CHAPTER IV

PRINCIPLES, TECHNIQUES AND METHODS OF STUDY

In order to classify the various formations and to understand the laws of sedimentation which governed their origin, a scientific study of the sediments was undertaken. With a view to understand their true nature, the various formations were subjected to a very critical investigation, both in the field as well as in the laboratory. On the basis of these investigations, the nomenclature

and classification of the different rocks were worked out.

The field study included (1) a critical investigation of the geological setting of different rock-types, and (2) identification and recognition of various sedimentary structures. The details of the field study have already been discussed in the foregoing chapter.

In this chapter, the author has discussed in brief, the principles and techniques applied by him in studying the different lithological types in the laboratory.

COLLECTION OF SAMPLES:

On account of the fact that considerable variation in lithology exists across and along the strikes of the formations, to obtain a comprehensive and representative collection suitable for subsequent analyses, a very careful and systematic sample collection was made. The following procedure was adopted for collecting the samples:

(1) A sort of reconnaissance survey in all parts of the area, in the form of long traverses across the strike was carried out and representative samples were collected, mainly on the basis of lithological and textural variations as recognised in the field. The samples were subjected to a critical examination in order to enable the author to fix up traverses to collect typical samples in required number suited for detailed laboratory investigations.

(2) Based on the above findings, the author selected ten N-S traverses for systematic collection of samples. These samples were then subjected to a number of analyses, with a view to understand the true sedimentary nature of the various rock formations.

(3) In the course of his traverses the author also collected as many fossils as he could from the fossiliferous beds. Similarly, the samples of basic dykes, wherever encountered, were collected. (As these do not have any direct bearing on the scope of

the present investigation, only brief descriptions of the fossils and the igneous rocks, have been included as Appendices I and II at the end of this thesis).

Methods of Analysis

In the laboratory, following methods of analysis were adopted:

(1) Heavy Mineral Analysis;

(2) Grain-Size Analysis

(a) Sieve Analysis
(b) Pipette Analysis.

The presentation of the size-analysis data has been done by preparing (a) Histograms,
(b) Cumulative curves - arithmetic ordinate,
(c) Cumulative curves - probability ordinate.

The CM pattern diagrams have been constructed from the cumulative curves by using arithmetic ordinate, while the cumulative curves by using probability ordinate, have enabled the author to calculate statistical parameters of grain-size.

(3) Shape Analysis

(a) Roundness measurements
(b) Sphericity measurements.

(4) Clay-Mineral Determination by Colouration Method.

(5) Microscope Study of

(a) Heavy and Light minerals
(b) Thin sections of selected samples.

(1) HEAVY MINERAL ANALYSIS:-

Unconsolidated sediments like loss and friable sandstones were placed on a sheet of glazed paper and crushed with fingers or rubber cork.

Weakly consolidated sediments like fine-grained clayey sandstones and siltstones were crushed initially in porcetain mortar, and finally the small fragments were crushed by rubber cork.

Consolidated samples like hard calcareous siltstones and ferruginous siltstones were crushed in steel mortar into small pea-size chunks.

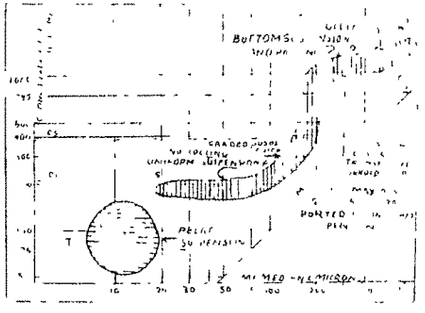
The crushed samples were subjected to splitting by conning and quartering method.

Sample thus obtained was then treated with hydrochloric acid of suitable strength and then gently heated for a suitable period. This was done to remove the unwanted cementing material etc. The resulting mud or scum was washed away with cold (distilled) water by decantation. The remaining portion was then dried in oven. When dry and cold, it was passed through a 36 mesh sieve, and the material finer than 36 mesh (0.42 mm) was used for actual heavy mineral analysis. The material thus obtained, consisted of a number of minerals out of which those heavier than 2.89 were separated from the lighter ones. The heavy minerals were commonly zircon (4.7), rutile (4.2), tourmaline (3.2) and opaques (viz. hematite, limonite-3 to 5). For separating these heavy minerals Bromoform liquid which has a specific gravity of 2.89 was used.

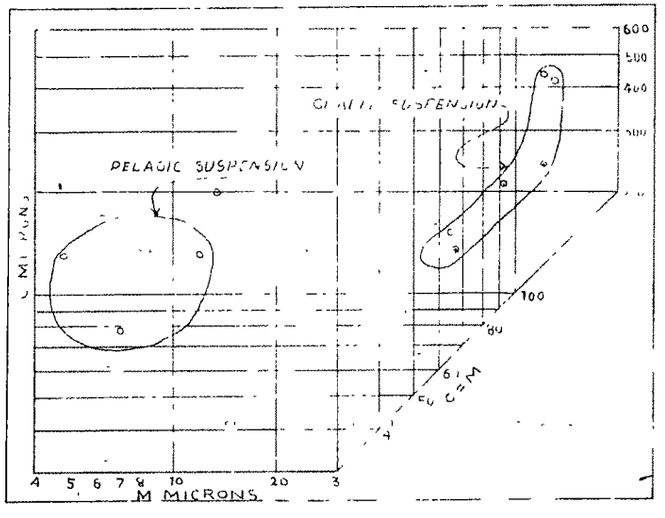
The usual procedure (Krumbein and Pettijohn, 1938, p.343) was followed for the separation of the heavy minerals from the lighter ones. After drying, both the 'Light' and the 'Heavy' crops, were mounted on glass slides for their further microscopic study.

Fig 9

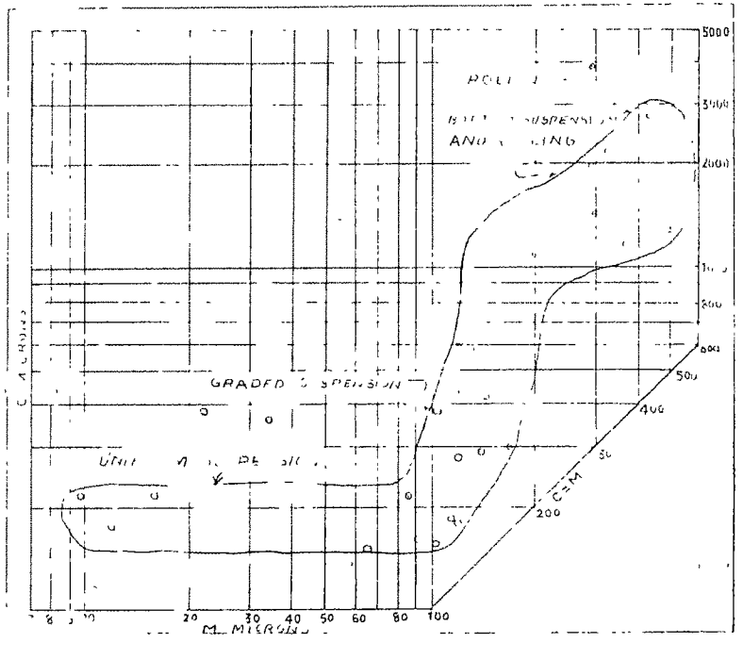
CM DIAGRAMS



Complete CM pattern of
tractive current deposite (Passega, 1964)



Chari Series

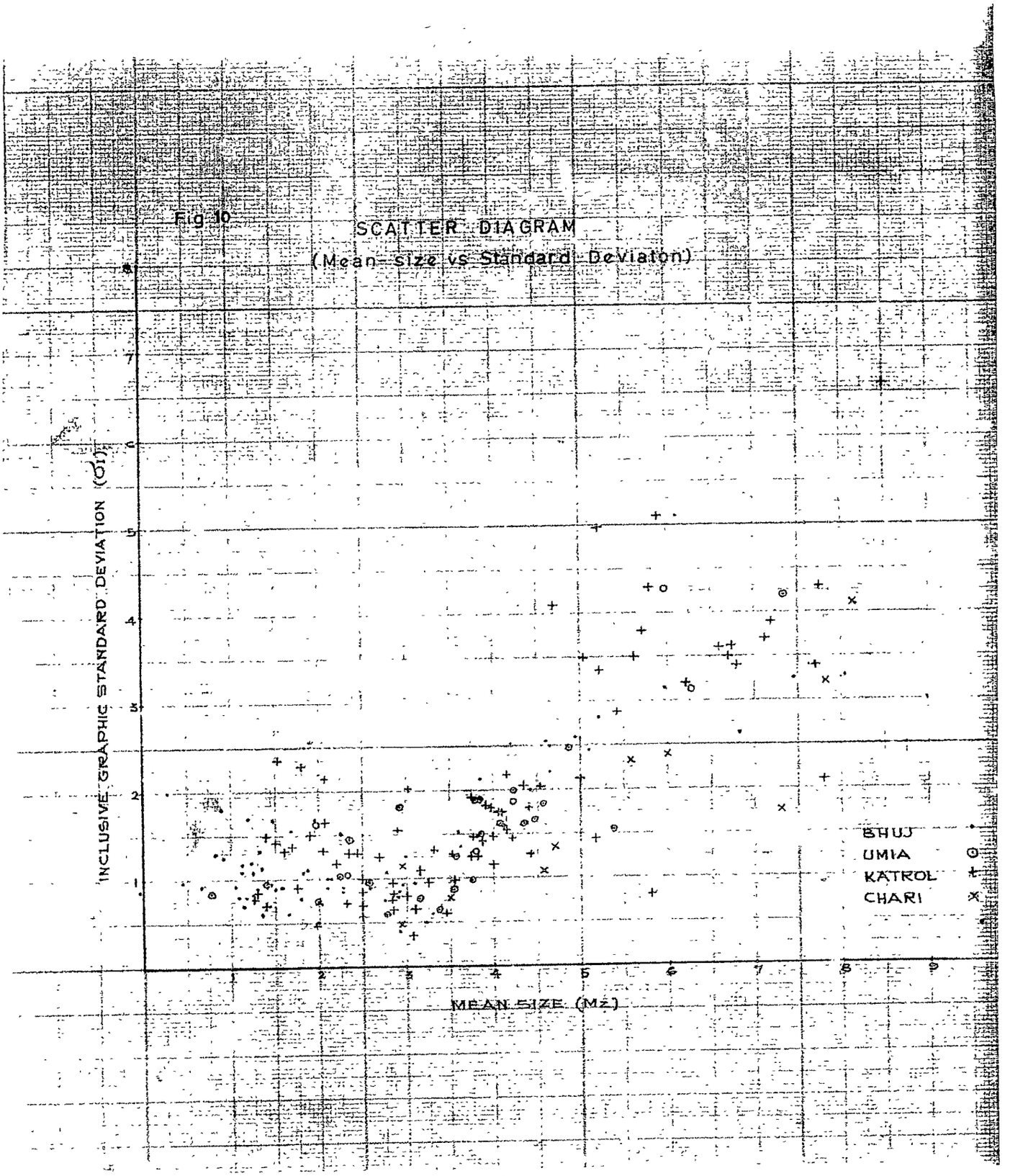


Katrol Series

Fig 10

SCATTER DIAGRAM

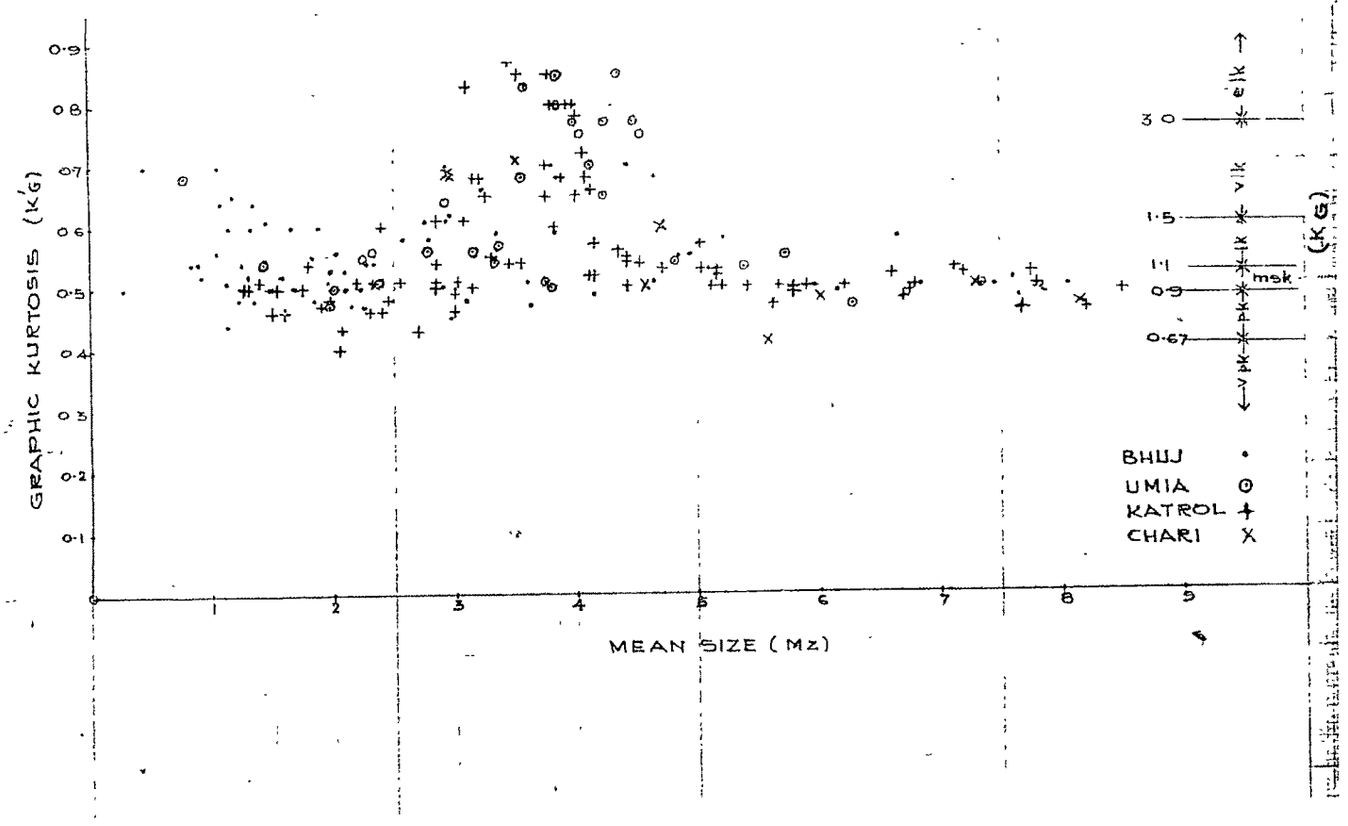
(Mean-size vs Standard Deviaton)



SCATTER DIAGRAM
(Mean-size vs Skewness)
Fig 11
MEAN SIZE (Mz)
INCLUSIVE GRAPHIC SKEWNESS (SKi)
BHUJ
UMIA
KATROL
CHARI

Fig 12

SCATTER DIAGRAM
(Mean-size vs Kurtosis)



(2) GRAIN SIZE ANALYSIS:-

The purpose of this analysis was to obtain the size of the clastic grains as they were deposited. This analysis can not always beem done. Sometimes it becomes rather difficult to obtain a correct picture of the original size of the particles, because of the following reasons: (i) Clastic sand grains quite often acquire overgrowths or get cemented (both ferruginous and calcareous), into tough aggregates. (ii) Chemically-precipitated materials introduced into the rock form discrete grains, and these if not removed will give erroneous size values (because size of the clastic particles is to be measured and not the size of the introduced cement), and (iii) Clay minerals because of their flaky characters and surface electrical charges tend to cluster in lumps around the clastic particles.

The desired clastic particles were separated from the matrix and cement by the processes of disaggregation and dispersion. The disaggregation is done for the samples suitable for sieve analysis

while the dispersion is found to be suitable for pipette analysis. These processes have been described subsequently.

Sieve Analysis:

Sieve analysis was adopted for those particles whose grains were of sand size i.e. coarser than 0.0625 mm. The field sample was first disaggregated. In case of soft friable rocks, the disaggregation was accomplished by crushing it with fingers only, but harder rocks were crushed in iron and porcelain mortars by pounding. The crushed particles of the latter, were then treated with hydrochloric acid, the concentration of which depended upon the nature of cementing material. The particles of sand size obtained were dried and then subjected to sieve analysis. (To prevent the loss of clays which were suspended in acid after this treatment, the acid and wash water was poured through a filter paper which was previously weighed, and the same was then dried. The weight of this dried material was then added to the 'pan' fraction of the sieve analysis).

The required quantity (about 50 to 60 gm.) of the disaggregated particles were obtained by splitting a process of repeated conning and quartering.

For the sieve analysis, a set of B.S.(British Standard) sieves was used. Sieves of diameter 8" and the following mesh-sizes were used:-

7	mesh	(2.411 mm)
14	"	(1.204 mm)
25	"	(0.599 mm)
36	"	(0.422 mm)
52	"	(0.295 mm)
100	"	(0.152 mm)
150	"	(0.104 mm)
200	"	(0.076 mm)
240	"	(0.062 mm)

The millimetre size values were calculated with the help of the chart given by Milner (1962,p.167).

The sieving was done in an electrically operated Ro-Tap sieve-shaking machine. Each sieve-fraction was carefully weighed on a chemical balance. The weight was obtained upto third place of decimal. After weighing, the coarser sieve fractions were carefully scrutinised by a magnifying glass for small fragments, which might have escaped disaggregation in the first instance. When the coarser fraction contained over 25% aggregates, these were again subjected to disaggregation and run through sieves,

when the fraction of aggregates was found to be less than 25% it was estimated visually and subtracted from the sample weight as shown in the computation data given by Folk (1965, p.35).

(b) Pipette Analysis:

Pipette analysis was done for the grain-size determination of particles smaller than 0.062 mm. As it was difficult to separate clay lumps into individual particles of which size-measurement was to be done, dispersion of clay particle, as per following procedure, was essential.

The sample was first crushed and split by conning and quartering. About 20 gm. of the crushed sample was placed in a 250 cc flask with 100 cc of N/100 sodium oxalate solution and allowed to soak for a period of 24 hrs.

After this preliminary soaking, the sample was transferred into an evaporating dish and rubbed with finger or rubber pestle to disperse the lumps.

Simultaneously, N/100 sodium oxalate solution (in distilled water) was intermittently added till the

total volume of the suspension was about 400 cc. During the addition of the sodium oxalate solution, the whole mass was continuously stirred. The stirring was continued till all traces of floculated clusters were removed. Examination of a drop of this suspension on a glass-slide under the microscope could immediately give the idea if the dispersion was achieved. Absence of bead like strings and clustres of individual particles would indicate complete dispersion. In order to ensure full and complete dispersion, the suspension was diluted to about 800 cc with N/100 sodium oxalate solution, and boiled. As soon as the boiling point was reached, the heating was stopped and the suspension was allowed to cool.

The suspension was then poured through the 230 mesh (1/16 mm) sieve of A.S.T.M.(American Society for Testing Materials). The residue on the sieve was washed by N/100 sodium oxalate solution and dried and finally weighed. Whenever the amount of residue was found to be more than 60% of the original quantity of sample, it was subjected to sieve analysis.

The volume of the suspension passing through '230 mesh sieve' was made exactly to 1000 ml. by adding sodium oxalate solution (N/100), thoroughly stirred and allowed to stand overnight.

This suspension was then subjected to '<u>Pipette Analysis</u>'. This analysis is based on the settling velocity of the particles, usually computed on the basis of Stoke's law. The procedure for the analysis is as under.

The suspension in the cylinder (a graduated one) was stirred vigorously. As soon as the stirring rod was taken out, the timer (Stop-Watch) was started. At the end of 20 seconds the pipette was inserted into cylinder to a depth of 20 cm. and exactly 20 ml. of suspension was withdrawn. After this first withdrawal at specified intervals, subsequent withdrawals were carried out. Before each withdrawal, the suspension was thoroughly stirred and accurately timed, as above.

The suspension (20 ml.) sucked each time was transferred to a weighed 50 ml. beaker. The pipette

was rinsed with distilled water (20 ml.) and this was added to the above suspension. The array of beakers in which successive instalments of suspension were collected, was then evaporated in oven. After complete drying, the fractions were allowed to cool and then weighed.

The sizes of the grains obtained by pipette analysis were calculated by the method suggested by Folk (1965, p.38).

Graphic Presentation of Size Analysis Data:

The data of grain-size analysis have been presented by preparing following graphs.

(i) Histogram.

(ii) Cumulative Curve: (a) Arithmetic Ordinate.

(b) Probability Ordinate.

In all the graphical methods grain-size values were plotted along the abscissa (horizontal scale) and measures of percentage frequency (individual as well as cumulative) as the ordinate (vertical scale).

Only for those cumulative curves which were being utilized for preparing CM diagrams, the grain-size values were considered in mm. unit. For the rest, the grain size values were plotted in ø units after Krumbein (1934). The 'Phi-scale' is based on the fact that any diameter value may be expressed in terms of Wentworth's scale as $\xi = 2^{-\phi}$ where ξ is the diameter in millimetres and ø is a value along the phi scale. By taking logs of this expression, one obtains $\phi = -\log_2 \xi$. Thus analyses may be conducted on any convenient scale with true geometric intervals, and by the choice of approximate transformation equations, the statistical values may be expressed in terms of ø units. Phi scale is more convenient and accurate since ø intervals are equal and ordinary arithmetic graph paper can be conveniently used.

(i) Histogram: A histogram is essentially a bar graph in which the individual percentages for each grade-size are plotted as columns. It is easy to prepare, and from which general features of the sediments can be easily interpreted. However, it is a

pictorial method and can not be used for determination of statistical parameters. Further, its shape is greatly affected by the sieve interval chosen. (It may be pointed that in the histograms prepared by the author, the width of the various bars are not uniform, and this fact is on account of the unequal sieve intervals taken into account).

(ii) Cumulative Curve: This is the most commonly used graphic method. In this, the grain-size is plotted along the abscissa, while the percentages are plotted along the ordinate. Semi-log paper is used in the case of mm. values, while ordinate graph paper is suitable for ø units. The sample analyses normally form S - shaped curves when arithmetic ordinate graph peper is used. This type of curves are better than histographs because their shapes are independent of the sieves used and are better suited for obtaining statistical parameters. However, the S-shaped cumulative curves (plotted on arithmetic ordinate) are getting absolete as they can not be satisfactorily used for calculating statistical parameters. As these curves depend much on the

artistry of the sketching and less on the sample characteristics, the values of skewness and kurtosis read off the curves of this type tend to be less meaningful. In the present work, therefore, these curves have been utilized only for the CM pattern diagrams, and for obtaining the statistical parameters, cumulative curves have been plotted on probability-ordinate paper.

The advantages of the use of probability-ordinate paper have been ideally given by Folk (1965, p.41-42), "Most sediments tend to approach 'normal probability curve,' in their size frequency distribution -- in other words, most of the particles are clustered about a given size, with less and less material on each side of this size. If the cumulative curve of a sediment following the normal, symmetrical probability distribution is plotted on probability paper, the result is a perfectly straight line whose position depends on the average particle size and whose slope depends on the sorting. This happens because the probability scale is very condensed in the middle of the scale (30 to 70%) and very much expanded at the ends

(under 10 or over 90%), thereby straightening out the S-shaped curve which would result if arithmetic ordinates were used. Thus it is very valuable for studying the departure of sediments from the normal probability law. Moreover, since the 'tails' are straightened out and the sample tends to plot as a straight line, it is possible to read the statistical parameters with much greater accuracy because of the ease of interpolation and extrapolation. HENCE, THIS IS THE CURVE THAT MUST BE USED FOR ALL DETERMINATION OF PARAMETERS. The only disadvantage is that it is even less pictorial than the arithmetic cumulative curve, and is not commonly used."

Statistical Parameters of Grain Size:

The curves obtained by plotting the grain-size and the cumulative percentages of the various fractions reveal ideally the true nature of the sediments. However, these curves only furnish a qualitative information. In order to obtain quantitative data, one has to resort to various statistical measures which describe quantitatively certain features of the curves. These values are

then tabulated and certain combinations are obtained which are used in interpreting the sedimentary environments.

Statistical measures commonly taken into account are (1) Mean size, (2) Sorting coefficient, (3) Skewness and (4) Kurtosis. These parameters are calculated by reading selected percentiles off the curves. Such measures are adequate for normal (normal kurtosis) curves, but for the curves where the kurtosis values are not normal, reading of a few points off the curves is not sufficient. In order to obtain the comprehensive coverage of the parameters, accordingly Folk and Ward (1957) have rightly suggested large number of readings off the curves. They have further mentioned that the method suggested by them should be followed for normal curves also, in the interest of the consistency.

The approach and procedure suggested by Folk and Ward (1957) is definitely an improvement upon those of the previous workers as will be seen from the following comparison given by Folk (1966).

GRAPHIC MEASURES	FOLK AND WARD (1957)	PREVIOUS WORKERS
Mean Size	$M_z = \frac{(\phi16+\phi50+\phi84)}{3}$	Median, $\phi50$ (Trask, 1930), $M_\phi = \frac{(\phi16+\phi84)}{2}$ (Otto, 1939 and Inman, 1952).
Sorting	$\sigma_I = \frac{(\phi84-\phi16)}{4} + \frac{(\phi95-\phi5)}{6.6}$	$QD_\phi = \frac{(\phi75-\phi25)}{2}$ (Trask, 1930), $\sigma_\phi = \frac{(\phi84-\phi16)}{2}$ (Otto, 1939 and Inman, 1952).
Skewness	$Sk_I = \frac{(\phi16+\phi84-2\phi50)}{2(\phi84-\phi16)} + \frac{(\phi5+\phi95-2\phi50)}{2(\phi95-\phi5)}$	$Sk = \frac{(Mm25)(Mm75)}{(Mm50)}$ (Trask, 1932), $a_\phi = \frac{\phi16+\phi84-2\phi50}{\phi84-\phi16}$ $a2_\phi = \frac{\phi5+\phi95-2\phi50}{\phi84-\phi16}$ (Inman, 1952).
Kurtosis	$K_G = \frac{\phi95-\phi53}{2.44(\phi75-\phi25)}$	$K_{qa} = \frac{\phi75-\phi25}{2(\phi90-\phi10)}$ (Kelley, 1924; Krumbein and Pettijohn, 1938), $B_\phi = \frac{(\phi95-\phi5)-(\phi84-\phi16)}{\phi84-\phi16}$ (Inman, 1952).

In the present work, the following four parameters of the grain size (Folk and Ward,-1957; Folk, 1965), have been calculated.

(1) Graphic Mean (M_Z)

(2) Inclusive Graphic Standard Deviation (σ_I)

(3) Inclusive Graphic Skewness (Sk_I)

(4) Graphic Kurtosis (K_G).

(1) Graphic Mean (M_Z): This is the measure of average size, and is the best graphic measure for determining overall size. The formula used by Folk (1965) is $M_Z = \frac{\phi16 + \phi50 + \phi84}{3}$.

(2) Inclusive Graphic Standard Deviation (σ_I): This is a measure of average dispersion or spread of the distribution around the mean size. Following Folk (1965), the formula for obtaining this measure is

$$\sigma_I = \frac{\phi84-\phi16}{4} + \frac{\phi95-\phi5}{6.6}$$

This is the measure used in the present work. This gives best overall measure of sorting. Following verbal classification scale for sorting is given by Folk (1965).

σ_I		
under	- 0.35 Ø	very well sorted
0.35	- 0.50 Ø	well sorted
0.50	- 0.71 Ø	moderately well sorted
0.71	- 1.00 Ø	moderately sorted
1.00	- 2.00 Ø	poorly sorted
2.00	- 4.00 Ø	very poorly sorted
over	4.00 Ø	extremely poorly sorted.

(3) Inclusive Graphic Skewness (Sk_I): Skewness is a measure of the symmetry around the mean. It denotes the degree of asymmetry as well as the sign i.e. depending upon whether a curve has an asymmetrical tail on the left or right.

Folk (1965) has improved upon the earlier methods of measurements and has introduced the term Inclusive Graphic Skewness, represented by the following formula.

$$Sk_I = \frac{\phi 16+\phi 84-2\phi 50}{2(\phi 84-\phi 16)} + \frac{\phi 5+\phi 95-2\phi 50}{2(\phi 95-\phi 5)}$$

This is the most suitable skewness measure because it determines the skewness of the tails as well as the central part of the curves. The tails are very important as it is they which decide the modality of the sediments.

Symmetrical curves have $Sk_I = 0.00$, those with excess fine material (a tail to the right) have

positive skewness and those with excess coarse material (a tail to the left) have negative skewness. The more the skewness value departs from 0.00, the greater the degree of asymmetry. The following verbal limits on skewness have been suggested by Folk (1965).

Sk_I from	+ 1.00	to+0.30	- strongly fine-skewed
	+ 0.30	to+0.10	- fine-skewed
	+ 0.10	to-0.10	- near-symmetrical
	- 0.10	to-0.30	- coarse-skewed
	- 0.30	to-1.00	- strongly coarse-skewed.

(4) Graphic Kurtosis: Kurtosis measures the ratio of the sorting in the tails of the distribution as compared to the sorting in the central part and as such is a sensitive test of the normality of distribution. It is noteworthy that many curves considered as "normal" by the skewness measure turn out to be markedly non-normal (This word has been used by Folk, 1965), when the kurtosis is computed. The Graphic Kurtosis is given by Folk (1965) in the Formula:

$$K_G = \frac{(\phi 95 - \phi 5)}{2.44(\phi 75 - \phi 25)}$$

In the normal probability curve the diameter intervals between the ϕ5 and ϕ95 points should be

exactly 2.44 times the diameter interval between the ø25 and ø75. Thus using the above equation normal curves will have K_G = 1.00.

The following verbal limits for the Kurtosis measure have been suggested by Folk (1965).

K_G	under		0.67	very platykurtic
	0.67	to	0.90	platykurtic
	0.90	to	1.11	mesokurtic
	1.11	to	1.50	leptokurtic
	1.50	to	3.00	very leptokurtic
	over		3.00	extremely leptokurtic.

The distribution of K_G values in natural sediments is itself strongly skewed (non-normal) since most sediments are around 0.85 to 1.4. Therefore, Folk (1965) suggested that for all graphic and statistical analysis, the kurtosis distribution must be normalised by using the transformation, $K_G/(1+K_G) = K_G'$. With this modification a normal curve will have a value of kurtosis 0.50. In the present work, therefore, Graphic Kurtosis values have been transformed into K_G' and the latter only has been considered for the interpretation.

Inter-relation of The Four Grain-Size Parameters:-

It is necessary to plot all the four grain-size parameters against each other as Scatter Diagrams to understand the geological significance of the four size-parameters. Scatter diagrams reveal the inter-relationship between the parameters and thus a wealth of information about modes of deposition is obtained. This adds one more criterion for identifying the environments of deposition by size analyses. Accordingly, scatter-diagrams covering all the four parameters in different combination were prepared.

CM Patterns:-

The CM patterns are a geological tool which can be used to analyse the deposition of sediments and to reconstruct the conditions of deposition of ancient sediments. Passega (1957) who has suggested these studies, writes, "Clastic sediments can be much more precisely characterised by C-an approximation of their maximum grains size and M- their median, than by other parameters of grain-size distribution." CM patterns are plotted by utilising the cumulative curves drawn

on semi-log paper. Such cumulative curves, "show the amount by weight of the sample coarser than any given grain size. This is the amount that would be caught on a sieve with mesh of this given size. The median size is the size such that 50 per cent of the sample is coarser than this size. The one percentile grain size is such that one percent of the sample is coarser than this size. For brevity, in this paper M and C are respectively used as symbols of the median and the one percentile. These values are readily obtained by intersecting the cumulative curve at 50 percent and 1 percent lines and reading the diameters equivalent to these percentile values" - (Passega, 1957, p.1952). The values of C and M for different samples are plotted on double log paper, to obtain the CM Patterns.

In the present investigations the author, following the procedure suggested by Passega (1957) selected 10 to 15 samples each from different series and prepared the CM diagrams.

(3) SHAPE ANALYSIS:

Shape analysis includes study of roundness and sphericity. Roundness has to do with sharpness of the

edges and corners of clastic fragment. It is expressed as the ratio of the average radius of curvature of the several corners or edges to the radius of curvature of the maximum inscribed sphere, or to the nominal radius of the fragment. The original concept of Sphericity as given by Wadell is

$$\text{True Sphericity} = \frac{\text{Surface of the particle}}{\text{Surface area of the sphere of same value.}}$$

But more appropriately Krumbein and Sloss (1963, p.106) have defined sphericity as the relation of the particle intercepts to each other.

Grains of coarser range (0.25 to 1.0Ø) and finer range (3.25 to 3.75Ø) obtained after sieving were mounted on glass slides, and images were projected on a drawing board by using a microprojector.

Roundness:

As Pettijohn (1956, p.57) has suggested, it is more convenient, and in many cases necessary, to work with a two dimensional figure - a section or a projection of the fragment - rather than the three dimensional objects. The author has followed the

procedure given by Pettijohn (1956, p.57), where the roundness is defined as the average radius of the maximum inscribed circle and in the present work, therefore, the individual radii of the corners, the number of such corners and the radius of the maximum inscribed circle were obtained from the projected images of the grains. Roundness of the grain was calculated as

$$\text{Roundness - P(rho)} = \frac{\Sigma \frac{ri}{R}}{N}$$

Where Σ = expression of summation

ri = individual radii of the corners.

N = Number of corners

R = Radius of maximum inscribed circle.

The following roundness grades of Pettijohn (1956, p.58) were found to be very suitable for the present work.

Angular	-	0 to 0.15
Subangular	-	0.15 to 0.25
Subrounded	-	0.25 to 0.40
Rounded	-	0.40 to 0.60
Well rounded	-	0.60 to 1.00

Sphericity:

In the present work the two dimensional measure as proposed by Dapples and Romingar (1954) was

found suitable. This measure, called Elongation is expressed as the ratio of Least Projection Width (W) to Least Projection Length (L), both measuredon a rectangular grid. The images of grains were projected and the values of least width and length x were measured, and the Sphericity (S) was calculated by formular S = W/L.

Folk (1965) has suggested the following scale for sphericity ranges and the same has been adopted in the present work.

Under	0.60	Very elongated;
	0.60 to 0.63	elongate;
	0.63 to 0.66	subelongate;
	0.66 to 0.69	intermediate shape;
	0.69 to 0.72	subequant;
	0.72 to 0.75	equant
over	0.75	very equant.

(4) CLAY MINERAL DETERMINATION BY COLOURATION METHOD:

The clay minerals were identified by colouration method as proposed by Raju and Tatarasky (1961).

About half a gram of shale sample well crushed by means of porcelain mortar and pestle, was taken

in a test-tube, which was filled with distilled water. It was then thoroughly shaken and kept undistarted for 24 hrs. After this period, generally the particles of size less than 0.001 mm would remain in suspension. About 6 cc. of the upper part of the suspension was then decanted into another test tube. Care should be taken in removing all unwanted salts from the suspension, if necessary by repeating the above process several times.

To the test-tube containing decanted clay suspension an equal quantity of Methylene Blue of 1/100,000 concentration was added, and shaken well. The colour of the solution was then noted. Half the quantity of this solution was then transferred to a third test-tube and a few drops of saturated KCl - solution was added. The test-tube was shaken well and kept undisturbed. The colour of the solution changed, depending upon the type of the mineral present. Following table has been prepared by Raju and Tatarsky (1961) for identification of clay minerals.

MINERALS	COLOURS OF THE SOLUTION		
Type of Clay mineral	With Methylene Blue.	With Methylene Blue +KCl	Nature of Precipitate
Kaolinite	violet	violet	Dense and Compact
Montmorillonite	violet	blue, sky-blue, green	Jelly like
Illite	violet, blue, sky-blue	blue, sky-blue	Dense and compact
Beidellite	green	green	Jelly like

(5) MICROSCOPIC STUDY:

Microscopic study was mainly confined to the (a) identification of heavy and light minerals and visual estimation of roundness and sphericity, and (b) thin sections of rocks.

(a) Study of Heavy and Light Minerals:-

The slides of heavies and lights were studied by means of polarizing microscope fitted with mechanical stage. The percentages of 'heavies' were obtained by counting-method and their frequencies

were calculated as per following chart given by Evans, Hayman and Majeed, (1934).

8 +	90-100%	)	5. 7-13%	Very common
8	75-89%	)Very	4. 4-6%	Common
8 -	60-74%	)abundant	3. 2-3%	Fairly common
7 +	45-59%	)	2. 1-2%	Sporadic
7	35-44%	)Abundant	1. ½-1%	)
7 -	28-34%	)	1. One or two grains or less than ½%	)Rare
6 +	23-27%	)		
6	18-22%	)Fairly	X. Absent.	
6 -	14-17%	)abundant		

Study of light minerals included the identification and estimation of quartz and felspar. The visual estimation of roundness and sphericity of quartz grains was also made.

(b) Study of Thin Section of Rocks:-

Thin section of selected samples of indurated and hard rocks were studied for their textural characters and mineralogical compositions.