plot, standard deviation vs. skewness.

Fig. 6 Bivariate plot, Mean grain-size vs. skewness.

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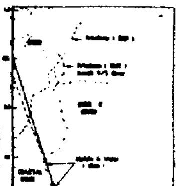

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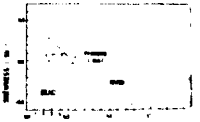

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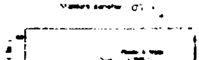

Fig. 4 The Bivariate parameters (vs. Mz) of the Jaisalmer sand examined against the r produced boundary lines of Friedman (1961, 67) and Moiola and Weiser (1968)

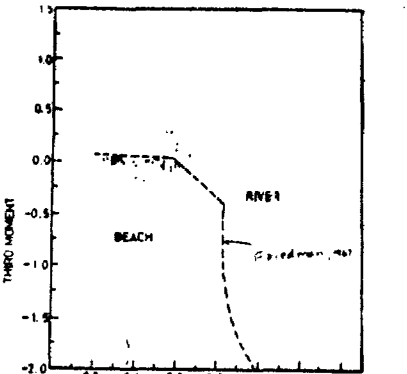

FIG.7. SCATTER PLOT, STANDARD DEVIATION VERSUS THIRD MOMENT (AFTER G.M.FRIEDMAN, 1967)

In the Fig. 4 the bivariant parameters ($\sigma 1$ vs. Mz) of Jaisalmer samples have plotted and examined against the reproduced boundary lines of Friedman (1961, 1967) and Moiola and Weiser (1968). From the Fig. 4, a discrepancy has been observed and that discrepancy in interpretation deduced from the bivariant analysis of the Jaisalmer samples, using the discriminate field of Friedman (1961, 1967) and Moiola and Weiser (1968) and is perhaps due to various considerations. The foremost among them is the consideration that the discriminatory field of dune, river, etc, formulated by these authors appear to be based primarily on assumptions. Moreover, it may also be noted that only a limited number of samples, derived from a limited number of environments, have been examined to deduce conclusions pertaining to their discriminate fields. The regional variations in grain size, climate, sedimentation rate, and relative energy conditions within final environments (Amaral and Pryor, 1977) seem to have been ignored. Thus, the present samples for providing additional evidence on depositional environments have plotted on Sahu's (1983) multigroup discriminatory plot using all grain-size statistics together (Fig. 8). Figs. 5 and 6 based on bivariate parameters show the dominant beach environment of sands. The multigroup discriminatory plot using all the grain-size parameters suggest a beach to shallow marine environment. The presence of dune environment is also shown by some samples.

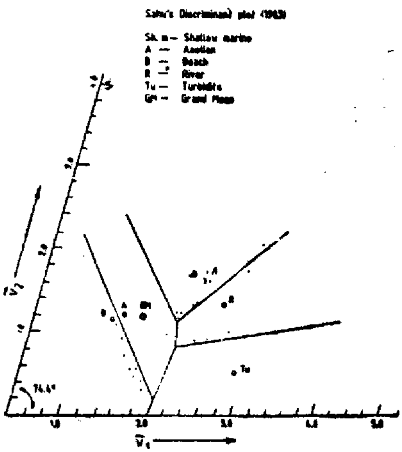

Fig. 8 Multigroup discriminant plot using for size statistics (Sahu, 1983)

CONCLUSIONS

The present study shows that different physical characteristics of sediments may provide important clues to understanding the environments of their deposition and transportational mechanisms. The present Jaisalmer samples have been interpreted upon the evidences provided particularly by the grain - size distribution curves and the univariant bivariant and the multivariant grain - size parameter combinations. All these parameters show dominant fluvial transportation and deposition in a nearshore probably beach to shallow marine environment of these sands belonging to Jaisalmer Formation. However, there has been observed a change in Mz, σ 1, Sk and K_G values from base to the top of the formation. This variation is an indicative of change in the energy conditions of the different way in having the fine grained, illsorted to moderately sorted sands. This could be due to development of lagnoonal conditions as evidenced by the presence of evaporites. In general the Jaisalmer sands, as s whole, represent a beach to shallow marine environment of deposition after a fluvial transportation. The fluvial nature of the deposits is evident from their grain - size distributions, which show saltation and suspension as the major means of transportation. The bimodality to polymodality is indicative of two or more sources of sdiment supply.

REFERENCES

Amaral, E. J. and Pryor, W. A. 1977. Depositional environment of St. Peter Sandstone deduced by textural analysis. *J. Sediment. Petrol.* V. 47, pp. 32-52.

Duane, D. B. 1964. Significance of skewness in Recent sediment, Western Pamlico sound, North Carolina. *Jour Sed. Petrol,* V. 34, pp. 864-874.

Folk, R. L. 1966. A review of grain size parameters, *Sedimentology,* V. 6, pp. 73-93.

Folk, R. L. and Ward, W. C. 1957. Brazos river bar; a study in the significance of grain size parameters. *J. Sediment. Petrol.* V. 27, pp. 3-26.

Friedman, G. M. 1961. Distinction between dune, beach, and river sands from their textural characteristics. *J. Sediment. Petrol.* V. 31, pp 514-529.

Friedman, G. M. 1962. On sorting on-efficients and the lognormality of the grain size distribution of sandstones. *J. Geology*, V. 70, pp. 737-753.

Friedman, G. M. 1967. Dynamic processes and statistical parameters compared for size frequency distribution of beach and river sands. *J. Sediment. Petrol.* V. 37, pp 327-354.

Griffiths, J. C. 1957. *Scientific methods in analysis of sediments*, McGraw-Hills Book Co., 508 p.

Mahender, K. and Banerji, R. K. 1989. Textural study and depositional Environment of sand grains from rocks of Jaisalmer Formation. *J. Geological Society.* V.33, pp 228-242.

Mason, C. C. and Folk, R. L. 1958. Differentation of beach, dune and aeolian flat environments by size analysis. Mustang Island, Texas. *J. Sediment. Petrol.* V. 28, pp 211-216.

Moiola, R. J. and Weiser D. 1968. Textural parameters: an evaluation. *J Sediment Petrol.* V. 38, pp. 45-53.

Passega, R. 1964. Grain - size representation by C M patterns as a geological tool. *J Sediment. Petrol.* V. 34, pp. 840 - 847.

Sahu, B. K. 1983. Multigroup discrimination of depositional environments using size statistics. *Indian Earth Science* V. 10 (1), pp. 20 - 29.

Spencer, D. W. 1963. The interpretation of grain - size distribution curves of clastic sediments. *J. Sediment. Petrol.* V. 33, pp. 180 - 190.

Stewart, H. B. Jr. 1958. Sedimentary reflections on depositional enviroments in san Migue Lagoon, Baja California, Mexico. *Bull. Ame. Assoc. Petrol Geologists*, V. 42, pp. 2567 - 2618.

Tanner, W. F. 1958. The zig - zag nature of type 1 and type IV curves. *J Sediment. Petrol*, V. 28, pp. 372 - 375.

Visher, G. S. 1969. Grain - size distributions and depositional process. *J. Sediment. Petrol*, V. 39, pp. 1074 - 1106.

TABLE–1 : General Jurassic Stratigrapy of Jaisalmer

Age	Formation	Member	Lithology
Portlandian	Bhadasar (100 m.)	Mokal Kolar-Dungar	Hand argiliaceous sandstone with fossil wood, fish-teeh and ammounites, red gritty sandstone with clayey and calcareous intercalations with fossils.
Kimmeridgian	Baisakhi (250 m.)	Rupsi Ludharwa Baisakhi	Intercalated fine grained argillaceous sandstone and grey shales, hard argillaceous sandstone and grey to black shales, sandy siltstones, gypseous claystreaks carbonaceous bands and rare plant remains.
Oxfordian to Callovian	Jaisatmer (490 m.)	Kuldhar Badabag Fort Joan Hamira	Shales and oolitic fossiliferous limestone, calcareous cross-bedded sandstone, dolomitized limestone, cross-bedded oolitic limestone intercalations of limestone and cleys soft friable sandstone, hard coquinoidal limestone, coarse gritty sandstond, ferrugenous sandstone, sandy limestone with marl bands and coarse grained calcareous sandstone with fragmentary bivalves.
? Bathonian to Liass	Lathi (350.m)	Thaiat Odania	Calcareous sandstone and variegated calcareous sandy siltstone, conglomerate with fossil tree trunks in coarse sandstone, coarse dark grey siltone with fossil wood, ill-sorted sandstone, sandy silt and basal conglomerate.

TABLE 2 : Sample Statistics of Grain Size Data (by Moment Method)

Sr. No.	Sample Code	Mean size Mz	Std devn. σ_1	Skewness S_K	Kurtosis (K_G)	Variance (m_2)	m_3	m_4
1	K.1	4.1628	0.3422	0.0908	1.1437	0.1171	0.0363	0.0568
2	K.2	3.4689	0.3132	-0.0812	1.9080	0.0981	-0.0285	0.0473
3	K.3	3.4488	0.3314	0.1059	2.2384	0.1099	0.0404	0.0632
4	K.4	4.1326	0.2832	0.0692	2.7832	0.0802	0.0209	0.0372
5	K.5	4,1816	0.3393	0.0988	3.5342	0.1151	0.0391	0.0866
6	K.6	4.3653	0.6115	0.1012	-0.2261	0.3739	0.0968	0.3879
7	B.1	3.3073	0.3011	0.0105	-0.2378	0.0906	0.0035	0.0227
8	B.2	3.0810	0.5312	0.6314	1.7130	0.2822	0.4889	0.3753
9	B.3	3.4030	0.4084	-0.0335	0.8030	0.1668	-0.1746	0.1058
10	B.4	3.3172	0.2811	0.0108	-0.2479	0.0790	0.0032	0.0172
11	B.5	3.3476	0.3246	0.0809	-0.3328	0.1054	0.0299	0.0296
12	B 6	4.0228	0.4224	0.0906	1.1687	0.1784	0.0497	0.1327
13	B.7	4.2849	0.5815	0.1132	0.0568	0.3381	0.1004	0.3495
14	B.8	4.0108	0.3936	-0.0154	-0.0124	0.1549	-0.0076	0.0717
15	B.9	3.0846	0.2634	0.0986	1.8238	0.0694	0.0267	0.0232
16	B.10	3.9658	0.3936	0.0852	1.3128	0.1549	0.0421	0.1035
17	B.11	3,1634	0.5876	-0.0182	-0.1258	0.3453	-0.0168	-0.1258
18	F.1	3.3279	0.3746	0.0273	-0.3448	0.1403	0.0125	0.0523
19	F.2	3.3038	0.5446	-0.0016	-0.8151	0.2966	-0.0013	0.1922
20	F.3	3.2054	0.5975	-0.0146	0.1395	0.3570	-0.0136	0.4002
21	F.4	4.1816	0.3393	0.0988	3.5342	0.1151	0.0391	0.0866
22	F.5	4.3653	0.6115	0.1012	-0.2261	0.3739	0.0968	0.3879
23	F,6	3.3124	0,3489	0.0794	1.4177	0.1217	0.0321	0.0655
24	F.7	4.0832	0.4956	0.1016	0.1158	0.2456	0.0709	0.1880
25	J.1	1.8383	0.5765	0.3643	0.9520	0.3324	0.3189	0.4365
26	J.2	1.8246	0.6687	0.1645	1.9840	0.4472	0.1799	0.9966
27	J.3	1.6801	0.4597	0.0969	4.3515	0.2113	0.0604	0.3283
28	J.4	1.9811	0.2435	0.2316	0.7205	0.0593	0.0557	0.0131
29	J.5	2.9207	0.5328	-0.1032	0.7549	0.2839	-0.0803	0.3026
30	J.6	2.7668	0.4563	-0.3562	0.8839	0.2082	-0.2194	0.1684
31	J.7	1.8543	0.5538	0.3234	1.0012	0.3067	0.2666	0.3764
32	J.8	3.0420	0.5832	0.2238	1.7630	0.3401	0.1994	0.5510
33	J.9	2.0428	0.2814	0.1936	1.0215	0.0792	0.0578	0.0252
34	J.10	3.0842	0.4658	0.0152	1.2658	0.2170	0.0097	0.2008
35	J.11	3.1970	0 3432	0.0085	0 2758	0.1178	0.0034	0.0454
36	J.12	3.7760	0.4856	0.0014	-0.2436	0.2355	0.0009	0.1533
37	J.13	3.1640	0.5136	0.0805	0.6856	0.2638	0.0593	0.2564
38	H.1	2.8501	0.5481	-0.1134	0.6949	0.3004	-0.0920	0.3335
39	H.2	2.3565	0.2884	-0.0176	-2.9851	0.0832	0.0055	1.0308
40	H.3	2.9448	0 5295	0.4178	0.9489	0.2804	0.3220	0.3104
41	H.4	3.8836	0,5846	0.0012	-0.2537	0.3418	0.0011	0.3208
42	H 5	3.1834	0.6275	-0.0152	-0.0138	0.3938	-0.0151	0.4630
43	H.6	2.3936	0.3188	0.1102	0.1428	0.0985	0.0387	0.0305