Geol. Bull. Univ. Peshawar, 1983, Vol. 16. pp. 85–96

STATISTICAL STUDY OF THE DHOK PATHAN FORMATION, PUKI GUDIKHEL, SURGHAR RANGE, KARAK

IFTIKHAR AHMED ABBASI, IFTIKHAR ALI ABID & M. ATTAULLAH KHAN

NCE and Department of Geology, University of Peshawar.

ABSTRACT

Size analyses of a part of the Dhok Pathan Formation, Surghar Range, was carried out to study the behaviour of different size fractions and to interpret the environments of deposition. The measures obtained on phi-scale reveal that the sandstone of the area is medium to fine-grained, moderately sorted, positively skewed and has platykurtic distribution. The C-M pattern for these sediments suggests suspension and tractive current deposits, and is comparable in appearance with the basic pattern IV and V of Passega (1957). There is no systematic horizontal or vertical variation in different statistical measures but present a rather zigzag pattern which indicates that the material of variable size was brought to the basin between each cycle.

INTRODUCTION

A thick sequence of molasse sediments of the Siwalik Group is exposed in the western limb of the Makarwal Anticline, Surghar Range. These sediments, ranging in age from Late Miocene to Pleistocene, are divided stratigraphically into:

1. Upper Siwalik — Soan Formation (Late Pliocene to Early Pleistocene)
2. Middle Siwalik —
   (a) Dhok Pathan Formation (Early to Middle Pliocene)
   (b) Nagri Formation (Early Pliocene)
3. Lower Siwalik — Chinji Formation (Late Miocene)

As a whole the Siwalik Group comprises sandstone, shale and conglomerate, and rests unconformably over the Eoncene Limestone. The basal formation, the Chinji, is composed dominantly of reddish shale with subordinate sandstone interbeds. The Nagri Formation, in contrast to the other formations of the group, is composed predominantly of sandstone with occasional shale beds, while the Dhok Pathan Formation is marked by alternating sandstone and shale with many conglometate beds. The Soan Formation is composed of reddish-brown shale with greyish-brown sandstone.

No detailed account about the geology of the studied area is available except the recent work of Abid *et al.* (this volume). On a regional scale, however, the Surghar Range has been mapped and studied by Danilchik (1961) and Meissner *et al.* (1974). Pakistan Atomic Energy Commission's geologists have worked on the area, especially on the Dhok Pathan Formation and the Soan Formation for the exploration of radio-active minerals.

This paper is based on size analyses and textural studies of the sandstone units in the Dhok Pathan Formation, near the village of Puki Gudikhel 32°11'—21'N 71°43'–45'E, Takht-e-Nasrati (Fig. 1). The major aim is to determine the probable environments at the time of deposition through the study of textural variations and the grain-size parameter. Systematic samples were collected from all the "7" units of sandstone present in the Dhok Pathan Formation. A few samples were also analysed both from the underlying Nagri and the overlying Soan Formation for the sake of comparison. The results have been incorporated in Table 2, and also illustrated graphically by histograms (Fig. 2) and cumulative curves (Fig. 3).

Procedure

Carefully disaggregated sandstone specimens were sieved for 20 minutes by using a set of sieves of 18, 36, 60, 120, 240 mesh sizes and container more than 240. Each fraction was weighed upto 0.01gm accuracy to get better results when plotted on the probability graphs. The data is expressed in the form of histograms and cumulative curves.

DETERMINATION OF STATISTICAL DATA

Histograms.

In histograms, size data is plotted against the weight percentage (Fig. 2) to study the nature of their modes (Rizvi, 1972). The size distribution in the study area is variable. Most of the specimens exhibit unimodal size distributions, while some show bimodal distribution. The modal class in majority of the specimens lies between 0.25mm and 0.50mm, while in some it ranges from 0.125mm to 0.25mm. No definite generalization can be made on the basis of histograms, because little quantitative data can be read from them.

Cumulative Curves.

Most of the statistical interpretation was done with cumulative curves which were obtained by plotting cumulative percentage against phi-diameter on arithmatic probability graph (Fig.3), which are prefered over other types of graphs where interpolation between data points is much more inaccurate and is not produceable (Folk and Ward 1957). All curve parameters were read to the nearest of 0.01, an accuracy which is meaningful only when probability paper is used. The precise measures of average size, sorting, skewness and kurtosis are determined graphically from the study of selected percentiles of the cumulative curves. A percentile is the grain size at a given weight percentage obtained from the cumulative curve by interpolation (Koldijk, 1968). These percentiles are put in the formulae of Folk and Ward (1957) to calculate the graphic measures (Table 1). The different percentiles used were 5, 16, 25, 50, 75, 84, 95.

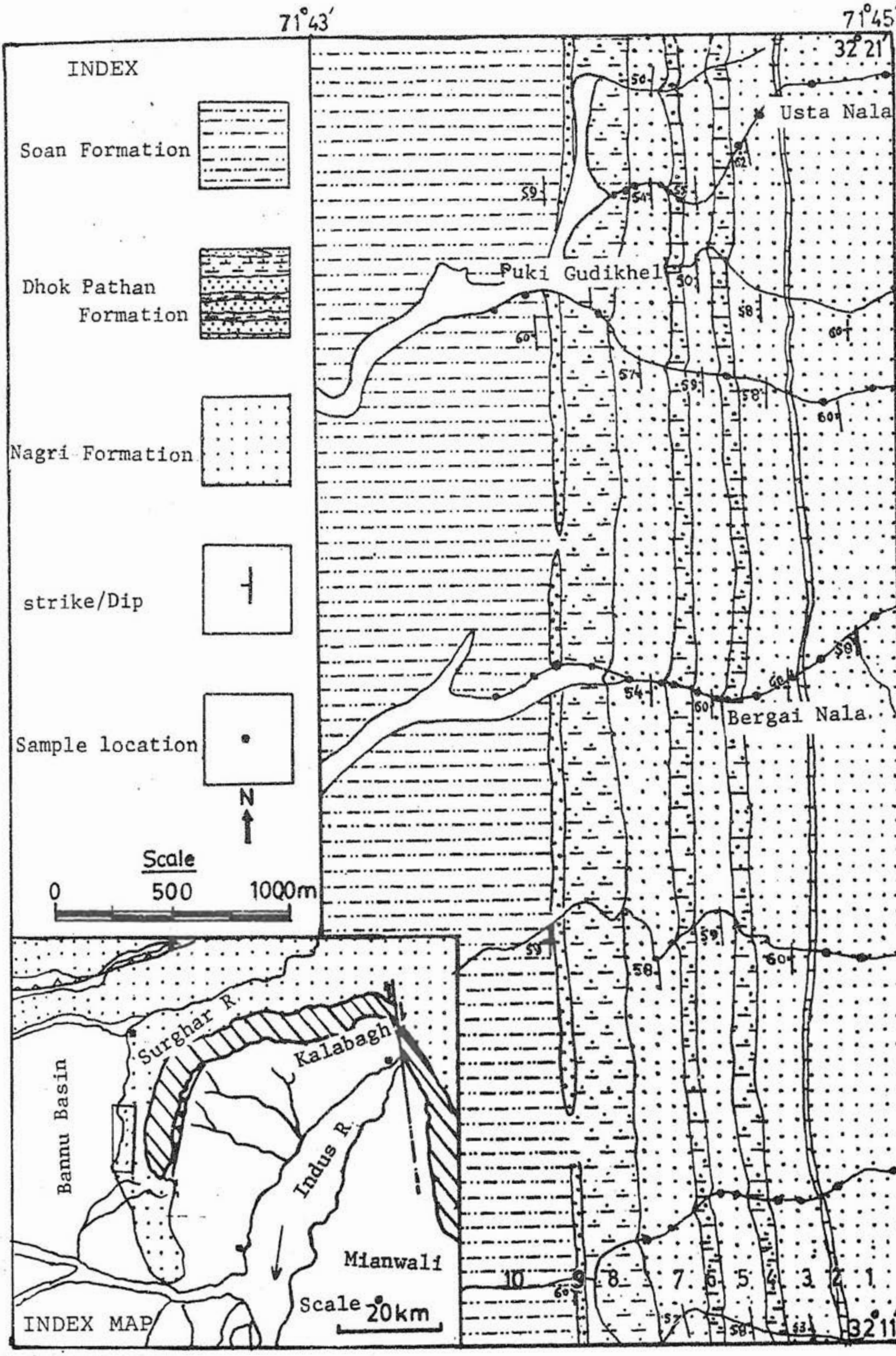

Fig. 1. Lithological subdivision of the Dhok Pathan Formation, near Puki Gudi Khel, Surghar Range.

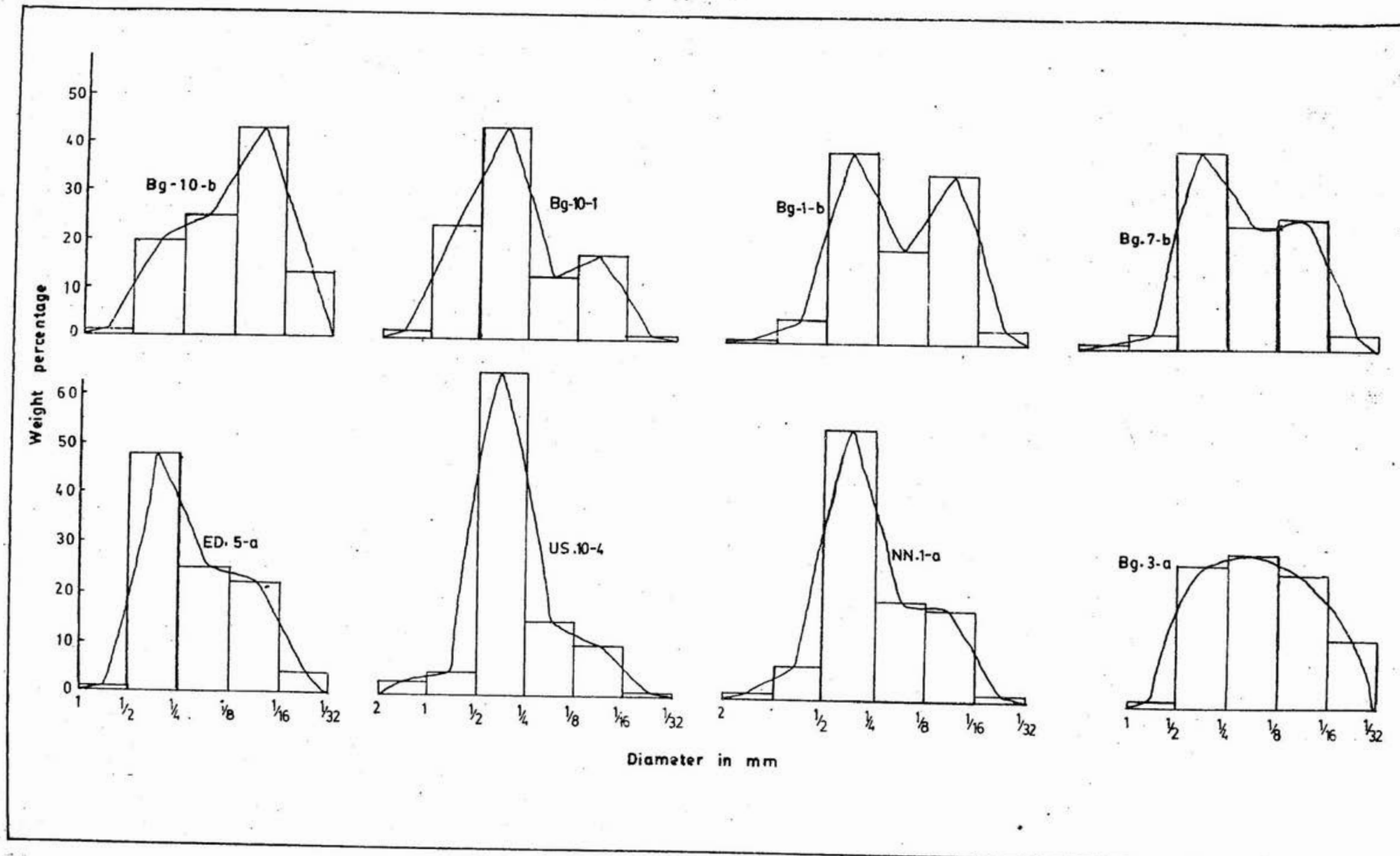

Fig. 2. Histograms of sandstones of the Dhok Pathan Formation.

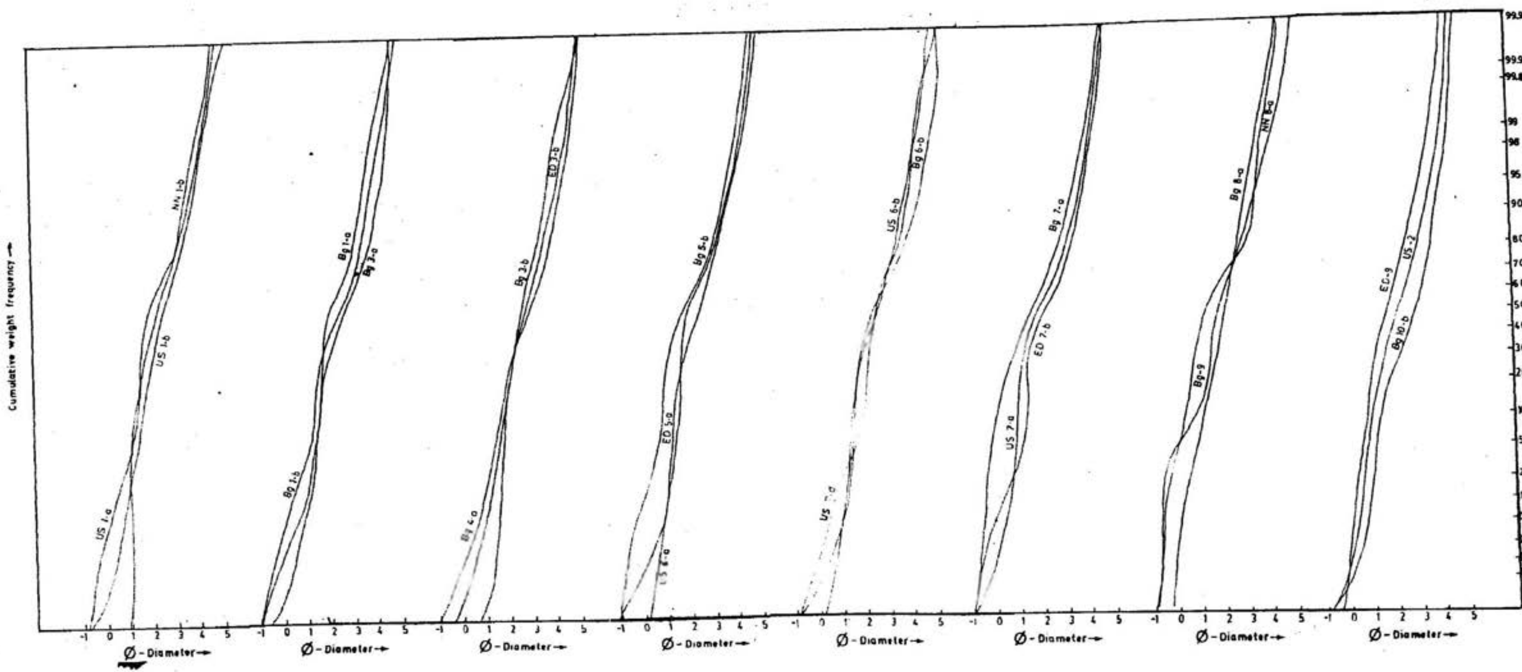

Fig. 3. Cumulative frequency curves of sandstone of the Dhok Pathan Formation.

TABLE 1. GRAPHICAL PARAMETERS (after Folk and Ward, 1957).

Parameter	Name	Abbrevation	Formula
Average	Mean Size	M_z	$\frac{\varnothing 16 + \varnothing 50 + \varnothing 84}{3}$
Sorting	Inclusive Graphic standard Deviation	σ_I	$\frac{\varnothing 84 - \varnothing 16}{4} + \frac{\varnothing 95 - \varnothing 5}{6.6}$
Symmetry	Inclusive Graphic Skewness	Sk_I	$\frac{\varnothing 84 + \varnothing 16 - 2\varnothing 50}{(\varnothing 84 + \varnothing 16)2} + \frac{\varnothing 95 + \varnothing 5 - 2\varnothing 50}{2(\varnothing 95 - \varnothing 5)}$
Peakedness	Graphic Kurtosis	K_G	$\frac{\varnothing 95 - \varnothing 5}{2.44(\varnothing 75 - \varnothing 25)}$

INTERPRETATION OF STATISTICAL DATA

Mean Size

Different measures of mean size proposed by Trask (1930), Otto (1939), Inman (1952), and many others are inadequate in case of bimodal and/or skewed distribution because they ignore the tails of distribution. The measure of mean size (M_z), presented by Folk and Ward (1957, Table 1) is more satisfactory as it can be divided into three categories; $\varnothing 16$ representing the averages size of the coarsest 1/3 of the sample, $\varnothing 84$ as the finest 1/3, while $\varnothing 50$ as the average of middle 1/3.

The M_z value for the specimens of the sandstone unit – 1 (Nagri Formation) varies from 1.86$\varnothing$ to 2.45$\varnothing$, with an average of 2.21$\varnothing$ (Table 2). This shows that the sandstone is medium-to fine-grained. In the upper units of the sandstone (3, 4, 5, 6, 7, 8, 9), representing the Dhok Pathan Formation, the M_z values range from 1.77$\varnothing$ to 2.8$\varnothing$, whereas the averages of the individual units fall between 2.05$\varnothing$ to 2.55$\varnothing$. Most of the M_z values cluster in the range of 2.2$\varnothing$ to 2.4$\varnothing$ which means that the sandstone of these units is medium- to fine-grained. The sandstone unit–9, which marks the boundary between the Dhok Pathan Formation and the Soan Formation in the area under study, is relatively pure and coarser, with M_z values ranging from 1.95$\varnothing$ to 2.16$\varnothing$. The M_z values for sandstone unit–10 (Soan Formation) are in the range of 1.79$\varnothing$ to 2.97$\varnothing$ with an average of 2.3$\varnothing$.

These grain-size variations are attributed to the dynamics and potency of the depositional currents. These sediments were probably deposited by relatively sluggish currents, carrying the load comprising medium to fine sand.

TABLE 2. SIGNIFICANT VALUES DERIVED FROM CUMULATIVE CURVES

Samples No.	Sorting (σ_1)	Skewness (Sk_1)	Kurtosis (K_G)	Mean (M_z)	1 Percentile 'C' in micron	Median 'M' (50 percentile) in micron
US, 1—a	0 872	0.144	0.863	2.45	500	230
US. 1—b	0.794	0.356	0.670	2.21	596	88
Bg, 1—b	0.966	0.090	0.572	2.416	841	177
Bg. 1—a	0.758	0.485	0.770	2.31	500	250
NN. 1—a	1.253	0.191	0.808	1.866	1189	297
NN, 1—b	0.866	0.493	0.851	2.026	1000	297
US, 3—a	0.824	0.746	0.632	2.266	595	149
Bg, 3—a	1.021	0.122	0 667	2.756	—	—
Bg, 3—a	1.021	0.122	0.667	2.756	460	158
Bg. 3—b	0.731	0.107	1.133	2.433	500	177
ED. 3—a	0.737	—0.108	0.873	2.706	—	—
ED, 3—b	0.777	0.186	0.829	2.666	354	158
Bg. 4—a	1.006	0.038	0.890	2.653	595	149
NN, 4—a	0 934	0.189	0.773	2.29	640	210
Bg, 5—a	0.899	—0.431	0.819	2.533	500	149
Bg. 5—b	1.004	0.25	0.69	2.2	1000	250
ED. 5—b	0.855	0.22	0.687	2.48	460	177
ED, 5—a	0.83	0.50	0.819	2.416	460	230
Bg. 6—a	0.989	0.514	0.768	2.35	460	230
US. 6—a	0.752	0.056	0.923	2.80	—	—
US. 6—b	0.853	0.073	0.706	2.5	500	177
US. 7—d	0.743	0.628	1.673	2.603	707	177
US 7—a	1.137	0.008	0.786	2.4	640	230
ED. 7—a	0.863	0.257	0.927	2.27	707	230
ED. 7—b	1.01	0.297	0.665	2.4	841	210
Bg, 7—a	1.243	0.001	0.749	1.776	1414	297
Bg. 7—b	0.921	0.048	0.843	2.333	640	149
Bg. 8—a	0.908	0.100	0.942	2.606	707	177
NN 8—a	1 003	0.090	1.196	2.233	1502	230
US. 8—a	0.673	0.087	1.393	2.216	—	—
US. 8—b	0.653	0.182	1.152	2.80	—	—
Ed. 9	0.928	0 022	0.957	2.16	707	149
Bg. 9	1.24	0.321	0.695	1.95	1414	354
Bg 10—2	1.006	—0.288	0.817	2.97	500	105
US 10—4	0.964	0.043	2.227	1.95	1414	297
US. 10—2	0.964	0.43	0 811	2.52	500	177
Bg. 10—1	1.065	0.626	1.060	1.793	1189	420

Note:— For formulae of various measures see table 1.

Standard deviation

The two most applicable measures regarding sorting are those of Inman (1952) and Folk and Ward (1957). The latter covers a wider range of dispersion (5–95 percentiles) and is thus more sensitive environmentally. The standard deviation value (σ_1) of the sandstone from the area under study, computed from Folk and Ward (1957) formula, has a range from 0.653Ø to 1.253Ø, while the average value of σ_1 for the individual sandstone units ranges from 0.823Ø to 1.084Ø (Table 2). In sandstone unit–1 (Nagri Formation) one sample has σ_1 value of 1.253Ø and is poorly sorted, while the major clustring of σ value is at 0.8Ø to 1.0Ø which shows a moderate sorting. The moderate sorting persists in the upper units (3, 4, 5, 6, 7, 8) representing the Dhok Pathan Formation, as shown by the

G_1 values ranges from 0.809∅ to 0.907∅. However, three samples from the sandstone unit–7 show values lying between 1.00∅ to 2.00∅ and are thus poorly sorted. The uppermost sandstone unit of the Dhok Pathan Formation (unit–9) is poorly sorted as shown by the range of σ_1 values (1.00∅ to 2.00∅). The sandstone unit–10 (Soan Formation) shows σ_1 value between 0.96∅ and 1.06∅ and is moderately sorted.

Therefore, based on the sorting coefficient of Folk and Ward, the sandstone of the area is generally moderately-sorted with some samples showing poor sorting. In Siwaliks, the variations in sorting coefficient can by attributed to the irregular conditions of deposition, in a gradually sinking basin.

MEAN SIZE Vs. STANDARD DEVIATION

The plotting of mean size versus standard deviation is important as the latter is a function of changing mean size. The curves thus formed depend upon the range of grain size for their trends, being 'M'– shaped when the grain size has a comparatively wide range, 'V'– or inverted 'V'– shaped when the grain size has a limited range. As the sandstone of the study area is characterized by a limited grain-size range, only one limb of the 'V' is developed (Fig. 4). Our plot shows that sorting of the sandstone improves with the decrease of grain size. The best sorted samples are characterized by M_z = 2.2∅ to 2.7∅ with σ_1 0.6∅ and consist of pure sand. Those samples having silt fraction have a comparatively poor sorting.

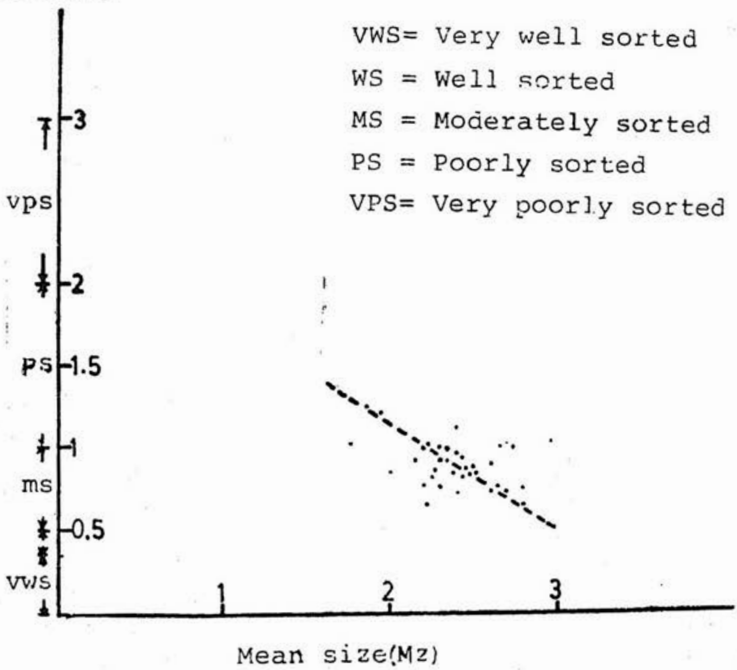

Fig. 4. Standard deviation (σ_1) Vs. Mean size (M_z).

Skewness

Skewness describes the asymmetry of grain size distribution which is geometrically independent of sorting. Therefore, taking entire size range into consideration, Folk and Ward (1957) proposed the formula of 'Inclusive Graphic Skewness) Sk_I (Table 1). Based on a number of analyses they also suggested a verbal scale of skewness for cmoparative studies. Perfectly symmetrical curves have $Sk_I = 0.00\varnothing$ and absolute mathematical limits are $-1.00\varnothing$ to $+1.00\varnothing$ though natural sediments with skewness value beyond $+0.8\varnothing$ or $-0.8\varnothing$ are very rare (Folk, 1966).

Three samples, ED 3–a, Bg 5–a and Bg 10–b, show negative skewness values, while the rest of the samples are positively skewed with a few showing symmetrical distribution (Table 2). The Sk_I values for the sandstone samples of units–1 (Nagri Formation) range between $+0.1\varnothing$ and $+0.4\varnothing$ with an average of $+0.293\varnothing$. In sandstone units of the Dhok Pathan Formation the lowest mean value of Sk_I is $+0.05\varnothing$ (for sandstone unit–7) while the highest mean Sk_I value is $+0.371\varnothing$ (for the sandstone unit–5). For the rest of the sandstone units, the mean value of Sk_I lies between $+0.01\varnothing$ and $+0.03\varnothing$. For the sandstone unit–10 (Soan Formation), Sk_I varies from $+0.288\varnothing$ to $+0.626\varnothing$ with an average of $+0.366\varnothing$. This suggests that the Soan Formation (unit–10) is more positively skewed than the other two formations of the area, i.e., Nagri Formation and Dhok Pathan Formation.

Most of the studied specimens exhibit positive skewness, which is characteristic of river deposits. According to Koldijk (1968), river samples tend to be chopped off at the coarser end of their grains size distribution, resulting in a positive sign of the skewness.

Kurtosis

The measure of Kurtosis computes ratio between the spreads in the central part and in the tails of the distribution. Thirty four specimens of the sandstone from the area were analysed for kurtosis (K_G) based on the formula devised by Folk and Ward (1957). According to this formula normal curves have a $K_G = 1.00\varnothing$, when plotted on this scale and compared with the verbal scale of Folk and Ward (1957). It is found that specimens Bg 8–a, ED–9, Bg 10–1, US 6–a and ED 7–a have nearly normal kurtosis value (K_G ranging from 0.92 to $1.1\varnothing$) while specimens NN 8–a, US 8–b, US 10–4, US 7–d and Bg 3–b have leptokurtic distribution (K_G ranging from 1.11 to $2.22\varnothing$). The rest of the specimens from the area show a platykurtic distribution (Fig. 2) with a large clustering about $K_G = 0.6\varnothing$ to $0.9\varnothing$. There are neither systematic changes in the kurtosis value from the rocks of older ages to the rocks of younger ages, nor there is any systematic change within the individual sandstone units.

C.M. Pattern

Passega (1957) suggested that a relationship exists between the texture of sediments and process of deposition. As texture is represented by grain-size parameters, the logarithmic plots of coarsest "I" percentile grain size (C) and the median grain size (M) of clastic deposits make patterns, characteristic of depositional environments. By studying several environments, it has become obvious that the coarsest fractions of sediments almost invariably are more representative of the depositional agent than the fine fractions. In sediments deposited from the material transported in suspension, in certain cases each value of 'M' has a compatible value of 'C' but there are instances when the value of 'C' varies considerably for the given value of 'M'. Such variations in 'C' are caused by local variations in textures, and study of these two factors gives clues regarding the depositional environments.

The one percentile (C) and median (M) of the 32 samples were plotted on a logarithmic paper. The data for different units of sandstone is plotted collectively and their trend follows the basic pattern IV extending to the basic pattern V of Passega (1957) shown in Fig. 5. This shows that the sediments were deposited by suspension and tractive currents of rivers. The particles concentrated in the form

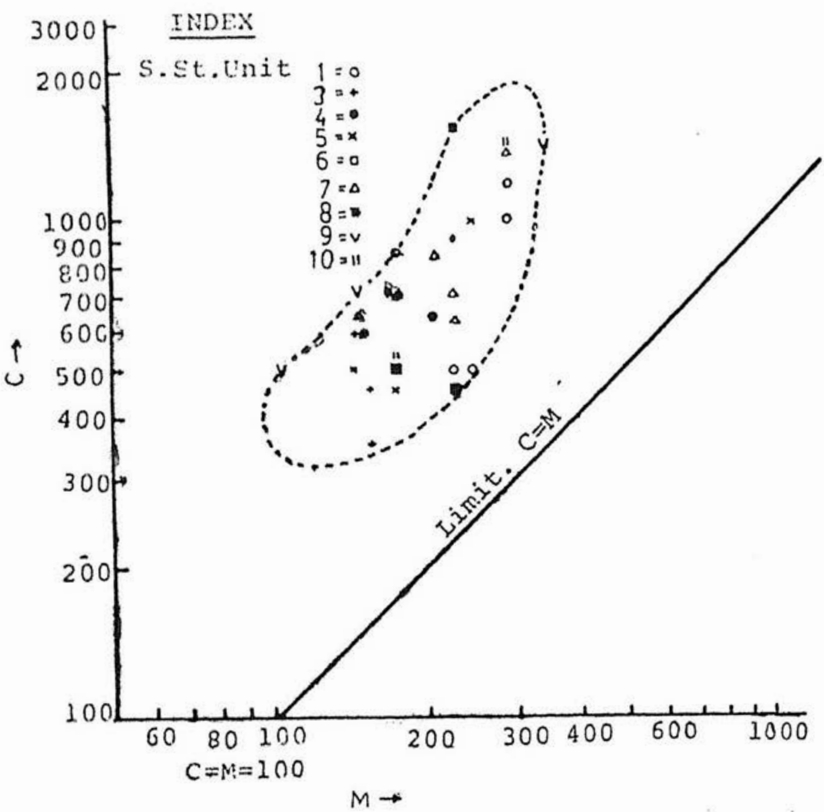

Fig. 5. C-M pattern of sandstone of the Dhok Pathan Formation.

of suspension during deposition follow the pattern IV, while the sediments which were coarser enough, not to be held in suspension, were transported by tractive currents and fall along the pattern V. The wide range of difference in 'C' values amongst the samples may be due to turbulance in the currents which was responsible for transportation and deposition of the material of all available sizes.

DISCUSSION

Textural studies are helpful for determination of mode of deposition and the effects of transportation (Saxena, 1963). The Dhok Pathan Formation is dominantly composed of alternating sandstone and shale with many pebbly beds. These lithological characteristics indicate fluvial system of laterally migrating streams (Allen, 1965). The sandstone units were laid down as point bar deposits through lateral accretion while the mudstones were deposited on the flood plain after overbank flooding through vertical accretion. The gravelly beds generally are only a few clasts thick, associated with erosion surfaces and are interpreted as channel lags. As the channel migrates, laterally accreted deposits are overlain by vertically accreted deposits, resulting in a fining upward cycle.

Different statistical measures for the formation do not follow any vertical or horizontal trends but present a rather zigzag pattern. It leads to the conclusion that material of variable size was brought to the basin between each cycle as marked by the bounding pebbly layers. The sandstone in the area is medium- to fine-grained (M_z ranges from $1.77\varnothing$ to $2.8\varnothing$) and is moderately sorted (mean σ_1 lies between $0.823\varnothing$ to $1.084\varnothing$). The grain-size variations may by attributed to the dynamics and potency of the depositional currents. Generally, sediments of the fine sand sizes are best sorted ($\sigma_1 = 0.35\varnothing$) and sorting becomes worse for both coarser and finer sediments (Hough, 1942; Griffiths, 1951). The improvement in sorting is a function of decreasing mean size and not the transported distance (Folk and Ward, 1957). The sorting coefficient for the bimodal sediments of the Siwalik varies due to the irregular conditions of deposition because the basin of deposition was associated with the fluctuating tectonic framework.

The environment was undoubtedly undergoing changing conditions with the different phases of tectonism (cf. Tandon, 1972). The sediments of the Dhok Pathan Formation exhibit a positive skewness which is characteristic of river deposits. According to Sahu (1964) polymodal or bimodal distribution may have resulted because of fluctuations in the velocity of streams in combination with the relative increase of fine material possibly contributed from a soft rock source area. The C–M pattern resembles the one obtained for the river and tractive current deposits. Normally a river deposit will contain from coarse gravel to very fine suspended material.

The basin of deposition was a shallow one and the enormous thickness of the sandstone could only be due to continued sinking. The cyclic deposition in the basin in marked by the presence of pebbly beds, which bound the cross-bedded sandstone. The pebbles were spread only when the basin was completely filled up and the currents were strong enough to move the pebbles. It can be assumed that the basin of deposition was never deeper than the thickness between the two pebbly layers. The changes in the rate of deposition, as shown by the variations in the thickness of various units, depend on the rate of supply of material and sinking of the basin. At the start of a cycle, the rate of deposition first exceeded the rate of gradual sinking. The break in the accumulation is marked by the deposition of pebbly beds. When the continuously sinking basin attained some depth, redeposition of sand began.

Acknowledgements. Mr. M. Asif Khan is thanked for useful suggestions while Mr. Obaidur Rehman read the manuscript critically. Mr. M. Banaras is thanked for his help in drafting the figures.

REFERENCES

Abid, I.A., Abbasi, I.A., Khan. M.A. & Shah, M.T., 1983. Petrography and geochemistry of the Siwalik Sandstone and their relationship with Himalayan orogeny. This volume.

Allen, J.R.L., 1965. Finding upward cycles in alluvial successions. Gtol. Jour. 4, 229-246.

Danilchik, W., 1961. The Iron formation of the Surghar and western Salt Range, Mianwali district, West Pakistan. U.S. Geol. Surv. Prof. Paper 424-D, 228-231.

Folk, R.L., 1966. A review of grain size parameters. Sedimentalogy 6, 73-93.

——— & Ward, W.C., 1957. Brazos River Bar: A study in the significance of grain size parameters. J. Sed. Petrol 27 3-26.

Griffiths, J.C., 1951. Size versus sorting in some Carribbean sediments. J. Geol. 59, 211-243.

Hough, J.V., 1942. Sediments ofCape Cod Bay, Massachusetts. J. Sed. Petrol. 12., 10 30.

Inman, D.L. 1952. Measures for describing the size distribution of Sediments. J. Sed. Petrol. 22, 125-145.

Koldijk, W.C., 1968. On environment sensitive grain size parameters. Sedimentalogy 10, 57 68.

Meissaer, C.R., Master, J.M., Rashid, M.A. & Hussain, M., 1974. Stratigraphy of the Kohat Quardrangle, Pakistan, U.S.G.S. Prof. Pap. 716-D.

Otto, G.H. 1939. A modified logarithmic probability graph for the interpretation of mechanical analysis of sediments, J. Sed. Petrol. 9, 62-75.

Passega, R., 1957. Texture as characteristic of clastic deposition. Bull. Am. Assoc. Petrol. Geol. 41, 1952-1984.

Rizvi, S.R.A., 1972. Geolgy and sedimentation trends in Palamau Coalfields, Bihar, India. Mem. Geo. Surv. Ind. 104, 54-61.

Sahu, B.K., 1964. Depositional mechanisms from the size analysis of the Clastic Sediments J. Sed. Petrol. 34, 72-83.

Saxena, S.K., 1963. The Pachmarhi Sandstones: a statistical study of size analysis. Jour. Geol. Surv. Ind. 4, 116-129.

Tandon, S.K., 1972. Mechanical analysis of Middle Siwalik Sandstones from Ramnagar, Nainital District, Kumaon Himalaya J. Geol. Soc. Ind. 13, 51-58.

Trask, P.D., 1930. Mechanical analysis of sediments by centrifuge. Econ. Geol. 25, 581-599.

Fig. 1. Lithological sub-division of the Dhok Pathan Formation, near Puki Gudi Khel, Surghar Range.